LONDON SCIENCE COLLEGE

Name:

Date:

GRAVITATIONAL FIELDS
TEST 2

A2-Level

Mark | Grade

PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

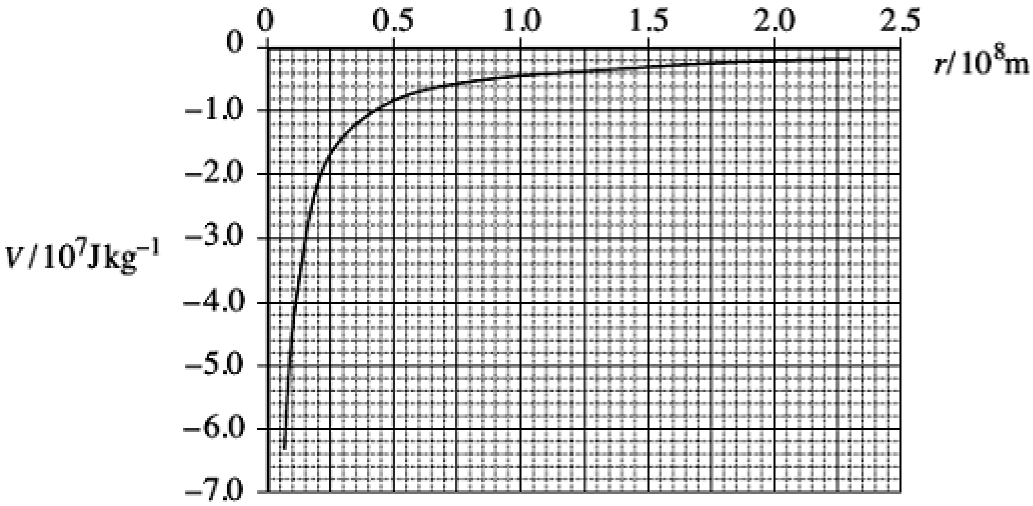
Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

Information

- The marks for the questions are shown in brackets

1 The figure below shows the variation of gravitational potential, V, with distance from the centre of the Earth, r. The radius of the Earth is 6.4×10^6 m.



(a) Explain why the V values are negative.

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(3)

(b) Use data from the graph to show that the mass of the Earth is approximately 6×10^{24} kg.

(3)

(c) (i) Calculate the work done in raising a satellite of mass 2100 kg from the surface of the Earth to a height of 850 km above the surface of the Earth.

work done ______________________ J

(3)

(ii) Calculate the change in the kinetic energy of the satellite when it moves from its 850 km orbit to one at a height of 700 km above the Earth's surface. Make it clear whether the change in kinetic energy is an increase or decrease.

kinetic energy change ______________________ J

(4)

(iii) Without performing any further calculations explain how the change in kinetic energy relates to the change of the potential energy when the satellite's orbit alters as in part (c)(ii).

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(2)

(Total 15 marks)

2 (a) Explain why the mass of an object is constant but its weight may change.

(3)

(b) The table gives the gravitational potentials, V, at three different distances, r, from the centre of the Earth.

distance from centre of Earth **r / km**	**gravitational potential** **V / 10^7 J kg^{-1}**
7500	–5.36
12500	–3.22
22500	–1.79

(i) Explain why the gravitational potential at a point in a gravitational field is negative.

(2)

(ii) Show that the data in the table are consistent with $V \propto r^{-1}$.

(3)

(iii) A satellite of mass 450 kg is moved from an orbit of radius 7500 km around the Earth to an orbit of radius 12 500 km.

Use data from the table to show that the potential energy of the satellite increases, by about 10 GJ.

(2)

(c) The kinetic energy of a 450 kg satellite orbiting the Earth with a radius of 7500 km is 12 GJ.

(i) Calculate the kinetic energy of the 450 kg satellite when it is in an orbit of radius 12 500 km.

mass of the Earth = 6.0×10^{24} kg

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kinetic energy ____________________ GJ

(4)

(ii) Calculate the change in kinetic energy of the satellite when it moves into the higher orbit.

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change in kinetic energy ____________________ GJ

(1)

(iii) Calculate the **total** energy that has to be supplied to move the 450 kg satellite from an orbit of radius 7500 km to an orbit of radius 12 500 km.

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total energy ____________________ GJ

(1)

(Total 16 marks)

3 The Hubble space telescope was launched in 1990 into a circular orbit near to the Earth. It travels around the Earth once every 97 minutes.

(a) Calculate the angular speed of the Hubble telescope, stating an appropriate unit.

answer = ______________________

(3)

(b) (i) Calculate the radius of the orbit of the Hubble telescope.

answer = ______________________ m

(3)

(ii) The mass of the Hubble telescope is 1.1×10^4 kg. Calculate the magnitude of the centripetal force that acts on it.

answer = ______________________ N

(2)

(Total 8 marks)

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

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(2)

(b) In 1798 Cavendish investigated Newton's law by measuring the gravitational force between two unequal uniform lead spheres. The radius of the larger sphere was 100 mm and that of the smaller sphere was 25 mm.

(i) The mass of the smaller sphere was 0.74 kg. Show that the mass of the larger sphere was about 47 kg.

density of lead = 11.3×10^3 kg m^{-3}

(2)

(ii) Calculate the gravitational force between the spheres when their surfaces were in contact.

answer = ______________________ N

(2)

(c) Modifications, such as increasing the size of each sphere to produce a greater force between them, were considered in order to improve the accuracy of Cavendish's experiment. Describe and explain the effect on the calculations in part (b) of doubling the radius of both spheres.

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(4)

(Total 10 marks)

5 (a) The weight w of an object on the Earth can be represented either as $w = mg$ or $w = \frac{GMm}{r^2}$.

(i) Explain the meaning of g and G in these equations.

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(3)

(ii) Use the equations above to show that $M = \frac{gr^2}{G}$.

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(1)

(iii) Calculate the mass of the Earth to a precision consistent with the data below.

mean radius of the Earth, = 6.4×10^6 m

$G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}

$g = 9.8$ N kg^{-1}

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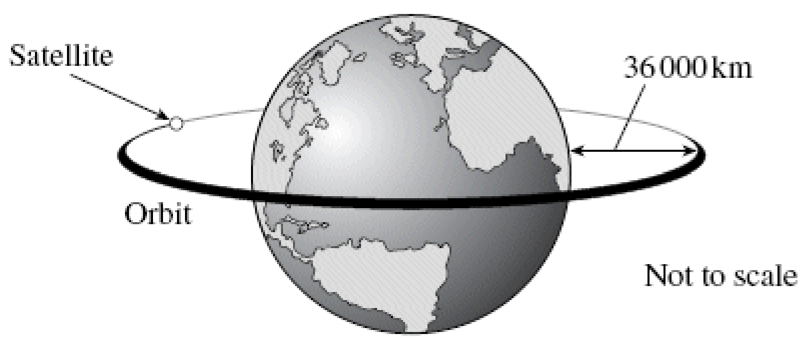
mass of the Earth ______________________ kg

(3)

(b) The figure below shows a satellite in a geostationary orbit around the Earth.



(i) State the time period for a geostationary satellite.

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(1)

(ii) The height of a geostationary satellite in orbit is approximately 36 000 km above the surface of the Earth.
Calculate the radius of a geostationary orbit.

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radius ______________________ m

(1)

(iii) Calculate the speed, in km s^{-1}, of a satellite in a geostationary orbit.

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speed ______________________ km s^{-1}

(3)

(iv) State a common use for a geostationary satellite.

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(1)

(v) Explain why a geostationary orbit is necessary for this use.

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(1)

(Total 14 marks)

6 (a) (i) State the relationship between the *gravitational potential energy*, E_p, and the *gravitational potential*, V, for a body of mass m placed in a gravitational field.

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(1)

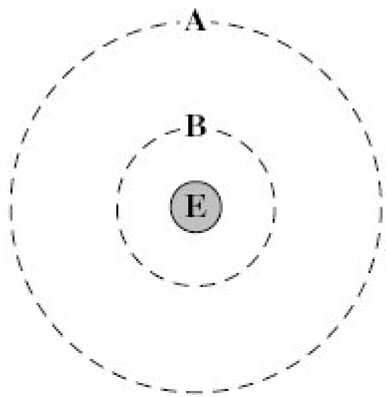
(ii) What is the effect, if any, on the values of E_p and V if the mass m is doubled?

value of E_p ____

value of V ____

(2)

(b)



The diagram above shows two of the orbits, **A** and **B**, that could be occupied by a satellite in circular orbit around the Earth, **E**.
The gravitational potential due to the Earth of each of these orbits is:

orbit **A** – 12.0 MJ kg^{-1}
orbit **B** – 36.0 MJ kg^{-1}.

(i) Calculate the radius, from the centre of the Earth, of orbit **A**.

answer = ____________________ m

(2)

(ii) Show that the radius of orbit **B** is approximately 1.1×10^4 km.

(1)

(iii) Calculate the centripetal acceleration of a satellite in orbit **B**.

answer = ____________________ m s^{-2}

(2)

(iv) Show that the gravitational potential energy of a 330 kg satellite decreases by about 8 GJ when it moves from orbit **A** to orbit **B**.

(1)

(c) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of a satellite as it moves between these orbits.

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(1)

(Total 10 marks)

7 The distance between the Sun and Mars varies from 2.1×10^{11} m to 2.5×10^{11} m.
When Mars is closest to the Sun, the force of gravitational attraction between them is F.

What is the force of gravitational attraction between them when they are furthest apart?

A $0.71F$ ☐

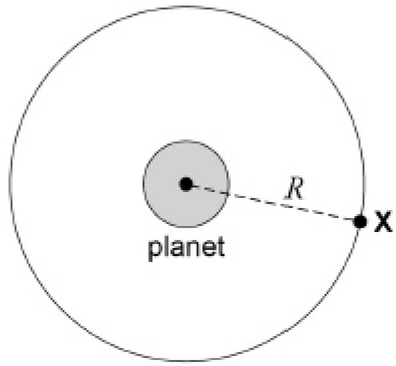
B $0.84F$ ☐

C $1.2F$ ☐

D $1.4F$ ☐

(Total 1 mark)

8 A satellite **X** of mass m is in a concentric circular orbit of radius R about a planet of mass M.



What is the kinetic energy of **X**?

A $\frac{GMm}{2R}$ ☐

B $\frac{GMm}{R}$ ☐

C $\frac{2GMm}{R}$ ☐

D $\frac{4GMm}{R}$ ☐

(Total 1 mark)

9 A capacitor of capacitance C has a charge of Q stored on the plates. The potential difference between the plates is doubled.

What is the change in the energy stored by the capacitor?

A $\frac{Q^2}{2C}$ ☐

B $\frac{Q^2}{C}$ ☐

C $\frac{3Q^2}{2C}$ ☐

D $\frac{2Q^2}{C}$ ☐

(Total 1 mark)

10 The distance between the centres of the Earth and the Moon is 3.8×10^8 m. The mass of the Earth is 6.0×10^{24} kg and the mass of the Moon is 7.4×10^{22} kg.

A spacecraft of mass 10×10^3 kg is moving along a line joining their centres.

At what distance from the centre of the Earth would the spacecraft experience no resultant force due to the Earth and the Moon?

A 3.8×10^7 m ☐

B 4.8×10^7 m ☐

C 3.4×10^8 m ☐

D 3.8×10^8 m ☐

(Total 1 mark)