8 **(a)** State Newton's law of gravitation.

....

....

....

....

[2]

(b) A satellite of mass m moving at speed v in a circular orbit of radius r about the Earth (as shown in Fig. 8.1) behaves as though the Earth's mass M were concentrated at its centre.

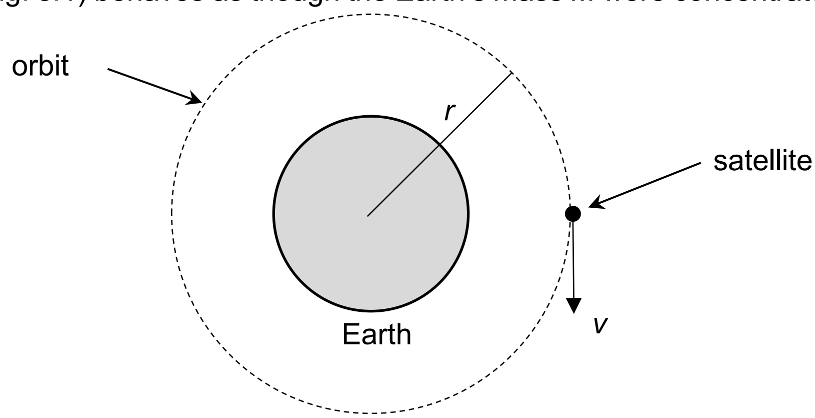

Fig. 8.1 (not drawn to scale)

(i) Show that the satellite's potential energy E_p and kinetic energy E_k are related by the expression $E_p = -2E_k$.

[3]

(ii) Sketch on Fig. 8.2 the variation with orbital radius of the satellite's
1. gravitational potential energy E_p,
2. kinetic energy E_k
3. total energy E_T

Fig. 8.2

[2]

(c) It is given that $r = 6.70 \times 10^6$ m, $m = 1.80 \times 10^3$ kg and $M = 5.98 \times 10^{24}$ kg.

(i) Calculate the satellite's orbital speed.

orbital speed = ………………………….. km h^{-1}

[2]

(ii) For the satellite to be geostationary at this orbital radius, it must orbit at a speed of about 487 m s^{-1}. Explain, in terms of centripetal force, why the geostationary orbit is not possible at this orbital radius.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

[1]

(d) As a result of atmospheric friction, the radius of the satellite's orbit about the Earth decreases by 0.2% in a week.

(i) State the energy conversion taking place during the orbital decay.

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

(ii) Assuming that the orbit remains circular, determine the percentage change in the satellite's total energy in a week. The total energy of the satellite is given by $E_T = -\dfrac{GMm}{2r}$.

percentage change = ………………………….%

[1]

(iii) By considering the satellite's rate of loss of energy and your answer to **(c)(i)**, show that the frictional force acting on the satellite is 0.023 N.

[3]

(e) To counter orbital decay, the satellite carries a small booster motor. The force exerted by the motor is equal to uz where z is the rate at which fuel is burnt (mass per unit time), and u has a value of 2.00×10^3 N s kg^{-1}.

(i) Draw in Fig. 8.3 labelled arrows showing (at this particular instant)

1. the direction of the satellite's change in velocity (label X) and

2. the direction of the force exerted by the booster motor (label Y).

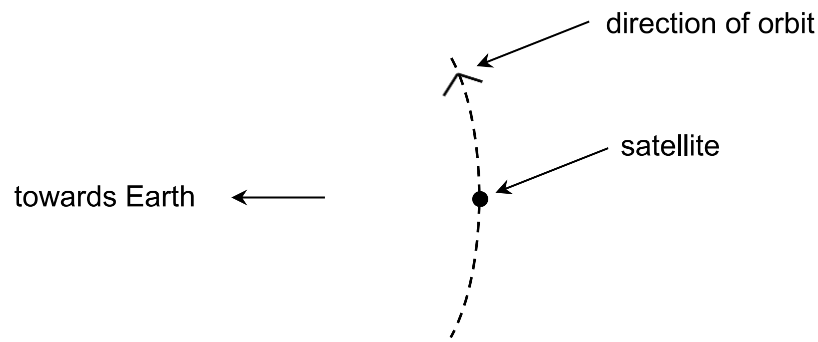

Fig. 8.3

[2]

(ii) Determine the amount of fuel necessary for the satellite to maintain its orbit for 24 hours.

amount of fuel = …………………………..kg

[2]