PHYA5 Section B (Astrophysics) - Unofficial MS

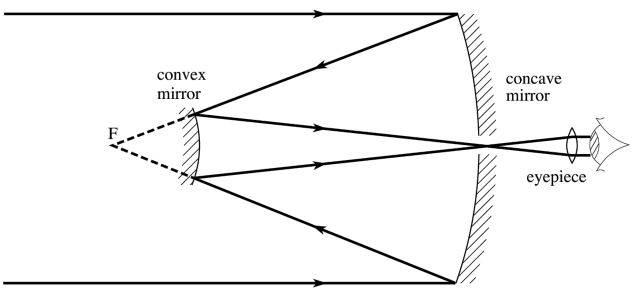
Question 1 (10 marks)

(a) (i) Maximum distance to Vesta $3.57\,AU = 5.36 \times 10^{11}\,m$ **(2)**

(ii) Show that the angle subtended by Vesta as viewed from Earth is $3.12 \times 10^{-6}\,rad$

$$\theta = \left(\frac{diameter\ of\ Vesta}{distance\ to\ Vesta}\right)$$ ($tan\theta \approx \theta$ for small angles) **(2)**

(b) (i) Draw a ray diagram for a Cassegrain telescope. **(2)**



(ii) Calculate the diameter of the IRTF telescope.

$$\theta = \frac{\lambda}{D} \quad \therefore \quad D = \frac{\lambda}{\theta} = 3.0\,m$$ **(2)**

(c) Vesta can be observed with a high level of detail. This is because the minimum angle of resolution of the IRTF is much smaller than the angle subtended by Vesta as viewed from Earth. **(2)**

Question 2 (11 marks)

(a) Explain the shape of both graphs and show how the period and speed of the binary system can be determined. Include calculations in your answer. **(6)**

- The peaks on the first graph occur when one of the stars passes in front of the other.
- This results in the binary system appearing dimmer from Earth (apparent magnitude value is greater).
- The peaks on the second graph occur due to the blue-shift and red-shift of light from one of the stars.
- When the star is moving towards Earth in its orbit around a centre of mass, the light is blue-shifted (smaller wavelength). When the star is moving away from Earth, the light is red-shifted (bigger wavelength).
- The period of the system can be determined using either graph.
- Distance between two peaks x2 in the first graph, and distance between maxima (or minima) in the second graph.
- The period is **4 days**.
- The speed of the system can be calculated as follows:

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \quad \therefore \quad v = \frac{\Delta\lambda c}{\lambda} = 1.1 \times 10^4\,m\,s^{-1}$$

(b) Hydrogen Balmer lines are present in the star's spectrum. This is because its temperature is high enough for hydrogen atoms in its atmosphere to exist in the n=2 state. **(2)**

(c) Calculate the absolute magnitude of the binary system when it appears dimmest (the answer to this question depends on the value for apparent magnitude you used).

$$M = m - 5log\left(\frac{d}{10}\right) \qquad d = 25\,pc \quad m = 1.981$$

$$\implies \quad M = -8.7 \times 10^{-3}$$ **(3)**

Question 3 (8 marks)

(a) (i) Calculate the black body temperature of 40 Eridani B.

$$\lambda_{max} T = 0.0029\,m\,K \quad \therefore \quad T = \frac{0.0029}{\lambda_{max}} = 16000\,K$$ **(3)**

(ii) Calculate the radius of 40 Eridani B. **(2)**

$$P = \sigma A T^4 \quad A = 4\pi r^2 \quad \therefore \quad r = \sqrt{\frac{P}{4\pi\sigma T^4}} = 9.37 \times 10^6\,m$$ **(2)**

(b) (i) Dwarf star ✓ **(1)**

(ii) 40 Eridani B is a dwarf star because it has a very small radius (similar to that of the Earth) and a high temperature. **(2)**

Question 4 (6 marks)

(a) A black hole is an extremely dense object with a gravitational field so great that its escape velocity is greater than the speed of light. **(1)**

(b) Calculate the Schwarzschild radius.

$$R = \frac{2GM}{c^2} = 2.95 \times 10^{13}\,m$$ **(2)**

(c) Use the data to estimate a value for the age of the universe in seconds.

$$age = \frac{1}{H} \quad v = Hd \quad \therefore \quad age = \frac{d}{v} \approx 5 \times 10^{17}\,s$$ **(3)**

Total for Section B - 35 marks