8 **(a)** State what is meant by a *geostationary orbit*.

……

……. [1]

(b) The planet Saturn has the most extensive and complex ring system of any planet in the Solar System. The rings have varying width and thickness. They are made up of mainly ice particles, with a trace of rocky material which are in orbit around Saturn. One of the rings, the D-ring, has an outer radius of 7.45×10^7 m and a particle on the outer circumference of the ring has a speed of 2.26×10^4 m s^{-1}.

(i) Calculate the angular velocity of the particle about Saturn.

angular velocity = …….. rad s^{-1} [1]

(ii) A stationary orbit about Saturn is defined in the same way as a geostationary orbit about Earth, except that it applies to Saturn instead.

The rotational period of Saturn is 10 hours and 14 minutes. Use your answer in **(i)** to deduce whether the particle is in a stationary orbit about Saturn.

……..

……..…….. [2]

For Examiner's Use

(iii) Show that the radius r of the orbit of a particle moving with angular velocity ω around Saturn is given by the expression

$$r^3\omega^2 = GM,$$

where M is the mass of Saturn. Assume that Saturn is a point mass.

[2]

(iv) Hence, show that the mass of Saturn is 5.7×10^{26} kg.

[2]

[Turn over

For Examiner's Use

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

……..

……..

…….. [2]

(ii) On Fig 8.1, draw equipotential lines to illustrate the gravitational field around Saturn.

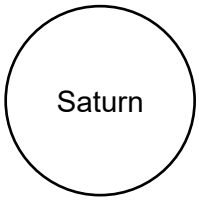

Fig. 8.1

[2]

(iii) Determine the minimum additional velocity required for the particle in **(b)** to escape from Saturn's gravitational field.

minimum additional velocity = ……... m s^{-1} [3]

For Examiner's Use

(d) Saturn's largest moon, Titan, is the second largest moon in the solar system. Titan has a radius of 2580 km and is 1.22×10^6 km from Saturn. The mass of Titan is 1.4×10^{23} kg. Ignore the effect of other nearby masses.

(i) Determine the distance from the centre of Titan where the resultant gravitational field strength between Titan and Saturn is zero.

distance = ... m [3]

(ii) On Fig. 8.2, sketch the variation with distance from the centre of Titan of the gravitational field strength along the line joining the centres of Titan and Saturn. The graph should range from Titan's surface to Saturn's surface.

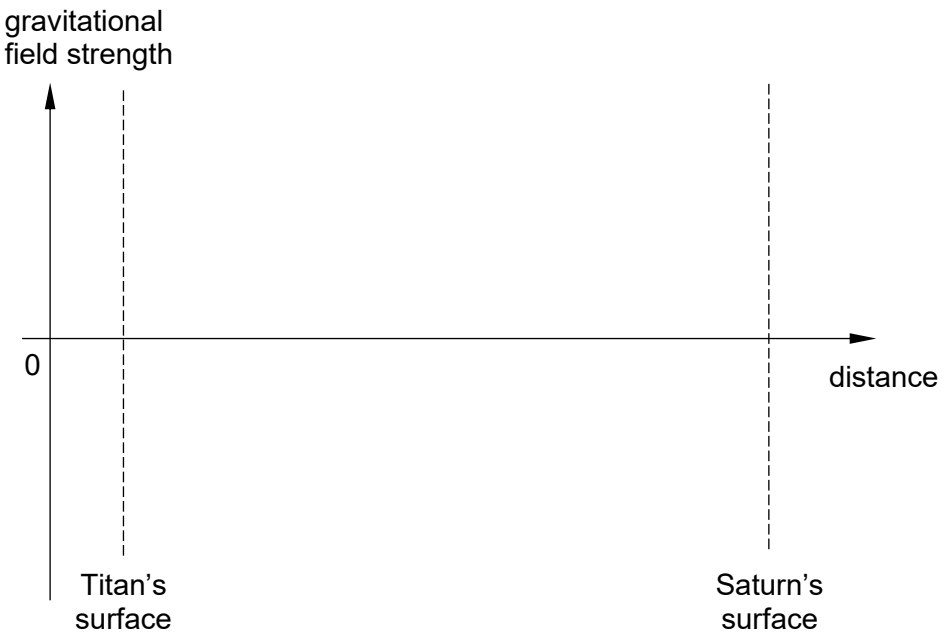

Fig. 8.2

[2]

[Total: 20]