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Transcript Me and My Shadow - Making the Sun-Earth Connection I have a little shadow that goes in and out with me, And what can be the use of him is more than I can see.... - My Shadow, Robert Louis Stevenson Me and My Shadow - Mills Brothers Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium Me and My Shadow Making the Sun-Earth Connection On a sunny day, drive a stake into the ground and observe how its shadow changes throughout the day or year--a simple yet profound way to demonstrate the interconnection between the Sun and Earth! The following Web resources may help you to more fully comprehend the deeper meaning of these simple observations. The Analemma Use a sundial to measure Solar Time. Get the current Standard Time from The Official U.S. Time Web page. Most days, Solar Time is slightly different from Standard Time (up to 16 min. fast or 14 min. slow). This time difference is known as the Equation of Time. Are You Clock-wise? Ever wonder why is Clockwise clockwise? As it turns out, for objects in the Northern Hemisphere, shadows cast by the Sun move in a clockwise direction. In fact, the word hour means "the day" or "Sun's path." For details, see the How Sundials Work Web page. Every day, shadows... ...are shortest at noon, and longest at sunrise & sunset. On June 21, noon shadows Ever notice the odd-looking figure eight that appears on many globes? It's called an analemma. Visit the Analemma Web site to learn more about, well, analemmas, including an explanation of how the analemma is derived from the stake you drove into the ground. See Dennis di Cicco's award-winning time lapse photograph of the Sun (showing the analemma). See also Building an Analemma Curve, courtesy the Analemma Society. Construct an indoor analemma; construct an outdoor analemma. Calculate & chart an analemma for any location at any time of day. A graph of the analemma for Washington, D.C. shows the Equation of Time (Offset of the Sun) corrected for the eight-minute solar time difference between Washington, D.C. (77°W) and 75°W--the Standard Time Meridian for the Eastern Time Zone. Can you tell when the maximum & minimum altitude of the midday Sun occurs during the year? Close examination of an almanac reveals that the latest sunrise and earliest sunset do not occur--as one would expect--on the December Solstice (on average, 21 DEC), the day with the fewest hours of daylight in the Northern Hemisphere. As it turns out, the earliest sunsets occur in early December and the latest sunrises occur in early January. [A similar situation occurs before/after the June Solstice (on average, 21 JUN).] A puzzling mystery easily solved by the analemma! For details, see Why the earliest sunset, latest sunrise, and shortest day of the year occur on different days. Sun Calculators Explore the daily and annual cycles of change in the apparent path of the Sun across the sky. Great Circle Studio's Solar Calculator will calculate the Sun's altitude and azimuth for a user-specified location, date & time, and data interval. A variety of output modes are available. Use this wsanford/exo/sundials/shadows.html (1 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection are the shortest of any day during the year (for northern mid-latitude locations), and vice-versa on December 21 (see solstice/equinox diagram). Due to the geometry of equatorial sundials, the gnomon shadow is the same length for the entire day (although its length varies from day-to-day according to the annual cycle of change in the declination of the Sun). Longitude is... ...equivalent to time, and vice versa. If you know the time difference between two locations, then you can use the rate of the Earth's rotation (15°/hr or 1°/4 min) to calculate the difference in longitude between the two places. For example, Solar Noon occurs eight minutes later in Washington, D.C. than it does on the Standard Time Meridian for the Eastern Time Zone (75°W); how many degrees of longitude separate the two locations? 8 min x 1°/4 min = 2° Therefore, the longitude of Washington, D.C. is 77°W. Simple, huh? Well, it wasn't always so easy! Read The Illustrated Longitude, the story of clockmaker John Harrison, who solved the problem that Newton and Galileo failed to conquer--how to determine longitude at sea. See also, Lost at Sea--the Search for Longitude from PBS/NOVA Online. Long story short, sundials must be corrected for longitude (as well as the Equation of Time) so that information to predict how the length of your shadow would change daily and annually (at the same time each day). Verify your predictions using the SCSA Shadow Length Calculator. How can you determine the height of objects too tall to measure directly? Using shadows, of course! Use the SCSA Object Height Calculator to calculate the height of tall shadow-casters, e.g., buildings, flagpoles, utility poles, trees, etc. Using user-specified times of sunrise and sunset, the SCSA Daylight Calculator calculates the number of hours of daylight, also known as the Duration of Insolation (Incoming Solar Radiation). The Solar Noon Calendar calculates tables showing either the exact time of Solar Noon for your location for each day of the year, or the Standard Time Correction (the amount you have to add to, or to subtract from, solar time on your sundial to get the time shown on your wristwatch). The NASA J-Track Web page shows where on Earth the Sun is currently directly overhead (see small Sun icon, correctly oriented with respect to latitude and longitude). You Can Make a Sundial! Tell time using shadows! As its name suggests, the You Can Make a Sundial! Web site generates sundials for a user-specified location. Several types of sundials are available in a variety of output formats (GIF, PDF, and EPS). Start by making a customized horizontal sundial similar to the "Sandburg Sundial," a ready-to-use horizontal sundial available for downloading in two file formats (some assembly required): ● Lower Resolution - dial.gif (16k) plus gnomon.gif (7k) ● Higher Resolution - sandburg_sundial.pdf (54k) [Download free Adobe Acrobat Reader.] Enhanced Sandburg Sundial (29k) - featuring arcs showing apparent solar altitude from 10-70 degrees above the horizon, courtesy sundialist Robert "Shadow Master" Hough [Note: The "dot" that appears along the upper edge of the gnomon (technically known as the style) is called the nodus. Determine the solar altitude by observing when the nodus shadow falls among the arcs on the dial face (mnemonic: notice the nodus).] Print sundial templates using cover stock. For directions regarding set-up and use, visit the How to Set Up & Use a Horizontal Sundial Web page. For reference, visit the North American Sundial Society Horizontal Sundial Glossary. ● Experiment with several other interesting types of sundials (designed for 39°N latitude): ● Combination Analemmatic-Horizontal Sundial - Unlike other types wsanford/exo/sundials/shadows.html (2 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection Solar Time reads the same as Standard Time. of sundials that must be carefully oriented before they will work properly, the combination analemmatic-horizontal sundial is self-orienting. How it works: Assemble the horizontal sundial (lower dial). Place the combination sundial on a horizontal surface. Using the analemmatic sundial (upper dial), stick a vertical pin in today's date along the date scale (vertical line, center of dial). [Note that pin placement is more precise on the first day of each month (and the equinoxes).] Keep the paper horizontal and turn it until the two sundials display the same time--both sundials are now properly oriented and the compass rose indicates true direction. That's cool--a combination sundial-Sun compass! Why it works: The analemmatic sundial measures time with respect to the azimuth of the Sun; the horizontal sundial measures time with respect to the distance of the Sun from the meridian. Did You Know.... ...that Earth is eight light-minutes from the Sun? Huh? That's right. At the speed of light (186,000 miles per second, or 300,000 km/sec), it takes nearly eight minutes for sunlight to reach the Earth. The Earth is connected to the Sun, but it is a long-distance connection! 30 JUL 2002 ● ● Today's sunspot number is 304 / Sunspot No. Trend (past 24 hours) / Increasing -- Steady \ Decreasing Credits: Real-time image courtesy SOHO; sunspot number courtesy NOAA. Updated: 29 JUL 2002 ARCHIVES Today's Predicted UV Index is 8 Valid for Wash., DC during the Solar Noon hour on 30 JUL 2002 UV Index courtesy NOAA. Analemmatic Sundial - A relatively uncommon type of sundial (derived from the equatorial sundial), the analemmatic sundial features a gnomon that moves throughout the year. See the Analemmatic Sundials Web page for numerous examples of analemmatic sundials located around the world. Equatorial Sundial (assembly instructions) - The foundation of all gnomonics, the art and science of sundials. From an educator's point of view, the equatorial sundial is by far the best type of sundial for teaching a wide range of fundamental concepts in astronomy, geography, and mathematics. See the SCSA Educator's Guide to Equatorial Sundials for background information and suggested teaching strategies. You Can Construct a Sundial! The preceding section features a variety of ready-made, ready-to-assemble sundials--little if any prerequisite knowledge is necessary to begin sundialing. Sooner or later, you'll want to know what makes a sundial tick (pun intended)--at that point in time, you are ready to construct a sundial from scratch. The following information resources should help to get you started. Two highly recommended books from Dover Publications, Inc.: Sundials: Their Construction and Use, by R. Newton Mayall, Margaret W. Mayall, ©2000; and Sundials: Their Theory and Construction, by Albert Edmund Waugh, ©1973. Similar content; complementary coverage. Both books use the graphic (or geometric) method of sundial construction--a simple, non-mathematical approach to constructing sundials. In a word, these two books are a "must-have" for the novice sundialist. The first step in designing a sundial is to determine your exact location (latitude and longitude): ❍ Use a relatively inexpensive Global Positioning System (GPS) wsanford/exo/sundials/shadows.html (3 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection Today's Observed UV Index is 7.3 Sandburg Planetarium 19 MAY 2002, 01:05 p.m. Partly Cloudy (Sun Transit: 01:05 p.m.) UV Index Solarmeter courtesy EPA SunWise School Program I'm Being Followed.... ...by a moonshadow. - Moonshadow, Cat Stevens The Moon, especially the Full Moon, is bright enough to cast shadows at night. So, how bright does an astronomical object have to be to cast shadows? Good question! In fact, the question may be impossible to answer, since there are so many factors involved. However it is possible to quantify the brightness or magnitude of a light source. Oddly, negative magnitudes are brighter than positive ones. The Sky & Telescope magnitude Web page lists the following magnitudes for the Sun, Moon, brightest planet, and brightest star (in the night sky): ● Sun = -26.7m ● Full Moon = -12.5m ● Venus = -4.4m ● Sirius = -1.5m "Night is a shadow world. The only shadows we see at night are cast by the moonlight, or by artificial light, but night itself is a shadow." - Soul of the Sky, an essay by Diane Ackerman The "Morning Chorus" receiver, such as the Garmin 12, eMap, or eTrex Vista. ❍ U.S. Naval Observatory Complete Sun and Moon Data for One Day Web page: Use Form A - U.S. Cities or Towns; select State or Territory; enter City or Town Name; click "Get data"; among other useful information (especially the time of "Sun transit"), the database returns the location name and its longitude & latitude. Start simple. Your first homemade sundial should be either a horizontal sundial or an equatorial sundial. Before you start [tips from the North American Sundial Society (NASS)].... I. Horizontal Sundial - Four methods for determining the hour lines on the dial face, including the graphic method of horizontal sundial construction, as well as three methods for calculating the hour lines (in order of difficulty): . Graphic (or Geometric) Method of Construction: Make Your Own Horizontal Sundial, courtesy Paul R. Field, member, NASS. [Note: The horizontal sundial is derived from the equatorial sundial. See Figures 4-6.] B. Horizontal Sundial Hour Line Calculator: Calculates hour, half-hour, and quarter-hour lines for a user-specified latitude. Special thanks to Peter Daykin, Derbyshire Sundials, for this time-saving calculator! Use a NASS utility to convert from degrees/sec to decimal degrees or vice-versa. C. Microsoft® Excel Spreadsheet: Horizontal Dial.xls, courtesy Dr. Robert L. Kellogg, Treasurer, NASS. Enter your latitude & longitude. In order to calculate the longitudinal offset of your location from the Standard Time Meridian (STM) in your time zone, enter the longitude of the STM and your longitude (again). Enter "yes/no" in response to query, "Correct for longitude?" Enter size of dial (radius, in centimeters). Note results in columns labeled "Time (hh.mm)" and "Dial Angle (degrees)." D. Mathematical Calculation (of Hour Lines): Five simple sundial projects for you to make, courtesy Sundials on the Internet. See Project 2 - A horizontal sundial. Check your answers using either the hour line calculator or horizontal dial spreadsheet. See also Basic Trigonometry, courtesy NASS. [Note: Project 3 provides further proof that the horizontal sundial is derived from the equatorial sundial. See Steps 3 & 6.] II. Equatorial Sundial - The thickness of the gnomon determines the way in which the hour lines are drawn on the two dial faces: hour lines are spaced exactly 15 degrees apart and radiate from either the exact center of the dial face or tangentially from a small inner wsanford/exo/sundials/shadows.html (4 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection During the pre-dawn twilight, have you ever noticed that birds wake up and sing all at once? Ornithologists call this phenomenon the "Morning Chorus." Plan to wake up early tomorrow to see the sunrise and listen to the symphony of nature--a delightful way to feel more connected to the natural world! circle representing the diameter of the gnomon (for details, see Telling Time Using Shadows, Educator's Guide to Equatorial Sundials). Use the SCSA Equatorial Sundial Gnomon Length Calculator to calculate the length of the upper & lower segment of the gnomon. Horizontal Sundials and the Earth's Rotation The rotation of the Earth around its axis causes a daily cycle in the Sun's apparent path across the sky that can be observed indirectly using a horizontal sundial. In the northern mid-latitudes, the Sun rises in an easterly direction, arches across the southern sky, and sets in a westerly direction. Facing south, the Sun rises on your left and sets on your right. Sun shadows fall in the opposite direction as the Sun. Therefore, morning times are located on the right (or western) side of the dial plate of a horizontal sundial (shown upper left); afternoon times are located on the left (or eastern) side. Because the Earth rotates counterclockwise (as viewed from above the Northern Hemisphere), shadows cast by the Sun move in a clockwise direction. See a six-hour time lapse movie that shows the clockwise motion of the gnomon shadow around the dial face of a horizontal sundial from roughly 6 a.m. to 12 noon: sundial.avi (1.02 MB); sundial.mov (1.01 MB). [Time-lapse movie courtesy Film & Video Stock Shots.] Equatorial Sundials and the Earth's Revolution Although horizontal sundials are more familiar to most people (due to the fact that horizontal sundials are by far the most common type of sundial), experience has shown that an equatorial sundial is better suited for making the connection between the Earth's rotation and solar time-keeping (see Are You Clock-wise? sidebar, left), as well as the connection between the Earth's revolution around the Sun and the annual cycle of change in the Sun's apparent path across the sky. The subsolar point is the point on the Earth's surface at which the Sun is at the zenith at local solar noon. On any given day, the subsolar point moves east-west along a single line of latitude as the Earth rotates counterclockwise. The latitude of the subsolar point varies between zero degrees (0°) at the equinoxes and ±23.5° at the solstices. The latitude of the subsolar point varies directly with the declination of the Sun. The analemma--the odd-looking figure eight that appears on many globes--neatly traces the annual north-south migration of the subsolar point (caused by the tilt of the Earth's axis of rotation and the revolution of the Earth around the Sun). Theoretically, the gnomon (or style) of a properly oriented equatorial wsanford/exo/sundials/shadows.html (5 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection sundial will not cast a shadow on the dial plate during the equinoxes. Because the dial plate of an equatorial sundial is parallel to the Earth's Equator, the Sun is directly over the edge of the dial plate on the equinoxes, when the subsolar point moves east-west along the Equator. From the March Equinox to the September Equinox, when the subsolar point is located in the Northern Hemisphere (between 0° and 23.5°N latitude), the gnomon shadow falls on the upper dial face; from the September Equinox to the March Equinox, when the subsolar point is located in the Southern Hemisphere (between 0° and 23.5°S latitude), the gnomon shadow falls on the lower dial face (see example). Put a little theory into practice--assemble a simple equatorial sundial (courtesy StarDate Online and the University of Texas McDonald Observatory/SCOPE (Southwestern Consortium of Observatories for Public Education)) and empirically observe where the gnomon shadow falls as the seasons change. Gain valuable insight by checking the NASA J-Track Web page to see where on Earth the Sun is currently directly overhead (see small Sun icon, which is correctly oriented with respect to latitude and longitude). Related activity: calculate & chart a projection of the analemma. Light & Shadow - Suggested Activities for Grade K-12 ● ● Just Me and My Shadow - Kids create crazy creatures with shadows and a little sunshine. From Sesame Street Parents. Smithsonian Astrophysical Observatory Everyday Classroom Tools, featuring K-2, 2-4, and 4-6 threads for each activity: . Hello, Sun! B. You Light Up My Life C. Me and My Shadow D. This is a Stickup! (sundials) ● ● From the National Science Teachers Association, Astronomy with a Stick - Daytime Astronomy for Elementary and Middle School Students SCSA Educator's Guide to Equatorial Sundials - Background information and suggested teaching strategies, including the SCSA Equatorial Sundial Activity: 1. The Sandburg Planetarium Equatorial Sundial template (print using cover stock) - Designed for use with a pencil-sized gnomon, approximately 1/4" (7 mm) in diameter. 2. Assembly instructions (courtesy John Hoy) 3. Equatorial Sundial Activity Questions - Provide differentiated instruction by assigning multiple choice questions only, as appropriate. [Teacher's Answer Key available upon request.] ● From NASA Liftoff to Space Exploration, a set of sundial Web pages wsanford/exo/sundials/shadows.html (6 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection (upper elementary, middle school): . Sundials B. How Sundials Work C. Building a Simple [Equatorial] Sundial D. Pondering Sundials ● From StarDate Online and the University of Texas McDonald Observatory/SCOPE (Southwestern Consortium of Observatories for Public Education), the SCOPE solar poster educational activities and resources, including: . Equatorial Sundial Activity, two versions: HTML; PDF B. Dial Face Template (print using cover stock) ● Bill Nye the Science Guy Earth's Seasons video, Disney Educational Productions, No. 68A93VL00 - Entertaining demonstrations showing the reasons for the seasons. The program includes a brief segment (entitled "Try This") featuring a home-made horizontal sundial--the "Cardboard Sundial of Science"--that provides a fast-paced introduction to several fundamental concepts in sundialing, including the clockwise rotation of the gnomon shadow, style angle versus latitude (the style should be parallel to the Earth's axis), the noon line, and hour lines. The segment ends with a breadthrough introduction to the Equation of Time (EoT). [Editorial Commentary: The program script does not refer to the phenomenon as the EoT, rather it simply points out the observed difference between Solar Time and Standard Time ("noon won't quite say noon; 9 in the morning won't quite say 9 in the morning"). The program fails to mention the fact that the time difference could be caused, in part, by a difference in longitude between the location of the observer and the Standard Time Meridian. The complex topic of correcting Solar Time to get Standard Time is perhaps better covered by the classroom teacher rather than Bill Nye's "MTV" presentation style.] ● Tracing the Analemma . SCSA Calculate and Chart the Analemma - A year-long projection of the Sun's image on a horizontal surface. (See also Related Resources.) B. From the Smithsonian Institution, Eyes on the Sky, Feet on the Ground - Hands-On Astronomy Activities for Kids. See Chapter Two - The Earth's Orbit, Activity 2-4: The Analemma (constructing a ceiling analemma). C. Two interrelated activities from Paper Plate Education: Sub-Solar Cup; and Analemma Project. Me and My Shadow - A Rule-of-Thumb for Safe Sun Exposure The Sun is a star that radiates energy at all wavelengths of the electromagnetic spectrum; some wavelengths of solar radiation are hazardous to plants and animals. Visit the EPA Stay Healthy in the Sun Web site for information about the health risks posed by ultraviolet (UV) wsanford/exo/sundials/shadows.html (7 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection radiation, as well as the steps people can take to protect themselves from overexposure to the Sun. An easy way to tell how much ultraviolet (UV) radiation exposure you are getting is to look for your shadow: ● If your shadow is taller than you are (in the early morning and late afternoon), then your UV exposure is likely to be low. ● If your shadow is shorter than you are (around midday), then you are being exposed to high levels of UV radiation. Seek shade and protect your skin and eyes. The Ultraviolet Index (UV Index) overview includes a link to EPA's new SunWise School Program regarding Sun safety. The National Oceanic and Atmospheric Administration (NOAA) produces a daily UV Index U.S. map (showing predicted exposure levels). Sunspots and the Solar Cycle What is "The Solar Cycle?" In a regular cycle, the Sun undergoes a period of great activity called the "solar maximum" (predicted to occur during 2000-2001), followed by a period of quiet called the "solar minimum." One way scientists track solar activity is by observing sunspots. Sunspots are relatively cool areas that appear as dark blemishes on the face of the Sun. During solar maximum there are many sunspots; during solar minimum there are few. See sidebar (left) for today's sunspot number. For more information about sunspots, Solar Maximum, and the Sun-Earth Connection, visit the SCSA Themes Web page. For classroom teachers, a couple of suggested sunspot-related activities... ● Happy Birthday Sunspot Plot - Sunspots and the Solar Cycle (Grade Level 4-8) [Teacher's Answer Key available upon request.] ● Estimating the Size of Sunspots - Use the Internet to safely observe & measure sunspots [Teacher's Answer Key available upon request.] Sun-Earth Day, Astronomy Week/Day, Sky Awareness Week, and Space Day Plan to celebrate Sun-Earth Day--a national celebration of the Sun, the space around the Earth (geospace), and how all of it affects life on our planet--on 20 March 2002. Its theme is: "Celebrate the Equinox and the Seasons." Celebrate Astronomy Week/Day: Astronomy Week is April 15-21, 2002; Astronomy Day is Saturday, April 20th. Celebrate National Sky Awareness Week (NSAW), April 21-27, wsanford/exo/sundials/shadows.html (8 of 9) [3/2/2004 9:26:26 PM] Me and My Shadow - Making the Sun-Earth Connection 2002. Its theme is: "THE SKY - Where Meteorology Meets the Heavens and the Earth." Locally, the Sandburg Planetarium will host two special events: ● "Astronomy Day at Huntley Meadows Park," Saturday, 20 April 2002. (Rain Date: Sunday, 28 April 2002.) ● "Sun-Earth-Moon Day" on Mon., 06 May 2002, from 8:30 a.m. 'til 2:40 p.m. (Rain Date: Tue., 07 May.) The event is timed to coincide as closely as possible with Space Day (Thu., 02 May) and the Last Quarter Moon (Sat., 04 May). Amateur astronomers from the Maryland Sidewalk Astronomers (MSA), National Capital Astronomers (NCA), Northern Virginia Astronomy Club (NOVAC), and Shenandoah Astronomical Society (SAS) have volunteered to be our guides for a day of sundialing, safe sunspot observing, and Moon-watching. Sun-Earth-Moon Day 2002 | S-E-M Day 2001 | Sun "Block Party" 2000 | SCSA Home wsanford/exo/sundials/shadows.html (9 of 9) [3/2/2004 9:26:26 PM] Poem: My Shadow My Shadow by Robert Louis Stevenson I have a little shadow that goes in and out with me, And what can be the use of him is more than I can see. He is very, very like me from the heels up to the head; And I see him jump before me, when I jump into my bed. The funniest thing about him is the way he likes to grow-Not at all like proper children, which is always very slow; For he sometimes shoots up taller like an india-rubber ball, And he sometimes goes so little that there's none of him at all. He hasn't got a notion of how children ought to play, And can only make a fool of me in every sort of way. He stays so close beside me, he's a coward you can see; I'd think shame to stick to nurse as that shadow wsanford/exo/sundials/my_shadow.html (1 of 2) [3/2/2004 9:26:31 PM] Poem: My Shadow sticks to me! One morning, very early, before the sun was up, I rose and found the shining dew on every buttercup; But my lazy little shadow, like an arrant sleepy-head, Had stayed at home behind me and was fast asleep in bed. wsanford/exo/sundials/my_shadow.html (2 of 2) [3/2/2004 9:26:31 PM] Sundials on the Internet "Sundials on the Internet" is the leading world internet site for information about all aspects of sundials, including: ■ projects you can do ■ sundials you can commission or buy ■ books you can get ■ sundial trails all over the world ■ national societies to join ■ pictures you can see including the most recent ones on the sundials of the Camino de Santiago in northern Spain, and the sundials of the city of Oxford, England All sundial enthusiasts around the world are invited to join in the British Sundial Society's international conference in Oxford from 16-18 April 2004. Oxford is rich in sundials - see our new Oxford sundial trail Our traffic statistics show counter visitors to our home page since 19 May 2000.Please bookmark us - and come again! See our new Solar Noon Calculator giving the exact time of local solar noon for you Practical information Introduction Set up a dial Finding your latitude and longitude Mottoes Frequent questions 5 projects to do Mass dials Bevezetés a Napórákhoz (HU) Come preparare una meridiana (I) Faire un cadran solaire (F) Types of sundials Types de cadrans solaires(F) Tipos de relógios solares(P) Types Zonnewijzers (NL) Other languages Czech bullet deutsch bullet français bullet magyar bullet italiano bullet nederlands bullet portugues bullet español bullet Index of foreign language pages Can youhelp translate some more pages? Sundial pictures New sundials bullet Links to pictures of sundials The Sundial Fair bullet List of makers worldwide bullet Include your details? bullet Arthur Wilbur Co bullet Connoisseur Sundials bullet Harriet James Sundial makers BSS Home Page bullet What we do bullet Join us! bullet BSS Bulletin bullet "Make A Sundial" bullet Advertising bullet BSS Conference 2003 Other societies Full world list bullet Netherlands bullet Austria bullet Österreich (A) bullet N. America Sundial trails: in S. England The City of London sundial trail bullet The London Thames trail bullet Chipping Camden bullet Cotswolds trail bullet Cambridgeshire Hampshire sequents bullet Hornsman (London) bullet East Sussex bullet Test Valley (Hampshire) bullet rest of UK Derbyshire bullet County Down, N. Ireland bullet Leicester Time Trail bullet Oxfordshire bullet S. Norfolk bullet Suffolk bullet Winchester bullet Isle of Guernsey France: Central Paris, Briançonnais Finistère, Pays de Buech, Queyras (F) Queyras bullet rest of Europe & Middle East Austria : Österreich (A), Austria bullet Belgium: Rupelmonde, Flanders Germany: Gorlitz bullet Israel: Israel sundial trail , Italy: Milan/Bergamo, Milano/Bergamo(I) bullet Malta bullet Netherlands bullet Poland Spain: Barcelona bullet The Camino de Santiago bullet Complete world list bullet the Americas Seattle bullet Toronto bullet Kentucky bullet Ottawa bullet Ecuador Ecuador (SP) in Australia Sydney bullet Tasmania Let's hear from you Comments bullet Feedback page bullet Personals page bullet "Clocks" magazine articles by N. Ta'Bois. Adjusting for Longitude The Analemma Calculating hour lines Disc dials Equinoctial dials Gnomon or style Links Other interesting sundial sites bullet Wemaster's choice - a miscellany of links to other sites which we have found useful or interesting or both bullet How to set up a reciprocal link bullet This site is listed in the BBC Education Web Guide which brings you the newest and best websites for learning. Greenwich meridian Hours and hours Latitude & sundials Meantime dials Minor adjustments The Noon Mark Pillar dials Ring dials Significant dials "Sun time & clock time" Please bookmark Sundials on the Internet so we can see you again! This home page was completely redesigned in March 2000. If you would like to see our previous home pages, they are kept posted for your interest (though without links) at home99.htm, home98.htm and home97.htm. We have come quite a long way since then! Flags courtesy of ITA's Flags of All Countries. This site is one of the community websites maintained by Internetworks Ltd who are interested in developing similar successful website for other communities. Please visit our websites on the Camino de Santiago, the Inca Trail in Peru, the High Atlas, and a list of our other websites. We would be happy to build a website for you too! last revised Comments/ suggestions/ problems, please get in touch by E-mail (2 of 2) [3/2/2004 9:26:36 PM] Educator's Guide to Equatorial Sundials Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium Equatorial Sundials What is an Equatorial Sundial? An equatorial sundial (see a 360° view animated GIF) consists of a dial plate, and a gnomon (or style) that is perpendicular to the dial plate. The dial plate has an upper dial face (see example) and a lower dial face (see example), both of which are marked off in hours (every hour is exactly 15 degrees wide). The gnomon is a pole (or rod) that passes through the center of the dial plate, extending above the upper face of the dial plate, and extending below the lower dial face. The shadow of the gnomon (or style), cast among the hour lines on one of the two dial faces, shows the time. An equatorial sundial is actually a reduced model of the Earth, similar to a globe with its upper and lower halves removed: the dial plate represents the plane of the Earth's Equator; the gnomon represents the Earth's axis of rotation. The upper dial face represents the Northern Hemisphere; the lower dial face represents the Southern Hemisphere. For more information, visit The Equatorial Sundial Web page. Setting the Sundial Analogous to setting the correct time on a clock or wristwatch (by moving the hands of the timepiece into proper position), properly orienting an equatorial sundial will move the gnomon (or style) shadow into position so that the dial face displays the correct time. ● The gnomon should be parallel to the Earth's axis, inclined at an angle equal to the latitude of the observer (, phi). See A Tale of Two Sundials. ● The dial plate should be parallel to the plane of the Earth's Equator (perpendicular to the gnomon), inclined at an angle equal to the complement of the observer's latitude--the angle that when added to the angle of the observer's latitude equals a right angle (90°). This angle is also known as the colatitude. See A Tale of Two Sundials. ● Place the sundial on a horizontal surface; the top of the gnomon should point toward the Celestial North Pole (i.e., Polaris, the North wsanford/exo/sundials/equatorial_sundials.html (1 of 8) [3/2/2004 9:26:38 PM] Educator's Guide to Equatorial Sundials Star). More simply, align the upper dial face so that 12 noon points toward geographic north and the 12 noon hour line is aligned with your local meridian. The sundial may be used to align itself with your local meridian. Obtain the exact time of "Sun transit" from the U.S. Naval Observatory Complete Sun and Moon Data for One Day Web page. Set your wristwatch for the exact time of day.1 At the precise moment of Sun transit, align the sundial so that it reads exactly 12 noon (regardless of the time shown by your wristwatch); the sundial is now aligned with your local meridian. Mark the line of the time of Sun transit. For example, a tripod, nylon cord, and boat anchor were used to find the local meridian (see shadow of cord) during SUNdays in September, Huntley Meadows Park, Fairfax County, VA. Disclaimer: The preceding statements regarding the proper alignment of an equatorial sundial are based upon the assumption that the sundial does not feature a built-in correction for longitudinal offset from the Standard Time Meridian (see the following section, "Solar Time Versus Standard Time"). 1 Determine the exact time of day by using either a radio-controlled atomic clock (such as the ExactSet" RM806 from Oregon Scientific, Inc.), or a relatively inexpensive Global Positioning [illegible] Solar Time Versus Standard Time [illegible] 75°W, 90°W, 105°W, and 120°W for the Eastern, Central, Mountain, and Pacific Time Zones, respectively. [illegible] Telling Time Using Shadows [illegible] Earth's Rotation and Solar Time-Keeping Planet Earth is a magnificent timepiece! The Earth rotates counterclockwise once every 24 hours. [illegible] Earth's Revolution Around the Sun and the Annual Cycle of Change in the Sun's Apparent Path Across the Sky [illegible] Table of Equation of Time [illegible] Ancient Sumerians, Babylonians, Chaldeans, and Egyptians [illegible] the shadow at sunrise and sunset, you cannot evenly divide the space between for the individual hours. Try changing the latitude in the applet to the right and see how the hour marks change. There are several ways to overcome these problems. One is to build a horizontal sundial, where the base plate is level, and the "stick," called the style, is angled so it is parallel to the earth's axis. The hour marks can then be drawn by trigonometric calculations, correcting for the sundial's latitude. Another solution is an equatorial sundial, where the base plate is titled at an angle equal to the latitude, and the style is perpendicular to the base, which will align it with the earth's axis. The base can then be marked with regularly-spaced hour marks. (1 of 2) [3/2/2004 9:26:49 PM] The Seasons The tilt of the earth's axis is the reason for our seasons. Try aiming a flashlight straight down at the floor and notice the size of the light beam. Now tilt the flashlight (the earth is tilted 23º 27') and notice how the light beam is spread out over a larger area. In the same way, heat from the sun is spread out over a larger area in the winter. Sundials: How they work Time Zones There are currently 24 time zones, right? Well, not quite. There are several nations that have established time zones that are 30 minutes different from the "standard" zones. So there are actually 29 zones! Oh, yes, there's one more problem. Sundials only measure local solar time. If a friend had a sundial 5 degrees longitude to the west of your sundial, his sundial would read a different time than yours. This is a simple calculation: the earth turns 360 degrees in about 24 hours, therefore the sun's apparent position moves 360/24 = 15 degrees each hour. So your friend's sundial would read 20 minutes different (earlier) than yours. This difference is only affected by longitude, not latitude. To standardize things, the earth was divided into 24 time zones in the 1840's, each to be one hour different from the next. Next: Build a Simple Sundial Previous: What is a Sundial Updated February 10, 1999 . Contacts (2 of 2) [3/2/2004 9:26:49 PM] [3/2/2004 9:26:50 PM] wsanford/exo/sundials/globe_analemma.jpg wsanford/exo/sundials/globe_analemma.jpg [3/2/2004 9:26:50 PM] Analemma [3/2/2004 9:26:52 PM] NASS Links - Photo Time lapse photograph of the sun taken at 8:30 AM over a one-year period. Photo by Dennis di Cicco © Sky & Telescope. Used with permission. [3/2/2004 9:26:53 PM] Construction of an Analemma curve The Analemma Society Analemma Society construction class Building an analemma curve Great Falls Virginia ------------ Figure #1, 19th Cent. Analemma ------------ Figure #2, Building an analemma curve ------------ 1. Draw a perpendicular to a line proportional to the gnomon. 2. Determine length of equinoctial shadow. 3. Mark off this length on gnomon. (For "Observatory Park" latitude the equinoctial shadow for a 20' gnomon is 15' 6".) 4. From the point of intersection of gnomon and line, make a mark to the right on the line and on the gnomon the length of the equinoctial shadow. 5. Connect, with straight line, top of gnomon to mark on line; this is equinoctial shadow of gnomon. 6. Construct a circle from top of gnomon using length of gnomon as radius; this is the meridian. 7. Construct a straight line through circle parallel to line using length of gnomon as distance; this is known as the horizon. 8. Calculate I/15 of circumference. 9. Using this length as radius, make two marks on circle on intersection of equinoctial shadow line and circle. 10. Draw lines from top of gnomon through two points of intersection of the two circles. Line on right is winter solstice sun-ray; line on left is summer solstice sun-ray. 11. From these two points of intersection, draw two lines to opposite side of circle parallel to the equinoctial shadow line; these are called winter and summer diameters. 12. Divide these two lines in half. 13. Construct two semicircles using these points on the outside of the lines. Semicircle on right represents (1 of 2) [3/2/2004 9:26:55 PM] Construction of an Analemma curve 14. 15. Figure #3, Greek analemma, drawn for a 20' gnomon, Greek hours, 90i projection not shown 16. OA - Length of gnomon 18. AB - Length of equinox shadow 17. summer hours; semicircle on left represents winter hours. Extend summer and winter solstice shadow lines to opposite side of circle. Construct straight line through circle connecting centers of the two semicircles; this is the axis. From the intersections of summer and winter diameters, construct line parallel to axis to semicircles. Construct parallel line connecting the points of intersection of the two circles. Using intersection of this line with the equinoctial line as center, describe a circle that passes through intersections of the meridian circle with the summer and winter solstice lines. Support the Observatory Park project Contact us Join the Analemma Society Home/ Roll-top Project/Support Roll-to Project/ Mission / By-laws / Park / History / Park project / Reference / Dark skies / Telescopes / Educational adults / Educational students / Community / Events (2 of 2) [3/2/2004 9:26:55 PM] Great Falls Analemma Society, Astronomy Park FEBRUARY 21TH : Attend our benefit luncheon and help developping astronomy activities in the Observatory Park of Great Falls VIEWING : Analemma Society Observatory Park Great Falls, Virginia Latitude N 38° 59' 40", Longitude W 77° 18' 45" A park to learn science as it developed through astronomy *Our sky tonight *Roll-Top Observatory Project Support the roll-top observatory project Observatory Park Calendar of events *Mission *By-Laws *Existing buildings and future plans *History of the site *The Analemma Society Park project *Reference:Pascal Moon Easter *Great Falls dark skies *Telescopes *Educational program adults *Educational program students *Related Web Sites The President's Pen: Park is open to the public for viewing every Friday night from 7:30 pm weather permitting (Check by clicking HERE the weather forecast for Great Falls and HERE for detailed sky and temperature information). To check special openings see our calendar or contact Charles Olin DIRECTIONS The Analemma Society, formed in 1998, is developing an astronomy park where students can learn about the origin and nature of science as well as experience first hand the wonders of the Universe. This is a great opportunity for Northern Virginia Schools and the community to observe the day and night sky. Support our project and get involved by becoming a member. Use this web site for details on membership, send your support using this web site. Copyright © 2000-2003, Analemma Society. All rights reserved. *THE ANALEMMA, origin and definition Construction class : (1 of 2) [3/2/2004 9:26:56 PM] Contact us Park is located in Great Falls, VA, at the corner of Springvale Road and Georgetown Pike (Rt.#193). Please click HERE for detailed map of Observatory Park access and parking) The 2004 bond referendum is now being finalized. For the Observatory Park to be added to the referendum list we need you to show as soon as possible your Great Falls Analemma Society, Astronomy Park *THE GREEK ANALEMMA Weather forecast : interest and support. BOND REFERENDUM SUPPORT Click here and view the Observatory Park interactive master plan *Support / Join *Become a member *Support our project *Tell us what you think about this project News from NASA : The Space Calendar covers space-related activities and anniversaries for the coming year. Included are over 1,000 links to related home pages. This Calendar is compiled and maintained by Ron Baalke Monthly Calendar (2 of 2) [3/2/2004 9:26:56 PM] An Indoor Annalemma - Robert Terwilliger In the fall of 1995 I moved to a new home where I placed my office in a room high in the north east corner of the building. The room has a large east-facing window through which the sun came - suddenly and brightly - each morning at about 7:30. At first I found this annoying, but then I realized I could take advantage of the situation and project an 8:00am analemma which would demonstrate the Equation of Time. Preliminary observations indicated that the analemma would wind its path across the walls, furniture and floor on the west side of the room. I mounted a cardboard arrow high on the east window for a gnomon, and each morning at 8:00 I placed a small Avery dot where its shadow fell at Standard Time. My first dot was placed on the 1995 winter solstice. During the winter the analemma snaked its way across the north wall, through a bookcase, and onto a filing cabinet on the west wall. A GNOMON'S EYE VIEW of its own ANALEMMA It made it! - this depiction 12-21-1996, the winter solstice Click in the drawing to see a color version. The morning of the vernal equinox was clear and sunny. I placed dots at 5 minute intervals following the path of the shadow as long as the sun entered the room. (1 of 2) [3/2/2004 9:26:58 PM] An Indoor Annalemma - Robert Terwilliger I realized from the Loss Of Sun on the equinox that I was in for some damage control. An eave overhanging the window was going to block the sun during high summer. Also, the point where the loops of the analemma crossed was going to come right where the shadow dropped off the filing cabinet and into the closet. I decided to plot the smaller, summer loop with a second gnomon 10 inches below the first. This had the effect of moving the loop out into the room where it makes an interesting conversation piece. The effect of lowering the gnomon is not obvious in the drawing. On the morning of the summer solstice, I again traced the path of the shadow, this time into and out of the closet, then across the floor. Here is a photograph of the small loop taken a few days after the summer solstice. The photo also shows a portion of the path of the summer solstice shadow as it moved across the floor. The journey through the autumnal equinox and back across the filing cabinets was uneventful, and eventually the shadow crept up onto the north wall. Although the morning of the winter solstice was cloudy I had already placed enough dots to indicate that analemma had found its home, and the year-long project was successfully completed. The timing for the placement of the dots was provided by The Dialist's Companion, a program written by Fred Sawyer and myself recently published by The North American Sundial Society. Analemma started 12-21-1995. Drawing started and put on line 6-22-1996. Updated 7-6, 8-21, 9-24, 10-16, 10-30, 11-10, 11-23, 11-30, 12-9, 12-21 of 1996 Return to The (2 of 2) [3/2/2004 9:26:58 PM] Dialist's Notebook The M&M Millenial Analemma The M&M Millenial Analemma The children are working on our analemma, marking the position of the sun, as shown by a shadow, on their playground. Every week or two for two years, we have run outside at exactly the same time and used a black permanent marker to outline the shadow cast by a ring of metal. We use a small, battery-powered, radio-controlled clock, linked to the atomic clock in Denver, CO, to get the exact time, so that we can mark the shadow at precisely the middle of the day. This is 12:00 noon Central Standard Time and 1:00 PM during Daylight Saving Time. We set a small alarm clock to go off five minutes before 12:00. When the alarm goes off, the kids scream "Analemma" and go into action. One grabs the RC Clock, another gets a black permanent marker, and two more begin to sweep off the spot where we will mark the shadow. This has been one our most successful astronomy activities. The children love it. They watch the shadow of the sun, and say things like "Look how fast it's moving!" Each child in her own way now understands that the sun is low in the wintertime and high in the summertime. Definition of Analemma (1 of 2) [3/2/2004 9:26:59 PM] The M&M Millenial Analemma An analemma is a plot of the declination of the sun versus the Equation of Time. The declination of the sun, loosely speaking, is how "high" it is in the sky; the Equation of Time is how far the sun time is ahead of or behind time shown by an accurate clock. If you are over the age of 40, you may remember seeing an elongated fugure 8 printed on any world globe. For a more complete definition and explanation of the analemma, go to . Return to Astronomy with Children (2 of 2) [3/2/2004 9:26:59 PM] Calculate and Chart the Analemma Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium Calculate and Chart the Analemma Finding the Analemma by Computation. Given the latitude & longitude of the observer, the Sun's altitude & azimuth (A & az) at exactly 12:00 noon Standard Time, and the height of an aperture through which the Sun's image is cast (d), the x,y coordinates for points along the analemma may be calculated using the following formulas (after Waugh, Sundials: Their Theory and Construction, pp. 21-28): VS = d · COT(A) BV = VS · COS(a) BS = BV · TAN(a) (1) (2) (3) Where: \|/ --o-/|\ (to Sun) \ \ = \ \ C |\ | \ | \ | \ d | \ | \ | \ | \ | \ V---------\---B \ \ \ S C d V BV CS S ∠A ∠a = = = = = = = = Sun aperture (a hole ~1/4 in. diameter) 48 in. (given height of Sun aperture) the base, i.e., the point on the floor (or ground) vertically below aperture the meridian beam of sunlight passing through aperture Sun's image ("spot" on the floor) CSV (Altitude of Sun) BVS (azimuth of Sun or angle from the south) Note: Solar altitude & azimuth data are obtained from the USNO Altitude and Azimuth of the Sun or Moon During One Day Web page. The values for COT(A), COS(a), and TAN(a) are obtained from Table 1. Any point along the analemma can be located on the Cartesian Plane by an ordered pair of numbers (x,y), called the coordinates. The origin represents Point V, and in this case, also represents the center of a compass rose. The y-axis represents the meridian (BV): north is toward the top of the y-axis; south is toward the bottom. East is wsanford/exo/sundials/analemma_calc.html (1 of 5) [3/2/2004 9:27:01 PM] Calculate and Chart the Analemma toward the right end of the x-axis; west is toward the left. Construct a graph of the approximate shape of an analemma (as projected on a horizontal surface) using the values for "x" & "y" in Table 2 (see orange columns). The shortest and longest and distances from the base (Point V) are inferred from the values of BV for JUN 21 and DEC 21 respectively. Washington, D.C., ~39°N (38°53'N), ~77°W (77°02'W) Table 1. Altitude & Azimuth of the Sun (at 12:00 noon EST) Month Day Altitude (A) ∠VCS = 90 -A JAN COT(A) = TAN(∠VCS) Azimuth (az) a = az 180 COS(a) TAN(a) 1 15 FEB 1 28.1 29.9 33.8 61.9 60.1 56.2 1.8728 1.739 1.4937 177.0 175.3 173.8 -3.0 -4.7 -6.2 0.9986 -0.0524 0.997 -0.082 0.9941 -0.1086 15 38.2 51.8 1.271 173.1 -6.9 0.993 MAR 1 15 43.3 48.8 46.7 41.2 1.0611 0.875 173.0 173.5 -7.0 -6.5 0.9925 -0.1227 0.994 -0.114 21 51.2 38.8 0.804 173.9 -6.1 0.994 1 15 55.6 60.9 34.4 29.1 0.6847 0.557 174.7 175.8 -5.3 -4.2 0.9957 -0.0927 0.9973 -0.0734 MAY 1 15 66.2 70.0 23.8 20.0 0.4411 0.36397 176.9 176.9 -3.1 -3.1 0.9985 -0.0542 0.9985 -0.0542 JUN 1 15 73.1 74.3 16.9 15.7 0.3038 0.281 175.3 172.7 -4.7 -7.3 0.9966 -0.0822 0.992 -0.128 21 74.5 15.5 0.2773 171.6 -8.4 0.9892 -0.1476 COT(A) = TAN(∠VCS) Azimuth (az) a = az 180 COS(a) TAN(a) APR Month Day Altitude (A) ∠VCS = 90 -A JUL -0.121 -0.107 1 15 74.0 72.4 16.0 17.6 0.2867 0.317 170.0 169.2 -10.0 -10.8 0.9848 -0.1763 0.982 -0.191 AUG 1 68.9 21.1 0.3858 170.4 -9.6 0.9859 -0.1691 15 65.0 25.0 0.466 172.7 -7.3 0.992 1 15 59.3 54.1 30.7 35.9 0.5937 0.724 176.0 178.6 -4.0 -1.4 0.9975 -0.0699 0.9997 -0.024 23 OCT 1 15 51.0 47.9 42.6 39.0 42.1 47.4 0.810 0.9035 1.087 179.8 180.8 182.0 -0.2 +0.8 +2.0 0.9999 -0.003 0.9999 0.0139 0.999 0.035 NOV 1 15 36.6 32.6 53.4 57.4 1.3465 1.564 182.5 182.1 +2.5 +2.1 0.9990 0.0436 0.999 0.037 DEC 1 15 29.3 27.9 60.7 62.1 1.7819 1.8887 180.8 179.2 +0.8 -0.8 0.9999 0.0139 0.9999 -0.01396 21 27.7 63.3 1.905 178.4 -1.6 0.9996 -0.028 SEP -0.128 Washington, D.C., ~39°N (38°53'N), ~77°W (77°02'W) Table 2. Sample Values of the Analemma (at 12:00 noon EST) Month Day VS (in.) y (in.) = BV x (in.) = BS JAN 1 89.904 89.814 -4.670 wsanford/exo/sundials/analemma_calc.html (2 of 5) [3/2/2004 9:27:01 PM] Calculate and Chart the Analemma FEB 15 1 15 83.472 71.712 61.008 83.222 71.282 60.581 -6.824 -7.7697 -7.330 MAR 1 50.928 50.572 -6.220 15 21 42.000 38.592 41.748 38.360 -4.759 -4.105 1 32.880 32.748 -3.045 15 26.736 26.664 -1.957 MAY 1 21.173 21.141 -1.146 JUN 15 1 15 17.471 14.592 13.488 17.445 14.548 13.380 -0.946 -1.193 -1.713 Month 21 Day 13.296 VS (in.) 13.1497 y (in.) = BV -1.946 x (in.) = BS JUL 1 13.776 13.569 -2.388 15 15.216 14.942 -2.854 1 15 1 18.528 22.368 28.512 18.269 22.189 28.455 -3.087 -2.840 -1.992 15 34.752 34.742 -0.834 23 1 15 38.880 43.392 52.176 38.876 43.349 52.124 -0.117 +0.607 +1.824 NOV 1 15 64.656 75.072 64.591 74.997 +2.842 +2.775 DEC 1 15 85.536 90.658 85.450 90.649 +1.196 -1.265 21 91.440 91.403 -2.559 APR AUG SEP OCT Figure 1.0 Approximate shape of an analemma projected on a horizontal surface. The analemma shows the Sun's annual north-south and east-west migration caused by changes in the Sun's declination (see reference table) and Equation of Time (see reference table) respectively. The actual shape and orientation of the analemma depends upon the time of day as well as the time difference between the location of the observer and wsanford/exo/sundials/analemma_calc.html (3 of 5) [3/2/2004 9:27:01 PM] Calculate and Chart the Analemma the Standard Time Meridian (STM): See a side-by-side comparison of the analemma for the same location at two different times: Washington, D.C. at 10 a.m. & 12 noon. For locations east of the STM, the figure eight is offset to the right of the y-axis; for locations west of the STM, the offset is to the left. For example, Washington, D.C. (77°W) is located two degrees west of the STM for the Eastern Time Zone (75°W), therefore the noon analemma for D.C. (shown right) is offset to the left of the y-axis (meridian). Contrast the shape and orientation of the D.C. analemma with the analemma for the ETZ STM (at the same latitude and time). See a side-by-side comparison of the analemmas for the same latitude (39°N) at two different longitudes: 75°W and 77°W (at 12 noon). Experiment with analemmas for other locations (both real-sky and projected) as well as the Equation of Time using SunAnalemma.xls, the Microsoft® Excel workbook by Dr. Robert L. Kellogg, Treasurer, North American Sundial Society. Download and open the workbook. At the following external prompt, click the "Enable Macros" button: [Note: If you launch Microsoft Excel from within Microsoft Internet Explorer, the following prompt appears in an external dialog box: The Sandburg Center for Sky Awareness is a trusted source; click the "Yes" button.] ENTER the "Longitude of [Standard Time] Meridian" and "Longitude of Concern" (e.g., your longitude). Voila! Related Resources ● Charting an Indoor Analemma, honoring the work of the late Dr. James R. Griffith, Ph.D., U.S. Naval wsanford/exo/sundials/analemma_calc.html (4 of 5) [3/2/2004 9:27:01 PM] Calculate and Chart the Analemma Research Laboratory, Washington, D.C. ● An Indoor Analemma projection by Robert Terwilliger, Coconut Grove (Miami), Florida (Webmaster, North American Sundial Society) ● The M&M Millenial Analemma, an outdoor analemma projection by Michael Kauper, Minneapolis, Minnesota (See also Astronomy with Children: Our Backyard Analemma Project, Sky & Telescope magazine, March 2003, pp. 77-81.) Determine the exact time of day by using a radio-controlled atomic clock, such as the ExactSet" RM806 from Oregon Scientific, Inc. ● © Copyright 2003-2004 Walter Sanford. All rights reserved. Me and My Shadow - Making the Sun-Earth Connection | SCSA Home wsanford/exo/sundials/analemma_calc.html (5 of 5) [3/2/2004 9:27:01 PM] Position of the Sun at Noon in Washington, DC Position of the Sun at Noon Washington, DC Click on the image to view a full-resolution PDF file (only 11 kB). (1 of 2) [3/2/2004 9:27:04 PM] Position of the Sun at Noon in Washington, DC For a very nice web site with information about analemmas, see Marc A. Murison Astronomical Applications Dept. U.S. Naval Observatory 19 November 1996 (2 of 2) [3/2/2004 9:27:04 PM] [3/2/2004 9:27:05 PM] [3/2/2004 9:27:06 PM] Altitude ALTITUDE Height above the surface of a planet, measured as an angle between 0 degrees at the horizon and 90 degrees at the zenith. wsanford/exo/altitude.html [3/2/2004 9:27:06 PM] Special Events for 2001-2002 scsa home | mission & goals | scheduling | site visits | curriculum | planetarium visits what's up? | sos | com | special events | resources | wow! | what's new? | contact us | credits "Ye stars! Which are the poetry of heaven!" - Lord Byron (1788-1824) "To see the world in a grain of sand, And heaven in a wildflower; Hold the universe in the palm of your hand, And eternity in an hour." - William Blake Visit the Sandburg Sky Poetry Web page, including CSMS student-authored sky poems. Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium '00-01 Special Events | '99-00 Special Events | '98-99 Special Events Special Events for 2001-2002 (Events sorted in reverse chronological order, ending SEP 2001.) The Dog Days of Summer Ever heard the expression, "the dog days of summer?" "Dog Days is the name for the most sultry period of summer, from about July 3 to Aug. 11. Named in early times by observers in countries bordering the Mediterranean, the period was reckoned as extending from 20 days before to 20 days after the conjunction of Sirius (the dog star) and the Sun." Source: Columbia Encyclopedia Sirius is much like a Greek word meaning "scorcher." The "Dog Days of Summer" refers to the time period during the summer when Sirius--the brightest star in the night sky--is high in the daytime sky, supposedly adding to the heat of the summer Sun (Sirius is searing us). Safe Solar Observing There's more than meets the eye to the little yellow ball in the sky! See what you're missing--plan to attend the Smithsonian National Air and Space Museum Albert Einstein Planetarium FREE Monthly Star Lecture: Safe Solar Observing on Saturday 27 July 2002 at 6:00 p.m. Earth at Aphelion The shape of the Earth's orbit around the Sun is an ellipse (although it is almost perfectly circular); the point at which the Earth is farthest from the Sun is known as aphelion. The Earth reaches aphelion on 06 July 2002 (04h UT)--at a distance of 94,507,300 miles, the Earth is now 3,101,000 miles farther from Sun than at perihelion on 02 January 2002. Food for thought: if the Earth is farthest from the Sun, then why is it summer in the northern mid-latitudes? The answer lies in the annual cycle of change in the apparent path of the Sun across the sky (refer to June Solstice below). Earliest Sunrise/Latest Sunset Washington, D.C. - From June 10-18, the Sun rises at 5:42 a.m. EDT, the earliest time of sunrise all year. From June 20 to July 5, the Sun sets at wsanford/exo/special_events.html (1 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 8:37 p.m. EDT, the latest time of sunset all year. Event Earliest Sunrise Latest Sunset Date(s) 06/10/02 - 06/18/02 06/20/02 - 07/05/02 Time (EST) 05:42 p.m. 08:37 a.m. June Solstice The Summer Solstice occurs at 9:24 a.m. EDT on 21 June 2002. On this date, the Sun reaches the northernmost line of latitude (the Tropic of Cancer, 23.5°N) where the midday Sun is at the zenith (the imaginary point directly overhead). At northern mid-latitude locations, the midday Sun reaches its maximum altitude (annually) and the duration of insolation (number of hours of daylight) is greatest. For example, in Washington, D.C. the midday Sun will reach an altitude of 74.5 degrees above the horizon and there will be nearly 15 hours of daylight (14h54m). Also, the Sun rises farthest to the north of east (to the far left of the Washington Monument in the accompanying photograph) and sets farthest to the north of west than at any other time of year. It's interesting to note that the apparent paths of the Sun and Moon across the sky are exactly opposite at the solstices: near the time of the June Solstice, the Full Moon follows the path of the Sun during the December Solstice; near the time of the December Solstice, the Full Moon follows the path of the Sun during the June Solstice. For more information, see Yin and Yang - Dynamic Equilibrium in the Universe. By jimminy, it's time to say, "Bye, Gemini!" Ever heard the old expression, "by jimmy?" Originally, the phrase meant something like, "with any luck," derived from the mythological association between the Gemini Twins and good luck. By the middle of June, your luck has run out as the constellation Gemini (No. 3, FCPS Starfinder) slips below the western horizon shortly after 9 p.m. National Hurricane Awareness Week The National Weather Service has declared May 19-25, 2002 as National Hurricane Awareness Week. Each day of the week will have a special emphasis: SUN : History M-W : Hurricane Hazards THU : Forecast FRI : Prepare SAT : Take Action wsanford/exo/special_events.html (2 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 "The goal of Hurricane Awareness Week is to educate you about the hazards of Hurricanes and provide you with knowledge which can be used to help protect you, your family, and your property." [Quote courtesy the NOAA/NWS Tropical Prediction Center (TPC), formerly known as the National Hurricane Center (NHC).] Sandburg Sun-Earth-Moon Day 2002 Weather permitting, the Sandburg Planetarium will host "Sun-Earth-Moon Day" on Mon., 06 May 2002, from 8:30 a.m. 'til 2:40 p.m. (Rain Date: Tue., 07 May.) The event is timed to coincide as closely as possible with Space Day (Thu., 02 May) and the Last Quarter Moon (Sat., 04 May). Amateur astronomers from the Maryland Sidewalk Astronomers (MSA), National Capital Astronomers (NCA), Northern Virginia Astronomy Club (NOVAC), and Shenandoah Astronomical Society (SAS) have volunteered to be our guides for a day of sundialing, safe sunspot observing, and Moon-watching. Editor's Note: Good friends and good conditions combined for a great day for firsthand observation of the real sky: fair weather prevailed for most of the day (relatively clear skies and comfortable temperatures); and the daily sunspot number was high (317). In a word, S-E-M Day 2002 was another smashing success! For details, read Sandburg "Sun-Earth-Moon Day 2002" - a special report highlighting Sandburg Planetarium's local celebration of Space Day. Astronomy Day at Huntley Meadows Park Due to inclement weather, has been rescheduled for Sunday, 28 April, 3-9 p.m. Weather permitting, join Planetarium Teachers from Fairfax County Public Schools (Sandburg, Edison, & TJHSST), volunteers from the Northern Virginia Astronomy Club (NOVAC), and Fairfax County Park Authority Naturalists for a local celebration of National Astronomy Day 2002 on Saturday, 20 April 2002, at Huntley Meadows Park, Fairfax County, VA. A variety of activities are planned. From 3:00 'til 9:00 p.m., astronomy experts will be on-hand to provide guidance and answer questions. Planetarium Teachers will provide a guided tour of the evening sky, featuring all five of the visible planets as well as prominent stars & constellations visible with the unaided eye. Binoculars and wsanford/exo/special_events.html (3 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 telescopes will be available for public observation of day and night sky phenomena, including sunspots (3:00 - 6:00 p.m.), the First Quarter Moon (day & night), planets, especially Jupiter and Saturn (beginning at twilight), and other night sky targets such as binary stars, star clusters, and galaxies. Two formal workshops (reservations required) will be held at the Huntley Meadows Park Visitor Center: ● 4:00 - 6:00 p.m. - Making & Using an Equatorial Sundial/Real-Sky Solar Observation; and ● 6:30 - 9:00 p.m. - Making & Using a Starfinder/Night Sky Observation Workshops are open to adults and families with children nine (9) years and older. Space may be infinite, but in this case, space is limited! For more information or to make reservations, contact Kitty Keller, FCPA Naturalist, at 703-768-2525. Rain Date: Sunday, 28 April 2002 [Astronomy is part of the program, "Bringing Astronomy to the People"--the Sandburg Planetarium public outreach initiative for 2001-2002.] Editor's Note: During a three-hour window of opportunity between morning and evening rain events, approximately 50-70 people participated in See photographs of the special event as well as the park, courtesy Phil Wherry. A Gathering of Planets During late-April and early-May, all five planets visible with the unaided eye can be seen in the western sky during twilight. For more information, including graphics illustrating where to look for the planets from 20 April 'til 03 June 2002, visit A Gathering of Five Planets, courtesy the Henry Buhl, Jr. Planetarium and Observatory, Carnegie Science Center. For additional narrative and graphics, see either Planets Gather in Evening Sky, a 15 March 2002 press release from Griffith Observatory, or Spring's Dancing Planets, courtesy Astronomy.com. First 90-Degree Day wsanford/exo/special_events.html (4 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 Tuesday, 16 April 2002 the high temperature at Reagan National Airport (DCA) exceeded 90°F--the first 90-degree day for the year 2002 (May 19 is the average date of the first 90-degree day at DCA; September 12 the last). Spring Forward... At 2:00 a.m. on Sunday, 07 April 2002 set your clocks forward one hour to begin "Daylight Saving Time" (EDT). Something of a misnomer, we merely shift the increasing daylight hours from morning to evening. Daylight Saving Time begins on the first Sunday in April (spring forward...) and ends on the last Sunday in October (...fall back). April is National Poetry Month Celebrate National Poetry Month and increase your sky awareness by reading some of Carl Sandburg's sky-related poetry, or by reading Carl Sandburg Middle School student-authored sky-related poetry. Comet Ikeya-Zhang A simple comet-watching mnemonic: I C IC C I-Z? (I see icy Comet Ikeya-Zhang?) Maybe. "A newly discovered comet, now approaching the Sun and Earth, could develop into a relatively bright naked-eye object in coming weeks, researchers say. The best views of the comet may be reserved for those under dark skies far from bright lights, but even city dwellers should be able to spot it. ... Ikeya-Zhang's expected path across the sky in the coming weeks will greatly favor Northern Hemisphere observers. During most of March on into early April, the comet will be visible near to the north-northwest horizon about an hour after sundown. Bright moonlight may hinder observations during the last week of March." [Source: Comet makes its celestial entrance, courtesy MSNBC.] As of 15 February, Ikeya-Zhang's apparent magnitude was +6.8m. For reference, +6.0 is the naked-eye limit at a dark site; +9.0 is the limiting magnitude of 50mm binoculars. Comet Ikeya-Zhang is expected to peak somewhere between +3.5 and +3.0. "The 1986 appearance of Halley's Comet, considered disappointing by many, also peaked at around magnitude 3.0. In contrast, Comet Hale-Bopp, which put on a memorable show in April 1997, attained a brightness close to magnitude -1, or about 60 times brighter than Halley." [Source: ibidem, MSNBC] For more information (including graphics showing where to look in the sky for the comet), read Comet Ikeya-Zhang (updated 01 MAR '02), an wsanford/exo/special_events.html (5 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 article featured at Sky & Telescope online. Ikeya-Zhang Updates: ● Finder Charts for 13-19 March 2002 ● Finder Charts for 20-26 March 2002 ● Finder Charts for 27 March - 02 April 2002 March Equinox The March Equinox occurs at 19:16 UTC (2:16 p.m. EST) on 20 March 2002. The word equinox literally means "equal nights," referring to either of two times of the year when the Sun crosses the plane of the Earth's Equator and day and night are of nearly equal length, that is, about March 21 and September 21. The Sun rises exactly due east (just to the right of the Washington Monument in the accompanying photograph) and sets due west. The March Equinox is the beginning of astronomical spring in the Northern Hemisphere and autumn in the Southern Hemisphere (in the Northern Hemisphere, meteorological spring is MAR, APR, and MAY). Celebrate the Equinox and the Seasons by participating in a local observance of NASA Sun-Earth Day, Wednesday, 20 March 2002. [Teachers: See the SCSA/Themes/Sun-Earth Connection Web page for theme-related information resources and suggested teaching strategies.] Sundials & Equinoxes: Theoretically, the gnomon (or style) of a properly oriented equatorial sundial will not cast a shadow on the dial plate during the equinoxes. Because the dial plate of an equatorial sundial is parallel to the Earth's Equator, the Sun is directly over the edge of the dial plate on the equinoxes, when the Sun is at the zenith along the Equator. From the March Equinox to the September Equinox, when the Sun is at the zenith in the Northern Hemisphere (between 0° and 23.5°N lat.), the gnomon shadow falls on the upper dial face; from the September Equinox to the March Equinox, when the Sun is at the zenith in the Southern Hemisphere (between 0° and 23.5°S lat.), the gnomon shadow falls on the lower dial face. March: In Like a Lion; Out Like a Lamb. You've probably heard the old saying, "March comes in like a lion and goes out like a lamb." Usually, this saying is used to describe typical March weather: in the beginning of March, the weather is often wild; by the end of March, the weather is usually mild. But this modern weather proverb actually originates from astronomy: in the late-February/early-March night skies, Leo, the Lion (No. 5, FCPS Starfinder) is rising in the east ("coming in") at the same time that Aries, the Ram (lamb) is setting in the west ("going out"). wsanford/exo/special_events.html (6 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 Perigee & the Full Moon; the Moon Illusion 27 February 2002, the closest perigee of the year coincides with the Full Moon (see the Lunar Perigee and Apogee Calculator). Huh? The Moon's orbit around the Earth is an ellipse (not a perfect circle), therefore the Earth-Moon distance varies: perigee is when the Moon is closest to the Earth; apogee is when the Moon is farthest. Does the Earth-Moon distance vary enough to affect the apparent size of the Moon? In a word, yes (see Inconstant Moon - The Moon at Perigee and Apogee or Big Moonshine), although the difference may be imperceptible to all but the most careful observers. Read about the "Moon Illusion," an unrelated phenomenon wherein some people perceive that the Moon appears to be larger when it is near the horizon than when it is higher in the sky: ● Explaining The Moon Illusion - why the Moon looks larger close to the horizon (by Lloyd Kaufman and James Kaufman for the Proceedings of the National Academy of Sciences) [reference: USNO Data Services FAQ] ● Scientists Offer Answer to Baffling Lunar Illusion Moon Occults Saturn Webster's Dictionary defines occult (transitive verb) as "to shut off from view or exposure, to cover, or eclipse." On 20 February 2002, the Moon occults Saturn. Slightly past First Quarter, the Moon is 55% illuminated (right side). In Washington, D.C., Saturn disappears behind the Moon's dark limb (upper left side) at 7:17 p.m. EST; it reappears on the bright limb (slightly above center, right side) at 8:39 p.m. The Moon's limb takes approximately two minutes to cover/uncover Saturn from ring tip to ring tip. The occultation may be seen with either the unaided eye or binoculars, however magnification of at least 30x is required to resolve the rings of Saturn (a small, "department store" telescope should be satisfactory). 18 February 2002 - Pluto Anniversary Pluto was discovered 72 years ago today by Clyde W. Tombaugh, February 18, 1930. 02 February 2002 - Groundhog Day According to legend, if the groundhog sees his shadow on February 2nd, then there will be six more weeks of winter weather; if he doesn't see his shadow, then there will be an early spring. Hogtivities provides a list of activities for celebrating Groundhog Day with younger students. Editor's Note: Punxsutawney Phil saw his shadow, and we know what wsanford/exo/special_events.html (7 of 14) [3/2/2004 9:27:11 PM] Special Events for 2001-2002 that means.... Sigh! Cold Facts to Warm Your Heart! At last, winter's icy grip may be slipping! Tuesday, 29 January, the daily average temperature in Washington, D.C. begins increasing--yippee!!! Latest Sunrise/Earliest Sunset The date(s) of latest sunrise occurs at the end of December/beginning of January; the date(s) of earliest sunset occurs in early December: Event Latest Sunrise Earliest Sunset Date(s) Time (EST) 12/31/01 - 01/10/02 12/02/01 - 12/12/01 07:27 a.m. 04:46 p.m. Earth at Perihelion The shape of the Earth's orbit around the Sun is an ellipse (although its orbit is almost perfectly circular); the point at which the Earth is closest to the Sun is known as perihelion. The Earth

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See details. Amazon.com now offers bargains on these brand-name essentials, all priced so low they've sunk to the bottom of the page! We take up to 50% off standard retail prices and deliver right to your door--no club fees, no hassle, no parking lot. Check back every day at noon (central time) for all-new Bottom of the PageTM Deals. Conditions of Use | Privacy Notice © 1996-2004, Amazon.com, Inc. or its affiliates 3D2-1/ref%3Dsr%5F2%5F1/102-8971606-4734554 (6 of 6) [3/2/2004 9:28:37 PM] Amazon.com: Books: Sundials, Their Theory and Construction Your Gold Box Search Browse Subjects Bestsellers Magazines Corporate Accounts e-books & docs Bargain Books Used Books Sundials, Their Theory and Construction by Albert Waugh (Author) Books WEB SEARCH buying info List Price: $8.95 Sign in to turn on 1-Click ordering. Price: $8.95 & eligible for FREE 76 used & new from $2.35 Super Saver Have one to sell? Shipping on orders over $25. See Look inside this book details. Don't have one? We'll set one up for you. Availability: Usually ships within 24 hours Only 4 left in stock--order soon (more on the way). customer reviews look inside Want it delivered Thursday, March 4? Choose One-Day Shipping at checkout. See details. RECENTLY VIEWED Sundials : Their Construction and Use by R. Newton Mayall (Author), Margaret W. Mayall (Author) The Illustrated Longitude by Dava Sobel, William J. H. Andrewes See more in the Page You Made Featured Item: The Riddle of the Compass by Amir D. Aczel (Author) 76 used & new from $2.35 Edition: Paperback Other Editions: Hardcover List Price: Our Price: Other Offers: $25.50 $25.50 2 used & new from $23.50 See more product details Better Together Buy this book with Sundials by R. Newton Mayall (Author), Margaret W. Mayall (Author) today! Buy Together Today: $19.31 Customers who bought this book also bought: ● Easy-to-Make Wooden Sundials by Milton Stoneman (Author) ● Sundials : History, Theory, and Practice by Rene R.J. Rohr 3D1026666293/sr%3D12-1/102-8971606-4734554 (1 of 7) [3/2/2004 9:28:40 PM] Amazon.com: Books: Sundials, Their Theory and Construction RATE THIS BOOK I dislike it 1 2 ● I love it! 3 4 ● Latitude Hooks and Azimuth Rings: How to Build and Use 18 Traditional Navigational Instruments by Dennis Fisher ● Time's Pendulum: From Sundials to Atomic Clocks, the Fascinating History of Timekeeping and How Our Discoveries Changed the World by Jo Ellen Barnett 5 Edit your ratings Favorite Magazines! (Author) Making a Clock-Accurate Sundial Customized to Your Location (for the Northern Hemisphere) by Sam Muller Explore Similar Items: 20 in Books Customers interested in Sundials, Their Theory and Construction may also be interested in: Sponsored Links (What's this?) Feedback Explore our new Magazine Subscriptions store. ● ● ● Premium Garden Products Fountains, Statuary, Decor & More. 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On one hand, it is a rigorous appraisal of the science of sundials including mathematical treatment 3D1026666293/sr%3D12-1/102-8971606-4734554 (2 of 7) [3/2/2004 9:28:40 PM] Amazon.com: Books: Sundials, Their Theory and Construction and pertinent astronomical background. On the other hand, it provides a nontechnical treatment simple enough so that several of the dials can be built by children. 106 illustrations. All Customer Reviews Average Customer Review: Write an online review and share your thoughts with other customers. 7 of 7 people found the following review helpful: Overall the best available sundial text., March 18, 2002 Reviewer: Alex (see more about me) from Melbourne Australia I have read and viewed the major English language texts on Sundials. These being 1.Waugh, 2. Mayall & Mayall, and 3. Rohr. The Waugh text has good, mostly clear, intructions and gives both graphical and equation based methods of constructions. Mayall and Mayall perhaps has better graphical constuctions but Waugh excells in the variety of tables in the appendix. Waugh also has the clearest explanation of determining the declination of a wall. This is very important as many buildings are aligned along magnetic north (& south & east &west) rather than true north (south etc...). A shortcoming of the almost every book including Waugh, is the lack of clear instruction on how to draw other types of hours. Most importantly of these interesting alternatives types of hours are babylonian and Italian hours. These hours are still useful today. So far I've only found the Rohr text to have any attempt of explaining how to draw these lines. However the Rohr text simply doesn't match the clarity and breadth of Waugh and Mayall and Wayall. Waugh (and Mayall and Mayall) both could do with an update on trigonometry. With the easy availability of scientific calculators, the need for log versions of equations and the use of things like "cot" functions is not needed and simply makes the calculations clumsy to perform on a key pad. The book by Cousins is an excellent higly detailed text if you can get it, but it seems to be out of print. It is useful if you really want to get into the maths of spherical geometry and it wouldn't be the best book you'd want to read first. It makes you appreciate the wonderful elegance of the graphical solutions but it may convince you that it is all too hard when it actually isn't in a practical sense. Just about anyone can make a simple sundial. The text by Rohr also has a good section on how to do hour lines on just about any shaped surface (bowl, sphere, plane etc..) if you have a rod for a gnomen. This is about the only strength of this text over the others. So to conclude Waugh would be the best first text, very closely followed by Mayall and Mayall, then Rohr. The text by Cousins is excellent but at a much higher level that isn't needed for the construction for the standard types of dials. Was this review helpful to you? 3D1026666293/sr%3D12-1/102-8971606-4734554 (3 of 7) [3/2/2004 9:28:40 PM] Amazon.com: Books: Sundials, Their Theory and Construction 3 of 3 people found the following review helpful: Definitely a classic..., January 6, 2002 Reviewer: Dan Lamb (see more about me) from Calgary, Canada I agree with the other reviewers...This is a very clear and concise treatment of the theory and practice of sundial construction. It is a very easy read, (anyone over the age of around 12-13 should have no difficulty with it at all,) and entertaining to boot! It has a few items that some of the other 'classics' on sundials do not. (Rene Rohr;s book "Sundials:History, Theory and Practice" and Mayall & Mayall's "Sundials":Their Construction and Use".) The only thing this book really misses, (and the same holds true for virtually every book on sundials!) is the link between sundials telling time, and their potential use for navigation. Apart from that, this is a great book, and I highly recommend it. Was this review helpful to you? 6 of 6 people found the following review helpful: Best book on sundials I've ever seen, August 29, 1998 Reviewer: (red) from Rising Sun, MD This book not only covers everything from time itself to more marks to fancy sundials, it is well written and fun to read - a rare combination in a "technical" book. Was this review helpful to you? 15 of 15 people found the following review helpful: The all-time classic work on dialing, July 24, 1998 Reviewer: An Amazon.com Customer Albert Waugh's "Sundials: Their Theory and Construction" is a veritable treasure-house of information on the ancient science of gnomonics. As a dedicated dialist of several years, I never could have achieved such wonderful results without Waugh's classic book. The work presents the art of building sundials from two perspectives: for the advanced dialist, Waugh's book approaches the theory from a highly complex, mathematical viewpoint, including some aspects of celestial mechanics; for the average "do-it-yourself-er", Waugh presents several projects that are simple and well-explained. Accompanying this fine work is a collection of solar tables, astronomical information, and various data of inestimable value that would alone justify the purchase price of the book. So whether your purpose is to further your technical interest in the fascinating science of gnomonics, or merely to build an attractive sundial for your garden over the weekend, "Sundials": Their Theory and Construction" should be in your collection. It is considered the very "bible" of dialmaking. I couldn't brag about it more had I written it myself! Was this review helpful to you? 3Dtab%5Fm%5Fgw%5Fl/102-8971606-4734554 (4 of 7) [3/2/2004 9:28:40 PM] Amazon.com: Books: Sundials, Their Theory and Construction See all 5 customer reviews... Customers who bought titles by Albert Waugh also bought titles by these authors: ... R. Newton Mayall ... Customers who bought this book also bought: ... Amazon.com: Books: Sundials, Their Theory and Construction ...

exists in the atmospheres of these planets. Daytime temperatures range from 600 K (621 F) on Mercury to 300 K (81 F) on Mars. In addition, the most striking difference between the terrestrial planets and outer solar system planets lies in average density. Mercury: 5430 kg/cubic meter Venus: 5250 kg/cubic meter Earth: 5520 kg/cubic meter Mars: 3950 kg/cubic meter Jupiter: 1330 kg/cubic meter Saturn: 660 kg/cubic meter Uranus: 1290 kg/cubic meter Neptune: 1640 kg/cubic meter Pluto: 2030 kg/cubic meter But the outer planets dominate in size, ranging from Jupiter (11.21 Earth diameters) to Neptune (3.88 Earth diameters). Pluto is the smallest planet in our solar system, 0.18 the Earth's diameter and even labeling Pluto a planet has recently been debated. thermonuclear fusion A star's light or photon engine. Every star on the main sequence converts mass into energy through thermonuclear fusion. The process demands high temperature and pressure in order to fuse the hydrogen into helium, due to powerful electromagnetic forces separating neighboring H atoms. tidal force The difference between gravitational forces on opposite sides of an object, like a planet or moon. Gravity is a force that depends on both the involved masses and distance between the masses. The Moon-Earth gravitational interaction results in sea tides on Earth. Elsewhere in the solar system, the magnitude of gravitational force on Jupiter's moon, Io, is greatest on the Jupiter side of Io, and least on the backside. The difference between the two forces compresses and stretches Io, which in turn heats up Io's interior. As a result, Io is the most geologically active body in the solar system. total solar eclipse Results from the Moon completely blocking out the Sun in the sky (see eclipse). The Moon's shadow narrowly projects onto the Earth, making this a rare experience. transit The time at which a celestial object is highest in the sky. This is the best time to view the object. At transit, the object's light travels through the thinnest possible layer of Earth's atmosphere, which can distort an object's appearance. At times of rise and set, when an object is nearest the horizon, its light travels through the most atmosphere. See also right ascension (2 of 3) [3/2/2004 9:28:44 PM] StarDate Online | AstroGlossary | T declination A B C D E F G H I J K L M N O P Q R S T U V W X Y Z Home | Site Map | Privacy | Copyright ©1995-2004 The University of Texas McDonald Observatory Información en español (3 of 3) [3/2/2004 9:28:44 PM] Solartech Model 6.5 Specifications Sensor Silicon Carbide (SiC) Photodiode packaged on gold plated header via gold wire bonding under UV glass window cap, hermetically sealed. Radiometer Peak sunlight response bandwidth: 297-310nm Total solar response: 290-400nm, Diffey Display: 3 ½ digit LCD Resolution: 0.1 UVI Power Source: 9V DC battery Accuracy: +-5% ref NIST (NBS) standards Model 6.5 Price: $179.00 If you cannot find this meter at a local distributor, you can order direct. Proper usage of Solarmeter Ultraviolet Radiometer for Outdoor UV Index Measurement The instrumentation used to measure UV index for the U.S. E.P.A./NWS program is directed toward the sky in a global normal (perpendicular to level ground) inclination. Therefore the Solarmeter ® is designed to operate in the same fashion. Solar irradiance measured this way includes direct (reduced by cosine law depending on solar zenith angle) plus global (diffused by the atmosphere). This verticle reading represents an average intensity value your body will experience while being active on a tennis or volleyball court, or lying flat on a blanket on the grass. If however, you are reclined in a lounge chair facing the sun perpendicular to the sun angle, you will experience a higher UV intensity, as represented by pointing the Solarmeter ® directly at the sun. This value will typically exceed the UV index number. (1 of 3) [3/2/2004 9:28:48 PM] Solartech To obtain the UV index instantaneous value, the following instructions will provide the most consistent, accurate results: ● Stand clear of buildings, trees, etc. to avoid absorption, diffusion effects of surroundings. ● Face the sun direction and hold meter verticle in front of you (Figure 1) ● Press and hold button on front of meter case. Note reading on LCD. This value represents the instantaneous UV index. ● If planning to sunbathe in a lounge chair facing the sun, or if sitting in a stadium facing the sun, tilt meter directly toward sun to obtain direct reading. Take extra precaution under these conditions to reduce sun damage. Note that various cloud conditions reduce UV index. When partly cloudy, take readings often and average clear with cloudy readings to correlate with UV index. Interpretation of UV index Relative to Proper Precautions U.S. EPA publication #430-F-94-016 dated January 1995 provides an excellent overview describing exposure levels and precautions. Also, the sunscreen manufacturer industry may offer SPF values proportional to the UV index. However, the best source of precautionary information should be your own medical physician relative to your skin type, family history and other variables. Detailed UV index reports from the EPA #430-F-94-017 and 019 equate the index values to skin type and (2 of 3) [3/2/2004 9:28:48 PM] Solartech minutes to burn according the graph to the right. There are five skin types ranging from Type I (always burns/never tans) to Type V (always tans/rarely burns). This chart indicates the range from most sensitive to least sensitive skin. Since minutes to burn for previously unexposed Types I and II are so short, these types should follow all of the following precautions regardless of the UV index values. Consult your physician to verify your skin type. Precautions Outdoors To reduce the chance of sunburn, skin cancer, and eye damage: ● ● ● ● ● ● ● Minimize sun exposure at midday (10:00 a.m. to 4:00 p.m.) Apply sunscreen with SPF-15 or higher to all exposed areas of the body. Reapply sunscreen every two hours, even on cloudy days, especially after swimming or perspiring. Be aware of reflective surfaces (water, sand, snow) which increase UV exposure. Wear clothing that covers the body and shades the face. Protect children by keeping them from excessive sun and applying sunscreen frequently to children older than 6 months of age. Wear sunglasses that absorb 99-100% of the full UV spectrum when outdoors in bright sun. Remember, the most important UV damage prevention is to avoid sunburn! The Solarmeter® model SM6.5 is not a medical instrument, but rather an affordable scientific instrument designed to help you avoid sunburn by providing an instantaneous UV index value. Among the outdoor variables affecting UV intensity are: ● Seasonality/Sun Zenith Angle ● Location/Latitude/Geography ● Reflective Surroundings ● Altitude ● Weather conditions ● Ozone Layer Thickness By regularly using the Solarmeter® you will become very informed of damaging UV levels in many and varied conditions. This knowledge, along with following the outdoor precautions mentioned above, should help enable you to avoid sun damage. Rev. 26 May 2003 Copyright © 1998-2003 Solartech, Inc. (3 of 3) [3/2/2004 9:28:48 PM] Solartech Solartech, Inc. UV Meters Welcome to Solartech, Inc., the UV meter specialists. We supply the best value high quality hand-held UV measurement devices in the industry. Click HERE to go to Japanese ("ú–{Eê) Page. Rev. 26 May 2003 [3/2/2004 9:28:49 PM] Copyright © 1998-2003 Solartech, Inc. Environmental Protection Agency Protecting human health, safeguarding the natural environment Recent Additions | Contact Us | Print Version Advanced Search EPA Newsroom Special Features Browse EPA Topics ● Clear Skies Laws, Regulations & Dockets ● Budget, Goals and Performance Where You Live Information Sources Educational Resources About EPA Programs Business Opportunities Jobs Recursos en Español Search: ● Winter Wise Tips ● Ongoing 9/11 response Top Stories EPA and nations counties announce energy efficiency challenge Mar. 1 - The National Association of Counties, representing more than 1,500 county officials, joined EPA in challenging counties to protect the environment, save energy and cut operating costs by improving the energy efficiency of county courthouses and office buildings. News release | comunicado de prensa | ENERGY STAR Expert panel to study World Trade Center health Mar. 1 - EPA is convening an expert technical review panel to obtain greater input on ongoing efforts to monitor health effects for workers and residents impacted by the collapse of the World Trade Center. The panel will characterize any remaining exposures and risks, identify unmet public health needs, and recommend any steps to further minimize the risks associated with the aftermath of the World Trade Center attacks. News release | World Trade Center Expert Technical Review Panel EPA and Department of Energy sign agreement to link supercomputers Feb. 19 - Under a (1 of 2) [3/2/2004 9:28:51 PM] Mike Leavitt Administrator's Web site Key Topics Air Cleanup Compliance & Enforcement Economics Ecosystems Emergencies Environmental Management Environmental Technology Human Health Industry International Cooperation Pesticides Pollutants / Toxics Pollution Prevention Environmental Protection Agency memorandum of understanding, this agreement will strengthen the scientific foundation for environmental, energy and public health issues. News release | comunicado de prensa Radiation 39 new facilities join Performance Track program Feb. 11 - Performance Track rewards facilities that voluntarily exceed regulatory requirements and set goals to continuously improve their environmental performance. News release | comunicado de prensa | Performance Track Water Research Treatment & Control Wastes [Browse EPA Topics] Smartway Transport announces 50+ partners Feb. 9 - Voluntary freight industry program promotes fuel efficiency and reduction of greenhouse gas and pollutant emissions. More than 50 shippers and carriers have signed partnership agreements. News release | comunicado de prensa | SmartWay Transport Partnership [More from the EPA Newsroom and News Around the Nation] EPA Home | Accessibility | Privacy and Security Notice | FOIA | Civil Rights Statistics | Contact Us (2 of 2) [3/2/2004 9:28:51 PM] Welcome to the EPA SunWise Site SunWise School Program Recent Additions | Contact Us | Print Version EPA Home > SunWise Overview Ozone Layer UV Index Action Steps Publications Glossary Links FAQs Recognition Program Recursos en Español (1 of 3) [3/2/2004 9:28:54 PM] Search: Welcome to the EPA SunWise Site EPA Home | Privacy and Security Notice | Contact Us (2 of 3) [3/2/2004 9:28:54 PM] Welcome to the EPA SunWise Site (3 of 3) [3/2/2004 9:28:54 PM] CDNOW All Products Hello. Sign in to get personalized recommendations. New customer? Start here. Top Sellers in Music Feels Like Home • Music • DVD • Video Norah Jones blew everybody away with her jazzy, country-tinged, Grammy-winning debut CD, Come Away With Me. On this recording, Jones doesn't mess with her trademark formula. Under Arif Mardin's cozy... Read more More Top Sellers: Leslie Sansone - Walk Away the Pounds 3 Pack (includes weight set) VHS ~ Leslie Sansone Stargate SG-1 Season 6 Boxed Set DVD ~ Richard Anderson New and Future Releases Memorex 2.4x DVD+RW (25 Pack Spindle) Amazon.com Product Description The DVD+RW rewritable disc is single sided and can store 3Dtab%5Fm%5Fgw%5Fl/102-8971606-4734554 (1 of 3) [3/2/2004 9:28:57 PM] CDNOW up to 4.7 GB of data and 2 hours Top Sellers of video. Each disc is designated as RW to avoid user confusion. Music The disc was developed for new Feels Like Home DVD+RW drives,... Read more The Passion of the Christ (Score) 3rd Degree by James More Music bestsellers Patterson, Andrew Gross Apple 15 GB iPod DVD M9460LL/A by Apple Computer Stargate SG-1 Season 6 Lost In Translation Boxed Set Lost In Translation (Widescreen Edition) DVD ~ (Widescreen Edition) Scarlett Johansson Ocean Wonders Aquarium More DVD bestsellers by Fisher-Price Listmania! (What is this?) Video Leslie Sansone - Walk Away the Pounds 3 Pack (includes weight set) Winged Migration More Video bestsellers My Favorite Albums of 2003 in No Particular Order (25 item list) About the CDNOW/Amazon.com Alliance Must own NEW music (10 item list) ● Best Music Ever(in no order) ● My favorite music ● Albums On My Newest CD Rack About the CDNOW Preferred Buyer's Club Your Privacy 3Dtab%5Fm%5Fgw%5Fl/102-8971606-4734554 (2 of 3) [3/2/2004 9:28:57 PM] CDNOW Where's My Stuff? • Track your recent orders. • View or change your orders in Your Account. Shipping & Returns • See our shipping rates & policies. • Return an item (here's our Returns Policy). Search All Products Need Help? • Forgot your password? Click here. • Redeem or buy a gift certificate. • Visit our Help department. for Turn your past purchases into $$$ Learn more about selling at Amazon.com today! Top of Page Directory of Amazon.com Stores Help | Shopping Cart | Your Account | Sell Items | 1-Click Settings | Join Advantage Conditions of Use | Privacy Notice © 1996-2004, Amazon.com, Inc. or its affiliates 3Dtab%5Fm%5Fgw%5Fl/102-8971606-4734554 (3 of 3) [3/2/2004 9:28:57 PM] Imagine the Universe! Dictionary enter search text Imagine the Universe! Dictionary Please allow the whole page to load before you start searching for an entry. Otherwise, errors will occur. [A B C D E F G H I J K L M N O P Q R S T U V W X Y Z] (Note - Greek letters are written out by name - alpha, beta etc.) A accretion Accumulation of dust and gas onto larger bodies such as stars, planets and moons. accretion disk A relatively flat sheet of gas and dust surrounding a newborn star, a black hole, or any massive object growing in size by attracting material. active galactic nuclei (AGN) A class of galaxies which spew massive amounts of energy from their centers, far more than ordinary galaxies. Many astronomers believe supermassive black holes may lie at the center of these galaxies and power their explosive energy output. Tell me about AGN! Tell me more about AGN! angstrom A unit of length equal to 0.00000001 centimeters. This may also be written as 1 x 10-8 cm (see scientific notation). angular momentum (1 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary A quantity obtained by multiplying the mass of an orbiting body by its velocity and the radius of its orbit. According to the conservation laws of physics, the angular momentum of any orbiting body must remain constant at all points in the orbit, i.e., it cannot be created or destroyed. If the orbit is elliptical the radius will vary. Since the mass is constant, the velocity changes. Thus planets in elliptical orbits travel faster at perihelion and more slowly at aphelion. A spinning body also possesses spin angular momentum. apastron The point of greatest separation between two stars which are in orbit around each other. See binary stars. Opposite of periastron. aphelion The point in its orbit where a planet is farthest from the Sun. Opposite of perihelion. apoapsis The point in an orbit when the two objects are farthest apart. Special names are given to this orbital point for commonly used systems: see apastron, aphelion, and apogee. apogee The point in its orbit where an Earth satellite is farthest from the Earth. Opposite of perigee. Ariel V A UK X-ray mission, also known as UK-5 Tell me more about Ariel V ASCA The Japanese Asuka spacecraft (formerly Astro-D), an X-ray mission Tell me more about ASCA ASM All Sky Monitor. An instrument designed to observe large areas of the sky for interesting astronomical phenomena. An ASM measures the intensity of many sources across the sky and looks for new sources. Many high-energy satellites have carried ASM detectors, including the ASM on Vela 5B, Ariel V, and the Rossi X-ray Timing Explorer. Astro E A X-ray/gamma-ray mission built jointly by the United States and Japan. Astro E was destroyed in February 2000, when a Japanese M-5 rocket failed to lift the instrument into orbit. A replacement mission, Astro-E2, is planned for 2005. Tell me more about Astro E astronomical unit (AU) 149,597,870 km; the average distance from the Earth to the Sun. astronomy The scientific study of matter in outer space, especially the positions, dimensions, distribution, motion, composition, energy, and evolution of celestial bodies and phenomena. astrophysics The part of astronomy that deals principally with the physics of the universe, including luminosity, density, temperature, and the chemical composition of stars, galaxies, and the interstellar medium. (2 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary atmosphere The gas that surrounds a planet or star. The Earth's atmosphere is made up of mostly nitrogen, while the Sun's atmosphere consists of mostly hydrogen. AXAF The Advanced X-ray Astrophysics Facility. AXAF was renamed Chandra X-ray Observatory, CXO, and launched in July 1999. Tell me more about AXAF B Balmer lines (J. Balmer) Emission or absorption lines in the spectrum of hydrogen that arise from transitions between the second (or first excited) state and higher energy states of the hydrogen atom. They were discovered by Swiss physicist J. J. Balmer. baryon Any of the subatomic particles which interact via the strong nuclear force. Most commonly, these are protons and neutrons. Their presence in the universe is determined through their gravitational and electromagnetic interactions. BATSE BATSE (Burst and Transient Source Experiment) was an instrument aboard the Compton Gamma Ray Observatory that detected and located gamma-ray bursts in the sky. BBXRT The Broad Band X-Ray Telescope, which was flown on the Astro-1 space shuttle flight (Dec. 1990) Tell me more about BBXRT Big Bang A theory of cosmology in which the expansion of the universe is presumed to have begun with a primeval explosion (referred to as the "Big Bang"). binary stars Binary stars are two stars that orbit around a common center of mass. An X-ray binary is a special case where one of the stars is a collapsed object such as a white dwarf, neutron star, or black hole, and the separation between the stars is small enough so that matter is transferred from the normal star to the compact star star, producing X-rays in the process. Tell me about X-ray binary stars Tell me more about X-ray binary stars black dwarf A non-radiating ball of gas resulting from either a white dwarf that has radiated all its energy or gas which has contracted but contains too little mass to begin nuclear fusion. black hole An object whose gravity is so strong that not even light can escape from it. (3 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary Tell me about X-rays from black holes Tell me about gamma rays from black holes and neutron stars Tell me more about black holes black-hole dynamic laws; laws of black-hole dynamics 1. First law of black hole dynamics: For interactions between black holes and normal matter, the conservation laws of mass-energy, electric charge, linear momentum, and angular momentum, hold. This is analogous to the first law of thermodynamics. 2. Second law of black hole dynamics: With black-hole interactions, or interactions between black holes and normal matter, the sum of the surface areas of all black holes involved can never decrease. This is analogous to the second law of thermodynamics, with the surface areas of the black holes being a measure of the entropy of the system. blackbody radiation Blackbody radiation is produced by an object which is a perfect absorber of heat. Perfect absorbers must also be perfect radiators. For a blackbody at a temperature T, the intensity of radiation emitted I at a particular energy E is given by Plank's law: I(E,T) = 2 E3[h2c2(eE/kT - 1)]-1 where h is Planck's constant, k is Boltzmann's constant, and c is the speed of light. blackbody temperature The temperature of an object if it is re-radiating all the thermal energy that has been added to it; if an object is not a blackbody radiator, it will not re-radiate all the excess heat and the leftover will go toward increasing its temperature. blueshift An apparent shift toward shorter wavelengths of spectral lines in the radiation emitted by an object caused by motion between the object and the observer which decreases the distance between them. See also Doppler effect. bolometric luminosity The total energy radiated by an object at all wavelengths, usually given in joules per second (identical to watts). Boltzmann constant; k (L. Boltzmann) A constant which describes the relationship between temperature and kinetic energy for molecules in an ideal gas. It is equal to 1.380622 x 10-23 J/K (see scientific notation). Brahe, Tycho (1546 - 1601) (a.k.a Tyge Ottesen) Danish astronomer whose accurate astronomical observations of Mars in the last quarter of the 16th century formed the basis for Johannes Kepler's laws of planetary motion. Brahe lost his nose in a dual in 1566 with Manderup Parsberg (a fellow student and nobleman) at Rostock over who was the better mathematician. He died in 1601, not of a burst bladder as legend suggests, but from high levels of mercury in his blood (which he may have taken as medication after falling ill from (4 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary the infamous meal). Show me a picture of Tycho Brahe ! bremsstrahlung "braking radiation", the main way very fast charged particles lose energy when traveling through matter. Radiation is emitted when charged particles are accelerated. In this case, the acceleration is caused by the electromagnetic fields of the atomic nuclei of the medium. C calibration A process for translating the signals produced by a measuring instrument (such as a telescope) into something that is scientifically useful. This procedure removes most of the errors caused by environmental and instrumental instabilities. Cataclysmic Variable (CV) Binary star systems with one white dwarf star and one normal star, in close orbit about each other. Material from the normal star falls onto the white dwarf, creating a burst of X-rays. Tell me more about Cataclysmic Variables Cepheid Variable A type of variable star which exhibits a regular pattern of changing brightness as a function of time. The period of the pulsation pattern is directly related to the star's intrinsic brightness. Thus, Cepheid variables are a powerful tool for determining distances in modern astronomy. Tell me more about Cepheid Variables CGRO The Compton Gamma Ray Observatory Tell me more about CGRO Chandra X-ray Observatory (CXO) One of NASA's Great Observatories in Earth orbit, launched in July 1999, and named after S. Chandrasekhar. It was previously named the Advanced X-ray Astrophysics Facility (AXAF). Chandrasekhar, S. (1910 - 1995) Indian astrophysicist reknowned for creating theoretical models of white dwarf stars, among other achievements. His equations explained the underlying physics behind the creation of white dwarfs, neutron stars and other compact objects. Chandrasekhar limit A limit which mandates that no white dwarf (a collapsed, degenerate star) can be more massive than about 1.4 solar masses. Any degenerate object more massive must inevitably collapse into a neutron star. cluster of galaxies A system of galaxies containing from a few to a few thousand member galaxies which are all gravitationally bound to each other. collecting area The amount of area a telescope has that is capable of collecting electromagnetic radiation. Collecting (5 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary area is important for a telescope's sensitivity: the more radiation it can collect (that is, the larger its collecting area), the more likely it is to detect dim objects. Compton effect (A.H. Compton; 1923) An effect that demonstrates that photons (the quantum of electromagnetic radiation) have momentum. A photon fired at a stationary particle, such as an electron, will impart momentum to the electron and, since its energy has been decreased, will experience a corresponding decrease in frequency. Tell me more about Dr. Compton and the Compton Effect Tell me how gamma-ray astronomers use the Compton effect Copernicus NASA ultraviolet/X-ray mission, also known as OAO-3 Tell me more about the Copernicus mission Copernicus, Nicolaus (1473 - 1543) Polish astronomer who advanced the theory that the Earth and other planets revolve around the Sun (the "heliocentric" theory). This was highly controversial at the time, since the prevailing Ptolemaic model held that the Earth was the center of the universe, and all objects, including the sun, circle it. The Ptolemaic model had been widely accepted in Europe for 1000 years when Copernicus proposed his model. (It should be noted, however, that the heliocentric idea was first put forth by Aristarcus of Samos in the 3rd century B.C., a fact known to Copernicus but long ignored by others prior to him.). Show me a picture of Nicholas Copernicus ! corona (plural: coronae) The uppermost level of a star's atmosphere. In the sun, the corona is characterized by low densities and high temperatures (> 1,000,000 degrees K). Tell me about X-rays from the Sun's corona Tell me about X-rays from other stellar coronae COS-B A satellite launched in August 1975 to study extraterrestrial sources of gamma-ray emission. Tell me more about COS-B cosmic background radiation; primal glow The background of radiation mostly in the frequency range 3 x 108 to 3 x 1011 Hz (see scientific notation) discovered in space in 1965. It is believed to be the cosmologically redshifted radiation released by the Big Bang itself. cosmic rays Atomic nuclei (mostly protons) and electrons that are observed to strike the Earth's atmosphere with exceedingly high energies. cosmological constant; Lambda A constant term (labeled Lambda) which Einstein added to his general theory of relativity in the mistaken belief that the Universe was neither expanding nor contracting. The cosmological constant was found to be unnecessary once observations indicated the Universe was expanding. Had Einstein believed what his equations were telling him, he could have claimed the expansion of the Universe as perhaps the greatest and most convincing prediction of general relativity; he called this the "greatest (6 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary blunder of my life". cosmological distance A distance far beyond the boundaries of our Galaxy. When viewing objects at cosmological distances, the curved nature of spacetime could become apparent. Possible cosmological effects include time dilation and redshift. cosmological redshift An effect where light emitted from a distant source appears redshifted because of the expansion of spacetime itself. Compare Doppler effect. cosmology The astrophysical study of the history, structure, and dynamics of the universe. CXO The Chandra X-ray Observatory. CXO was launched by the Space Shuttle in July 1999, and named for S. Chandrasekhar. Tell me more about CXO D Dark Matter Name given to the amount of mass whose existence is deduced from the analysis of galaxy rotation curves but which until now, has escaped all detections. There are many theories on what dark matter could be. Not one, at the moment is convincing enough and the question is still a mystery. de Broglie wavelength (L. de Broglie; 1924) The quantum mechanical "wavelength" associated with a particle, named after the scientist who discovered it. In quantum mechanics, all particles also have wave characteristics, where the wavelength of a particle is inversely proportional to its momentum and the constant of proportionality is the Planck constant. Declination A coordinate which, along with Right Ascension, may be used to locate any position in the sky. Declination is analogous to latitude for locating positions on the Earth, and ranges from +90 degrees to -90 degrees. deconvolution An image processing technique that removes features in an image that are caused by the telescope itself rather than from actual light coming from the sky. For example, the optical analog would be to remove the spikes and halos which often appear on images of bright stars because of light scattered by the telescope's internal supports. density The ratio between the mass of an object and its volume. In the metric system, density is measured in grams per cubic centimeter (or kilograms per liter); the density of water is 1.0 gm/cm3; iron is 7.9gm/cm3; lead is 11.3.gm/cm3 disk (a) A flattened, circular region of gas, dust, and/or stars. It may refer to material surrounding a (7 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary newly-formed star; material accreting onto a black hole or neutron star; or the large region of a spiral galaxy containing the spiral arms. (b) The apparent circular shape of the Sun, a planet, or the moon when seen in the sky or through a telescope. Doppler effect (C.J. Doppler) The apparent change in wavelength of sound or light caused by the motion of the source, observer or both. Waves emitted by a moving object as received by an observer will be blueshifted (compressed) if approaching, redshifted (elongated) if receding. It occurs both in sound and light. How much the frequency changes depends on how fast the object is moving toward or away from the receiver. Compare cosmological redshift. dust Not the dust one finds around the house (which is typically fine bits of fabric, dirt, and dead skin cells). Rather, irregularly shaped grains of carbon and/or silicates measuring a fraction of a micron across which are found between the stars. Dust is most evident by its absorption, causing large dark patches in regions of our Milky Way Galaxy and dark bands across other galaxies. E eccentric Non-circular; elliptical (applied to an orbit). eccentricity A value that defines the shape of an ellipse or planetary orbit. The eccentricity of an ellipse (planetary orbit) is the ratio of the distance between the foci and the major axis. Equivalently the eccentricity is (ra-rp)/(ra+rp) where ra is the apoapsis distance and rp is the periapsis distance. eclipse The passage of one celestial body in front of another, cutting off the light from the second body (e.g. an eclipse of the sun by the moon, or one star in a binary system eclipsing the other). It may also be the passage of all or part of one body through the shadow of another (e.g. a lunar eclipse in which the moon passes through the Earth's shadow). ecliptic The plane of Earth's orbit about the Sun. Eddington limit (Sir A. Eddington) The theoretical limit at which the photon pressure would exceed the gravitational attraction of a light-emitting body. That is, a body emitting radiation at greater than the Eddington limit would break up from its own photon pressure. Einstein, Albert (1879 - 1955) German-American physicist; developed the Special and General Theories of Relativity which along with Quantum Mechanics is the foundation of modern physics. Show me a picture of Albert Einstein ! Einstein Observatory, The first fully imaging x-ray telescope in space, launched by NASA in 1978. Originally named "HEAO-2" (High Energy Astrophysics Observatory 2), it was renamed for Albert Einstein upon launch. Also see HEAO. (8 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary Tell me more about HEAO-2 (Einstein Observatory) ejecta Material that is ejected. Used mostly to describe the content of a massive star that is propelled outward in a supernova explosion. Also used to describe the material that is blown radially outward in a meteor impact on the surface of a planet or moon. electromagnetic spectrum The full range of frequencies, from radio waves to gamma rays, that characterizes light. Introduce me to the electromagnetic spectrum Tell me more about the electromagnetic spectrum electromagnetic waves (radiation) Another term for light. Light waves are fluctuations of electric and magnetic fields in space. electron A negatively charged particle commonly found in the outer layers of atoms. The electron has only 0.0005 the mass of the proton. electron volt The change of potential energy experienced by an electron moving from a place where the potential has a value of V to a place where it has a value of (V+1 volt). This is a convenient energy unit when dealing with the motions of electrons and ions in electric fields; the unit is also the one used to describe the energy of X-rays and gamma rays. A keV (or kiloelectron volt) is equal to 1000 electron volts. An MeV is equal to one million electron volts. A GeV is equal to one billion (109) electron volts. A TeV is equal to a million million (1012) electron volts. elements The fundamental kinds of atoms that make up the building blocks of matter, which are each shown on the periodic table of the elements. The most abundant elements in the universe are hydrogen and helium. These two elements make up about 80and 20 % of all the matter in the universe respectively. Despite comprising only a very small fraction the universe, the remaining heavy elements can greatly influence astronomical phenomena. About 2 % of the Milky Way's disk is comprised of heavy elements. ellipse Oval. That the orbits of the planets are ellipses, not circles, was first discovered by Johannes Johannes Kepler the careful observations by Tycho Brahe erg/sec A form of the metric unit for power. It is equal to 10-10 kilowatts (see scientific notation). event horizon The distance from a black hole within which nothing can escape. In addition, nothing can prevent a particle from hitting the singularity in a very short amount of proper time once it has entered the horizon. In this sense, the event horizon is a "point of no return". See Schwarzschild radius. evolved star A star near the end of its lifetime when most of its fuel has been used up. This period of the star's life is characterized by loss of mass from its surface in the form of a stellar wind. (9 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary EXOSAT European Space Agency's X-ray Observatory Tell me more about EXOSAT extragalactic Outside of, or beyond, our own galaxy. F Fast Fourier Transformation (FFT) A Fourier Transform is the mathematical operation that takes measurements made with a radio interferometer and transforms them into an image of the radio sky. The Fast Fourier Transform is technique used by computer programs that allows the Fourier Transform to be computed very quickly. Fermi acceleration In order to explain the origins of cosmic rays, Enrico Fermi (1949) introduced a mechanism of particle acceleration, whereby charged particles bounce off moving interstellar magnetic fields and either gain or lose energy, depending on whether the "magnetic mirror" is approaching or receding. In a typical environment, he argued, the probability of a head-on collision is greater than a head-tail collision, so particles would be accelerated on average. This random process is now called 2nd order Fermi acceleration, because the mean energy gain per "bounce" is dependent on the "mirror" velocity squared. Bell (1978) and Blandford and Ostriker (1978) independently showed that Fermi acceleration by supernova remnant (SNR) shocks is particularly efficient, because the motions are not random. A charged particle ahead of the shock front can pass through the shock and then be scattered by magnetic inhomogeneities behind the shock. The particle gains energy from this "bounce" and flies back across the shock, where it can be scattered by magnetic inhomogeneities ahead of the shock. This enables the particle to bounce back and forth again and again, gaining energy each time. This process is now called 1st order Fermi acceleration, because the mean energy gain is dependent on the shock velocity only to the first power. flux A measure of the amount of energy given off by an astronomical object over a fixed amount of time and area. Because the energy is measured per time and area, flux measurements make it easy for astronomers to compare the relative energy output of objects with very different sizes or ages. frequency A property of a wave that describes how many wave patterns or cycles pass by in a period of time. Frequency is often measured in Hertz (Hz), where a wave with a frequency of 1 Hz will pass by at 1 cycle per second. FTOOLS A suite of software tools developed at NASA's Goddard Space Flight Center for analyzing high-energy astronomy data. FTP File Transfer Protocol -- A widely available method for transferring files over the Internet. fusion (10 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary The process in which atomic nuclei collide so fast that they stick together and emit a large amount of energy. In the center of most stars, hydrogen fuses into helium. The energy emitted by fusion supports the star's enormous mass from collapsing in on itself, and causes the star to glow. G galactic halo A spherical region surrounding the center of a galaxy. This region may extend beyond the luminous boundaries of the galaxy and contain a significant fraction of the galaxy's mass. Compared to cosmological distances, objects in the halo of our galaxy would be very nearby. galaxy A component of our universe made up of gas and a large number (usually more than a million) of stars held together by gravity. When capitalized, Galaxy refers to our own Milky Way Galaxy. Galilei, Galileo (1564 - 1642) An Italian scientist, Galileo was renowned for ...

the sky. polarization A special property of light; light has three properties, brightness, color and polarization. Polarization is a condition in which the planes of vibration of the various rays in a light beam are at least partially aligned. positron The antiparticle to the electron. The positron has most of the same characteristics as an electron except it is positively charged. proton A particle with a positive charge commonly found in the nucleus of atoms. protostar Very dense regions (or cores) of molecular clouds where stars are in the process of forming. Ptolemy (ca. 100-ca. 170) A.k.a. Claudius Ptolemaeus. Ptolemy believed the planets and Sun to orbit the Earth in the order Mercury, Venus, Sun, Mars, Jupiter, Saturn. This system became known as the Ptolemaic system and predicted the positions of the planets accurately enough for naked-eye observations (although it made some ridiculous predictions, such as that the moon should vary by a factor of two over its orbit). He authored a book called Mathematical Syntaxis (widely known as the Almagest). The Almagest included a star catalog containing 48 constellations, using the names we still use today. Show me a picture of Ptolemy ! pulsar A rotating neutron star which generates regular pulses of radiation. Pulsars were discovered by observations at radio wavelengths but have since been observed at optical, X-ray, and gamma-ray energies. Tell me about pulsars! PVO Pioneer Venus Orbiter Tell me more about PVO Q quasar An enormously bright object at the edge of our universe which emits massive amounts of energy. In an optical telescope, they appear point-like, similar to stars, from which they derive their name (quasar = quasi-stellar). Current theories hold that quasars are one type of AGN. quasi-stellar source (QSS) Sometimes also called quasi-stellar object (QSO); A stellar-appearing object of very large redshift that is a strong source of radio waves; presumed to be extragalactic and highly luminous. (22 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary R radial velocity The speed at which an object is moving away or toward an observer. By observing spectral lines, astronomers can determine how fast objects are moving away from or toward us; however, these spectral lines cannot be used to measure how fast the objects are moving across the sky. radian; rad The supplementary SI unit of angular measure, defined as the central angle of a circle whose subtended arc is equal to the radius of the circle. One radian is approximately 57 degrees. radiation Energy emitted in the form of waves (light) or particles (photons). radiation belt Regions of charged particles in a magnetosphere. radio Electromagnetic radiation which has the lowest frequency, the longest wavelength, and is produced by charged particles moving back and forth; the atmosphere of the Earth is transparent to radio waves with wavelengths from a few millimeters to about twenty meters. Rayleigh criterion; resolving power A criterion for how finely a set of optics may be able to distinguish the location of objects which are near each other. It begins with the assumption that the central ring of one image should fall on the first dark ring of another image; for an objective lens with diameter d and employing light of wavelength lambda (usually taken to be 560 nm), the resolving power is approximately given by 1.22 x lambda/d Rayleigh-Taylor instabilities Rayleigh-Taylor instabilities occur when a heavy (more dense) fluid is pushed against a light fluid -like trying to balance water on top of air by filling a glass 1/2 full and carefully turning it over. Rayleigh-Taylor instabilities are important in many astronomical objects, because the two fluids trade places by sticking "fingers" into each other. These "fingers" can drag the magnetic field lines along with them, thus both enhancing and aligning the magnetic field. This result is evident in the example of a supernova remnant in the diagram below, from Chevalier (1977). red giant A star that has low surface temperature and a diameter that is large relative to the Sun. redshift An apparent shift toward longer wavelengths of spectral lines in the radiation emitted by an object caused by the emitting object moving away from the observer. See also Doppler effect. (23 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary reflection law For a wavefront intersecting a reflecting surface, the angle of incidence is equal to the angle of reflection, in the same plane defined by the ray of incidence and the normal. relativity principle The principle, employed by Einstein's relativity theories, that the laws of physics are the same, at least qualitatively, in all coordinate frames. This principle, along with the principle of the constancy of the speed of light, constitutes the founding principles of special relativity. relativity, theory of Theories of motion developed by Albert Einstein, for which he is justifiably famous. Relativity More accurately describes the motions of bodies in strong gravitational fields or at near the speed of light than Newtonian mechanics. All experiments done to date agree with relativity's predictions to a high degree of accuracy. (Curiously, Einstein received the Nobel prize in 1921 not for Relativity but rather for his 1905 work on the photoelectric effect.) resolution (spatial) In astronomy, the ability of a telescope to differentiate between two objects in the sky which are separated by a small angular distance. The closer two objects can be while still allowing the telescope to see them as two distinct objects, the higher the resolution of the telescope. resolution (spectral or frequency) Similar to spatial resolution except that it applies to frequency, spectral resolution is the ability of the telescope to differentiate two light signals which differ in frequency by a small amount. The closer the two signals are in frequency while still allowing the telescope to separate them as two distinct components, the higher the spectral resolution of the telescope. resonance A relationship in which the orbital period of one body is related to that of another by a simple integer fraction, such as 1/2, 2/3, 3/5. retrograde The rotation or orbital motion of an object in a clockwise direction when viewed from the north pole of the ecliptic; moving in the opposite sense from the great majority of solar system bodies. revolution The movement of one celestial body which is in orbit around another. It is often measured as the "orbital period." Right Ascension A coordinate which, along with declination, may be used to locate any position in the sky. Right ascension is analogous to longitude for locating positions on the Earth. Ritter, Johann Wilhelm (1776 - 1810) Ritter is credited with discovering and investigating the ultraviolet region of the electromagnetic spectrum. Roche limit The smallest distance from a planet or other body at which purely gravitational forces can hold together a satellite or secondary body of the same mean density as the primary. At less than this distance the tidal forces of the larger object would break up the smaller object. (24 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary Roche lobe The volume around a star in a binary system in which, if you were to release a particle, it would fall back onto the surface of that star. A particle released above the Roche lobe of either star will, in general, occupy the `circumbinary' region that surrounds both stars. The point at which the Roche lobes of the two stars touch is called the inner Lagrangian or L1 point. If a star in a close binary system evolves to the point at which it `fills' its Roche lobe, theoretical calculations predict that material from this star will overflow both onto the companion star (via the L1 point) and into the environment around the binary system. Röntgen, Wilhelm Conrad (1845 - 1923) A German scientist who fortuitously discovered X-rays in 1895. Tell me more about Wilhelm Röntgen ROSAT Röntgen Satellite Tell me more about ROSAT rotation The spin of a celestial body on its own axis. In high energy astronomy, this is often measured as the "spin period." S SAS-2 The second Small Astronomy Satellite: a NASA satellite launched November 1972 with a mission dedicated to gamma-ray astronomy. Tell me more about SAS-2 SAS-3 The third Small Astronomy Satellite: a NASA satellite launched May 1975 to determine the location of bright X-ray sources and search for X-ray novae and other transient phenomena. Tell me more about SAS-3 satellite A body that revolves around a larger body. For example, the moon is a satellite of the earth. Schwarzschild black hole A black hole described by solutions to Einstein's equations of general relativity worked out by Karl Schwarzschild in 1916. The solutions assume the black hole is not rotating, and that the size of its event horizon is determined solely by its mass. Schwarzschild radius The radius r of the event horizon for a Schwarzschild black hole. scientific notation A compact format for writing very large or very small numbers, most often used in scientific fields. The notation separates a number into two parts: a decimal fraction, usually between 1 and 10, and a power of ten. Thus 1.23 x 104 means 1.23 times 10 to the fourth power or 12,300; 5.67 x 10-8 means (25 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary 5.67 divided by 10 to the eighth power or 0.0000000567. second; s The fundamental SI unit of time, defined as the period of time equal to the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom. A nanosecond is equal to one-billionth (10-9) of a second. semimajor axis The semimajor axis of an ellipse (e.g. a planetary orbit) is half the length of the major axis, which is the line segment passing through the foci of the ellipse with endpoints on the ellipse itself. The semimajor axis of a planetary orbit is also the average distance from the planet to its primary. The periapsis and apoapsis distances can be calculated from the semimajor axis and the eccentricity by rp = a(1-e) and ra = a(1+e). sensitivity A measure of how bright objects need to be in order for the telescope to detect them. Seyfert galaxy A spiral galaxy whose nucleus shows bright emission lines; one of a class of galaxies first described by C. Seyfert. shock wave A strong compression wave where there is a sudden change in gas velocity, density, pressure and temperature. singularity The center of a black hole, where the curvature of spacetime is maximal. At the singularity, the gravitational tides diverge; no solid object can even theoretically survive hitting the singularity. Although singularities generally predict inconsistencies in theory, singularities within black holes do not necessarily imply that general relativity is incomplete so long as singularities are always surrounded by event horizons. A proper formulation of quantum gravity may well avoid the classical singularity at the centers of black holes. solar flares Violent eruptions of gas on the Sun's surface. solar mass A unit of mass equivalent to the mass of the Sun. 1 solar mass = 1 Msun = 2 x 1033 grams. special relativity The physical theory of space and time developed by Albert Einstein, based on the postulates that all the laws of physics are equally valid in all frames of reference moving at a uniform velocity and that the speed of light from a uniformly moving source is always the same, regardless of how fast or slow the source or its observer is moving. The theory has as consequences the relativistic mass increase of rapidly moving objects, time dilatation, and the principle of mass-energy equivalence. See also general relativity. (26 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary spectral line Light given off at a specific frequency by an atom or molecule. Every different type of atom or molecule gives off light at its own unique set of frequencies; thus, astronomers can look for gas containing a particular atom or molecule by tuning the telescope to one of the gas's characteristic frequencies. For example, carbon monoxide (CO) has a spectral line at 115 Gigahertz (or a wavelength of 2.7 mm). spectrometer The instrument connected to a telescope that separates the light signals into different frequencies, producing a spectrum. A Dispersive Spectrometer is like a prism. It scatters light of different energies to different places. We measure the energy by noting where the X-rays go. A Non-Dispersive Spectrometer measures the energy directly. spectroscopy The study of spectral lines from different atoms and molecules. Spectroscopy is an important part of studying the chemistry that goes on in stars and in interstellar clouds. spectrum (plural: spectra) A plot of the intensity of light at different frequencies. Or the distribution of wavelengths and frequencies. Tell me more about spectra speed of light (in vacuum) The speed at which electromagnetic radiation propagates in a vacuum; it is defined as 299 792 458 m/s (186,212 miles/second). Einstein's Theory of Relativity implies that nothing can go faster than the speed of light. star A large ball of gas that creates and emits its own radiation. star cluster A bunch of stars (ranging in number from a few to hundreds of thousands) which are bound to each other by their mutual gravitational attraction. Stefan-Boltzmann constant sigma (Stefan L. Boltzmann) The constant of proportionality present in the Stefan-Boltzmann law. It is equal to 5.6697 x 10-8 Watts per square meter per degree Kelvin to the fourth power (see scientific notation). Stefan-Boltzmann law (Stefan L. Boltzmann) The radiated power P (rate of emission of electromagnetic energy) of a hot body is proportional to the radiating surface area, A, and the fourth power of the thermodynamic temperature, T. The constant of proportionality is the Stefan-Boltzmann constant. stellar classification Stars are given a designation consisting of a letter and a number according to the nature of their spectral lines which corresponds roughly to surface temperature. The classes are: O, B, A, F, G, K, and M; O stars are the hottest; M the coolest. The numbers are simply subdivisions of the major classes. The classes are oddly sequenced because they were assigned long ago before we understood their relationship to temperature. O and B stars are rare but very bright; M stars are numerous but dim. The Sun is designated G2. stellar wind The ejection of gas off the surface of a star. Many different types of stars, including our Sun, have stellar winds; however, a star's wind is strongest near the end of its life when it has consumed most of its fuel. (27 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary Sun is designated G2. steradian; sr The supplementary SI unit of solid angle defined as the solid central angle of a sphere that encloses a surface on the sphere equal to the square of the sphere's radius. supernova (plural: supernovae) The death explosion of a massive star, resulting in a sharp increase in brightness followed by a gradual fading. At peak light output, supernova explosions can outshine a galaxy. The outer layers of the exploding star are blasted out in a radioactive cloud. This expanding cloud, visible long after the initial explosion fades from view, forms a supernova remnant (SNR). Tell me about X-rays from supernovae supernova remnant Tell me more about supernova remnants sunspots Cooler (and thus darker) regions on the sun where the magnetic field loops up out of the solar surface. SXG The Spectrum X-Gamma mission Tell me more about SXG Swift Swift is a NASA mid-sized mission whose primary goal is to study gamma-ray bursts and address the mysteries surrounding their nature, origin, and causes. Swift is expected to launch in 2003. Tell me more about Swift synchronous rotation Said of a satellite if the period of its rotation about its axis is the same as the period of its orbit around its primary. This implies that the satellite always keeps the same hemisphere facing its primary (e.g. the Moon). It also implies that one hemisphere (the leading hemisphere) always faces in the direction of the satellite's motion while the other (trailing) one always faces backward. synchrotron radiation Electromagnetic radiation given off when very high energy electrons encounter magnetic fields. Systeme Internationale d'Unites (SI) The coherent and rationalized system of units, derived from the MKS system (which itself is derived from the metric system), in common use in physics today. The fundamental SI unit of length is the meter, of time is the second, and of mass is the kilogram. (28 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary T Tenma The second Japanese X-ray mission, also known as Astro-B. Tell me more about Tenma Thomson, William 1824 - 1907 Also known as Lord Kelvin, the British physicist who developed the Kelvin temperature scale and who supervised the laying of a trans-Atlantic cable. Show me a picture of Lord Kelvin! time dilation The increase in the time between two events as seen by an observer who is outside of the reference frame in which the events take place. The effect occurs in both special and general relativity, and is quite pronounced for speeds approaching the speed of light, and in regions of high gravity. U Uhuru NASA's first Small Astronomy Satellite, also known as SAS-1. Uhuru was launched from Kenya on 12 December, 1970. The seventh anniversary of Kenya's independence. The satellite was named "Uhuru" (Swahili for "freedom") in honor of its launch date. Tell me more about Uhuru ultraviolet Electromagnetic radiation at wavelengths shorter than the violet end of visible light; the atmosphere of the Earth effectively blocks the transmission of most ultraviolet light. universal constant of gravitation G The constant of proportionality in Newton's law of universal gravitation and which plays an analogous role in A. Einstein's general relativity. It is equal to 6.664 x 10-11 m3 / kg-sec2 (see scientific notation). Universe Everything that exists, including the Earth, planets, stars, galaxies, and all that they contain; the entire cosmos. V Vela 5B US Atomic Energy Commission (now the Department of Energy) satellite with an all-sky X-ray monitor Tell me more about Vela 5B The Venera satellite series The Venera satellites were a series of probes (fly-bys and landers) sent by the Soviet Union to the planet Venus. Several Venera satellites carried high-energy astrophysics detectors. Tell me more about Venera 11 & 12 (29 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary Tell me more about Venera 13 & 14 visible Electromagnetic radiation at wavelengths which the human eye can see. We perceive this radiation as colors ranging from red (longer wavelengths; ~ 700 nanometers) to violet (shorter wavelengths; ~400 nanometers.) W wave-particle duality The principle of quantum mechanics which implies that light (and, indeed, all other subatomic particles) sometimes act like a wave, and sometimes act like a particle, depending on the experiment you are performing. For instance, low frequency electromagnetic radiation tends to act more like a wave than a particle; high frequency electromagnetic radiation tends to act more like a particle than a wave. wavelength The distance between adjacent peaks in a series of periodic waves. Also see electromagnetic spectrum. white dwarf A star that has exhausted most or all of its nuclear fuel and has collapsed to a very small size. Typically, a white dwarf has a radius equal to about 0.01 times that of the Sun, but it has a mass roughly equal to the Sun's. This gives a white dwarf a density about 1 million times that of water! Tell me more about white dwarfs Wien's displacement law For a blackbody, the product of the wavelength corresponding to the maximum radiancy and the thermodynamic temperature is a constant. As a result, as the temperature rises, the maximum of the radiant energy shifts toward the shorter wavelength (higher frequency and energy) end of the spectrum. WWW The World Wide Web -- a loose linkage of Internet sites which provide data and other services from around the world. X X-ray Electromagnetic radiation of very short wavelength and very high-energy; X-rays have shorter wavelengths than ultraviolet light but longer wavelengths than gamma rays. XSELECT A software tool used by astrophysicists in conjunction with the FTOOLS software to analyze certain types of astronomical data. XTE X-ray Timing Explorer, also known as the Rossi X-ray Timing Explorer (RXTE) Tell me more about RXTE (30 of 31) [3/2/2004 9:29:03 PM] Imagine the Universe! Dictionary Y Z Z The ratio of the observed change in wavelength of light emitted by a moving object to the rest wavelength of the emitted light. See Doppler Effect. This ratio is related to the velocity of the object. In general, with v = velocity of the object, c is the speed of light, lambda is the rest wavelength, and delta-lambda is the observed change in the wavelength, z is given by z = (delta-lambda)/lambda = (sqrt(1+v/c) / sqrt(1-v/c)) - 1. If the velocity of the object is small compared to the speed of light, then z = (delta-lambda)/lambda = v/c Objects at the furthest reaches of the known universe have values of z = 5 or slightly greater. [A B C D E F G H I J K L M N O P Q R S T U V W X Y Z] Home Imagine Science Special Exhibits Satellites and Data Teacher's Corner Feedback Ask a High Energy Astronomer Show me a printable version of this page. Imagine the Universe is a service of the High Energy Astrophysics Science Archive Research Center (HEASARC), Dr. Nicholas White (Director), within the Laboratory for High Energy Astrophysics at NASA's Goddard Space Flight Center. The Imagine Team Project Leader: Dr. Jim Lochner Curator: Meredith Bene Ihnat Responsible NASA Official: Phil Newman All material on this site has been created and updated between 1997-2004. Useful plugins NASA's privacy statement Do you have a question, problem or comment about this web site? Please let us know. External links contain material that we found to be relevant. However, they're not maintained by us and the content may have changed. If you find any external links that contain inappropriate material, please let us know! (31 of 31) [3/2/2004 9:29:03 PM] Sky & Telescope - Sky & Telescope Magnitude System The Stellar Magnitude System By Alan M. MacRobert Sky & Telescope illustration Most ways of counting and measuring things work logically. When the thing you're measuring increases, the number gets bigger. When you gain weight, the scale doesn't show a smaller number of kilograms or pounds. But things are not so sensible in astronomy — at least not when it comes to the brightnesses of stars. Ancient Origins Star magnitudes do count backward, the result of an ancient fluke that seemed like a good idea at the time. The story begins around 129 B.C., when the Greek astronomer Hipparchus produced the first well-known star catalog. Hipparchus ranked his stars in a simple way. He called the brightest ones "of the first magnitude," simply meaning "the biggest." Stars not so bright he called "of the second magnitude," or second biggest. The faintest stars he could see he called "of the sixth magnitude." Around A.D. 140 Claudius Ptolemy copied this system in his own star list. Sometimes Ptolemy added the words "greater" or "smaller" to distinguish between stars within a magnitude class. Ptolemy's works remained the basic astronomy texts for the next 1,400 years, so everyone used the system of first to sixth magnitudes. It worked just fine. Galileo forced the first change. On turning his newly made telescope to the sky, Galileo discovered that stars existed that were fainter than Ptolemy's sixth magnitude. "Indeed, with (1 of 6) [3/2/2004 9:29:07 PM] The Stellar Magnitude System the glass you will detect below stars of the sixth magnitude such a crowd of others that escape natural sight that it is hardly believable," he exulted in his 1610 tract, Sidereus Nuncius. "The largest of these ... we may designate as of the seventh magnitude." Thus did a new term enter the astronomical language, and the magnitude scale became open-ended. There could be no turning back. As telescopes got bigger and better, astronomers kept adding more magnitudes to the bottom of the scale. Today a pair of 50-millimeter binoculars will show stars of about 9th magnitude, a 6-inch amateur telescope will reach to 13th magnitude, and the Hubble Space Telescope has seen objects as faint as 30th magnitude. By the middle of the 19th century astronomers realized there was a pressing need to define the entire magnitude scale more precisely than by eyeball judgment. They had already determined that a 1st-magnitude star shines with about 100 times the light of a 6th-magnitude star. Accordingly, in 1856 the Oxford astronomer Norman R. Pogson proposed that a difference of five magnitudes be defined as a brightness ratio of exactly 100 to 1. This convenient rule was quickly adopted. One magnitude thus corresponds to a brightness difference of exactly the fifth root of 100, or very close to 2.512 — a value known as the Pogson ratio. The Meaning of Magnitudes Tthe difference in magnitudes ... means this ratio in brightness 0 1 to 1 0.1 1.1 to 1 0.2 1.2 to 1 0.3 1.3 to 1 0.4 1.4 to 1 0.5 1.6 to 1 0.6 1.7 to 1 0.7 1.9 to 1 0.8 2.1 to 1 0.9 2.3 to 1 1.0 2.5 to 1 1.5 4.0 to 1 2 6.3 to 1 2.5 10 to 1 (2 of 6) [3/2/2004 9:29:07 PM] The Stellar Magnitude System 4 40 to 1 5 100 to 1 7.5 1,000 to 1 10 10,000 to 1 15 1,000,000 to 1 20 100,000,000 to 1 The resulting magnitude scale is logarithmic, in neat agreement with the 1850s belief that all human senses are logarithmic in their response to stimuli. The decibel scale for rating loudness was likewise made logarithmic. (Alas, it's not quite so, not for brightness, sound, or anything else. Our perceptions of the world follow power-law curves, not logarithmic ones. Thus a star of magnitude 3.0 does not in fact look exactly halfway in between 2.0 and 4.0. It looks a little fainter than that. The star that looks halfway between 2.0 and 4.0 will be about magnitude 2.8. The wider the magnitude gap, the greater this discrepancy. Accordingly, Sky & Telescope's computer-drawn sky maps use star dots that are sized according to a power-law relation. But the scientific world in the 1850s was gaga for logarithms, so now they are locked into the magnitude system as firmly as Hipparchus's backward numbering.) Now that star magnitudes were ranked on a precise mathematical scale, however ill-fitting, another problem became unavoidable. Some "1st-magnitude" stars were a whole lot brighter than others. Astronomers had no choice but to extend the scale out to brighter values as well as faint ones. Thus Rigel, Capella, Arcturus, and Vega are magnitude 0 — an awkward statement that suggests they have no brightness at all! But it was too late to start over. The magnitude scale extends farther down into negative numbers: Sirius shines at magnitude –1.5, Venus reaches –4.4, the full Moon is about –12.5, and the Sun blazes at magnitude –26.7. (3 of 6) [3/2/2004 9:29:07 PM] The Stellar Magnitude System Fifty-seven magnitudes of apparent brightness encompass the things that astronomers study, from glaring Sun to the faintest objects detected with the Hubble Space Telescope. This range is equivalent to a brightness ratio of nearly 100 billion trillion. Sky & Telescope illustration Other Colors, Other Magnitudes By the late 19th century astronomers were using photography to record the sky and measure star brightnesses, and a new problem cropped up. Some stars having the same brightness to the eye showed different brightnesses on film, and vice versa. Compared to the eye, photographic emulsions were more sensitive to blue light and less so to red light. Accordingly, two separate scales were devised. Visual magnitude, or mvis, described how a star looked to the eye. Photographic magnitude, or mpg, referred to star images on blue-sensitive black-and-white film. These are now abbreviated mv and mp, respectively. This complication turned out to be a blessing in disguise. The difference between photographic and visual magnitudes was a convenient measure of a star's color. The difference between the two kinds of magnitude was named the "color index." Its value is increasingly positive for yellow, orange, and red stars, and negative for blue ones. But different photographic emulsions have different spectral responses! And people's eyes differ too. For one thing, your eye lenses turn yellow with age; old people see the world through yellow filters. Magnitude systems designed for different wavelength ranges had to be more firmly grounded than this. Today, precise magnitudes are specified by what a standard photoelectric photometer sees through standard color filters. Several photometric systems have been devised; the most familiar is called UBV after the three filters most commonly used. U encompasses the near-ultraviolet, B is blue, and V corresponds fairly closely to the old visual magnitude; its wide peak is in the yellow-green band, where the eye is most sensitive. Color index is now defined as the B magnitude minus the V magnitude. A pure white star has a B-V of about 0.2, our yellow Sun is 0.63, orange-red Betelgeuse is 1.85, and the bluest star (4 of 6) [3/2/2004 9:29:07 PM] The Stellar Magnitude System believed possible is –0.4 — pale blue-white. So successful was the UBV system that it was extended redward with R and I filters to define standard red and near-infrared magnitudes. Hence it is sometimes called UBVRI. Infrared astronomers have carried it to still longer wavelengths, picking up alphabetically after I to define the J, K, L, M, N, and Q bands. These were chosen to match the wavelengths of infrared "windows" in the atmosphere — wavelengths at which water vapor does not entirely absorb starlight. In all wavebands, the bright star Vega has been chosen (quite arbitrarily) to define magnitude 0.0. Since Vega is dimmer at infrared wavelengths than in visible light, infrared magnitudes are, by definition and quite artificially, brighter than their visual counterparts. The left-hand map of Canis Major uses dot size to indicate apparent magnitude, while the right-hand one indicates absolute magnitude — a measure of intrinsic stellar luminosity. Which chart better matches your own eyeball impressions? Sky & Telescope illustration Appearance and Reality What, then, is an object's real brightness? How much total energy is it sending to us at all wavelengths combined, visible and invisible? The answer is called the bolometric magnitude, mbol, because total radiation was once measured with a device called a bolometer. The bolometric magnitude has been called the God's-eye view of an object's true luster. Astrophysicists value it as the true measure of an object's total energy emission as seen from Earth. The bolometric correction tells how much brighter the bolometric magnitude is than the V magnitude. Its value is always negative because any star or object emits at least some radiation outside the visual portion of the electromagnetic spectrum. Up to now we've been dealing only with apparent magnitudes — how bright things look from Earth. We don't know how intrinsically bright an object is until we also take its distance into account. Thus (5 of 6) [3/2/2004 9:29:07 PM] The Stellar Magnitude System astronomers created the absolute magnitude scale. An object's absolute magnitude is simply how bright it would appear if placed at a standard distance of 10 parsecs (32.6 light-years). Seen from this distance, the Sun would shine at an unimpressive visual magnitude 4.85. Rigel would blaze at a dazzling –8, nearly as bright as the quarter Moon. The red dwarf Proxima Centauri, the closest star to the solar system, would appear to be magnitude 15.6, the tiniest little glimmer visible in a 16-inch telescope! Knowing absolute magnitudes makes plain how vastly diverse are the objects that we casually lump together under the single word "star." Absolute magnitudes are always written with a capital M, apparent magnitudes with a lower-case m. Any type of apparent magnitude — photographic, bolometric, or whatever — can be converted to an absolute magnitude. However. for comets and asteroids a very different "absolute magnitude" is used. It tells how bright they would appear to an observer standing on the Sun if the object were one astronomical unit away. ---Alan MacRobert is a senior editor of Sky & Telescope magazine and an avid backyard astronomer. ©2004 Sky Publishing Corp. (6 of 6) [3/2/2004 9:29:09 PM] Amazon.com: Books: Soul of the Sky: Exploring the Human Side of Weather Search Browse Subjects Bestsellers Magazines Corporate Accounts Soul of the Sky: Exploring the Human Side of Weather by Dave Thurlow (Editor), C. Ralph Adler (Editor), Paul M. Breeden (Illustrator) Books WEB SEARCH e-books & docs Bargain Books Used Books Sign in to turn on 1-Click ordering. List Price: $12.95 Price: $12.95 & eligible 39 used & new from $0.44 for Have one to sell? FREE Super Saver Shipping on orders over $25. Don't have one? See We'll set one up for you. Look inside this book details. buying info editorial reviews Availability: Usually ships within 1 to 3 weeks customer reviews look inside 39 used & new from $0.44 RECENTLY VIEWED Sundials, Their Theory and Construction by Albert Waugh Sundials: Their Theory and Construction by R. Newton Mayall (Author), Margaret W. Mayall (Author) The Illustrated Longitude by Dava Sobel, William J. H. 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Is there an book you'd recommend instead of or in addition to this I love it! one? Use the search box below to find it. Then select one item and click Submit. Enter the book's ASIN (what's an ASIN?) in the box below, select advice type, then click Submit. 4 5 Edit your ratings Format to Submit) I recommend: in addition to this book instead of this book Editorial Reviews Weatherwise Magazine, November/December, 1999 "There are stories of tornadoes, floods, hurricanes, fog, ice storms, and lightning strikes. ... In these, the unruly atmosphere not only provokes a memorable event, but also serves as a backdrop while the human drama plays out. Often, the storms retold in Soul of the Sky explore our new damage property and take lives, but that is not all. Weather, however Magazine Subscriptions adventure, can bring communities and families together and cause us to store. reassess whats most valuable in our lives. You cannot read these stories without recalling your own experiences with weather. Be it wind, lashing rain, the threat of hurricane or tornado, a muggy day we have all been there, messing up the instrument we know best: ourselves." The Orlando Sentinel, October 3, 1999 "This anthology ... contributors take weather personally, writing about everything from drought in Georgia to snow storms in New England and how climate changes affect their towns. Annie Dillard evokes Tinker Creek in flood; Robert Henson recalls the tornadoes of his Oklahoma upbringing; Diane Ackerman reminds us how much weather shapes our lives and imaginations. The Soul of the Sky is a collection of essays that illustrates how the weather can inspire and terrify, connect us and urge us on to new adventures, and invite us to gain a deeper appreciation of how weather and climate affect our everyday lives. Contributors include Diane Ackerman, Catherine Buni, David Clark, Jan DeBlieu, Jerry Dennis, Annie Dillard, Gretel Ehrlich, Robert Henson, Sebastian Junger, David Laskin, John Hanson Mitchell, Chet Raymo, and others. See all editorial reviews. All Customer Reviews Average Customer Review: Write an online review and share your thoughts with other customers. 3Dsr%5F11%5F0%5F1/102-8971606-4734554 (2 of 6) [3/2/2004 9:29:09 PM] Amazon.com: Books: Soul of the Sky: Exploring the Human Side of Weather 1 of 1 people found the following review helpful: Fresh Rain, January 17, 2002 Reviewer: Susan Strom from Arizona "Soul of the Sky" is fresh rain amidst the usual smorgasbord of weather textbooks and technical guides. Explained by the sensory experiences of weather, "Soul of the Sky" is a compilation of well written stories of human interaction with the weather. As a stormchaser myself, I particularly enjoyed "Only a Storm", an essay by Robert Henson about a tornado outbreak lifetime under the moody skies of Tornado Alley. Was this review helpful to you? 1 of 1 people found the following review helpful: Soul of the Sky, May 8, 2000 Reviewer: barb_tn from Washington, DC This book is well written and will bring back memories of storms you have weathered throughout your life. And if you've never experienced some of nature's harshest weather, you'll get a feel for it after reading this book. I was quite a fascinating read. Was this review helpful to you? Customers who bought this book also bought Look for similar books by subject: recommended: ● Thurlo, Dave, Ed.: Soul of the Sky: Exploring the Human Side of Weather (Price: $7.50) Look for similar books by subject: Browse for books in: ● Subjects > Literature & Fiction > Essays > General ● Subjects > Science > Earth Sciences > Meteorology ● Subjects > Outdoors & Nature > Environment > Weather Search for books by subject: Weather Social aspects Storms Nature / Field Guide Books Nature Meteorology Essays Literary Criticism & Collections Find books matching ALL checked subjects i.e., each book must be in subject 1 AND subject 2 AND ... Feedback ● I have read this book, and want to Write a So You'd Like to... guide. 3Dsr%5F11%5F0%5F1/102-8971606-4734554 (3 of 6) [3/2/2004 9:29:09 PM] Amazon.com: Books: Soul of the Sky: Exploring the Human Side of Weather ● Is there a specific product you'd like us to sell? Tell us about it. Suggestion Box Your comments can help make our site better for everyone. If you've found something incorrect, broken, or frustrating on this page, let us know so that we can improve it. Please note that we are unable to respond directly to suggestions made via this form. If you need help with an order, please contact Customer Service. Please mark as many of the following boxes that apply: Product information is missing important information. Some product information is incorrect. Propose corrections to product information using our Online Catalog Update Form. The page contains typographical errors. The page takes too long to load. The page has a software bug in it. Content violates Amazon.com's policy on offensive language. Product offered violates Amazon.com's policy on items that can be listed for sale. Comments or Examples: Examples: Missing information such as dimensions and model number, typos, inaccuracies, etc. Where's My Stuff? • Track your recent orders. • View or change your orders in Your Account. Shipping & Returns • See our shipping rates & policies. • Return an item (here's our Returns Policy). Search Books Need Help? • Forgot your password? Click here. • Redeem or buy a gift certificate. • Visit our Help department. for Your Recent History Learn More Recently Viewed Products Sundials, Their Theory and Construction by Albert Waugh (Author) Sundials by R. Newton Mayall (Author), Margaret W. Mayall (Author) The Illustrated Longitude by Dava Sobel, William J. H. Andrewes Customers who bought items in your Recent History also bought: Longitude by Dava Sobel The Riddle of the Compass by Amir D. Aczel (Author) 3Dsr%5F11%5F0%5F1/102-8971606-4734554 (4 of 6) [3/2/2004 9:29:09 PM] Amazon.com: Books: Soul of the Sky: Exploring the Human Side of Weather Visit the Page You Made Turn your past purchases into $$$ Learn more about selling at Amazon.com today! Top of Page Books Search | Browse Subjects | Bestsellers | Magazines | Corporate Accounts | e-Books & Docs | Bargain Books | Used Books Amazon.com Home | Directory of All Stores Our International Sites: Canada | United Kingdom | Germany | Japan | France Contact Us | Help | Shopping Cart | Your Account | Sell Items | 1-Click Settings Investor Relations | Press Releases | Join Our Staff Bottom of the Page TM Deals for March 02 Amazon.com = low prices. Save up to 50% on these 24-hour deals, updated every day at noon (central time). Our Price You Save Dove Plush Bath Robe, White You'll look simply marvelous, darling, in this 100% plush white cotton robe! $29.99 $11.00 (28%) Panasonic SD-YD250 Bread Maker Automatic Power-Failure Light Next time the power goes off, don't get left in the dark. $26.99 $13.00 (33%) Canon RC-1n Multipack Ink Tanks (4 Pack) Keep the cartridge, replace the ink, save money. $33.99 $16.00 (32%) Show Brrr Sleeping Sleep Set Shop Stretch Amerika Leggings Mirror Sabe the clothes soft and fresh with Fasts. $19.99 $20.00 (50%) Neutrogena Moisture Rich Shower and Bath Gel, 35 Ounces (2 Bottles) Pamper skin and senses with this refreshing shower and bath gel. $29.99 $28.00 (48%) Bose Wave Radio Black ... Stainless Steel Toaster $39.99 $20.00 (33%) Snugsafe Fabric Softener Dryer Sheets, Fresh Rain 120 count 6 boxes Eliminate static cling and leave your clothes soft and smelling. $19.99 $20.00 (50%) Neutrogena Moisture Rich Shower and Bath Gel, 35 Ounces (2 Bottles) Pamper skin and senses with this refreshing shower and bath gel. ... We take up to 50% off standard retail prices and deliver right to your door--no tax--just ... Garmin ... Check back every day at noon Bottom of the Page TM Deals. Amazon.com: Books: Soul of the Sky: Exploring the Human Side of Weather Conditions of Use | Privacy Notice © 1996-2004, Amazon.com, Inc. or its affiliates 3Dsr%5F11%5F0%5F1/102-8971606-4734554 (6 of 6) [3/2/2004 9:29:09 PM] Garmin International Search: About Garmin About Garmin Investor Relations Virtual Pressroom Employment Customer Support Software Updates Product Registration FAQs Dealer Locator MapSource® Unlock Aviation Databases Online Only Garmin® is a leader in Global Positioning System (GPS) technology and an innovator in consumer electronics. We serve both the aviation and consumer markets. Our products are used in flying, boating, driving, hiking, and many other activities. We're customer focused and committed to producing quality products that improve people's everyday lives. 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Download now Video Overview Hi-res Overview 26.3MB mpeg Lo-res Overview 9.95MB mpeg Package includes: ● ● ● ● GPS 12 receiver with built-in antenna Wrist strap Owner's manual quick reference guide Garmin ® GPS 12 Personal Navigator® an affordable 12 parallel channel handheld for outdoor adventures The GPS 12 offers outdoor enthusiasts an entry-level way to gain the power and performance of a 12-channel receiver with fast satellite acquisition in the toughest conditions—even in heavy tree cover. The GPS 12's rugged, waterproof case features military-tough construction, and its rocker keypad design provides true one-hand operation that keeps you on the move—day or night, rain or shine. It also features 500 available waypoints and 1024 track log points, nine prominently display speed on a customizable map to mark and store your location, and Garmin's innovative TracBack® function—a feature that turns your track log into an instant breadcrumb trail and allows you to reverse your route in order to quickly navigate back home. As an added bonus, the GPS 12 also boasts a position averaging feature which diminishes the effects of Selective Availability (SA) upon position error and displays a value that reflects the estimated accuracy of the averaged position. Include a host of advanced navigation features like enhanced moving map graphics, average and maximum speed data, and trip timers, and you have all the things that make the GPS 12 a preferred Garmin—innovation, performance, and value. Outdoor (1 of 2) [3/2/2004 9:29:15 PM] Garmin: GPS 12 Marine TOP Copyright 1996-2004 Garmin Ltd. or its subsidiaries Privacy Statement/Terms of Use (2 of 2) [3/2/2004 9:29:15 PM] Garmin: eMap Home > Outdoor > Products > eMap Search: Specifications Testimonials Search: MapSource Compatibility Garmin Recommends: Accessories Manuals Software Updates FAQs Select MapSource Product Go * denotes limitations Product Training Video Produced by Garmin Buy Now Available from local dealers or our online store. More Info> Interactive Demo Package Includes: ● ● ● ● eMap® Basemap: Americas Highway or Atlantic Highway Wrist strap User's manual 360° Product View (164K) The interactive demo requires Macromedia Flash 4 plug-in. Download now Video Overview Hi-res Overview 11.3MB mpeg Lo-res Overview 4.61MB mpeg Here's another reason to toss out those paper maps: the eMap. It's the size of a small, flat calculator, contains a 12 parallel channel GPS receiver, and weighs a mere six ounces. Even with its compact style, the eMap boasts an extra-large display for showing even more map data and the same power you've come to expect from Garmin handhelds—even while operating for up to 12 hours on just two AA batteries. The eMap features an internal basemap containing information on North and South America including state and country boundaries, lakes, rivers, streams, airports, cities, towns, coastlines, and U.S., state, and interstate highways. In addition, the eMap provides exit information for the federal interstate highway system. With the eMap, you will know when you are near services such as food, lodging, and service stations. (1 of 2) [3/2/2004 9:29:15 PM] Garmin: eMap The eMap is compatible with Garmin's complete line of downloadable MapSource® CD-ROMs including U.S. Roads and Recreation, WorldMap, U.S. Topo, and MetroGuide® U.S.A. When paired with the MetroGuide U.S.A. CD-ROM, the eMap has the ability to look up address and telephone number information for nearby services and points of interest. The eMAP will store eight or 16 megabytes of downloaded CD-ROM information at a time depending on the size of the cartridge you use in the unit. Designed with everyone in mind, this unit will take you from the car, to the hiking trail, to the beach without missing a beat. TOP Copyright 1996-2004 Garmin Ltd. or its subsidiaries Privacy Statement/Terms of Use (2 of 2) [3/2/2004 9:29:15 PM] Garmin: eTrex Vista Home > Outdoor > Products > eTrex Vista Search: Specifications Testimonials Accessories Manuals Software Updates FAQs MapSource Compatibility The eTrex Vista combines a basemap of North and South America, with a barometric altimeter and electronic compass. The compass provides bearing information while you're standing still and the altimeter determines your precise altitude. The Vista is also designed to provide precise Enlarge image GPS positioning using Package includes: correction data obtained from the Wide Area Augmentation ● eTrex System (WAAS). This product Vista® will provide position accuracy ● Database: Marine Point to less than three meters when receiving WAAS corrections. Database The eTrex Vista also boasts an ● Basemap: internal memory capacity of 24 Americas Highway or megabytes, which allows it to accept downloaded mapping Atlantic data from Garmin's Highway or MapSource®® CD-ROMs, Pacific including Fishing Hot Spots®. Highway A silver case gives this unit a high-tech look. New to the ● PC interface product design, Garmin will cable include marine aids to ● Wrist strap navigation in addition to the ● User's guide basemap. These navigational ● Quick aids will be pre-loaded into reference each unit from the factory. guide Suggested Retail Price: $321.41 U.S.D. (for domestic US market only) Garmin Recommends: Select MapSource Product Go * denotes limitations eTrex Family Quick Links eTrex® Camo Summit Venture Legend eTrex Family Comparison Chart eTrex Product Showcase Which eTrex is right for YOU? Check out and compare the entire eTrex product line. Click Here The interactive demo requires Flash 5 plug-in. Download now Product Training Video Produced by Garmin Buy Now Available from local dealers or our online store. More Info> Video Overview Hi-res Overview 20.3MB mpeg Lo-res Overview 7.64MB mpeg TOP Copyright 1996-2004 Garmin Ltd. or its subsidiaries Privacy Statement/Terms of Use [3/2/2004 9:29:17 PM] Complete Sun and Moon Data for One Day U.S. Naval Observatory Astronomical Applications Department Complete Sun and Moon Data for One Day You can obtain the times of sunrise, sunset, moonrise, moonset, transits of the Sun and Moon, and the beginning and end of civil twilight, along with information on the Moon's phase by specifying the date and location in one of the two forms below and clicking on the "Get data" button at the end of the form. Use Form A for cities or towns in the U.S. or its territories. Use Form B for all other locations. Both forms are immediately below. Be sure to check Notes section, located after the two forms. Form A - U.S. Cities or Towns Year: 2004 Month: January Day: 1 State or Territory: D.C. City or Town Name: The place name you enter above must be a city or town in the U.S. The place's location will be retrieved from a file with over 22,000 places listed. Either upper- or lower-case letters or a combination can be used. Spell out place name prefixes, as in "East Orange", "Fort Lauderdale", "Mount Vernon", etc. The only exception is "St.", which is entered as an abbreviation with a period, as in "St. Louis". You need only enter as many characters as will unambiguously identify the place. Get data Form B - Locations Worldwide Year: 2004 Longitude: Latitude: Month: January Day: 1 east west degrees minutes north south degrees minutes (1 of 3) [3/2/2004 9:29:19 PM] Complete Sun and Moon Data for One Day Time Zone: hours east of Greenwich west of Greenwich Place Name: The place name you enter above is used only in the table header; you can enter any identifier, or none (avoid using punctuation characters). Need coordinates? Try NIMA's GEOnet Names Server. Need a time zone? Try the time zone map. Get data Notes For information on the definitions of terms used, see Rise, Set, and Twilight Definitions or Phases of the Moon and Percent of the Moon Illuminated in FAQ. If you need rise/set or twilight times for a series of dates for a U.S. location, use our rise/set table program, which computes a one-page table covering an entire year. For U.S. cities or towns (Form A), the output times will be on a 12-hour clock (with "a.m." or "p.m." listed); for worldwide locations (Form B) the output times will be on a 24-hour clock. For U.S. cities or towns (Form A), the times of the phenomena are presented in the standard time of the place requested, using the current time zone of the place. Standard time in time zones was introduced in the U.S. in 1883, but the time zone boundaries have evolved considerably since then, with places shifting from one zone to another. There is no attempt here to track such changes. Daylight time is implemented only for U.S. cities or towns (Form A) and only for years 1967 and later, in accordance with the Uniform Time Act of 1966 and subsequent legislation. Daylight time is not used for places currently exempt from it. At the bottom of the output page for U.S. cities or towns there is a link to the map-generating service of the U.S. Census Bureau. Clicking on this link will provide a map of the area surrounding the location for which astronomical data have been given. The large red dot in the middle of the map indicates the location for which the data were computed. The width of the map is 0.25 degrees of longitude, equivalent to 1 minute of time in rise/set phenomena. Except for some critical cases in Alaska, the map roughly indicates the area within which the computed astronomical data are valid. For worldwide locations (Form B) that require it, the time zone can be entered in hours and a fraction. For example, for locations in India, the time zone may be entered as 5.5 hours east of Greenwich. The time zone field can accommodate up to five characters. If you are having trouble seeing the date fields on this page, try the version without JavaScript. Sunset photo by Lu Rarogiewicz from Mt. Wilson, California. (2 of 3) [3/2/2004 9:29:19 PM] Complete Sun and Moon Data for One Day Need other kinds of astronomical information? Start at our home page. Back to . . . top Form A Form B [Publications | Data Services | Software | FAQ | Research | About AA] [News | Site Map | Index | Home] Need help? (3 of 3) [3/2/2004 9:29:19 PM] NASS FAQ - Before you start Before You Start Latitude and Longitude You will need to know your latitude - and if you wish to include a longitude correction (time zone offset) - you will need to know your longitude. If you don't know them they can be found from Internet sources. IMPORTANT Some sites will indicate longitudes west of Greenwich (i.e. in North America) as negative. Most methods of sundial construction require west longitudes entered as positive. If you live in the western hemisphere, do not use the minus sign when considering your longitude Correcting for your position in your Time Zone When solar time became inadequate for railway timekeeping, a system of time zones was initiated creating 24 time zones, each 15° wide - within which all clocks would tell the same time. (Basic arithmetic: The earth's 360° circumference was divided into 24 one hour segments, and the result was 24 time zones each 15° wide.) However, the sun moves across each artificial time zone at its own pace. If you wish your sundial to compensate for its position in its 15° time zone and approach Standard (clock) Time, you will need to apply a longitude correction. This correction is determined by the relationship between the longitude of your sundial and the longitude of the central meridian of your time zone. The central meridians of all 24 time zones can be found in the table below. If you are setting up a commercial sundial, the longitude correction will not be built into the dial, but it will be a constant amount which you must apply at each reading. If your longitude is west of your central meridian, add four minutes to the time on the dial for each degree. If you are east of your central meridian, subtract. This correction can be built into your dial if you are making one. Even after the longitude correction is applied, your dial will not consistently tell Standard Time due to The Equation of Time which varies throughout the year. See below. Time Zone Number (offset) Central Meridian (1 of 4) [3/2/2004 9:29:20 PM] Locations NASS FAQ - Before you start GMT-11hrs 11 165 Midway, Samoa GMT-10hrs 10 150 Hawaii, Society Is. NORTH AMERICA GMT-9hrs 9 135 Alaska, Pitcairn Island US Pacific 8 120 Whitehorse, Seattle, Los Angeles US Mountain 7 105 Yellow Knife, Denver, Phoenix, W. Mexico US Central 6 90 Churchill, Chicago, New Orleans, E. Mexico US Eastern 5 75 Montreal, New York, Columbia, Peru Atlantic 4 60 Nova Scotia, Venezuela, (Newfoundland -30m) GMT-3hrs 3 45 Greenland, E. Brazil, Argentina GMT-2hrs 2 30 Georgia & S. Sandwich Islands GMT-1hrs 1 15 Cape Verdes, Azores Greenwich 0 0 WET, British Isles, Iceland, W. Africa Middle Europe -1 -15 MET, Europe, Scandinavia, C. Africa Eastern Europe -2 -30 EET, OEZ, Europe, Mid East, E.C. Africa GMT+3hrs -3 -45 Mos, Moscow, E. Africa GMT+4hrs -4 -60 Gorki, Oman, Mauritius GMT+5hrs -5 -75 Pakistan, (India +30m GMT+6hrs -6 -90 Bangladesh, Burma (2 of 4) [3/2/2004 9:29:20 PM] NASS FAQ - Before you start GMT+7hrs -7 -105 S.E. Asia, Sumatra GMT+8hrs -8 -120 China, Philippines, W. Australia GMT+9hrs -9 -135 Korea, Japan, (C. Australia +30m) GMT+10hrs -10 -150 P. New Guinea, Guam, E. Australia GMT+11hrs -11 -165 Sakhalin Peninsula, Solomon Islands GMT+12hrs -12 -180 New Zealand, Wake, Marshall Islands The Equation of Time Even if your dial includes the longitude correction, its timekeeping will vary throughout the year due to a phenomenon called The Equation of Time. Simply put, the apparent motion of the sun will cause your dial to be as much as 16 minutes fast or slow at various times of the year. The Equation is caused by the earth's elliptical orbit, and the 23.44° tilt of its axis from the plane of its orbit. The chart below shows the amount your dial will vary from clock time through the year. Download it, print it out, and keep it close to your dial. There are dials which compensate for the Equation of Time, but they are complicated. (3 of 4) [3/2/2004 9:29:20 PM] NASS FAQ - Before you start Right-click in the graph, then "Save As" (4 of 4) [3/2/2004 9:29:20 PM] Sundials Make your own Horizontal sundial: Materials required: A pencil, protractor, compass and a straight edge. Draw a vertical line, now draw a line perpendicular (AB) to the vertical line. (Fig. #1) Now draw a line from A through the vertical line so that angle B'AB is equal to the latitude of the place where the dial is to be used. Remember this angle for making the gnomon. (Fig. #2) Draw a line perpendicular to line AB' that intersects line AB at point B. (Fig. #3) abraxas2/horz.htm (1 of 6) [3/2/2004 9:29:26 PM] Sundials Now use the distance A'B to find C (use the compass), draw a semi-circle centered at C and divide it into 15 degree pieces (use the protractor). (Fig. #4) Why 15 degrees? One day is 24 hours, or the amount of time it take for "the sun to go around the earth". So in 24 hours the sun "moves" through 360 degrees (recall that there are 360 degrees in a circle). Therefore to find how many degrees are in 1 hour we divide 360 by 24. 360/24=15 degrees, this is called the hour angle of the sun. Connect the 15 degree points along line BB' to point A. These are the hour lines for your sundial. Draw a line through A and parallel to line BB', this is the 6:00 hour line. (Fig. #5) abraxas2/horz.htm (2 of 6) [3/2/2004 9:29:26 PM] Sundials To find the morning hour line "flip" the afternoon hour lines over the 6 hour line. In other words angle B-A-11 is equal to angle B-A-1, likewise angle B-A-10 is equal to angle B-A-2 etc. (Fig. #6) All that is left is to add the gnomon and set the dial in the sun. The gnomon is a triangular piece that has one angle equal to the latitude of the place where the dial is to be used. See the diagram below on how to afix the gnomon to the dial. It's now time to take the dial outside and start to tell time. Orient your dial so that the 12:00 hour line and gnomon (which lies along the 12:00 line) are pointing toward TRUE NORTH. abraxas2/horz.htm (3 of 6) [3/2/2004 9:29:26 PM] Sundials Point of interest: The above procedure for graphically making a horizontal sundial was used by James Madison. He designed a dial using this same formula while an undergraduate at Princeton circa 1769. The image below is the actual work done by James Madison. abraxas2/horz.htm (4 of 6) [3/2/2004 9:29:26 PM] Sundials abraxas2/horz.htm (5 of 6) [3/2/2004 9:29:26 PM] Sundials NOTE: The faint image of the Sun at the center of the document and the faint concentric circles are Madison's notes about the Copernican System which are on the other side of the sundial calculation page. If you live in the Northern hemisphere finding true north is as easy as finding the North star and setting your dial to point at it, also if you measure the angle of the North star (Polaris) above the horizon you will have your latitude. DO NOT use a compass to find north, a compass shows magnetic north NOT true north. Another way to find true north is to watch the shadow of a vertical rod, when the shadow is at its shortest length it is pointing true North/South. Make your own Equatorial Sundial. Make your own Vertical Sundial. This page accessed times. Page created by: Changes last made on: October 22, 2002 Copyright (c)2002 I/O Asso. abraxas2/horz.htm (6 of 6) [3/2/2004 9:29:26 PM] Horizontal Sundial Shadow angle Calculator HORIZONTAL SUNDIAL SHADOW ANGLE CALCULATOR Ashover Bakewell Baslow Brassington Carsington Chapel-en-le-Frith Darley Dale Eyam Hartington Kedleston Over Haddon Ripley More sundials including scratch dials To find the Horizontal Sundial shadow hour angles for your locality you need to know your latitude. In the UK the latitude can be found by reference to an Ordnance Survey map. This will give your latitude in units of degrees and minutes. Convert this angle to decimal degrees before typing in to the first box below, i.e. if your latitude is 53° 30', type it in as 53.5 Then click the calculate button to see the results... Reset Calculator For horizontal dials Calculator For vertical dials Sundial time = 12 Noon Sundial time = 11:45 am and 12:15 pm Sundial time = 11:30 am and 12:30 pm Sundial time = 11:15 am and 12:45 pm Home page Sundial time = 11:00 am and 1:00 pm Sundial time = 10:45 am and 1:15 pm Sundial time = 10:30 am and 1:30 pm Sundial time = 10:15 am and 1:45 pm Sundial time = 10:00 am and 2:00 pm Sundial time = 9:45 am and 2:15 pm Sundial time = 9:30 am and 2:30 pm Sundial time = 9:15 am and 2:45 pm Sundial time = 9:00 am and 3:00 pm Sundial time = 8:45 am and 3:15 pm Sundial time = 8:30 am and 3:30 pm Sundial time = 8:15 am and 3:45 pm Sundial time = 8:00 am and 4:00 pm Sundial time = 7:45 am and 4:15 pm Sundial time = 7:30 am and 4:30 pm (1 of 2) [3/2/2004 9:29:30 PM] Email Links Page.. Horizontal Sundial Shadow angle Calculator Sundial time = 7:15 am and 4:45 pm Sundial time = 7:00 am and 5:00 pm Sundial time = 6:45 am and 5:15 pm Sundial time = 6:30 am and 5:30 pm Sundial time = 6:15 am and 5:45 pm Sundial time = 6:00 am and 6:00 pm ^^^Back to the top 2000 This revision 13 November 2002 (2 of 2) [3/2/2004 9:29:30 PM] NASS - Convert Deg/Min/Sec to Decimal Degrees and Vise-Versa Convert Degrees Minutes Seconds to Decimal Degrees You must enter all three values separated by spaces. Latitude: 48 18 40.2 Longitude: 99 57 56.9 Convert Decimal Degrees to Degrees Minutes Seconds Latitude: 48.311167 Longitude: 99.965806 [3/2/2004 9:29:30 PM] Sundials on the Internet - Five sundial projects for you to make For a full overview click here Five simple sundial projects for you to make Here are five sundial projects which will demonstrate the principles of a sundial and ensure that you end up with a sundial which tells accurate sun time. The projects are: an equatorial sundial a horizontal sundial another horizontal sundial (with a link to the original in French) and copiously illustrated a diptych dial an equiangular dial You can find some other projects for sundials and other sun-related phenomena on the Event Inventor's page visitors have come to this page since 1 June 2001 - we hope you enjoy them too. (1 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Project One - An Equatorial Sundial This project is summarised from "Make a Sundial" project no.3, by kind permission of the British Sundial Society For this project, you will need: ● a piece of card slightly wider than the protractor and say 25cm (10 in.) long ● a drinking straw or knitting needle ● a protractor 1. Draw lines across the card dividing the length into sections of 1, 10, 14, and 1 cm. (The length of 14 is alright for latitudes of 50 deg. or more, but if you live at a lower latitude, you will need to make this length longer) We'll call these lines A, B,and C. Mark the centre point O of line A, and the centre point P of line C. Draw a line OP connecting the two centre points. 2. Place the centre of the protractor on O and draw round it. Make a pin hole through O, turn the card over, and place the centre of the protractor on the pin hole. Draw round the protractor again so you have two semicircles back to back 3. Mark 15 degree intervals and number the hours as shown, on both semi-circles. 4. Score and fold the card along the lines A, B, and C 5. Enlarge the pin hole at O and push the straw through. Make sure the straw is at 90 deg. to the card around O. 6. Move the bottom end of the straw along the line OP until the angle it makes with the horizontal is the same as the latitude of the place where you are (this is about 30 deg. for Perth and for New Orleans, 45 deg for Bordeaux and for Minneapolis, 51.5 deg. for London, and 55 deg for Edinburgh) You may find it easier to calculate the correct angle, and mark off the correct length along the straw. The correct length is 10 x (cotangent of the latitude). In the examples above, the correct lengths would be 17.3 cm. for Perth or for New Orleans, 10 cm for Bordeaux and for Minneapolis, 8 cm for London, and 6.9 cm for Edinburgh 7. When you've found the correct location for the bottom end of the straw, bend up a tab as shown in the diagram, or put a pin through from the other side to hold the straw in the right place 8. The straw forms the gnomon. The shadow of the gnomon will fall on the hour lines on the top of the dial in summer, and on the underside in winter. 9. You can colour your dial and write a motto such as "AIM HIGHER THAN THE MARK" underneath. You now have a working equatorial sundial. The dial plate, with the 15 degree angles marked on it, is parallel to the equator, and the straw forming the gnomon is parallel to the earth's axis. The sun appears to revolve round the earth's axis at 360 deg. every day, which is 15 deg. every hour (which is why you marked out your hour lines at 15 deg. intervals) (2 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make You can also see from your model how a horizontal sundial is constructed. Wait till the shadow is exactly on one of your hour lines, and mark a line where the shadow of the base of your straw falls on the horizontal piece of your card, and mark the hour alongside. When you have marked out a number of lines in this way, you will see that the angles are not a regular 15 deg. on the horizontal surface. You will also see that the shadow line along the "equator" surface meets the shadow line along the horizontal surface, along the line of the fold B. The hour lines on the horizontal surface are, in fact, the projection, on the horizontal surface, of the 15 deg. lines on the equatorial surface. This forms the basis of the graphical method of determining the hour lines for horizontal sundials, which of course are different for each latitude. "Make a Sundial" contains lots of other interesting sundial projects, so why not order a copy today, and support the British Sundial Society who wrote this page for you and helped to sponsor Sundials on the Internet. (3 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Project 2 - A horizontal sundial This project was devised and written by Tony Helyar, and is one of a number of interesting pages on his site at To Construct a Horizontal Sundial The first step is to mark out the hour angles. A base line with a centrally rising perpendicular gives the noon, 6am and 6pm lines as follows:- Various methods exist for generating the remaining hour angles, we will use the computational method. The formula for calculating the angles quoted in many works on the subject is: log tan D = log tan t + log sin Ø and was used in this form to save the need for long multiplication of fractions. However in these days of pocket calculators we can use the more straightforward: tan D = (tan t)(sin Ø) In both these formula D is the angle which the hour line makes with the noon line, t is the is the time measured from noon in degrees and minutes of arc [the earth completes the 360° round the sun in 24 hours so 1 hour = 15° and 1 minute = 15' of arc], and Ø is the latitude of the place where the dial is to be positioned. Each angle calculated for times before noon also gives the angle for the equivalent times after noon:- (4 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make It's best to draw up a table: time t tan t sin Ø tan D D 9.30 (2.30) 37°30' 0.7673 0.7749 0.5945 30.73° I have put in one set of figures assuming a latitude of 50°48' (Ø = 50.8). Of course this is an obvious spreadsheet application. Having plotted all the hour angles required, normally hours and half hours, the shadow casting component, known as a gnomon or style, can be fitted along the noon line as shown below. The angle or height of the style is equal to the latitude of the dial location. It is a good idea to draw the whole thing out on a large sheet of paper fixed to a board and make a style out of thin card. This will check the design before committing it to a more permanent medium. The sundial should be positioned where it will be in the sun for the maximum length of time with the dial plate perfectly level and with the noon line pointing directly north. (5 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Project 3 - How to make a sundial by Andre E. Bouchard Ce projet en francais (Andre E. Bouchard is the chairman of Communications ABC inc., a communications research company, and is Secretary General of the Commission des Cadrans Solaires du Quebec) One might imagine that we could measure time simply by setting up a vertical pole on level ground. After a few days, it would become clear that tis idea does not work. The shadow of a vertical object does not fall in the same direction nor extend to the same distance at the same time on successive days. This is because the Sun passes across the sky each day on a path which rises and falls with the changing seasons. This difficulty is overcome by observing the shadow cast by a fixed object set up so that its straight edge, known as the style, is parallel to the Earth's polar axis. This is achieved by elevating it at the same angle from the northern horizon as the latitude of the intended location of the sundial. Of course, our sundial will indicate Sun Time, which may differ from the time told by a watch. For one thing, the apparent circular motion of the Sun varies in speed with the time of year, so that a day may last for slightly more, or slightly less, than the annual average of 24 hours. At certain times of year, this causes Sundial Time and Clock Time to differ by as much as 16 minutes. 1. Choose your materials for the style and dial face on the basis of appearance, durability and ease of working. 2. Cut out the style as shown and cut a straight rod, slightly longer than the sloping upper edge. The style angle (at the point that is to be fixed at the centre of the dial) must equal the latitude of the place where it will stand, as shown on a map of your country. . 3. Draw a semi-circle on the lower half of a piece of stiff paper, marking out angles of 15 degrees with a protractor. Fold back the upper half of the paper. (6 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make 4. Attach the style to the dial face. 5. Fasten the rod along the sloping edge of the style.. 6. Fit the paper semi-circle so that it rests against the end of the style plate opposite to the measured angle and fits closely around the sloping rod. Attach one end of a length of cord around the rod and, but stretching it in line with each 15 degree line, mark out point to left and right across the dial face. Temporary extensions to left and right of the dial face will be needed, where points can be added in line with the wider angles. Remove the paper protractor and with a straight ruler, draw in the hour lines of the sundial, joining the marked points to the point of emergence of the sloping style.. 7. Use a magnetic compass to orientate the sundial, so that the base of the style is in line with the North/South axis. Remember that the compass indicates magnetic north, and allow for the magnetic declination. (7 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make (8 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Project 4 - The diptych dial (9 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make DIRECTIONS FOR DIPTYCH DIAL ASSEMBLY The folding sundial you are about to make is called a diptych dial. Such dials have been made for four centuries and were traditionally made of ivory or boxwood. The diptych dial provided here was designed by Dr. Allan Mills, Astronomy Group, Leicester University, UK. The scanned images and text have been prepared by Dr. Randall Brooks, National Museum of Science and Technology, Ottawa, Canada. Step 1: Print the template dial (provided as JPEG graphics to download) on a piece of A4 or letter sized paper. The downloaded files may be resized if desireable. Paste the paper dial onto a piece of bristol board or heavy card making sure that glue is spread evenly over the entire surface. To download the full size template (55kb) click here Step 2: Trim along the outside lines on the template diagram. Step 3: To provide accurate time, the sundial must be orientated properly. The first step is to determine the latitude of the site using an atlas. On the right and left of the lower half of the dial (the base), you will see two scales marked 35°-55°. Once you have determined the required latitude mark, the latitude angle off on both scales drawing lines through each of the X symbols at the top. Cut the flaps off along these lines. At the top you may want to write the location and latitude and/or perhaps your name, i.e. "Sam Smith, Fecit" (Fecit is Latin for "maker" and often appears on early instruments). NB: If your site is outside the 35-55° latitude range, you can move the position of the "X" until you get the required tilt to the dial's base. (10 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Step 4: Note the dashed lines; two of these are marked "score on back, fold forward" and two marked "score on front, fold down". Folds must be made along these lines and to get nice clean folds score along these lines lightly with a sharp craft knife, the folds will be sharper and the sundial will stand better and look more finished. However, in making these scores, do not cut all the way through the card backing! After scoring, make the necessary folds in the direction indicated. Step 5: Along the line with "Moon" above and "a.m. p.m." below, make another score line on the back and fold the upper section forward so that the two parts make a right angle. Step 6: To finish the dial attach a string (preferably elastic string) through holes at the top and bottom at the points where the hour lines converge. The easiest way to accomplish this is to use a thick needle and thread the string through using knots on each end so that the string is taught when the dial is folded and ready for use. This string is the gnomon (pronounced no-mon) and casts the shadow to indicate the time. Step 7: You may wish to embellish the back of your dial with an old-style graphic from a book on sundials, a drawing of your pet or whatever appeals to you. This is where you can individualize your diptych dial! Positioning your sundial: The sundial must be orientated with the gnomon pointing north/south and, of course, the dial must be located where a shadow will be cast by the gnomon most of the day (though one can move the dial from window to window as the day progresses if necessary). Method 1: (The Purist's Method) To determine the orientation without reference to other mechanical devices, North can be found by observing Polaris, the North Star, at night. In orientating the sundial, the gnomon is actually being pointed to the North Celestial Pole which is within 1° of the North Star. Thus, if you can find Polaris at the end of the Little Dipper, line up your dial by pointing the gnomon towards Polaris. You might want to record the orientation for your dial by making light pencil marks on a window sill for future reference. Those in southern latitudes will not be able to use this method as there is no bright star near the South Celestial Pole. Method 2: (The Practical Method) A magnetic compass may be used to determine the north/south line, but, because of the difference between magnetic north and true north, the dial reading could be out by an hour or more depending on the local difference between magnetic north and true north (or south if in southern latitudes). Method 3: (The Lazy Person's Method) To a first approximation, the orientation can be found by finding the orientation at any time from a clock of known accuracy and orientating the dial so the shadow shows the correct time. However, if left in this position, there could be an error of up to 30 minutes over the year as a result of what is known as the "equation of time". Because of the Earth's orbital motion around the Sun, the solar day (apx. 24 hours) is not exactly the same length from day to day varying by up to ±16 minutes a day. However, if the orientation is carried out on April 15, June 10, Sept. 1 or Dec. 20, this error will be negligible and any orientation made between April 15 and 1 Sept. will be in error by, at most, a few minutes (but don't forget the effect of daylight savings time). Happy dialling! (11 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Project 5 - The equatorial dial For a full size version of this image, click on the image This dial is of a rather unusual and not very well-known type. It was invented by Samuel Foster in the seventeenth century and has been forgotten and re-discovered more than once since then. The version described below is based on a description by F.W. Sawyer of the North American Sundial Society. Unlike a common horizontal dial with a fixed gnomon, this one has its hour lines equally spaced on the circumference of a circle, and no calculations involving latitude are required. The positioning of the dial does not depend on a prior knowledge of the North- South meridian and it can be used as a sun compass. DIRECTIONS FOR EQUINOCTIAL DIAL ASSEMBLY Step 1. Take the page of patterns and paste it to a piece of card at least 1.5 mm thick. Suitable material can be obtained from a good stationer or artists' supplier. Step 2. Using a sharp knife or scalpel, cut out the two rectangular pieces with the hour scales: also the gnomon, taking particular care with the shadow-casting edges, a and b. The angle C is 51.50, the latitude of London. If the dial is to be used at a different latitude, the angle should be altered accordingly, but sides a and b must always be at right angles to each other. (Do you need help in finding your latitude? Step 3. Join the two rectangular pieces, using pasted strips of card applied along the dotted lines. A gap should be left, just sufficient to allow the gnomon to pass through it. Step 4. The slotted squares help to maintain the gnomon vertical and the hour-plate at right angles to it. (12 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make HOW TO USE THE EQUIANGULAR DIAL Slide the hour-plate to a position where the V of the gnomon coincides with the appropriate date on the month scale. With the base on a horizontal surface, rotate the assembly until the indicated times are the same for each shadow. The upper shadow is to be read on the clockwise scale, the lower on the anti-clockwise one. The indicated time is then the correct Solar Time, and the gnomon is in the North-South plane. The dial functions best at times one or two hours before or after midday. Around noon precise settings are rather difficult. For a full size print of this image, click on the image. (13 of 14) [3/2/2004 9:29:35 PM] Sundials on the Internet - Five sundial projects for you to make Comments/ suggestions/ problems, please get in touch with the Webmaster (14 of 14) [3/2/2004 9:29:35 PM] NASS FAQ - Basic Trigonometry Basic Trigonometric formulas for calculating the hourlines on a horizontal sundial tan X = tan h sin lat Where X = the result, the angle the hour line makes with the 12 o'clock line, h = the time (hour angle) measured from noon in degrees. The earth rotates 360 degrees in 24 hours, or 15 degrees in 1 hour lat = the latitude of the dial. Here is the framework for a BASIC program for computing the angles for the hourlines from 6 AM to 6 PM on a horizontal dial located at 35°. The program will not work as-is because most BASICs require angles to be computed in radians. Use the format to build your own programs; or for a calculator or spreadsheet. 1 2 3 4 5 6 7 CLS lat = 35 FOR h = -90 to 90 STEP 15 X = ATN((TAN(h)*SIN(lat)) PRINT X NEXT END You can apply the longitude correction time zone offset by changing line 3. For instance, if your longitude is 4.56 degrees east of your central meridian, you would add 4.56 to the value for h, and line 3 would be: 3 FOR h = -90 + 4.56 to 90 + 4.56 STEP 15 But let's do the arithmetic, and while we're at it, let's change the STEP value to produce half-hours. 3 FOR h = -85.44 to 94.56 STEP 7.5 (1 of 2) [3/2/2004 9:29:36 PM] NASS FAQ - Basic Trigonometry (2 of 2) [3/2/2004 9:29:36 PM] Sunrise, Sunset, & Twilight Map 2002 APR | MAY | JUN Sunrise Sunset 1 5 10 15 20 25 Begin Civil Twilight 05:42 a.m. 05:37 a.m. 05:31 a.m. 05:26 a.m. 05:21 a.m. 05:17 a.m. 06:10 a.m. 06:04 a.m. 05:56 a.m. 05:52 a.m. 05:48 a.m. 05:45 a.m. 06:38 a.m. 06:30 a.m. 06:25 a.m. 06:19 a.m. 06:15 a.m. 06:11 a.m. End Civil Twilight 08:29 p.m. 08:34 p.m. 08:38 p.m. 08:43 p.m. 08:48 p.m. 08:49 p.m. 08:53 p.m. 08:55 p.m. 08:57 p.m. ... Note: All times are EDT for Washington, D.C. ... Griffith Observatory Star Awards The Griffith Observatory Star Awards were established to recognize excellence in web sites that promote public awareness of astronomy. These are the best astronomy sites on the World Wide Web, and they present useful, thorough, and accurate information in a well-organized and attractive way, making the sky more accessible. The exclusive Star Award is presented once each week to a deserving site. Feb. 29 - Mar. 6 Tranquility Base Today The Apollo 11 landing site as it exists today. Feb. 22 - 28 Solar System Collisions Simulate the collision of an asteroid or a comet with any planet in our Solar System. Feb. 15 - 21 Kuiper Belt ... Feb. 8 - 14 Feb. 1 - 7 Lunar Picture of the Day An engaging photo of the moon each day. Jan. 25 - 31 The Soviet Exploration of Venus Details of 30 Soviet Venus missions, 1961 - 1984. Jan. 18 - 24 Venus Transit 2004 Resources to understand, enjoy, and participate in the transit. Jan. 11 - 17 Curious About Astronomy? Ask an Astronomer Astronomy questions answered by Cornell astronomers. Jan. 4 - 10 Explore Mars Now Walk through and explore an interactive Mars habitat. (1 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award Dec. 28 - Jan. 3, 2004 Exploratorium's Journey to Mars Images, webcasts, and information from the Mars landers. 2004 above 2003 below Dec. 21 - 27 Map of the Universe Display of range of astronomical scales from the Earth's neighborhood to the cosmic microwave background. Dec. 14 - 20 Mt. Wilson Observatory History and current research at historic Mt. Wilson. Dec. 7 - 13 Paul Carlisle's Earth Viewer and Moon Calendar Earth illumination for any day + moon phases for any month. Nov. 30 - Dec. 6 Sky Router Portal to astronomy links with news and sky events. Nov. 23 - 29 Myths and Tales Associated with the Constellations Sky maps, constellation mythology, space news. Nov. 16 - 22 Deep Sky Database Online observing list generator for deep sky objects. Nov. 9 - 15 Nov. 2 - 8 Oct. 26 - Nov. 1 Stardome Guide to CCD Imaging Guidance on taking and processing CCD images. Geological Lunar Research Group Resources for observers interested in geology of the moon. Astronomy Programs Links to about 200 freeware, shareware, and commercial astronomy programs. Oct. 19 - 25 View of Our Universe A view of our universe as it is at this minute. Oct. 12 - 18 Astrotips "All and only about astronomy software." Oct. 5 - 11 Sept. 28 - Oct. 4 Sept. 21 - 27 Stanford Solar Center A collection of fun educational activities based on the sun. Digital Lunar Orbiter Photographic Atlas of the Moon The definitive searchable on-line moon atlas. ... (2 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award ... 1997 ... Nine Planets A complete guide to the solar system Best of the Hubble Space Telescope Images ... January 12 - 18 Cosmic Mirror Astronomy news from across the universe January 19 - 25 Views of the Solar System Selected images of the planets and their moons January 26 - Feb. 1 February 2 - 8 History of Astronomy Includes astronomers biographies and many historical links. Comet Observation Home Page The latest information on current comets February 9 - 15 Mike Boschat's Astronomy Page A huge alphabetical directory of astronomy sites. February 16 - 22 The Comet's Tale An activity that teaches the composition of comets. Feb. 23 - March 1 The Constellations Astronomy and mythology of all 88 constellations. March 2 - 8 Extrasolar Visions All about the planetary systems around other stars. March 9 - 15 NASA's Observatorium A huge site that takes you to images, games, tutorials, and more. March 16 - 22 Solar System Live An interactive orrery lets you view the solar system for any date or orientation. March 23 - 29 The Case for Mars Why we should return to Mars. March 30 - April 5 Astronomical Applications Department of the US Naval Observatory Calculate all sorts of things about astronomical objects with precison. (15 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award April 6 - 12 Eclipse Home Page All you could want to know about upcoming eclipses. April 13 - 19 Astronomy Cafe "The Web Site for the Astronomically Challenged." April 20 - 26 Astronomical Society of the Pacific Astronomy education and articles for the whole world. April 27 - May 3 May 4 - 10 Welcome to the Planets The Jet Propulsion Laboratory's planets page. Project Galileo Images, activities, latest news, and more about Jupiter. May 11 - 17 The Basics of Space Flight A slick introduction into the basics of space flight. May 18 - 24 Astronomy Picture of the Day Each day a different image or photograph of our fascinating universe is featured. May 25 - 31 Space Day Space exploration resource includes space trivia and games and educational resources for teachers and students. June 1 - 7 June 8 - 14 Space Telescope Science Institute All about the Hubble Space Telescope, its operation, and pictures. The Search for Extraterrestrial Intelligence SETI Institute home page – Are we alone in the universe? June 15 - 21 Calendar Zone Everything you want to know about calendars around the world. June 22 - 28 Planetarium Software List of selected astronomy computer software with links. June 28 - July 5 July 6 - 12 FAQ on Telescope Buying and Usage Good advice on selecting telescopes and related equipment. Leonid Home Page All about November's annual shower. July 13 - 19 Informal Science Education Resource Educational resources for the Hubble Space Telescope with photos and activities. July 20 - 26 Extrasolar Planets Encyclopedia Detailed information about planets around other stars. (16 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award July 27 - Aug. 2 Careers in Astronomy Learn how to pursue the goal of becoming an astronomer. Aug. 3 - 9 Windows to the Universe Exhaustive graphical astronomy tutorial and encyclopedia Aug. 10 - 16 National Geographic's Star Journey Exciting site with lots to explore for all ages. Aug. 17 - 23 Solar System 3D: Planets and Satellites Stereo atlas of the solar system (red-blue or red-green glasses required). Aug. 24 - 30 Earth and Moon Viewer Various maps of the earth or moon with named features, lighting conditions, etc. Aug. 31 - Sept. 6 Sept. 7 - 13 SKY Online Sky & Telescope's home page: observing information, software, news, reviews, etc. Cosmos in a Computer Immense multimedia guide to the cosmos from National Center for Supercomputing Applications, University of Illinois. Sept. 14 - 20 Mars Global Surveyor NASA's homepage for the Mars orbiter Sept. 21 - 27 Cassini: Voyage to Saturn NASA's homepage for the Cassini mission to Saturn and its moons Sept. 28 - Oct. 4 The Constellations and their Stars All about the constellations. Oct. 5 - 11 The Mars Meteorite Home page All about SNC (also called "Snicks") Mars meteorites. Oct. 12- 18 NASA Origins Program The Origins program– astrobiology, the search for extrasolar planets. Oct. 19 - 25 NASA Spacelink The aeronautics and space resource for educators. Oct. 26 - Nov. 1 Nov. 2 - 8 Nov. 9 - 15 The USGS Flagstaff Space Mission Support Page The home page for the USGS Astrogeology Branch; emphasizes planetary cartography. Black Holes and Neutron Stars The laypersons guide to black holes and neutron stars. National Space Science Data Center Astrophysics, space physics, solar physics, lunar and planetary data from NASA space flight missions (17 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award Nov. 16 - 22 Life in the Universe Web site to accompany Stephen Hawking's CD-ROM of the same name. Nov. 23 - 29 Berit's Best Astronomy Sites for Children Selected astronomy web sites for children. Nov. 30 - Dec. 6 Dec. 7 - 13 Messier Catalog The popular Messier Catalog in information and pictures. Solar System Simulator Renders planets and satellites from any point in space looking in any direction. Dec. 14 - 20 Comets and Meteor Showers Background on historic, present, and future comets and meteor showers. Dec. 21 - 27 Mission to Mars Interactive educational site lets you design your own Mars mission. 1998 (below) Dec. 28 - Jan. 3 1998: Jan. 4 - 10 Space Educators' Handbook An immense assortment of space-related educational resources including Spinoff magazine. National Solar Observatory / Sacramento Peak Information on many aspects of astronomy from the sun and planetary alignments to colliding galaxies and bad astronomy reporting. Jan. 11 - 17 Universe at Your Desktop Hundreds of famous and obscure astronomy catalogs Jan. 18 - 24 The Galileo Project Galileo, his discoveries, times, instruments, and contemporaries. Jan. 25 - 31 Stanford Solar Center Providing Solar On-Line Activity Resources for the joy of solar science exploration. Feb. 1 - 7 Other Worlds, Distant Suns Yet another cool extrasolar planets page. For full effect, it requires a VRML plug-in. Feb. 8- 14 Maps of the Solar System Global image mosaics of large bodies in the solar system, most from spacecraft observations. Feb. 15 - 21 Introduction to Cosmology Basic concepts of modern astronomy and the Microwave Anisotropy Probe Feb. 22 - 28 Space Calendar Space-related activities and anniversaries for the coming year. Mar. 1 - 7 The Space, Planetary, and Astronomical Cyber-Experience Enter "CyberSpace" and discover the wonders of the online universe. (18 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award Mar. 8 - 14 Lunar Prospector Information about the Lunar Prospector Mission as well as lunar history and mythology. Mar. 15 - 21 Center for Mars Exploration Headquarters for the exploration of the Red Planet. Mar. 21 - 27 Mount Wilson Observatory Take a virtual tour of America's historical observatory and create your own star charts. March 28 - Apr. 3 Apr. 4 - 10 Skyview Virtual Observatory Generate images of the sky in a variety of wavelengths with this virtual observatory. Sea and Sky Explore the sky through pictures, games, and links. Apr. 11 - 17 [revoked] Apr. 18 - 24 Apr. 25 - May 1 May 2 - 8 May 9 - 15 Izzy's Skylog Backyard Astronomy for the beginner. Great horizon maps! Visual Satellite Observers Home Page Spot Mir, HST and others crossing the night sky. NASA's Planetary Photojournal Easy access to the publicly released images from the many solar system exploration programs. Exploring the Moon Everything you wanted to know about the lunar exploration efforts of the U.S. and Soviet Union. May 16 - 22 Windows to the Universe A fun and different Web site about the earth and space sciences. May 23 - 29 NASA Human Spaceflight Shuttle and Space Station news and links. May 30 - June 5 StarTimes OnLine Daily astronomy and space headlines with links; keep informed. June 6 - 13 Telescopes In Education Operate a remotely controlled 24-inch telescope and CCD camera on Mt. Wilson. June14 - 20 Astronomical Imaging by Brad Wallis and Robert Provin Advanced amateur astrophotography page. June 21 - 27 Skywatcher's Diary A day-to-day description of what to watch for in the sky this month. June 28 - July 4 The Basics of Radio Astronomy The title says it all. (19 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award July 5 - 11 Eclipse Chaser Guide to recent and future solar eclipses with photos, maps, travel tips, observing hints, and more. July 12 - 18 Mysteries of Deep Space Astronomy information and activies, by PBS Online July 19 - 25 Volcanoes of Other Worlds Volcanoes around the solar syste July 26 - Aug 1 Aug. 2 - 8 Aug. 9 - 15 JPL Solar System Dynamics Provides detailed information related to all known bodies orbiting the sun. Eyes on the Sky Robotic Solar Observatory Robotic solar viewing telescope and BBS The Space Place JPL's new educational (primarily K-12) web site. Aug. 16 - 22 Near-Earth Asteroid Tracking Home Page Keep up to date on "Near-Earth" asteriod discoveries. Aug. 23 - 29 Astronomy Now Breaking News Daily astronomy news from Britain's Astronomy Now magazine. Aug. 30 - Sept. 5 Sept. 6 - 12 Spacezone A well-rounded page of space history, news, and education. Backyard Astronomy Tips on observing the universe from Sky & Telecope magazine. Sept. 13 - 19 Infrared Astronomy All about infrared astronomy from NASA's IR center. Sept. 20 - 26 Cyberhole Online Astronomy Complete astronomy site with links, news, software, etc. Sept. 27 - Oct. 3 Oct. 4 - 10 Mission and Spacecraft Library Comprehensive spacecraft, facts, pics and more. Today at NASA NASA news stories, press releases, and links. Oct. 11 - 17 StarChild Learning center for young astronomers. Oct. 18 - 24 Planetarium Web Sites Planetarium Websites around the world. (20 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award Oct. 25 - 31 Nov. 1- 7 Nov.8 - 14 The Hitchhikers Guide to the Moon Lunar observing at its best. Sonoma State University Favorite Astronomy Links Links for everyone. Cosmobrain Astronomy and Astrophysics Excellent list of selected astronomy web sites. Nov. 15 - 21 Forum for Amateur AstroSpectroscopy For the amateur interested in learning about and doing astronomical spectroscopy. Nov. 22 - 28 Big Bear Solar Observatory Amazing views of our nearest star. Nov. 29 - Dec. 5 Dec. 6 - 12 Space Team Online Join the men and women who work on NASA's Space Shuttle and the International Space Station. Structure and Evolution of the Universe Explain, explore, and examine our evolving universe. Dec. 13 - 19 Munich Astro Archive Astronomy information and catalogs (in English). Dec. 20 - 26 CERES Astronomy Education 20 astronomy classroom lessons for K-12 teachers and students. 1999 (below) Dec. 27 - Jan. 2, 1999 Jan. 3 - 9 From Stargazers to Starships High-school level tutorial on astronomy, Newtonian mechanics, and spaceflight. Planetary Society Your connection to the exploration of the cosmos and the search for extraterrestrial life and intelligence. Jan. 10 - 16 SkyTour [No longer available.] Jan. 17 - 23 Itty Bitty Scienceguides Neat to know, cool science stuff! Jan. 24 - 30 Ned Wright's Cosmology Tutorial Cosmology resources including news and a tutorial. Jan. 31 - Feb. 6 Feb. 7 - 13 Hubble Heritage Archive Selected HST images and descriptions. The Lunascan Project Moon maps and moon images galore. (21 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award Feb. 14 - 20 Deep Space 1 Information on new technologies currently being "validated" on this mission for future space flights. Feb. 21 - 27 The Electronic Universe Project A smorgasboard of astronomy images and good information to go with them. Feb. 28 - March 6 March 7 - 13 International Supernovae Network Supernova hunting for the advanced amateur. Astronomy Notes College-level astronomy textbook (a great reference). March 14 - 20 Star of the Week A site dedicated to showing that the stars are not all the same. March 21 - 27 The Arcturus Observatory CCD images courtesy of The Arcturus Observatory. March 28 - Apr. 3 April 4 - 10 Peoria Astronomical Society Astronomical Handbook, three-D star map and more. Students for the Exploration and Development of Space Comprehensive site with tons of useful astronomy information. April 11 - 17 Aboriginal Star Knowledge Astronomical info developed principally by the Lakota Indians over many generations. April 18 - 24 Encyclopedia Astronautica All about the many space programs through history. April 25 - May 1 Space Connection News of space for teachers, parents, and students. May 2 - 8 Astronomy for Kids Explore the sky through facts, puzzles, and maps. May 9 - 15 Astronomical Image Library Comprehensive and ambitious image bank of deep-space objects. May 16 - 22 Association of Universities for Research in Astronomy Interesting projects from the operators of major telescopes worldwide. May 23 - 29 Tom's Astronomy Web Good links to lots of astronomy web sites. May 30 - June 5 Feltz Field Guide to the Night Sky A detailed on-line "field guide" to the night sky. (22 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award June 6 - 12 Meteorite Central Meteorites, facts, chat and more. June 13 - 19 Space Online Keep up to date with all the news from and about space. June 20 - 26 Hubble Constant dot Com Information on the Hubble Constant, cosmology, and the size and age of the universe. June 27 - July 3 July 4 - 10 Astronomy Now Breaking News Daily news from the UK's leading astronomy magazine. Regulus The astronomy newsletter for amateurs of all levels. July 11 - 17 Astronomy Homework Help User friendly resource page for high school and undergraduate college students. July 18 - 24 The Solar and Heliospheric Observatory (SOHO) Views of the sun, SOHO real-time web watch. July 25 - 31 Adventures in Deep Space Challenging observing projects for amateur astronomers. Aug. 1 - 7 Aug. 8 - 14 Aurora Web Aurora facts and resources, including forecasts. Near-Earth Object Program Information on asteroids that may strike the earth. Aug. 15 - 21 NASA Space Science News Astronomy and space science news presented by the Marshall Space Flight Center. Aug. 22 - 28 Space & Astronomy For Kids An astronomy guide for children, with many links. Aug. 29 - Sept. 4 Sept. 5 - 11 Bad Astronomy If it's bad and it's on TV or the in the movies, this explains how it really works. Your Sky View a map of the sky from any place on earth at any time. Sept. 12 - 18 International Occultation Timing Association Master index and information site for lunar occultations and grazes. Sept. 19 - 25 Kuiper Belt Page Clearinghouse for information on cometary bodies that orbit beyond Pluto. (23 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award Sept. 26 - Oct. 2 Oct. 3 - 9 Association of Lunar and Planetary Observers Detailed information on observing solar system objects and phenomena from the sun to meteors. International Meteor Organization Promotes international coordination of amateur meteor observations. Oct. 10 - 16 American Lunar Society Moon equipment, books, youth education, and observing projects. Oct. 17 - 23 Amateur Astrophotography and CCD Image Links Very attractive, slick, and helpful page with a great raison d-etre. Oct. 24 - 30 Planetary Nebulae Observer's Home Page A site devoted to the astronomical objects known as planetary nebulae. Oct. 31 - Nov. 6 Nov. 7 - 13 The Virtual Observatory - List Generator Generate custom object lists with this great resource! Central Bureau for Astronomical Telegrams (CBAT) Clearinghouse for announcements on new and transient astronomical events. Nov. 14 - 20 Sunspots and the Solar Cycle Facts, daily pictures, history, tutorials, and predictions. Nov. 21 - 27 MarsNews.com Stay informed with with the Mars Society with news about the Red Planet. Nov. 28 - Dec. 4 Dec. 5 - 11 The Astronomy Guide A search engine for everything in astronomy. The NGC/IC Project A comprehensive, and growing, database of the original NGC and IC deep space objects. Dec. 12 - 18 Star Trails An initiative by the Goddard Space Flight Center to involve amateurs in scientific research. Dec. 19 - 25 Solar Terrestrial Dispatch Space Weather, Solar & Geophysical Support Services. Dec. 26 - Jan. 1, 2000 STSPLUS Excellent resource for past/current shuttle missions, satellite tracking, and related software. General Info | Tour of Observatory | Planetarium | Special Events | Renovation | Sky Info Star Awards | Griffith Observer | Calif. Astro. Clubs | Bookshop | FOTO | IPS Journal (24 of 25) [3/2/2004 9:29:39 PM] Griffith Observatory Star Award contact: (25 of 25) [3/2/2004 9:29:39 PM] SCSA Equatorial Sundial Gnomon Length Calculator Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium Equatorial Sundial Gnomon Length Calculator An equatorial sundial consists of a dial plate, and a gnomon (or style) that is perpendicular to the dial plate. The dial plate has an upper dial face and a lower dial face, both of which are marked off in hours. The gnomon is a pole (or rod) that passes through the center of the dial plate, extending above the upper face of the dial plate, and extending below the lower dial face. Use the following rule-of-thumb to determine the length of the upper segment of the gnomon: "If the shadow of the gnomon is to reach the circle of hour numbers at the times of the solstices, the gnomon must be about half as long as the radius of that circle. (The theoretical value is 0.44 times the radius.)" Quote courtesy Sundials: Their Theory and Construction, Albert E. Waugh, Dover Publications, Inc., ©1973, p. 32. Input the radius of the dial plate (one-half the diameter) and your latitude to calculate the length of the lower segment of the gnomon required to properly orient your equatorial sundial. Note: Input fractions as decimals. For example, input 4 ½ as 4.50. Radius of dial plate (including height of "foot"): Latitude: 39.00 4 (unit-independent) (0-90 degrees) The gnomon should extend horizontal surface. units from the center of the lower dial face to a For 0° latitude (the Equator), the gnomon lower segment is theoretically infinite in length. Note that the computer is unable to display infinity (∞) properly. © Copyright 2002-2004 Walter Sanford. All rights reserved. Me and My Shadow - Making the Sun-Earth Connection | SCSA Home wsanford/es_gnomon_length.html [3/2/2004 9:29:40 PM] Rotation ROTATION The turning of a body around an imaginary axis running through it. As viewed from above the North Pole, the Earth rotates counterclockwise once every 24 hours (one day), causing day and night. wsanford/exo/rotation.html [3/2/2004 9:29:41 PM] Film & Video Stock Shots, Inc. Home NEW FEATURE: Film & Video Stock Shots Featured Footage Gallery Current Feature: • On this site you will find the premiere stock footage provider , and the tools to secure that footage for your project(s). [3/2/2004 9:29:45 PM] • Use of provided media for commercial purposes without the express written consent of Film & Video Stock Shots is strictly prohibited. British Sundial Society Register Register Facts 1. Numbers of Dials by County or Region - UPDATED (09/07/2001) The numbers of dials (above zero!) that are currently known in different parts of the UK & Eire are listed below: Gloucestershire Cornwall Devon Wiltshire Yorkshire (N) 310 197 193 174 158 Powys Borders Region Sussex (W) Nottinghamshire Central Region 28 27 27 25 24 Cumbria Oxfordshire Hampshire Kent Suffolk London (Greater) Cheshire Somerset Dorset Cambridgeshire Hereford & Worcester Northumberland Northamptonshire Lothian Region Tayside Region Strathclyde Region Warwickshire Sussex (E) Essex 157 150 135 128 125 121 115 110 96 95 92 92 91 84 78 73 72 66 63 Hertfordshire West Midlands Manchester (Greater) Yorkshire (ER) Clwyd Area Yorkshire (S) Highland Region Antrim & Belfast Bedfordshire Isle of Wight Tyne & Wear Isle of Man Dyfed Area Overseas Dials Down Dublin Glamorgan (South) Gwent Area Bristol 24 23 22 22 21 20 18 16 14 13 10 9 8 8 7 5 5 4 3 Derbyshire Shropshire Lancashire Leics & Rutland 61 59 58 58 Glamorgan (West) Armagh Cork Kildare 3 2 2 2 (1 of 3) [3/2/2004 9:29:46 PM] British Sundial Society Register Grampian Region Yorkshire (W) Dumfries & Galloway Lincolnshire Staffordshire Durham Surrey Fife Norfolk Berkshire Gwynedd Area Merseyside 53 50 47 44 42 41 41 38 37 36 34 32 Buckinghamshire Channel Isles 31 30 Louth Galway Glamorgan (Mid) Isles of Scilly Offaly Tipperary Tyrone Western Isles Wexford Wicklow Info from P Powers 2. Numbers of Dials by Type The numbers of dials by type are as follows: Horizontal Vertical (S) Vertical (D) Equatorial Mult Cube Multiple Mult Facet Head Vertical (W) Analemmatic Other Vertical (E) Mult Obelisk Complete 1257 1192 796 206 147 142 68 45 37 34 33 30 Mult Cube Market Cross Polar Azimuth Mult Lectern with Star 21 20 18 18 (2 of 3) [3/2/2004 9:29:46 PM] 2 1 1 1 1 1 1 1 1 1 British Sundial Society Register Mult Lectern no Star Mult Diptych Mult Obelisk Partial Noon mark Scaphe Spherical Mult Composite Facet Head Incl/Recl Vertical (N) Equiangular Altitude Info from P Powers (3 of 3) [3/2/2004 9:29:46 PM] 16 15 15 15 12 12 7 6 4 1 1 Revolution REVOLUTION The motion of one body around another. The Earth revolves counterclockwise around the Sun once every 365 days (one year). Orbit is a synonym for revolution. (Remember that synonyms are two words which have the same meaning.) wsanford/exo/revolution.html [3/2/2004 9:29:47 PM] Sun-Moon Yin-Yang Sun and Moon Data for Washington, D.C. Azimuth (0-360°) of Sunrise/Sunset & Moonrise/Moonset During Full Moon Year 2001 2002 Month SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG Day 02 02 01 30 30 28 27 28 27 26 24 24 22 SR/SS 80/280 94/265 108/251 118/242 120/240 113/247 100/260 86/275 72/289 62/298 59/301 64/296 74/285 MR/MS 105/252 89/268 72/285 64/294 59/301 63/299 78/285 91/274 111/254 119/244 123/237 119/239 111/246 N=0, NE=45, E=90, SE=135, S=180, SW=225, W=270, NW=335 Maximum Altitude (0-90°) of Sun & Moon During Full Moon Year Month Day Sun Moon SEP 02 59 39 2001 OCT NOV 02 01 30 47 37 29 52 63 67 DEC 30 28 75 JAN 28 33 74 2002 FEB MAR APR MAY 27 28 27 26 43 54 65 72 64 55 39 31 JUN 24 75 26 JUL 24 71 27 AUG 22 63 35 Horizon=0, Zenith=90 Duration of Sunlight & Moonlight During Full Moon Date 09/02/01 10/02/01 11/01/30 11/30/01 12/30/01 01/28/02 02/27/02 03/28/02 Sunrise 06:39 a.m. 07:06 a.m. 06:36 a.m. 07:07 a.m. 07:27 a.m. 07:18 a.m. 06:44 a.m. 05:59 a.m. Sunset 07:37 p.m. 06:49 p.m. 05:08 p.m. 04:47 p.m. 04:56 p.m. 05:25 p.m. 05:59 p.m. 06:28 p.m. Duration 12h58m 11h43m 10h32m 09h40m 09h29m 10h07m 11h15m 12h09m Moonrise 07:28 p.m. 06:53 p.m. 05:13 p.m. 04:14 p.m. 04:16 p.m. 03:59 p.m. 05:13 p.m. 05:17 p.m. Moonset 06:08 a.m. 06:55 a.m. 06:47 a.m. 06:42 a.m. 07:40 a.m. 07:16 a.m. 07:14 a.m. 06:15 a.m. Duration 10h40m 12h02m 13h34m 14h28m 15h24m 15h17m 14h01m 12h58m 04/27/02 05/26/02 06/24/02 07/24/02 08/22/02 06:16 a.m. 05:48 a.m. 05:44 a.m. 06:03 a.m. 06:28 a.m. 07:57 p.m. 08:24 p.m. 08:38 p.m. 08:27 p.m. 07:54 p.m. 13h41m 14h36m 14h54m 14h24m 13h26m 07:35 p.m. 07:40 p.m. 07:42 p.m. 08:24 p.m. 07:43 p.m. 06:46 a.m. 05:54 a.m. 05:16 a.m. 05:58 a.m. 05:53 a.m. 11h11m 10h14m 09h36m 09h34m 10h10m wsanford/exo/sun-moon_yin-yang.html (1 of 2) [3/2/2004 9:29:47 PM] Sun-Moon Yin-Yang Related Web Sites ❍ Yin and Yang - Dynamic Equilibrium in the Universe ❍ United States Naval Observatory (USNO) Phases of the Moon ❍ USNO Complete Sun and Moon Data for One Day ❍ USNO Sun or Moon - Altitude/Azimuth Table for One Day wsanford/exo/sun-moon_yin-yang.html (2 of 2) [3/2/2004 9:29:47 PM] Zenith ZENITH The imaginary point in the sky directly overhead an observer. Everyone has their own personal zenith, and it follows you everywhere you go! wsanford/exo/zenith.html [3/2/2004 9:29:48 PM] BSS Glossary - A through Z Figure 1. Basic sundial nomenclature. A aberration (of light): the effect by which the apparent direction of distant astronomical bodies is altered by the velocity of the Earth and the finite speed of light. Discovered by James Bradley, it has a value of 20.47 arc-sec and is thus totally insignificant to dialling. accuracy (of a dial): a measure of how closely the time indicators (lines or points) of a dial indicate the true time. Contrast with resolution. See also precision. Act of 1751: {1752} refers to an act of the British parliament in that year which finally adopted the Gregorian calendar and set the beginning of the (English) year to 1 January, rather than 25 March. As a result, there can be some confusion about the year, prior to 1752, for dates between January and March. Scotland's New Year's Day had already been set to 1 January since 1600. Dates in the Julian calendar are usually denoted "Old Style", with those in the Gregorian "New Style. British dials made before 1752 and which have EoT or sunrise/sunset tables show dates 11 days earlier than the current ones, e.g. the vernal equinox is on 10 March instead of 21 March, and the EoT will be shown as zero on 5 April, 3 June, 23 August and 15 (1 of 45) [3/2/2004 9:29:56 PM] BSS Glossary - A through Z December. Note that the Act was passed in 1751 but did not come into operation until the following year, hence the alternative dates sometimes seen. acute angle: an angle of less than 90º. age of the moon: see phase of the moon. almanac: an annual calendar of months and days, with astronomical and other data. They usually include an ephemeris of the Sun and some other celestial bodies, the equation of time, the Sun's declination etc. Almanacs are sometimes inscribed on, or accompany, C16-18 dials. The annual Nautical Almanac, produced by the Royal Greenwich Observatory, derives from the version first published by Astronomer Royal Nevil Maskelyne in 1767. almucantar: (pron. al-moo-can-tar) a circle of equal altitude on the celestial sphere. It is a small circle on the celestial sphere, parallel to the horizon. alidade: the revolving arm of an astrolabe through which sightings of the stars are made. Sometimes used on sundials where a pinhole at one end of the ~ forms an image of the Sun on a plate at the other end carrying an analemma. altazimuth: {alt-azimuth} a mounting system for an astronomical instrument that allows it to be set in altitude and azimuth. The term is also used to describe the horizon co-ordinate system which uses these two parameters. altitude (of the sun): {elevation} [a, ALT] the angular distance of the (centre of) the sun's disk above the observer's horizon (negative values indicate that the Sun is below the horizon). It is measured along the principal plane to the sun's centre, and is the complement to the zenith distance. It is part of the horizon co-ordinate system. See Equations. Note that aviators and others use the term altitude to measure a height (distance) above the ground. anaphoric (clock): a clock with a dial face like an astrolabe, showing seasonal hours. ante meridiem (a.m.): before noon. analemma: (pron. ana-lem-a) in modern usage it is a graphical plot with the Equation of Time on one axis and the sun's declination on the other. In appearance, a tall thin figure of eight. The dates of various points around the curve are often shown. The shadow of a point falling onto an arbitrary plane at the same clock time each day will trace out an analemma over the course of a year. Normally seen on the noon line of a dial, but can be on any hour line. The exact appearance of the analemma will depend on the plane upon which it is projected. Figure 2. The components of the analemma The word analemma has had several other meanings in the history of astronomy and dialling. In the first century BC, the Roman engineer Vitruvius used the word to refer to a graphical construction, equivalent to today's orthographic projection. In the second century AD Ptolemy used analemma to mean an instrument acting as a nomograph for defining the angles of a dial. The use of a modern analemma on a dial dates to around 1640, and the first treatment in English was by Samuel Foster in 1654. angle: (units of measurement) may be decimal degrees; degrees, arc-minutes and arc-seconds; radians (2 radians = 360º); or (seldom, military equipment) mils (6400 mils = 360º); or (very rare) grade (1/100th of a right angle). Preferred notations are: [dd.ddº or ddº mm' ss"]. Note that trigonometric functions in computer spreadsheets (e.g. ExcelTM) are always defined in radians. The mathematical convention is that positive angles are measured counter-clockwise, usually with the zero angle position in the 3 o'clock direction or along the x-axis (see cartesian co-ordinates). In dialling, it is (2 of 45) [3/2/2004 9:29:56 PM] BSS Glossary - A through Z more common to measure angles counter-clockwise from the noon line, although some authors measure from the sub-style line. Antarctic Circle: the parallel of latitude at 66° 34' S. Note that this defines the northern limit of the region around the S pole having at least one day a year with no night. antisolar point: the point on the celestial sphere directly opposite the sun's position. aperture: a small transparent hole in an opaque surface, designed to let a small beam of sunlight through to fall on a dial plate or alidade e.g. for noon dials, ring dials and heliochronometers. aphelion: (pron. ap-heel-eon) the point where the Earth's orbit takes it furthest from the sun. It occurs during the first week of July. apogee: (pron. apo-gee) the point in the Moon's (or other satellite's) orbit when it is furthest from the Earth. arc: a curve which is part of the circumference of a circle. arc-minutes {or minutes of arc}: an angular measure equal to 1/60th of a degree. Preferred notation [' or arcmin]. arc-seconds {or seconds of arc}: an angular measure equal to 1/60th of an arc-minute. Preferred notation [" or arcsec]. Arctic Circle: parallel of latitude at 66° 34' N. Note that this defines the southern limit of the region around the N pole having at least one day a year with no night. Aries (first point of): see equinoxes. armillary sphere: a skeleton model of the celestial sphere with rings representing the equator, tropics etc. Often finely made in brass, but versions in wood with paper scales were common in 19th century France. It is also the basis of a form of dial - see armillary, dial (types of). ascendant: rising towards the zenith. Note: astrologers have a different definition. astro compass: see solar compass. astroid: (pron. as-troy-d) a mathematical curve which is formed by the envelope of a series of straight lines, and has the equation: $x^{2/3} + y^{2/3} = 1$. In dialling, it is the shape of a vertical gnomon used in the latitude-independent astroid dial. The astroid curve is also one branch of the shape which is traced out by a point on the circumference of a circle as it rolls inside a circle of four times the radius. astrolabe: an early astronomical instrument in the form of a heavy disk (the mater) which was suspended vertically and had an angular scale marked around it (the limb). A coplanar klimata and an alidade rotated about its centre. A fretted rete gave the positions of the brightest fixed stars. The various components were held on the central pivot (the pin or axis) by a small wedge or horse; sometimes dog. The planispheric ~ represents the celestial sphere by a two-dimensional stereographic projection, showing the position of the sun and major stars at different times and dates, as well as different latitudes. A separate plate is required for each latitude. It was probably a Greek invention of the 2nd century BC, but it was developed extensively by the Islamic cultures from the 9th century AD. It fell out of use in the late 17th century in the west. The universal ~ uses modified projections of the celestial sphere so that they are latitude-independent. The Gemma Frisius type (developed in the west in the early 16th century) retains the stereographic projection but moves the centre to the First (3 of 45) [3/2/2004 9:29:56 PM] BSS Glossary - A through Z point of Aries. The Rojas type (by J. de Rojas of Sarmiento, 1550) uses an orthographic projection with a projection point at infinity. The La Hire type (late 17th century) moved the projection point in an attempt to make it easier to read. The mariner's ~ is a much-simplified instrument designed to measure the sun's altitude, using an open frame and weighted at the bottom to make it more stable onboard ship; it is a precursor to the sextant. See Appendix X for further astrolabe terminology. astronomical triangle: the spherical triangle on the celestial sphere whose vertices are the observer's zenith, the elevated celestial pole, and the position of the Sun (or other celestial body). atmospheric refraction: see refraction. autumnal {or fall} equinox: see equinoxes. axis (of the Earth's rotation) or polar axis: the line running through the true North and South poles about which the Earth rotates. azimuth (of the sun): [A, AZ] the angle of the sun, measured in the horizontal plane and from true south. Angles to the west are positive, those to the east, negative. Thus due west is 90°, north is ±180°, east –90°. It is part of the horizon co-ordinate system. See Equations. Note that navigators (and some astronomers, but not Meeus) measure azimuth or bearings clockwise from the north. B back-staff: an old instrument for measuring the altitude of the Sun while facing away from it. The Davis quadrant, designed by the English captain John Davis, is actually a form of back-staff. bay (or bay en imy wenut): literally a "palm rib of the observer of the hours". It was an ancient Egyptian instrument or sighting device, used in conjunction with a merkhet to observe and time transits. Beltane {Beltaine}: an ancient Celtic festival held on the 1st of May, when bonfires were lit. It is one of the cross-quarter days bissextile: a leap-year (from bis sextus dies, or doubled 24 February). blue moon: there are at least two possible meanings. It can mean a second full moon in a given calendar month. It seems that this "meaning" was accidentally invented by Sky and Telescope magazine in 1946, but it has passed into wide usage. Alternatively, it may mean that the Moon actually has a blue coloration, due to smoke or other aerosols in the atmosphere. Both phenomena are rare (the second more so), hence the expression "once in a blue moon". brachiolus: (pron. brak-e-o-lus) from the Latin for "little arm" it is a movable arm which acts as a suspension point for a cord on a card dial. break of day: see daybreak. British Summer Time [BST]: see time (types of). C Candlemas: the festival of the purification of the Virgin Mary, on 2nd February. It also corresponds to the Celtic festival of Imbolic, and is a cross-quarter day. (4 of 45) [3/2/2004 9:29:56 PM] BSS Glossary - A through Z calendar: a system for counting days and defining the date. Campbell-Stokes: see sunshine recorder. Cancer: see tropics. canting out: see wedging out. Capricorn: see tropics. cardinal point (of the compass): North, South, East or West [N, S, E or W]. These points are the intersections of the celestial meridian (N, S) and the prime vertical (E, W) with the horizon. Note that the Latin terms are Septentrio, Meridies, Oriens and Occidens, so that a compass rose on a mediaeval dial simply identifying "S" is ambi guous. cartesian co-ordinates: see co-ordinates . celestial equator: the intersection of the extended plane of the Earth's equator with the celestial sphere. celestial latitude: see ecliptic latitude. celestial longitude: see ecliptic longitude. celestial pole: the points on the celestial sphere where it meets the Earth's axis. The stars appear to rotate around these poles. celestial sphere: an imaginary sphere, arbitrarily large and co-centred with the Earth, on which all the stars appear to be fixed. centre (of a dial): the point where all the hour lines, and a polar-pointing style, meet. This point does not always exist (e.g. on polar dial and direct E or W dials, the lines meet at infinity). In simple horizontal or vertical dials, this point coincides with the root of a (thin) gnomon. In the case of a thick gnomon having two styles, there are two centres to the dial. The centre is often, but not necessarily, the origin of the co-ordinate system used to describe the dial. See Figure 1. chapter ring: the ring on a dial face carrying the hour numerals. The term is more widely used for clocks, but it also finds use, for example, on dials with several separate rings for different locations. chilindrum: see Dial (types of); cylinder ~. civil time: see Time (types of) civil~. clinometer: an instrument for measuring the inclination or slope of a surface. Also called an inclinometer. cloisonné: a term sometimes used to describe the technique of making metal dials by deeply etching the lines and numerals and then filling them with coloured material. It derives from the jewellery method of separating enamels into shallow compartments with metal edges. co-latitude: equals 90° – latitude. compass bowl: a bowl sunk into the dial plate of a (portable) horizontal dial to house a magnetic compass. compass rose: a drawing of the compass directions, showing as a bare minimum the cardinal points, but more usually eight, sixteen or thirty-two points. compendium: normally used to describe a collection of scientific instruments in one (5 of 45) [3/2/2004 9:29:56 PM] BSS Glossary - A through Z case. Also, Compendium: the journal of the NASS. conic section: any of the range of geometric curves produced by the intersection of plane with a cone (i.e. circles, ellipses, parabolas and hyperbolas). co-ordinates: a system of measurements used to describe any point in two or three dimensions. Co-ordinate Systems: Cartesian ~ [x,y,z] in which the axes are mutually perpendicular, are normally used for positions of points within a dial. For simple horizontal dials the preferred axes have x increasing to the E of the dial plane, y increasing to the N of the dial plane and z (in 3-D only) increasing. perpendicularly to the dial plane (upwards). For vertical and other plane dials, x increases to the left, y increases downwards, and z perpendicular to the plane in the direction towards the observer. The origin of the system must be defined explicitly. Note that these definitions produce a conventional right-handed co-ordinate system, and are also those used by the Zonwvlak programs. ecliptic ~: {celestial ~} [, e] or [ELAT, ELON] the system of ecliptic (or celestial) latitude and longitude, defined with respect to the ecliptic and the celestial poles. Ecliptic co-ordinates predominated in Western astronomy until the Renaissance but, with the advent of national nautical almanacs, the equatorial system, more suited to observation and navigation, gained ascendancy. Figure 3. Celestial co-ordinates seen by an observer in mid-northern latitudes. equatorial ~: [,] or [RA, DEC] is the most common astronomical co-ordinate system and is defined by the celestial equator and poles. The right ascension and declination are directly analogous to terrestrial latitude and longitude. Figure 4. The equatorial system of celestial co-ordinates, showing the right ascension (RA) and declination (dec) of a star. galactic ~: is used for studying the structure of the galaxy. It is unlikely to be encountered in dialling. geographic ~: (or terrestrial ~) [,] or [Lat, LON] the standard method of determining any location on the Earth's globe, using latitude and longitude. horizon ~ system: {or altazimuth system} [a,A] or [ALT,AZ] the simplest celestial co-ordinate system, it is based on altitude and azimuth. It is fundamental in navigation as well as in terrestrial surveying. However, for specifying the position of the Sun or other celestial bodies, other co-ordinate systems fixed with respect to the celestial sphere are far more suitable. Ordnance Survey co-ordinates: (also referred to as the British National Grid, BNG) the system of Eastings and Northings used to define locations in the UK. They are cartesian co-ordinates with a basic grid consisting of 100km squares, each of which has a unique two-letter code (e.g. SZ). See Appendix XI for a map of the grid squares. The full OS grid reference comprises these two letters followed by a three-digit easting and a three digit northing, eg SZeeennn. This (6 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z gives a resolution of 100m in both directions. Higher resolution ("6-figure" or BNG) references usually replace the letter code with their numerical values, eg eeeeee nnnnnn, giving a 1m resolution. Here, the first two digits of the easting (northing) are the distance in 10 km increments east (north) of the datum point at the bottom left of the map. Note that the OS maps on which the co-ordinates are based use the transverse Mercator projection, with a projection origin at 49º N; 2° W. polar ~ :[r,] an angle-based co-ordinate systemal sometimes used for defining points on a dial plane, where r is the distance from the origin and is measured anti-clockwise from the S. Note: navigators also make use of polar co-ordinates and usually define them as (, r). Ptolemaic co-ordinates [hec, hor]: an angular co-ordinate system loosely based on the geometry of Ptolemy. terrestrial : see geographic ~. End of Co-ordinate systems cross: for a discussion of the cross sometimes seen on the noon line of a dial, see noon cross and cross patty. cross-quarter days: days which are (approximately) midway between the Quarter days, hence dividing the year into eight parts. They are occasionally used instead of the zodiac signs for declination lines on dials, and have become adopted as modern celebrations or holidays. See Appendix XII for their names and dates. cross patty {c. pattée or c. formée}: an heraldic term for a form of square cross shape ( ) sometimes seen instead of XII on the noon line of dials. It is perhaps the most common of the noon crosses. cross-staff: a simple instrument for determining t he altitude of a celestial body. A cross piece or transom is moved along a staff, calibrated with a cotangent scale, and sighted by eye against the body and the horizon. Old illustrations often show a ~ with three transoms fitted but, in use, only one would be used at a time. Also called a fore-staff or Jacob's staff. culmination (of the sun): to lie on the meridian or, in more general language, to reach its highest point. Equivalent to the superior transit. From the Latin "culmen", meaning summit. cursor: a part of a mathematical instrument which slides backwards and forwards over a scale. cusp: (mathematical) a sharp point where two curves meet e.g. the "horns" of the Moon (strictly, where the second derivative of a curve changes sign). (astrological) the initial point of an astrological house or sign. cycloid: (pron. si-cloy-d) a geometric curve which is traced out by a point on the circumference of a circular disk rolling (without slipping) along a straight line. D daeg mael: one of the Anglo-Saxon tides, it may also have been the word for a dial in the early Anglo-Saxon period. (7 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z dagsmork: an Icelandic term ('daymarks') referring to landmarks in the countryside which, when viewed from a fixed location, indicated the direction of the Sun at fixed times of the day. date: a single day in a chosen calendar system. Note that the agreed international date system (and British Standard 4795) specify "year, month, day" - for example 1951 August 10. Common UK usage is the reverse of this - beware the illogical American usage of month, day, year, especially in all-numeric forms. Date Line see International Date Line. dawn: the first light of day, taken as the onset of morning twilight. day: the period for one rotation of the Earth. Solar ~ : measured between successive transits of the sun: Mean solar ~ :measured between successive transits of the fictitious mean sun. Equal to 24 hours, it is the usual meaning of ~ unless it is further qualified. Sidereal ~ : measured between successive transits of the First point of Aries (or, in everyday language, any 'fixed' star). A sidereal day is 23 hours 56 minutes 4.1seconds. Beware the possible confusion between day and daytime. daybreak (or break of day): an old term for first light, usually taken as the onset of astronomical twilight. daytime: that period of a day between sunrise and sunset. Daylight Saving Time: see time (types of). declination (of a wall) {sometimes called the declining angle or the deviation, to avoid confusion with the sun's declination}: [d, DEC] the angle, measured in a horizontal plane, that a wall's perpendicular makes with due south (i.e. a wall facing S has d = 0°). Walls declining westward have positive declinations, those eastward, negative. Beware – this is not a universal convention and some authors define the angle with respect to the nearest cardinal point of the compass. declination (of the sun): [, DELTA, DEC] the angular distance of the Sun above or below the celestial equator. Its value follows an annual sine wave like curve, varying between 0º at the equinoxes and ±23.4º (approx.) at the solstices. It has positive values when the Sun is above the celestial equator (summer in the Northern hemisphere) and negative when below. The same system is used as part of the equatorial co-ordinate system (together with right ascension) to locate other celestial bodies. See Figure 1 and Equations. declination lines: lines on a dial showing the sun's declination on a particular date. They are read by observing the shadow of a nodus. degree: [º or deg] an angle equal to 1/360 of a complete circle. descendant: falling from the zenith. Note: astrologers have a different definition. diagonal scale: a device for interpolating between scale divisions, pre-dating the vernier scale. It is constructed by drawing diagonals between individual divisions across a wide band, with a series of equi-spaced arcs parallel to the main scale crossing them. It is read by noting the position of the fiducial line with one of these arcs. Most usually found on astronomical instruments, a similar design was used by Sir Christopher Wren for indicating the minutes on his famous vertical dial on All Souls' College, Oxford. dial: a Middle English word, apparently deriving from the Latin 'dies' though the medieval Latin 'dialis', used for what is now called a sundial. It later became used for many types of indicators, hence the necessity (from 1599) for the qualifying 'sun' prefix. The word ~ in modern English has now become common again as a shortened version of sundial. Hence dialling {dialing}, the art and science of designing and constructing (8 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z dials; diallist {dialist}, one who designs or makes dials. Dial types: Ahaz (Dial of Ahaz): supposed refraction dial, from the Bible story (Kings 20 v8-11) which may allude to a dial showing time running backwards. altitude ~: {or elevation ~} any dial which uses the sun's altitude, rather than its azimuth, for indicating the time. Usually does not need to be aligned N-S. Examples are ring dials, flag dials, and shepherds' dials. Altitude dials were also often incorporated in quadrants and folding rules. analemmatic ~: (pron. ana-lem-mat-ic) dials consisting of hour points, (rather than lines) laid round an ellipse, and a movable gnomon perpendicular to the dial plane. It may be on any plane, but the most usual form is horizontal. In the horizontal version of the dial, gnomon position lies on the straight N-S minor axis, at a point determined by the sun's declination (i.e., the date). Most usually found set in the ground in parks, where the observer acts as the gnomon. Note that some of these dials show an analemma drawn about the gnomon positioning line. This is a method of indicating the EoT for the appropriate date, but it must be remembered that the gnomon is not positioned on the analemma. The analemmatic dial may be regarded as a projection of the universal equatorial ring dial. Analemmatic dials were once common paired with a horizontal ~ in a self-orienting portable compendium. analemmic ~: this term has sometimes been used to describe dials which have an analemma-shaped gnomon, or analemmas on the hour lines, enabling them to read mean time. Note, the dials have no direct link to analemmatic ones. Anglo-Saxon ~ {sometimes just Saxon ~}: a sundial from the Anglo-Saxon period (c 650 – 1050 AD); designed to show unequal hours, or the basic tides, with a horizontal gnomon. Similar to the mass dials which superseded it, a Saxon ~ shows much higher levels of craftsmanship and is often finely decorated. Also, it is invariably engraved in a separate (circular or rectangular) stone, not into a pre-existing wall. Saxon dials are often taken to be the precursors to the later scientific dials. In the early part of the period the semicircle was divided by five lines into four segments. During the latter part of the period it was subdivided into eight or twelve segments and the dial sometimes carried an inscription in Old English. Throughout the period the principal lines had a cross bar near the perimeter giving the appearance of Latin crosses. See Appendix II for the basic time periods shown on the dial. antiboreum: an ancient form of dial in which a partial-sphere is hollowed into a stone, and a ray of sunlight enters the partial-sphere through a south-facing pinhole through the stone. armillary: (pron. ar-mil-ar-y) (or armillary dial; some authors also use the term armillary sphere) a form of equinoctial sundial which comprises, as a minimum, two circular bands plus a rod through the poles representing the Earth's axis and acting as the gnomon. One band represents the equator (carrying the hour scale) and the other the local meridian. Usually, other great circles are added representing the Prime meridian and the ecliptic plane, sometimes together with small circles for the tropics and arctic circles. These add artistically, but detract from its clarity as a dial. The gnomon sometimes carries a nodus at the centre of the sphere; this may be used for indicating the date. (9 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z astroid ~: a ~ which uses the sun's declination, altitude and azimuth to give the hour angle. It is latitude-independent, and is named after the geometric shape which forms its gnomon. auxiliary ~: a small equatorial dial used as a mechanical aid to constructing dials on other planes (particularly vertical decliners) by co-mounting on a common gnomon and projecting the hour lines. Often used with a trigon. azimuthal ~ (or azimuth ~): any dial which uses the sun's azimuth for indicating the time. It usually needs to be aligned N-S, and has a vertical style (if it has no dependence on altitude). Berossos ~: another term for a hemispherium, named after its inventor Berossus Chaldaeus, a Babylonian astronomer who flourished on the Greek island of Cos around 270 B.C. bifilar ~: invented in 1922 by Hugo Michnik in its horizontal form, although it can be on any plane. The time is indicated by the intersection on the dial plate, of the shadows of two wires (or other lines in space) stretched above and parallel to it. The wires often run E-W and N-S, with their (different) heights above the plane being a function of the location of the dial. It may have equiangular hour markings, and hence can be delineated to show many kinds of hours. Bloud ~ : a portable, magnetic azimuth ~ made mostly in Dieppe by makers such as Charles Bloud. book ~ {open book ~}: a modification of the polar ~, with the dial plate consisting of two planes set in a vee, with their intersection line lying parallel to the Earth's axis. A polar gnomon can be placed bisecting the angle of the two planes. Alternatively it may be arranged so that the outer edge of each plane acts as the gnomon for the other. The term book ~ can also be applied to diptych dials which are designed to look like a book when closed. Butterfield ~: a pocket sundial by, or in the style of, Michael Butterfield (Paris, 17th century). Typically it consists of an octagonal silver horizontal dial with a gnomon of adjustable angle, often with a bird's head pointer, with several rings of hour lines for cities of different latitudes. A magnetic compass is fitted in the same case. cannon ~: see noon gun. Capuchin ~ {or Capucine ~}: a latitude-specific card dial, related to the Regiomontanus dial. So-called because the outline of the hour-lines is said to resemble a hooded Capuchin monk. card ~: a class of portable dials built on a single plane, e.g. a card which is suspended in the vertical plane. They usually have a sun sighting device along one edge, and a cord with a bead which hangs vertically below a movable suspension point. ceiling ~{also known as a mirror ~ or reflected ~}: a dial marked on a ceiling where the time and date are indicated by a beam of sunlight reflected from a small horizontal mirror placed on a windowsill. chalice ~ (or cup, bowl etc.): a form of refraction ~ where the hourlines are drawn on the inside of a drinking vessel. Early examples, often in precious metals are rare and valuable. Chinese ~: a wide range of dials have been used in China, from the vertical gnomon of the mythical astronomer Xi, through equiangular ~ with sun-pointers and 100-segment time scales from the 1st - 2nd centuries BC, equatorial dials for (10 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z equal hours in the Ming dynasty (1368 to 1664), to conventional horizontal dials in the 19th century. compass ~: a portable horizontal dial with an accompanying compass to allow it to be correctly oriented. The compass is often below the pierced dial plate, and the gnomon is hinged for packing. Beware: the term compass dial is often used to mean a magnetic dial. complementary ~: a (hypothetical) horizontal ~ used as an aid to designing a vertical declining and/or reclining dial. Its gnomon and hour lines are calculated not for the site of the proposed (real) dial, but for the location where the Earth's surface is parallel to the dial plate of the proposed dial. For a simple direct south dial, the complementary dial would be located at the co-latitude. cone ~: a term used to describe several entirely different types of dial.(a) a class of dials where the dial plate is an inverted, truncated cone, giving dials similar to a scaphe dial or a hemicyclium, or (b) a class of modern dials which use a cone lying on its side as the gnomon. Many varieties, including sidereal, exist. cross ~: (or cruciform ~ or crucifix ~) a dial in the form of a cross, usually of stone, with the "front" surface of the cross parallel to the equatorial plane, and the top pointing south. The side surfaces of the cross can each form a dial plane, with its gnomon being a corresponding edge of the cross itself. Usually found as churchyard memorials. Rare. Portable cross dials have the long arm parallel to the polar axis and the short arm E-W. cube ~: a (set of) dials on the surfaces of a cube. There may be up to 6 dials, but more often 5 e.g. direct N, S, E, and W, together with a horizontal on the top surface. Alternatively, it is possible to set the cube so that its top surface is parallel to the equatorial plane, i.e. the base makes an angle equal to the co-latitude with the horizontal. Both portable (usually adjustable) and monumental versions are known. cycloid (polar) ~: a variation of the standard polar dial in which the gnomon has a cycloid shape, with the result that the hour lines are equally spaced. cylinder ~ (also known as a shepherd's ~ or pillar ~): a portable, altitude dial in which hour lines for different dates are delineated around the surface of a cylinder, which is allowed to hang or stand vertically. A horizontal gnomon projects radially from the top of the cylinder, and is adjusted to the appropriate date around its periphery. Sometimes two gnomon are supplied; a long one for winter and a short one for summer. The dial is held with the gnomon facing the Sun so that the shadow falls vertically. Latitude specific. This was the chilindrum of Chaucer's monk. declining ~: a vertical dial which does not face any of the cardinal points of the compass. The sub-style will be displaced from the noon line, although the latter will still lie vertically below the dial centre. diametral ~ : one of the equatorial projection dials, first described by Samuel Foster of Gresham College in the 17th century, it is a horizontal dial with a moveable style and hour points which lie along a straight line lying E-W. diffraction ~: a dial invented in 1999 by M. Catamo & C. Lucarini. It has no gnomon, but the dial plate consists of a circular diffraction pattern, which forms a bright, multicoloured diametrical line pointing at the Sun when viewed perpendicularly to the centre of the dial plate. Horizontal, altitude and equinoctial versions are possible. The dial plate is usually made from a CD (compact disc), hence "CD dial". (11 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z digital ~: an ingenious 20th century dial. The "gnomon" consists of a rectangular sandwich of shadow masks set parallel to the polar axis. This gnomon casts a shadow in which digits representing the time are sunlit. Patented, and requires great precision in manufacture. diptych ~: (pron. dip-tich or dip-tic) a portable (pocket) dial in which a vertical and horizontal dial are hinged together, and a common cord gnomon running between them also ensures that they open to a right angle. Latitude specific. This term is, confusingly, sometimes also used to describe a monumental open book dial. direct ~: a vertical dial which directly faces one of the cardinal points of the compass e.g. direct S. double horizontal ~ : a horizontal dial with (usually) a combined polar pointing gnomon and a vertical one showing the time/date on a stereographic projection of the sky onto the horizontal plate. Capable of self orientating, although normally fixed in position. Usually attributed to William Oughtred in the early 17th century, early hand-engraved versions are very fine. Egyptian ~: a range of sundials from ancient Egypt (portable and fixed) exists, the earliest being from the time of Tuthmosis III (1479-1425 BC). The portable devices appear as a long, thin 3-D letter "L", laid with the long shaft horizontal along the sun's azimuth, with the upturned foot casting a shadow onto the shaft. It is very similar to the merkhet but has a dedicated hour scale equant ~: (pron. ek-want) a modified horizontal ~ in which the hour-lines are replaced by hour points. These points are arranged round a geometric curve chosen so that the points are equally spaced, allowing the use of a vernier scale and more accurate interpolation of times. Not related to Ptolemy's equant point. equatorial ~: a dial in which the dial plate is set parallel to the equatorial plane and the polar-pointing gnomon is perpendicular to it. The dial has hour lines equally spaced at 15º intervals around the gnomon, and hence the dial plate may be rotated to account for EoT, longitude and BST/DST corrections. Sunlight falls on the underside of the dial plate from the autumnal equinox until the vernal equinox. For this period, the gnomon must project below the dial plate, which is delineated on both sides. An alternative form replaces the dial plate by a narrow hour ring (or half-ring) allowing the scale, inscribed on its inner circumference, to be read throughout the year. With this form, special analemma-shaped gnomons can be used to show mean time. Note: some authorities insist that this dial should be called an equinoctial ~. equiangular ~: a term used for dial types where the hour points are placed at equal angles (15º) around a circle (or part of). If the dial plane is not parallel to the equatorial plane, the mounting of the gnomon, (which does not need to be polar) must be movable to accommodate this. equatorial projection ~: a class of dials obtained by projecting a universal equatorial ring dial onto any plane. Members of the class include analemmatic, diametral, Foster-Lambert and Parent dials. equinoctial ~: (pron. ec-we-noc-te-al) another (historical) name for an equatorial ~, preferred by some authors. flag ~: an altitude ~, formed by "unwrapping" the scale of a shepherd's ~ into a flat plane which can be shaped like a flag or pennant and is positioned perpendicular to the sun. (12 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z Foster-Lambert ~: a form of equatorial projection dial, with the projection arranged to produce a circular ring of equiangular hour points. A good example is the large reclining dial (now back at Herstmonceux Castle after a period at Cambridge) designed in 1975 by Gordon Taylor for the Royal Greenwich Observatory. geographical ~: a dial in which the dial plate shows a map of the world, with curved hour lines allowing the time at any location to be indicated. globe ~ (or spherical ~): a class of dial in which the "dial plate" is a globe or sphere, usually set with its axis parallel to the Earth's polar axis and often with the observer's position at the top. The gnomon is in the form of a thin semi-circular vane which can swivel around the globe about its axis. In use, the vane is rotated until the shadow is minimised and the time read from an equiangular scale around the equator. It indicates the meridian of longitude where it is currently noon. An alternative type of globe dial (a terrella) simply uses the globe itself to form the shadow, and the time is indicated by the terminator. Transparent globe ~ are also possible (the Wenger ~). where the shadow of a movable point on the surface is made to fall on the centre of the globe. Graeco-Roman ~: a general class of dial from about the 3rd century BC (Greek) to the 4th century AD (Roman). Made of stone, they include the hemispherium, the hemicyclium, and some conical dials. great decliner: usually indicates a declining dial which nearly, but not quite, faces E or W. The centre of the dial falls off the dial plate and, as a consequence, it does not show a noon line. hâfir dial: an Islamic dial with unequal hours, vertical gnomon and equiangular date scale of 12 segments. halazûn dial: an Islamic dial with unequal hours, vertical gnomon and a date scale of 6 segments (each representing two signs of the zodiac). hat ~: an altitude dial comprising a circular disk mounted concentrically on top of a vertical cylinder. The dial is read by the maximum vertical length of the disk's shadow on the outside of the cylinder. heliochronometer: a precision sundial which incorporates some means to allow it to read civil (or mean) time. This is usually achieved by incorporating an EoT cam (as in the Pilkington and Gibbs heliochronometers), or by projecting a spot of light onto an analemma. Note: some authors use this term to describe any precision sundial. hemispherium: an ancient dial with the dial surface formed by a hemisphere hollowed into a horizontal (or occasionally vertical) stone face. The gnomon is a vertical spike (length equal to the radius of the sphere) set in the bottom of the hemisphere. It is essentially a horizontal altitude dial, with a shaped dial plate which prevents sunrise and sunset being at infinite distances. hemicyclium: similar to the hemispherium, but with the south-facing part of the hemisphere cut away, and with the gnomon now projecting horizontally from the N edge. horizontal ~: the common or garden sundial with a horizontal dial plate and polar-pointing gnomon. Latitude specific. inclining ~: usually applied to portable dials in which a horizontal dial, designed for a high latitude, typically 60º , may be inclined by raising its southern edge (in (13 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z the N hemisphere) so that it may be used at locations with lower latitudes. The opposite arrangement is also sometimes found. The term is also sometimes confusingly used for near-vertical dials where the top leans away from the observer. Islamic ~: a ~ with unequal hours and showing the Islamic prayer times. Lambert ~: see Foster-Lambert ~. Little Ship of Venice {or Navicula}. A portable dial in the shape of a Venetian ship with a central mast. Based on the Regiomontanus dial, the few early examples are valuable. magnetic ~ {or magnetic compass ~} : a small portable ~ in which a complete horizontal ~ is mounted on a compass card, and hence is self-orienting. In principle, the magnetic variation of the place and date where it will be used can be accommodated by rotating the dial from the magnetic N-S line of the compass. Beware: this type of dial is sometimes described as just a compass dial. magnetic azimuth ~: a portable ~, usually in diptych form. There is no string gnomon but instead the lid is lined up to fall exactly on the base, the time being read from the compass needle on a chapter ring. The chapter ring position is moved in a N-S direction from a calendar volvelle on the under side. mass ~ (or mass clock. Also known as a scratch ~): a rather basic dial from the medieval period scratched or engraved into the south-facing stonework of a church or similar building, often near the main door or the priest's door. Although later than Anglo-Saxon dials, they are generally less well executed. Usually circular or semicircular in form, with a hole in the centre to accommodate a horizontal gnomon rod (invariably missing). Delineated, probably empirically, to show some form of unequal hours, there is a huge variety of design types. Some are event markers rather than true sundials. mechanical universal equinoctial ~ (sometimes minute ~): a ~ that uses gearing to show accurate time on a clock face, i.e. a solar clock. mirror ~: a ~ having no gnomon, but using a small, appropriately angled mirror to reflect a small spot of sunlight onto the dial face. The dial may be on a vertical wall facing N or within a building. See also ceiling dial or reflecting dial (separate definitions). monofilar ~: a ~ in which time is marked by the point where the shadow of a thread (or other thin gnomon) held between the dial face and the Sun intersects a set of date lines. moon ~: a sundial calibrated in some way so that it can tell the time by moonlight. No change to the basic dial is required, but a correction factor for the time is required which accounts for the age or phase of the Moon. Never very accurate because of the complex nature of the Moon's orbit, they generally require a nearly full Moon to be able to be read clearly. Purpose-built moon dials have either spiral hour lines or a table of moon phases (as in the famous Queens' College, Cambridge, dial). multiple ~: simply more than one dial physically incorporated into the same dial structure. multiple gnomon ~: a ~ in which there is a separate shadow casting element (gnomon) for each hour line. The elements can be points, lines or planes. navicula de Venitiis: see Dial Types (Little Ship of Venice) (14 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z noon (or meridian) dial or line: a dial which has only one hour line, for noon. It has a nodus rather than a full gnomon. This may be in the form of a small ball on the end of a shaft or, more usually, an aperture in a plate or window opening into a building. Very long, accurately-levelled meridian lines (running N-S) built into cathedrals were intended for the accurate determination of the equinoxes, solstices and other solar parameters. A noon dial (as opposed to noon line) is usually taken to mean a complete noon analemma, possibly including dates. noon gun: a small cannon mounted such that focussed sunlight from an appropriately angled lens falls on the touch-hole and fires the gun at noon. A novelty rather than an accurate time indicator. noon mark: a stone, or line marked on a stone, set to receive the noon shadow of a building or other feature. The term is, however, often used interchangeably with a noon ~. Nuremberg ~: a loose collective term used for the diptych dials made around Nuremberg, Germany, during the 16th and 17th centuries. The majority were made of ivory, featured a compass bowl in the lower leaf and had a string gnomon. Oughtred ~: another name for a double horizontal dial. Parent ~: a form of analemmatic ~, with the dial plane parallel to the Earth's axis so that the ellipse of hour points becomes a segment. First designed by Parent in 1701. pelekinon ~: a form of ~ attributed to the Greeks around 100 BC. In appearance, the dial resembles a butterfly or double-headed axe, and was delineated to show unequal hours. pillar ~: see cylinder ~. Sometimes also confusingly used to describe monumental dials mounted on tall pillars. poke ~: an old term for a pocket or portable dial. polar ~: a ~ in which the dial plate is set along the E-W direction and reclines so that it is parallel to the polar axis. The standard polar-pointing gnomon is thus also parallel to the dial plate. Simple to construct, but the hour lines disappear to infinity when the Sun is in the plane of the dial. For a south-facing polar dial, the theoretical limits at the summer solstice are 6am to 6pm. polarised light ~: a gnomon-less dial which detects the orientation of the polarised skylight. Its polariser/analyser system is best arranged to view a region of the sky near the N celestial pole (S in the southern hemisphere), allowing the hour lines to follow a standard 15º per hour scale. Although not particularly accurate, it has the advantage that it does not require direct sunlight to work as long as there is clear sky towards the N celestial pole. Thought to have been invented by Sir Charles Wheatstone in 1848. polyhedron ~: a multiple dial in the form of a solid polyhedron, with a separate dial on each face. Usually each dial is some form of decliner/recliner, but may include scaphe and polar dials as well. Particularly common as the monumental Scottish stone lectern and obelisk dials. portable ~: simply a dial meant to be moved from place to place, either as a pocket dial or simply being transportable. In most forms, some means of orienting the dial is included, and they are often either universal or capable of being read at a number of fixed latitudes. (15 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z prism ~: a term occasionally used to describe a multiple dial with two or three dial faces set on the sides of a triangular prism. proclining ~: a term sometimes used to describe a dial which is approximately upright but which leans forward towards the observer. A dial which leans forward by 10º will have an inclination of +100º. They are sometimes also called inclining dials, although that term is best reserved for dials derived from a horizontal ~. reclining ~ : strictly, an approximately vertical dial which leans backwards away from the observer. However, often used as a catch-all term for any non-vertical dial. The angle is defined from the horizontal towards the observer, so a dial which leans backwards by 10º from the vertical has an inclination +80º. reflecting ~: these dials have no gnomon, but reflect sunlight by means of a semi-cylindrical mirror, set with the axis of the mirror parallel to the polar axis. The mirror reflects the light to form a caustic curve amongst the hour points. For the special case of the mirror having a cycloid shape, the hour points are equally spaced. Note that the term reflecting dial may also be used for ceiling dials. refraction ~: dials which use a clear liquid in a solid cup to compress the hour lines. Sometimes drawn on the inside of a drinking cup - a chalice dial - (see Dial of Ahaz) or on the bottom of a fountain basin or swimming pool. A second form uses a cylindrical lens to focus sunlight onto a curved dial plate. Regiomontanus ~: a universal form of card dial, usually with the suspension point of the cord movable in two dimensions in the card plane. It is the basis for many other variants of dial. ring ~ : a portable, altitude dial in the form of a ring, with a small aperture in its circumference. The ring is suspended in a vertical place such that the aperture faces the sun. The time is then indicated on a time/date scale on the inside of the dial. The suspension point may be adjustable on the circumference to allow for latitude changes. Not very accurate, due to their usually small size and the fact that a very compressed date scale is needed to prevent the ring becoming too wide. These dials were known by Vitruvius in the first century BC. Beware: this term is also sometimes loosely used to described a universal equinoctial ring dial. Saxon ~: see Anglo-Saxon ~. scaphe ~: (pron. sk-af-e) {skafe, scaphion} a dial in which the dial plate is a shallow dish in any plane (usually a horizontal or, rarer, vertical one). The name comes from the Greek word for boat, and the dial itself is thought to have developed from the hemispherium. Normally with a vertical gnomon. scientific ~: a term usually taken to mean a dial which is designed to show equal hours, or at least in which the effect of latitude been mathematically accounted for. Thus any dial with a polar-pointing gnomon is scientific, but, for example a mass dial is not. Mostly, they date from the 16th century onwards. scratch ~: see mass dials. self-orienting ~ : any dial which, when correctly adjusted for he latitude and/or date, can be used to find the direction of south. Sometimes also called "self-southing". shadow plane ~: a class of dial in which the gnomon is movable and is set by the observer so that it, and its shadow, lie in the sun's hour plane. The gnomon may be a plane, line or point. The dial plate can, if required, be any surface. A (16 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z globe dial with a movable vane is an example of a shadow plane ~. shepherd's ~: see cylinder dial for the usual meaning. A second type of shepherd's dial is a set of marks cut in the turf, so that the shepherd's crook could be used as a vertical gnomon – see Shakespeare's Henry VI part 3, act 2, scene 5. sidereal ~: (pron. sy-deer-e-al) a ~ designed to show sidereal time by means of introducing a variable offset to the time shown by the solar shadow on an equiangular dial. The dials are rare, with no known public dial in the UK(?) solar clock (or solar chronometer): an instrument in which a sighting of the sun, through a movable telescope or open sights, is made to display the time on a clock face by a set of gears. A famous example by Sir Charles Wheatstone is in the Science Museum. Note: this term is often used as a synonym for heliochronometer, but is best reserved for the definition given here. spherical ~: see globe dial. spoon ~: a rare form of scaphe ~ delineated in the bowl of a spoon. stained glass ~: a (generally vertical) dial in which the dial face is of stained glass, and is viewed from the back, i.e. through the glass from inside the building. The gnomon remains on the outside of the building, and frequently causes cracking of the glass if supported directly from it. Typically, they were incorporated into church windows in the 17th century, although most are now in museums and there are some notable modern examples. standing ring ~: a form of universal equinoctial ring dial mounted on a stand, usually including a compass. Star of David ~: a monumental dial similar in concept to the cross dial, except that the six-pointed star with 60º angles gives opportunities for numerous dials. sun clock: see solar chronometer, dial (types of). tidal ~: a dial delineated to give the times of the marine tides. Based on some form of equiangular dial (e.g. an equatorial dial). It bears the compass points in a circle with the names of various ports written against them. The 'establishment' of a port is given as a compass point and, together with the hour markers, indicate the interval of time between the passage of the Moon over the meridian of the port and its high tide. Not to be confused with dials showing the Anglo-Saxon tides. universal ~: any portable dial with a means of allowing it to work at, or be adjusted for, any latitude. Note: sometimes the range of usage is limited to one hemisphere. The term is also sometimes applied, with qualifications, to dials which operate over a more limited range of latitudes, e.g. dials with, say, 30º60ºN scales. universal equatorial ring ~ (or - equinoctial -): a portable dial which looks similar to a folding version of an armillary dial, but with a movable suspension point to provide latitude adjustment. A stylised version of the hour ring and gnomon forms the BSS logo. In some versions, an aperture gnomon mounted on the central axis is used, the position of the aperture being adjusted to suit the sun's declination. This form is self-orienting. Large well-made versions are accurate and valuable. vertical ~: any dial in which the dial plate is vertical. window ~: (or projecting ~) a ~ in which the hour lines are marked on a window in such a way that their shadows fall across a single reading point inside the (17 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z room. The lines, as drawn on the window, form an inverted, mirror-imaged vertical dial. This form is related to stained glass and mirror (or ceiling) ~. - End of Dial types - dialling scales: ruler-like (or rule-like) scales designed to help in the geometrical layout of dial. Their non-linear scales are effectively analogue computers for solving dialling equations. Standard scales, following George Serle's original version of 1657, and themselves developed from Samuel Foster's 1638 work, have separate scales for : hours, latitude (prime) and latitude (meridian). dial plane: the plane in which the dial plate, and the hour indicators, lie. dial plate (or ~ face): the physical plate on which the hour lines and furniture lie. It (usually) supports the gnomon. diffraction grating: a plate with a set of closely spaced slits (usually parallel and equi-distant) which disperses incoming light into its constituent wavelengths (i.e. colours). The surface of a CD acts as a circular reflection diffraction grating. dioptra {diopteral}: a form of alidade, used as the index of a volvelle (and also sometimes of a quadrant or an astrolabe), rotating against an angle scale. dip (of the horizon): the angle of the observed horizon (due to the curve of the Earth's surface and the height of the observer, but neglecting refraction) below the true or astronomical horizon. It is given by: dip (arc-minutes) = 1.811 x height (metres). dip (magnetic): the angle that the Earth's magnetic field makes with the horizontal. It varies with geographical location and (slowly) with the date. See Appendix IX for values. It is measured with an inclinometer. dipleidoscope: (pron. dip-ly-do-skop) from the Greek words for "double image viewer". Devised by James Bloxham and patented by Edward Dent in 1843. It is an instrument for observing the transit of the Sun to an accuracy of a few seconds. Essentially, it comprises a hollow equilateral prism, with the front, semi-reflecting face facing south and parallel to the polar axis. At noon, the reflection of the Sun from this surface exactly coincides with a second image doubly reflected from the other two faces. diptych: literally, two leaves or pages. See dial types, diptych . diurnal: daily, or occupying one day. Can also mean of the daytime (as opposed to nocturnal: of the nighttime). domifying circles: (from the Latin Domus Coelestris - celestial house.) Circles on the celestial sphere which show the hourly position of the Sun in the six Regiomontanus (astrological) houses that are above the horizon. On a vertical south dial, they are represented by straight lines emanating from the intersection of the noon line and the horizon line (i.e. the horizontal line on the dial plate perpendicular to the nodus). The domifying lines are angled similarly to the hour lines, but are numbered in the reverse direction as DOM. VII (horizontal, E),DOM.VIII, DOM.IX, DOM.X (along the noon line), DOM.XI, DOM.XII and DOM.I (horizontal, W). On a horizontal dial, these lines all lie parallel to the noon line. See Appendix V. Dominical cycle: a letter-cycle originating in the Roman period, when each day of the year was allocated the letters A,B,C,D,E,F and G in a repeating sequence. In a given year, every weekday (e.g. Monday) has the same letter, and the cycle repeats with the 28-year Julian leapyear cycle. The Dominical letter (for Sundays) is often found on (18 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z portable dials, and is used with the Golden Number to find Easter. dusk: the evening twilight period. E earthshine: the illumination resulting from sunlight reflected from the Earth, particularly when providing low-level illumination of the "dark" portion of the Moon. East: the point on the horizon 90º (measured clockwise) from the North. The Sun appears to rise from the East point on the equinoxes. Easter: the requirement to set the date of this Christian festival drove much of the early astronomy and calendar reforms. The standard astronomical algorithm for the date is now "the first Sunday after the full moon (paschal moon) that occurs upon, or next after, the vernal equinox". However, because the rules were set by the Christian clergy before the dates of the equinoxes could be defined accurately, the vernal equinox for this calculation is always taken as 21 March. See Meeus or Duncan in Sources for a full algorithm. The extreme dates of Easter are 22 March and 25 April eccentricity (of the Earth's orbit): [ec, EC] a measure of the relative sizes of the major and minor axes of the Earth's elliptical orbit. ec = 0.01671... in the year 2000 and is slowly decreasing. ec = 0 would imply a circular orbit. The earliest accurate value was found by John Flamsteed, the first Astronomer Royal, in about 1700 (most of his results were only published after his death in 1707). eclipse (of the Moon or the Sun): the phenomenon which occurs when the Earth (or at least the observer's location), Sun and Moon lie on a straight line. If the Moon lies in the ecliptic plane between the Sun and the Earth, a solar eclipse occurs (either full, partial or annular, depending on the relative distances). If the Earth lies between the Sun and the Moon (i.e. at a full moon) a lunar eclipse is seen. ecliptic (plane): (pron. e-clip-tic) the plane that the Earth's orbit traces during a year. The orbits of the Moon and the planets are also close to this plane. It is the plane in which eclipses occur since, by definition, the Sun is always on the ecliptic. It is a great circle on the celestial sphere. ecliptic latitude: {celestial latitude} [, ELAT] is the position of a body on the celestial sphere, measured along the great circle from the ecliptic. Positive to the north, negative to the south, range –90º to +90º. It is part of the ecliptic co-ordinate system. ecliptic longitude: {celestial longitude} [, e, ELON] is the position of a body on the celestial sphere measured around the ecliptic from the vernal equinox positive to the east. Range 0º to 360º. It is part of the ecliptic co-ordinate system. elevation: see altitude. ellipse: a conic section and the path the Earth follows during a year (neglecting only the small perturbations caused by the moon and the other planets). It is defined by two foci, and by a major and a minor axis. A circle is a special case of an ellipse with the two foci coincident, and the major and minor axes equalling the diameter. The elongation of an ellipse is characterised by its eccentricity. Also, the outline shape of an analemmatic dial. ellipsoid: a closed geometric surface obtained by rotating an ellipse around its major or minor axis. elongation (of the Moon): the angle of the Moon relative to the Sun, as viewed from an observer on the Earth. The term may also be applied to the planets. An elongation of (19 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z 180º implies a full Moon. epact (number): the number of days past the full moon on the 1st January of any year in a 19-year metonic cycle (the period before the Sun and the Moon are again in the same relative positions in the constellations). Epact tables are found on old dials, particularly portable ones, in conjunction with lunar volvelles and calendars. In conjunction with an almanac, they can be used to predict the date of Easter. ephemeris: (pron. ef-em-er-is) a table of predicted positions of celestial objects as a function of time. Astronomical almanacs invariably include an ephemeris for the Sun. ephemeris second: an obsolete definition of a second used between 1955 and 1965, based on the Earth's speed of rotation. Now replaced – see second (of time). epicycle: a small circle whose centre moves around the circumference of a larger one. It was proposed as the shape of the orbit of some of the planets by Ptolemy. epoch: a particular fixed instant used as a reference point on a time scale for astronomical calculations, e.g. J2000.0 or noon 1 Jan 2000 (2451545.0 JD). The word epoch also occurs on some dials, for example, in tables for calculating Easter. Equation of Time: [E, EoT] the time difference between Local Apparent Time (apparent solar time) and mean solar time at the same location. Its value varies between extremes of about +14 minutes in February and –16 minutes in October. It arises because of the elliptical orbit of the Earth, and the tilt of the Earth's axis to the ecliptic. The preferred usage by diallists is: mean solar time = apparent solar time + EoT but this sign convention is by no means universal and the opposite sign is used in modern almanacs. Irrespective of the sign convention adopted, sundials will always appear slow compared to mean time in February, and fast in October/November. See Equations. Figure 5. The Equation of Time and its components. EoT varies continuously, but is usually tabulated for noon each day at a particular location. Hence values for America (e.g. as printed in the NASS Compendium) can be a few seconds different from those in Europe. The noon EoT on a particular day varies slightly over the leap year cycles (4, 100, 400 years), and more significantly over millennia. The first published tabulation of the EoT was by Christiaan Huygens in 1665, but the knowledge of its existence probably goes back to Ptolemy. The first Astronomer Royal, John Flamsteed (1646-1719) produced the first English tables in 1672. EoT can also be expressed as an equivalent hour angle equant point [Ea,EOTA]: a point in Ptolemy's model of the solar system around which the Sun and the planets rotate. equator: the great circle of the Earth (or other celestial body) which is equidistant from the poles. It has, by definition, a latitude of 0º. equatorial mount: a mount for an instrument (e.g. a telescope) which has one axis parallel to the polar axis and another at 90º to this (the declination axis). The diurnal motion of a celestial body can be followed by rotation about the polar axis alone. A polar-pointing gnomon could act as the axle for such a mount. equatorial plane: the plane through the Earth defined by the equator. equinoctial plane: the plane of the equator extended to the celestial sphere, i.e. defined (20 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z by the celestial equator. equinoctial line (on a dial): is the line followed by the shadow of a nodus on the equinoxes. For a plane dial, it is a straight line perpendicular to the sub-style. equinoxes: (vernal or spring ~, autumnal or fall ~) literally "equal nights" i.e. equal amounts of daylight and night-time. Astronomically, the points where the plane of the ecliptic cuts the celestial equator, or the moments when the Sun is at these positions. The vernal ~, around 20-21 March, is also called the First point of Aries and represents the zero of ecliptic longitude and right ascension. Thus the Sun has an ecliptic longitude of 0º or 180º at the ~. Day numbers of the Earth's orbit are usually counted from this point. The autumnal equinox is around 22-23 September, and has a right ascension of 12h. The Sun's declination at the equinoxes is 0º. See Figure 1. establishment (of a port): the interval between the time of the moon passing the meridian and high tide at the port. It is indicated on some equiangular dials which can indicate the times of the tides (tidal dials). F fiducial line (or ~ edge): (pron. fid-oo-shal) the edge of an index plate or pointer against which a scale is read. filem: an old term for a plumbline, particularly on a card dial, to show the vertical. First point of Aries: see the definition for equinoxes. Note that, because of the precession of the equinoxes, this point currently lies in the constellation of Pisces. fleur-de-lis {fleur-de-lys}: an heraldic symbol of a stylised Madonna Lily, composed of three petals bound together near their bases. Often used on dials to denote the half-hour lines. furniture: all features on a dial plate other than the hour lines and their numerals are referred to as dial ~. This may include declination lines, compass rose, EoT graphs or tables, mottoes etc. Other common furniture includes: date, maker's and/or benefactor's name, coats of arms, and latitude and (rarer) longitude. See Figure 1. G Geographic Position (GP): the point on the Earth's surface directly beneath a celestial body (i.e. where a line to the body from the centre of the Earth intersects the surface). geoid: the Earth's shape, formed by the mean sea level and its supposed extension under the land masses. It cannot sensibly be represented mathematically, and is often approximated by one of many ellipsoids. Those most likely to be encountered are the Airy 1836 ellipsoid, used to define Ordnance Survey maps, and the WGS 84 ellipsoid, used in the GPS system. globe: a spherical chart of the Earth. Note that although the Earth's geoid is actually a flattened ellipsoid (i.e. slightly melon-shaped with an equatorial radius of 6378 km, and a polar radius of 6357 km) the spherical representation is used for all dialling activities with the exception, for example, of the model used by the GPS system. gnomon: (pron. no-mon) the physical structure of a sundial which casts the shadow (from the Greek for "indicator"). The gnomon today is most-often polar pointing (sometimes described as an "axial gnomon"), although it may also be horizontal or vertical. The special properties of a polar pointing gnomon were known to the Moorish astronomer Abdul Hassan Ali in the first half of the 13th century, but its first use may be earlier. The distinction between gnomon and style made (and encouraged in this (21 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z Glossary) in modern dialling literature is not the one used in early works, and the two words are still sometimes used interchangably. Originally (in English from 1546), gnomon meant a vertical pillar or rod which cast a time-indicating shadow. See Figure 1. Hence gnomonics: the science of sundialling and gnomonist (seldom used): a person who practices gnomonics. Golden Number: a number sequence (1-19) used to describe the year number in the metonic cycle. It was used, together with the Dominical letters, to find Easter, and is often found on portable dials. grade (or grada or gons (obsolete)): [grad] a unit of angular measurement, equal to 1/100th of a right angle, or /200 radians. Used particularly in France in the 18th and 19th centuries. great circle: a circle on the surface of a sphere whose diameter is equal to the diameter of that sphere. Thus the circle has the same centre as the sphere. The shortest route between two points on the surface of a (solid) sphere lies on the circumference of the great circle connecting them. GPS (Global Positioning System): a system of polar-orbiting satellites, run by the US Dept. of Defense, which allows hand-held radio receivers to provide accurate 3-D location information anywhere on (or near) the Earth's surface. It also provides a highly accurate clock, based on UTC. The system uses the WGS84 co-ordinate system and description of the Earth's geoid. grazing incidence: a term used to describe illumination in which the rays are parallel to the receiving surface. The shadow of a point above the surface falls at infinity. green flash: an atmospheric phenomenon occasionally observed during the final phase of sunset, when the upper limb of the Sun shows as a green flash due to the complex wavelength-dependence of atmospheric refraction. Greenwich Mean Time (GMT): see GMT, time (types of) Greenwich Meridian: the line of longitude (or half a great circle) passing through the centre of the Airy transit circle at the old Royal Greenwich Observatory in London, and which defines the origin of Longitude (º = 0º). It is now designated the Prime Meridian. Note: prior to 1884, there was no single fixed prime meridian, and hence early sundials sometimes refer to different origins, notably Paris. Gregorian calendar: the calendar first introduced by Pope Gregory XIII in 1582 AD and now the accepted calendar throughout the vast majority of the world. It introduced the modern system of leap years which results in an error of only 3 days in 10,000 years. Note that adoption of this calendar throughout Europe took an extended period. Its introduction in Britain in 1752 produced a step change of 11 days which can be detected in the difference between EoT tables on dials earlier than this and those on later ones. H halcyon days: (pron. hal-ce-on) originally, 14 days about the winter solstice. Now taken as simply calm, peaceful. Hallomas (Halloween in USA): All Saints' day on 1st of November. It is one of the cross-quarter days. hectemoros angle: [hec] (pron. hec-tem-or-os) the angle from the western horizon to the sun's position, measured around the hectemoros circle. Part of the ptolemaic co-ordinate system, and related to the seasonal hours. (22 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z hectemoros circle: the great circle that passes through the E-W points on the horizon and through the sun's position. heliacal rising: (pron. he-le-ac-l) the instant of the earliest visibility of a star in the East at dawn. The heliacal rising of the star Sirius was used by the ancient Egyptians to predict the coming of the annual Nile flood. Since their year had 365 days, this occurrence had a variable date. height (of a style): see style height. heliocentric: an adjective to describe a model of the solar system which places a stationary Sun in the centre, with the planets revolving around it. heliograph: has two distinct meanings: (i) a device for transmitting morse signals over extended distances by using an accurately aligned mirror to send flashes of sunlight to the receiving station. For long messages, the ~ has a mechanism for tracking the sun's motion. (ii) an astronomical instrument for studying sunspots, as built by George Airy at Kew in 1873. heliometer: a telescope which produces two images of the Sun which can be manipulated to determine its angular size accurately. Invented in 1754 by John Dollond of London, it is also used to measure angular distances between stars. heliostat: a scientific instrument which holds an image of the Sun stationary, allowing extended observation (e.g. for solar spectrometry). hemisphere (northern ~ and southern ~): one half of the Earth's globe, either north of or south of the equator. Note that a sundial at a particular latitude in one hemisphere must be reversed for use at the reciprocal latitude in the other hemisphere. horarius circle: (pron. hor-ar-e-us) the great circle that passes through the N-S points on the horizon and through the sun's position. horarius angle: [hor] the angle from the southern horizon to the sun's position, measured around the horarius circle. One of the ptolemaic co-ordinates. horizon: the line of intersection between the sky and the Earth. For normal astronomical purposes, the observer's horizon is taken to be the great circle on the celestial sphere on which every point is 90º from the observer's zenith. The observed horizon (accounting for the curve of the earth and the height of the observer above its surface, but excluding refraction) is below the astronomical horizon by an angle called the dip. This can have a significant affect on the times of sunrise/sunset. horologia: the collective Latin name for dials, water-clocks and sand-glasses, used in the Middle Ages. horologium: a name used to describe medieval manuscripts listing shadow lengths, deriving from the Latin name for timepieces. Modern versions have also been produced. In modern astronomy, it is also the name of a faint southern constellation ("the Clock"). hour: usually means 1/24th of a mean solar day, unless otherwise stated. Scientifically, it is defined as 3600 standard seconds. See Hour (types of) for other definitions. The word derives from the Latin "hora", which was synonymous with prayer. hour angle: [h, HA] the angle corresponding to the sun's position around its daily (apparent) orbit. Measured westward from local noon, it increases at a rate of 15º per hour. Thus 3pm (Local Apparent Time) is 45º and 9 am is –45º. hour circle: a great circle on the celestial sphere that passes through the celestial poles. It is orthogonal to the celestial equator. hour line: the line on a dial plate indicating the shadow position at a particular time (23 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z (includes fractional as well as whole hours). See Figure 1. hour line angle: [X, HLA] the angle that an hour line on a dial plate makes with the noon line. The angle increases with time (i.e. positive for the p.m. hours). Thus, for a horizontal dial, the angle increases clockwise (hence the origin of the term) whereas for a vertical south-facing dial, it increases counter-clockwise . Beware, this convention is not used by all authors, and some define the angle with respect to the sub-style line. hour point: a point on the dial plane indicating the crossing of the gnomon's shadow at a particular time. Hour points replace hour lines on dials where the shadow edge does not pass through the dial centre. hour plane: the plane which, at any instant, contains the sun, the observer and the N celestial pole. The style and the appropriate hour line lie in the hour plane. Hours (types of): antique ~: same as unequal hours or seasonal hours. Babylonian ~: number of hours elapsed since sunrise, with 24 equal hours per day. The origin of the term is unclear, but may be related to the fact that the ancient Babylonians originated the base-60 counting system for angles etc. They are sometimes written as "horae ab ortu solis" or H. AB ORT." on dials. See Equations for conversion from equal hours to Babylonian hours. biblical ~: same as unequal hours or seasonal hours. Bohemian ~ : same as Babylonian ~. Canonical ~: the seven times of the day (as opposed to time periods) used to define the services or divine offices in the medieval church. These offices were based on the sixth century Rule of St. Benedict. See Appendix IV for details. An alternative definition of the term canonical hours, sometimes applied in lines on early Italian dials, is the system of putting equi-angular hour lines around the base of a horizontal gnomon on a vertical south dial. common ~: the standard 2 x 12 equal hour system, also called German or French ~. In Latin "horae communes", they are often labelled "kleine uhr" (small hours) on Nuremberg dials. decimal ~: an hour system with ten equal hours per day (as sometimes used by the Chinese and ancient Egyptians, and during the French Revolution). equal ~: any hour system where the length of an hour is independent of the date, and the same during daytime and night-time. French ~: an early name for the equal hour system with 2 x 12 hours per day, beginning at midday and midnight. Sometimes written "Oltramontane". French revolution ~: the decimal hour system. Great ~ : a term for any of the unequal hour systems. Often labelled "grosse uhr" on Nuremberg dials. Greek ~: same as Babylonian ~. Italian ~: {sometimes Italic ~} the number of hours that have elapsed since the most recent sunset (hour 0), with 24 equal hours per day. They were used in (24 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z many European countries during the period 1200 to 1800. They are sometimes written "horae ab occasu solis" or "H. AB OCC." on dials. The two terms (Italian and Italic) are often used synonymously in modern works but there is some evidence in older works that Italian hours were counted from 30 minutes after sunset. See Equations for conversion from equal hours to Italian hours. modern ~: the equal hours as used in modern time systems. They may occasionally be referred to as common, European, French, German or vulgar hours. Nuremberg ~: a hybrid equal hour system. The daylight hours were measured using the Babylonian ~ system, starting with 1 at sunrise, while the night hours started with 1 at sunset and used the Italian ~ system. In Latin, "horae norimbergenses". octaval ~: a time system with the period of daylight divided into eight hours. Probably introduced by the Romans, circa 250AD. See Appendix III for the names of the daylight periods. planetary ~: a planetary hour is the time needed for 15º of the celestial equator to rise above the horizon, counting from sunrise. As there is always 180º of the celestial equator above the horizon, there are 12 planetary hours from sunrise to sunset but they are unequal not only from day to day but also from hour to hour. Note: this definition is based on the writings of Sacrobosco, but some authors use planetary hours simply as another form of seasonal hours, with the hours associated with the "planets". See Appendix VIII for the symbols of the planets and this association. The Zonvlak program uses the definition of the German scholar Joseph Drecker (1925) who defines a planetary hour as the time for 15º of the ecliptic to rise above the horizon (counting from sunrise) and are hence very irregular. seasonal ~: a form of unequal hours, usually 12 daytime and 12 night-time hours. Named from the fact that the length of an hour varies with the seasons. temporal ~ or temporary ~: an unequal hour system with 12 hours from sunrise to sunset, and 12 hours (of a different duration) from sunset to sunrise. unequal ~: any hour system where the duration of an hour depends on the date and is different from day-time to night (except at the equinoxes). The number of hours during day-time is usually 12, but may be 8 and just possibly 10 (e.g. on some mass dials). Counting of the daytime hours begins at sunrise. Welsch ~: i.e. foreign. Same as Italian ~. End of Hours (types of) (25 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z house: (astrological) a segment of the celestial sphere. Several methods of dividing the sphere into segments exist, the most common of which produce the signs of the zodiac, and the Regiomontanus houses. hyperbola: a conic section, its most common use in dialling is the shape of the declination lines on a dial. I Imbolic: an ancient Celtic festival held on the 1st of February, celebrating fertility. It is one of the cross- quarter days inclination: [i, I] the angle between the back of the dial plane and the horizontal for inclining or reclining dials. Equivalently, it is the angle between the zenith and the positive z co-ordinate of the dial. i = 0º implies a horizontal dial. For an inclining dial, 0 < i < (the latitude of the place). For a reclining dial leaning away from the observer, i = 90º; whilst i > 90º implies a proclining dial leaning forward towards the observer. Beware: this convention is not followed by all authors. inclinometer (or clinometer): an instrument for measuring the inclination or slope of a surface. Two types are common: simple devices with a plumb-line hanging across a protractor, or precision ones where a sensitive spirit level is moved to the horizontal position against an accurate scale. Note: the term inclinometer is also used to describe an instrument - also called a dip circle - for measuring the vertical component of the Earth's magnetic field. index: besides its normal meaning of an alphabetical list, an ~ is a pointer on a scientific instrument, indicating a point on a graduated scale. The index arm of a sextant is the movable arm carrying the index mirror and the fiducial line. inferior: refers to an event on the celestial sphere below the horizon. Opposite of superior. inhiraf: the angle which the qibla line makes with the north ray of the meridian at any location. International Date Line: the line from the N to S poles, approximately following the 180º line of longitude, through which the date alters by one day (positively if travelling from W to E). Variations from the 180º meridian are made to avoid political and geographic boundaries. Islamic prayer lines: the lines on Islamic dials where the shadow of the nodus falls at the times when Muslims must pray. The times of the three most common lines are determined by a linear relationship to the noon shadow length of a vertical gnomon: zuhr: noon shadow + 0.25 x gnomon height asr-awwal: noon shadow + gnomon height asr-tânî: noon shadow + 2 x gnomon height isogonals: lines of equal magnetic deviation plotted on some navigational charts. J Jaipur: (pron. Ji-poor) a famous early 18th century solar astronomical centre in India, constructed by the Maharaja Jai Singh around 1724. It includes many monumental sundials, including a famous equatorial one with a gnomon 27 metres high. Julian calendar: the calendar system introduced by Emperor Julius Caesar and devised (26 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z by the Greek philosopher (and court astronomer of Egypt) Sosigenes. Widely used from 45BC to 1582AD. By this date, it was in error (compared to the Earth's orbit) by 10 days due to the imperfect use of leap years (i.e. it assumed the length of a year was 365.25 days). Julian Day {sometimes Julian Ephemeris Day}: [JD] the astronomer's scale of date and time. Used in dialling, for example, for the accurate calculation of the EoT and sun's declination. Measured continuously in decimal days since noon GMT 1 Jan, 4713BC. By tradition, since midnight is difficult to define without an accurate clock, the JD begins at Greenwich Mean noon, that is, 12:00 UT. As an example, 9:36 GMT on 26 April 1977 is JD2,443,259.9. See Sources: Meeus for a full algorithm for converting modern date/time to JD. The Julian Day count was defined by John Herschel in 1849, based on the 4713 BC epoch used in 1583 by Joseph Scaliger (France). It is commonly stated (probably erroneously) that Scaliger named the system after his father. K kamâl: an early Arabic navigational instrument for determining the Sun's altitude by means of a transom and a knotted cord. Kepler's Laws (of planetary motion): three laws which describe the motion of the planets around the Sun, after Johannes Kepler (1571-1630). They are: 1. Planets travel in elliptical (rather than circular or epicyclic) orbits, with the Sun at one of the foci. 2. The line joining the Sun and the planet sweeps out equal areas of space in equal time intervals (so that the planet moves faster when it is nearer the Sun, and establishing the Sun as the main controller of the planets) 3. The link between the size of the planet's orbit and its period of rotation is described mathematically. klimata: (pron. clim-arta) part of an astrolabe, it is a disk rotating on the mater with the north celestial pole in the centre and showing almucantar lines for the design location. After the Ancient Greek meaning "angle of the Sun's rays", and hence the modern word "climate". L Lambert's circles: circles of construction used when drawing sets of nested ellipses to represent analemmatic dials for different latitudes, these dials using a common scale for the (vertical) gnomon position. Such sets of dials are particularly useful for a solar compass, e.g. the Cole sun compass used in N. Africa during the Second World War. After the mathematician Lambert (b. 1728, Alsace). Lammas (or Lammas Day): one of the cross-quarter days. It is on 1st August, and was formerly observed as the harvest festival. latitude (geographical, of a place): [, PHI, LAT] Note: avoid LAT, since it implies local apparent time. It is the angular position of a place north or south of the equator. Positive values in the Northern hemisphere, negative in the South (i.e. the South Pole has = -90º). Part of the geographic co-ordinate system, the term comes from the Greek "latus" (breadth). leap second: an extra second inserted into UTC at the end of some years between 24:00:00 Dec 31 and 00:00:00 Jan 1 to ensure that UTC remains in step with the Earth's diurnal rotation. It may also be added at the end of June. The addition is not predictable as it depends on many factors, such as the increased atmospheric drag on the Earth in El Niño years. The actual addition is performed by the Bureau International des Poids et (27 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z Mesures near Paris. Leap seconds are gradually becoming more common as the rate of the Earth's rotation slows due to energy dissipation by the tides. leap year: years in which an extra day (February 29) is introduced so that the (Gregorian) calendar keeps step with the Earth's orbit. The rule for leap years is that a year is a leap year if and only if the year number: is divisible by 4, except years divisible by 100 which are not leap years unless they are also divisible by 400. This corresponds to the length of the year being 365.2425 mean solar days. This can be compared to the 365.25 days in the earlier Julian calendar. (The Julian leap year doubled February 24.) The leap year system causes the EoT (and Sun's declination) on a particular day of the year to exhibit a small periodic variation. lemniscate curve): the figure of eight shaped curve. The term is used in Latin countries for the analemma. From lemniscus, meaning ribbon. In English, the ~ is a mathematical curve which is similar to a spiral and is sometimes used in road design; it also looks similar to one lobe of the analemma. libration (of the Moon): the periodic oscillation of the Moon from 'side to side' (and 'up and down') which allows an observer on the Earth to see somewhat more than half its surface. limation: (rare) a term used by Flamsteed to mean the correction of a calculation or observation, having originally (1612) had the meaning 'filing or polishing'. limb: part of an astrolabe, it is the outer ring with a scale of hours and degrees. Its first recorded English use was in 1593. limb (of the Sun): the outer circumferential region of the Sun (or other celestial body). The term limb darkening indicates that the disk of the Sun does not have uniform brightness but is dimmer around the "edges" due to increased optical absorbtion by the photosphere. local apparent time: [L.A.T.] solar time see LAT (types of). Hence local apparent noon, at the Sun's superior transit. local hour angle (or just hour angle): [h, HA] Local Apparent Time expressed as the angular position of the Sun in its daily track. Measured from noon, it increases by 15º per hour with increasing time (i.e., morning hours are negative). Beware, this convention is not universal. lodestone: a naturally occurring oxide of iron, mounted with two iron poles in a non-magnetic frame. Used for magnetising compass needles, small ones were made specially for portable dials. longest day: a term in common parlance, defined as the day of the year with the greatest (astronomical) sunrise to sunset period. It is normally used synonymously with the summer solstice although, strictly, it can vary by a day depending on the exact time of the solstice and the relationship between the rate of change of the EoT and that of the local sunset/sunrise. longitude (or geographic ~ to distinguish it from the ecliptic ~): [, t, LON] the angular location of a place on the Earth's surface measured east or west of the Prime meridian though Greenwich. Longitudes W are positive, E negative. Part of the geographic co-ordinate system, the term comes from the Greek "longus" (length). See also Prime Meridian. Longitude Act: a 1715 act of the British parliament which established a Board of Longitude to manage a prize of £20,000 for a practical method of finding longitude at sea. longitude correction: the correction required to local apparent time to translate it to the (28 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z L.A.T. for the central meridian of that time zone. The correction is +4.0 minutes for every 1º longitude W of the time zone meridian (and -4.0 minutes for E). Sometimes, this correction is built into the hour lines by calculating the local hour angle for times at the zone meridian. lunar angle: the difference between the right ascensions of the Sun and the Moon. On a standard sundial used as a moon dial, the L.A.T. equals the time shown by the lunar shadow plus the lunar angle expressed in hours. lunation: the time interval between successive New Moons. The mean interval is 29 days 12 hours 44 minutes 3 seconds (the synodic month) but, because of the perturbing action of the sun, the difference between the shortest and longest lunations in the 20th century is 5 hours 19 minutes. M Mach bands: (pron. mak) subjective light and dark bands which an observer sees when looking at a black-white edge. They are produced by the brain's visual processing (i.e. they are not real) and have the effect of sharpening up edges. First described by the German physicist Ernst Mach (1838-1916). magnetic variation {magnetic declination, magnetic deviation}: Note, the use of the term magnetic declination is best avoided because of confusion with the other types of declination. It is the angle between the true N pole and the magnetic N pole. At present in the UK, the magnetic pole is very approximately 3º W of true north, and decreasing by about 12' annually. See Appendix IX for more detailed and historical values. There can be large local variations to the general values, some of which can be found mapped on navigational charts. The use of a magnetic compass for aligning a permanent dial is not recommended: even if due corrections are made, the presence of steel or magnetic rocks will cause very local variations. manaeus: (pron. man-ay-us) the circle of months which formed part of the ancient orthographic spherical projection used by late Middle age diallists. It establishes the sun's declination. maquette: a sculptor's small preliminary model. The term is used to describe small mock-ups of three-dimensional dials. Martinmas: St Martin's day, on 11th November. It is one of the cross-quarter days. mass dial: see Dial types (mass dial). mater: the heavy disk which forms the base of an astrolabe. mean solar day: the time between successive transits of the fictitious mean Sun (i.e. an imaginary sun which appears to circle around the celestial equator at a constant rate equal to the average rate of the Earth's real rotation). The basis of civil time keeping. mean time: see Time (types of). mean local time (or local mean time) : see Time (types of). Mercator projection: the most common projection used to produce a 2-D map of the globe. Developed by Gerardus Mercator in Belgium, 1586. It has straight meridians and parallels of latitude that intersect them at right angles. Scale is true at the equator or at two standard parallels equidistant from the equator. The Transverse Mercator projection is obtained by projecting the sphere onto an enclosing cylinder tangent to a central meridian. This is the projection used for Ordnance Survey maps of the UK. merkhet: a transit instrument from ancient Egypt, consisting of a horizontal "L" shaped stone with a plumb-bob supported from the short vertical arm. It was used in (29 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z conjunction with a bay. meridian: the great circle (or, more usually, half of a great circle) passing through the N and S poles. The same as a line of longitude. The term is sometimes used to mean the meridian line instrument for finding the solar azimuth, consisting of a magnetic compass and an alidade, with some means (e.g. mirrors, prisms, shades) of viewing the Sun and the compass needle. penumbra: the area of partial shadow surrounding the central umbra. It is due to the finite size of the sun. An observer standing in the penumbra would observe only part of the sun's disk. perigee: (pron. pe-ri-gee) the point in the Moon's (or other satellite's) orbit when it comes closest to the Earth. perihelion: (pron. perry-he-le-on) the point in the Earth's orbit when it comes closest to the sun. It occurs during the first week of January. perpetual calendar: a device, usually in the form of a circular plate with one or two rotating engraved disks, for finding the day of the week for any date (over a wide range of years). They are often combined with portable dials as part of a compendium. More sophisticated versions have extra tables for Saint's Days and similar data. phase (or age) of the Moon: the approximately monthly variation of the angular separation of the Sun and the Moon, leading to the sequence of new, waxing, full and waning moons. The age (as seen, for example, in tables associated with moon dials) is measured in days since the last new moon. Astronomically, the phase of the Moon is defined as the angle between the Sun and the Moon measured from the Earth (the lunar angle). The mean length of the synodic (i.e., lunar) month is 29.53059 days (usually approximated to 29½ days in the lunar mechanisms of clocks). photosphere: the outer envelope of the Sun which produces the visible light by which it is seen. pinnules: sighting pinholes (usually in pairs) in an alignment device, e.g. an alidade. planet: astronomically, a celestial body in orbit around a star. The five planets of the solar system known to the ancients were Mercury, Venus, Mars, Jupiter and Saturn. In addition, they often counted the Sun and the Moon as planets; for example, in the planetary hours system. See Appendix VIII for symbols. (33 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z planetarium: see orrery. planisphere: a map of part of the celestial sphere, formed by a stereographic projection of the sphere onto a flat plane and showing (or adjustable for) the positions of the stars at a particular time and location. plinth: the base part of a pedestal, normally resting on the ground. Note that some authors use ~ to refer to the whole of the pedestal. See Appendix VII for more details of architectural terms. plumb-line: a freely suspended line with a weight (or plumb-bob) at its lower end, used for defining the vertical. plummet: the form of plumb-line incorporated in a portable dial and used for levelling it. It usually consisting of a solid elongated cylinder suspended, by a joint with free movement in the horizontal axes, above a datum point. pobble: the bead on the plumb-line of a card dial. polar axis: see axis. polar co-ordinates: see co-ordinates. polar distance: the distance (as an angle) of the Sun from the elevated celestial pole; the complement of the declination. polarised light: light in which the electromagnetic waves have a single plane of vibration in a direction perpendicular to the direction of propagation. Polarising filters allow the transmission of light rays with only a selected plane of polarisation. Discovered by Christiaan Huygens (1635-1703). Sunlight is randomly polarised, but skylight is partially plane polarised, with the direction of polarisation at any point in the sky being perpendicular to the plane containing the point, the Sun and the observer. The proportion of the skylight which is polarised is a maximum in the principal plane and at 90º to the sun. The proportion is always less than 75%, and substantially less in slightly hazy conditions. Polaris (or Pole Star): actually Ursae Minoris, it is the star which appears quite close to the N celestial pole and is frequently used for finding north by navigators. It currently appears to rotate daily around a circle of radius 1º, so it requires some knowledge if it is to be used for aligning a sundial. The size of this circle varies over the centuries with the precession of the equinoxes. polar plane: any plane which is parallel to the Earth's axis. polar triangle: the spherical triangle on the celestial sphere whose vertices are at the pole, the zenith, and a celestial body, with respective angles of the hour angle, the azimuth, and the parallactic angle. The arcs joining these are the co-latitude, the north polar distance (90º -) and the zenith distance. The polar triangle is fundamental to the operation of most types of sundial, whose function it is to derive the hour angle, and hence the time, given any three of the other quantities. poles (N and S of the Earth): the locations on the Earth's sphere with latitudes of +90º (N) and –90º (S). polos: an old term for a polar-pointing style. post meridiem (p.m.): the portion of the day between noon and midnight. precession (of the equinoxes): the slow westward progression of the equinoxes on the ecliptic. It is caused by the drift of the Earth's axis in space, as in a precessing spinning top. The position of Polaris turns around the pole of the celestial pole once in about (34 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z 26,000 years. As a consequence, the vernal equinox regresses by about 50 arcseconds per year along the ecliptic. It is caused predominantly by the gravitational force of the Sun and the Moon on the Earth's equatorial bulge. Secondary effects, due to the other planets, give a rotation of the ecliptic plane of 47 arc-seconds per century. The first measurement of precession was made by Hipparchus in 129 BC. precision (of a dial): a combination of the resolution and accuracy of a dial, it gives a measure of how exactly (and correctly) it indicates any time. Prime meridian: the meridian line defined as the origin for longitudes. Now synonymous with the Greenwich meridian, before 1884 various countries defined their own origin. The early Greeks used Rhodes or Alexandria. Ptolemy used the Fortunate Islands, assumed to be Ferro in the Canary Islands by scholars in the Renaissance. Nuremberg was common for dials made there, and in relatively modern times many maritime nations had their own locations; Paris in particular continued to be used even post-1884. Note that the 0º longitude line used by the GPS system is actually a mean value, periodically recalculated to allow for tectonic drift etc. and currently lies approximately 38 m (80 feet) east of the Greenwich line. Prime vertical: the vertical circle perpendicular to the meridian. It passes through the E and W points. Primum Mobile: (pron. pree-mum mo-be-lay) an old term for the supposed crystal sphere carrying the stars in their orbits around the earth. principal plane {or vertical plane}: the plane obtained by varying the Sun's altitude whilst its azimuth is constant. Perpendicular to the almucantar. prosthaphaereetical arc: a term introduced by Samuel Foster to describe an arc on the surface of the earth between the location of an inclining/declining dial and the position where it would be identical to a horizontal dial (i.e. the complementary dial). In astronomy, prosthaphaeresis is the adding of a small amount to an observed value. Ptolemy's rulers: an interconnected set of three linear scales used to measure the angular positions of stars, used particularly by Regiomontanus and the Nuremberg group in the 1460s. Q Qibla line: sometimes found on Arabic dials, it is an azimuth line on the dial plate starting at the centre and pointing to Mecca. quadrant: a term used for a large genus of astronomical and navigational instruments. In the form of a quarter-circle, it incorporates a sun or star sighting device along one of its radial edges and a plumb-bob hanging from the centre of the circle. The old quadrans vetus was originally an Islamic invention which provides seasonal hours but is only truly accurate for an observer on the equator. The quadrans novus, invented by Profatius in 1288) was more accurate, incorporating the circular scale of the astrolabe folded into a quadrant but it was difficult to read. The 1438 horary quadrant of von Gmunden was one of several attempts to improve on this. The Gunter ~ (after Edward Gunter, Gresham College, 1623) is latitude dependent and employs a stereographic projection. The navigational ~ is actually an octant (eighth of a circle) with two reflecting mirrors replacing the plumb-bob. For the Davis ~, see back-staff. Quarter days: the first or last days of each quarter of the year on which rent or interest is due. These dates are occasionally used instead of the zodiac signs for declination lines on dials. See Appendix XII for their names and dates. quincunx: five dots arranged as on dice. It sometimes appears on mass dials at noon or (35 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z service times. R radian: [rad] the primary unit of angular measurement, it is the central angle subtended by an arc of a circle equal in length to its radius. 2 radians = 360ºor 1 rad 57.3º. ray: a single line or narrow beam of light. reclination: a term sometimes used for the angle by which a reclining dial leans away from the observer (i.e. the complement of the inclination). It is more consistent, however, to translate this into the equivalent inclination. rectificatory: an old term for a right-angled triangle where the other two angles are the latitude and co-latitude. Used particularly in the graphical construction of dials. reflex angle: an angle of greater than 180º. refraction: the "bending" of light at the interface of two materials of different refractive indices. It accounts for the focusing action of lenses. In dialling, use is made of ~ in dials which use a clear liquid in a solid cup to compress the hour lines, or which use a cylindrical lens to focus sunlight onto a curved dial plate. Atmospheric refraction (due to the curve of the Earth's surface and the variation of atmospheric density with height, in turn dependent on meteorological conditions) is the effect which makes the Sun (or other celestial body) look slightly higher in the sky than its true astronomical position. It is only significant when the Sun is within a few degrees of the horizon. At 0º altitude, the bending is equivalent to approximately 34 arc-minutes, so that it is possible to see the Sun when it has actually just sunk below the horizon. See Equations. This effect is not generally included in normal sundials but it must be allowed for when calculating solar parameters from observations using meridian lines. The refractive index [, MU] of a medium (or its index of refraction), needed to calculate these effects, is defined as the ratio of the speed of light in a vacuum to its speed in the medium. Regiomontanus houses: an astrological division of the celestial sphere into 12 segments or houses. The division is performed in equal segments around the celestial equator, rather than around the ecliptic as is done for the normal signs of the zodiac. The houses are numbered I to XII, beginning at the east point of the horizon and are, confusingly, associated with the standard zodiac signs with I corresponding to Aries. Only the last 6 of the signs appear above the horizon. They are shown as domifying circles on some old dials. resolution (of a dial): the smallest time increment to which the scale on a dial can be read. Contrast with accuracy. See also precision. rete: {or net or spider} (usually pron. ree-tee) part of an astrolabe, it is the fretted disc containing a number of star pointers, and which can be turned on the limb until the star's pointer crosses the altitude circle on the stereographic projection, allowing the time to be read off (assuming the date is known). The term ~ has sometimes (first reference in 1677) been used as a graduated scale fixed to an astronomical telescope. reticule: fine lines or scales on an optical element in a sighting device (e.g. a telescope) to aid in alignment or measurement of an object. revolve: (astronomical) to orbit around another body, e.g. the Earth revolves around the Sun. Contrast to rotate. right ascension: [, RA] a co-ordinate used by astronomers, as part of the equatorial co-ordinate system, (together with declination) to define the position of a celestial body. (36 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z It is the angular distance measured along the celestial equator (positive to the east) from the vernal equinox to the intersection of the celestial equator to with the hour circle through the point in question. Usually measured from 0 to 24 hours, but sometimes 0º to 360º. root (of a gnomon): The fixing between the gnomon and the dial plate. See Figure 1 rotate: (astronomical) to spin on its own axis, e.g. the Earth rotates on its polar axis. Contrast to revolve.. S Samhain: an ancient Celtic festival held on the 1st of November. It is one of the cross-quarter days. saros cycle: a cycle of 18 years 11 days 8 hours (223 lunations) between repetitions of eclipses. scales: see dialling scales. sciagraphy: {skiagraphy} the art or science of shading and shadows. From sciaterics or scioterics - the name for gnomonics in ancient Greece. seasons: the seasons are defined astronomically as follows: Spring: from the vernal equinox to the summer solstice Summer: from the summer solstice to the autumnal equinox Autumn: from the autumnal equinox to the winter solstice Winter: from the winter solstice to the vernal equinox In popular parlance, the seasons of the northern hemisphere comprise the following months: Spring March, April, May Summer June, July, August Autumn September, October, November Winter December, January, February The signs of the zodiac for the seasons are given in Appendix I. second (of angle): see arc-second. second (of time): the fundamental unit of time. The accepted scientific definition of the second is now 9,192,631,770 periods of radiation corresponding to the transition between the two hyperfine levels in the ground state of caesium 133. This definition was adopted in 1967, and replaced the earlier (since 1955) ephemeris second which was defined in terms of a fraction of the mean tropical year in 1900. The above frequency was chosen because it gives a close approximation to the number of seconds in a day (86,400). Fluctuations in the Earth's rotational rate since about 1969 have been such that the day is between 1 and 3 ms longer than this number of seconds. These variations are totally insignificant to even the best sundial. The word ~ derives from the Latin "secunda minuta" or second minute. semidiameter (of the sun): [s, S] half the angular size of the Sun (or, more correctly, its (37 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z photosphere). As the distance from the Earth to the Sun varies during its orbit, the semi-diameter varies from 15.76 arc-minutes in July to 16.29 arc-minutes in January. In dialling, it is usual to take the sun's full diameter as ½º . septentrional: a term now rarely used for "of the north" and sometimes applied to north-facing dials. shadow sharpener: any of the various devices for sharpening the edge of a shadow, allowing more accurate time readings to be made. Usually a physical addition to the gnomon or nodus, it casts a secondary shadow, with its own penumbra, in which the primary shadow can be located more accurately (although it may have less contrast). The term is sometimes also used to refer to a movable lens which produces an image of the shadow edge. shadow square: a square (or rectangular) scale often found on quadrants and astrolabes which allows the tangent or cotangent of the altitude of a celestial body to be found. shortest day: a term in common parlance, defined as the day of the year with the least (astronomical) sunrise to sunset period. It is normally used synonymously with the winter solstice although, strictly, it can vary by a day depending on the exact time of the solstice and the relationship between the rate of change of the EoT and that of the local sunset/sunrise. sidereal time, sidereal day: see time (types of). signs of the zodiac: see Zodiac. Sirius: (the Dog star) the brightest star in the night sky, used by the Egyptians as a means of determining the beginning of the Nile floods. See heliacal rising. skylight: light which reaches the observer from the general (blue) sky. It is sunlight which has undergone multiple scattering events with the molecules of the Earth's atmosphere (i.e. Rayleigh scattering) or with clouds or other aerosols in the atmosphere. High levels of skylight reduce the contrast of a shadow. It also tends to be polarised. slant: see obliquity. small circle: a circle on the surface of a sphere whose centre does not coincide with that of the sphere (and hence it must always have a smaller diameter). solarium: Latin for sundial. Beware, it can also be interpreted as "sunning place". solar compass: an instrument for direction finding which uses dialling principles. The most common are modified versions on an analemmatic dial with a vertical gnomon. Sometimes called an astro-compass, although these latter more properly use sightings of the fixed stars. solar longitude: the ecliptic longitude of the Sun, it varies from 0º (at the vernal equinox) to 360º during the year. By Kepler's Second Law, the rate of change of the solar longitude is such that the Earth sweeps out equal areas on the ecliptic plane in equal times. solar parallax: the difference between the Sun's altitude as observed from the Earth's surface and its true astronomical value from the centre of the Earth./ solar time: see time(types of). solstices: (Summer ~, Winter ~) literally, "Sun stands still". In the Northern hemisphere, they represent the beginning of summer (on or around 21 June) and the beginning of winter (on or around 21 December). They are (usually) the same as the longest and shortest days, respectively. Astronomically, they are the occasions when the Sun's ecliptic longitude is 90º or 270º, respectively, and correspond to the extreme values of (38 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z declination. See Figure 1. South: one of the cardinal points of the compass, it is the direction opposite north, in the direction of the south celestial pole. It is also the direction of the Sun at local noon (in the northern hemisphere). southing: another term for a southern transit. South Pole: the location on the Earth's surface where it intersects the axis, and opposite the North Pole. It has a latitude of -90º. spherical angle: the angle whose vertex is at the intersection of two great circles of the celestial sphere. Spherical trigonometry deals with spherical angles and triangles. spherical triangle: the figure formed on the surface of a sphere by three intersecting great circles. The fundamental (or nautical) triangle is the special case of a spherical triangle on the celestial sphere with vertices at the zenith, North celestial pole and the Sun. split noon: see noon gap. standard time zone: [TZ] a geographical region which uses the same civil time. These are approximately regions between two lines of longitude, set 15º apart, and hence with 1 hour time difference between adjacent zones. The standard time for each zone is the mean solar time at the central or standard meridian for the zone. For the UK, which is in Zone 0, the standard meridian is the Prime Meridian at Greenwich, and the zone nominally extends from 7½º W to 7½º E. For political reasons, other time zones have their boundaries adjusted to follow country borders or other features. The zones were defined at the same international conference in 1884 that set Greenwich as the Prime meridian. steradian: (pron. ster-ade-e-on) unit of solid angle. It is the central solid angle of a sphere subtended by a surface area equal to the square of its radius. The whole sphere supports an angle of 4 steradians around its centre. stereography: (hence stereographic projection) a drawing method in which a sphere is projected from a point on its surface to a plane which is tangent to it. Its main property is that circles on the celestial sphere are projected as circles or straight lines on the plane. It is fundamental to the construction of planispheres and astrolabes as the rete is a stereographic projection. Its use is difficult in the construction of sundials due to the vast length of some of the radii required (although this can be overcome by calculating in cartesian coordinates and then converting). Its use was advocated by 17th century diallists. string gnomon: a gnomon in the form of a flexible cord which is pulled tight when the dial, typically in diptych form, is opened. style {stile}: the line in space which generates the shadow edge used to indicate the time on the dial plate. Note that a gnomon with finite thickness will have two styles (one along each of the upper edges) which will each be operational for parts of every day. If the gnomon is in the form of a long rod, the style will be the virtual line running along the centre of the rod and the dial is read by estimating the centre of the shadow. Note: this modern distinction between gnomon and style is not the one found in earlier literature where (from 1577) the word style was used to indicate a polar-pointing gnomon (a polos) or, more rarely, a nodus. Hence stylar: pertaining to the style or gnomon of a dial (first used 1688). See Figure 1. style height: [SH] of a polar style is the angle that the style makes with the sub-style line. Note that this is an unusual use of the word "height", and style angle could be regarded as a better term. For a style which is perpendicular to the dial plane, style (39 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z height is simply the distance from its top to the foot. See Figure 1. sub-nodus (point): the point on the dial plane that lies perpendicularly below (or behind for a vertical dial) a nodus. The distance from this point to the nodus is sometimes called the ortho-style distance. sub-style angle: [SD] the angle that the sub-style makes with the noon line, measured positively clockwise (towards the p.m. hours for a south-facing vertical dial). sub-style (line): the line lying in the dial plane which is perpendicularly below (or behind for a vertical dial) the style. See Figure 1. sub-style triangle: the right angled triangle formed with the polar style as the hypotenuse, with the other sides lying along the sub-style and the ortho-style distance. summer solstice; see solstices. Sun: the star at the centre of our solar system. The mean distance to the Earth (designated the Astronomical Unit or AU) is 149.6 x 106 km. It has a surface temperature of about 5800 º K. The solar spectral irradiance reaching the Earth's surface (at AM1 - air mass 1 - i.e. looking through a standard atmosphere with the Sun at the zenith) ranges from about 250 nm to 2000 nm, with the main peak at 490 nm. See semi-diameter for the apparent size of the Sun. sun clock: see Dial types. sun compass: see solar compass sundial: an instrument for telling the time and/or date from the position of the Sun. More generally, it can give any function of the Sun's co-ordinates. See dial for the origins of the term, and Dial (types of) for types. sunlight: light reaching the observer directly from the Sun. Contrast with skylight. Note that the Sun's rays reaching the Earth are always taken as parallel, but coming from an extended source (see semi-diameter). sunrise, sunset: the first (last) appearance of the Sun above the horizon each day. This occurs when the sun's altitude reaches -0º 50'. Note that astronomers define the rising of an object as an altitude of 0º. The difference is due to the combined effects of the Sun's mean semi-diameter (16 arcmin) and atmospheric refraction (34 arcmin). See Equations for expressions to calculate sunrise and sunset. sunshine recorder: a meteorological instrument for recording the hours in which the Sun shines. The most interesting type is the Campbell-Stokes ~, which uses a spherical lens to focus bright sunlight onto a paper chart, burning a track along it. superior: refers to an event on the celestial sphere above the horizon. Opposite of inferior. synodic: pertaining to the successive conjunctions of a planet (or moon) with the Sun. T tellurian: a demonstration model, similar to an orrery, but showing the Earth-Sun system, or the Earth-Sun-Moon system. This latter is sometimes referred to as a lunarium. Note: the tellurian is sometimes called a tellurium but this term is best avoided as it is the name of the 52nd element in the periodic table. terminator: the edge of the shadow cast by a self-shadowing object, such as the edge of the illuminated part of the Moon. terrella: from the Latin for "little globe". See globe dials. (40 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z tide(s): the divisions of a day used in the Anglo-Saxon period. The time from sunrise to sunset was divided into four tides or time periods. See Appendix II for the names of the tides. Lines showing the tides are found on Anglo-Saxon and some mass dials. Some dials also have lines denoting the half-tide. Note that this use of the word has no connection with the marine tides. Time, (types of): Apparent solar ~: the measure of time based on the diurnal motion of the true sun. British Summer Time: [BST] civil time in the UK during the "summer", one hour ahead of GMT. Invented by William Willett and first introduced in 1916. A sundial showing BST in Petts Wood, near Chislehurst, Kent, is his memorial. BST usually begins on the last Sunday in March, and ends on the last Sunday in October. These dates are now co-ordinated with Summer Time in the rest of the EU. civil ~: the legally-accepted time scale in a particular country or region. It is based on the standard time for that standard time zone, but may have fixed differences (eg BST). Measured in modern hours from the most recent midnight, with either a 24 hour or 2 x 12 hour format. clock ~: simply the times shown by a clock, usually civil time. Hence the appendage "o'clock" to some times. Daylight Saving Time: [DST] civil time during the summer in much of the USA (and some other countries) obtained by advancing clock time one hour from local standard time. Equivalent to BST in the UK. dynamical ~: [or Terrestrial Dynamical Time, TDT] "scientific time" – it superseded ephemeris time in 1984, and is based on a uniform scale of time derived from atomic clocks (i.e. not subject to fluctuations in the Earth's rate of rotation). Now usually called international atomic time (TAI). ephemeris ~: [ET] "scientific time" - used between 1960 and 1983, this uniform timescale was based on the ephemeris second, itself derived from the period of rotation of the Earth at a particular date. It was succeeded by dynamical time when the second was redefined in 1984. French revolution ~: a decimal timescale (10 equal hours or decidays per day) devised in 1790 by the French Academy after the French Revolution. Each hour was divided into 100 millidays (of 86.4 seconds) and each milliday into 1000 microdays (0.0864 seconds each). The decimal timescale, which had been used previously in ancient Egypt and China, was never fully implemented and was quickly dropped, with the result that sundials so calibrated are extremely rare. Greenwich Mean Time: [GMT] the basis for civil time standards worldwide, it is the time at Greenwich as given by the fictitious mean sun. It is derived from UT, but GMT is measured from midnight. Local Apparent Time: [L.A.T. - the use of the full-stops is encouraged to avoid confusion with the common contraction of "latitude"] this is solar time, as derived from the real Sun at any particular location. It is the hour angle of the Sun + 12 hours. Some authors (non-UK) may refer to it a Local True Time. (41 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z local mean ~ {mean ~}: [LMT] this is solar time which has been corrected for the EoT but not for longitude, so it is still location specific. English towns used this form of time prior to the coming of national railways and the telegraph, e.g. Oxford time. Mean Solar Time: the authoritative (by the National Physical Laboratory) definition is: a measure of time based conceptually on the diurnal motion of the fictitious mean Sun, under the assumption that the Earth's rate of rotation is constant. railway ~: (or London time) a colloquial term used for Greenwich time as it began to replace local time with the introduction, in the mid-1800s, of railways and the resulting need for unified timetables. sidereal ~: [, SDT] "astronomical or star time". This is timekeeping based on the sidereal day, and hence it runs ahead significantly with respect to solar-based time. Local sidereal time is equal to the hour angle of the first point of Aries and is, to a first approximation, sidereal time with a longitude correction. solar ~: the same as Local Apparent Time. Summer time: a generic term for BST, DST etc. standard ~: [ST] is mean solar time at the central meridian of a given time zone. universal ~ :[UT or UTC] this is the basis for terrestrial and civil timekeeping, and was adopted in January 1972. It is tied to the rotation of the Earth, and hence has to be periodically adjusted by the addition of leap seconds to account for the gradual slowing of the Earth, and the vagaries of its rotation. UT is by definition measured from the superior transit of the fictitious mean sun (i.e. mean noon at Greenwich), and hence is 12 hours behind GMT (although this difference only tends to be recognised by astronomical calculations). UT measurement is based on standard seconds. The version referred to as UTC (Universal Time, Co-ordinated) simply means the value averaged over a number of atomic clocks world-wide. In aviation, it is referred to as Z or zulu. zonal solar time: sometimes used to denote solar time at a time zone meridian. Thus it is local apparent time with a longitude correction but without EoT. In the UK, it would be denoted Greenwich Solar Time. - End of Time (types of) - time zone: see standard time zone. torquetum: (pron. tor-kwet-um) an early (known to be before 1326 AD) astronomical instrument capable of fixing star positions and producing conversions between equatorial and ecliptical co-ordinates. Some forms may have been used to help delineate dials, and torquetum-style dials for solar and sidereal time were made in the late 17th century. Most famously, it features amongst the instruments in Holbein's 1533 painting "The Ambassadors" (National Gallery). transit: the meridian passage of a celestial body. For the sun, this occurs when it is directly south of the observer. It can also refer to the time of this occurrence. Transits may be either superior or inferior. transom: a crosspiece of fixed length, as on a cross-staff. Sometimes called a vane. triangle (fundamental or nautical): see spherical triangle. (42 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z triens: an extended quadrant, with a 120º arc. It can usually tell the time in both equal and unequal hours. trigon: in dialling, a mechanical aid to drawing lines of declination on dial plates. It consists of an instrument which is fitted to, and can swivel around, the nodus on a polar-pointing gnomon, and can be set at an angle equal to the sun's declination angle to the gnomon. Often used with an associated auxiliary dial. Trigon is also an archaic term for a triangle. From the Greek "trigonon" or "three-cornered. triptych: (pron. trip-tick) literally "three leaves", it refers to a set or compendium of three instruments, including at least one dial. Other instruments often include a compass and perpetual calendar. tropical year: see year. tropics: geographical bands of the Earth's surface, extending from the equator to latitude 23º 26' N (tropic of Cancer) or to 23º 26' S (tropic of Capricorn). The terms are also used to refer to these specific latitudes. Note that they represent the extremes of the region where the Sun can reach the zenith when the sun's declination is at its extreme values. twilight: the interval after sunset or before sunrise when the Sun illuminates the upper atmosphere and hence it is not completely dark. It is determined by the sun's altitude falling within a given range, as follows: civil twilight: -0º 50' and -6º nautical twilight: -6º and -12º astronomical twilight: -12º and -18º These values reflect the need for decreasing light levels for various activities. U umbra: the central, darkest portion of a shadow, i.e. the region which does not receive direct rays from any part of a distributed light source (e.g. the Sun). umbra recta: Latin for "upright shadow", it is the label often found on the cotangent scale of altitudes < 45º on a shadow square. umbra versa: Latin for "reverse shadow", it is the label often found on the tangent scale of altitudes > 45º on a shadow square. Universal Time (UT): see time (types of). V vernal {spring} equinox: see equinoxes. verdigris: (pron. ver-de-gree) the green patination found on weathered brass and copper. vernier: a small moveable scale for obtaining fractional parts of the subdivisions of a fixed scale. Invented by Pierre Vernier in 1631 (published Brussels, 1638). For circular scales, a Type A vernier has a central zero. After about 1780, sextants commonly had a Type B vernier with the zero on the right of the scale. European instruments often have the very similar nonius. vertical angle: the angle from the zenith to the horarius circle passing through the sun, (43 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z measured along the prime vertical (the E-W vertical circle). It is one of the ptolemaic co-ordinates. vertical plane: see principal plane. volvelle: (pron. vol-vel) an old device consisting of one or more movable circles surrounded by other graduated or figured circles. It is used for showing the rising and setting times of the Sun and Moon, the state of the (marine) tides etc. A ~ has sometimes been included around the rod-gnomon of equiangular dials. W wedging out: (or canting out) placing wedges between a dial plate and its mounting surface. (a) for a horizontal dial: to compensate for moving a dial to a different latitude from the one it was designed for, (b) for a vertical dial: to ensure that it faces a cardinal point of the compass (usually S). West: the point on the horizon 90º (measured anti-clockwise) from the north point. The Sun appears to set at the west point at the equinoxes. winter solstice: see solstices. X Y year: the time that it takes the Earth to make one orbit of the sun. The tropical year is the interval in which the mean ecliptic longitude of the Sun increases by 360º. This is the version of the year used in normal calendars and has a length of 365.24219 days. Other versions of a year (e.g. the sidereal, anomalistic and Julian years) have differences of about a hundredth of a day to this figure. Yule: an ancient Celtic festival held on or around the 21st of December, celebrating the winter solstice. It is one of the cross-quarter days, and has now become synonymous with Christmas. Z zenith: (astronomical) the point on the celestial sphere vertically above the observer. In everyday parlance, ~ usually implies the highest point. This gives rise to confusion as the mid-day Sun is often described as its ~, irrespective of the latitude. zenith distance (or zenith angle): [z] the complement of the altitude i.e. (90º - a) zodiac: an imaginary band, centred on the ecliptic, across the celestial sphere and about 16º wide, in which the Sun, Moon and the planets Mercury, Venus, Mars, Jupiter and Saturn are always located. The band is divided in 12 intervals of 30º , each named (the Signs of the Zodiac) after the constellation of stars which it contains. The sun's ecliptic longitude may be measured against this scale. The names (and/or signs) of the constellations are given in Appendix I and are often used in sundials, instead of the date, to specify declination lines etc. Because of the effects of precession over the period of 2,300 years since the constellations were first named, the signs of the zodiac have slipped by a whole sign, i.e. at the vernal equinox (defined as the first point of Aries), the Sun is actually in the constellation of Pisces. Zonwvlak: a major suite of computer programs for calculating sundial lines. Written by Fer de Vries (Netherlands) it is available at www/iaehv.nl/users/ferdv. The name is short for zonnewijzer (sundial) vlak (plane). (44 of 45) [3/2/2004 9:29:57 PM] BSS Glossary - A through Z (45 of 45) [3/2/2004 9:29:57 PM] wsanford/exo/sundials/uco7.jpg wsanford/exo/sundials/uco7.jpg (1 of 2) [3/2/2004 9:29:59 PM] wsanford/exo/sundials/uco7.jpg (2 of 2) [3/2/2004 9:30:04 PM] DIAL FACE TEMPLATE LATITUDE STRIP North Face Spring/Summer 20 E W 6 6 25 7 5 T A F 8 4 9 3 R I N G E 2 10 11 1 O N 30 N N O M O R 35 12 20 6 5 7 4 7 8 35 N 9 O 9 10 4 1 1 3 60 55 50 45 1 12 40 40 8 2 O 5 30 3 1 0 N 25 6 1 1 1 45 O 1 T 2 F E R 50 9 O 3 O M N R A G 10 N IN 11 Finished Sundial N 4 55 8 60 7 W 5 6 6 Bottom 20.00 South Face Fall/Winter 15.00 Sundial Fast (Mins) minutes 10.00 5.00 0.00 Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec -5.00 -10.00 Sundial Slow (Mins) -15.00 Correction for the "Equation of Time" S T A R D AT E / U N I V E R S O T E A C H E R G U I D E 19 E StarDate Online | Activities | Equatorial Sundial Contact StarDate | About StarDate | Friends of McDonald | Sign up for Sky Tips FAQs News & Features Image Gallery Solar System Guide Explorations Constellation Guide Star Guide Galaxy Guide Astroglossary Resource List Program Search search » Keywords » Site search Go Teacher Guide Equatorial Sundial One of astronomy's first tools to measure the flow of time, a sundial is simply a stick that casts a shadow on a face marked drawing and the actual objects themselves which are outside in the world. Does everyone have an idea, and can they explain it to others? Draw the Sun where everyone agrees it should appear in the picture. Use the fist measurement tool to relate the Sun's position to the horizon, to nearby buildings and trees, and perhaps to due south. Return to the classroom. How would we go about making some good observations of the Sun to understand what is happening in a day? Most students will tell you to go out every so often and check. Why? What might change? Does our world change? How has it changed since spring? How will it change in four months? How will it change in five hours? How have we changed in a year? The changing world means we need to keep an eye on it. What is the scale for watching the Sun move in a day? If no one else does, suggest that observations be made every hour. Have the students devise a plan for carrying the easel and markers and making sure journals get collected for observing outside. Does anyone have a clue about where the Sun might be next? Let's all make some predictions with accompanying reasons in our journals. Return with them every hour to make another observation and drawing. Where is the Sun now? Is it noticeably different? How many fists up in the sky is it? Maybe they can help you draw the Sun in. How did their predictions turn out? Does anyone have a theory about the movement? Where is the Sun going? What happened to their shadows? Many will come to your class already able to tell you that the Earth spins, but they will not be able to explain it well. Ask them if they could explain the apparent movement of the Sun with a spinning Earth. Is it important right now that everyone believe the Earth is spinning? No, not really. It is important only that they have had this day-long observation and been able to model it in the classroom on paper and then later on the board as a geometrical model. We can then talk about our experiences back in the classroom and think of some good explanations for what we saw. So, where does the Sun go in the evening? We could interview other classrooms who have not had the same experiences as us and see what they think. What about classes who have had the same experiences as we did outside? What do they think? Many will say the Sun goes to the other side of the world. What is it like for people on the other side of the world when it is day for us? Can anyone point to a place on the globe which is having night right now? The Internet has a database of live cameras set around the world. If you are able, access a site and find the country your students chose. Looking at a real picture "live" from that place will help solidify their theory and strengthen their resolve. See page 61 for a list of Internet sites with live cameras. After a few more observations, a definite shape is appearing in the movement of the Sun, if you use each Sun plot as a dot in an outlined shape. What shape is emerging to describe the movement of the Sun? This shape is known as an arc. How might we extend this shape into a bigger shape? Draw this arc (10 of 13) [3/2/2004 9:30:16 PM] ECT: Hello, Sun! high on the board, leaving room on the sides and the bottom for thoughts about the larger shape of this arc. Ask them if this is the shape they saw the Sun moving in. Students will see a semi-circle and a full circle, some may even be silly and make some squiggle. Perhaps they should put their bigger shape in their journals and give it a name. Can anyone think of a reason why the Sun is making this shape? Is the Sun moving? Do we think the Sun is moving around the Earth in this shape? Where in our drawing on the board is the Earth? If this is too hard to think about, where then were we in the picture? If the shape were a semi-circle, what would happen to us? Would the Sun go right through us? What about the other side of the Earth. Do people live there? What would happen to their day if the Sun just went zipping past in a straight line like that? Do they think this is probable? What might be a more likely shape for this situation? A circle! What do we know that is special about a circle? How many degrees are in a circle? How many hours are there in a day? Could we figure out some things about where the Sun might be shining in one hour? What about in five hours? Where will the Sun be? On a globe, we could try to guess this place and look on the Internet. (The Thread, Time Warp, begins some thoughts on Time Zones.) England is five hours from Eastern Standard Time, and there is a great Internet site for Cambridge, England, where a live camera takes a wide angle shot of the University there every few minutes. This visual proof can be turned around in such a way: Thinking about a circle seems very mathematical and not related to our world very much. However, if we recall that we made a circle from the motion of the Sun in our experience, then it must be said that what can be predicted from a circle can be applied to the apparent motion of the Sun. Does that circle mean that the Sun is moving around the Earth? Could there be another way of seeing the Sun do what we've just seen it do? Here is the challenge of perspective, and this will be the most difficult of all. Imagine you were born and lived on a spinning carousel. You've never known the ground. What would your view be like? All around you the world would be spinning past, but the things on the carousel would stay in place. How easy it would be to believe that you are standing still and everything else is moving, if you've never been off of the carousel. Place a bright light source or even a student at the front of the room. Have the students stand such that their left shoulders are pointing to the light source in the same way their shoulders had pointed to the Sun. Ask the students to then say where in their vision does the light source lie. Give them a blank piece of paper. They should say or even draw the light at the very left of their view or paper. Just drawing where the light source is in their view might be superior to drawing the room and the light (11 of 13) [3/2/2004 9:30:16 PM] ECT: Hello, Sun! source. The reason for this is, as they are spinning about past the light source, the room is also appearing to spin. Thus, the idea of the light source appearing to move becomes moot, because the entire room will appear to move. This is not what we saw when we watched the Sun all day long. We saw the Sun appear to move past the scenery. So, perhaps saying that they should draw where the light source is instead of what they are seeing will help them develop a better mental model of what is happening. Ask them to turn counter-clockwise until they are facing the light source. Have them again say or draw where the light is in their field of vision. The view will be that there is a room with a light source in the middle. Then ask them to turn again so that the light source is on their right shoulder. Have them tell you about or draw this final view. This time, the room should appear to be filling their view except for the very right side, where there is a light source. They may want to glue or staple the drawings into their journals later. Putting the pictures in the order of their movement, does anyone see a pattern? Put the easel and its drawing in the front of the room. Does anyone see a connection? What two types of motion do we now know can cause the pattern we have observed? If the light source were the Sun, what time of day would the first drawing represent? Where is mid-day? What would happen if we spin around past the point where the light source was at our right shoulder? Our backs would be to the light source. Is this what happens at night? Ask the students if everyone on the Earth gets sunlight sometime. This will lead into the question of what kind of spinning shape allows that to happen. Now the big challenge is to find out what the students think this motion means. The light source "Sun" was always at the front of the room, but on the drawing of our turning, we saw it move across our field of view. Is it possible then that the Earth might be the thing that is moving while the Sun actually stands still? At some point, it would be good to discuss with your students why you had them face South when they were outside. What would happen if we all had faced the other way? Could we go out and see that? We could explore the school's Daymarks by using the Appendix, Telling Time Without a Clock. What objects around the school could help us to keep track of time without a watch? (12 of 13) [3/2/2004 9:30:16 PM] ECT: Hello, Sun! (13 of 13) [3/2/2004 9:30:16 PM] ECT: You Light Up My Life You Light Up My Life Next, we want to determine the behavior of sunlight from observations outside and inside the classroom. We will learn about how light travels by using mirrors, prisms, and shadow makers. The National Science Education Standards state that the nature of light is an important topic to be learned in this age group, and the manipulation of tools is crucial. The vocabulary which can be introduced to help talk about our experiences are light, shadow, shade, opaque, transparent, translucent, waves, colors, mirror, rainbow, spectrum, and ray. For a new approach to learning some of these vocabulary words, visit Word Lore, an appendix dedicated to exploring the history of words pertaining to this curriculum. Light is a very odd thing, but a very special thing. It travels faster than everything else in the Universe. It defines how we measure everything we do, for it travels around, hitting objects and bouncing their images to our eyes. When the images of objects reach us, they allow us to judge the positions of those objects. In that way it is our only good means of determining time. If something moves from one minute to the next, we are most likely to notice this if we can see its image. We can only see its image, if light is bouncing around. Therefore, light can tell us about the world and its changes. Our current scientific knowledge suggests that light can act in ways that are wave-like and ways that are particle-like. That light acts as a wave means it bounces off things or interacts with other lights similar to the way that waves in water do. That light acts as a particle means that when it bounces off things, it carries with it energy that can be transferred to the things it hits. An example of this is a sunburn, where sunlight has hit and been absorbed into the skin, burning the cells. This wave particle thing called light travels in a very straight way, in rays, from its source. Anything in the path of the light ray will block the ray to some degree. If the object is very dense and dark, preventing the light from passing beyond it, it is called opaque. Beyond this object, then, on the side farthest from the light source, is what is know as a shadow - where there is an absence of the bright light. You can usually still see things in the shadow because there is other light scattered or bounced about the room or yard hitting that area indirectly. Some transparent objects like glass even let light travel almost completely

[illegible]

Sun/Blocker/Shadow which hopefully will root important scientific concepts in a fun game. Five- to eight-year-olds are not very adept at grasping the nature of light. Most undergraduate physics students have difficulty with the concept. However, being comfortable with the way light works is crucial for understanding shadows. Make sure that children understand that when someone says "there is no light" that it's different from how we talk about dark in everyday language. If a room is slightly darkened but they can still see, it is because there is light available! Providing the concrete experiences offered in this Thread helps children develop a strong base for the complete concepts they will learn when they're older. What are shadows? Where do they come from? How do you make one? What things do you need to make a shadow? Could we make a shadow outside? Inside? In a dark room or at night? Under water? Outside, the Sun lights up the world. But what happens when things get in the way of the sunlight? Does everything make a shadow? Where are our shadows? Can I walk up to someone and step on her shadow? Playing a game of shadow tag would be fun here. After the energy is released from play, gather the students around again. Let's face the Sun and try to find our shadows. Are they in front of us? They are behind us. Let's face our shadows. Where is the Sun? It is behind us now. So, where are shadows going to be when (3 of 9) [3/2/2004 9:30:18 PM] ECT: You Light Up My Life the Sun is over there (point to the left)? Let's face that way. Our shadows would be behind us again, on the other side. So, where do shadows form? On the side of us away from the Sun. Is this true for any light? Can both the Sun and shadow ever be on the same side of us? Could we face the Sun and face our shadows at the same time? Why or why not? What is it about the Sun's light that is not making that happen? The overhead projector in the classroom gives off a nice light. Turn it on and ask someone to stand in front of it with his eyes covered (otherwise it will hurt). Where is his shadow? He can't see it, but the class can see it behind him. Where should he move to see his own shadow? He turns around and there it is. What is the Sun? What is the light? Are there things in our classroom which give off light? What are they? Could we think about the sunlight as we do the classroom light? Are there such things as portable lights? Could we use them to think more about light and blockers of light? What about with flashlights? Could we shine a flashlight on something and make a shadow behind it? In pairs in the classroom, have students shine a flashlight on objects they have in front of them. You could give them wooden shapes and other things. Where are the shadows? Can they change the shape of the shadow or the size? There seems to be some kind of lining up that has to happen: Sun, blocker of Sun, and the shadow. Could we find a tree and see if it works with a tree? Find a nearby tree and see if the same is true. What about a car or the school? Where is the Sun? Where is the shadow? Emphasize "Sun/Blocker/Shadow" while pointing to each of these elements in the set-up. Move the flashlight to another spot and show again the different pieces of the Sun/Blocker/Shadow. Let them quiz each other with teams at their own desks. For the youngest grades this may require supervision. You may just want them to play with the flashlights, see if they can tell someone else one special thing they found out about the light and shadows. A short assessment handout is included that you could use tomorrow to see how many have experienced this fact of light: Light travels in straight lines, so that shadows are directly away from the light source.This handout was created by a first grade teacher as part of the Everyday Classroom Tools curriculum. She had great success with it, and used it repeatedly to reinforce the ideas. (4 of 9) [3/2/2004 9:30:18 PM] ECT: You Light Up My Life This Thread allows teachers to direct questions towards the nature of light through repeated experiences with it and objects which block it. These students can juggle ideas such as the seen and the unseen. This will help us to get a firm enough grasp of what light is doing that we will be able to predict some things about both it and shadows. Try getting them to notice the world around them, especially things that don't seem to make sense. Encourage them to take the next step in problem solving by coming up with the kinds of questions they would ask to solve the mysteries. Be aware: they will come up with questions that they may not be able to completely answer! Encourage your students to write their questions down in a journal where they could call upon them as they gain further understandings. What are shadows? What is shade? Are they the same? What is light? Where does it come from? How is it made? Let's go outside and think more about this. Grab stuff you want to see shadows of and maybe some paper if you want to draw shadows to show people later. Does anybody think there is something which does not make a shadow? Bring it along. Outside, find a place where there is space to spread out clipboards and people without overlapping shadows. It may be better to do this closer to mid-day when the shadows are shorter. Have everyone place their test objects on the paper. What do we see? Which objects make really good shadows? Which make weirdly colored shadows? Why might this be so? (5 of 9) [3/2/2004 9:30:18 PM] ECT: You Light Up My Life In all of this, where is the Sun? Look again at the shadows. Which way do they point in relation to the Sun? Is there anything we could do to change that? Trace the shadow there right now. Then try to find some way to make the shadow look different on the paper. Some will move the object, some will move their position on the ground, others will twist their paper a bit. Draw the shadow again. Whose shadow looks different? Why? What happens when you move the object itself? How did the shadow change? Is it pointing in a different direction? Where is the Sun? What about when you move to a different place? Where and how did you move? How might that have affected the way your shadow looks? Where is the Sun? What about those of you who twisted the paper? Where is your new shadow? Is it still pointing away from the Sun? But where is it on the paper? The paper moved and not the Sun, right? Why are shadows always pointing away from the Sun? How is light working to do that? How does the Sun know the wooden block is there? Light is somehow hitting the block and making that shadow. What is that area behind the block and away from the Sun? Is there light in there? Not as much as there is around it. So, when light hit the block, did it go through the block? A shadow must be the area behind an object facing the Sun which can get no direct light. Why is it cooler in the shade? Is the Sun warm? What happens in the shade? It is not getting the light and so is not as warm. Cool. Exactly. (6 of 9) [3/2/2004 9:30:18 PM] ECT: You Light Up My Life This Thread offers fourth through sixth grades the opportunity to tackle the theory of light through different and more serious experiences outdoors. They are ready to ask and be asked some deep questions which will hopefully open their analytical minds to the possibilities of even deeper questions for real understanding. Providing them with tools and time is all we need for them to create a fairly good theory of the nature of light. Even if they don't come up with the same theory that scientists currently hold, they are learning about theory generation, how we come up with the best explanations that we can until we learn something new to help us generate a better explanation. Why can we see the world around us? What outside conditions cause us to see worse or better? Students will mention the weather and amount of light. Why does the weather affect our view? It will become obvious that the weather can block light, such as on a cloudy or rainy day. So, really, the only factor is light. What is this light stuff? Where does it come from? Does it only come from the Sun? What other things give off light? Fire and friction are good examples, friction being what causes light bulb filaments to glow. (This may be new to this age group. If so, it would be useful to have all of the class rub their hands together and tell you what happens to the temperature. Can they think of other familiar objects that produce heat in this way?) Phosphorescence is another way of making light, but a very confusing way at that. How does that little sky spot of the Sun make the whole town light up? What is light doing? How might we figure out more about it? Have the class make strategies for learning more about the Sun. Brainstorm about ways to test theories. For example, one hypothesis might be that the sunlight glows in the air. How could we test that? Is there a way? One way might be to get a clear container of air and shine a light in it, then turn the lights off. If the air is still glowing inside, that could be interpreted as evidence for the theory. What other thoughts might they have about how light works? Now might be good time to talk about reflection. Bring outside (on flat ground or pavement with paper) all of the things they might need to discover properties of light. We suggest you bring mirrors, objects of varying opacity, closed boxes, flashlights, paper, tape, etc. (Please note: It is an unfortunate fact that children outside with mirrors often will try to aim the bright sunlight into the faces of others. You should (7 of 9) [3/2/2004 9:30:18 PM] ECT: You Light Up My Life consider using mirrors indoors with flashlights, which are weaker, or mentioning that mirrors will be taken away if students cannot behave properly with them.) Encourage your class to build devices for trapping or analyzing light. Why are shadows on only one side of an object outside? Do they ever move? Why or why not? Most will say that the Sun is shining and hitting the object on one side of it, and the shadow forms because the light can't get through to the other side of the object, so there's no light there. Trace the shadow on the paper. Twist the paper. Where is the shadow on the paper? Where is the Sun? Is the shadow still pointing away from the Sun? But where is it on the paper? Did the Sun move? But the shadow changed because what we were measuring it on moved. Keep this in mind when we do the Sun stick measurements. Why can you still see the pavement in that shadow? Surely there must be some light coming from somewhere? What is happening? What happened to the light that hit the block? Did it get sucked into the block? Did it bounce off the block? How can light bounce? What other things can bounce like that? Many will say playground balls or something like that. Is light made of little balls of bright stuff? If so, what could we do to test that? Here is where the mirrors come in. It is hard to see the light bouncing from the block, but easy to detect light which is being bounced from a mirror. Can we bounce light around the yard? How far can we get before it is difficult to catch the beam of light? If light can bounce so well off mirrors, might it not bounce around off other things, but not as well? Probably. That is why it still gets around the whole yard, even the pavement inside a shadow, when the Sun is in one place in the sky. This is why it gets bright out in the morning even before the Sun rises, and that it is still light just after the Sun sets. Light indeed travels in very straight lines, but light itself can bounce though it still travels in straight lines from object to object. (8 of 9) [3/2/2004 9:30:18 PM] ECT: You Light Up My Life (9 of 9) [3/2/2004 9:30:18 PM] ECT: Me and My Shadow Me and My Shadow In this Thread, we will become familiar with the orientation of shadows, their size in relation to the object casting them, and how the alignment of the Sun, the object, and the shadow tells us much about how shadows work. The National Science Education Standards stress that geometry and light should be integrated into curricula as tools for learning about three dimensional objects. Vocabulary words which can be used to help talk about our experiences are alignment, casting, angle, and light source. The height of a tilted light source (in other words, the angle between the light source and the ground) and the size of the object it is illuminating determine the length of the shadow that the object casts. The object blocks the light coming from the source so that nothing behind the object gets any direct light. The length of the shadow is a result of how high above or below the top of the object the light source is. Imagine if the light source were directly above the top of the object. Would there be a shadow? No, not one that would be visible around the object. Twist the light source a little down from the top, and a shadow appears behind the object, but is very short. This is because as the light source moves down, the shadow is being created by the small area of the object blocking the light. Imagine straight lines coming down from the light and hitting the object. The higher the light, the less light lines get blocked by the object and hence the less shadow. Thus, the lower the light source is aimed at the object, the more the object blocks the lines, or rays, of light. The key to understanding shadows is to realize that the light source and object must be lined up in order to make a shadow appear. In fact, if the object is placed anywhere along that line, it will produce a shadow of the same length behind the object. It is only when you change the orientation of the light source that the shadow changes. That makes sense in one order: light hits an object and casts a shadow. But experiencing the connection of these fundamentals in a different arrangement is good for rooting our experiences more firmly. In other words, trying to predict where to place an object to cast a shadow at a specific location: essentially trying to locate the path of the light. We've made a brief page about solar eclipses. Solar eclipses are excellent examples of light and shadow. (1 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow Download This Thread invites Kindergartners through second graders to continue to think about light and shadow while using their bodies to make observations. This roots our experiences by relating them to ourselves, which is fitting for this age group. It engages students in manipulating objects with a focus in mind as well as exercising balance and movement skills which are good for this age group. Teachers of second graders should consider using the grade 2-4 version of this Thread. Remember the game Sun/Blocker/Shadow? Why does it work? What other game could we devise to play with the way light works? Everyone grab a marble or cube. (Don't call the cubes "blocks" or it will confuse the game.) (2 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow Together, let's go outside and find a place to spread out on an area of asphalt or concrete, etc. Where are our shadows? Can everyone find his or her own shadow? Where is it? Is everyone's shadow visible? Can the teacher come and step on someone's shadow? Does it hurt to step on a shadow? How far away from the person is the teacher who is stepping on the shadow? Is it hard to reach the person from where the teacher is standing? Why are shadows so far away from their makers? Play Shadow Tag again, this time with some questions afterward. Was it hard to play this game? We had to be careful to watch our shadows and the person who was "It" very carefully. When was it hardest to be careful: when running towards the Sun or away from it? Why? How are shadows made, then? Now it is time to reverse our thinking. Everyone, drop your cube somewhere. Where is your shadow? Can you move your shadow so that the shadow of your hand can cover the little cube on the ground? This will at first seem quite difficult, but soon they will begin to cry out that they have done it. Helping is definitely OK. How did you knew where to put your fingers? They will begin to vocalize in their own ways an important fact: that the sunlight is in straight lines to their hands and they need only line themselves up with the Sun and the cube to cast a shadow on it. In this way, they have figured out that one can determine the position of the light source from the angle of a shadow they can cast. Can anyone think of a way to play this game in the classroom? (3 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow This Thread will examine the orientation of the Sun, ourselves, and shadows from the reverse way around. It will seem like a tricky game, but once the idea of the linear nature of light travel is experienced, we can talk more about light in the next Thread. To do so, again we will exploit this age group's fascination with mystery, team learning, and the ability to string two or more variables together into a model. Second grade teachers should consider choosing this version of the Thread over the version intended for younger (K-2) students. What has to happen before we can see a shadow of ourselves? There must be light. There is light and us, but there is something else we need to actually see the shadow. We need something for the shadow to land on. So, three things are required for shadows: a light, an object, and a surface. Is there any guideline for where the shadow should land when we are standing in the light? Does it matter where we put the light? What about in outer space? Everyone should grab one small shiny object like a new penny or an interlocking math cube, a pink eraser or a marble. Let's go outside. Find an asphalt or concrete area with a lot of space, enough that the entire class can spread out and be bathed in sunlight. Is there enough room for their shadows? You might consider timing this for between 11 a.m. and 1 p.m., when the shadows are shorter but not so short as to make this impossible. Everyone should spread out enough that they can twirl in place and not hit anyone. Next, everyone should drop their shiny object somewhere about 4-5 feet from them in any direction. Now find your own shadows and stick your arms out. Make an OK sign with your fingers, so that your shadows show a little ring or circle for your hands. Can you, without squatting, move your shadow ring so that it encircles the shiny object on the ground? They will mock this as easy at first, until they find it is very difficult. There is some kind of trick to doing this, and it will be fun watching them catch on. What has to happen before the shadow can line up with the object? What else is needed to make a shadow besides the surface (shiny object) and the thing making the shadow? The Sun. See how many can incorporate this into their struggle. There has to be an alignment of the three crucial items needed in making a shadow happen. (4 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow Soon, (it takes about 3-4 minutes), they will begin crying out that they have figured it out, one by one. Ask them what they did, and they will try to explain they made things line up or they looked back to where the Sun was. It is the lining up of these objects which is so crucial to learning about how light and shadows work. If someone has managed to ring the object by luck, ask about the positions of the things needed to make a shadow. Is there any pattern? Can we shuffle from side to side and still make the shadow happen on the object? Can we shuffle forward and backward and still make the shadow happen on the object? How? Where must the Sun be in order for this to work? Directly behind our hand. Where must the object be in order for this to work? Directly in front of our hand. Where is the Sun? Where is our shadow? Have them face the Sun. Where is our shadow? Turn to the left. Where is the Sun? Where is our shadow? Is there a pattern here? What if the Sun were over there (point to the left)? Where would our shadows be? What is true then about shadows and the Sun? Shadows point away from the Sun. Do shadows point away from a lamp as well? We can play with this back in the classroom. They will want to play more with this trick once they all have caught on. You can ask them if they can get two people to circle the object at once from different positions. Break into teams of shadow makers. Can anyone make other shapes with your body to circle the object? Does everyone have to stand at the same distance from the object to ring it? How many people can you line up who are casting a shadow around the object but are standing apart from each other? Back in the classroom, let's pool what we've seen. We saw that we had to line our hand up with the Sun to make a shadow, but we also had to line that shadow up with the shiny object. We had to move our entire bodies so that the Sun was at our back to get the OK sign over the object. We found that we could also move towards it and away from it and still keep the OK ring around the object by moving our hand only slightly. Draw on the board a Sun, a person with her hand out, and the object, but do not line them up in the proper was for the person's shadow to hit the object. Will this person's shadow hit the object? Why or why not? Students should gather in the same teams that they were in outside. They should think about the question on the board and then come up with an answer. Ask the teams in turn what they think. They will hopefully mostly say no, this cannot happen. Why not? They will talk about things not being lined up. You could prod them some more by asking them if they mean you can't draw a straight line which connects them all. Draw a line that connects the three items, first asking what the order is. Sun, object, shadow....It should be a terrible looking line, with connections between points not meeting at a 180 degree (5 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow angle. In other words, not a straight line. Where would I need to put the person to make the line straight? Teams can confer and answer you in rotation. Have them come up to the board and place an X where they think the person's hand should be. Different colored chalk would work well for different teams, otherwise numbers will suffice. Does everyone agree? If not, more examples like this could be done. Is this what we experienced outside? We had to line up everything to make it work! Why? What must be true about sunlight or any other light source? It travels in straight lines. For this age group, this Thread involves a quick investigation outside to (6 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow exercise our powers of perception. Although this is probably a little easy for them, it is still a good idea for them to be familiar with every aspect of the shadow making process. What makes a shadow? Most will know that shadows are caused by the Sun or other light hitting an object and blocking the path of light behind the object. This is easy, right? You can make a shadow fairly easily and determine where the light source is from just looking carefully at a shadow. But can you aim a shadow at an object? Huh? Everyone should grab one small shiny object like a new penny, interlocking math cube, a pink eraser or a marble. Let's go outside. Find an asphalt or concrete area with a lot of space, enough that the entire class can spread out and be bathed in sunlight. Is there enough room for their shadows? (You might consider timing this for 11 a.m. or 1 p.m., when the shadows are shorter.) Everyone should spread out enough that they can twirl in place and not hit anyone. Next, everyone should drop their shiny object somewhere about 4-5 feet from them in any direction.Now find your own shadows. Make an OK sign with your fingers, so that your shadows show a little ring or circle for your hands. Can you, without squatting, move your shadow ring so that it encircles the shiny object on the ground? They will mock this as easy at first, until they find it is difficult. There is a trick to doing this, and it will be fun watching them catch on. What has to happen before the shadow can line up with the object? What else is needed to make a shadow besides the surface (shiny object) and the thing making the shadow? The Sun. See how many can incorporate this into their struggle. There has to be an alignment of the three crucial items needed in making a shadow happen. Soon, (it takes about 1-2 minutes), they will begin calling out that they have figured it out, one by one. Ask them what they did, and they will try to explain they made things line up or they looked back to where the Sun was. It is the lining up of these objects which is so crucial to learning about how light and shadows work. If someone has managed to ring the object by luck, ask about the positions of the things needed to make a shadow. Is there any pattern? Can we shuffle from side to side and still make the shadow happen on the object? Can we shuffle forward and backward and still make the shadow happen on the object? (7 of 8) [3/2/2004 9:30:21 PM] ECT: Me and My Shadow How? Where must the Sun be in order for this to work? Directly behind our hand. Where must the object be in order for this to work? Directly in front of our hand. (8 of 8) [3/2/2004 9:30:21 PM] ECT: This is a Stickup! This is a Stickup! In this Thread, we are continuing to examine the passage of time from observations we can make about the outside world. In Hello, Sun!, we saw that the Sun appears to jog across the sky during the school day. It looks like a nice and smooth motion. By using the shadow of the Sun during the day, we may make safe and accurate measurements of that motion. The National Standards require that students be learning what causes light, heat and shadow, and how time passes, how to use rulers and other measuring tools. The vocabulary words which can be introduced to help us talk about our experiences are line, length, angle, sphere, straight, and model. We have already explored the way the Sun moves in the sky during the day. The next step is to try and see that motion from another perspective. Some classes may have been able to determine the height of the Sun in fists and found that the Sun first gets higher then lower in the sky. Did students also notice that their shadows got shorter and then longer again? Do they have a record of that? As we saw from the Thread, Me and My Shadow, the height of a light source changes the lengths and orientations of shadows. Using a standard stick with careful measurements can give us a better record of the changing shadow lengths outside in the Sun and also good data for exploring deeper. If we measure shadow lengths during the day using a standard stick, the shadow pattern will look like a fan of lines, first long, then shorter, then long again. This fan will begin with its first shadow line on the left of the stick, if you are looking from South of the stick This fan pattern will then proceed with lines moving ever more to the right and at steeper angles to the edge of the paper. This is because the Sun rises in the East, or to the right of the stick. A light source on the right will cast a shadow of an object to the left. The angle of the Sun above the horizon determines the length of the shadows it causes behind objects. The higher the Sun is, the shorter the shadow. This is why the fan gets shorter at mid-day. In fact, if the Earth did not tilt on its axis 23.5° as it does, then the Sun's height at mid-day would be the same every day of the year. The Thread called Latitudes and Attitudes will let us explore this further. At one point in the investigation, you will talk about the relationship between angles and sides of a (1 of 14) [3/2/2004 9:30:26 PM] ECT: This is a Stickup! right triangle. A right triangle is one which has a 90° angle in it. In such a triangle, the tangent of an angle is defined as the length of the side opposite the angle divided by the length of the side next to the angle. The hypotenuse, or longest side, is not used in finding the tangent. In the sunstick investigation, the tangent of the angles use the "sides" made by the length of the stick and the length of the shadow. So, depending on which angle you are trying to find, you will divide one by the other. In a calculator or using a table of tangents, you can find the angle. In the upper grades, you will use a protractor and some string to measure the angles directly as well as finding them with the tangent. If you are interested in making sundials with your class, please check out this pattern for a simple design for a sundial. Download This age group cannot yet manage the precision required for the Investigation in this Thread. They will not be able to make good measurements nor understand their importance. What we want them to learn from this adventure is that as it moves across the sky, the Sun's light changes the stick's shadow, something which they should remember from Me and My Shadow. However, we can emphasize using the Sun as a clock in this Thread. It is suggested that instead of employing the measuring stick and paper that you instead use a sapling or pole in the school yard and bright marking objects or flags. This way we can express the same basic concept in a very big and personal way, using first our bodies to mark where the shadows are and then special flags we place to make semi-permanent records of the shadows. Decorating personal flags would be a fine

[illegible]

introducing transfinite numbers. Vehement opposition to his views strained him greatly; Cantor suffered recurrent breakdowns and depressions, and eventually died in an asylum. [from The Illustrated Almanac of Science, Technology, and Invention] 03/04/2004 Satellite Broadcasts Take Students Along as Scientists Track Habitat Change Atlanta, Georgia April 14, 2004 Convention strands: Maintaining the Professional Edge; Science Beyond the Printed Word; Hooking Kids on Science; Integrating Technology. [more] New! Convention Personal Scheduler: Plan your professional development itinerary, whether or not you've registered yet. Virtual Exhibitor Workshops 03/05/2004 - 06/11/2004 "TLC Elementary School" Cablecast To Feature Earth's Changing Surface 03/08/2004 - 09/10/2005 BRAIN—The World Inside Your Head, a Traveling Exhibit More Events copyright © 2004 NSTA If you are not a member of NSTA and would like to receive our free electronic newsletters - Science Class (monthly) and NSTA Express (weekly) - enter your e-mail address and location below and click submit. E-mail: State/province: Not applicable NSTA members: you will receive these newsletters (unless you have opted out). To check the e-mail (2 of 3) [3/2/2004 9:30:32 PM] NSTA - National Science Teachers Association address we have on file for you, click here. Newsletter archives (3 of 3) [3/2/2004 9:30:32 PM] NSTA - Astronomy With A Stick Unit 1: Tracking a Moving Shadow Unit 2: The Rise and Fall of Daylight Hours Unit 3: Making and Using Models Daytime Astronomy for Elementary and Middle School Students by SYLVIA K. SHUGRUE Changes in the length of daylight hours profoundly affect the daily and annual rhythms of our lives. Yet studies have shown that even college graduates fail to understand the relationships between the Sun and the Earth that cause these changes (Sadler and Schneps 1988). Students who learn by rote in a classroom do not fully understand or retain these important concepts. Astronomy skills properly introduced in elementary school will produce adults who understand the Earth's place in the universe. You can help your upper elementary students experience these relationships through indirect observations of the Sun on the school playground and with models built in the classroom. These Students from Garrison Elementary in D.C., prepare a circle on activities provide a continuous Washington, the ground in order to place a gnomon to indirectly observe the Sun's exercise in critical thinking movement in the sky. [photo by W.T. Webb.] and combine well with practice in the use of mathematics and language skills. (1 of 2) [3/2/2004 9:30:35 PM] NSTA - Astronomy With A Stick The science information and skills gained in the activities form a foundation for future studies in astronomy and geography. The over-arching question addressed by the following activities is "Why do daylight hours vary in length where we live?" The following activities have been arranged for convenience into three interchangeable units. It is best to begin the observations in September and continue at intervals throughout the school year. Unit 1 requires sunny weather to make observations, although some of the calculations are done later in the classroom. The unit 2 graphing activities, and unit 3 modeling activities can be done throughout the year and on overcast or rainy days. We are currently registering classes worldwide to participate in AWS. Registered classes will be able to share data, and share what they are using AWS in their classrooms, stories and myths about the sky overhead, and other information. Join today. SYLVIA K. SHUGRUE, now retired, was a science teacher in the Washington, D.C., public schools for many years. She is a past president of the National Science Teachers Association. These activities were developed with the help of the students of the Gage-Eckington Elementary School in Washington, D.C. The Reverend Francis J. Heyden, former chief astronomer at the Manila Observatory and later, chief astronomer at the Georgetown University Observatory, offered guidance and support throughout the 4 years during which these units were developed and tested. Stephen Berr, Director of the Colonial School District Planetarium, Norristown, Pennsylvania, reviewed this article. Reprinted from Science Activities, Published by HELDREF PUBLICATIONS, 1319 Eighteenth Street, NW, Washington, D.C. 20036-1802. Join Now! Click Here! See also the companion site Day Into Night >> National Science Teachers Association 1840 Wilson Blvd Arlington, Virginia 22201-3000 (703) 243-7100 www.nsta.org Questions? Contact (2 of 2) [3/2/2004 9:30:35 PM] How to assemble and use your equatorial sundial. If you have the old version you should download the new and improved version now! Find it in both PostScript and PDF (and several other dials) at my sundial page. Assembly Fold the paper lengthwise along the printed centerline. If you are careful you can get the crease right on the line. I hold it up to a light and make sure the dial faces on the two sides are lined up before I crease it. You may find it helpful to score the fold lines. An empty ball point pen and a straight edge work great. If you are using a dot matrix printer the compression from the pins helps the paper fold nicely. Next fold the paper on the other line. If you are in the northern hemisphere you'll fold it so the latitude scale is on the outside. Take an ordinary sharpened pencil and poke it through the paper in the center of the dial. This is the most difficult part of assembly. If you take your time and work at it you can get the pencil right through the center. You can cut away the excess paper to make the hole neater if you wish. Poke a thumbtack through the latitude scale at your latitude. Slide the paper along the pencil until they form a right angle and then stick the eraser onto the thumbtack. For greatest accuracy use a pencil with a new eraser and carefully put the tack into the center of the eraser. If you wish you can put tape or glue at the hole where the pencil passes through. This is especially helpful if the hole gets enlarged through wear. Telling Time You are now ready to tell time. Place the sundial somewhere in the sunshine so that it is facing north. That is, the pencil should be pointing north (really the pencil should point almost directly at Polaris, the "north Star.") Be sure the paper is perpendicular to the pencil. Read the time. Find other sundials at my sundial page. wsanford/exo/sundial/equa.html (1 of 2) [3/2/2004 9:30:35 PM] Equatorial Sundial - Activity Questions Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium Equatorial Sundial Activity Questions Teacher's Answer Key available upon request. Multiple Choice (circle correct answer within brackets): 1. The gnomon (or style) of an equatorial sundial represents the Earth's [axis, Equator] of rotation. 2. The dial plate of an equatorial sundial represents the [Northern Hemisphere, Southern Hemisphere, Equator]. 3. The upper dial face of an equatorial sundial represents the [Northern Hemisphere, Southern Hemisphere]. 4. The lower dial face of an equatorial sundial represents the [Northern Hemisphere, Southern Hemisphere]. 5. The 12 o'clock hour line (also known as the meridian line) that divides the dial face in half represents your [line of latitude, line of longitude]. 6. Relative to a horizontal surface, the dial plate of an equatorial sundial is tilted at an angle equal to your [latitude, longitude]. 7. Relative to a horizontal surface, the gnomon of an equatorial sundial should be inclined at an angle equal to the [complement, supplement] of your latitude. 8. [Complementary, Supplementary] angles are two angles for which the sum of their degree measures equals 90 degrees. 9. As viewed from above the North Pole, the Earth appears to rotate [clockwise, counterclockwise]. 10. As viewed from above the South Pole, the Earth appears to rotate [clockwise, counterclockwise]. (If necessary, experiment with a globe before answering this question.) 11. Sun shadows fall in the [same, opposite] direction as the Sun. 12. During the day, the gnomon shadow appears to move [clockwise, counterclockwise] around the [upper, lower] dial face. 13. The Earth's [rotation, revolution] causes the gnomon shadow to appear to move around the dial face. 14. The Earth's [rotation, revolution] causes the gnomon shadow to fall on the upper dial face for the lower dial face, and vice versa. 15. When Daylight Saving Time is in effect, Solar Time (sundial time) is [earlier, later] than Standard Time (wristwatch time). Hint: Remember the mnemonic, "Spring forward; fall back." Short Answer (be clear and concise): 1. When doesn't an equatorial sundial work? 2. On the day of the equinoxes (MAR 20, SEP 22), the gnomon (or style) of a properly oriented equatorial sundial will not cast a shadow on the dial plate. Explain. 3. The Earth rotates once every 24 hours (approximately). How many degrees does the Sun appear wsanford/exo/sundial/esaq.html (1 of 2) [3/2/2004 9:30:36 PM] Equatorial Sundial - Activity Questions to move across the sky in one hour? Hint: One complete rotation of the Earth is 360 degrees. Verify your answer by using a protractor to measure the angle formed by the sundial center and two adjacent hour lines on the dial face. 4. Why do time zones generally run north-south instead of east-west? Why are time zones 15 degrees of longitude in width? 5. The Sun and Earth are parts of an interconnected system. Use the words "rotation" and "revolution" to summarize your short-term (day-long) and long-term (year-long) observations of the equatorial sundial. For Further Thought: 1. Are you clock-wise? Why is "clockwise" clockwise? 2. Why is it incorrect to say that 12 noon is 12 p.m.? 3. Longitude is equivalent to time (and vice versa). Explain. What would be the difference in longitude between two sundials separated by a 12-minute time difference? Hint: Reduce the rate of the Earth's rotation from degrees/hour to degrees/minute. 4. Would your sundial read the same time as another sundial 100 miles directly north of you? Would the sundials have the same length? 5. Does an equatorial sundial work equally well at the North and South Poles? Bonus Question: Explain three reasons that Solar Time (sundial time) may be different from Standard Time (wristwatch time). © Copyright 2002-2004 Walter Sanford. All rights reserved. wsanford/exo/sundial/esaq.html (2 of 2) [3/2/2004 9:30:36 PM] The North American Sundial Society Sundials on the Internet By the British Sundial Society Sundial Mottoes by the British Sundial Society Glossary: gnomon style shadow. The earliest and simplest form of sundial is the shadow stick. The time of day is judged by the length and position of the stick's shadow. The technical name for a shadow stick is a gnomon. As the sun moves through the sky from sunrise to sunset, the shadow of the gnomon rotates clockwise. The shadow is shortest when the sun is directly in the south, defining local noon. As early as 3500 B.C. the Egyptians began building slender, tapering, four-sided obelisks which served as timepieces. The moving shadow of the obelisk formed a type of sundial, and markers arranged about the base separated the day into divisions as well as indicating the longest and shortest days of the year. However, because of the earth's tilt, the sun's path through the sky changes slightly from day to day, so the shadow cast by the gnomon is not the same every day. Many sundials overcome this problem by angling the gnomon and aiming it north. This type of gnomon is called a style. Because its alignment compensates for the Earth's tilt, the hour marks remain the same all year round. In the quest for accuracy, many types of sundials evolved, including some very complex portable sundials. In about 30 B.C. Marcus Vitruvius, a Roman architect, described 13 different sundial designs used in Greece, Asia Minor, and Italy. The invention of more accurate mechanical clocks and (1 of 2) [3/2/2004 9:30:37 PM] Egyptian Obelisk Marcus Vitruvius A 1st century B.C. Roman architect who authored a famous 10-volume treatise named "De Architectura". The books dealt with city planning and architecture; temple construction; public and private buildings; clocks; hydraulics and civil and military devices. De Architectura was a classic text book from Roman times to the Renaissance. Sundials the standardization of time using time zones made sundials obsolete. Nevertheless, sundials are still used mostly for ornamental purposes. Next: How a Sundial Works Updated August 24, 1998. Contacts (2 of 2) [3/2/2004 9:30:37 PM] Sundials: Building a Simple Sundial Liftoff Home Building a Simple Sundial one Read More Ahead: Make a Sundial Now by the Exploratorium Sundial Builder by Washington University Determine your latitude. Using a map for your area, estimate your latitude (most road maps indicate latitude and longitude). Your latitude will be the number of degrees north if you live in the northern hemisphere, or south if you live in the southern hemisphere. Or, you can locate your latitude using the internet at one of these sites: ● U.S. Census Bureau (U.S. Only) ● Make a Complete Sundial by Indiana University Glossary: latitude hemisphere International (Confusing Interface). two Print the sundial construction template. Choose a template based on your hemisphere (e.g. if you live above the equator, choose Northern Hemisphere). You will need Acrobat to print these files. ● Northern Hemisphere (PDF) ● Southern Hemisphere (PDF) three Construct the sundial. You will need scissors and some tape. The more carefully you make the folds, the more accurate your sundial will be. four Find North. A compass points to magnetic north, which is not the same as true north. For the best accuracy, a sundial's style should point to true north. To find true north, find a level spot of ground and place a straight stick upright in the ground. Mark the end of the shadow every 15 minutes through the middle part of the day. Notice where the shadow is the shortest. That is true north. Sundials: Building a Simple Sundial Next: Some Questions to Ponder Previous: How Sundials Work Updated February 10, 1999. Contacts (2 of 2) [3/2/2004 9:30:38 PM] Sundials Liftoff Home Pondering Sundials Now that your sundial is working, here are some things to think about. 1. When doesn't a sundial work? 2. Does your sundial match your watch time? Why? 3. If the earth rotates every 24 hours (approximately), how many degrees does the sun appear to move in one hour? (Hint: one full rotation of the earth is 360 degrees). 4. How can you make a sundial that would be more accurate? 5. The sun's diameter in the sky is about 0.5 degrees. About how long does it take for the sun to appear to move its own diameter across the sky? 5. Why don't we use local solar time instead of time zones in our everyday lives? Would it be easy to know what time your favorite TV program starts? 6. Why do time zones generally run north-south instead of east-west? 7. Does a sundial work the same north and south of the equator? 8. What would be different about a sundial at the North Pole? The South Pole? 9. Why didn't the ancient Egyptians use watches instead of sundials and obelisks? 10. Would your sundial read the same time as another sundial 100 miles directly north of you? Would the shadows be the same length? Back to: Building a Sundial Updated September 3, 1998 Contacts SCOPE Poster Apache Point Observatory Kitt Peak National Observatory McDonald Observatory The activities and resources on the back of this poster are downloadable in Acrobat Reader format (PDF). Click here to download the free Adobe Acrobat Reader. National Radio Astronomy Observatory SCOPE state programs: (English) (Spanish) Print References Shadow Play Activity Reflective Solar Cooker Activity (English) (Spanish) (English) (Spanish) Equatorial Sundial Activity Sundial Template (English) (Spanish) (1 of 2) [3/2/2004 9:30:40 PM] (English) (Spanish) Sunspots Activity (English) (Spanish) SCOPE Poster Please take a moment to fill out our Poster Activity Evaluation Form after you have tried any of the above activities. We will use your input to improve the next set of activities. (2 of 2) [3/2/2004 9:30:40 PM] ● Ask Mr. Sunspot ● McDonald Observatory - StarDate's Guide to the Solar System: The Sun ● NOAO Resource List about the Sun ● Exploratorium: Making a Sun Clock ● NASA Kids: Sundials ● You Can Make a Sundial ● Sundials on the Internet ● Knowledge Hound: Solar Cooking and Food Preparation ● Solar Cooking Archive (2 of 2) [3/2/2004 9:30:40 PM] Equatorial Sundial Analysis 1. For your data, when is the stick's shadow shortest? Can you predict what time of day it would be the shortest if you had a perfect sundial? 2. The sundial time did not match clock time, explain why. 3. Why does this sundial have front and back dial faces? Answers Each 1 degree east or west of the center of your time zone (your longitude difference from the center), there is a correction of 4 minutes of time. Also, the Sun's orbit in the sky changes with the seasons, and a correction of up to about 15 minutes for the "Equation of Time" must be made. Read the correction from the graph below. Daylight Savings Time changes results by one hour. 3. The north face is for use from March 21 to September 21, and the south face is for use from September 21 to March 21. The Sun is north of the celestial equator during the first period (spring and summer) and south of the celestial equator during the second period (fall and winter). Construction: 15 minutes. Activity: Spread over the course of several hours. Sundials were one of astronomers' first tools to measure the flow of time. This instrument is simply a stick that casts a shadow on a face marked with units of time. As Earth spins, the stick's shadow sweeps along the face. ACTIVITY This sundial allows you to read the solar time of day. The face of the sundial is the plane of Earth's equator, whereas the stick represents Earth's axis pointing to the North Celestial Pole. Preparation: First, find your latitude and longitude and an outdoor observing site. Determine the direction north (from a map, or by finding the north star at night and marking its location). Assemble the equipment as described below. Use lamps to demonstrate how to position and read the sundial indoors before going out. Experiment On a sunny day, take the sundial outside and direct the pointed end toward north. Record the time on the sundial at least four times in one day. Each time, also record the "clock" time for your date and location. Try this experiment during different times of the year. Materials: a. Sundial Template b. Scissors c. Glue or tape. Instructions and Construction 1. Photocopy the template and one latitude strip. 2. Attach the latitude strip to a stick, such as a 7-inch (18-cm) pencil or straw. Thinner sticks cast thinner shadows. 3. Fold and glue the template. Make sure the dial faces are lined up. 4. Cut out the center hole. 5. Place the stick in the hole with the top face lined up with your latitude. 20.00 15.00 Sundial Fast (Mins) 10.00 Minutes 5.00 0.00 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec -5.00 -10.00 Sundial Slow (Mins) -15.00 Correction for the "Equation of Time" Finished model Degrees of Latitude Science Standards: Earth and Space Science (5-8) Going Wild! With Jeff Corwin Complete Series 4. Simply Season with Winnie the Pooh 5. Beyond the Page Complete Series MORE > (2 of 2) [3/2/2004 9:30:48 PM] Eyes on the Sky, Feet on the Ground Welcome to our collection of children's online astronomy activities. In the following six chapters are hundreds of fun explorations into astronomy as a classroom tool for learning how to theorize, experiment, and analyze data. The activities are fully illustrated and contain detailed, step-by-step instructions and discussion questions. This book is lots of fun for teachers and students alike. This site contains the complete text and graphics of the collection along with related links, a table of contents, an explanation of how to use this book, and email links to the authors. We do hope you enjoy these adventures in astronomy as much as we enjoyed designing them. Table of Contents | Everyday Classroom Tools (1 of 2) [3/2/2004 9:30:49 PM] Eyes on the Sky, Feet on the Ground Selected as a Valued Internet Site for the Discovery Channel Online This site is best viewed with Netscape Communicator. Download Netscape Now! Copyright © 1996 Smithsonian Institution These pages designed by Tania Ruiz. Last updated September 9, 1998. (2 of 2) [3/2/2004 9:30:49 PM] Eyes on the Sky, Feet on the Ground: Chapter Two While the Earth rotates once a day about its axis between the north and south poles, it revolves about the Sun in its orbit but once a year. The seasons are caused by the tilt of the Earth's axis of rotation. Rather, the Earth's axis is tilted some 23°.5 away from the perpendicular, as shown in the figure (which is NOT to scale). As the Earth orbits the Sun, the orientation of its rotational axis is held fixed, so that if we imagine it extended into space, it is always pointing towards Polaris, the pole star. As the Earth orbits around the Sun, for a portion of the year the Sun is in the same direction as the tilt happens to be. This means that the Northern Hemisphere will have warmer temperatures and hence summer. For the other portion of the year, the Earth has moved around the Sun. With the top of the Earth now tilted away from the Sun, the Southern Hemisphere can enjoy summer. There are, of course, times in between as the Earth is orbiting when it has the Sun neither towards or away from the direction of the tilt. These times are when no hemisphere is experiencing any greater amount of sunlight than another, and so this is Spring or Fall for the hemispheres. This chapter investigates both the causes and the effects of the changing of the seasons. We start simply by trying to quantify the observation "it's colder (1 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two in the winter" and end by measuring the tilt of the Earth itself! Topic 1: Observations of The Seasons If you ask students what a particular season means to them, they'll probably mention the weather usually associated with it. Summer is hot. Winter is cold. Spring and Fall are in between. (For those of us living close enough to the poles, winter means snow, too!) A common misconception (even among a disturbingly large number of college graduates) is that the Earth is closer to the Sun during the summer, causing summer's warmer temperatures. This model, of course, is inconsistent with the fact that when the Northern Hemisphere has summer, the Southern Hemisphere has winter. Furthermore, while it's summer for the Northern Hemisphere, the Earth is actually slightly farther away from the Sun than during the winter. As we know, during the Northern summer, the North Pole is tilted towards the Sun. During the winter, it is tilted away. This tilt causes the Sun to appear higher in the sky during the summer than during the winter. The higher Sun causes more hours of daylight and more intense, direct sunlight, or hotter conditions on the surface of the Earth. Questions to ask the class include: How is summer different from winter? What changes in where or how the Sun is? Why do you think it's warmer in the summer? What changes are there as summer becomes fall? What about when winter approaches? (2 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two Activity 2-1: The Sun's Changing Path The shadow stick measurements (Topic 2, "Sun Shadows") and measurements of the Sun's path on a dome (Topic 3, "Tracking the Sun Path in the Sky") from the previous chapter can be continued from week to week and month to month to show seasonal changes. Both will illustrate that the Sun follows a higher arc through the sky in the summer than in the winter. A comparison of shadow lengths all measured at midday will show that the shadow lengths increase as winter approaches becoming longest about December 21 (the shortest day) and then decrease again until June 21 (the longest day). One way to keep track of the shadow lengths is to draw a graph by hand or on the computer. The plot should have midday shadow length (on the vertical axis) versus the date of the observation (on the horizontal axis). Each week, make a new measurement and update the graph. The measurements on the dome require more time, but provide a much better record of the Sun's path through the sky during more of the day rather than just at midday. Repeating the dome measurements each month (perhaps using the same plastic dome with different colored markers) will very clearly record the changes in the Sun's path through the sky during the year. Activity 2-2: Recording Daily Temperatures Weather is the result of an almost incalculable number of events. As such, it would be folly to attempt to predict a given city's temperature for a given date, far into the future. It would be equally foolish to point to an exceptionally cold day in June and declare "Winter's coming!" There are just too many variables for such a simplistic view. However, hidden among the randomness are trends which can be measured, and from which conclusions like "winter's coming" can be made. The class can measure the outside temperature at a particular time each day, (3 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two perhaps noon or lunch time. From newspapers or broadcast newscasts, the class can collect local high and low temperature readings for each day. These can be plotted on a graph or entered into a data base. For younger students, a classroom chart with cartoon thermometers with daily temperature marks can be made. The exact time of measurement is not important. One should emphasize the importance of recording data in an appropriate way. Sometimes making a simple graph can explain pages and pages of numbers. Simplicity is the key. With clear presentation of data, it is much easier to move forward and, for example, correlate the temperature measurements with the shadow stick and dome measurements. Activity 2-3: Tracking Sunrise and Sunset Times The tilt of the Earth's axis not only affects the angle of the Sun's path in the sky, but also the number of daylight hours. In the Northern Hemisphere, the longest day (summer solstice) occurs around June 21, the shortest day (winter solstice) around December 21. There are two equinoxes, during which the hours of daylight and night are equal: the Vernal Equinox (around March 21) and the Autumnal Equinox (around September 22). One can observe these changes by recording the times of sunrise and sunset and measuring the length of the day. Changes in these times are large enough (about a minute a day) to be seen on a graph. The figure below shows such a graph made from sunrise and sunset times at the National Optical Astronomical Observatory located on Kitt Peak near Tucson, Arizona for September to December. It begun in September and continued through the Winter Solstice (about December 22), the graph should show the gradual decrease in the number of daylight hours (in the Northern hemisphere) with the minimum at the Winter Solstice. It would be interesting to include either of the equinoxes on the graph as well. (4 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two Materials: Large paper from roll (3'X6'); yardstick; pencil; circle labels; paints; adhesive dots; daily local newspaper. ● 1. On a large sheet of paper, make a grid on which to plot the sunrise and sunset times. The time of day should run along the vertical axis, leaving about one inch for every hour. The date of the observation will be recorded along the horizontal axis. ● 2. Look up the times of sunrise and sunset in a daily newspaper. Plot these times on the graph, marking the points with adhesive dots. After plotting for several weeks, connect the dots with a line. ● 3. Optional: These can be stored and plotted with a computer spreadsheet like AppleWorks. Discussion The figure below shows a plot of sunrise and sunset times taken once a week from September through December. Notice that the shortest day occurs around December 21, as expected. In order to reinforce the connection between the number of daylight hours and average daily temperature, try making a wall-sized chart combining sunrise-sunset data with the daily temperature, as collected in the previous activity. While daily fluctuations in the temperature will be apparent, it is the general trends which we seek. How (5 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two does the length of the day change with season? Does the temperature match this trend also? Activity 2-4: The Analemma This simple, long-term activity provides an easy way to record the changes of the Sun's apparent motion. We already know that the Earth's tilt causes the Sun's path to be higher in the sky during the summer than in the winter. Because the Earth's orbit around the Sun is not perfectly circular, the Sun's position at a specific time (as given by the clock) changes Eastwardly and Westwardly as well. By reflecting sunlight onto the classroom ceiling and marking the Sun's position at the same time every week, we can record the change of the Sun's apparent motion, after a year, should notice a figure-eight-like figure known as the analemma. Materials: Small mirror; masking tape; adhesive dots (optional) ● 1. Choose a Southern window with direct sunlight which will remain unblocked throughout the year. ● 2. Place a very small mirror on the window sill and adjust so the sunlight shines on a clear area of the ceiling (typical lights, mobiles, etc.). A mirror only an inch across is adequate. It is best to be able to tape the mirror there permanently, but at the very least, mark the mirror's position with masking tape. (6 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two ● 3. Once or twice a week, at exactly the same time by the clock, mark the location of the Sun's reflection on the ceiling with an adhesive dot or a piece of masking tape (watch out for Daylight Savings Time changes- adjust the time so that you always make measurements in the same time reference, Standard Time). ● 4. Record the date and time of the observation on the marker. Discussion Where would the spot of sunshine be if the Sun were lower in the sky? Higher? more Easterly? more Westerly? How much does the Sun appear to move each week? Is this change constant throughout the year? After we have measured for a year, could we use the previous year's analemma as a rough calendar? Would it work for every day or are there some periods of ambiguity? When are they? The analemma is longer in one direction than the other. The other variation (east-west) of the analemma is due to the eccentricity of the Earth's orbit around the Sun. (Eccentricity, while previously defined, can be thought of as an ellipse's lack of circularity- for more information on planetary orbits, see Chapter 4 on The Solar System) If the Earth's orbit were perfectly circular, there would still be variations in temperature from one location to another, caused mainly by the curvature of the earth. Locations closer to the equator would still, on the average, be warmer than locations closer to the poles. Light and heat (radiation) from the Sun would still strike polar regions at more of an angle than nearer the Equator. Angle tends to "spread out" the same amount of energy over a larger area, thereby decreasing its intensity and the amount of heat it brings to the Earth. The activities in this topic demonstrate and test this assertion. Activity 2-5: Energy from the Sun Solar radiation is emitted in various forms, including visible light. Our eyes can only see radiation as visible light, but radiation also occurs as radio waves, infrared rays, ultraviolet rays, X-rays and gamma rays. Together these waves make up the electromagnetic spectrum. Questions to ask: How can we measure the warmth from the Sun? Is it possible to find a way to measure it outside? What could we use and how could we show differences in temperature? How long would we have to wait until we saw a temperature reading? Can we predict the variations? What might influence fluctuations in warmth? What experiences have students had which help in these predictions? Does this change during the day? Materials: Thermometers; soil; sunlight; cardboard; stick; glue; pencils; flashlight; paper ● 1. Students (in small groups) predict the time of day and temperature changes. ● 3. Return at various intervals to read and record the time and temperature. ● 3. Students compare their predictions and the actual readings. ● 4. They read the temperature of the air at the same time as the recordings of the earth temperature and compare these. ● 5. These experiments may be repeated in a few months. This data may then be recorded and compared to earlier readings. Discussion Students discuss results of their experiments. What caused the highest or hottest temperature? What was this related to the time of day? What were students able to discover from their measurements? How accurate were their predictions? What factors helped them to predict well? What conclusions can they make about the effect of the Sun's rays on the Earth? If done at intervals over a period of time, did earlier experiments help their predictions? Students may make a graph using this information either on graph paper or on the Bank Street Filer or on the database of AppleWorks. What other elements could students use to measure temperature? How could we devise an experiment to predict and record the temperature of water in the sunlight? Activity 2-6: How Angle Spreads a Flashlight Beam This activity requires a darkened room. You may want to do this as a large (9 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two group activity for younger students. Older students should try it in small groups and compare their results. Does the illuminated spot on the graph paper always remain the same size? When is it larger? smaller? Is the spot always the same brightness? When is it brighter? fainter? Materials: Graph paper; cardboard or plywood; masking tape; flashlight; markers. ● 1. Attach a sheet of graph paper to the cardboard or plywood with the masking tape. Hold the board perpendicular to the floor and shine the flashlight directly onto the graph paper from the side, about two feet away. Be sure the flashlight is parallel to the floor, and perpendicular to the paper. You might try placing the flashlight on a table or pile of books. ● 2. Trace the outline of the flashlight's beam on the graph paper. ● 3. Keeping the same distance from the paper to the flashlight, try tilting the board at various angles. What happens to the bright spot on the paper? Tilt the board at a large angle like 45° or 60° and trace the new outline of the beam with a different color. Try a couple of other angles, marking the outlines with different colors. ● 4. By counting the squares on the graph paper enclosed or partially enclosed by the circle of light, you can quantify the observation that more area is covered by the beam when the board is tilted at larger angles. Discussion No matter how the board is tilted, nothing changes the amount of light which the flashlight produces. When the board is tilted, and the flashlight illuminates a larger area of the graph paper, the same amount of light energy (10 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two must be spread over the larger area. The lighting is then less intense. Is there any difference between tilting the board and tilting the flashlight? What if we were using a larger, hotter light source, like a halogen lamp, or a star? Wouldn't the heat carried also be less intense when the board is tilted at larger angles? The next activity explores just this question using the Sun. Activity 2-7: How Angle Spreads Sunlight look directly at the Sun. This activity is similar to the previous activity in that it shows how light falling upon a tilted surface is less intense than if it were falling directly. With light comes the energy to heat. This activity examines this "spreading out" of light by measuring how quickly and how much sunlight can warm two sheets of paper, one tilted, one not. Materials: Two sheets of black construction paper; two pieces of cardboard or plywood; bricks or blocks to prop up board; masking tape; two thermometers. ● 1. Cut an inch-wide slit in the middle of each piece of construction paper. Tape one sheet of black construction paper to each of the cardboard or plywood boards. Place a thermometer into each slit such that the bulb is between the board and the paper, and the scale can be (11 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two read without removing the thermometer. Tape the thermometers in place. Leave the assembled thermometers in the shade long enough so that they read the same outside temperature. ● 2. Tilt one board so that it faces the Sun and the Sun's rays fall nearly perpendicular to the board. The other should be flat on the ground, or even tilted slightly backwards from the Sun if the Sun is especially high in the sky. ● 3. Periodically (every minute or so) record the temperature on each thermometer until the temperatures level off and stop climbing. Let the thermometers sit for a few minutes. Record their final temperatures. Discussion Which paper was heated more quickly? Which got warmer? You might want to try different angles. Beware the effects of clouds and wind, as well as the shadows of over-anxious students! What do the results of this experiment tell you about the changes in temperature from Activity 2-5? What was the angle of the Sun when the temperature dropped? When the temperature was the highest? Activity 2-8: Sunlight on a Curved Surface This activity requires a darkened room. We have already seen how the angle at which light strikes a surface affects its intensity. This activity will demonstrate that light shining on a curved surface may be more intense in one place than in others. If we shine a light (12 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two on a uniformly colored ball, like a dodge ball or kick ball, the area experiencing more intense illumination will appear brighter than those receiving less intense light. Materials: Slide or overhead projector or other source of directed light such as a bright flashlight; large, uniformly colored dodge or kick ball; books to lift light source to desired height ● 1. Place the ball on a table. Aim the light source such that it shines directly on the center of the ball, but be sure the beam is wide enough to illuminate the entire ball at once. ● 2. Examine the brightness of the light across the surface of the ball. Rotate the ball. What happens to the bright spot? Does it follow the ball's rotation, or does it always face the light source? ● 3. Experiment with changing the orientation of the ball, the light, or both. Can you provide even illumination of the ball? Why not? Discussion Where on the ball was the light the brightest? Where was it the faintest? If you changed the orientation of the ball, what parts would be brightest? Which would be faintest? What if you moved the light source? Activity 2-9: Sunlight on the Curved Earth This activity duplicates the previous activity using a globe of the Earth instead of a plain ball. It, too, requires a darkened room. The previous activity demonstrated that the curvature of an object can cause different areas of the surface to receive light of differing intensities. This activity shows that the Earth is subject to this effect as well. We have seen in our earlier thermometer experiment that less intense light cannot heat a surface as quickly or as completely as intense, direct light. Therefore, we can predict that there should be areas of the Earth where the sunlight is more intense than at others. These areas should be warmer than other areas. This is (13 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two why locations near the Equator are generally warmer than those closer to the Poles. Our observations show that the Sun is higher in the sky during the summer than during the winter. Summer approaches for a given hemisphere (North or South) when the Earth moves to a place in its orbit in which that hemisphere's Pole (North or South) is tilted towards the Sun. This causes the Sun to be higher in the sky and its light to be more intense (less spread out). This more intense summer sunlight is better able to heat the land, air, and water. This warming is certainly consistent with our observations of the seasons. Materials: Slide or overhead projector or other source of directed light such as a bright flashlight; large globe of the Earth; books to lift light source to desired height ● 1. Place the globe on a table with the North Pole upward. Aim the light source such that it shines directly on the center of the globe, but be sure the beam is wide enough to illuminate the entire globe at once. ● 2. Notice that the light appears brighter towards the equator of the Earth. This configuration, with neither Pole tipped towards the Sun corresponds to the equinoxes (strictly speaking, the Earth's axis is still tilted by 23°.5 with respect to its orbit but on an equinox, that tilt is sideways with respect to the Sun, and not towards or away from it). ● 3. Try tilting the North Pole by about 23°.5 towards and away from the light source (the angular distance between noon and one o'clock on a clock's face is 30°, so don't exceed this angle). ● 4. The previous chapter's activity "Day and Night on the Spinning Globe" could be repeated with a tilted Earth, to measure the variation of sunrise and sunset times with season angle. Discussion Does the bright area move across the face of the Earth? How should the globe be positioned to show winter? summer? spring? fall? (14 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two Topic 3: The Tilt of the Earth We have built a model of the seasons which agrees with our observations, but there is one important loose end; we accepted the tilt of the Earth as 23.°5. The next activity will allow us to measure this value! The final activity summarizes and demonstrates our model for the class. Activity 2-10: Measuring the Earth's Tilt This activity is suitable for grades 3 through 6. While the effects of the tilted Earth model are consistent with observation, might it not be possible to measure the Earth's tilt directly? Using observations with a simple shadow stick, we can measure the Sun's angular height in the sky over the course of weeks and months. As we've seen, it is the tilt of the Earth's axis which causes the height of the Sun's path to change. In this activity, we will measure this change to infer the amount of the Earth's tilt. shows that as the height of the Sun changes, it casts different length shadows at midday. By recording these midday shadow lengths and the height of the shadow stick, we can "reconstruct" the situations from these days and measure the angular height directly. The difference of the angular heights of the Sun between an equinox (September 21 or March 21) and a solstice (December 21 or June 21) is equal to the tilt of the Earth's axis, 23.°5. Materials: Shadow stick from Chapter 1; observations of the midday shadow lengths; large sheet of paper; colored markers; protractor. ● 1. Obtain midday shadow lengths for convenient equinoxes or solstices (15 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two (September 21, December 21, March 21, June 21) as described in the activity "Sun Shadows" of the previous chapter. Also make sure to keep a record of the height of the shadow stick. ● 2. On a large sheet of paper, draw a line the same length as the shadow stick. To reconstruct the angle of the Sun's height for each equinox and solstice in your data, start at the bottom of the shadow stick and draw a line perpendicular to the shadow stick the same length as the midday shadow for each solstice and equinox in your data. Try using different color markers for each day. Your drawing should resemble the figure above. ● 3. Have the class measure the angular height of the Sun on the paper with a protractor for each equinox and solstice. The difference of the angular height between subsequent equinoxes and solstices should be about 23.°5. The difference in angular height between the two equinoxes or the two solstices should be twice that, or 47°. Analysis Option Mathematically, since the shadow stick and its shadows form right triangles, the shadow stick height and the shadow lengths are all that is needed to compute the Sun's angular height; it is simply the arctangent of the ratio between the shadow stick height and the shadow length. While such trigonometric functions are certainly beyond the scope of the elementary school classroom, this fact can be used to verify the students' results. Discussion When are the midday shadows the longest? Why? When are they the shortest? Why? What causes the shadow lengths to change? Can you relate your measurements to our model of the seasons? (16 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two Activity 2-11: Demonstrating the Tilted Earth This activity is suitable for students in grades 3-6. This activity demonstrates the model of the seasons we have been developing- that of an Earth whose axis of rotation is tilted by 23.°5 degrees with respect to the plane of its orbit around the Sun. By aligning the Earth's axis with a stationary point in space (the location of Polaris), it is easy to demonstrate the tilt of the Earth's axis during the course of an orbit about the Sun (i.e. a year). Materials: Globe of the earth; sign to mark North; and masking tape. A student can act the part of the Sun and another student can hold the globe. ● 1. Place the Sun student in the middle of the room. Place the Earth student about six feet away. Mark one corner of the room "North". If we could extend this corner much higher, the North Star would be at its top. ● 2. Tilt the globe so that the North Pole tilts towards the ceiling at the corner marked North. The student holding the globe must be careful to preserve this alignment. ● 3. Walk the Earth around the Sun making sure to keep the North Pole properly aligned. When the North Pole points away from the Sun, this is winter for the Northern Hemisphere. When it points towards the Sun, it is summer for the Northern Hemisphere. ● 4. Walk the Earth around the Sun again, and watch the changes in the Southern Hemisphere. When it is summer in the Southern Hemisphere, what is it in the Northern? ● 5. After all of the students understand this example, try this experiment with the Earth turned such that its axis is perpendicular to the plane of its orbit about the Sun. If the Earth had this orientation, there would be no seasons. (17 of 18) [3/2/2004 9:30:53 PM] Eyes on the Sky, Feet on the Ground: Chapter Two Discussion What differences in climates and seasons can you determine from the observations in these experiments? How would seasonal changes appear to you if you were on the equator or at the north or south poles? What is the pattern of sunlight at the equator? At the North Pole? At the South Pole? What were the differences in how the light was hitting the Northern Hemisphere as you carried the globe around the Sun? Related Sites Comments? Contents | Back to Top (18 of 18) [3/2/2004 9:30:53 PM] | Home Sub Solar Cup Paper Plate Education "Serving the Universe on a Paper Plate" Activity: Sub-Solar Cup [Note: A version of this activity is included in the Paper Plate Astronomy video. We recommend you see video excerpts for more detailed activity instructions and pictures.] Throughout the year, this simple device will indicate where on the Earth the sun is currently overhead. See the Analemma activity to plot a figure-8 analemma on a globe using the Sub-Solar Cup. Drill a small hole out of the bottom of a dark plastic cup. On the top of the cup secure two pieces of thread to make a set of cross hairs. Cut out a viewing window on the side of the cup. Secure the globe on its side so that a figure standing at the observer's location is upright on the globe. That is, a tangent at the observer's location is parallel to the ground. Align the figure's line of longitude on the globe with your north-south meridian. Position the cup upside down on the globe so that sunlight goes through the small hole and is centered over the cross hairs. That location is the current sub-solar point. View the location of the sun at local noon throughout the year to track the sun's annual migration between the tropics. (1 of 2) [3/2/2004 9:30:55 PM] Sub Solar Cup This activity, contributed with original reference by Gary Tomlinson, is an adaptation of an activity written by Robert Mitchell. See The Physics Teacher, May 1991, pp. 318-319. GLPA Proceedings, 1999, pp. 36-36. [Note: This activity is detailed in the Paper Plate Astronomy video.] The contents of this site may be reproduced for non-profit educational purposes only. Please cite the contributing author in credits. All other uses require the express written permission of the respective contributors. Copyright ©2003 Chuck Bueter. All rights reserved. (2 of 2) [3/2/2004 9:30:55 PM] Analemma Paper Plate Education "Serving the Universe on a Paper Plate" Activity: Analemma Project With the Sub-Solar Cup activity you can determine the position on the earth where an observer would see the sun directly overhead. Plotting the sub-solar point at the same time each day should yield an analemma, the figure-eight shape on a globe that expresses the sun's declination and the equation of time. In this ongoing project, we hope to track the sub-solar point for one year, provided the weather and personal commitments permit regular observations at noon. See the Analemma Project (same name, different project) for multiple exposure photographs that produce terrific visual image of analemmas. Paper Plate Education, being a very casual pursuit, will likely undertake this Sub-Solar Cup endeavor with less exactness. Enjoy. The results are in and appear at the bottom of this page... From the Sun Clock home page at see the Sun Path diagram for depictions of analemmas. It is a nice addition to this activity. For continuity, we secure our globe in a base so our location (see (1 of 10) [3/2/2004 9:31:03 PM] Analemma figurine at left) is atop the globe. Then we align our globe base with cracks in a driveway that are nearly north-south. Any minor offset from north-south will cause a slanted figure-eight. Another way to check the north-south alignment is to track the path of the sun through several hours. If the globe is properly aligned, the sun should move along one latitude for the entire day. At the end of 12 months we will mark the globe to clarify the path of the analemma. The sun appears just slightly above the Tropic of Cancer two days after the December solstice. Please recognize the sub-solar image is an approximate position, dependent on the accuracy of the globe's alignment relative to the real earth. December 25, 2002 Noon (Standard Time) For the first image, the base was wobbly on ice. The zoomed image is with the base steady. Weather is mostly cloudy. January 6, 2003 Noon (2 of 10) [3/2/2004 9:31:03 PM] Analemma January 9, 2003 Noon January 12, 2003 Noon Hands shaky from bitter cold. Intermittent snow, windy, temperature 10 degrees F. January 22, 2003 Noon (3 of 10) [3/2/2004 9:31:03 PM] Analemma January 30, 2003 Noon February 11, 2003 Noon Lesson learned: Do not align globe with intersection of four slabs of concrete running along cardinal points, for when the slabs heave in the winter the globe is not automatically level anymore. February 27, 2003 Noon (4 of 10) [3/2/2004 9:31:03 PM] Analemma March 13, 2003 12:10 p.m. March 21, 2003 12:10 p.m. March 30, 2003 Noon An upside not to move the clock forward to daylight time (DT): the time remains noon, Standard Time (ST). April 15, 2003 Noon (Standard Time) April 24, 2003 Noon (5 of 10) [3/2/2004 9:31:03 PM] Analemma April 29, 2003 Noon May 21, 2003 Noon Has been a large gap since last observation. June 17, 2003 Noon By tracking the summer solstice sun across the length of the day, we can see the globe is slightly skewed from ideal. In the morning the sub-solar point is slightly under the globe's Tropic of Cancer line; in the afternoon the solar dot is well above the line. June 22, 2003 (6 of 10) [3/2/2004 9:31:03 PM] Analemma June 24, 2003 approx. noon July 9, 2003 Noon July 16, 2003 Noon July 25, 2003 Noon August 12, 2003 Noon (7 of 10) [3/2/2004 9:31:03 PM] Analemma August 19, 2003 12:05 p.m. Meanwhile, Mars at opposition is making its closest approach to earth in nearly 60,000 years. August 28, 2003 Noon September 10, 2003 Noon September 15, 2003 Noon September 23, 2003 Noon September Equinox. The sun's position just above the equator hints that the globe is slightly out of alignment. As long as that error is kept nearly constant, we should still be able to plot a figure-8 (albeit misaligned) onto the globe at the end of one year. October 12, 2003 Noon (8 of 10) [3/2/2004 9:31:03 PM] Analemma October 27, 2003 11:55 a.m. EST November 6, 2003 12:05 p.m. EST Meanwhile, the big sunspot groups of 2003 come round again--a bonus while tracking the sun. November 26, 2003 Noon Image courtesy of SOHO (ESA & NASA). December 2, 2003 Noon December 21, 2003 Noon We're done! We have tracked the sun for 12 months. Now we just have to plot the points on the globe. To be more scientific about this, we could continue tracking the sub-solar point to see if its path is repeatable. You may notice that the sun does not exactly coincide with the tropic of Capricorn. In the past year, the globe has settled into the padded base and repeated handling has affected the (9 of 10) [3/2/2004 9:31:03 PM] Analemma positioning of the base, globe, and cup. THE OUTCOME The results are in, with mixed success. We first plotted the sub-solar point with yellow circles on the Tropic of Capricorn and moved up to the Tropic of Cancer. From there the red circles descend back to the Tropic of Capricorn. If the three points immediately after the vernal equinox were better positioned, then the figure-8 of the analemma would be more apparent. Again, the globe was repositioned after each observation, so plenty of error is introduced. globe-plot.jpg (286 KB) (275 KB) globe-plotzoom.jpg globe-plot2.jpg (50 K globe-plotzoom2.jpg (34 KB) [Note: The Sub-Solar Cup activity is detailed in the Paper Plate Astronomy video.] The contents of this site may be reproduced for non-profit educational purposes only. Please cite the contributing author in credits. All other uses require the express written permission of the respective contributors. Copyright ©2003 Chuck Bueter. All rights reserved. (10 of 10) [3/2/2004 9:31:03 PM] Page B, Ver. 2: The Sun SGH-B The Sun Sunspots and the Solar Cycle What is "The Solar Cycle?" In a regular cycle, the Sun undergoes a period of great activity called the "solar maximum," followed by a period of quiet called the "solar minimum." One way scientists track solar activity is by observing sunspots. Sunspots are relatively cool areas that appear as dark blemishes on the face of the Sun. During solar maximum there are many sunspots; during solar minimum there are few. On average, solar maximum occurs once every 11 years; the next solar maximum occurs in 2000-2001. Sunspot activity is monitored using an index called the "sunspot number." The sunspot number varies from day-to-day. As a rule of thumb, if you divide the official sunspot number by 15, then you'll get the approximate number of individual sunspots visible on the solar disk if you look at the Sun by projecting its image on a white screen with a small telescope. The real-time satellite image (upper left) shows some of the larger sunspots currently visible on the disk of the Sun. Caution: NEVER look directly at the Sun (especially through optical instruments such as telescopes) -- blindness may result! (This page should display for 30 seconds before advancing automatically to the next page. If the slideshow stops, then click on your Web browser's "Reload" or "Refresh" button to resume the presentation.) wsanford/exo/kiosk/pageB.html [3/2/2004 9:31:04 PM] Star STAR A self-luminous ball of gas that shines or has shone because of nuclear reaction (fusion) in its interior. wsanford/exo/star.html [3/2/2004 9:31:04 PM] Electromagnetic Spectrum MicroWorlds Contents | Advanced Light Source | Berkeley Lab Electromagnetic Spectrum The electromagnetic spectrum covers a wide range of wavelengths and photon energies. Light used to "see" an object must have a wavelength about the same size as or smaller than the object. The ALS generates light in the far ultraviolet and soft x-ray regions, which span the wavelengths suited to studying molecules and atoms. Look at the picture of the electromagnetic spectrum. See if you can find answers to these questions: 1. What kind of electromagnetic radiation has the shortest wavelength? The longest? 2. What kind of electromagnetic radiation could be used to "see" molecules? A cold virus? 3. Why can't you use visible light to "see" molecules? 4. Some insects, like bees, can see light of shorter wavelengths than humans can see. What kind of radiation do you think a bee sees? Return to "Electromagnetic Radiation" Return to "The Advanced Light Source: A Tool for Solving the Mysteries of Materials." MicroWorlds Contents | Registration & Comments Questions and Support Privacy and Security Notice [3/2/2004 9:31:05 PM] Themes for 2001-2002 scsa home | mission & goals | scheduling | site visits | curriculum | planetarium visits what's up? | sos | com | special events | resources | wow! | what's new? | contact us | credits "We have always a resource in the skies. They are constantly turning a new page to view. The wind sets the types in this blue ground, and the inquiring may always read a new truth." - Henry David Thoreau (1817-1862) "My heart leaps up when I behold A rainbow in the sky." - The Rainbow, William Wordsworth Sandburg Center for Sky Awareness A Fairfax County Public Schools Planetarium Sky Awareness | Sun-Earth Connection | Rays Awareness | Tracking Satellites | GPS 00-01 Themes Themes for 2001-2002 Increasing Your Sky Awareness ● Top 10 Reasons to Look Up! ● Basic Tools of the Skywatcher/Amateur Astronomer ● Are you aware that the sky is on the air? Huh? Look, listen (with RealPlayer), and enjoy the online version of the following sky awareness radio programs: ❍ The Weather Notebook, A Radio Show about Weather and Everyday Life from the Mount Washington Observatory (home of the world's worst weather). ❍ StarDate radio--the longest-running science feature in the country--is the daily astronomy-related radio program produced by the McDonald Observatory, University of Texas. ❍ Earth & Sky @World of Science includes a link to "Tonight's Sky," featuring a sky chart generated by Starry Night Deluxe. Do you remember how the sky looked this morning? How does it look now? Visit the WeatherNet4 CityCam Web site to see the current skyscape in Washington, D.C. You can also access the last three (3) hours of archived images, captured every 15 minutes (Netscape 4.x required). The Sandburg Center for Sky Awareness proudly presents the State of Sky Kiosk--an online automated "slideshow" presenting a series of sky-related Web pages, featuring the current sky (day & night) as well as some of the sky's greatest hits. In a little more than 10 minutes, the kiosk provides a fairly comprehensive picture of, well, the current state of the sky. For some "slides," the content is "randomized," meaning that a slightly different Web page will appear during subsequent cycles through the slideshow. Just point your Web browser to the kiosk "splash" page, sit back, and enjoy! Test Your Sky-Q (astronomy-related) ● Look Up! Quiz and Sky Awareness Activities (weather-related) "Night is a shadow world. The only shadows we see at night are cast by the moonlight, or by artificial light, but night itself is a shadow." - Soul of the Sky, Diane Ackerman Visit the Sandburg Sky Poetry Web page, including CSMS student-authored sky poems. Day & Night ● The line which divides day & night is called the terminator. As the Earth rotates counterclockwise, the terminator appears to move from east to west. ● (Graphic produced using Xearth.) ● wsanford/exo/themes.html (1 of 4) [3/2/2004 9:31:08 PM] Themes for 2001-2002 Plan to celebrate National Sky Awareness Week (NSAW), April 21-27, 2002. Its theme is: "THE SKY - Where Meteorology Meets the Heavens and the Earth." 30 JUL 2002 This year, Astronomy Week/Day precedes NSAW: Astronomy Week is April 15-21, 2002; Astronomy Day is April 20th. Astronomy Day has a special theme: "Sun-Earth Day." The NASA Sun-Earth Connection Education Forum has set up a special Web site providing Astronomy Day theme-related resources. Today's sunspot number is ● 304 / Sunspot No. Trend (past 24 hours) / Increasing -- Steady Credits: Real-time image courtesy SOHO; sunspot number courtesy NOAA. Updated: 29 JUL 2002 ARCHIVES Today's Predicted UV Index is Valid for Wash., DC during the Solar Noon hour on 30 JUL 2002 ● UV Index Solarmeter courtesy EPA SunWise School Program ❍ All about clouds (popular title, huh?) from USA TODAY Weather Australian Weather Photography. Also visit Harald Edens' Netherlands Weather Photography Web site, which features cloud, lightning, atmospheric optical phenomena, and astronomy photographs. ❍ Ever imagine that you see shapes in the clouds (technically known as nephelococcygia)? You're not alone! Visit Cool Clouds for "Kids" of All Ages to see the "Energizer Bunny" and other interesting shapes in the clouds. Also visit CloudE Momma's Web site to see a unique cloud "E"-clipse! Weatherwise magazine Annual Photo Contest Winners: 1999; 2000; 2001; 2002; 2003 Assuming the sky is cloud-free, approximately how many stars are visible in the night sky? Well, as you can see from a Light Pollution Map of the Washington, D.C. Area, that depends upon where you live. Fact of the matter is, in the most light-polluted areas of the region, only the 25-or-so brightest stars are visible! See what you're missing: visit your local planetarium. ● Snowflakes - A Thematic Approach provides K-12 teachers with a flurry of ideas for using snow to deliver interesting and exciting interdisciplinary instruction perfect for the winter season. Annotated links to a variety of other sky awareness resources Today's Observed UV Index is 7.3 Intellicast - Dr. Dewpoint Weather 101: All About Clouds ● UV Index courtesy NOAA. Sandburg Planetarium 19 MAY 2002, 01:05 p.m. Partly Cloudy (Sun Transit: 01:05 p.m.) ❍ ❍ \ Decreasing 8 Clouds, clouds, and more clouds! And even more clouds! ❍ Skywatcher's Cloud Chart - online, interactive version of the popular cloud chart from The Weather Channel & For Spacious Skies, a national effort to increase sky awareness and concern. ● Sun-Earth Connection ● ● Me & My Shadow - Making the Sun-Earth Connection - an SCSA Web page of theme-related resources and classroom-ready activities. The NASA Sun-Earth Connection Education Forum Solar Events Web page, featuring hyperlinks to Solar Webcast, Sun-Earth Day, Solar Week, and The Space Weather Center Exhibit. wsanford/exo/themes.html (2 of 4) [3/2/2004 9:31:08 PM] Themes for 2001-2002 Today's Moon ● ● ● Sunspots and the Solar Cycle (including today's sunspot number, What is "The Solar Cycle?", and many other interesting features) From NASA and the Exploratorium, two great Web sites: Solar Max 2000, Your Guide to the Year of the Active Sun; and Auroras 2000, Your Guide to the Northern and Southern Lights. From the Space Environment Center, the NOAA Space Weather Scales were introduced in November 1999 as a way to communicate to the general public the current and future space weather conditions and their possible effects on people and systems. Analogous to hurricanes, tornadoes, and earthquakes, the Space Weather Scales have numbered levels that convey severity. Ask Mr. Sunspot - This is one of those frames sites where you'll have to navigate to the resource. Click on "Mr. Sunspot" in the "Sections" menu (left column). The Space Weather Bureau ● Auroras - Paintings in the Sky ● ● (Graphic courtesy US Naval Observatory.) New Moon: First Quarter: Full Moon: Last Quarter: New Moon: The NASA Sun-Earth Connection Education Forum, including information and resources related to Sun-Earth Day, 20 March 2002. Sun-Earth Connection Tutorial ● Jul 10 Jul 17 Jul 24 Aug 01 Aug 08 ● Rays Awareness™ ● ● Rays Awareness™ - Don't get burned by too much of a good thing.™ "Rays Awareness is The Weather Channel's national campaign designed to educate people about the dangers of overexposure to the sun, while enabling them to enjoy the outdoors in a safe and healthy manner." What is ultraviolet (UV) radiation? Part of the Electromagnetic Spectrum. ● The Ultraviolet Index (UV Index) overview, including a link to EPA's new SunWise School Program regarding Sun safety; National Oceanic and Atmospheric Administration (NOAA) UV Index map. ● Ozone Depletion and UV Radiation; EPA's Ozone Depletion Home Page; Sunburn Cam, courtesy Discovery Channel Online. Tracking Satellites: Natural & Man-made Natural Satellites The Moon is planet Earth's only natural satellite, revolving around the Earth once a month. Get to know some of its prominent surface features using the space.com Skywatcher's Guide to the Moon (including a Printable Moon Map). Teacher Tips: Students discover the month-long cycle of Moon phases (see sidebar, left) in the interactive online activity, Birthday Moons - It's Just a Phase You're Going Through... (recommended for Grade 3 and higher). For activity extension wsanford/exo/themes.html (3 of 4) [3/2/2004 9:31:08 PM] Themes for 2001-2002 &/or enrichment, visit the Related Internet information resources Web page, featuring annotated links to a few selected Moon phase-related World Wide Web sites. Man-made Satellites Be they faint streaks or brilliant flares, satellite observing is like watching man-made "shooting stars!" Track the International Space Station (ISS) in real-time. The NASA Liftoff to Space Exploration Tracking Web page makes it easy to locate some of the larger man-made objects in space, including the ISS, Space Shuttle (when in orbit), Hubble Space Telescope, or NOAA polar-orbiting weather satellites. Or use J-Pass Version 2.5 beta to calculate the next visible pass of these man-made satellites (your Web browser must support Java applets). A highly recommended non-NASA satellite tracking Web site, Heavens-Above provides daily predictions for all satellites brighter than a user-specified limiting magnitude (use 3.5 for light-polluted urban areas), as well as detailed star charts showing the satellite's track through the heavens. All Heavens-Above Web pages, including the graphics, are generated in real-time and customized for the user's location and time zone. "Anonymous users" will need to specify their location (once per session), otherwise it is unnecessary to become a registered user. Editor's Note: Under light-polluted urban skies, it is difficult if not impossible to see most man-made satellites. But at an apparent magnitude of -1, the International Space Station (ISS) is as bright as some of the visible planets--I have seen the ISS every time I looked for it! GPS - The New North Star Location-Finding Using Global Positioning System (GPS), including annotated links to a variety of GPS-related resources. ● The Degree Confluence Project - where geography and GPS technology intersect. Visit virtually all of the points where a line of latitude and longitude meet (integer degree intersections), or trek to locate the point of confluence nearest you! ● Geocaching - the high-tech sport where you are the search engine! A handheld GPS receiver and a hunger for adventure are all you need to play this 21st century version of hide-&-seek. Geoscience-Related Information Servers | Geosystems in FCPS wsanford/exo/themes.html (4 of 4) [3/2/2004 9:31:08 PM] Happy Birthday Sunspot Plot Happy Birthday Sunspot Plot - Sunspots and the Solar Cycle Acknowledgements: Adapted from Happy Birthday Sunspot Plot, a NASA Thursday's Classroom activity. Background information includes excerpts from Sunspots and the Solar Cycle, sponsored by OBJECTIVES & UNDERSTANDINGS After completing this activity, you should be able to: ● Construct and interpret a bar graph of the annual sunspot number from 1986-1999. ● Infer the period of the solar cycle (by interpretting the graph). MATERIALS Each student will need a copy of the activity sheet and a pencil (to complete the graph). BACKGROUND What is "The Solar Cycle?" In a regular cycle, the Sun undergoes a period of great activity called the "solar maximum," followed by a period of quiet called the "solar minimum." One way scientists track solar activity is by observing sunspots. Sunspots are relatively cool areas that appear as dark blemishes on the face of the Sun. During solar maximum there are many sunspots; during solar minimum there are few. Sunspot activity is monitored using an index called the "sunspot number." The sunspot number varies from day-to-day; daily sunspot numbers are averaged to derive an annual sunspot number. In this activity, you will explore the long-term cycle of solar activity by graphing the past 14 years of annual sunspot numbers. Note: As a rule of thumb, if you divide the official sunspot number by 15, then you'll get the approximate number of individual sunspots visible on the solar disk if you look at the Sun by projecting its image on a white screen with a small telescope. [Caution: Never look directly at the Sun (especially through optical instruments such as telescopes) -- blindness may result!] PROCEDURE 1. Using the materials provided by your teacher, construct a bar graph of the annual sunspot number from 1986-1999. 2. Answer the following activity questions. wsanford/exo/sunspot_plot.html (1 of 2) [3/2/2004 9:31:08 PM] Happy Birthday Sunspot Plot ACTIVITY QUESTIONS 1. Calculate the mean "average sunspot number" (annual sunspot number) for the past 14 years. How does this number compare with today's sunspot number (wsanford/exo/n-m_themes.html)? 2. When (which year) was the last solar maximum? What was the annual sunspot number? Is the solar maximum a brief event, or does it tend to last for a period of months to years? 3. When (which year) was the last solar minimum? What was the annual sunspot number? 4. Assuming that the year 2000 turns out to be a solar maximum, how many years passed from the last solar maximum to the next (current) solar maximum? From such a relatively small data set, can the period of the solar cycle be determined with certainty? 5. When (which year) were you born? Were you born during a solar maximum, solar minimum, or sometime in between? If the year 2000 turns out to be a solar maximum, then predict how old you will be during the next solar maximum. wsanford/exo/sunspot_plot.html (2 of 2) [3/2/2004 9:31:08 PM] Estimating the Size of Sunspots Safely Estimating the Size of Sunspots PURPOSE There's more than meets the eye to the little yellow ball in the sky! Sunspots are relatively cool areas that appear as dark blemishes on the face of the Sun. Looking at solar telescope imagery, it's difficult to get a sense of the actual size of sunspots. In this activity, you will estimate the actual size of these features. MATERIALS 1. Internet access via Web browser, e.g., Netscape Communicator or Microsoft Internet Explorer 2. Pencil, metric ruler, and hardcopy of near-real-time solar telescope imagery (showing sunspots) 3. Scientific calculator PROCEDURE 1. Use a Web browser to access The very latest SOHO images Web page. Download/print the latest MDI Continuum solar image. 2. In the following data table, record the image date and time. [Note Date/Time format: Date = yy/mm/dd; Time = UTC. Refer to a Time Conversion Chart to convert UTC to EST/EDT.] 3. Using a metric ruler and the hardcopy solar image, carefully measure the diameter of the Sun (mm) and the width (mm) of the largest sunspot (along major axis); record these data in the data table (below). Circle and label the largest sunspot (e.g., "largest"). 4. Answer the Activity Questions. DATA Date Time (mm/dd/yy) (EST/EDT) Feature Scale Model Size Actual Size (mm) (km) Diameter of Sun Largest Sunspot Sunspot No. 2 Sunspot No. 3 ACTIVITY QUESTIONS 1. Use a proportion (two equivalent ratios) to solve for the actual size of the largest sunspot. Show your work (below); record your answer in the data table (above). s S --- = --d D Where: s = Scale Model Size of Sunspot wsanford/exo/sundials/size_sunspots.html (1 of 2) [3/2/2004 9:31:09 PM] Estimating the Size of Sunspots d = Scale Model Diameter of Sun S = Actual Size of Sunspot D = Actual Diameter of the Sun (1,400,000 km) Substitute, cross-multiply, do dimensional analysis, solve for "S": s (mm) S (km) -------- = -------------d (mm) 1,400,000 km s (mm) x 1,400,000 km S (km) = ----------------------d (mm) 2. Compare/contrast the size of the largest sunspot with the diameter of the Earth (12,735 km). Approximately how many Earth diameters would fit inside the Sun's diameter? Show your work; circle your answer. 3. The hardcopy MDI Continuum solar image is really a scale model of the Sun. Use the Sun's scale model diameter and actual diameter to determine the scale of the image (you may need to refer to a brief tutorial on determining fractional scale). Show your work; circle your answer. Use the image scale to estimate the size of two other sunspots; record the estimated size of these sunspots in the data table (above). Circle and label the two sunspots (e.g., "No. 2," "No. 3"). APPENDICES . The very latest SOHO images B. Time Conversion Chart wsanford/activities/timeconv.html C. Determining the Fractional Scale of a Map or Scale Model wsanford/activities/scale.html D. Converting Metric Units - Use the following list of metric units to count the number of units change, then move the decimal point (in the same direction in which you were counting) one place for each unit of change: (largest) km hm dam m dm cm mm (smallest) 2--1--0

thumb, if you divide the official sunspot number by 15, then you'll get the approximate number of individual sunspots visible on the solar disk if you look at the Sun by projecting its image on a white screen with a small telescope. [Caution: Never look directly at the Sun (especially through optical instruments such as telescopes) -- blindness may result!] PROCEDURE 1. Using the materials provided by your teacher, construct a bar graph of the annual sunspot number from 1986-1999. 2. Answer the following activity questions. wsanford/exo/sunspot_plot.html (1 of 2) [3/2/2004 9:31:08 PM] Happy Birthday Sunspot Plot ACTIVITY QUESTIONS 1. Calculate the mean "average sunspot number" (annual sunspot number) for the past 14 years. How does this number compare with today's sunspot number (wsanford/exo/n-m_themes.html)? 2. When (which year) was the last solar maximum? What was the annual sunspot number? Is the solar maximum a brief event, or does it tend to last for a period of months to years? 3. When (which year) was the last solar minimum? What was the annual sunspot number? 4. Assuming that the year 2000 turns out to be a solar maximum, how many years passed from the last solar maximum to the next (current) solar maximum? From such a relatively small data set, can the period of the solar cycle be determined with certainty? 5. When (which year) were you born? Were you born during a solar maximum, solar minimum, or sometime in between? If the year 2000 turns out to be a solar maximum, then predict how old you will be during the next solar maximum. wsanford/exo/sunspot_plot.html (2 of 2) [3/2/2004 9:31:08 PM] Estimating the Size of Sunspots Safely Estimating the Size of Sunspots PURPOSE There's more than meets the eye to the little yellow ball in the sky! Sunspots are relatively cool areas that appear as dark blemishes on the face of the Sun. Looking at solar telescope imagery, it's difficult to get a sense of the actual size of sunspots. In this activity, you will estimate the actual size of these features. MATERIALS 1. Internet access via Web browser, e.g., Netscape Communicator or Microsoft Internet Explorer 2. Pencil, metric ruler, and hardcopy of near-real-time solar telescope imagery (showing sunspots) 3. Scientific calculator PROCEDURE 1. Use a Web browser to access The very latest SOHO images Web page. Download/print the latest MDI Continuum solar image. 2. In the following data table, record the image date and time. [Note Date/Time format: Date = yy/mm/dd; Time = UTC. Refer to a Time Conversion Chart to convert UTC to EST/EDT.] 3. Using a metric ruler and the hardcopy solar image, carefully measure the diameter of the Sun (mm) and the width (mm) of the largest sunspot (along major axis); record these data in the data table (below). Circle and label the largest sunspot (e.g., "largest"). 4. Answer the Activity Questions. DATA Date Time (mm/dd/yy) (EST/EDT) Feature Scale Model Size Actual Size (mm) (km) Diameter of Sun Largest Sunspot Sunspot No. 2 Sunspot No. 3 ACTIVITY QUESTIONS 1. Use a proportion (two equivalent ratios) to solve for the actual size of the largest sunspot. Show your work (below); record your answer in the data table (above). s S --- = --d D Where: s = Scale Model Size of Sunspot wsanford/exo/sundials/size_sunspots.html (1 of 2) [3/2/2004 9:31:09 PM] Estimating the Size of Sunspots d = Scale Model Diameter of Sun S = Actual Size of Sunspot D = Actual Diameter of the Sun (1,400,000 km) Substitute, cross-multiply, do dimensional analysis, solve for "S": s (mm) S (km) -------- = -------------d (mm) 1,400,000 km s (mm) x 1,400,000 km S (km) = ----------------------d (mm) 2. Compare/contrast the size of the largest sunspot with the diameter of the Earth (12,735 km). Approximately how many Earth diameters would fit inside the Sun's diameter? Show your work; circle your answer. 3. The hardcopy MDI Continuum solar image is really a scale model of the Sun. Use the Sun's scale model diameter and actual diameter to determine the scale of the image (you may need to refer to a brief tutorial on determining fractional scale). Show your work; circle your answer. Use the image scale to estimate the size of two other sunspots; record the estimated size of these sunspots in the data table (above). Circle and label the two sunspots (e.g., "No. 2," "No. 3"). APPENDICES . The very latest SOHO images B. Time Conversion Chart wsanford/activities/timeconv.html C. Determining the Fractional Scale of a Map or Scale Model wsanford/activities/scale.html D. Converting Metric Units - Use the following list of metric units to count the number of units change, then move the decimal point (in the same direction in which you were counting) one place for each unit of change: (largest) km hm dam m dm cm mm (smallest) 2--1--0

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