Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
TOTAL	

AQA

General Certificate of Education
Advanced Level Examination
June 2011

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

Tuesday 21 June 2011 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.

Answer **all** questions.

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

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(3 marks)

1 (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
12 500	–3.22
22 500	–1.79

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

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(2 marks)

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

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(3 marks)

1 (b) (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.

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(2 marks)

Question 1 continues on the next page

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

1 (c) (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 marks)

1 (c) (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 mark)

1 (c) (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 mark)

16

Turn over for the next question

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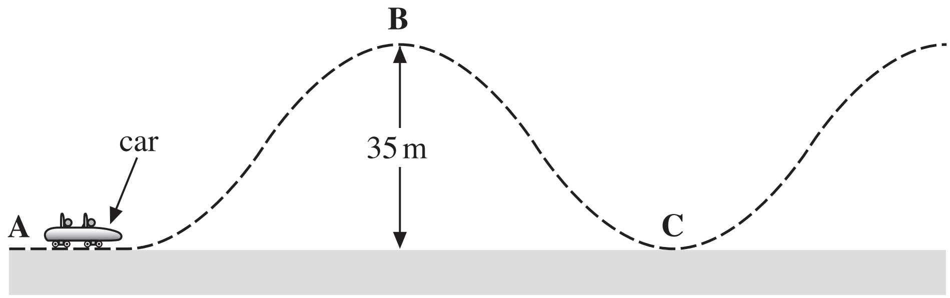
ANSWER IN THE SPACES PROVIDED

2 **Figure 1** shows a car on a roller coaster track. The car is initially at rest at **A** and is lifted to the highest point of the track, **B**, 35 m above **A**.

Figure 1



The car with its passengers has a total mass of 550 kg. It takes 25 s to lift the car from **A** to **B**. It then starts off with negligible velocity and moves unpowered along the track.

2 (a) Calculate the power used in lifting the car and its passengers from **A** to **B**. Include an appropriate unit in your answer.

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power............................... unit..............................

(3 marks)

2 (b) The speed reached by the car at **C**, the bottom of the first dip, is 22 m s^{-1}. The length of the track from **B** to the bottom of the first dip **C** is 63 m.

Calculate the average resistive force acting on the car during the descent. Give your answer to a number of significant figures consistent with the data.

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resistive force .... N

(4 marks)

Do not write outside the box

2 (c) Explain why the resistive force is unlikely to remain constant as the car descends from **B** to **C**.

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(3 marks)

2 (d) At **C**, a passenger of mass 55 kg experiences an upward reaction force of 2160 N when the speed is 22 m s^{-1}.
Calculate the radius of curvature of the track at **C**. Assume that the track is a circular arc at this point.

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radius of curvature of the track .... m

(3 marks)

13

Turn over for the next question

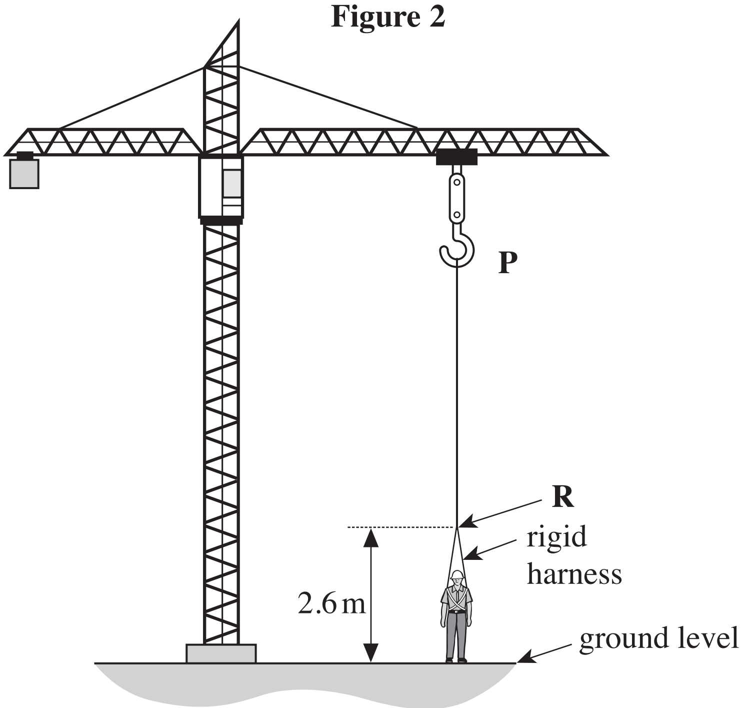
Do not write outside the box

3 In a reverse bungee experience a 'rider' is catapulted high into the air.
A designer creates a less extreme version for more timid participants, as shown in **Figure 2**.

The rider is strapped into a rigid harness attached to one end of an elastic rope **PR**. The rider and the rope behave in the same way as a mass-spring system.

The rider is initially held at rest at ground level. The top end of the rope, **P**, is raised to stretch the rope. The rider is then released and moves upwards, reaching a maximum height when the rope is at its unstretched (natural) length. The rider then oscillates vertically until eventually coming to rest, suspended above the ground.

Figure 2



The rope has an unstretched length of 20 m. When stretched, the rope obeys Hooke's law and has a stiffness of 92 N m^{-1}. In the following questions ignore the mass of the rope.

3 (a) (i) The rider and harness have a total mass of 55 kg.
Calculate the overall length of the rope when the rider comes to rest, suspended above the ground, at the end of the ride.

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overall length .... m

(3 marks)

Do not write outside the box

3 (a) (ii) At the start of the ride, the lower end of the rope **R** is attached to the rigid harness at a point which is 2.6 m above the ground.
The top end of the rope, **P**, has to be adjusted so that the rope just becomes unstretched when the rider is at the highest point of the ride.
Determine the height of **P** above the ground.
Neglect air resistance in this part of the question.

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height of point **P** .... m

(1 mark)

3 (b) (i) Show that the frequency of oscillation of the rider on the end of the rope is about 0.2 Hz.

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(3 marks)

3 (b) (ii) Calculate the maximum speed reached by the rider when the amplitude of the oscillation is 4.2 m.

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maximum speed .... m s^{-1}

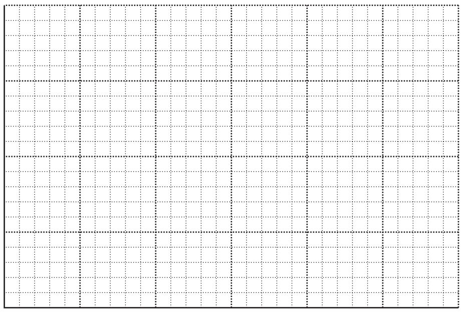
(2 marks)

Question 3 continues on the next page

Turn over ▶

3 (b) (iii) In practice, air resistance has an effect. Sketch below, a graph showing how you would expect the velocity to vary with time over the first two complete oscillations, from the instant the rider was released from ground level. Take an upward velocity as being positive.

Label the time axis with a suitable scale. No scale is required on the velocity axis.



(3 marks)

3 (c) (i) A rider of greater mass now uses the ride. Explain how the height of **P** has to be changed to produce the same initial amplitude of oscillations as that for the previous rider.

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(3 marks)

3 (c) (ii) A safety officer examines the design of the ride and thinks that, if the end **P** of the rope is raised too high so that the rope is stretched too much at the start, there is a risk that the rider could hit the ground after the first oscillation and suffer an injury.
Describe what would happen to the rider during the ride in this case and explain why, even if air resistance is negligible, the safety officer's concerns are unfounded.

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(3 marks)

18

Turn over for the next question

Do not write outside the box

4 (a) Explain how a rocket motor accelerates a spacecraft.

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(4 marks)

4 (b) A spacecraft of total mass 35 000 kg is travelling in outer space at 15 km s^{-1}. The spacecraft is accelerated in its original direction of travel by a rocket motor using a propellant consisting of liquid hydrogen and oxygen. The exhaust gases leave the motor at a speed of 2500 m s^{-1}, relative to the rocket, and at a rate of 55 kg s^{-1}. The total mass of the propellant available in the spacecraft is 30 000 kg.

4 (b) (i) Calculate the maximum final speed the spacecraft could achieve using all 30 000 kg of the propellant.

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maximum final speed .... km s^{-1}

(4 marks)

Do not write outside the box

4 (b) (ii) Estimate the initial acceleration of the spacecraft produced by the rocket motor.

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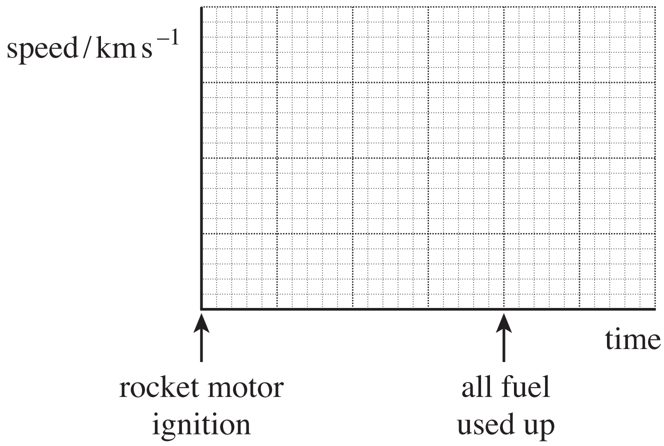
initial acceleration .... $m\,s^{-2}$

(3 marks)

4 (b) (iii) Sketch on the axes below a graph showing how the speed of the spacecraft would vary with time from ignition of the rocket motor until shortly after all the fuel has been used up.
No scale is required on the time axis which you should assume to be linear.
Include an appropriate scale on the speed axis.



(3 marks)

4 (b) (iv) Explain the shape of the graph you have drawn.

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(1 mark)

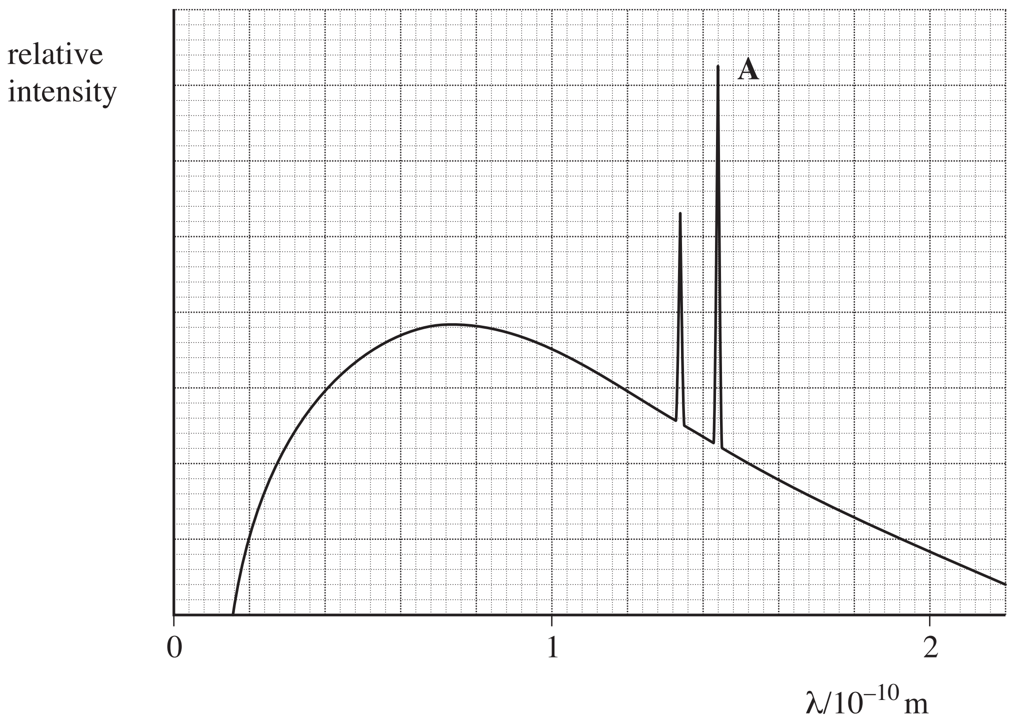
15

Turn over ▶

Do not write outside the box

5 **Figure 3** shows an X-ray spectrum produced by an X-ray tube when an accelerated electron beam is incident on a tungsten target. It shows a continuous spectrum with peaks at certain wavelengths.

Figure 3



5 (a) (i) Calculate the photon energy, in J, that corresponds to peak **A**.

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photon energy .... J

(3 marks)

Do not write outside the box

5 (a) (ii) The maximum energy of photons in the X-ray beam is 9.6×10^{-15} J.
The electrons leave the cathode with negligible speed.
Calculate the potential difference between the anode and the cathode in the electron gun used to accelerate the electrons in the X-ray tube.

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potential difference V

(2 marks)

5 (a) (iii) The beam current is 5.5 mA. Calculate the input power used to produce the beam of electrons.

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power .... W

(2 marks)

5 (b) In some X-ray tubes, the target is rotated. Explain why this is necessary and what would happen if the target stops rotating whilst the tube continues to operate.

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(3 marks)

Question 5 continues on the next page

Do not write outside the box

5 (c) Describe the different physical processes that take place to produce X-rays at the target in an X-ray tube. Your description should include explanations of how the continuous spectrum and the line of spectrum are produced.

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

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(6 marks)

16

Turn to page 18 for question 6

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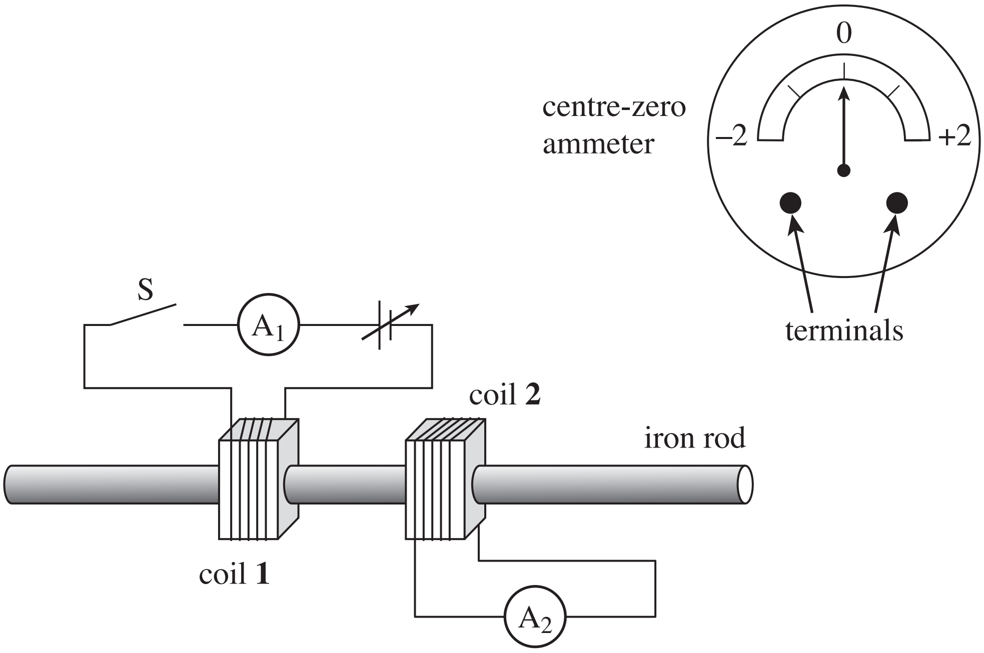
ANSWER IN THE SPACES PROVIDED

6 **Figure 4** shows an arrangement for demonstrating electromagnetic induction and the type of ammeter used.

Figure 4



The iron rod passes through both coils. The coils are made from insulated copper wire.
Coil **1** is connected to a switch, an ammeter and a variable dc power supply.
Coil **2** is only connected to an ammeter.
The ammeters A_1 and A_2 have zero at the centre of their scales as shown.

6 (a) Initially switch **S** is open so that there is no current in coil **1**.
State and explain what you would expect to observe in each of the following stages of the experiment.

6 (a) (i) Switch **S** is closed so that a current is produced in coil **1**.

Observation ....

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Explanation ....

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(3 marks)

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6 (a) (ii) Switch **S** is opened.

Observation ....

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Explanation ....

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(3 marks)

6 (a) (iii) The potential difference of the supply is increased and switch **S** is closed again as in part (a)(i).

Observation ....

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Explanation ....

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(3 marks)

Question 6 continues on the next page

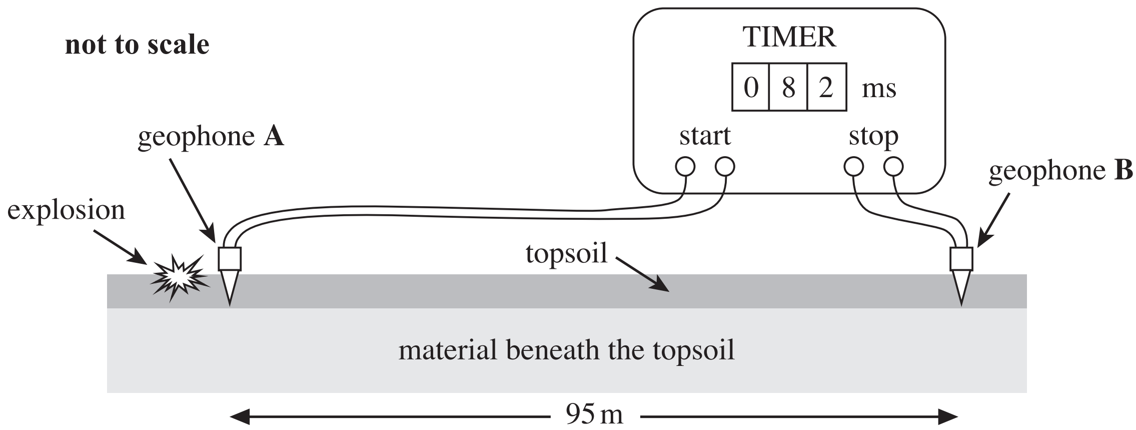
Turn over ▶

6 (b) A geophysicist is able to determine the type of material that is present under a layer of topsoil (the thin layer of soil that forms the surface of the Earth) without disturbing the topsoil. The table shows the speed of longitudinal waves in the materials that could be beneath the topsoil.

material	**speed of longitudinal waves / m s^{-1}**
granite	2900
sandstone	1100
clay	700

The geophysicist uses the arrangement shown in **Figure 5**.

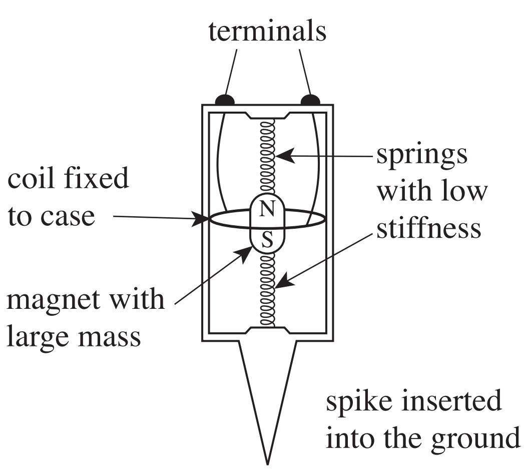
Figure 5



The geophysicist creates the longitudinal wave using a small explosion. When the wave passes geophone **A** the timer is started by an electrical pulse produced by the geophone. The wave is then detected by geophone **B** placed 95 m away which stops the timer. The timer has a precision of 1ms and records a time of 82 ms.

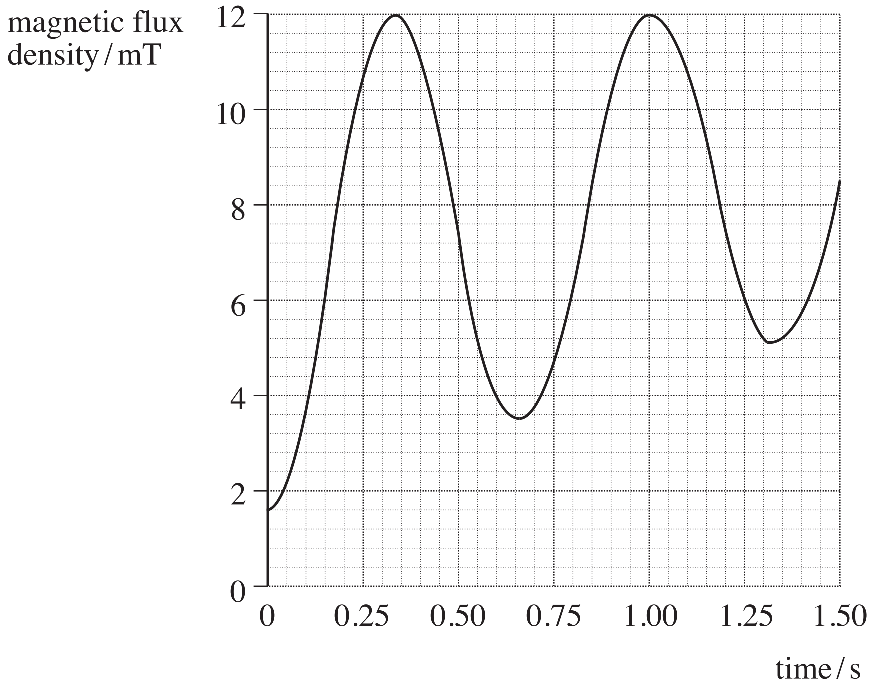
Figure 6 shows the structure of the geophone used to detect the wave.

Figure 6



When the wave arrives at geophone **A** the magnetic flux density inside the coil varies as shown in **Figure 7**.

Figure 7



6 (b) (i) The coil has 4500 turns and a diameter of 38 mm.
Determine the magnitude of the emf at the terminals of geophone **A** 0.50s after the pulse arrives.

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emf V

(4 marks)

6 (b) (ii) Deduce which **one** of the materials in the table on **page 20** is most likely to be present beneath the topsoil. Show your reasoning.

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(2 marks)

Turn over ▶

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6 (c) Similar timing methods to those given in the passage in 6 (b) **page 20**, may be used to determine the presence of buried features such as walls and cavities on archaeological sites. Describe with reasons the changes to the apparatus and procedure that would be needed to determine the position of such features.

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(3 marks)

6 (d) Ultrasound or ground penetrating microwaves (radar) could be used to determine the position of buried objects. State the differences between the waves used in ultrasound and microwaves and explain how the depth would be determined.

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(4 marks)

22

END OF QUESTIONS

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