Gravitational Fields

Question paper 3

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Gravitational Fields
Sub Topic	
Paper Type	Theory
Booklet	Question paper 3

Time Allowed: **69 minutes**

Score: **/57**

Percentage: **/100**

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

1 **(a)** Newton's law of gravitation applies to point masses.

(i) State Newton's law of gravitation.

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.....

..... [2]

(ii) Explain why, although the planets and the Sun are not point masses, the law also applies to planets orbiting the Sun.

.....

..... [1]

(b) Gravitational fields and electric fields show certain similarities and certain differences. State one aspect of gravitational and electric fields where there is

(i) a similarity,

.....

..... [1]

(ii) a difference.

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.....

..... [2]

2 **(a)** Define *gravitational field strength*.

.....

..... [1]

(b) An isolated star has radius R. The mass of the star may be considered to be a point mass at the centre of the star.
The gravitational field strength at the surface of the star is g_s.

On Fig. 1.1, sketch a graph to show the variation of the gravitational field strength of the star with distance from its centre. You should consider distances in the range R to $4R$.

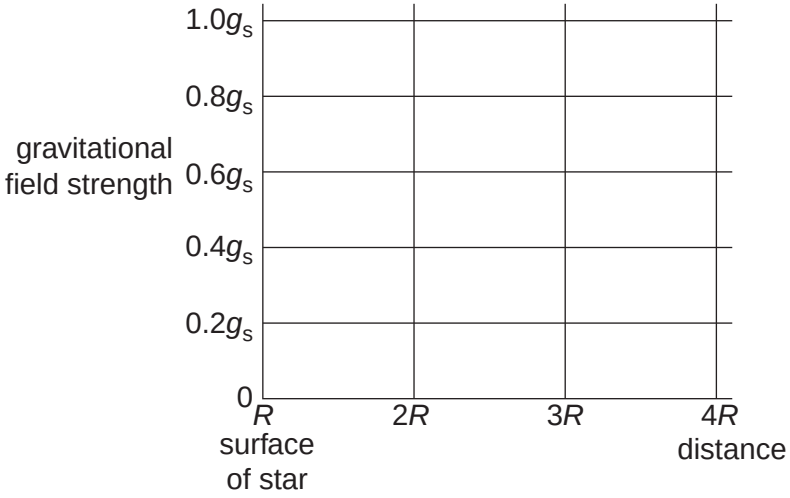

Fig. 1.1

[2]

(c) The Earth and the Moon may be considered to be spheres that are isolated in space with their masses concentrated at their centres.
The masses of the Earth and the Moon are 6.00×10^{24} kg and 7.40×10^{22} kg respectively.
The radius of the Earth is R_E and the separation of the centres of the Earth and the Moon is $60R_E$, as illustrated in Fig. 1.2.

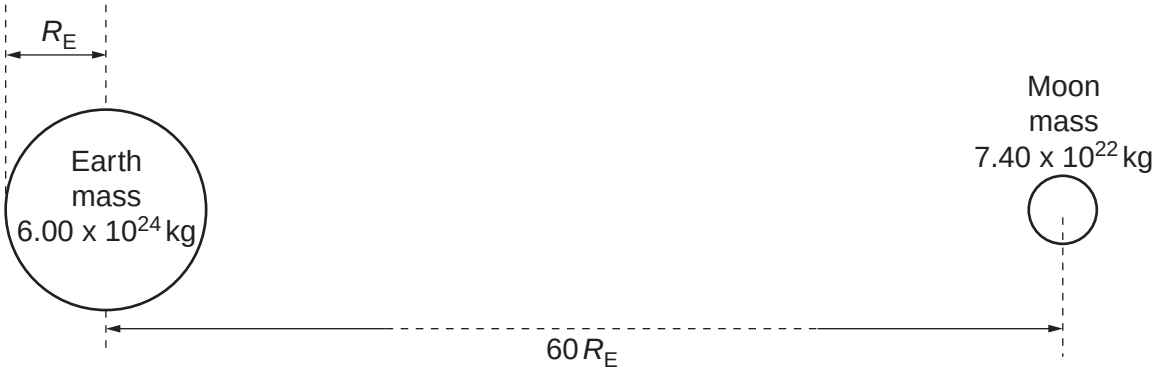

Fig. 1.2 (not to scale)

(i) Explain why there is a point between the Earth and the Moon at which the gravitational field strength is zero.

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.....[2]

(ii) Determine the distance, in terms of R_E, from the centre of the Earth at which the gravitational field strength is zero.

distance = ...R_E [3]

(iii) On the axes of Fig. 1.3, sketch a graph to show the variation of the gravitational field strength with position between the surface of the Earth and the surface of the Moon.

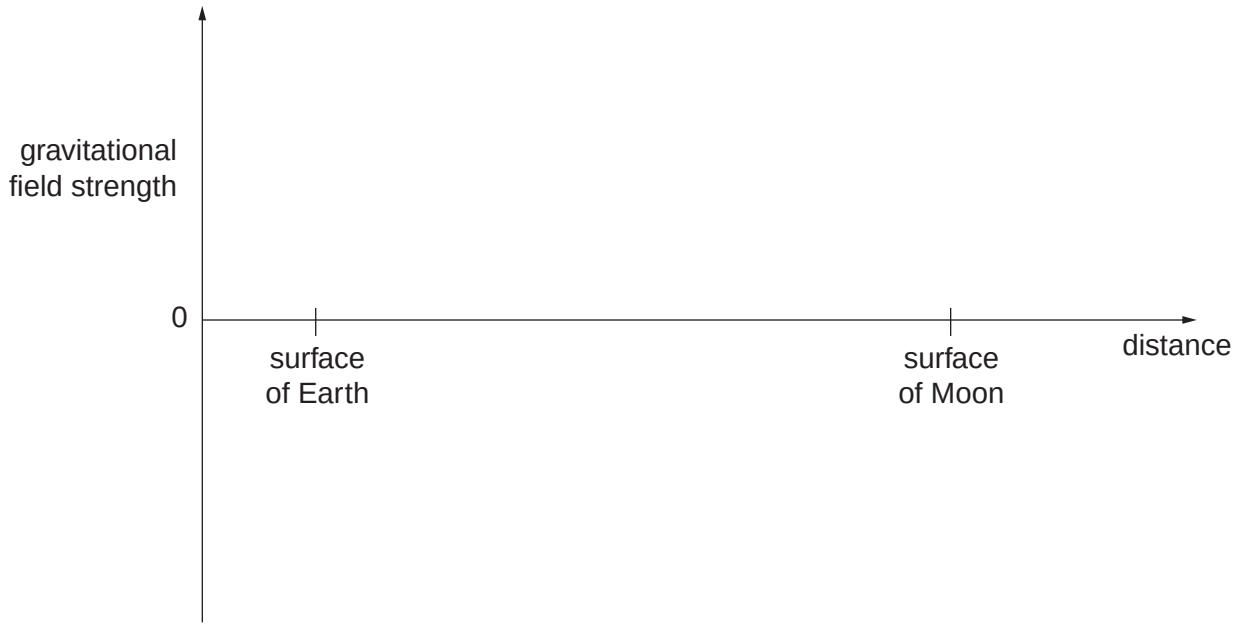

Fig. 1.3

[3]

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

.....

.....

..... [2]

(b) The Earth may be considered to be an isolated sphere of radius R with its mass concentrated at its centre.
The variation of the gravitational potential ϕ with distance x from the centre of the Earth is shown in Fig. 1.1.

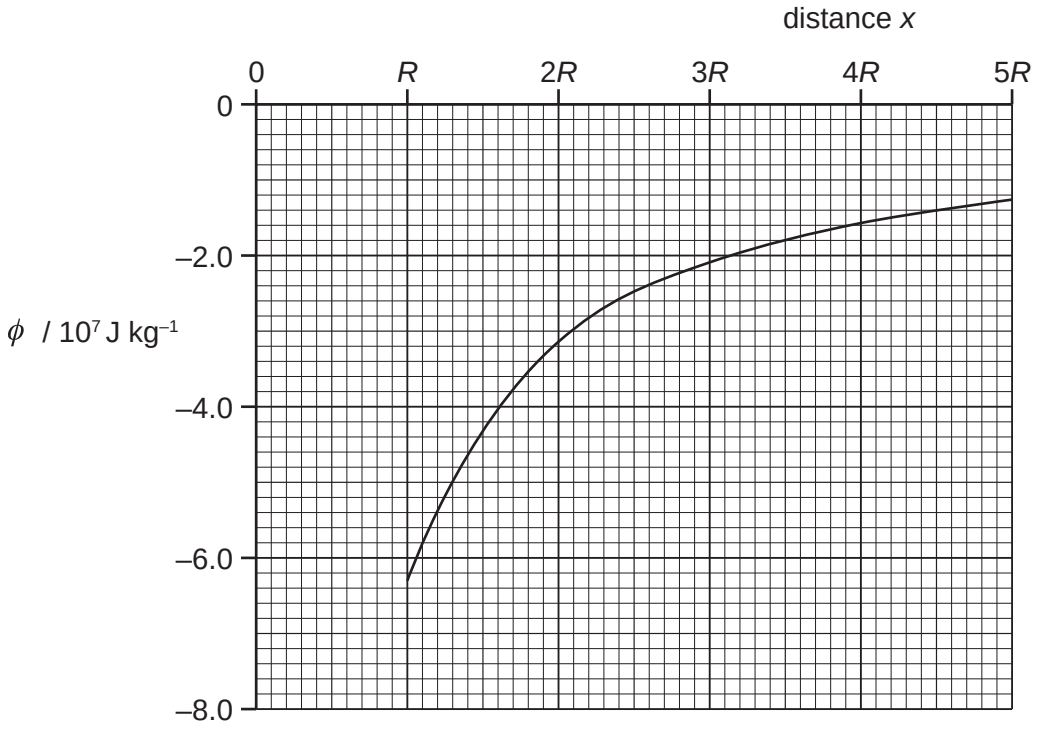

Fig. 1.1

The radius R of the Earth is 6.4×10^6 m.

(i) By considering the gravitational potential at the Earth's surface, determine a value for the mass of the Earth.

mass = ... kg [3]

(ii) A meteorite is at rest at infinity. The meteorite travels from infinity towards the Earth.

Calculate the speed of the meteorite when it is at a distance of 2*R* above the Earth's surface. Explain your working.

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

(iii) In practice, the Earth is not an isolated sphere because it is orbited by the Moon, as illustrated in Fig. 1.2.

Fig. 1.2 (not to scale)

The initial path of the meteorite is also shown.

Suggest two changes to the motion of the meteorite caused by the Moon.

1. .....

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2. .....

.....

[2]

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

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..... [2]

(b) The Earth may be considered to be a uniform sphere of radius R equal to 6.4×10^6 m.

A satellite is in a geostationary orbit.

(i) Describe what is meant by a *geostationary orbit.*

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.....

.....

..... [3]

(ii) Show that the radius x of the geostationary orbit is given by the expression

$$gR^2 = x^3\omega^2$$

where g is the acceleration of free fall at the Earth's surface and ω is the angular speed of the satellite about the centre of the Earth.

[3]

(iii) Determine the radius x of the geostationary orbit.

radius = ... m [3]

5 **(a)** The Earth may be considered to be a uniform sphere of radius 6.38×10^3 km, with its mass concentrated at its centre.

(i) Define *gravitational field strength*.

.....

..... [1]

(ii) By considering the gravitational field strength at the surface of the Earth, show that the mass of the Earth is 5.99×10^{24} kg.

[2]

(b) The Global Positioning System (GPS) is a navigation system that can be used anywhere on Earth. It uses a number of satellites that orbit the Earth in circular orbits at a distance of 2.22×10^4 km above its surface.

(i) Use data from **(a)** to calculate the angular speed of a GPS satellite in its orbit.

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

(ii) Use your answer in **(i)** to show that the satellites are not in geostationary orbits.

[3]

(c) The planes of the orbits of the GPS satellites in **(b)** are inclined at an angle of 55° to the Equator.

Suggest why the satellites are not in equatorial orbits.

.....

..... [1]

6 **(a)** Define *gravitational field strength*.

.....

..... [1]

(b) A spherical planet has diameter 1.2×10^4 km. The gravitational field strength at the surface of the planet is $8.6\,\text{N kg}^{-1}$.
The planet may be assumed to be isolated in space and to have its mass concentrated at its centre.
Calculate the mass of the planet.

mass = ... kg [3]

(c) The gravitational potential at a point X above the surface of the planet in **(b)** is $-5.3 \times 10^7\,\text{J kg}^{-1}$.
For point Y above the surface of the planet, the gravitational potential is $-6.8 \times 10^7\,\text{J kg}^{-1}$.

(i) State, with a reason, whether point X or point Y is nearer to the planet.

.....

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..... [2]

(ii) A rock falls radially from rest towards the planet from one point to the other.
Calculate the final speed of the rock.

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