2 (a) Planets have been observed orbiting a star in another solar system. Measurements are made for the orbital radius r and the time period T of each of these planets.

The variation with r^3 of T^2 is shown in Fig. 2.1.

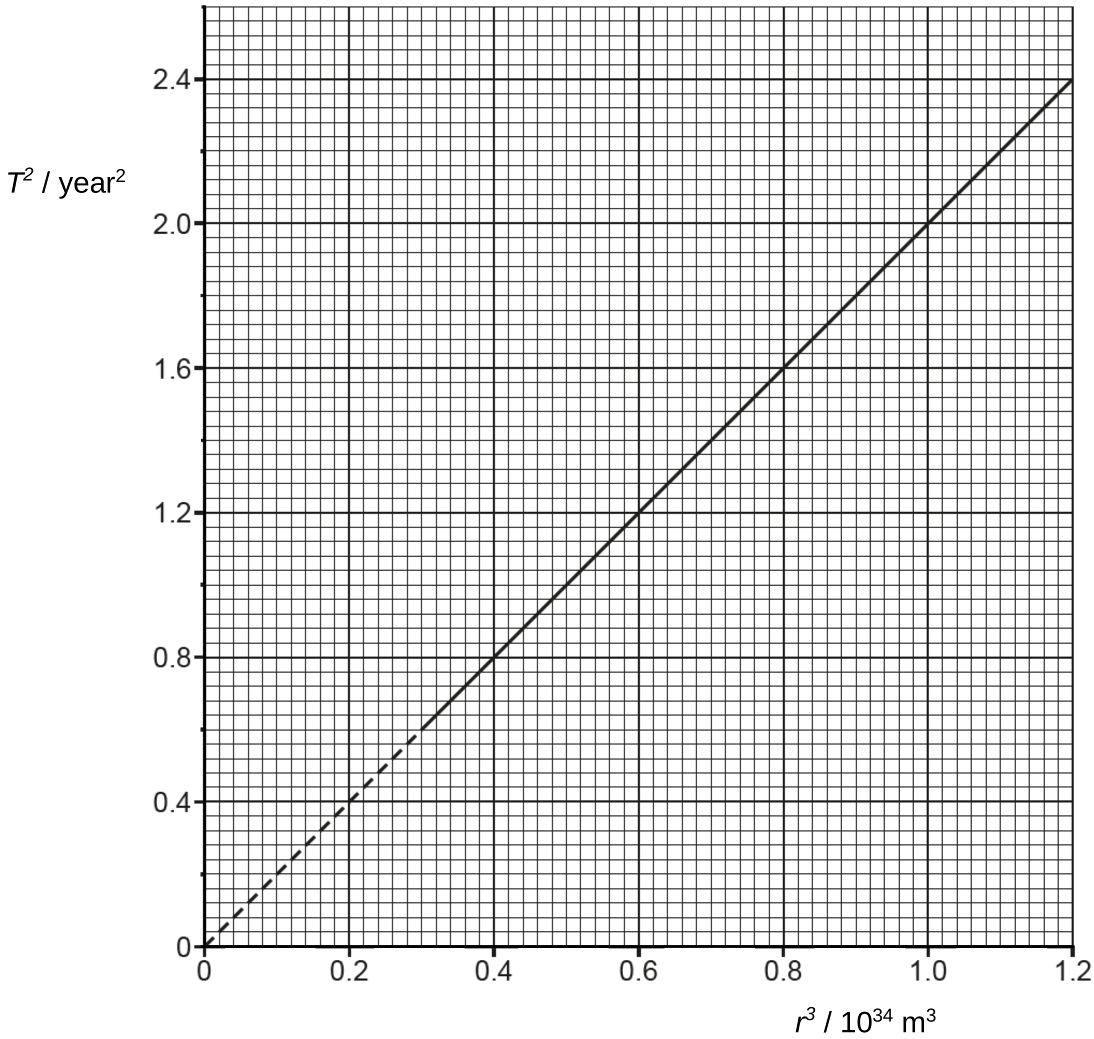

Fig. 2.1

The relationship between T and r is given by

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where G is the gravitational constant and M is the mass of the star.

(i) Determine the mass M of the star.

M = ... kg [2]

(ii) The radius of the star is 700 000 km. Determine the minimum speed with which gas particles from its surface have to be ejected to just escape from the star's pull of gravity.

minimum speed = ... m s^{-1} [2]

(iii) Hydrogen gas, consisting of hydrogen-2 particles, may be assumed to be an ideal gas. If the surface temperature of the star is 6000 K, determine whether hydrogen gas particles are able to escape the surface.

....

....[2]

(iv) Some gas particles have very large kinetic energy to be able to escape from the star.

Given that the star is rotating about an axis through its poles, suggest why the gas particles at the equator of the star are more likely to escape the surface than those at the poles.

....

....

....[2]

(b) A satellite of mass *m* is also in orbit around the star in **(a)**. The radius of the orbit is *r*.

(i) Show that the kinetic energy E_k of the satellite is given by

$$E_k = \frac{GMm}{2r}.$$

[1]

(ii) On Fig. 2.2, sketch graphs to show the variation with orbital radius *r* of the

1. gravitational potential energy of the satellite. Label the graph U.

2. kinetic energy of the satellite. Label the graph K.

3. total energy of the satellite. Label the graph T.

[3]

Fig. 2.2

[Total: 12]