Name: ______________________________ Form: ______

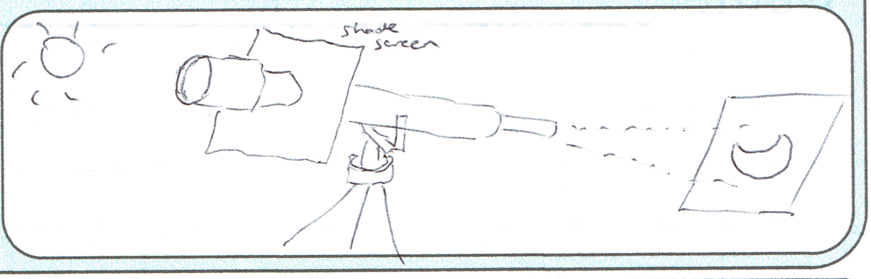
Astronomy Club

1.3 Earth, Moon, Sun

The Sun

a) Demonstrate an understanding of how the Sun can be observed safely by amateur astronomers

Draw a diagram to show how a telescope can be used to project an image of a solar eclipse.



b) Recall the Sun's diameter and its distance from Earth

The Sun's diameter: 1.392×10^6 km. The distance between the Sun and the Earth: ~~[illegible]~~ 149.5 $\times 10^6$ km.

c) Recall the temperature of the Sun's photosphere

The temperature of the Sun's photosphere: 5777 K

d) Describe the solar atmosphere (chromosphere and corona) and recall the approximate temperature of the corona.

Compare and contrast the chromosphere, corona and photosphere. State the temperature of the corona and explain the theories which attempt to explain why this is higher than the temperature of the photosphere.

The photosphere is the visible surface of the Sun. It is the lowest of the 3 atmospheric layers. All visible light is emitted from the photosphere as if a black body at 5800K. It also represents the top of the convection currents and is why it is grainy. Sunspots appear on the photosphere. The chromosphere is the middle layer. It cannot be seen against the brightness of the photosphere (and is transparent), but can be seen during a total eclipse. The temperature in the chromosphere increases with height: 4400 - 25000K. Solar prominences are found in the chromosphere. The outermost layer is the corona and extends out to a distance of several million km (and becomes the solar wind). The corona has a very high temperature (1-5m K) but is not 'hot' - it contains very little thermal energy as though the atoms move at very high speeds (producing X rays) there are few atoms/m^3. Coronal mass ejections occur here.

e) Describe the appearance and explain the nature of sunspots

Temporary phenomena on the photosphere that appear as visibly dark spots compared to surrounding regions. Sunspots are concentrations of magnetic field flux that inhibit convection and result in reduced surface temperature. Usually in pairs - opposite polarity. Approximately 11 year cycle. Sunspots last from a few days to a few months.

f) Recall that the Sun's rotation period varies from 25 days at the equator to 36 days at its poles ?

The Sun's rotation period at the equator: 24. ~~47~~ days. The Sun's rotation period at the poles: 36 days.

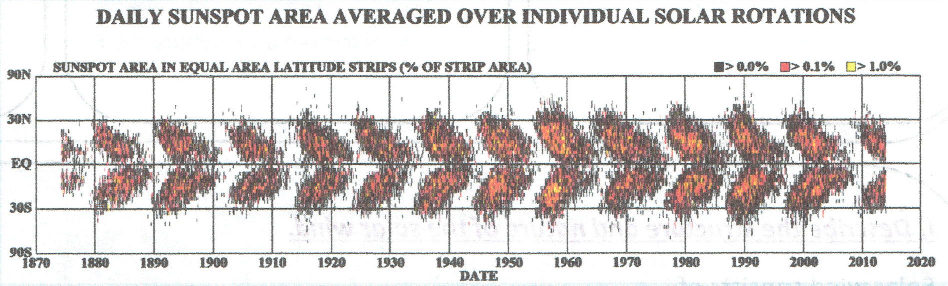
Explanation: The period varies with latitude because the Sun is made of plasma. Differential rotation is caused by (mass) convection (due to temperature gradients) – the movement of mass affects the sun's angular momentum (or velocity)

g) Demonstrate an understanding of how astronomers use observations of sunspots to determine the Sun's rotation period

Describe how to use sunspots to measure the Sun's Synodic and Sidereal rotation periods.

Viewed from the Earth, sunspots appear to move from left to right across the face of the Sun. Measurements are needed of the path over a series of days. Calculations are also needed of the sunspot's latitude and longitude. (a chord). Extrapolation allows calculation of the time taken for the spot to travel 360° (synodic) – the same observed position depends on the rotation of the Earth as well. The sidereal period is the time it takes for the sunspot to rotate 360° (and is the lower value)

h) Interpret data (for example a Butterfly Diagram) in order to describe the long-term latitude drift of sunspots, determine the length of the solar cycle and predict the year of the next solar maximum



Length of solar cycle: 11 yrs

Year of next solar maximum: 2022

Describe the long-term latitude drift of sunspots: Sunspots tend to appear at higher latitudes (35-40°) and move towards the equator as the cycle progresses. At solar maximum they are around 15° (and fade with the cycle around 7°)

Explain how you worked out the answers:

Cycle length – ave time between maxima. (most yellow at 15° N/S) Next maximum – last peak (~~2010~~ 2011) + 11 yrs.

Sunspots appear in the diagram early in the cycle at higher latitudes and move towards EQ before disappearing and it starts again.

i) Demonstrate an understanding that the Sun's energy is generated by nuclear fusion reactions at its core, converting hydrogen into helium

Describe the process of nuclear fusion in the core of the Sun, including an explanation of the conditions required for fusion to take place:

Nuclear fusion involves the joining of two atomic nuclei. Energy is released when this occurs (in the form of photons) – mass is not conserved. At the centre of stars, largely due to gravity, the temperatures and pressures are high enough for fusion to take place (essentially when Coulomb force is overcome and the strong nuclear force takes over) – lighter (or smaller) elements, but mostly $^1_1H + ^2_1H \rightarrow ^3_2He$ (up to iron when energy is absorbed not released).

J) Describe how astronomers observe the Sun at different wavelengths

Doing so highlights different aspects of the Sun's surface and atmosphere. Spectrometers observe different wavelengths simultaneously (+ how much of each wavelength). Other instruments produce conventional images of the sun focused around a narrow wavelength range to highlight a particular feature, eg corona or photosphere. Correlation with particular ions - visible, UV, near-IR, X-ray, radio, etc. Specialised telescopes often placed in space to avoid atmospheric absorption.

k) Demonstrate an understanding of the appearance of the Sun at different wavelengths of the electromagnetic spectrum, including visible, H-alpha, X-ray

The Sun viewed in the visible spectrum (+uv)

scied.ucar.edu/compare-sun-images-visible-ultraviolet

The Sun viewed in the H-alpha spectrum

~~astrop~~ astro-physics.com/gallery/astroph/pwand/sunaug20pw.htm

The Sun viewed in the X-ray spectrum

nasa.gov/mission_pages/GOES-P/news/xray_images.html

l) Describe the structure and nature of the solar wind.

Solar wind consists of a stream of high energy charged particles released from the heliosphere (upper atmosphere of the Sun). A plasma mostly made of electrons, protons and alpha particles, flowing supersonically to great distances.

Some effects of solar wind are: Interplanetary magnetic field (embedded in the wind plasma). Creation of heliosphere - the region of space dominated by the Sun (interstellar medium outside). Aurora, plasma tails of comets (pointing away from Sun). Geomagnetic storms on Earth. Space weather

We are protected from solar wind by: the Earth's magnetic field (which protects the atmosphere) (unlike eg Mars). The Earth's magnetosphere deflects the charged particles around the planet - some trapped in Van Allen belts and some do reach the ionosphere (aurora/geomagnetic storms)