LONDON SCIENCE COLLEGE

Name:

Date:

GRAVITATIONAL FIELDS
TEST 3

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

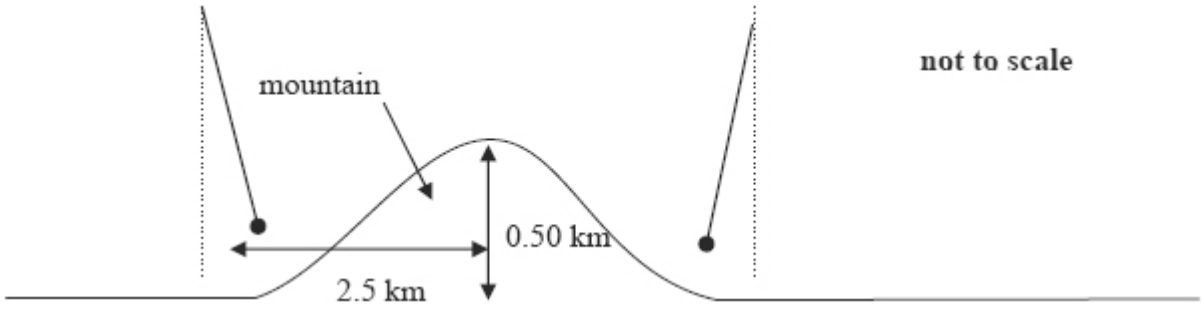
1 (a) Give **two** examples of the techniques used by geologists to obtain values of the strength of the local gravitational field of the Earth.
In each of your quoted examples, describe the information that the geologists can derive from their measurements.

(4)

In 1774, Nevil Maskelyne carried out an experiment near the mountain of Schiehallion in Scotland to determine the density of the Earth.

Figure 1 shows two positions of a pendulum hung near to, but on opposite sides of, the mountain. The centre of mass of the mountain is at the same height as the pendulum.

Figure 1



(b) (i) Explain why the pendulums do not point towards the centre of the Earth.

(2)

(ii) Suggest why Maskelyne carried out the experiment on both sides of the mountain.

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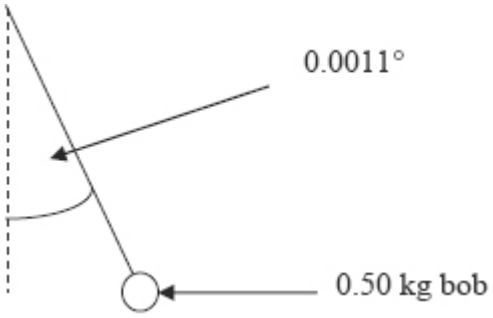
(1)

(c) **Figure 2** shows measurements made with the left-hand pendulum in **Figure 1**.

Figure 2



(i) The mountain is in the appropriate shape of a cone 0.50 km high and 1.3 km base radius; it rises from a locally flat plain.

Show that the mass of the mountain is about 2×10^{12} kg.

volume of a cone $= \frac{1}{3} \pi r^2 h$

density of rock = 2.5×10^3 kg m^{-3}

(3)

(ii) **Figure 2** shows the left-hand pendulum bob lying on a horizontal line that also passes through the centre of mass of the mountain. The bob is 1.4 km from the centre of the mountain and it hangs at an angle of 0.0011° to the vertical.

Calculate the mass of the Earth.

(3)

(iii) The answer Maskelyne obtained for the mass of the Earth was lower than today's accepted value even though he had an accurate value for the Earth's radius.

Suggest **one** reason why this should be so.

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(1)

(Total 14 marks)

2 (a) State, in words, Newton's law of gravitation.

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(3)

(b) By considering the centripetal force which acts on a planet in a circular orbit, show that $T^2 \propto R^3$, where T is the time taken for one orbit around the Sun and R is the radius of the orbit.

(3)

(c) The Earth's orbit is of mean radius 1.50×10^{11} m and the Earth's year is 365 days long.

(i) The mean radius of the orbit of Mercury is 5.79×10^{10} m. Calculate the length of Mercury's year.

(ii) Neptune orbits the Sun once every 165 Earth years.

Calculate the ratio $\frac{\text{distance from Sun to Neptune}}{\text{distance from Sun to Earth}}$.

(4)

(Total 10 marks)

3 (a) Explain what is meant by the *gravitational potential* at a point in a gravitational field.

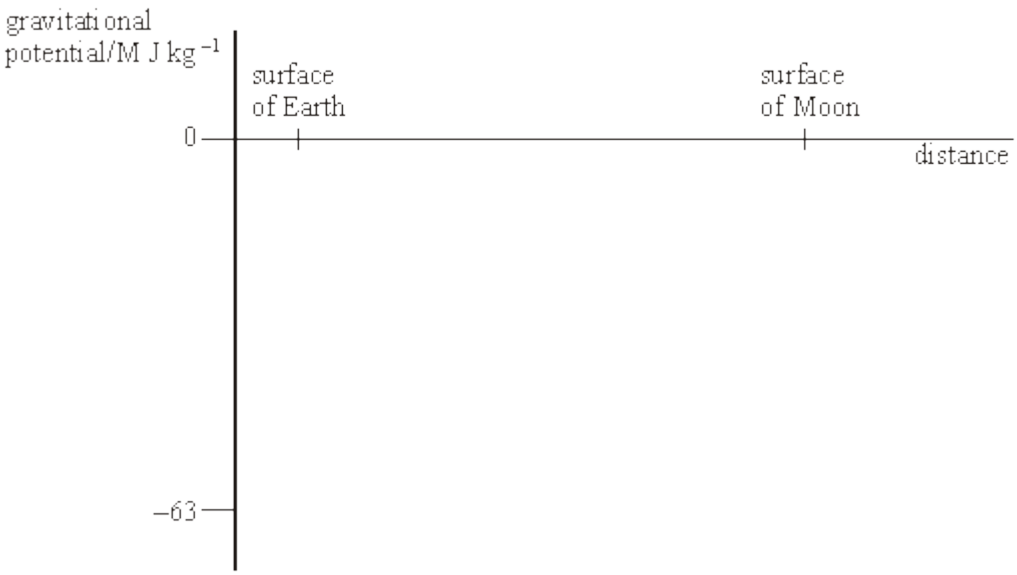
(2)

(b) Use the following data to calculate the gravitational potential at the surface of the Moon.

mass of Earth = 81 × mass of Moon
radius of Earth = 3.7 × radius of Moon
gravitational potential at surface of the Earth = –63 MJ kg^{-1}

(3)

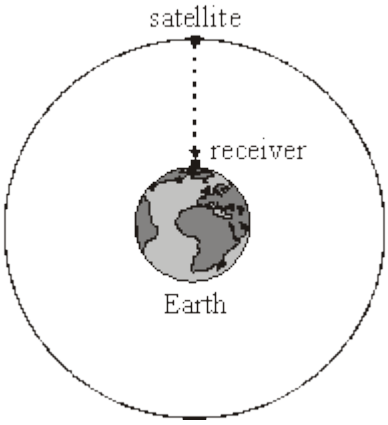
(c) Sketch a graph on the axes below to indicate how the gravitational potential varies with distance along a line outwards from the surface of the Earth to the surface of the Moon.



(3)

(Total 8 marks)

4 The Global Positioning System (GPS) is a system of satellites that transmit radio signals which can be used to locate the position of a receiver anywhere on Earth.



(a) A receiver at sea level detects a signal from a satellite in a circular orbit when it is passing directly overhead as shown in the diagram above.

(i) The microwave signal is received 68 ms after it was transmitted from the satellite. Calculate the height of the satellite.

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(ii) Show that the gravitational field strength of the Earth at the position of the satellite is 0.56 N kg^{-1}.

mass of the Earth = 6.0×10^{24} kg
mean radius of the Earth = 6400 km

(4)

(b) For the satellite in this orbit, calculate

(i) its speed,

(ii) its time period.

(5)

(Total 9 marks)

5 (a) Complete the table of quantities related to fields. In the second column, write an SI unit for each quantity. In the third column indicate whether the quantity is a scalar or a vector.

quantity	SI unit	scalar or vector
gravitational potential		
electric field strength		
magnetic flux density		

(3)

(b) (i) A charged particle is held in equilibrium by the force resulting from a vertical electric field. The mass of the particle is 4.3×10^{-9} kg and it carries a charge of magnitude 3.2×10^{-12} C. Calculate the strength of the electric field.

(ii) If the electric field acts upwards, state the sign of the charge carried by the particle

(3)

(Total 6 marks)

6 Communications satellites are usually placed in a *geo-synchronous orbit*.

(a) State **two** features of a geo-synchronous orbit.

(2)

(b) Given that the mass of the Earth is 6.00×10^{24} kg and its mean radius is 6.40×10^{6} m,

(i) show that the radius of a geo-synchronous orbit must be 4.23×10^{7} m,

(ii) calculate the increase in potential energy of a satellite of mass 750 kg when it is raised from the Earth's surface into a geo-synchronous orbit.

(6)

(Total 8 marks)

7 An electron on the surface of the Earth is placed in an electric field of strength 5000 N C^{-1}.

What is $\left(\frac{electric\ force}{gravitational\ force}\right)$ for the electron?

A 1.1×10^{-14} ⊙

B 2.9×10^{-10} ⊙

C 3.4×10^{9} ⊙

D 9.0×10^{13} ⊙

(Total 1 mark)

8 The radius of a planet is R. The gravitational potential at the surface of the planet due to its mass is −4000 J kg^{-1}.

What is the gravitational potential at a distance $2R$ from the centre of the planet?

A −1000 J kg^{-1} ⬭

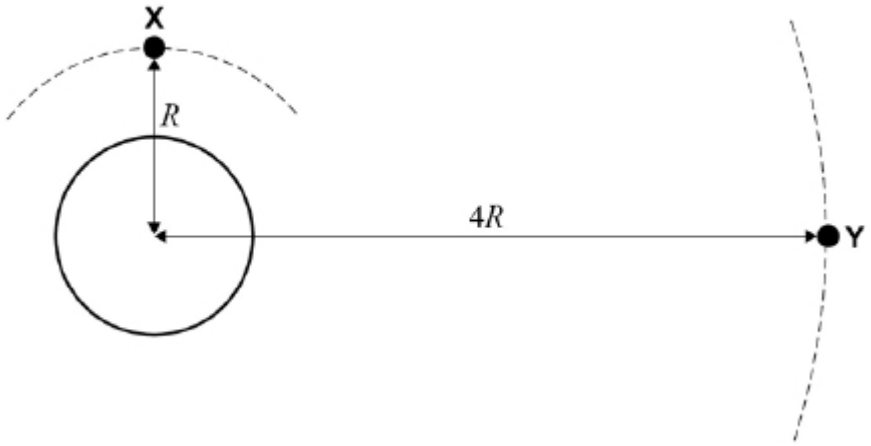
B −2000 J kg^{-1} ⬭

C −4000 J kg^{-1} ⬭

D −8000 J kg^{-1} ⬭

(Total 1 mark)

9 Satellites **X** and **Y** orbit the Earth at distances R and $4R$ respectively, as shown in the diagram.



Which statement is **incorrect**?

A The speed of **Y** is greater than the speed of **X** ⬭

B The time period of **Y** is greater than the time period of **X**. ⬭

C The potential energy of **Y** is greater than the potential energy of **X**. ⬭

D The gravitational force acting on **Y** is less than the gravitational force acting on **X**. ⬭

(Total 1 mark)

10 A planet has a radius half the Earth's radius and a mass a quarter of the Earth's mass. What is the approximate gravitational field strength on the surface of the planet?

A 1.6 N kg^{-1} ⬭

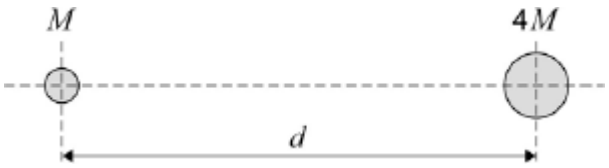
B 5.0 N kg^{-1} ⬭

C 10 N kg^{-1} ⬭

D 20 N kg^{-1} ⬭

(Total 1 mark)

11 Two stars of mass M and $4M$ are at a distance d between their centres.



The resultant gravitational field strength is zero along the line between their centres at a distance y from the centre of the star of mass M.

What is the value of the ratio $\frac{y}{d}$?

A $\frac{1}{2}$ ⬭

B $\frac{1}{3}$ ⬭

C $\frac{2}{3}$ ⬭

D $\frac{3}{4}$ ⬭

(Total 1 mark)