7 **(a)** **(i)** Define *gravitational potential at a point*.

....

....

.... [2]

(ii) Explain why the gravitational potential is negative.

....

....

.... [2]

(b) An isolated uniform spherical planet has gravitational potential ϕ at its surface.

A particle of mass m is projected vertically upwards from the surface. The particle is given just enough kinetic energy to travel to an infinite distance away from the planet, escaping from the gravitational pull of the planet, without any additional work being done on it.

Show that the speed v at which the particle is projected upwards from the surface of the planet is given by

$$v = \sqrt{-2\phi} .$$

[3]

(c) The Moon may be considered to be an isolated uniform sphere of mass 7.3×10^{22} kg and radius 1.7×10^{6} m.

Calculate the gravitational potential at the surface of the Moon.

gravitational potential = ... J kg^{-1} [2]

(d) A particle is moving upwards at the surface of the Moon.

Use the expression in **(b)** and your answer in **(c)** and to determine the minimum speed of this particle that will result in it escaping from the gravitational pull of the Moon.

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

(e) Hydrogen may be assumed to be an ideal gas.

The mass of a hydrogen molecule is 3.34×10^{-27} kg.

Calculate the root-mean-square (r.m.s.) speed of a hydrogen molecule in hydrogen gas that is at a temperature of 400 K.

r.m.s. speed = ... m s^{-1} [3]

(f) The surface of the Moon reaches temperatures of approximately 400 K when in direct sunlight.

With reference to your answer to **(d)** and **(e),** suggest why it is still possible for the Moon to not have an atmosphere consisting of hydrogen.

....

.... [1]

(g) Fig. 7.1 shows the path of a comet of mass 2.20×10^{14} kg as it passes around a star of mass 1.99×10^{30} kg.

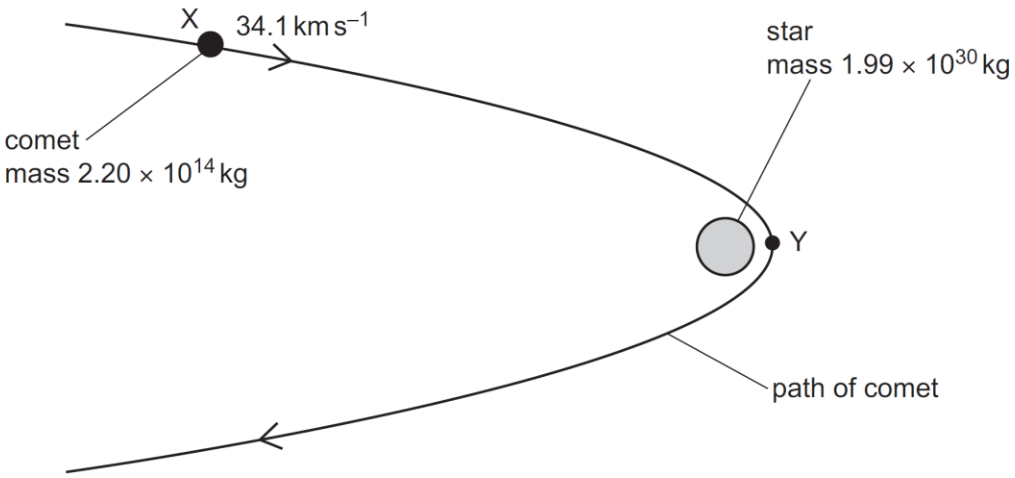

Fig. 7.1

At point X, the comet is 8.44×10^{11} m from the centre of the star and is moving at a speed of 34.1 km s^{-1}.

At point Y, the comet passes its point of closest approach to the star. At this point, the comet is a distance of 6.38×10^{10} m from the centre of the star.

Both the comet and the star can be considered as point masses at their centres.

(i) Determine the speed, in km s^{-1}, of the comet at point Y.

speed = ... km s^{-1} [4]

(ii) A second comet passes point X with the same speed as the original comet and travelling in the same direction. This comet is gradually losing mass. The mass of this comet when it passes point X is the same as the mass of the original comet.

Suggest, with a reason, how the path of the second comet compares with the path shown in Fig. 7.1.

....

....[1]

(iii) A third comet passes point X in the same direction as the original comet but with a greater speed. Sketch a possible path for this comet starting at X in Fig. 7.1 and label this path P.

[1]

[Total: 20]