Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

General Certificate of Education
Advanced Level Examination
June 2010

Physics (B): Physics in Context PHYB4

Unit 4 Physics Inside and Out

Module 1 Experiences Out of this World
Module 2 What Goes Around Comes Around
Module 3 Imaging the Invisible

Friday 18 June 2010 9.00 am to 10.45 am

For this paper you must have:
- a pencil and a ruler
- a calculator
- a Data and Formulae Booklet.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen. Use pencil only for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

Do not write outside the box

Answer **all** questions.

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

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

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(3 marks)

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

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(1 mark)

1 (a) (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 marks)

Question 1 continues on the next page

Turn over ▶

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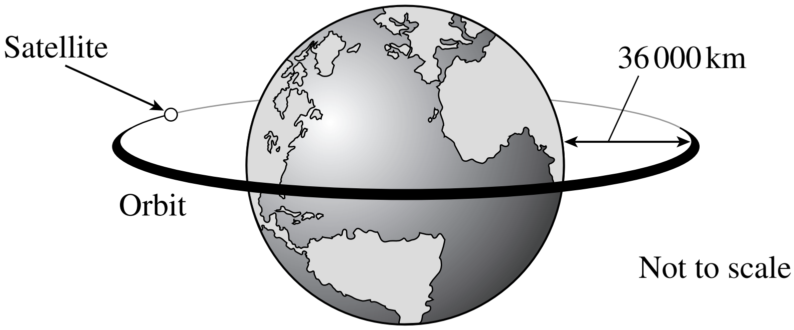
1 (b) **Figure 1** shows a satellite in a geostationary orbit around the Earth.

Figure 1



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

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(1 mark)

1 (b) (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 mark)

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

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speed .... $km\,s^{-1}$

(3 marks)

Do not write outside the box

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

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(1 mark)

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

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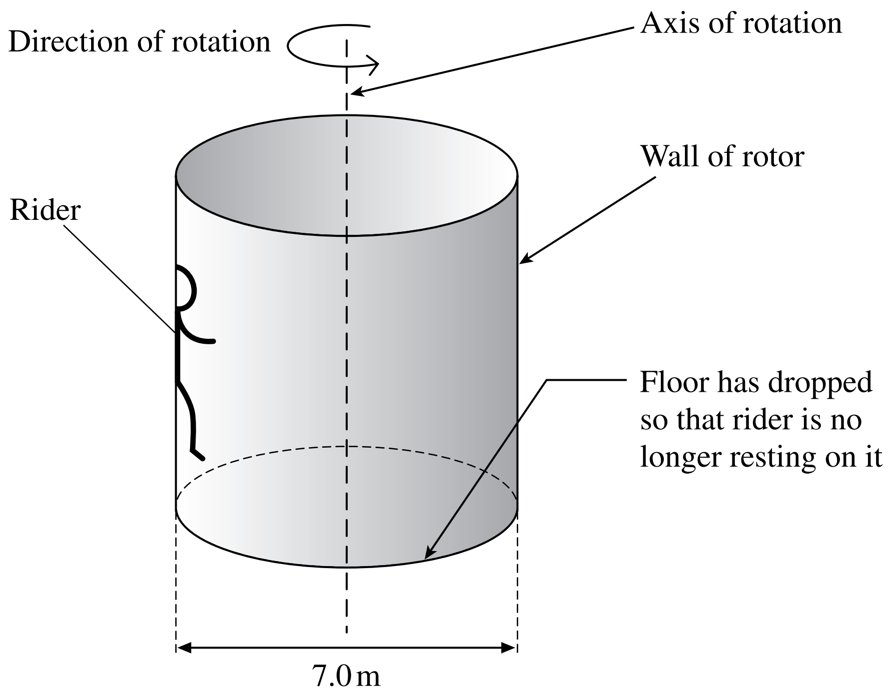
(1 mark)

14

Turn over for the next question

2 **Figure 2** shows a theme park ride known as a 'rotor'. As the rotor is rotated the rider is pinned to the wall.

Figure 2



2 (a) (i) Add to **Figure 2** labelled arrows to show the weight (w) of the rider, the reaction (R) of the wall on the rider and the frictional force (F) acting on the rider.

(3 marks)

2 (a) (ii) Explain why there is a minimum rotational speed required to ensure that the rider remains pinned to the wall when the floor is dropped.

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(4 marks)

2 (a) (iii) The frictional force F is related to the reaction R by the equation $F = 0.45\,R$.
The internal diameter of the wall of the rotor is 7.0 m.
Calculate the maximum period of rotation which will ensure that the rider remains pinned to the wall when the floor has dropped.

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maximum period .... s

(5 marks)

2 (a) (iv) While in motion the rider drops a glove in front of him.
Describe and explain the subsequent motion of the glove.

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(3 marks)

Question 2 continues on the next page

Turn over ▶

2 (b) Theme park rides are designed to thrill the riders.
Explain how a ride designer uses knowledge of physics to ensure that riders experience thrilling changes in motion.
Go on to explain any limits or constraints, to the ride design, made to ensure the riders are safe.

The quality of your written answer will be assessed in this question.

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(6 marks)

21

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3 (a) (i) Explain what is meant by the term *escape speed*.

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(2 marks)

3 (a) (ii) Mars has a radius of approximately 3.4×10^6 m and a mass of 6.4×10^{23} kg.
Show that the escape speed from Mars is approximately $5\,\text{km}\,\text{s}^{-1}$.

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(3 marks)

3 (a) (iii) Explain why a rocket would be able to escape from Mars with an initial speed much less than the escape speed given in part (a)(ii).

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(3 marks)

Question 3 continues on the next page

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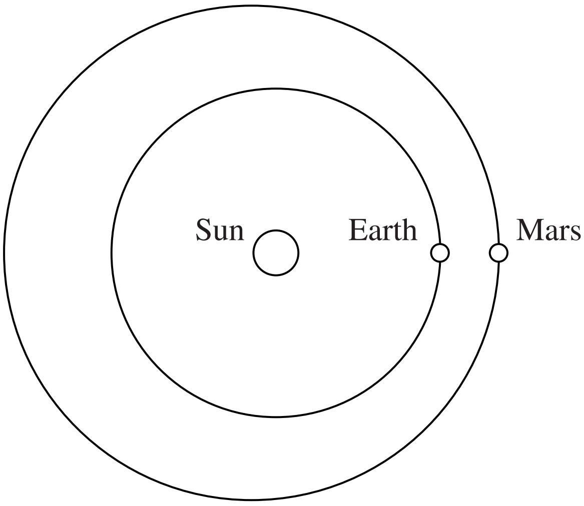
3 (b) **Figure 3** shows the Sun, Earth and Mars in alignment. Earth and Mars rotate around the Sun in the same directional sense.

Figure 3



Not to scale

3 (b) Explain why the distance between Mars and the Sun varies.

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(2 marks)

3 (c) With the planets in alignment as shown in **Figure 3**, a rocket of mass 2.05×10^6 kg leaves the surface of Mars closest to Earth and heads for Earth.

The table below gives data relevant to the rocket at the start of its journey.

Mass of astronomical object		**Distance of rocket from the centre of:**		**Rocket's gravitational potential energy due to:**		**Sign of gravitational potential energy**
Mars	6.42×10^{23} kg	Mars	3.39×10^6 m	Mars	2.59×10^{13} J	
Earth	5.97×10^{24} kg	Earth	5.57×10^{10} m	Earth		negative
Sun	1.99×10^{30} kg	Sun	2.28×10^{11} m	Sun	1.19×10^{15} J	

3 (c) (i) Complete the table by calculating the gravitational potential energy of the rocket due to the presence of Earth and the signs of the gravitational potential energies due to Mars itself and the Sun.

Use this space to do your working.

(5 marks)

Question 3 continues on the next page

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Do not write outside the box

3 (c) (ii) Calculate the **total** gravitational potential energy of the rocket on the surface of Mars.

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total gravitational potential energy .... J

(1 mark)

3 (c) (iii) State how the gravitational potential energy of the rocket changes as it moves from Mars to Earth

relative to Earth ....

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relative to Mars. ....

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(2 marks)

3 (c) (iv) Suggest why a space agency might wish to consider the relative positions of the planets when planning such a mission.

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(2 marks)

20

Turn over for the next question

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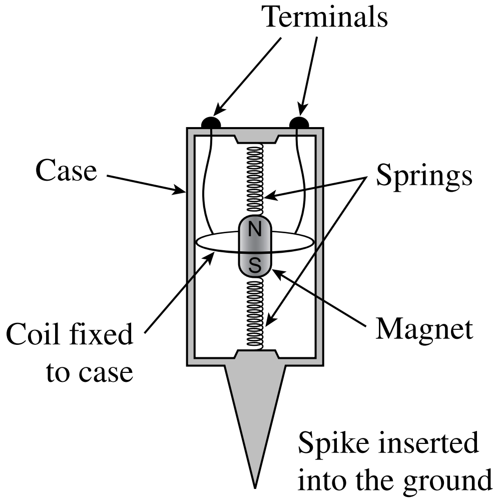
4 **Figure 4** shows a geophone. When a vibration moves the case and coil, the magnet remains stationary due to its inertia. This movement of the coil relative to the stationary magnet generates an emf across the coil. The magnitude of the emf is proportional to the speed of the coil relative to the magnet.

Figure 4



4 (a) (i) Explain how an emf is generated between the terminals and how the magnitude of the emf is related to the speed of the case.

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(2 marks)

4 (a) (ii) What properties of the magnet, the coil and the springs are necessary to make the geophone sensitive?

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(3 marks)

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4 (a) (iii) State the direction of the ground movement to which this type of geophone is sensitive.

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(1 mark)

4 (a) (iv) A coil of 50 turns generates a maximum emf of 85 mV in a geophone.
Calculate the rate of change of flux needed to generate this emf.
Give an appropriate unit for your answer.

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rate of change of flux .... unit ....

(3 marks)

4 (b) Seismic refraction measurement involves the timing of seismic waves travelling down to the top of rock layers where they are refracted and undergo total internal reflection, before returning to the surface. Seismic refraction is applicable only where the seismic speeds of layers increase with depth, for example where a clay layer is above a sandstone layer.

4 (b) (i) Explain what is meant by the phrase *seismic speeds of layers increase with depth.*

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(1 mark)

Question 4 continues on the next page

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4 (b) (ii) The speed of seismic waves in clay is 2400 m s^{-1} while that in adjoining sandstone is 3400 m s^{-1}.
Show that the critical angle between the clay and the sandstone is approximately 45°.

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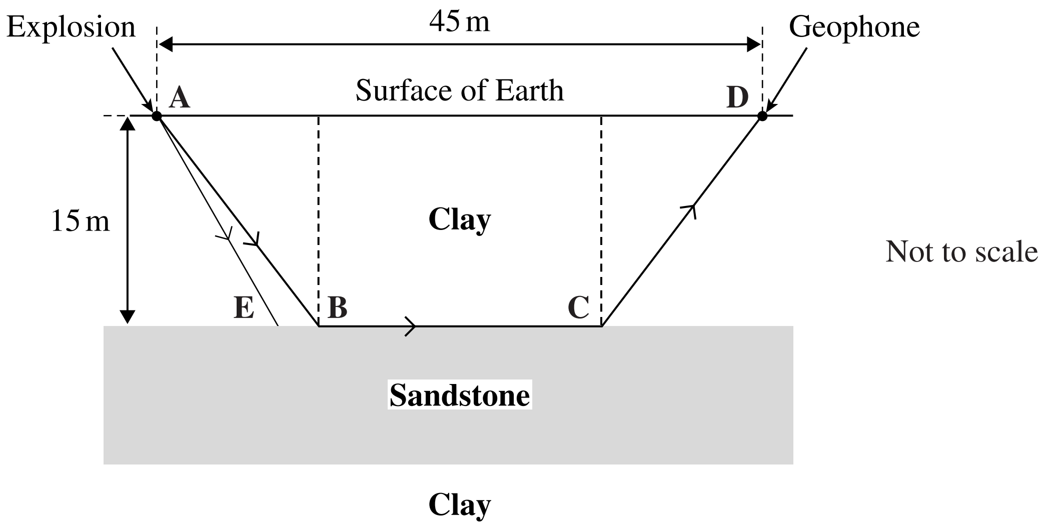
(3 marks)

Figure 5 shows how an explosion can be used with a geophone to measure the depth of a layer of clay above sandstone. The explosion causes seismic waves which travel along paths such as **AE** and **AB**.

Figure 5



4 (b) (iii) Mark on **Figure 5** the critical angle (Θ_c).

(1 mark)

4 (b) (iv) Show on **Figure 5** the path of the seismic wave travelling from **A** to **E** as it travels through the sandstone into the lower layer of clay.

(2 marks)

4 (b) (v) The depth of the upper layer of clay is 15 m and the distance between the explosion and the geophone along the surface **AD** is 45 m.
The seismic wave is travelling through sandstone from **B** to **C**.
The distances **AB** and **CD** are equal.
Assume that the critical angle is exactly 45°.

Calculate the time for the seismic wave to travel along the route **ABCD**.

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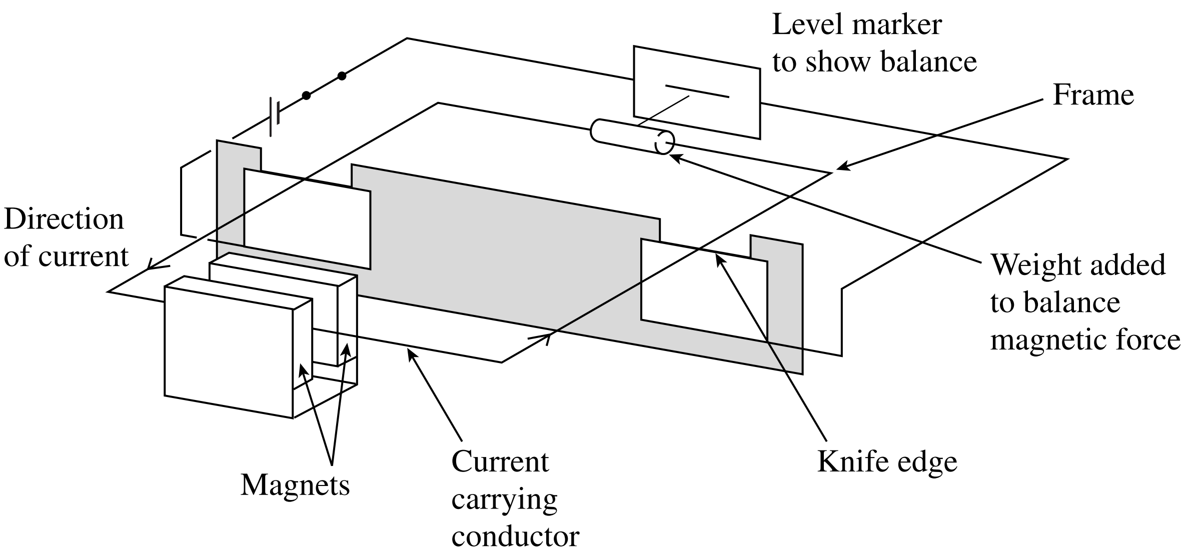
time .... s
(5 marks)

21

5 **Figure 6** shows a current balance in which a current passes through a wire inside the magnetic field between a pair of strong magnets.

Figure 6



5 (a) (i) When current flows in the pivoted frame, a weight must be added to restore balance. State and explain the direction in which the magnetic force must be acting on the current carrying conductor.

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(3 marks)

Do not write outside the box

5 (a) (ii) A length of 4.6 cm of the conductor is inside the uniform magnetic field. The current passing through the conductor is 4.5 A and the force acting on it is 24 mN.
Calculate the magnetic flux density.

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magnetic flux density .... T
(3 marks)

5 (a) (iii) The horizontal component of the Earth's magnetic flux density is approximately 18 μT.
Explain whether or not this should be considered as significant when measuring the flux density of the magnets using the current balance.

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(1 mark)

5 (a) (iv) State and explain how this apparatus could be adapted to be more sensitive to changes in the magnetic flux density.

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(3 marks)

Question 5 continues on the next page

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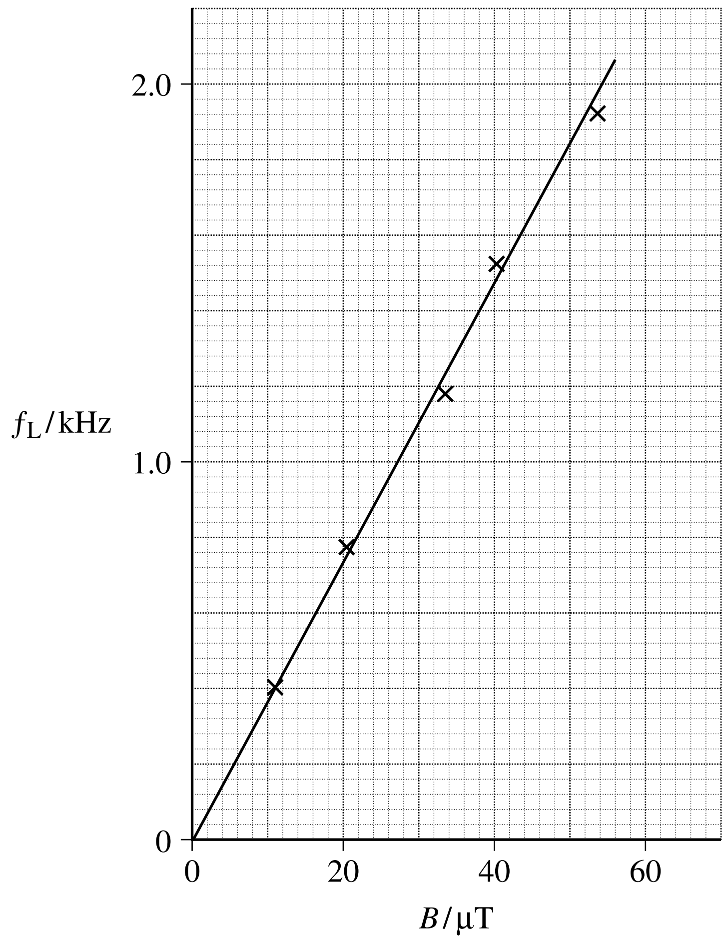
5 (b) Geophysicists use proton magnetometers to measure variations in the Earth's magnetic field. The spinning protons are normally arranged randomly but line up when placed in a strong magnetic field. When the magnetic field is removed the protons precess around the Earth's magnetic field lines at the Larmor frequency f_L. **Figure 7** shows the relationship between f_L and the applied magnetic flux density B.

Figure 7



5 (b) (i) The relationship between f_L and B takes the form $f_L = kB$

From the graph determine the numerical value of k.

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k ....

(3 marks)

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5 (b) (ii) State a unit consistent with your value for *k*.

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(1 mark)

5 (b) (iii) A proton magnetometer is capable of detecting a change in the magnetic flux density of 0.1 nT.
Calculate the minimum precision with which f_L must be measured to detect this change.

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minimum precision .... Hz

(2 marks)

5 (b) (iv) Explain what is meant by *precession*. You should draw a diagram and use the analogy with a spinning top to help your explanation.

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(3 marks)

5 (c) (i) The geophone and proton magnetometer can be used to show the presence of buried objects or geological structures.
Name **two** other methods of determining the presence of these objects or structures.

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(2 marks)

Question 5 continues on the next page

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5 (c) (ii) For **one** of your chosen methods suggest **one** advantage and **one** disadvantage compared with using a proton magnetometer.

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(2 marks)

5 (d) Suggest whether or not magnetic anomaly detection methods are useful for land-mine location.
Give a reason for your answer.

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(1 mark)

24

END OF QUESTIONS

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