Gravitational Field - 2021 A2

1. Nov/2021/Paper_41/No.2

(a) Define *gravitational potential*.

....

....

.... [2]

(b) The Earth E and the Moon M can both be considered as isolated point masses at their centres. The mass of the Earth is 5.98×10^{24} kg and the mass of the Moon is 7.35×10^{22} kg. The Earth and the Moon are separated by a distance of 3.84×10^{8} m, as shown in Fig. 2.1.

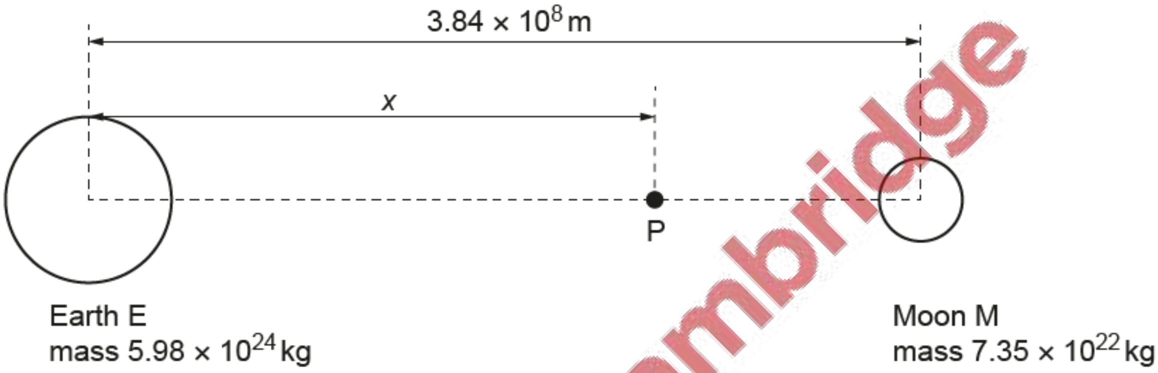

Fig. 2.1 (not to scale)

P is a point, on the line joining the centres of E and M, where the resultant gravitational field strength is zero. Point P is at a distance x from the centre of the Earth.

(i) Explain how it is possible for the gravitational field strength to be zero despite the presence of two large masses nearby.

....

....

.... [2]

(ii) Show that x is approximately 3.5×10^{8} m.

[2]

PapaCambridge

(iii) Calculate the gravitational potential ϕ at point P.

ϕ = ... $J\,kg^{-1}$ [3]

[Total: 9]

2. Nov/2021/Paper_42/No.2

(a) State the relationship between gravitational potential and gravitational field strength.

....

....

.... [2]

(b) A moon of mass *M* and radius *R* orbits a planet of mass 3*M* and radius 2*R*. At a particular time, the distance between their centres is *D*, as shown in Fig. 2.1.

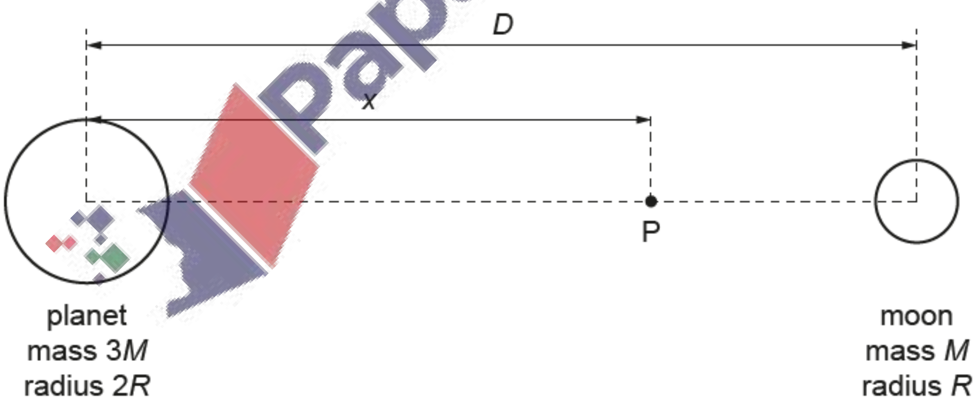

Fig. 2.1

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. 2.2.

PapaCambridge

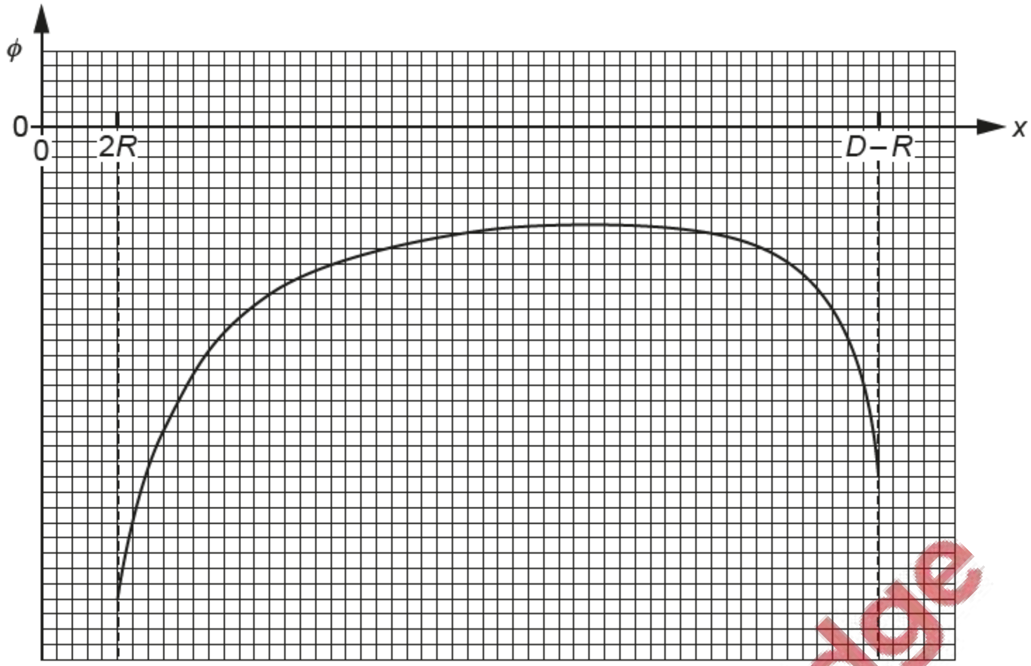

Fig. 2.2

(i) Explain why ϕ is negative throughout the entire range $x = 2R$ to $x = D - R$.

....

....

....

.... [3]

(ii) One of the features of Fig. 2.2 is that ϕ is negative throughout.

Describe **two** other features of Fig. 2.2.

1. ....

....

2. ....

....
[2]

PapaCambridge

(iii) On Fig. 2.3, sketch the variation with x of the gravitational field strength g at point P between $x = 2R$ and $x = D - R$.

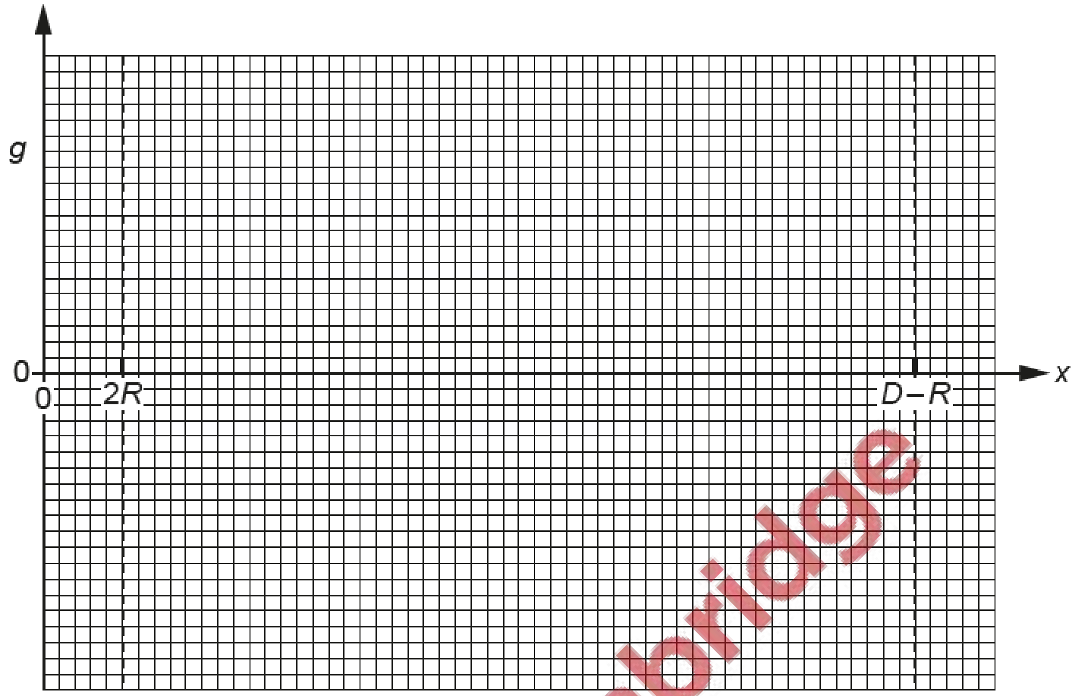

Fig. 2.3

[3]

[Total: 10]

PapaCambridge

3. June/2021/Paper_41/No.1

The Earth may be assumed to be an isolated uniform sphere with its mass of 6.0×10^{24} kg concentrated at its centre.

A satellite of mass 1200 kg is in a circular orbit about the Earth in the Earth's gravitational field. The period of the orbit is 94 minutes.

(a) Define *gravitational field strength*.

....

.... [1]

(b) Calculate the radius of the orbit of the satellite.

radius = ... m [3]

(c) Rockets on the satellite are fired so that the satellite enters a different circular orbit that has a period of 150 minutes. The change in the mass of the satellite may be assumed to be negligible.

(i) Show that the radius of the new orbit is 9.4×10^{6} m.

[2]

(ii) State, with a reason, whether the gravitational potential energy of the satellite increases or decreases.

....

.... [1]

PapaCambridge

(iii) Determine the magnitude of the change in the gravitational potential energy of the satellite.

change in potential energy = ... J [3]

[Total: 10]

4. June/2021/Paper_42/No.1

(a) Define *gravitational field strength*.

....

.... [1]

(b) An isolated planet is a uniform sphere of radius 3.39×10^6 m. Its mass of 6.42×10^{23} kg may be considered to be a point mass concentrated at its centre. The planet rotates about its axis with a period of 24.6 hours.

For an object resting on the surface of the planet at the equator, calculate, to three significant figures:

(i) the gravitational field strength

field strength = ... $N\,kg^{-1}$ [2]

PapaCambridge

(ii) the centripetal acceleration

acceleration = ... $m s^{-2}$ [2]

(iii) the force per unit mass exerted on the object by the surface of the planet.

force per unit mass = ... $N kg^{-1}$ [1]

[Total: 6]

PapaCambridge

5. March/2021/Paper_42/No.1

(a) State Newton's law of gravitation.

....

....

.... [2]

(b) Planets have been observed orbiting a star in another solar system. Measurements are made of the orbital radius *r* and the time period *T* of each of these planets.

The variation with R^3 of T^2 is shown in Fig. 1.1.

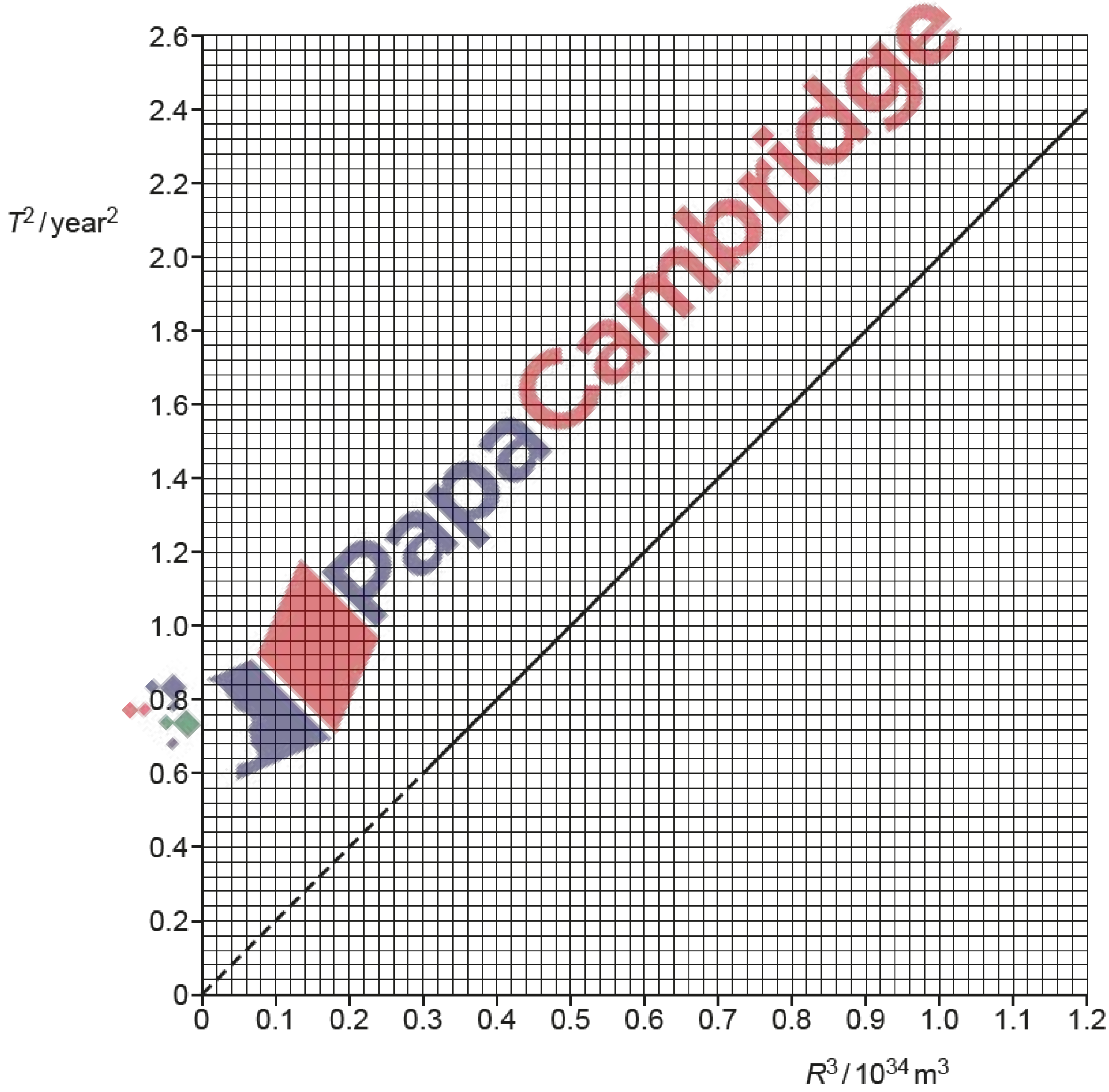

Fig. 1.1

The relationship between T and R is given by

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

where G is the gravitational constant and M is the mass of the star.

Determine the mass M.

M = ... kg [3]

(c) A rock of mass m is also in orbit around the star in **(b)**. The radius of the orbit is r.

(i) Explain why the gravitational potential energy of the rock is negative.

....

....

....

.... [3]

(ii) Show that the kinetic energy E_k of the rock is given by

$$E_k = \frac{GMm}{2r}.$$

[2]

(iii) Use the expression in **(c)(ii)** to derive an expression for the total energy of the rock.

[2]

[Total: 12]

PapaCambridge