9.2.2 Astronomical distances

Unsurprisingly, astronomical distances are large! Astronomers routinely use a couple of non-SI units to express these large distances – the *'astronomical unit'*, the *'light year'* and the *'parsec'*.

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The astronomical unit (AU)

The astronomical unit is the mean distance between the Earth and the Sun. It is approximately 150 million kilometres.

(1) ✐ What is this distance in metres?

(2) ✐ If light travels at $3 \times 10^8 ms^{-1}$ *in a vacuum, how long does it take light to reach us from the Sun?*

The light year (ly)

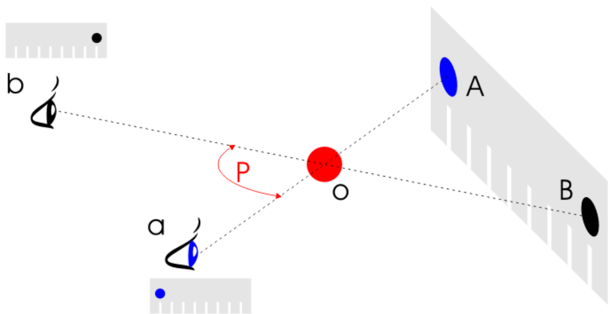
The light year is a measure of distance. It is the distance travelled by light, in a vacuum, in one year.

(3) ✐ What is 1 light year, in metres?

The parsec (pc)

The *parsec* originates from a method that uses 'parallax shift' measurements to determine the distance to an object.

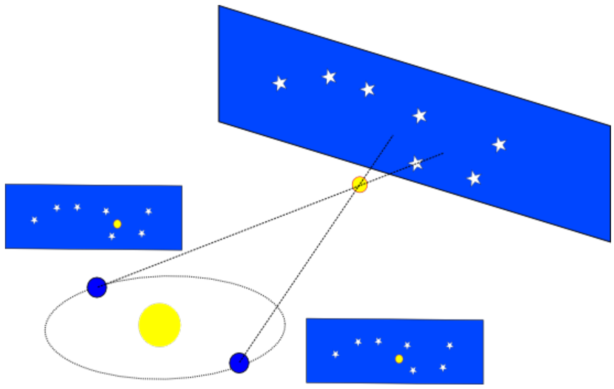
Consider the following diagram:



If we look at an object O from two different positions, we will see that it shifts position relative to a background screen. The closer the object is to the observer, the bigger this parallax shift becomes.

(4) ✐ Try the following: Hold up your thumb about 15cm from your face. Close one eye and look at your thumb's position relative to the background. Now do the same for the other eye. You should see that your thumb moves (parallax shift). Now hold your thumb at arm's length and repeat. How does the shift you see compare for the thumb close to your face and far away?

We can see that the amount of parallax shift is inversely related to the distance. This phenomenon can be used to work out the distance to some 'nearby' stars.



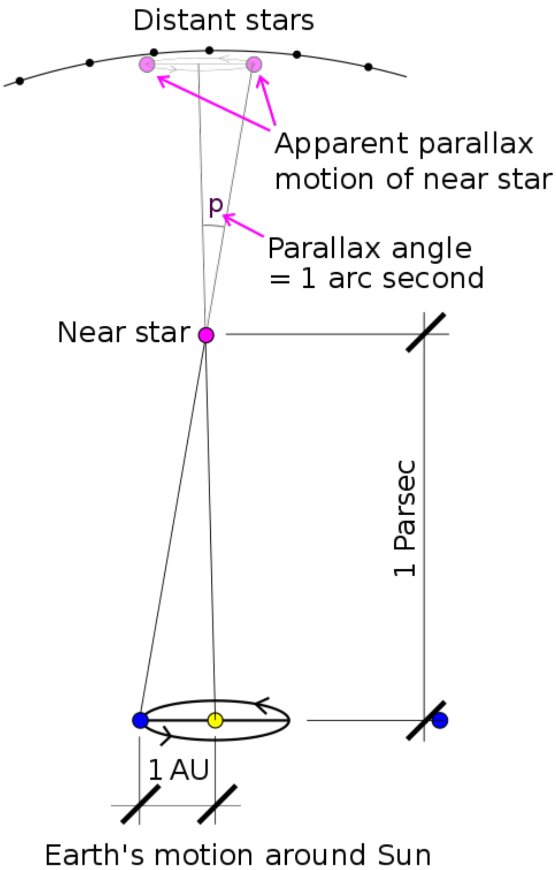
In the diagram, left, two observations are made of a nearby star. The observations are made six months apart. The position of the star is noted against the background (very distant) stars. A measurable shift is seen. This angular shift can then be used to work out the distance to the star. A star that is closer will show a bigger shift than a more distant star.

The distance (*measured in parsecs*) is given by:

$$D = \frac{1}{\theta}$$

where θ*=angle measured in 'seconds of arc' or 'arc seconds'* $(1\ arc\ second = \frac{1}{3600} degree)$

Note: The angle used in this equation is half the total angular shift observed. See the diagram, right.



An example:

The star alpha Centauri has a parallax $\theta = 0.742\ arc\ seconds$*, what is its distance in parsecs?*

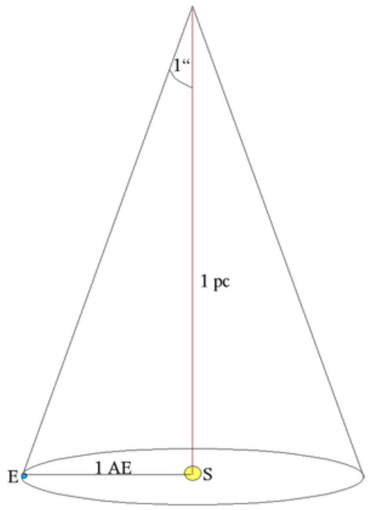
$$D = \frac{1}{\theta} = \frac{1}{0.742} = 1.35pc$$

(5) ✎ Another star has a parallax of 0.02 arc seconds. What is its distance from the Earth in parsecs?

Converting between units

You might be required to convert from one distance unit to another. Note: This may be given in your data sheet.

To convert from parsecs to metres, consider the following diagram:



Essentially, we have a right-angled triangle. The base has the length of 1AU = 150 million kilometres, and the angle (when the distance is 1parsec), is $\frac{1}{3600}\,degree$.

(6) ✏ Using trigonometry (i.e. the tan function), and substituting in the length of 1AU in metres, and the angle in degrees, calculate the length of 1 parsec in metres.

(7) ✏ What does one parsec equal in light years (ly)?