Gravitational Fields

Question paper 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Gravitational Fields
Sub Topic	
Paper Type	Theory
Booklet	Question paper 1

Time Allowed: **66 minutes**

Score: **/55**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) The planet Neptune has eight moons (satellites). Each moon orbits Neptune in a circular path of radius *r* with a period *T*.

Assuming that Neptune and each moon behave as point masses, show that *r* and *T* are related by the expression

$$GM_N = \frac{4\pi^2 r^3}{T^2}$$

where G is the gravitational constant and M_N is the mass of Neptune.

[3]

(c) Data for the moon Triton that orbits Neptune and for the moon Oberon that orbits the planet Uranus are given in Fig. 1.1.

planet	moon	radius of orbit $r\,/10^5\,\text{km}$	period of orbit $T\,/\,\text{days}$
Neptune	Triton	3.55	5.9
Uranus	Oberon	5.83	13.5

Fig. 1.1

Use the expression in **(b)** to determine the ratio

$$\frac{\text{mass of Neptune}}{\text{mass of Uranus}}.$$

ratio = ... [3]

2 **(a)** The Earth may be considered to be a uniform sphere of radius 6.37×10^3 km with its mass of 5.98×10^{24} kg concentrated at its centre. The Earth spins on its axis with a period of 24.0 hours.

(i) A stone of mass 2.50 kg rests on the Earth's surface at the Equator.

1. Calculate, using Newton's law of gravitation, the gravitational force on the stone.

gravitational force = ... N [2]

2. Determine the force required to maintain the stone in its circular path.

force = ... N [2]

(ii) The stone is now hung from a newton-meter.

Use your answers in **(i)** to determine the reading on the meter. Give your answer to three significant figures.

reading = ... N [2]

(b) A satellite is orbiting the Earth. For an astronaut in the satellite, his sensation of weight is caused by the contact force from his surroundings.

The astronaut reports that he is 'weightless', despite being in the Earth's gravitational field.

Suggest what is meant by the astronaut reporting that he is 'weightless'.

....

....

....

....[3]

3 An isolated spherical planet has a diameter of 6.8×10^6 m. Its mass of 6.4×10^{23} kg may be assumed to be a point mass at the centre of the planet.

(a) Show that the gravitational field strength at the surface of the planet is $3.7\,\text{N kg}^{-1}$.

[2]

(b) A stone of mass 2.4 kg is raised from the surface of the planet through a vertical height of 1800 m.
Use the value of field strength given in **(a)** to determine the change in gravitational potential energy of the stone.
Explain your working.

change in energy = ... J [3]

(c) A rock, initially at rest at infinity, moves towards the planet. At point P, its height above the surface of the planet is 3.5 *D*, where *D* is the diameter of the planet, as shown in Fig. 1.1.

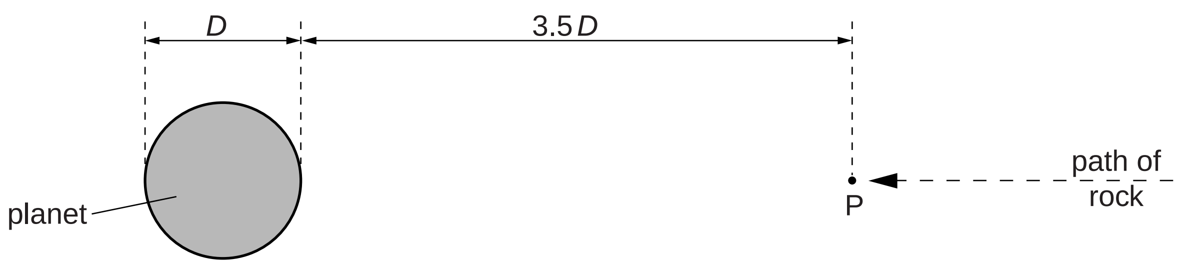

Fig. 1.1

Calculate the speed of the rock at point P, assuming that the change in gravitational potential energy is all transferred to kinetic energy.

speed = ... $m\,s^{-1}$ [4]

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

....

....

.... [2]

(b) A stone of mass m has gravitational potential energy E_P at a point X in a gravitational field. The magnitude of the gravitational potential at X is ϕ.

State the relation between m, E_P and ϕ.

.... [1]

(c) An isolated spherical planet of radius R may be assumed to have all its mass concentrated at its centre. The gravitational potential at the surface of the planet is $-6.30 \times 10^7\,\mathrm{J\,kg^{-1}}$.

A stone of mass 1.30 kg is travelling towards the planet such that its distance from the centre of the planet changes from 6R to 5R.

Calculate the change in gravitational potential energy of the stone.

change in energy = ... J [4]

5 The mass *M* of a spherical planet may be assumed to be a point mass at the centre of the planet.

(a) A stone, travelling at speed *v*, is in a circular orbit of radius *r* about the planet, as illustrated in Fig.1.1.

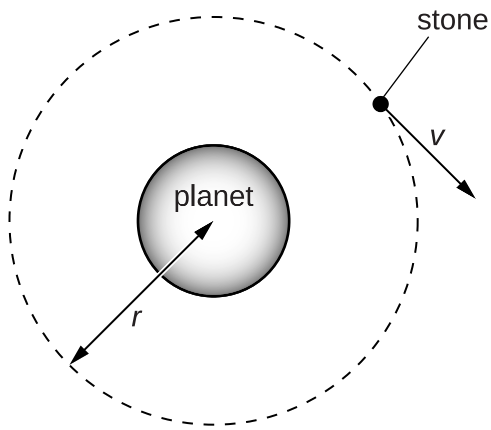

Fig.1.1

Show that the speed *v* is given by the expression

$$v = \sqrt{\left(\frac{GM}{r}\right)}$$

where *G* is the gravitational constant.
Explain your working.

[2]

(b) A second stone, initially at rest at infinity, travels towards the planet, as illustrated in Fig. 1.2.

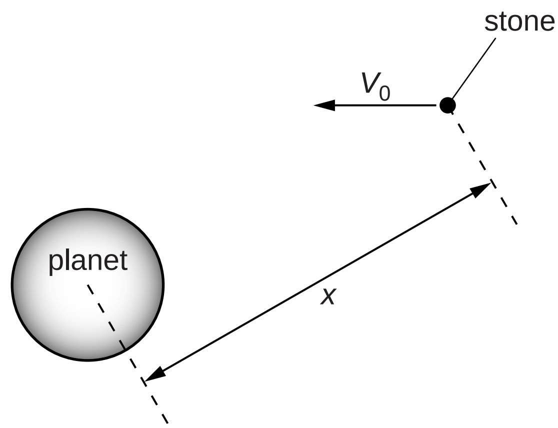

Fig. 1.2 (not to scale)

The stone does not hit the surface of the planet.

(i) Determine, in terms of the gravitational constant G and the mass M of the planet, the speed V_0 of the stone at a distance x from the centre of the planet. Explain your working. You may assume that the gravitational attraction on the stone is due only to the planet.

[3]

(ii) Use your answer in **(i)** and the expression in **(a)** to explain whether this stone could enter a circular orbit about the planet.

....

....

....

.... [2]

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

....

....

.... [2]

(b) The Moon may be considered to be an isolated sphere of radius 1.74×10^3 km with its mass of 7.35×10^{22} kg concentrated at its centre.

(i) A rock of mass 4.50 kg is situated on the surface of the Moon. Show that the change in gravitational potential energy of the rock in moving it from the Moon's surface to infinity is 1.27×10^7 J.

[1]

(ii) The escape speed of the rock is the minimum speed that the rock must be given when it is on the Moon's surface so that it can escape to infinity.
Use the answer in **(i)** to determine the escape speed. Explain your working.

speed = ... $m s^{-1}$ [2]

(c) The Moon in **(b)** is assumed to be isolated in space. The Moon does, in fact, orbit the Earth.
State and explain whether the minimum speed for the rock to reach the Earth from the surface of the Moon is different from the escape speed calculated in **(b)**.

....

....

.... [2]

7 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) A star and a planet are isolated in space. The planet orbits the star in a circular orbit of radius R, as illustrated in Fig. 1.1.

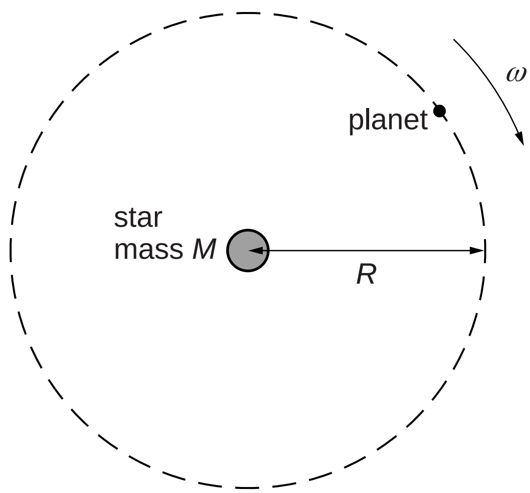

Fig. 1.1

The angular speed of the planet about the star is ω.
By considering the circular motion of the planet about the star of mass M, show that ω and R are related by the expression

$$R^3\omega^2 = GM$$

where G is the gravitational constant. Explain your working.

[3]

(c) The Earth orbits the Sun in a circular orbit of radius 1.5×10^8 km. The mass of the Sun is 2.0×10^{30} kg.
A distant star is found to have a planet that has a circular orbit about the star. The radius of the orbit is 6.0×10^8 km and the period of the orbit is 2.0 years.

Use the expression in **(b)** to calculate the mass of the star.

mass = ... kg [3]