

- 3 (a) (i) Define *gravitational potential* at a point.

.....

 [2]

- (ii) Explain why gravitational potential is negative.

.....

 [3]

- (b) A moon of mass M and radius R orbits a planet of mass $3M$ and radius $2R$. At a particular time, the distance between their centres is D , as shown in Fig. 3.1.

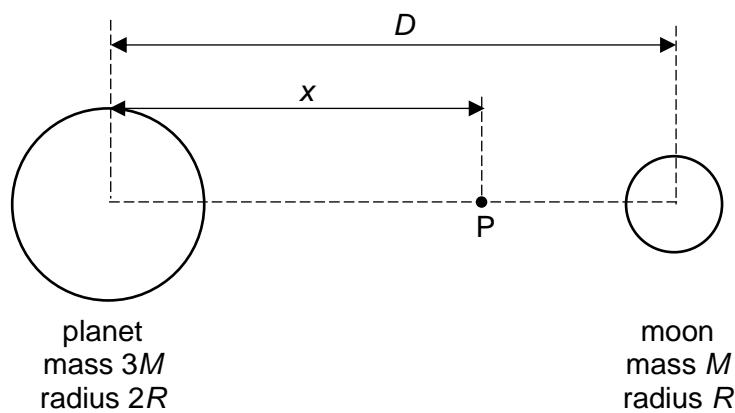
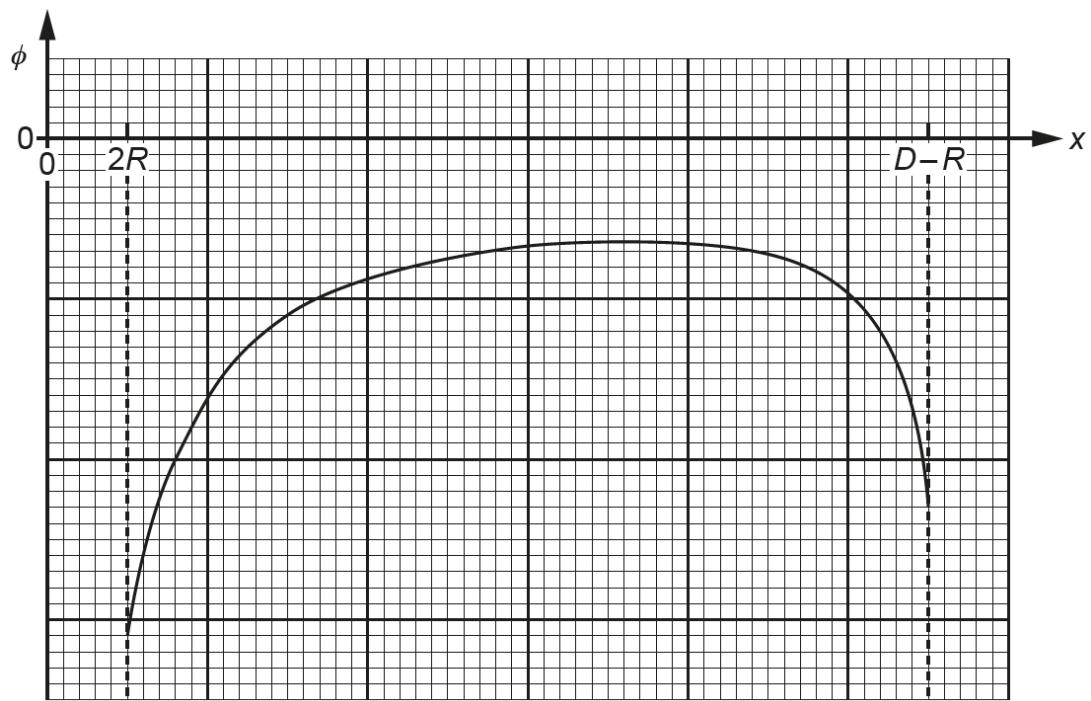


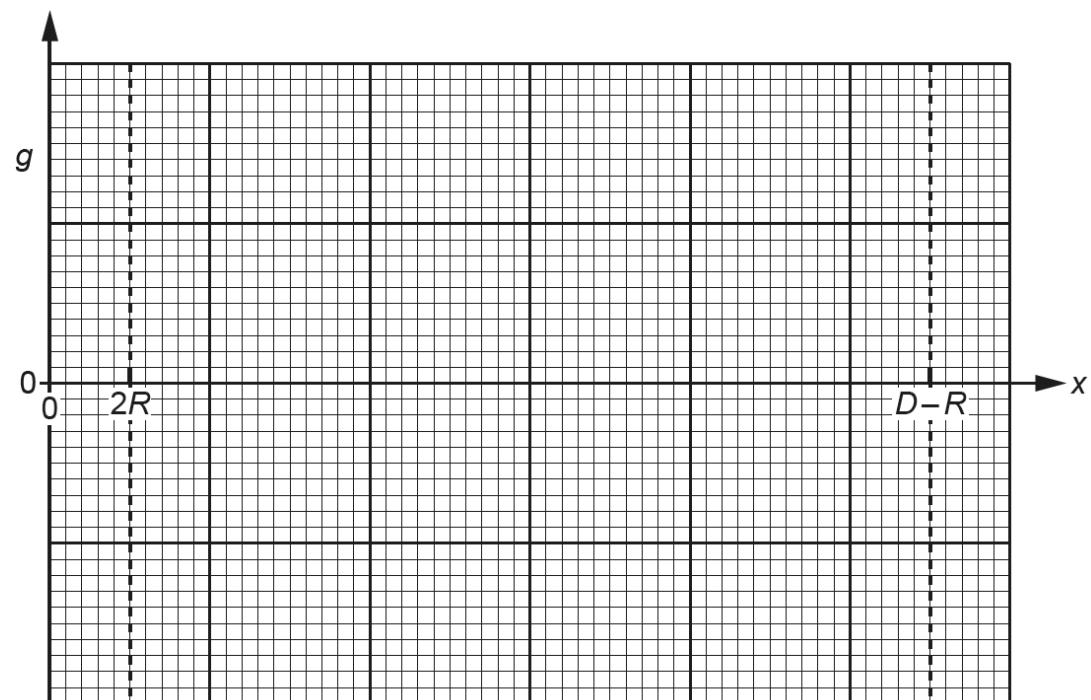
Fig. 3.1

Point P is a point along the line between the centres of the planet and the moon, at a variable distance x from the centre of the planet.

The variation with x of the gravitational potential ϕ at point P, for points between the planet and the moon, is shown in Fig. 3.2.

**Fig. 3.2**

On Fig 3.3, sketch the variation with x of the gravitational field strength g at point P between $x = 2R$ to $x = D - R$.

**Fig. 3.3**

[2]

- (c) The Earth and the Moon may be considered to be isolated in space with their masses concentrated at their centres.

The orbit of the Moon around the Earth is circular with a radius of 3.84×10^5 km.
The radius of the Earth is 6.37×10^3 km and the mass of the Moon is 7.35×10^{22} kg.

- (i) Given that the gravitational field strength at the Earth's surface is 9.81 N kg^{-1} , show that the gravitational force on the Moon is 1.98×10^{20} N.

[2]

- (ii) Tidal action on the Earth's surface causes the radius of the orbit of the Moon to increase by 4.0 cm each year.

Using the answer in (c)(i), calculate the change, in one year, of the gravitational potential energy of the Moon. Explain your working.

energy change = J [3]

[Total: 12]