Centre Number						Candidate Number				
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Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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TOTAL	

General Certificate of Education
Advanced Level Examination
June 2015

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 11 June 2015 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 (enclosed).

Time allowed
- 1 hour 45 minutes

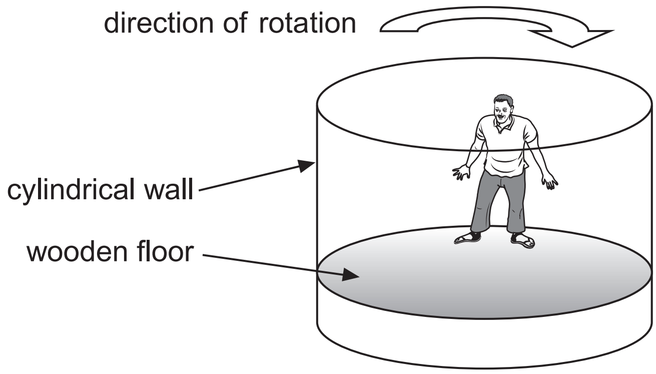
Instructions
- Use black ink or black ball-point pen. Use pencil only for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this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

1 **Figure 1** shows a fairground ride called a Rotor. Riders stand on a wooden floor and lean against the cylindrical wall.

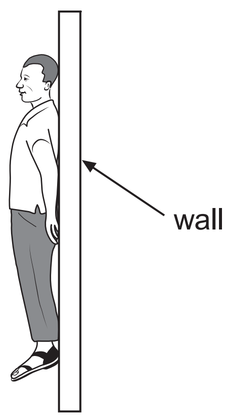
Figure 1



The fairground ride is then rotated. When the ride is rotating sufficiently quickly the wooden floor is lowered. The riders remain pinned to the wall by the effects of the motion. When the speed of rotation is reduced, the riders slide down the wall and land on the floor.

1 (a) (i) At the instant shown in **Figure 2** the ride is rotating quickly enough to hold a rider at a constant height when the floor has been lowered.

Figure 2



Draw onto **Figure 2** arrows representing all the forces on the rider when held in this position relative to the wall.
Label the arrows clearly to identify all of the forces.

[3 marks]

1 (a) (ii) Explain why the riders slide down the wall as the ride slows down.

[2 marks]

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1 (b) A Rotor has a diameter of 4.5 m. It accelerates uniformly from rest to maximum angular velocity in 20 s.
The total moment of inertia of the Rotor and the riders is $2.1 \times 10^5 \text{ kg m}^2$.

1 (b) (i) At the maximum speed the centripetal acceleration is 29 m s^{-2}.

Show that the maximum angular velocity of a rider is 3.6 rad s^{-1}.

[2 marks]

1 (b) (ii) Calculate the torque exerted on the Rotor so that it accelerates uniformly to its maximum angular velocity in 20 s.
State the appropriate SI unit for torque.

[3 marks]

torque .... SI unit for torque ....

1 (b) (iii) Calculate the centripetal force acting on a rider of mass 75 kg when the ride is moving at its maximum angular velocity.
Give your answer to an appropriate number of significant figures.

[1 mark]

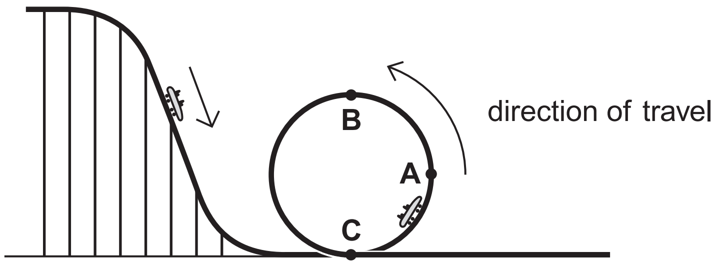
centripetal force .... N

Question 1 continues on the next page

Turn over ▶

1 (c) **Figure 3** shows the final section of a roller coaster which ends in a vertical loop. The roller coaster is designed to give the occupants a maximum acceleration of $3g$. Cars on the roller coaster descend to the start of the loop and then travel around it, as shown.

Figure 3



1 (c) (i) At which **one** of the positions marked **A**, **B** and **C** on **Figure 3** would the passengers experience the maximum reaction force exerted by their seat?
Circle your answer below.

[1 mark]

A **B** **C**

1 (c) (ii) Explain why the maximum acceleration is experienced at the position you have chosen.

[2 marks]

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14

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2 (a) (i) State what is meant by the term **escape velocity**.

[1 mark]

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2 (a) (ii) Show that the escape velocity, v, at the Earth's surface is given by $v = \sqrt{\frac{2GM}{R}}$

where M is the mass of the Earth
and R is the radius of the Earth.

[2 marks]

2 (a) (iii) The escape velocity at the Moon's surface is 2.37×10^3 m s^{-1} and the radius of the Moon is 1.74×10^6 m.

Determine the mean density of the Moon.

[2 marks]

mean density .... kg m^{-3}

2 (b) State **two** reasons why rockets launched from the Earth's surface do **not** need to achieve escape velocity to reach their orbit.

[2 marks]

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7

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3 (a) (i) The resistive force F acting on a spherical object of radius r falling with velocity v through a viscous medium is given by Stokes' law, $F = 6\pi\eta rv$.

Show that the unit of the coefficient of viscosity η is Pa s (pascal second).

[3 marks]

3 (a) (ii) Give **two** reasons why Stokes' law is **not** appropriate for the calculation of the air resistance experienced by a space vehicle as it descends through the Earth's atmosphere.

[2 marks]

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3 (b) Explain why astronauts in an orbiting space vehicle experience the sensation of weightlessness.

[2 marks]

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3 (c) A space vehicle has a mass of $16\ 800\ \text{kg}$ and is in orbit $900\ \text{km}$ above the surface of the Earth.

mass of the Earth = $5.97 \times 10^{24}\ \text{kg}$
radius of the Earth = $6.38 \times 10^{6}\ \text{m}$

3 (c) (i) Show that the orbital speed of the vehicle is approximately $7400\ \text{m s}^{-1}$.

[4 marks]

3 (c) (ii) The space vehicle moves from the orbit $900\ \text{km}$ above the Earth's surface to an orbit $400\ \text{km}$ above the Earth's surface where the orbital speed is $7700\ \text{m s}^{-1}$.

Calculate the total change that occurs in the energy of the space vehicle.
Assume that the vehicle remains outside the atmosphere after the change of orbit.
Use the value of $7400\ \text{m s}^{-1}$ for the speed in the initial orbit.

[4 marks]

change in energy .... J

15

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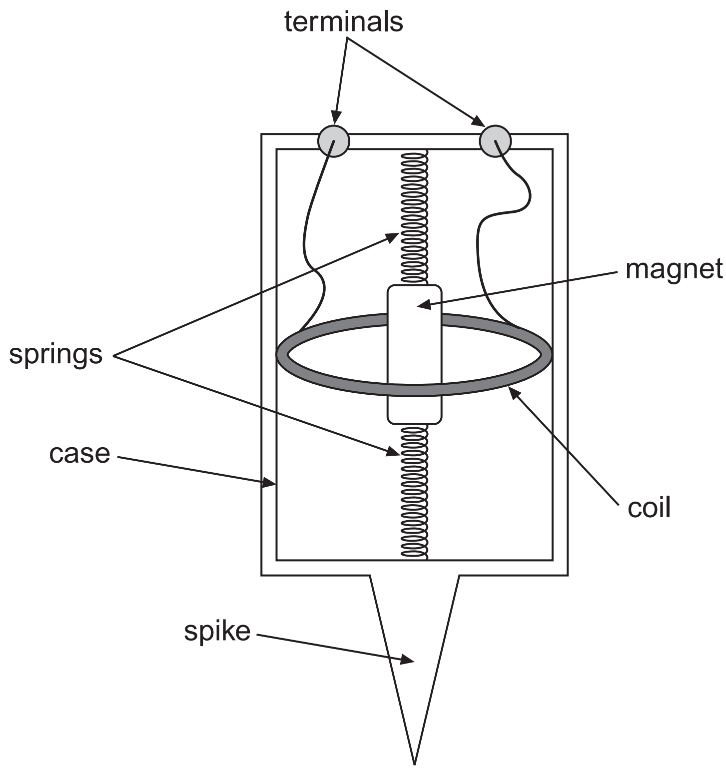
4 **Figure 4** shows the main parts of a geophone.

Figure 4



The spike attaches the geophone firmly to the ground. At the instant an earthquake occurs, the case and coil move upwards due to the Earth's movement. The magnet remains stationary due to its inertia. In $3.5\ \text{ms}$, the coil moves from a position where the flux density is $9.0\ \text{mT}$ to a position where the flux density is $23.0\ \text{mT}$.

4 (a) The geophone coil has 250 turns and an area of $12\ \text{cm}^2$.

Calculate the average emf induced in the coil during the first $3.5\ \text{ms}$ after the start of the earthquake.

[3 marks]

emf V

Do not write outside the box

4 (b) Explain how the initial emf induced in the coil of the geophone would be affected:

[2 marks]

if the stiffness of the springs were to be increased

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if the number of turns on the coil were to be increased.

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4 (c) (i) The geophone's magnet has a mass of 8.0×10^{-3} kg and the spring stiffness of the system is $2.6\ \mathrm{N\ m^{-1}}$.

Show that the natural period of oscillation of the mass–spring system is approximately 0.35 s.

[2 marks]

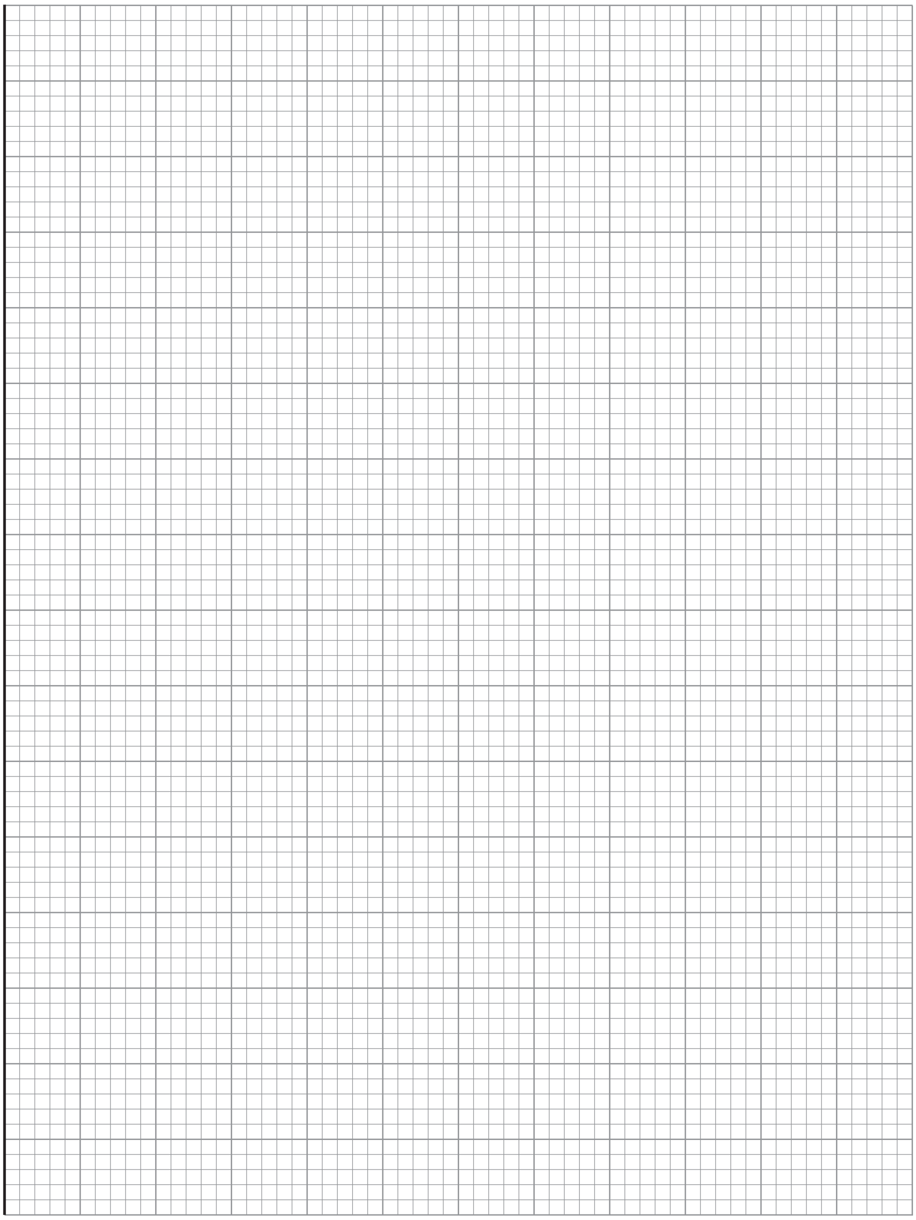
Question 4 continues on the next page

Do not write outside the box

4 (c) (ii) At the instant that the Earth stops moving after one earthquake, the emf in the coil is at its maximum value of $+8\ \text{V}$. The magnet continues to oscillate.

On the grid below, sketch a graph showing the variation of emf with time as the magnet's oscillation decays.
Show at least **three** oscillations.

[3 marks]



10

5 (a) A rocket of total mass 2.80×10^6 kg is launched vertically from the Earth's surface. The thrust from its motors is constant and has a magnitude of 34 MN. The thrust carries on for 168 s, during which time 2.42×10^6 kg of exhaust gases is expelled.

5 (a) (i) Calculate the initial acceleration of the rocket.

[4 marks]

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

5 (a) (ii) State and explain **two** reasons why the acceleration continues to increase during the time that fuel is being burned.

[3 marks]

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5 (a) (iii) State and explain **one** factor that will have an increasing effect to reduce the resultant force on the rocket during the period of fuel burn.

[2 marks]

Factor ....

Explanation ....

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Question 5 continues on the next page

Turn over ▶

5 (a) (iv) During the fuel burn, exhaust gases are expelled at a constant rate.

Calculate the initial velocity at which exhaust gases are expelled.

[4 marks]

initial exhaust velocity .... $\mathrm{m\ s^{-1}}$

5 (a) (v) State and explain in terms of the first law of thermodynamics what happens to the internal energy of the exhaust gases as they are expelled.

[3 marks]

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5 (b) Another rocket is moving in space where there is negligible gravity. It burns all its fuel and expels the exhaust gases at an effective velocity of $2100\ \mathrm{m\ s^{-1}}$.
The rocket achieves a final velocity of $3900\ \mathrm{m\ s^{-1}}$.

Calculate the percentage of the rocket's total mass that is initially made up of fuel.

[3 marks]

percentage .... %

19

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6 (a) When ultrasound is incident at an interface between two different media some energy is transmitted and some is reflected. The ratio of the reflected energy intensity I_r to the incident energy intensity I_i depends on the relative acoustic impedances of the two substances.
Acoustic impedance Z is a property of the substance and is given by $Z = \rho v$
where ρ is the density of the substance and v is the velocity of the ultrasound wave.
The ratio is given by

$$\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

Z_1 is the acoustic impedance of the substance into which the wave is reflected.
Z_2 is the acoustic impedance of the substance into which the wave is transmitted.

Table 1 shows the density and velocity of waves in two different substances.

Table 1

Substance	Density / kg m^{-3}	Velocity / m s^{-1}
1	1050	1540
2	925	1450

6 (a) (i) Calculate the percentage of incident energy that is reflected when ultrasound is incident on a surface while travelling from substance 1 into substance 2.

[3 marks]

percentage reflected .... %

6 (a) (ii) An ultrasound wave of frequency 2.00 MHz travels in substance 1.

Calculate the wavelength of the ultrasound in metres.

[2 marks]

wavelength .... m

Turn over ▶

Do not write outside the box

6 (b) Describe how ultrasound is used to produce an image of different tissues within the body.

Your answer should include:

- an explanation of how the image is produced
- an explanation of how the differences in acoustic impedance of body tissues affect the quality of the image produced.

The quality of your written communication will be assessed in your answer.

[6 marks]

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6 (c) The resolution of an image is an important factor in the design of ultrasound equipment.

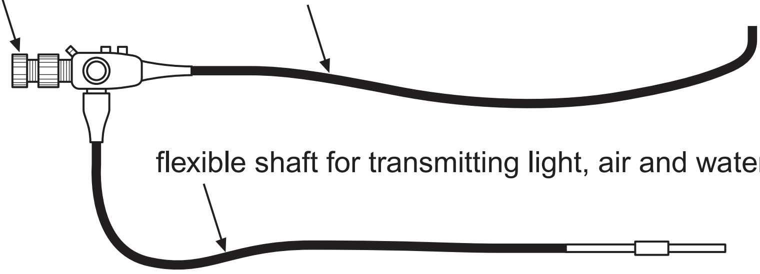
State what is meant by **resolution** and explain why the wavelength of the ultrasound determines the resolution of the image.

[2 marks]

13

7 **Figure 5** shows an endoscope. Some of the optical fibres in the endoscope are arranged in coherent bundles and others are in incoherent bundles. The eyepiece of the endoscope may be replaced with a digital camera.

Figure 5



7 (a) Explain the difference between **coherent bundles** and **incoherent bundles** of optical fibres and explain which are appropriate for the different parts of the endoscope.

[3 marks]

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7 (b) Explain how a digital camera can store the image produced by the endoscope.

[3 marks]

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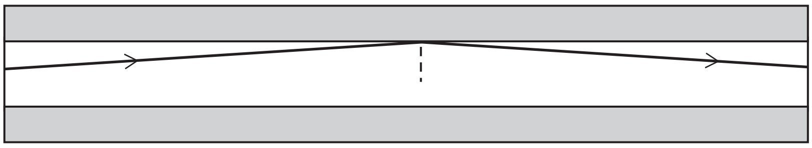
7 (c) **Figure 6** shows a ray of light travelling through an individual fibre consisting of cladding and a core. One part has a refractive index of 1.485 and the other has a refractive index of 1.511.

Figure 6



7 (c) (i) State which part of the fibre has the higher refractive index **and** explain why.

[1 mark]

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7 (c) (ii) Calculate the critical angle for this fibre.

[1 mark]

critical angle .... degrees

7 (c) (iii) The endoscope image quality may be reduced by crosstalk.

Explain what is meant by **crosstalk** and how it limits the usefulness of the endoscope.

[2 marks]

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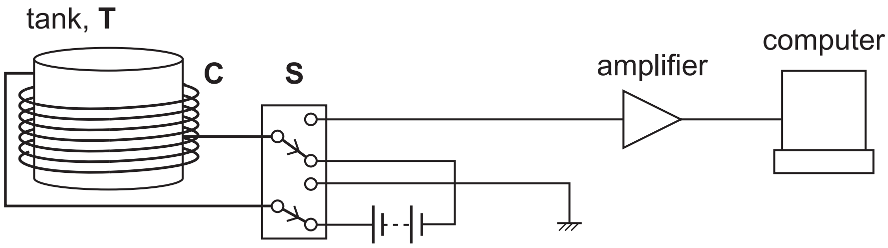
8 (a) **Figure 7** is a diagram of a proton magnetometer, showing the main components.

Figure 7



The switches, **S**, are both moved together repeatedly as the magnetometer is moved across an archaeological site. The output signal from the coil, **C**, is amplified before being processed by the computer.

8 (a) (i) Name a suitable substance to be held in the tank, **T**, and state why it is suitable.

[1 mark]

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8 (a) (ii) The switches, **S**, are initially in the lower position as shown in **Figure 7**.
State and explain the effect this has on the substance in the tank, **T**.

[2 marks]

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8 (a) (iii) When the switches, **S**, are moved to the upper position, the protons in the tank, **T**, begin to precess.
State and explain what happens to cause the precession of the protons when the switches are moved to the upper position.

[2 marks]

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8 (a) (iv) State the property of the signal that is measured by the computer.
Explain how the measurements made are used to investigate what may be beneath the surface of the ground at the archaeological site.

[4 marks]

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8 (b) In an MRI scanner, a gradient magnetic field of known strengths is used to indicate the presence of different structures in the body being investigated. The different parts of the body produce a signal in a similar way to that in a proton magnetometer but a different property of the signal is used to produce the image.

State the property of the signal that is used and explain how this can reveal the presence and location of tumours in the body.

[3 marks]

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12

END OF QUESTIONS

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