Gravitational Field - 2020 A2

1. Nov/2020/Paper_41/No.1

(a) **(i)** State what is meant by a *field of force*.

....

....

.... [2]

(ii) Define *gravitational field strength*.

....

.... [1]

(b) An isolated planet may be assumed to be a uniform sphere of radius 3.39×10^6 m with its mass of 6.42×10^{23} kg concentrated at its centre.

Calculate the gravitational field strength at the surface of the planet.

field strength = ... $N\,kg^{-1}$ [3]

(c) Calculate the height above the surface of the planet in **(b)** at which the gravitational field strength is 1.0% less than its value at the surface of the planet.

height = ... m [3]

[Total: 9]

2. Nov/2020/Paper_42/No.1

(a) Define *gravitational potential* at a point.

....

....

.... [2]

(b) The Earth may be considered to be a uniform sphere of radius 6.4×10^6 m with its mass of 6.0×10^{24} kg concentrated at its centre.

A satellite of mass 2.4×10^3 kg is launched from the Equator. It is placed in an equatorial orbit at a height of 5.6×10^6 m above the Earth's surface.

(i) Calculate the change ΔE_P in gravitational potential energy of the satellite for its movement from the surface of the Earth to its position in the equatorial orbit.

ΔE_P = ... J [3]

(ii) Determine the speed of the satellite when in orbit.

speed = ... m s^{-1} [3]

(c) Before the satellite in **(b)** is launched, its speed at the Equator due to the Earth's rotation is $470\,m\,s^{-1}$.

Suggest why the energy required to launch the satellite depends on whether the satellite, in its orbit, is travelling from west to east or from east to west.

....

.... [1]

[Total: 9]

3. June/2020/Paper_41/No.1

(a) State what is meant by a *gravitational force*.

....

.... [1]

(b) A binary star system consists of two stars S_1 and S_2, each in a circular orbit.

The orbit of each star in the system has a period of rotation T.

Observations of the binary star from Earth are represented in Fig. 1.1.

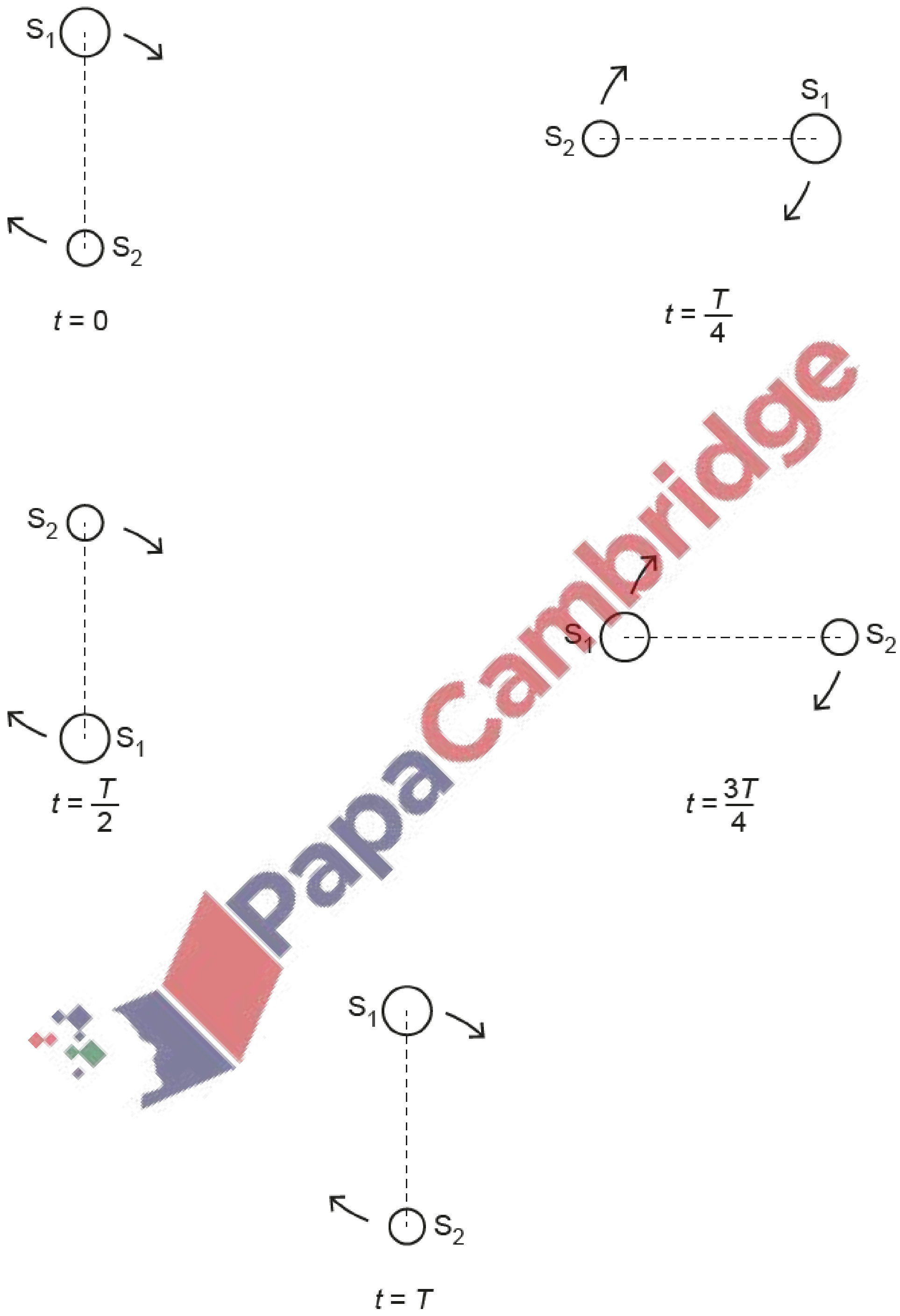

Fig. 1.1 (not to scale)

Observed from Earth, the angular separation of the centres of S_1 and S_2 is 1.2×10^{-5} rad. The distance of the binary star system from Earth is 1.5×10^{17} m.

Show that the separation d of the centres of S_1 and S_2 is 1.8×10^{12} m.

[1]

(c) The stars S_1 and S_2 rotate with the same angular velocity ω about a point P, as illustrated in Fig. 1.2.

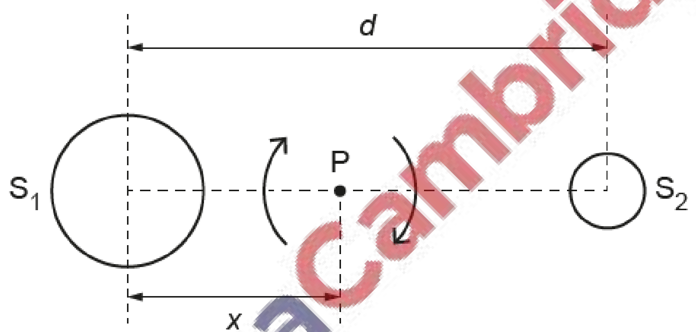

Fig. 1.2 (not to scale)

Point P is at a distance x from the centre of star S_1.
The period of rotation of the stars is 44.2 years.

(i) Calculate the angular velocity ω.

ω = ... rad s^{-1} [2]

(ii) By considering the forces acting on the two stars, show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d-x}{x}.$$

[2]

(iii) The mass M_1 of star S_1 is given by the expression

$$GM_1 = d^2(d-x)\omega^2$$

where G is the gravitational constant.

The ratio in **(ii)** is found to be 1.5.

Use data from **(b)** and your answer in **(c)(i)** to determine the mass M_1.

M_1 = ... kg [3]

[Total: 9]

4. June/2020/Paper_42/No.1

(a) Define *gravitational potential* at a point.

....

....

.... [2]

(b) An isolated solid sphere of radius *r* may be assumed to have its mass *M* concentrated at its centre. The magnitude of the gravitational potential at the surface of the sphere is ϕ.

On Fig. 1.1, show the variation of the gravitational potential with distance *d* from the centre of the sphere for values of *d* from $d = r$ to $d = 4r$.

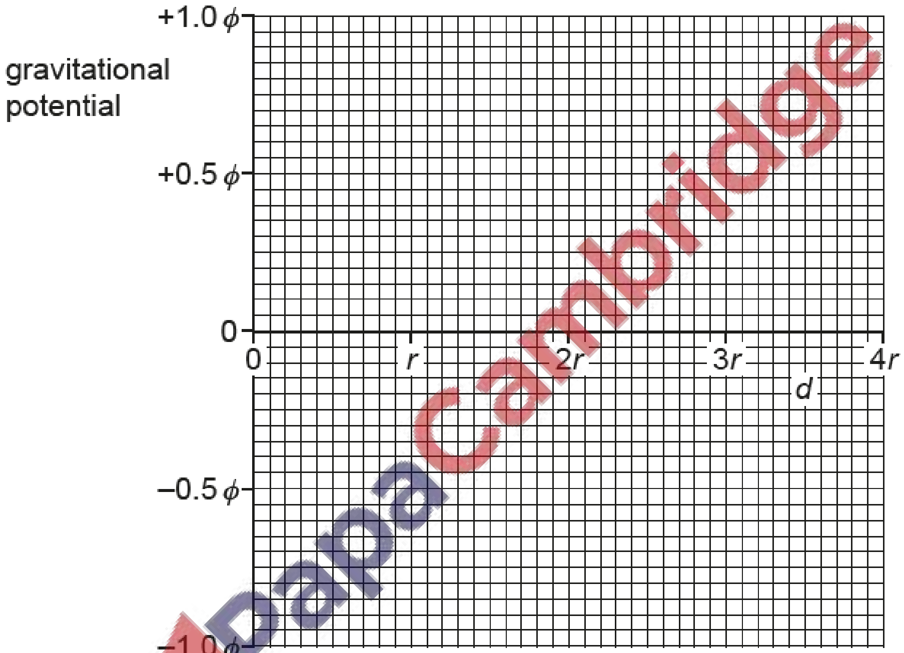

Fig. 1.1

[3]

(c) The sphere in **(b)** is a planet with radius r of 6.4×10^6 m and mass M of 6.0×10^{24} kg. The planet has no atmosphere.

A rock of mass 3.4×10^3 kg moves directly towards the planet. Its distance from the centre of the planet changes from $4r$ to $3r$.

(i) Calculate the change in gravitational potential energy of the rock.

change = ... J [3]

(ii) Explain whether the rock's speed increases, decreases or stays the same.

....

.... [2]

[Total: 10]

5. March/2020/Paper_42/No.1

(a) Define *gravitational potential* at a point.

....

....

.... [2]

(b) TESS is a satellite of mass 360 kg in a circular orbit about the Earth as shown in Fig. 1.1.

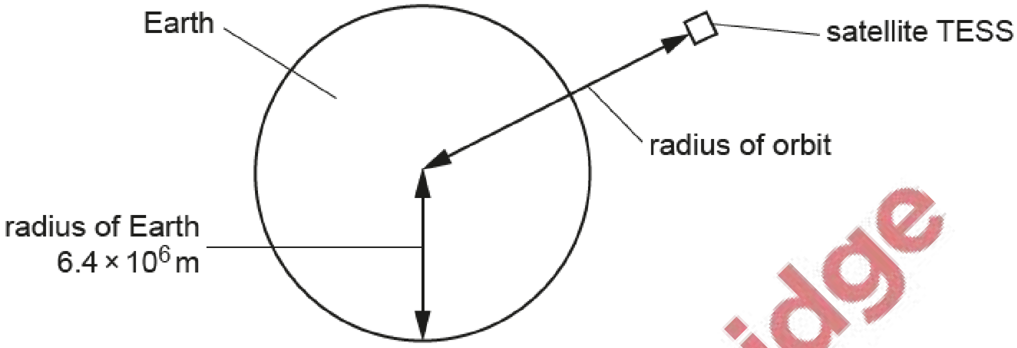

Fig. 1.1 (not to scale)

The radius of the Earth is 6.4×10^6 m and the mass of the Earth, considered to be a point mass at its centre, is 6.0×10^{24} kg.

(i) It takes TESS 13.7 days to orbit the Earth.

Show that the radius of orbit of TESS is 2.4×10^8 m.

[3]

(ii) Calculate the change in gravitational potential energy between TESS in orbit and TESS on a launch pad on the surface of the Earth.

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

(iii) Use the information in **(b)(i)** to calculate the ratio:

$$\frac{\text{gravitational field strength on surface of Earth}}{\text{gravitational field strength at location of TESS in orbit}}.$$

ratio = ... [2]

[Total: 10]