8 **(a)** Fig. 8.1 shows the variation of the gravitational potential ϕ with distance d from the surface of Pluto along a line joining the centers of Pluto and Charon.

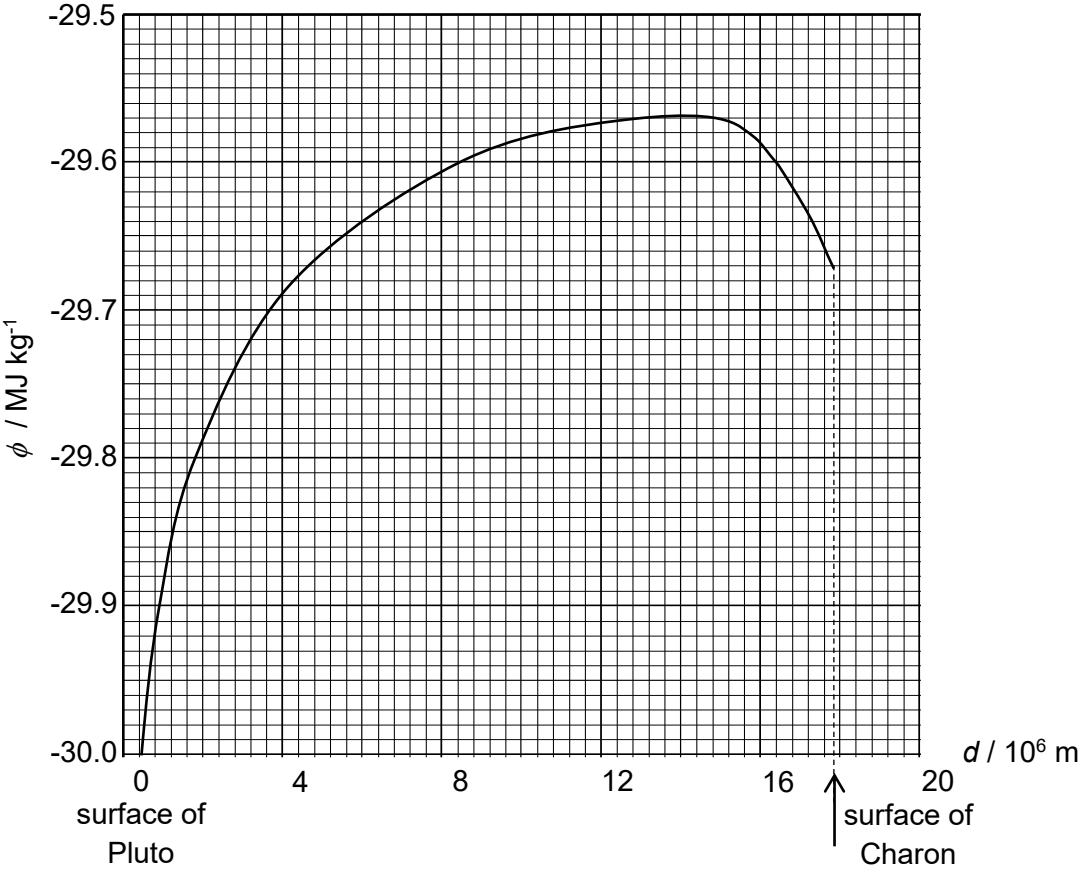

Fig. 8.1

The gravitational potential is taken as being zero at infinity.

(i) By considering the definition of gravitational potential, suggest why all values of ϕ in Fig. 8.1 are negative and explain how they may be obtained.

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[2]

(ii) Explain how Fig. 8.1 can be used to determine the resultant gravitational force acting on an object with mass *m* placed at a point between Pluto and Charon.

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[2]

(iii) A lump of rock of mass 5.0 kg is ejected from the surface of Charon such that it travels towards Pluto.

1. Using data from Fig. 8.1, determine the minimum speed of the rock as it hits the surface of Pluto.

minimum speed = **……..** m s^{-1} [3]

2. The rock is now projected from Pluto to Charon.

State and explain how its minimum speed when it hits the surface of Charon will be different from the answer in **(a)(iii)1**.

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[2]

(b) In another isolated planetary system, X and Y are two stars of equal mass *M* and separated by a distance 2*L*. The two stars rotate about their common centre of mass.

(i) State Newton's Law of Gravitation.

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[1]

(ii) Explain why the two stars will not collide with each other even though the gravitation force acting on each other are attractive.

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[2]

(iii) Derive an expression, in terms of *M*, *L* and the gravitational constant G, for the period *T* of their rotation.

[2]

(c) Fig. 8.2 shows three points A, B and C relative to the stars X and Y. All three points are equidistant from both X and Y and point B lies on the straight line joining the centres of mass of X and Y.

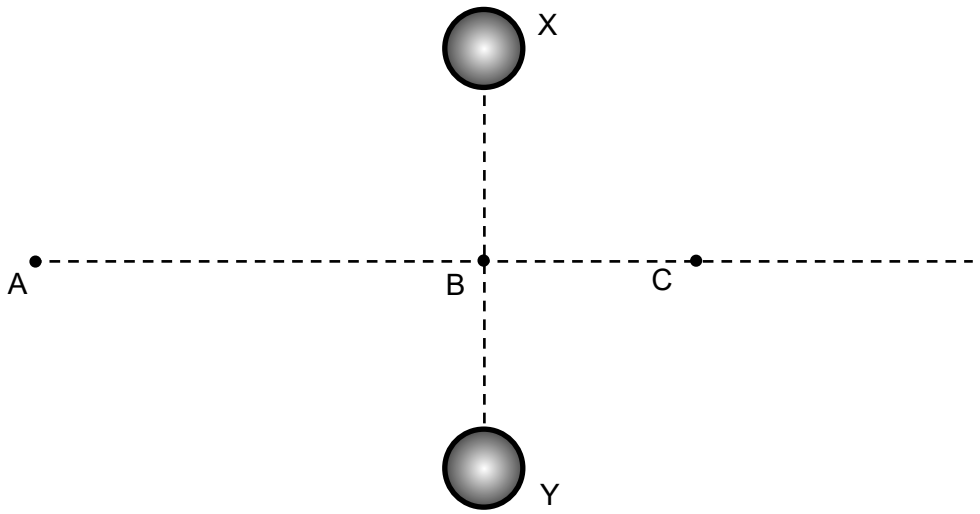

Fig. 8.2

(i) Draw arrows on Fig. 8.2 to represent the gravitational forces due to each star acting on a small mass placed separately at points A, B and C. The length of the arrow should be relative to their respective magnitudes. [2]

(ii) Fig. 8.3 shows another schematic of X and Y. P is a point equidistant from X and Y and is at a distance *s* from the straight line joining the centers of mass of X and Y.

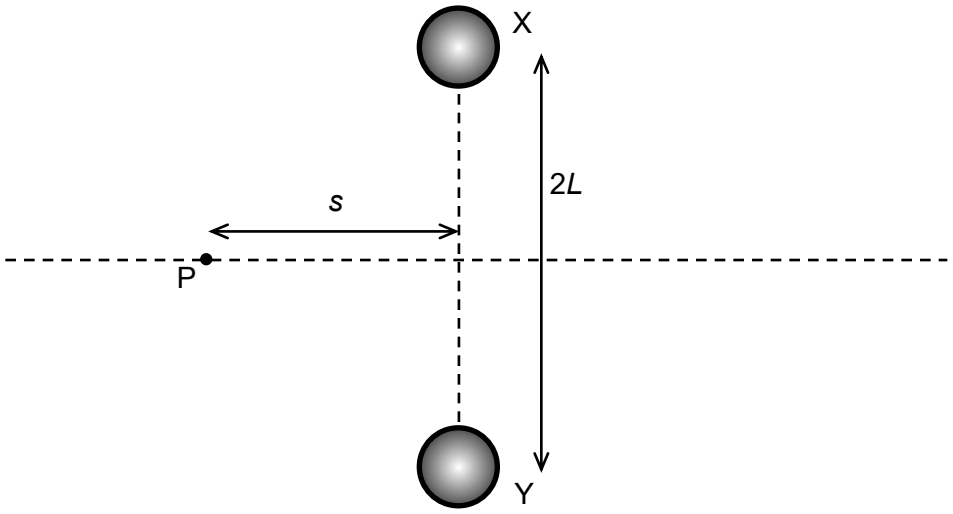

Fig. 8.3

1. Show that the magnitude of the resultant gravitational force acting on a mass *m* placed at P is

$$F_G = \frac{2GMms}{\left(s^2 + L^2\right)^{\frac{3}{2}}}$$

[2]

2. Hence, state and explain if the subsequent motion of a mass placed at rest at point P is simple harmonic.

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…….. [2]