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	

General Certificate of Education
Advanced Level Examination
January 2013

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

Wednesday 16 January 2013 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

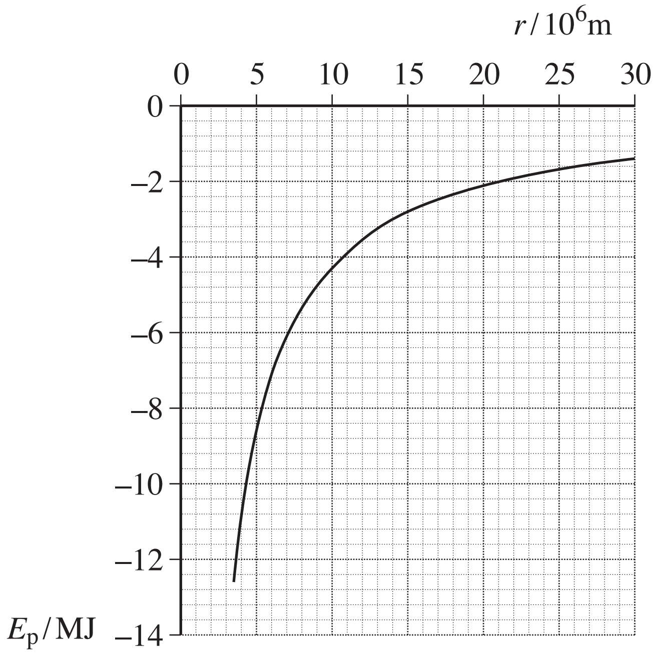
Instructions
- Use black ink or black ball-point pen. Use pencil only for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this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

1 The graph in **Figure 1** shows how the gravitational potential energy, E_p, of a 1.0 kg mass varies with distance, r, from the centre of Mars. The graph is plotted for positions above the surface of Mars.

Figure 1



1 (a) Explain why the values of E_p are negative.

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(2 marks)

1 (b) Use data from the graph to determine the mass of Mars.

mass of Mars .... kg

(3 marks)

1 (c) Calculate the escape velocity for an object on the surface of Mars.

escape velocity .... $m\,s^{-1}$

(3 marks)

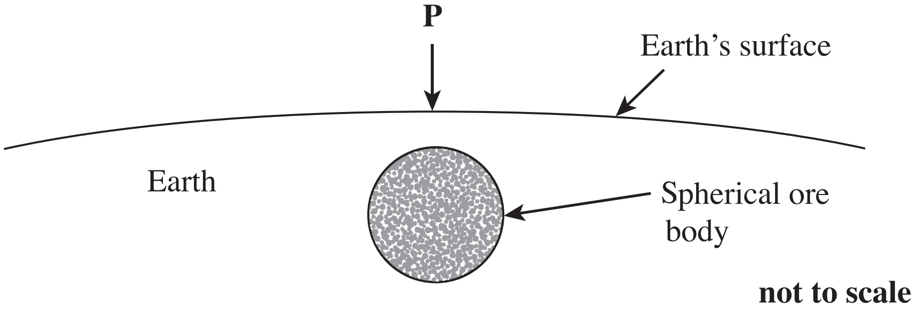
1 (d) Show that the graph data agree with $E_p \propto \frac{1}{r}$.

(3 marks)

11

2 (a) An ore body is a mass of granite or other material that contains useful metals. **Figure 2** shows a large spherical ore body lying just below the surface of the Earth.

Figure 2



The ore body has a diameter of 1200 m and a density of 7200 kg m^{-3} whilst the density of other material in the Earth's crust nearby is 2500 kg m^{-3}. The top of the ore body is 100 m below the surface.

2 (a) Calculate the difference between a measurement of the gravitational field strength at **P** and a measurement at a point on the surface of the Earth where there are no ore bodies below the surface. Give your answer in N kg^{-1} and in gal.

difference in gravitational field strength .... N kg^{-1}

difference in gravitational field strength .... gal

(4 marks)

2 (b) Gravimeters are used to investigate the variation of the gravitational field strength, g, at the surface of the Earth. One possible technique that could be used in a gravimeter is the variation in T, the period of oscillations of the mass in a simple pendulum.

2 (b) (i) Show that, for a simple pendulum, g is inversely proportional to T^2.

(3 marks)

2 (b) (ii) Using a suitable timer, it would be possible to detect a change of 0.0001 s in the period of a pendulum that has a period of about 25 s when g is 9.81 N kg^{-1}.
Assuming that the length of the pendulum is constant, calculate the change in g that would be detectable in an experiment using the pendulum.

Change in g .... N kg^{-1}
(3 marks)

2 (b) (iii) Explain why it is impractical to use a gravimeter that has a pendulum with a period of 25 s.

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(2 marks)

Turn over ▶

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2 (b) (iv) Explain why measurements of the period of oscillation of a mass-spring system cannot be used to determine changes in gravitational field strength.

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(2 marks)

14

3 A Simplified Aid for Extravehicular activity Rescue (a SAFER), is a device that astronauts have available in case they are accidently detached from their safety line when performing tasks outside the International Space Station. A SAFER is strapped to the astronaut's back and enables the astronaut to change direction and be propelled back to the Space Station.

A SAFER uses a tank that initially contains 1.40 kg of liquid nitrogen which the SAFER converts to nitrogen gas under pressure. A thrust is produced as the gas expands and is released through one or more of 24 nozzles. The design is such that each nozzle can produce a constant thrust of 3.56 N. Using all the nitrogen, the total velocity change that can be achieved is 3.05 m s^{-1}. The initial total mass of the astronaut, spacesuit and the SAFER unit is 151 kg.

density of liquid nitrogen = 810 kg m^{-3}
molar mass of nitrogen = 0.0280 kg

3 (a) (i) Calculate the volume of liquid nitrogen that is carried by the SAFER.

volume .... m^3
(2 marks)

3 (a) (ii) Calculate the volume of a container that 1.40 kg of nitrogen would occupy at a pressure of 1.0×10^5 Pa and a temperature of 25 °C. Assume that the nitrogen behaves as an ideal gas.

volume .... m^3
(3 marks)

Turn over ▶

3 (b) Explain how the release of gases from a nozzle propels the astronaut.

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(3 marks)

3 (c) (i) In one instance, gas is released from a single nozzle to produce only linear acceleration. Calculate the initial acceleration produced by the SAFER.

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

(2 marks)

3 (c) (ii) Assume that all the gas is released from a single nozzle. Calculate the speed at which gas leaves the nozzle.

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

(3 marks)

Do not write outside the box

3 (c) (iii) Calculate the mass of gas released per second by the nozzle.

mass released per second .... kg

(3 marks)

3 (d) Explain how the first law of thermodynamics applies when the gas that is under pressure in the SAFER expands through a nozzle.

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(3 marks)

19

Turn over for the next question

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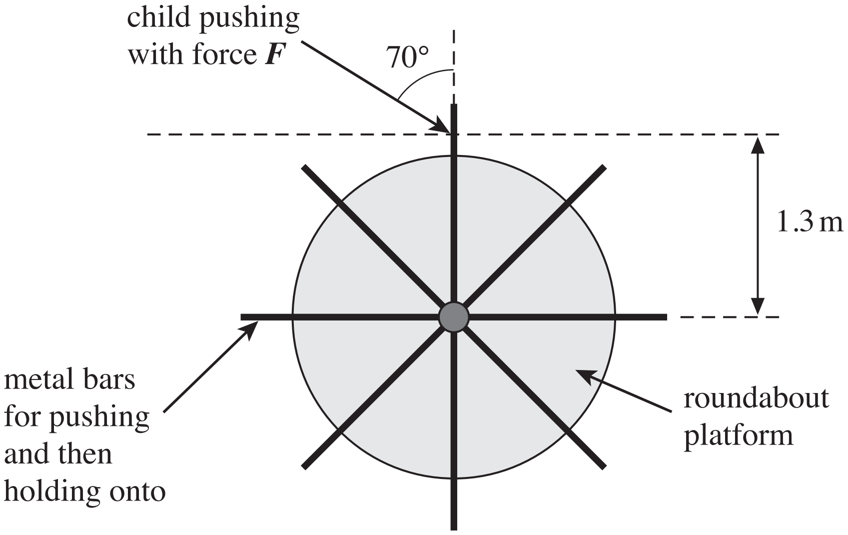
4 **Figure 3** shows the view from above of a roundabout in a children's playground.

Figure 3



The roundabout has a moment of inertia of 240 kg m^2 and is initially stationary.
A child exerts a force, ***F***, of constant magnitude on the roundabout. The force is applied 1.3 m from the axis of rotation and at an angle of 70° to one of the metal bars, as shown in **Figure 3**. The force produces a torque of 30 N m.

4 (a) Calculate the magnitude of the force ***F***.

force ***F*** .... N
(2 marks)

Do not write outside the box

4 (b) The child pushes with force ***F*** for half a revolution of the roundabout. The child stops running and then jumps on to the moving roundabout.

4 (b) (i) Show that the angular speed of the roundabout before the child jumps on is about $0.9\,\text{rad}\,\text{s}^{-1}$. Assume that frictional forces in the roundabout are negligible.

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(5 marks)

4 (b) (ii) When the child gets on to the roundabout the moment of inertia increases by $45\,\text{kg}\,\text{m}^2$.

Calculate the time taken for one revolution of the roundabout immediately after the child jumps on.
Assume that air resistance and frictional forces at the axle of the roundabout are negligible.

time taken .... s
(4 marks)

Turn over ▶

4 (b) (iii) Calculate the decrease in the rotational kinetic energy when the child jumps onto the roundabout.

decrease in kinetic energy .... J

(3 marks)

4 (b) (iv) Explain why the kinetic energy decreases.

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(1 mark)

4 (c) (i) Explain why the child is accelerating when on the roundabout even though the speed of rotation is constant.

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(3 marks)

4 (c) (ii) After jumping onto the roundabout platform, the child pushes on a bar in the direction of motion to try to make it go faster. Explain why the speed does not increase.

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(2 marks)

20

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ANSWER IN THE SPACES PROVIDED

5 Ultrasound is now commonly used to form images of organs inside the body in diagnosis of disease and for monitoring the development of a foetus during pregnancy.

The ultrasound is produced by a transmitter containing a crystal. To produce a single pulse of ultrasound a potential difference (pd) is applied to the crystal for a short time causing it to contract. When the pd ceases to be applied the crystal oscillates longitudinally, expanding and contracting at its natural frequency. **Figure 4** shows the displacement-time graph for the end of the crystal that is in contact with the patient's body. It shows that the crystal undergoes damped oscillations at its natural frequency.

The ultrasound wave produced by the crystal travels through soft body tissue at a speed of $1500\,\text{m s}^{-1}$. In one ultrasound scanner, the ultrasound has a frequency 15 MHz and the pulses are emitted by the transmitter at a frequency of 1.0 kHz. **Figure 5** shows a pulse of the ultrasound that has already passed positions **A** and **B** in the patient's body. When the pulse was at **B**, the amplitude of the leading edge of the ultrasound pulse had half the amplitude that it had when at position **A**. The distance between **A** and **B** is 25 mm.

Figure 4

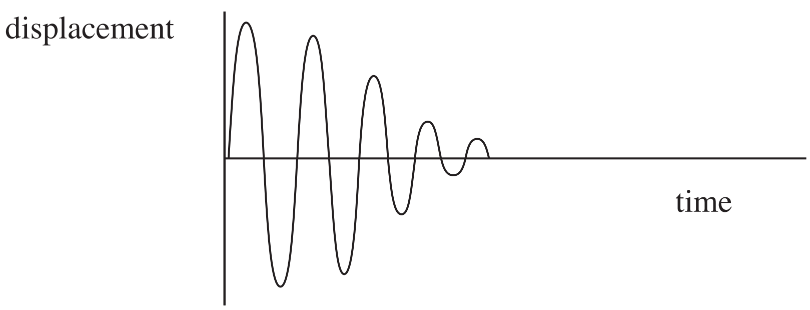
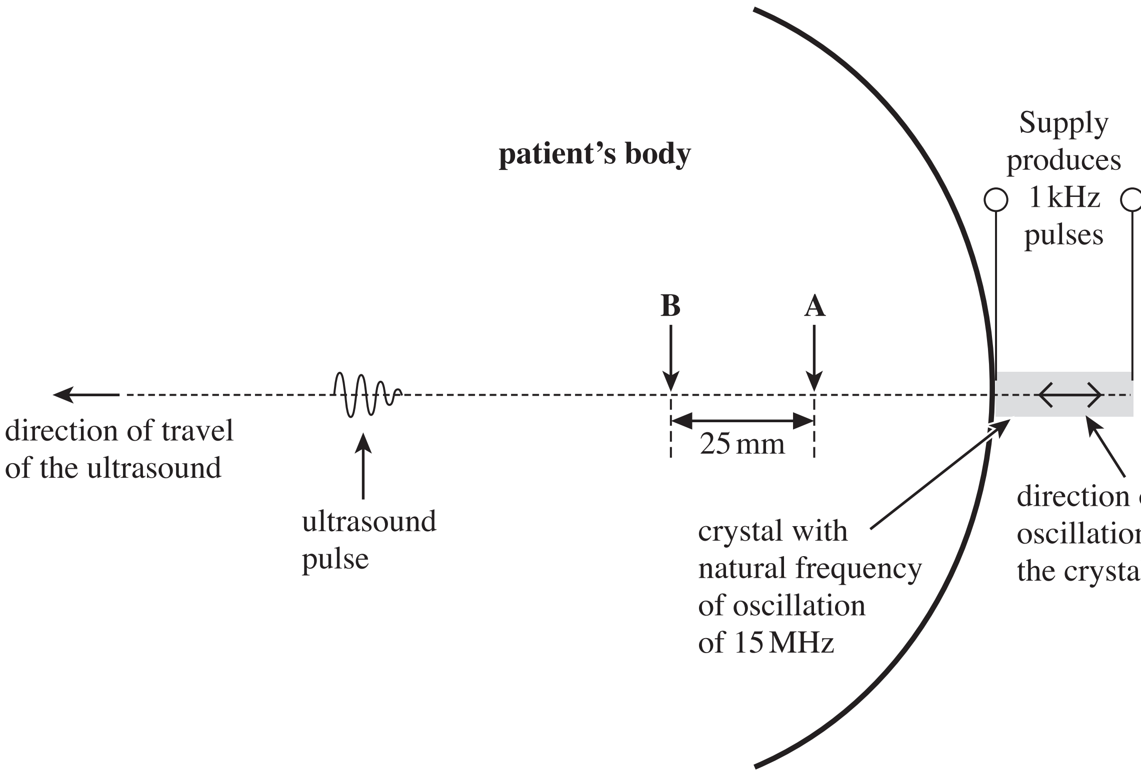


Figure 5



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5 (a) (i) Suggest the cause of the damping of the oscillation of the crystal when it produces a pulse, as shown in **Figure 4**.

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(2 marks)

5 (a) (ii) Calculate the average percentage energy loss per mm as a pulse travels from **A** to **B**.

loss of energy .... %

(3 marks)

5 (b) Explain why the designers of the equipment use ultrasound that has a very high frequency.

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(2 marks)

Turn over ▶

5 (c) Calculate the wavelength of the ultrasound wave as it passes through soft tissue.

wavelength .... m
(2 marks)

5 (d) Calculate the maximum number of oscillations in a pulse of the ultrasound wave so that one pulse does not overlap the next.

maximum number of oscillations ....
(3 marks)

5 (e) Explain how ultrasound imaging can be used to determine the depth at which a tumour is forming inside the body.
Go on to discuss a factor that limits its usefulness and name and explain an alternative diagnostic technique that overcomes this limitation.

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

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(6 marks)

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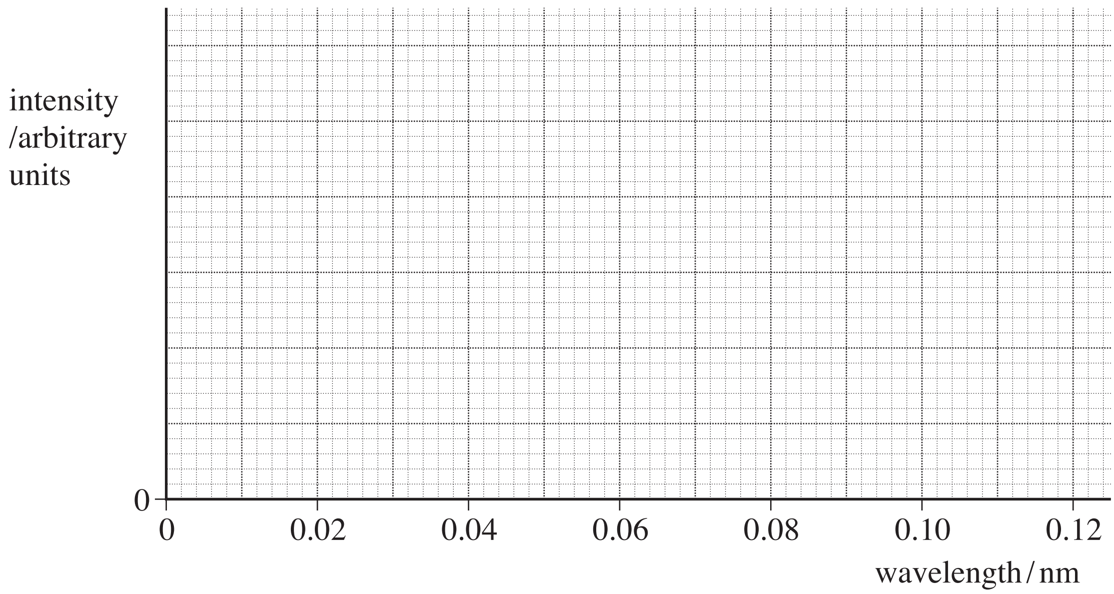
6 A manufacturer supplied the following data for one X-ray tube.

Minimum wavelength emitted	=	0.035 nm
Characteristic wavelengths emitted	=	0.065 and 0.075 nm
Electron beam power	=	1600 W

The efficiency for the conversion of energy in the electron beam to X-rays is 2.5%.

6 (a) Sketch on the axes below a graph showing how the intensity of the X-ray beam is likely to vary with wavelength for this tube over the range of wavelengths shown.



(3 marks)

6 (b) Calculate the potential difference that is used to accelerate the electron beam that produces the X-rays.

potential difference V

(3 marks)

6 (c) Explain how the characteristic X-rays are produced when the electron beam is incident on the target.

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(4 marks)

6 (d) (i) Calculate the energy in the X-ray beam that is **not** converted into X-rays each minute. Give your answer to an appropriate number of significant figures.

energy .... J

(2 marks)

6 (d) (ii) Describe and explain how the low efficiency of the tube influences its design.

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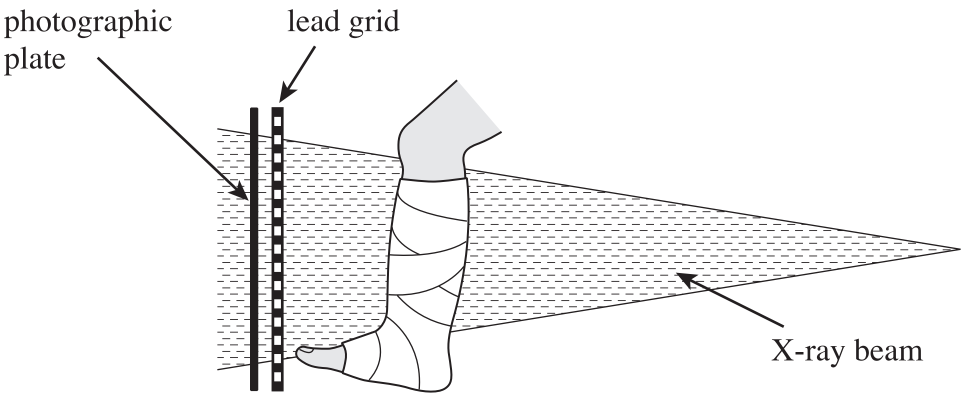
(3 marks)

Question 6 continues on the next page

Turn over ▶

6 (e) When using the X-ray tube a lead grid is often placed in front of the photographic plate, as shown in **Figure 6**.

Figure 6



State and explain the purpose of the lead grid.

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(3 marks)

18

END OF QUESTIONS