AQA

A Level

A Level Physics

ASTROPHYSICS: Stars 1

(Answers)

Name:

Mathsmadeeasy.co.uk

Total Marks: /30

1. The distances to stars are so large that is is convenient to use units other than m.

Total for Question 1: 8

(a) Define, in words, the units AU and ly. [2]

Solution: AU: average distance from the earth to the sun.
ly: the distance travelled by light in a vacuum in one year.

(b) Show that 1 pc=3.1×10^{16} m. One astronomical unit is equivalent to 1.5×10^{11} m. [2]

Solution: 1 pc is the distance at which a radius of 1 AU subtends an angle of 1 arcsecond (1/3600°).
Therefore, by trigonometry: $\tan(1arcsecond) = \frac{AU}{pc} \rightarrow 1\ pc = \frac{1.5\times10^{11}}{\tan(\frac{1}{3600})} = 3.1 \times 10^{16}$ m

(c) Calculate the distance to a star whose parallax angle measures 0.30 arcseconds. Give your answer in AU, ly and pc. [3]

Solution: 3.33 pc = 10.9 ly = 689 kAU

(d) Suggest why the parallax method for determining distances is limited to approximately 100 pc? [1]

> **Solution:** For distances greater than 100 pc, the angle becomes too small to measure accurately.

2. Stars were traditionally classified by their apparent brightness. This is a technique with origins dating back to the Ancient Greeks. Since then, numerous other classifications have been proposed.

Total for Question 2: 11

(a) State the major problem with the Hipparchus scale. [1]

Solution: Brightness is subjective.

(b) The stars Vega and Bellatrix have apparent magnitudes of 0.0 and 1.6, respectively. On the apparent magnitude scale, a star with a magnitude of 6 is one hundred times less bright than one with an apparent magnitude of 1 and the scale is logarithmic i.e. $\frac{magnitude_6}{magnitude_5} = \frac{magnitude_5}{magnitude_4}$. How many time brighter than Bellatrix is Vega? [4]

Solution: 4.4

A star's absolute magnitude, M, is defined as the apparent magnitude it would have were it at a distance of 10 pc. Given that each increment on the magnitude scale represents a factor of $100^{1/5}$, it can be shown that $y - x = 2.5 \log \frac{I_x}{I_y}$, where I_x and I_y are the intensities of the light emitted by stars with apparent magnitudes x and y.

(c) The inverse square law states that the intensity of radiation emitted from a spherical body decays according to the equation $I = \frac{P}{4\pi r^2}$, where P is radiant power and r is distance from the body. Show that the intensity of the light emitted by a star is related to the intensity of the light were it at a distance of 10 pc by the equation $\frac{I_{10}}{I} = \frac{r^2}{100}$. [3]

> **Solution:** $I_{10} = \frac{P}{4\pi \times 10^2}$ and $I = \frac{P}{4\pi r^2}$
> Therefore, $P = 4\pi r^2 I = 4\pi \times 10^2 I_{10}$
> Hence, $\frac{I_{10}}{I} = \frac{r^2}{100}$

(d) By assuming that I_x is the intensity at a distance of 10 pc, show that $y - M = 5 \log \frac{r}{10}$. [3]

> **Solution:** I_{10} replaces I_x in the log equation and M replaces x.
> This gives $y - M = 2.5 \log \frac{I_{10}}{I_y}$. But, from the previous part, $\frac{I_{10}}{I_y} = \frac{r^2}{100}$.
> Therefore, $y - M = 2.5 \log \frac{r^2}{10^2} = 5 \log \frac{r}{10}$, as requested.

3. The Sirius system is the brightest star system visible in the night sky. Sirius B is a white dwarf with a luminosity of only 0.056 $L_\odot$ and a peak spectral wavelength of $\lambda_{max} = 1.2 \times 10^{-7}$ m. In contrast, the red supergiant Betelgeuse has a peak wavelength of $\lambda_{max} = 8.5 \times 10^{-7}$ m and a surface temperature of 3400 K. The luminosity of our sun ($L_\odot$) is 3.85×10^{26} W. Total for Question 3: 11

(a) Define the term *black body*. [1]

Solution: A black body is an idealised object that absorbs all EM radiation that shines onto it and emits a characteristic distribution of wavelengths at a specified temperature.

(b) Sketch a graph to show how the reradiated power per m^2 of a black body varies with the wavelength of the emitted radiation. Include on your sketch three curves for bodies with temperatures of 3000 K, 4000 K and 5000 K, [3]

Solution: General shape: steep rise to peak, then more gradual tailing off. Two key features:
1/ hotter bodies emit more radiation.
2/ The peak intensity occurs at a shorter wavelength for hotter bodies.

(c) Arnav is asked to calculate the wavelength of starlight from Zeta using a diffraction grating. He measures the angle between the beam and the eighth-order maximum as 0.14°and uses a grating with a slit spacing of 1 mm. What is the wavelength of the light used? [3]

Solution: 310 nm

(d) Using a combination of Wien's displacement law and Stefan's law, calculate the radius of Sirius B. [4]

Solution: 9500 km