

- 5 (a) The value of the gravitational potential  $\phi$  at a distance  $x$  from a point mass  $M$  is given by the expression

$$\phi = -\frac{GM}{x}$$

where  $G$  is the gravitational constant.

- (i) Define *gravitational potential*.

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..... [1]

- (ii) Explain why gravitational potential is a negative quantity.

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..... [2]

- (b) A satellite is launched from the surface of the Earth.

- (i) The Earth has a radius of 6400 km and a mass of  $6.0 \times 10^{24}$  kg. The mass of the satellite is 1600 kg.

Calculate the change in gravitational potential energy  $\Delta E_p$  of the satellite as it moves from the surface of the Earth to a height of  $2.1 \times 10^7$  m above the surface of the Earth.

$$\Delta E_p = ..... \text{ J} \quad [2]$$

- (ii) The satellite then orbits the Earth about the centre of the Earth.

1. Show that the speed  $v$  of the satellite in its orbit is given by the expression

$$v = \sqrt{\frac{GM_E}{r}}$$

where  $M_E$  is the mass of the Earth and  $r$  is the radius of orbit.

Explain your working.

[2]

2. While in orbit, the thruster of the satellite is fired. The satellite is given a boost such that it has just enough energy to travel out into space.

Determine the ratio

$$\frac{\text{kinetic energy of the satellite just after the boost}}{\text{kinetic energy of the satellite just before the boost}}.$$

ratio = .....

[3]