1 **(a)** The angular velocity ω of a satellite in a circular orbit of radius r about the Earth is given by:

$$\omega = A r^{k}$$

where A and k are constants.

(i) Use Newton's law of gravitation to write an equation that relates the centripetal force on the satellite to the gravitational force acting on the satellite and determine the value of k.

k = ... [2]

(ii) A geostationary orbit has a radius of 42 000 km.

Determine the angular velocity of a satellite with an orbital radius of 6700 km.

angular velocity = ... rad s^{-1} [2]

(b) **(i)** By considering the potential energy and kinetic energy of the satellite, show that the total energy E_T of the satellite in a circular orbit of radius r about the Earth is given by:

$$E_T = -\frac{GMm}{2r}$$

where M and m are the masses of the Earth and the satellite respectively.

[2]

(ii) When a geostationary satellite is near the end of its useful life, it will be decommissioned and moved to a graveyard orbit. A graveyard orbit is an orbit that lies far away from common orbits used by satellites in service and its radius is at least 300 km more than that of the geostationary orbit.

The mass of the Earth is 6.0×10^{24} kg.

Determine the minimum energy needed to bring a geostationary satellite of mass 700 kg to a graveyard orbit from a geostationary orbit.

minimum energy = ... J [2]

(c) The Moon is the Earth's only natural satellite. Its orbital path is actually elliptical and not circular. Fig. 1.1 shows the orbit of the Moon about the Earth when viewed normal to the plane of the orbit of the Moon. There are points where the Moon is closer to the Earth and points when it is further from the Earth.

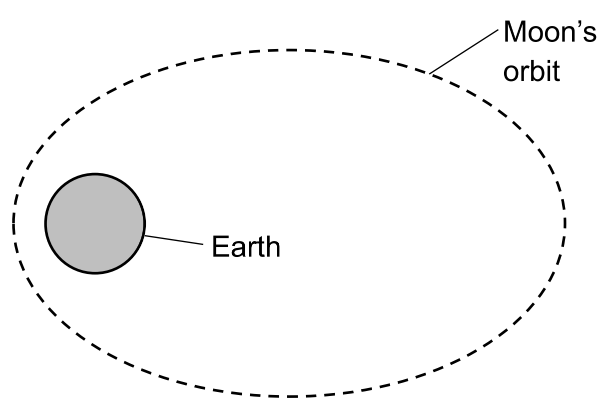

Fig. 1.1 (not to scale)

On Fig. 1.1, mark with a cross on the Moon's orbit where the Moon has the largest speed. Explain your answer.

....

....

.... [1]