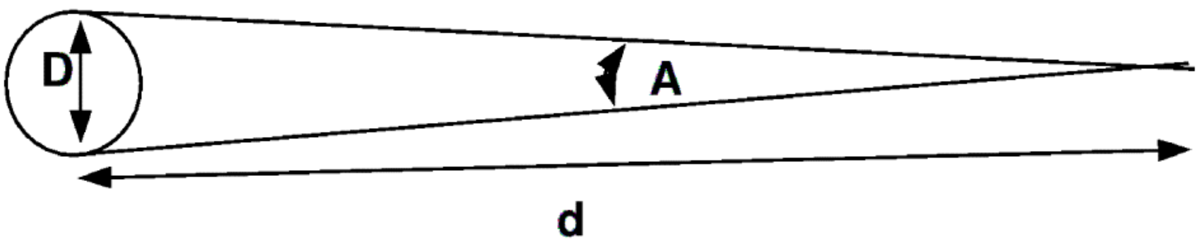
1. The small angle formula that relates angles to physical distances is this:



A=(D/d)x206,263 arc sec

If the Hubble Space Telescope can measure angles as small as 0.05 arcseconds, and the Moon is 384,000km away, then what would be the smallest object that you could detect on the Moon using the Hubble Space Telescope? (2)

Putting the values that we know into the small angle formula:

$$0.05 = \frac{D}{384000} \times 206263$$

Then, rearranging to find D:

$$\begin{aligned} D &= \frac{0.05 \times 384000}{206263} \\ &= 0.093\text{km} \\ &= 93\text{m} \end{aligned}$$

So the smallest object that you could resolve with the Hubble Space Telescope on the Moon would be 93m across

2. Copernicus is a well known crater on the Moon's surface. It has a diameter of 93km. The human eye can resolve objects as small as one arcminute across. Should you be able to see Copernicus with the naked eye? (2)

To calculate the apparent size of Copernicus, put the numbers we know into the equation:

$$\begin{aligned} A &= \frac{93}{384000} \times 206263 \\ &= 50.0\,arcseconds \\ &= 0.83\,arcminutes \end{aligned}$$

So, if the human eye can resolve objects an arcminute across, then Copernicus is just a bit too small to make out. In practice, it's much brighter than its surroundings, and has long bright 'rays' extending from it, so you might just about spot it.

3. The distance between the Earth and the Sun is 150,000,000km (an Astronomical Unit). How far away from the Solar System would you have to be for the Earth and Sun to appear one arcsecond apart? (2)

Putting the numbers into the equation:

$$1 = \frac{150{,}000{,}000}{d} \times 206263$$

Rearrange to get d, the distance required:

$$\begin{aligned} d &= 150{,}000{,}000 \, x \, 206{,}263 \\ &= 3.09 \times 10^{13} \, km \\ &= one \; parsec \end{aligned}$$

This is the definition of a parsec

4. The positions of astronomical objects on the sky are measured in Right Ascension and Declination. Define what these terms mean. (4)

Right Ascension is the distance eastwards from the First Point of Aries (that is, the point on the celestial equator where the apparent path of the Sun through the sky crosses from the southern hemisphere to the north) to a celestial object. It is measured in hours, minutes and seconds. Once the First Point of Aries has crossed the meridian, then the time until a given object crosses the meridian is equal to its RA.

Declination is the angular distance of an object from the celestial equator. Objects in the northern hemisphere have positive declinations, and those in the southern hemisphere have negative declinations.

5. Why do we have to specify what year a given Right Ascension is valid in? (2)

The First Point of Aries is unfortunately not a permanently fixed point in the sky. It isn't even in Aries any more! It moves because the gravitational pull of the Moon and Sun on the Earth cause the direction that the Earth's rotational axis points to slowly change, and so the point where the Sun crosses from the southern celestial hemisphere to the northern slowly moves. This effect is called *precession*.

6. What is the definition of a Solar day? What is the definition of a sidereal day? Why are these days not the same length? (3)

A solar day is the time between successive upper meridian transits of the Sun. A sidereal day is the time between successive upper meridian transits of the First Point of Aries. They are not the same length because the movement of the Earth in its orbit

around the Sun changes the position of the Sun relative to the stars: the Sun takes about four minutes longer than the First Point of Aries to move between successive upper transits.

7. What do we mean when we talk about a *black body*? What does the spectrum of a black body look like? Do the spectra of stars resemble those of black bodies? Do the spectra of nebulae resemble those of black bodies? (4)

A black body is one which absorbs all the radiation that falls on it. The radiation it emits is defined only by its temperature – that is, any black body behaves in the same way, regardless of what it's made of.

The spectrum of a black body is a smooth curve with a peak whose position depends on the temperature of the black body.

Dense, opaque bodies have spectra that are similar to black bodies. Stars are dense and opaque and so their spectra resemble those of black bodies. Nebulae have extremely low densities and are not opaque, so their spectra do not resemble those of black bodies.

8. The Very Large Telescope in Chile has a mirror 8.2m in diameter. What is the smallest angular separation that the WHT could measure, theoretically, when observing light with a wavelength of 550nm? Why might it not reach this limit in practice? (2)

The diffraction limit of a telescope, in arcseconds, is given by $2.5\times10^{-4}\ \lambda/D$, where λ is the wavelength you're observing in nanometres, and D is the diameter of the telescope in metres. So, if we were looking at wavelengths of 550nm with the VLT, we could resolve objects separated by 0.017 arcseconds.

In practice, the VLT mirror might not be perfectly figured to the right shape, and objects it observes are smeared out by the movement of the atmosphere.

9. The VLT is a reflecting telescope. Give three reasons why it would be impractical to build a refracting telescope this large. (4)

1. **An 8.2m lens would be extremely heavy – too heavy for a telescope tube to support without flexing.**
2. **An 8.2m lens with glass of sufficient quality for astronomical use would be extremely difficult and thus expensive to manufacture**
3. **Refracting telescopes suffer from chromatic aberration; correcting it requires a second or even third layer of glass in your lens – impractical for very large lenses.**

10. The VLT is designed to observe visible light, with a typical wavelength of 550nm. If you wanted to observe radio waves with a wavelength of 55cm, at the same resolution as the VLT has in the optical, how large a radio telescope would you need? (2)

55cm is 1,000,000 times larger than 550nm, and therefore you would need a telescope

1,000,000 times larger than the WHT – 8,200km across - to observe 55cm radio waves.