Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2002
Advanced Level Examination

PHYSICS (SPECIFICATION B) **PHB4**
Unit 4

ASSESSMENT and QUALIFICATIONS ALLIANCE

Friday 21 June 2002 Afternoon Session

In addition to this paper you will require:
- a calculator;
- a ruler.

Time allowed: 1 hour 30 minutes

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want marked.
- All working must be shown, otherwise you may lose marks.
- *Formulae Sheets* are provided on pages 3 and 4. Detach this perforated page at the start of the examination.

Information
- The maximum mark for this paper is 75.
- Mark allocations are shown in brackets.
- Marks are awarded for units in addition to correct numerical answers, and for the use of appropriate numbers of significant figures.
- You are expected to use a calculator where appropriate.
- You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary, where appropriate.
- The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
7			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

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Answer **all** questions in the spaces provided.

1 **Total for this question:** ***11 marks***

(a) Define the Young modulus of a material.

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(2 marks)

(b) **Figure 1** shows the stress-strain graphs for samples of copper and steel wires up to their breaking points.

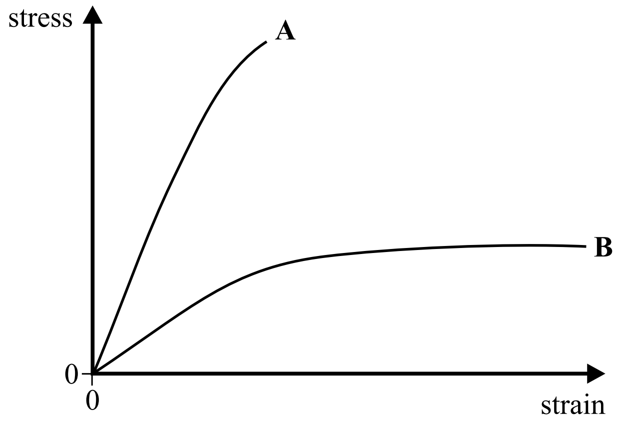

Figure 1

(i) Which sample, **A** or **B**, is steel?

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(1 mark)

(ii) Support your choice by relating **two** features of the graph to properties of steel.

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(2 marks)

Detach this perforated page at the start of the examination.

Foundation Physics Mechanics Formulae

moment of force $= Fd$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{1}{2}(u + v)t$

for a spring, $F = k \quad l$

energy stored in a spring $= \frac{1}{2}F \quad l = \frac{1}{2}k(\quad l)^2$

$T = \frac{1}{f}$

Foundation Physics Electricity Formulae

$I = nAvq$

terminal p.d. $= E - Ir$

in series circuit, $R = R_1 + R_2 + R_3 + ...$

in parallel circuit, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$

output voltage across $R_1 = \left(\frac{R_1}{R_1 + R_2}\right) \times$ input voltage

Waves and Nuclear Physics Formulae

fringe spacing $= \frac{\lambda D}{d}$

single slit diffraction minimum $\sin\theta = \frac{\lambda}{b}$

diffraction grating $n\lambda = d\sin\theta$

Doppler shift $\frac{\quad f}{f} = \frac{v}{c}$ for $v << c$

Hubble law $v = Hd$

radioactive decay $A = \lambda N$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\overline{\text{u}}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\overline{\text{d}}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Particle	Lepton number L		
	L_e	L_μ	L_τ
e^-	1		
e^+	–1		
ν_e	1		
$\overline{\nu}_e$	–1		
μ^-		1	
μ^+		–1	
ν_μ		1	
$\overline{\nu}_\mu$		–1	
τ^-			1
τ^+			–1
ν_τ			1
$\overline{\nu}_\tau$			–1

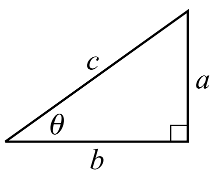
Geometrical and Trigonometrical Relationships

circumference of circle $= 2 \quad r$

area of a circle $= \quad r^2$

surface area of sphere $= 4 \quad r^2$

volume of sphere $= \frac{4}{3} \quad r^3$



$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

$c^2 = a^2 + b^2$

Turn over ►

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$$v = r\omega$$

$$a = -(2\ \ f)^2 x$$

$$x = A \cos 2\ \ ft$$

$$\text{maximum } a = (2\ \ f)^2 A$$

$$\text{maximum } v = 2\ \ fA$$

$$\text{for a mass-spring system, } T = 2\ \ \sqrt{\frac{m}{k}}$$

$$\text{for a simple pendulum, } T = 2\ \ \sqrt{\frac{l}{g}}$$

Fields and their Applications

$$\text{uniform electric field strength, } E = \frac{V}{d} = \frac{F}{Q}$$

$$\text{for a radial field, } E = \frac{kQ}{r^2}$$

$$k = \frac{1}{4\ \ \varepsilon_0}$$

$$g = \frac{F}{m}$$

$$g = \frac{GM}{r^2}$$

$$\text{for point masses, } E_p = GM_1 M_2 \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\text{for point charges, } E_p = kQ_1 Q_2 \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\text{for a straight wire, } F = BIl$$

$$\text{for a moving charge, } F = BQv$$

$$\phi = BA$$

$$\text{induced emf} = \frac{\ \ (N\phi)}{\ \ t}$$

$$E = mc^2$$

Temperature and Molecular Kinetic Theory

$$T/\text{K} = \frac{(pV)_T}{(pV)_{tr}} \times 273.16$$

$$pV = \tfrac{1}{3} Nm \langle c^2 \rangle$$

$$\text{energy of a molecule} = \tfrac{3}{2} kT$$

Heating and Working

$$\ \ U = Q + W$$

$$Q = mc\ \ \theta$$

$$Q = ml$$

$$P = Fv$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{power input}}$$

$$\text{work done on gas} = p\ \ V$$

$$\text{work done on a solid} = \tfrac{1}{2} F\ \ l$$

$$\text{stress} = \frac{F}{A}$$

$$\text{strain} = \frac{\ \ l}{l}$$

$$\text{Young modulus} = \frac{\text{stress}}{\text{strain}}$$

Capacitance and Exponential Change

$$\text{in series, } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\text{in parallel, } C = C_1 + C_2$$

$$\text{energy stored by capacitor} = \tfrac{1}{2} QV$$

$$\text{parallel plate capacitance, } C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$Q = Q_0 e^{-t/RC}$$

$$\text{time constant} = RC$$

$$\text{time to halve} = 0.69\ RC$$

$$N = N_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$

$$\text{half-life, } t_{\frac{1}{2}} = \frac{0.69}{\lambda}$$

Momentum and Quantum Phenomena

$$Ft = \ \ (mv)$$

$$E = hf$$

$$hf = \Phi + E_{k(max)}$$

$$hf = E_2 - E_1$$

$$\lambda = \frac{h}{mv}$$

(c) Describe a method for the accurate measurement of the Young modulus of a wire. Draw a labelled diagram of the apparatus to help your description. Two of the 6 marks in this question are for the quality of your written communication.

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(6 marks)

11

TURN OVER FOR THE NEXT QUESTION

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2 **Total for this question:** ***7 marks***

Figure 2 shows a mass suspended on a spring.

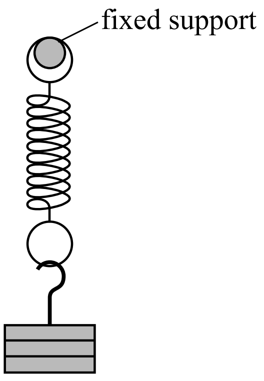
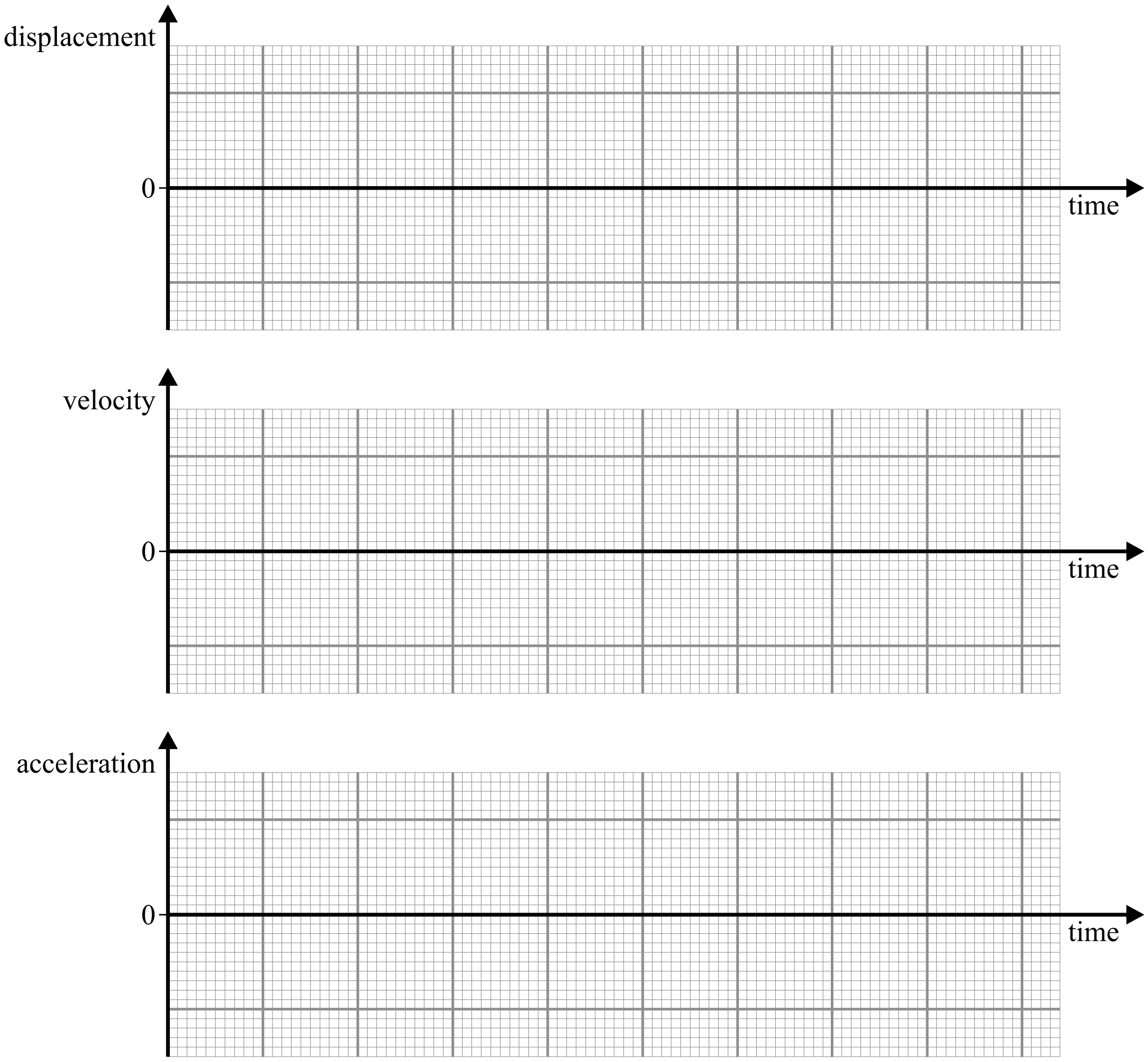


Figure 2

The mass is pulled down by a distance A below the equilibrium position and then released at time $t = 0$. It undergoes simple harmonic motion.

(a) Taking upward displacements as being positive, draw graphs on **Figure 3** to show the variation of displacement, velocity and the acceleration with time. Use the same time scale for each of the three graphs.



(4 marks)

Figure 3

(b) The spring stiffness, k, is $32\,\text{N}\,\text{m}^{-1}$. The spring is loaded with a mass of 0.45 kg. Calculate the frequency of the oscillation.

(3 marks)

7

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3 **Total for this question: *12 marks***

(a) The first law of thermodynamics may be written as:

$$\Delta U = Q + W$$

State the meaning of positive values for each of the symbols in this equation.

ΔU ....

Q ....

W ....

(3 marks)

(b) For an isothermal change in an ideal gas:

(i) explain why $\Delta U = 0$;

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(1 mark)

(ii) explain the effects on Q and W.

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(2 marks)

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(c) **Figure 4** shows an isothermal expansion for 1.2×10^{-3} mol of an ideal gas.

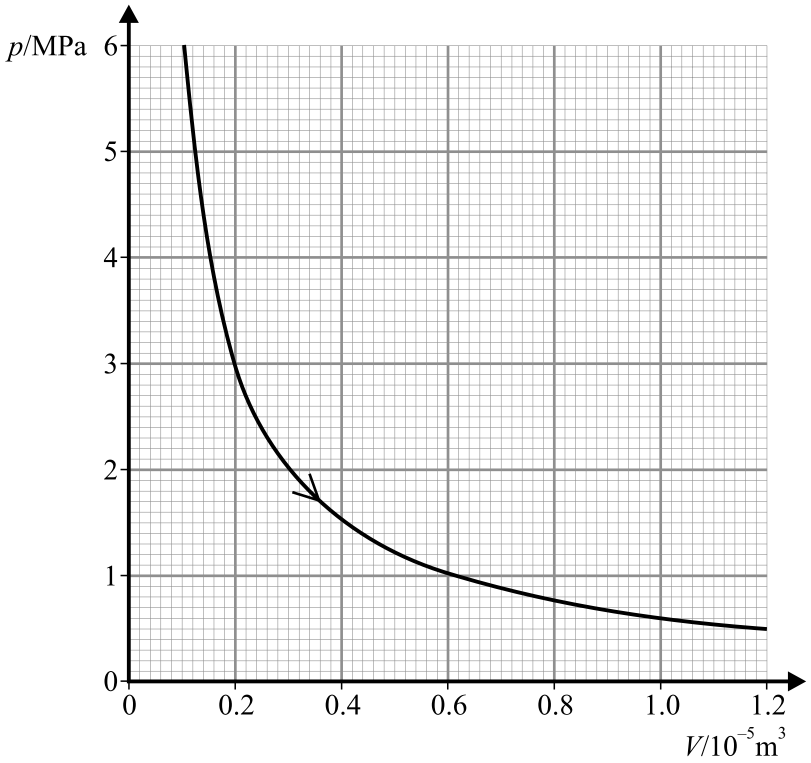

Figure 4

(i) Show that the temperature at which this expansion occurs is approximately 600 K.

molar gas constant, $R = 8.3\ \text{J mol}^{-1}\ \text{K}^{-1}$

(2 marks)

(ii) Add to **Figure 4** a second line to show the expansion of the ideal gas at a temperature of 400 K. Show how you have chosen your values.

(4 marks)

12

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4 **Total for this question: *11 marks***

A meteorite of mass 1.2×10^4 kg enters the Earth's atmosphere at a speed of 2.5 km s^{-1}.

(a) Calculate the kinetic energy of the meteorite as it enters the atmosphere.

(2 marks)

(b) The meteorite is initially at a temperature of 25 °C. It is made of iron of specific heat capacity 110 J kg^{-1} K^{-1} and of melting point 1810 °C. As the meteorite travels through the Earth's atmosphere friction causes its temperature to rise. Calculate the energy needed to raise the temperature of the meteorite to its melting point. You should assume that the specific heat capacity of iron remains constant.

(3 marks)

(c) When it reaches the surface of the Earth the mass of the meteorite has fallen to 5.5×10^3 kg and its speed to 150 m s^{-1} so that its kinetic energy is only 6.2×10^7 J. On striking the Earth this mass penetrates the Earth's crust and is brought to rest in a distance of 25 m. Calculate:

(i) the average force acting on the meteorite as it penetrates the Earth's crust;

(2 marks)

(ii) the time it takes for the meteorite to be brought to rest by the Earth's crust;

(2 marks)

(iii) the rate at which the meteorite dissipates energy in this time.

(2 marks)

11

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5 **Total for this question:** ***9 marks***

Figure 5 shows a dust particle at position **D** on a rotating vinyl disc. A combination of electrostatic and frictional forces act on the dust particle to keep it in the same position.

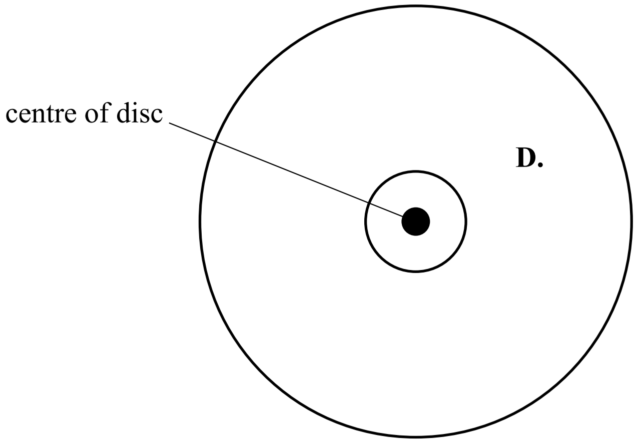

Figure 5

The dust particle is at a distance of 0.125 m from the centre of the disc. The disc rotates at 45 revolutions per minute.

(a) Calculate the linear speed of the dust particle at **D**.

(3 marks)

(b) (i) Mark on **Figure 5** an arrow to show the direction of the resultant horizontal force on the dust particle. *(1 mark)*

(ii) Calculate the centripetal acceleration at position **D**.

(2 marks)

Turn over ►

(c) On looking closely at the rotating disc it can be seen that there is more dust concentrated on the inner part of the disc than the outer part. Suggest why this should be so.

(3 marks)

9

6 **Total for this question:** ***15 marks***

Figure 6 shows a 2.0 μF capacitor connected to 150 V supply.

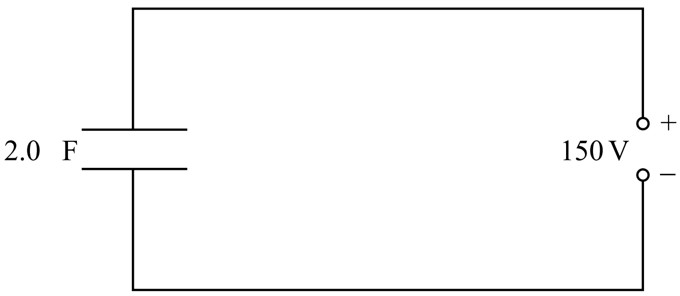

Figure 6

(a) Calculate the charge on the capacitor.

(2 marks)

(b) (i) Suggest a graph that could be drawn in order to calculate the energy stored in the capacitor by finding the area under the graph.

(1 mark)

(ii) Calculate the energy stored by the capacitor when it has a p.d. of 150 V across it.

(2 marks)

(c) The charged capacitor is removed from the power supply and discharged by connecting a 220 kΩ resistor across it.

(i) Calculate the maximum discharge current.

(1 mark)

(ii) Show that the current will have fallen to 10% of its maximum value in a time of approximately 1 s.

(4 marks)

(d) A pair of identical capacitors are connected across a d.c. power supply and connected (i) in series and (ii) in parallel. The energy stored in each arrangement is different. State and explain which arrangement stores the greater energy. Two of the 5 marks in this question are for the quality of your written communication.

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(5 marks)

15

Turn over ►

7 **Total for this question: *10 marks***

(a) Discovery of the photoelectric effect was largely responsible for the development of the theory that electromagnetic radiation can behave as a particle or as a wave under different circumstances. **Figure 7** shows an experimental arrangement used to demonstrate aspects of the photoelectric effect. When photoelectrons are emitted the ammeter registers a current.

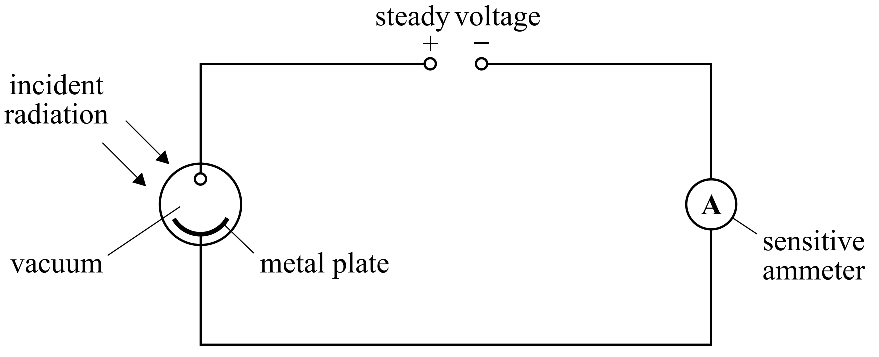

Figure 7

(i) The metal plate is illuminated with radiation but does not emit photoelectrons. The intensity of the radiation is increased. State and explain what effect this increase in intensity has.

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(2 marks)

(ii) The metal plate is illuminated with radiation such that photoelectrons are emitted. The intensity of the radiation is increased. State and explain what effect this increase in intensity has.

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(2 marks)

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(iii) The metal plate is illuminated with radiation such that photoelectrons are emitted. Air is now allowed to enter the enclosure. State and explain what effect allowing air into the enclosure has.

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(2 marks)

(b) (i) Show that the de Broglie wavelength of an electron travelling at 0.15c should be approximately 1.6×10^{-11} m.

the Plank constant, $h = 6.6 \times 10^{-34}$ J s
the speed of electromagnetic waves in a vacuum, $c = 3.0 \times 10^{8}$ m s^{-1}
the mass of an electron, $m_e = 9.1 \times 10^{-31}$ kg

(2 marks)

(ii) Suggest a suitable material to give an observable diffraction pattern with electrons. Explain your choice.

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(2 marks)

10

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE