Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	

General Certificate of Education
Advanced Level Examination
January 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

Thursday 27 January 2011 1.30 pm to 3.15 pm

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

Time allowed
- 1 hour 45 minutes

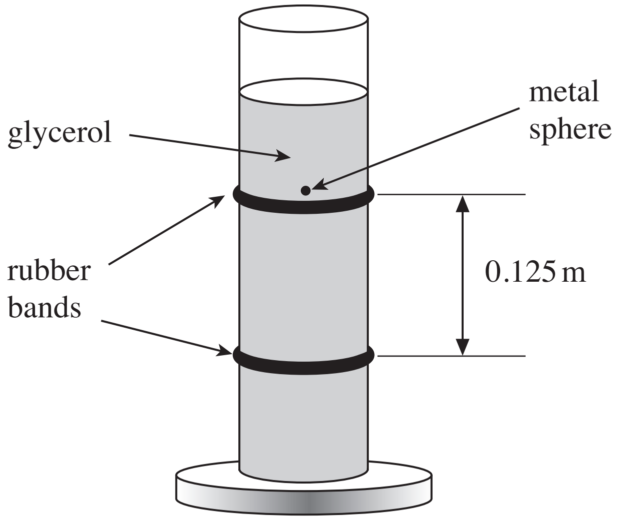
Instructions
- Use black ink or black ball-point pen. Use pencil only for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this 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 in the spaces provided.

1 **Figure 1** shows an arrangement used to measure the coefficient of viscosity of glycerol.

Figure 1



The terminal velocity of a metal sphere was determined by measuring the time taken for the sphere to fall a distance of 0.125 m between two rubber bands.

mass of metal sphere $= 1.38 \times 10^{-5}$ kg
diameter of metal sphere $= 1.54 \times 10^{-3}$ m
measured time $= 22.0$ s

1 (a) (i) Assume that when the terminal velocity is reached the viscous drag force, given by Stokes' law, is equal to the weight of the metal sphere.

Calculate the coefficient of viscosity of glycerol.

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coefficient of viscosity ....

(4 marks)

1 (a) (ii) State an appropriate unit for viscosity.

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(1 mark)

1 (b) The assumption in part (a)(i) was not correct because, as well as the viscous force, there is an upward force (an upthrust) acting on the sphere due to Archimedes' principle.

State and explain whether this means that the value for the coefficient of viscosity calculated in part (a)(i) is higher or lower than the actual viscosity.

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(2 marks)

1 (c) Give **two** reasons why the use of Stokes' law cannot be applied to determine the terminal velocity of a skydiver even if the mass of the skydiver and the viscosity of air are known.

Reason 1 ....

Reason 2 ....

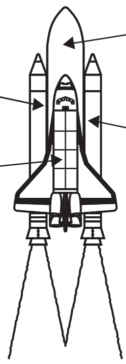
(2 marks)

9

Turn over for the next question

2 **Figure 2** shows a Space Shuttle taking off vertically when it is close to the Earth's surface.

Figure 2



The Shuttle consists of an Orbiter, which carries the astronauts and materials, two booster rockets and the fuel tank. Before lift-off, the total mass of the Shuttle is 2.0×10^6 kg. At lift-off, each booster rocket produces a thrust of 12.5 MN and the Orbiter's own engines produce a thrust of 5.5 MN.

2 (a) (i) The booster rockets and the Orbiter's engines are all fired at the same time. Estimate the initial acceleration of the Shuttle.

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

(4 marks)

2 (a) (ii) The thrust remains constant while the booster rockets are attached. Give **two** reasons why the acceleration does not remain constant as the Shuttle moves away from the Earth.

Reason 1 ....

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Reason 2 ....

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(2 marks)

Do not write outside the box

2 (b) In a typical mission an Orbiter delivers astronauts and materials to the International Space Station (ISS) which orbits the Earth at a speed of $7.7 \times 10^3\ \mathrm{m\,s^{-1}}$. In a typical mission the total mass of the payload (the Orbiter's cargo) is 2.3×10^4 kg.

mass of the Earth $= 5.97 \times 10^{24}$ kg
radius of the Earth $= 6400$ km

2 (b) (i) Show that the radius of the orbit of the ISS is about 6700 km.

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(3 marks)

2 (b) (ii) Calculate the total energy that has to be supplied **to the payload** so that it can reach and move in the same orbit as the ISS.
Neglect the kinetic energy that the payload has when on the Earth's surface due to the rotation of the Earth.
Give your answer to the number of significant figures that is consistent with the data used.

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total energy .... J

(5 marks)

14

Turn over ▶

3 **Figure 3** shows a schematic diagram of a swing carousel, or roundabout. The diagram shows two of the chairs in which passengers can ride. The chairs hang vertically when the ride is not moving and they move outwards when the ride rotates.

Figure 3

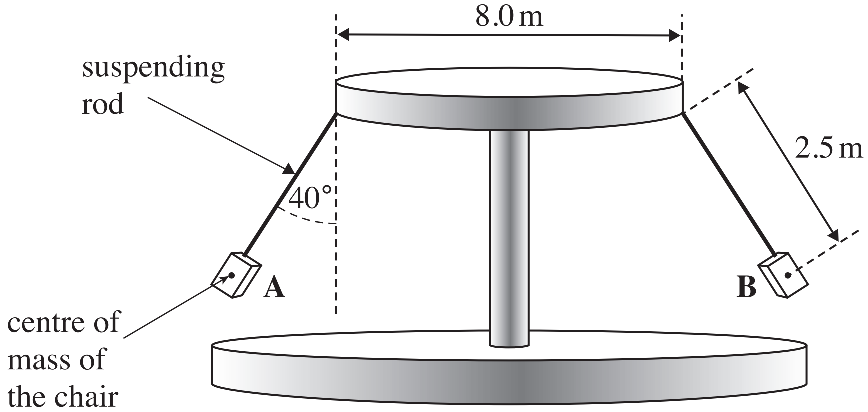

Figure 3 shows the position of the chairs when the frequency of rotation is a maximum. The dimensions are shown on the diagram.

When the ride is operating

- the chairs, each of mass 6.5 kg, move in a horizontal circle
- the maximum angular speed is 1.21 rad s^{-1}
- the suspending rods are inclined at an angle of 40° to the vertical.

Ignore the effects of air resistance when answering the following questions.

3 (a) (i) Show on **Figure 3** the direction of the resultant force acting on chair **A**. *(1 mark)*

3 (a) (ii) Show and label on **Figure 3**, the actual forces that are acting on chair **B**. *(2 marks)*

3 (a) (iii) Calculate the magnitude of the resultant force acting on each chair when the ride is rotating at an angular speed of 1.21 rad s^{-1} with no passengers in the chairs.

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resultant force .... N
(3 marks)

Do not write outside the box

3 (b) Calculate the maximum frequency of rotation of the ride in revolutions per minute.

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frequency of rotation .... revolutions per minute

(3 marks)

3 (c) (i) The ride takes 25 s to accelerate from rest to the maximum angular speed of 1.21 rad s^{-1}.
Assume that the acceleration is uniform.
Calculate the angle, in radian, through which the ride turns before reaching the maximum angular speed.

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angle .... radian

(3 marks)

Question 3 continues on the next page

Do not write outside the box

3 (c) (ii) When the ride is loaded with passengers, the moment of inertia of the ride when it reaches its maximum speed is $16\,000\,\mathrm{kg\,m^2}$ more than when it is unloaded.

Calculate the average extra power that has to be supplied for the loaded ride to reach the angular speed of $1.21\,\mathrm{rad\,s^{-1}}$ in 25 s.
Give an appropriate unit for your answer.

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extra power ....

unit ....

(4 marks)

3 (c) (iii) Explain why the moment of inertia changes as the loaded ride accelerates.

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(2 marks)

18

Do not write outside the box

4 In MRI scanners, superconducting coils are used to produce a strong magnetic field with a flux density of about 1.5 T. When a patient is inside the scanner, some of the protons in the nuclei of hydrogen atoms in the patient's body are aligned in the direction of the magnetic field.

4 (a) State how a magnetic flux density of 1 T is defined in terms of the force on a wire carrying an electric current.

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(2 marks)

4 (b) (i) State the factors that a designer of the coils needs to consider to produce a strong magnetic field suitable for use in a scanner.

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(3 marks)

4 (b) (ii) Explain the advantage of using superconductors in the construction of the coils.

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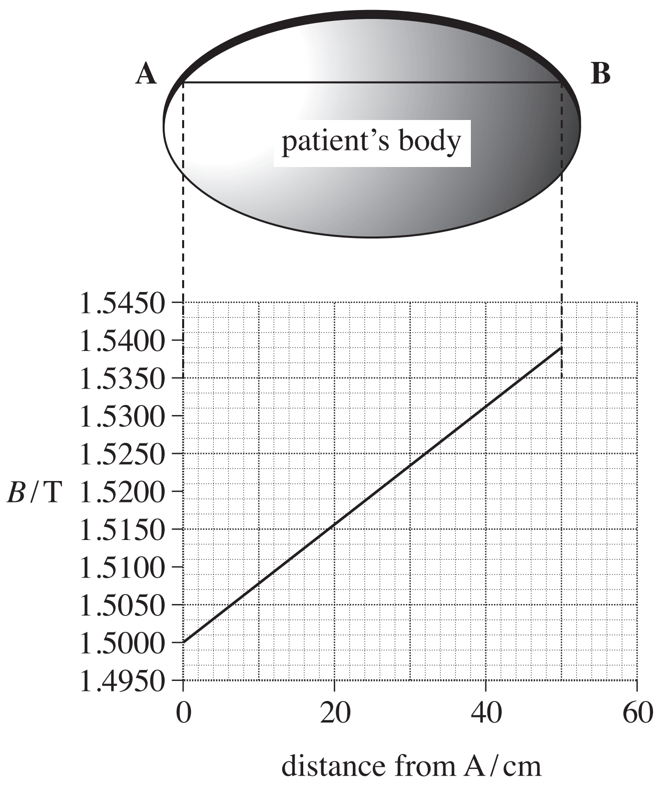
(2 marks)

Question 4 continues on the next page

4 (c) When scanning a patient, an additional gradient field is applied. This causes the aligned protons at different positions in the field to undergo precession at different frequencies. The precession frequency, in Hz, of a proton depends on the magnetic flux density at its position and is given by $4.258 \times 10^7 \times B$, where B is in tesla, T.

Figure 4 shows a vertical thin 'slice' through a patient's body. The graph shows how the magnetic flux density varies along the line **AB** at one time during the build up of an image.

Figure 4



4 (c) (i) Explain, in terms of the force on a charged particle, how a uniform magnetic field is different from a gradient magnetic field.

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(2 marks)

Do not write outside the box

4 (c) (ii) At what distance from **A** will protons in the gradient field undergo precession at 64.38 MHz?

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distance from **A** .... cm

(3 marks)

4 (d) The protons that are undergoing precession at 64.38 MHz emit a radio wave at this frequency. Detectors linked to a computer can locate the position of these protons.

To build up an image the computer has to record the variation in the density of protons that are emitting each radio frequency.

4 (d) (i) State the property of the signal that is related to the density of the protons at a given position in the patient's body.

....

(1 mark)

4 (d) (ii) State how the property you gave in part (d)(i) changes when the proton density increases.

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(1 mark)

4 (e) State **two** aspects relating to the design of the scanner, or advice to operators when using the scanner, that have to be considered to ensure that the device is safe for use with patients.

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(2 marks)

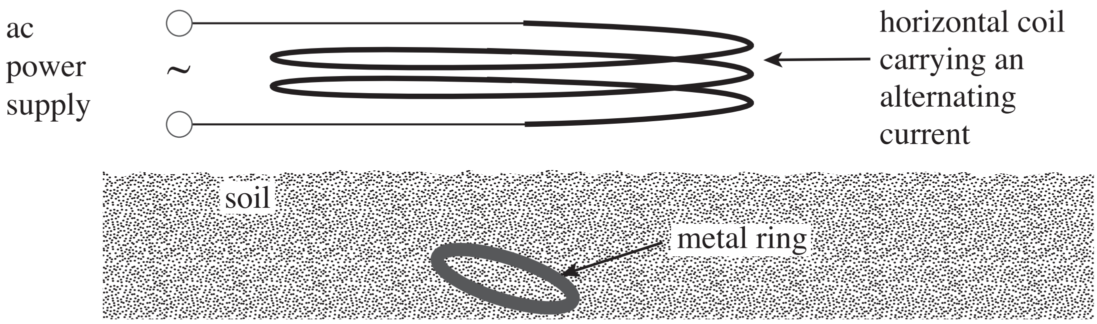
16

Do not write outside the box

5 The location of a buried metal object, such as a ring, can be found by detecting the presence of an eddy current in it.

Figure 5 shows the coil that is used to produce the eddy current.

Figure 5



5 (a) Explain what is meant by an eddy current, how an eddy current is produced in the ring and how the direction of the current in the ring compares with that in the coil.

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

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(6 marks)

Do not write outside the box

5 (b) State **three** factors, **concerning the ring**, that affect the magnitude of the induced current in the ring. In each case, explain how the factor will affect the induced current.

Factor 1 ....

Reason ....

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Factor 2 ....

Reason ....

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Factor 3 ....

Reason ....

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(6 marks)

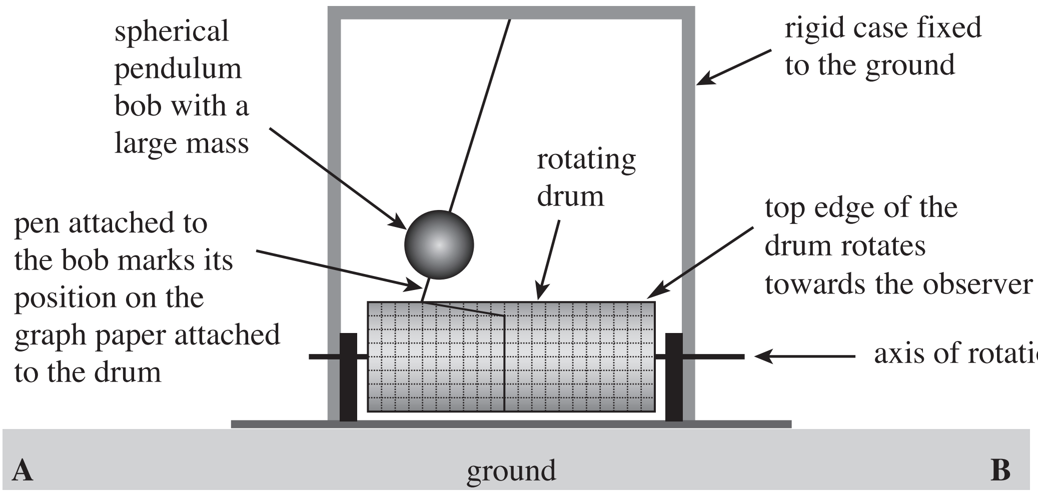
12

Turn over for the next question

Do not write outside the box

6 **Figure 6** shows a seismometer used for detecting the horizontal movement of the ground caused by an earthquake.

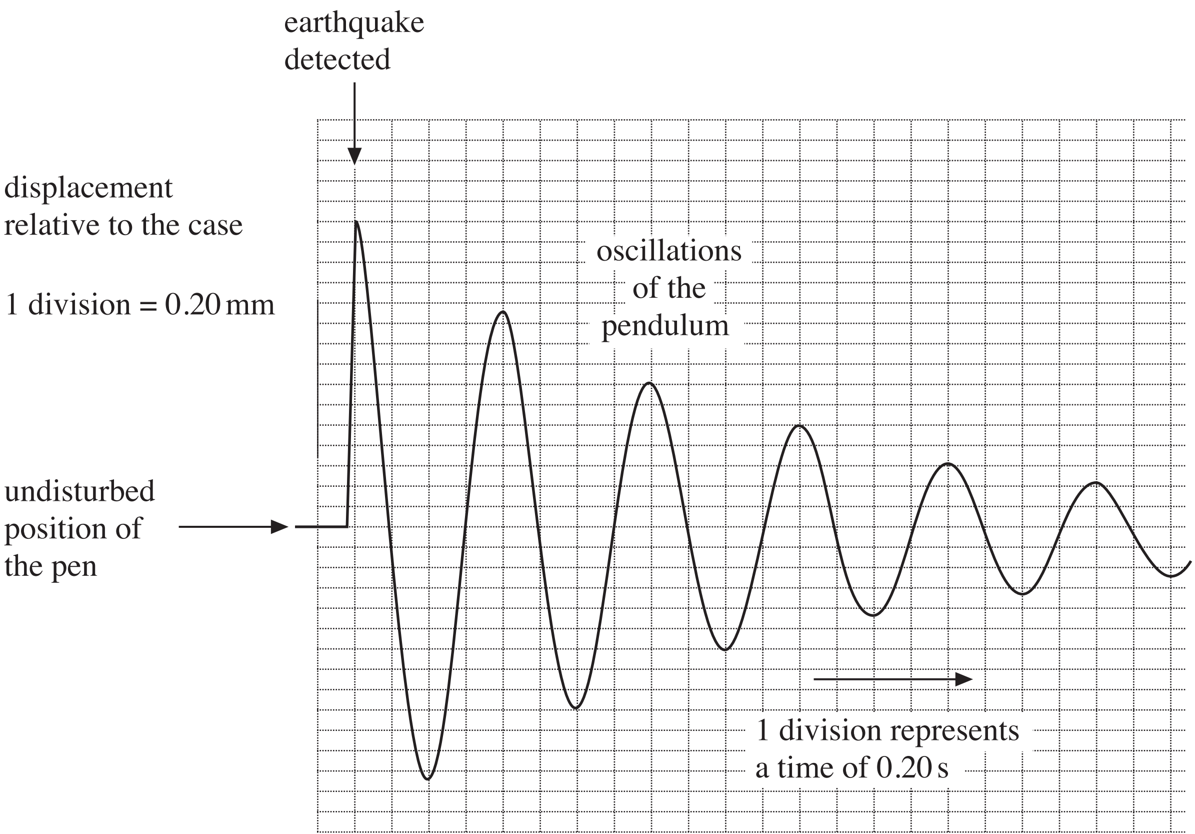
Figure 6



The rigid case is fixed to the ground. When an earthquake occurs, the ground moves horizontally so the rigid case also moves horizontally. Initially, the heavy pendulum bob remains in its original position due to its high inertia. **Figure 6** shows the pendulum immediately after an earthquake is detected.

The rotating drum moves at a steady speed. **Figure 7** shows the trace produced on the graph paper that is attached to the rotating drum following the earthquake.

Figure 7



Do not write outside the box

6 (a) (i) State whether the ground has moved towards **A** or **B** to produce the situation shown in **Figure 6**.

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(1 mark)

6 (a) (ii) Determine the magnitude of the initial displacement of the ground that caused the trace in **Figure 7**.

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(1 mark)

6 (b) (i) Use data from **Figure 7** to calculate the distance between the point of suspension of the pendulum and the centre of mass of the bob. Assume that the arrangement is a simple pendulum.

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distance .... m

(3 marks)

6 (b) (ii) State and explain the effect of using a bob of the same radius but smaller mass on

the initial displacement of the bob,

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the period of oscillation of the bob.

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(4 marks)

Question 6 continues on the next page

Turn over ▶

Do not write outside the box

6 (c) (i) Determine whether the amplitude of the oscillations shown in **Figure 7** decreases exponentially.

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(3 marks)

6 (c) (ii) Explain why the amplitude of the oscillations of the bob decreases following the initial displacement.

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(2 marks)

6 (c) (iii) State and explain the effect of using a bob with the same radius but smaller mass on the time taken for the bob to come to rest following the initial disturbance.

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(2 marks)

16

Do not write outside the box

7 (a) State the charge carriers that allow a current to be produced in

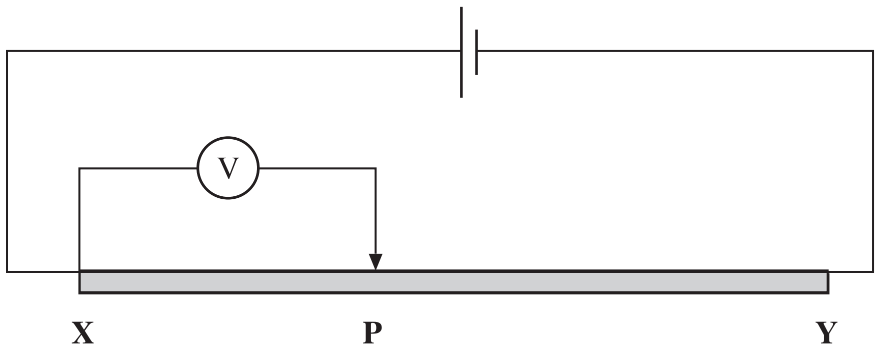
copper ....

copper sulphate solution. ....

(2 marks)

7 (b) **Figure 8** shows a uniform conducting wire **XY** connected to a cell with an emf of 1.5 V and negligible internal resistance. The wire has a resistance of 10.3 Ω. It is 1.20 m long and has a cross-sectional area of 0.13 mm^2.

Figure 8



7 (b) (i) Calculate the resistivity of the material from which the wire is made. Give an appropriate unit for your answer.

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resistivity ....

unit ....

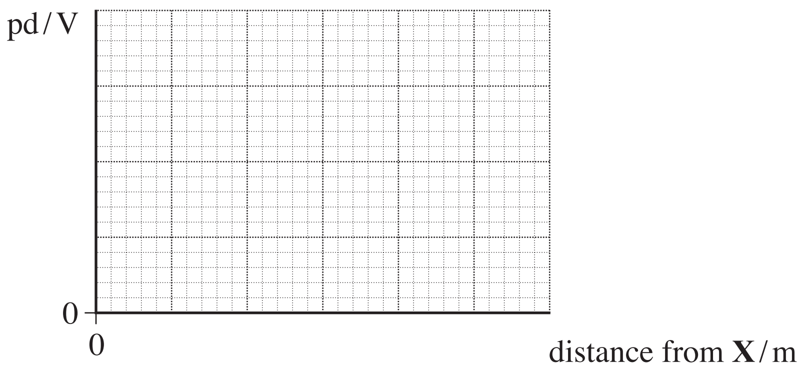
(4 marks)

Question 7 continues on the next page

Turn over ▶

7 (b) (ii) The voltmeter records the potential difference (pd) between **X** and **P**.
Sketch on the axes below a graph showing how the pd between **X** and **P** varies as the contact point **P** moves from **X** to **Y**.

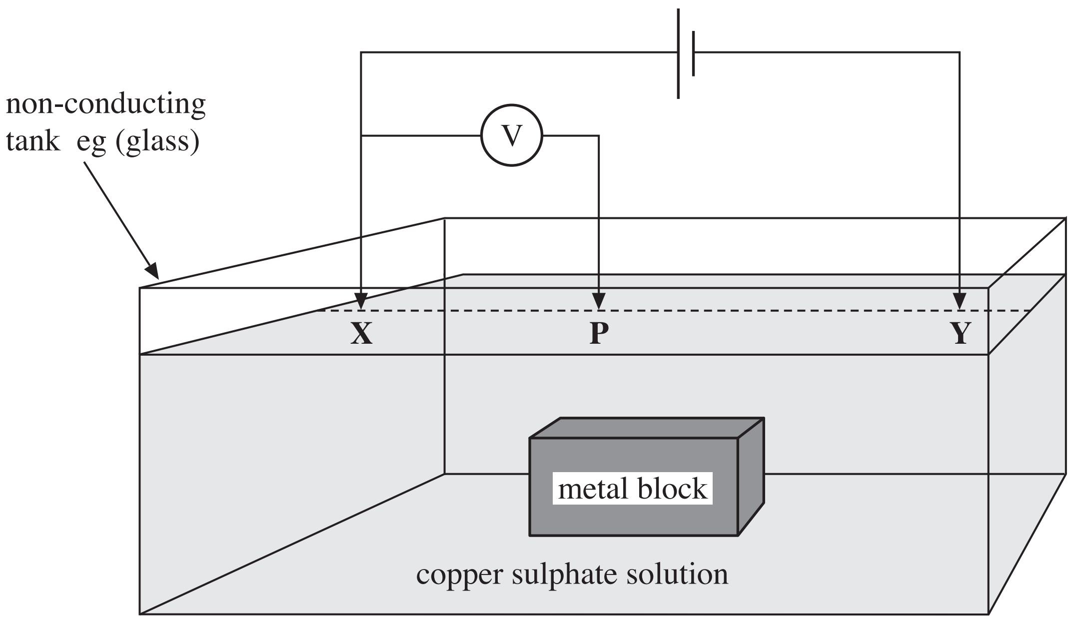
Include appropriate scales on each axis.



(2 marks)

7 (c) Variations in resistance can be used to determine the positions of ore deposits.
Figure 9 shows a laboratory simulation to demonstrate one way in which this is done. The copper sulphate solution represents the soil and the metal block represents an ore deposit.

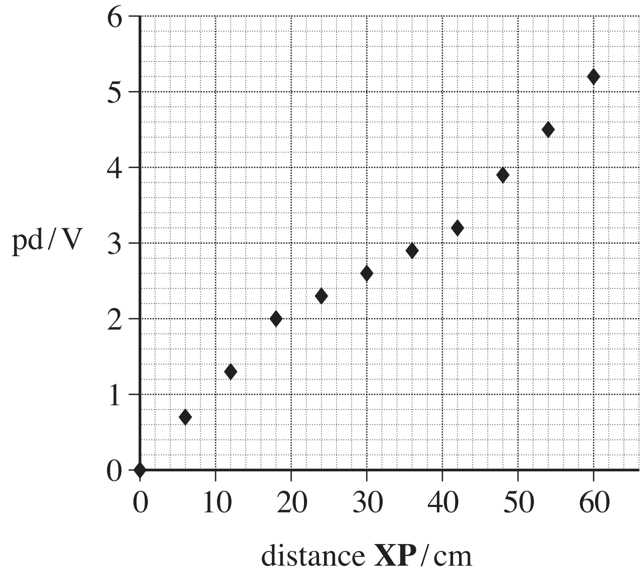
Figure 9



The conducting probes **X**, **P** and **Y** make contact with the surface of the copper sulphate solution. A student fixes the position of probes, **X** and **Y**, and records the pd between **X** and **P** for known positions of **P** as it is moved in a straight line along the surface.

Figure 10 shows a plot of pd against distance **XP**, for the student's data.

Figure 10



7 (c) (i) Explain why the points do not all lie on a straight line through the origin.

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(3 marks)

Question 7 continues on the next page

Turn over ▶

Do not write outside the box

7 (c) (ii) State **two** factors that determine the magnitude of the change in the gradient.

Factor 1 ....

....

Factor 2 ....

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(2 marks)

7 (c) (iii) Use **Figure 10** to estimate the length of the metal block.

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(2 marks)

15

END OF QUESTIONS