7 A binary star system consists of two stars that orbit about a fixed point **O** as shown in Fig. 7.1.

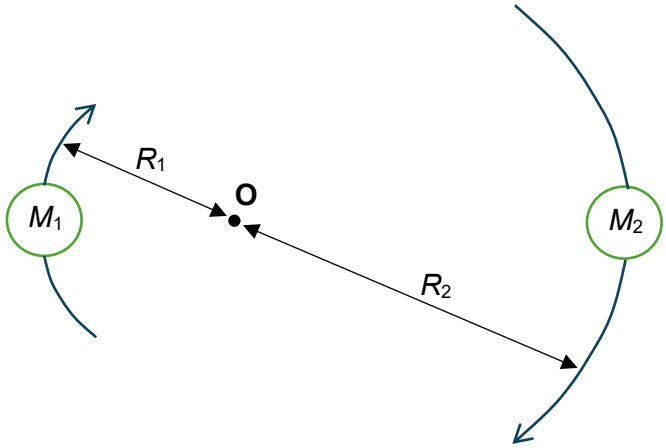

Fig. 7.1

The star of mass M_1 has a circular orbit of radius R_1 and the star of mass M_2 has a circular orbit of radius R_2. Both stars have the same angular speed ω about **O**.

(a) Using the symbols above and in the data list on page 2, write down the mathematical expression for

(i) the gravitational force, F_A, between the two stars,

[1]

(ii) the centripetal force, F_B, on the star of mass M_2.

[1]

(b) The stars orbit each other in a time of 1.26×10^8 s (~ 4 years). Calculate the value of ω.

ω = ... rad s^{-1} [2]

(c) **(i)** Show that the ratio of the masses of the stars is given by the expression

$$\frac{M_2}{M_1} = \frac{R_1}{R_2}.$$

[2]

(ii) The ratio of $\frac{M_2}{M_1}$ is equal to $\frac{1}{3}$ and the separation of the stars is 3.2×10^{11} m.

Calculate the values of R_1 and R_2.

R_1 = ... m

R_2 = ... m [2]

(d) The light from a particular binary star system is analysed by physicists. The time variation of the intensity of light received is shown in Fig. 7.2 below.

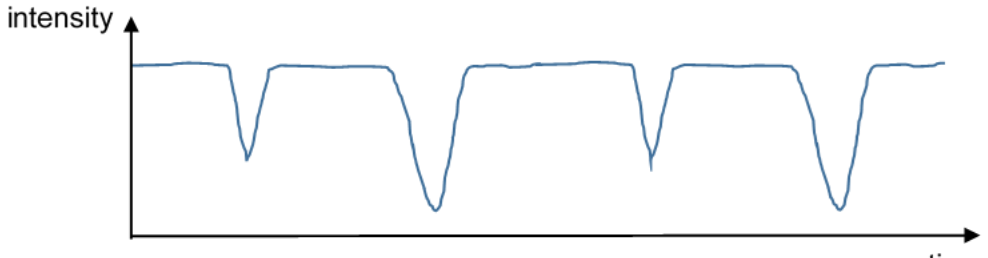

Fig. 7.2

By reference to the stars, suggest reasons for the shape of the graph above.

……

……

……[2]

(e) The potential in the gravitational field of a point mass increases with increasing distance from the mass.

Explain why the electric potential may increase or decrease with increasing distance from the charge.

……

……

……

……[2]

(f) The radius of a lithium ($^{7}_{3}\mathrm{Li}$) nucleus is 2.3×10^{-15} m whereas the radius of a proton is 1.2×10^{-15} m.

(i) Assuming that the lithium nucleus and proton act like point charges, determine the electric potential energy of the proton when it is just in contact with the lithium nucleus.

potential energy = …… J [3]

(ii) A particle accelerator is an apparatus that accelerates subatomic particles so that they collide with each other. By reference to the answer in **(f)(i)**, suggest why such accelerators, are usually referred to as 'high energy' accelerators.

……

……

……

……[2]

(g) Fig. 7.3 shows part of a particle accelerator. Here, electrons are used.

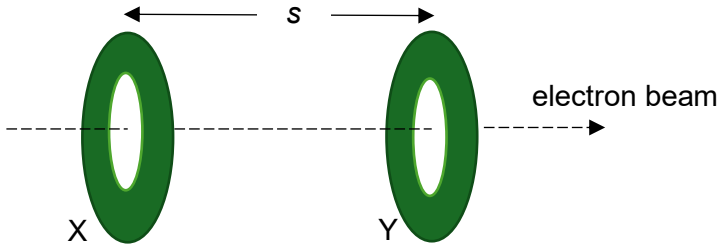

Fig. 7.3

The electrons pass through the opening in plate X with a speed of 6.0 Mm s^{-1} and reach the opening of plate Y with a speed of 9.0 Mm s^{-1}. If the electric field region between X and Y is uniform and of strength 1.4×10^5 N C^{-1}, determine the value of *s*, the separation between the plates.

s = ... m [3]

[Total: 20]