Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2003
Advanced Level Examination

PHYSICS (SPECIFICATION B) PHB4
Unit 4 Further Physics

Friday 20 June 2003 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 page 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			

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

Total for this question: ***16 marks***

1 **Figure 1** shows a way to measure the mass of a lorry. The vehicle and its contents are driven onto a platform mounted on a spring. The platform is then made to oscillate vertically and the mass is found from a measurement of the natural frequency of oscillation.

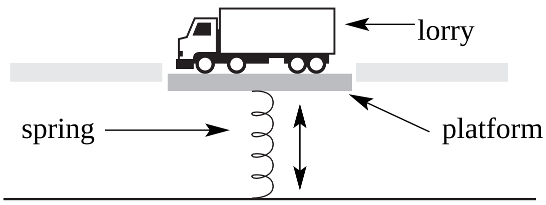

Figure 1

(a) (i) State whether the period of oscillation increases, decreases or remains unchanged when the amplitude of oscillation of the platform is reduced.

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(1 mark)

(ii) The spring constant k of the supporting spring is increased to four times its original value.

State the value of the ratio $\frac{\text{new oscillation period}}{\text{old oscillation period}}$.

....

(1 mark)

(iii) The time period of oscillation is T when a lorry is on the platform. The spring constant of the spring is k. Show that the total mass M of lorry and platform is given by

$$M = \frac{kT^2}{4\pi^2}$$

(2 marks)

Detach this perforated page at the start of the examination.

Foundation Physics Mechanics Formulae

$$\text{moment of force} = Fd$$

$$v = u + at$$

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

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

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

$$\text{for a spring, } F = k\Delta l$$

$$\text{rgy stored in a spring} = \tfrac{1}{2}F\Delta l = \tfrac{1}{2}k(\Delta l)^2$$

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

Foundation Physics Electricity Formulae

$$I = nAvq$$

$$\text{terminal p.d.} = E - Ir$$

$$\text{in series circuit, } R = R_1 + R_2 + R_3 + \ldots..$$

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

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

Waves and Nuclear Physics Formulae

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

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

$$\text{diffraction grating} \quad n\lambda = d\sin\theta$$

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

$$\text{Hubble law} \quad v = Hd$$

$$\text{radioactive decay} \quad A = \lambda N$$

Properties of Quarks

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

Lepton Numbers

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

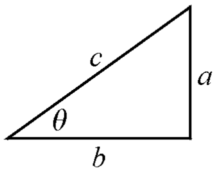
Geometrical and Trigonometrical Relationships

$$\text{circumference of circle} = 2\pi r$$

$$\text{area of a circle} = \pi r^2$$

$$\text{surface area of sphere} = 4\pi r^2$$

$$\text{volume of sphere} = \tfrac{4}{3}\pi r^3$$



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

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

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

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

Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$$v = r\omega$$

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

$$x = A\cos 2\pi f t$$

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

$$\text{maximum } v = 2\pi f A$$

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

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

Fields and their Applications

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

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

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

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

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

$$\text{for point masses, } \Delta E_p = GM_1M_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\text{for point charges, } \Delta E_p = kQ_1Q_2\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

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

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

$$\phi = BA$$

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

$$E = mc^2$$

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

$$\Delta U = Q + W$$

$$Q = mc\Delta\theta$$

$$Q = ml$$

$$P = Fv$$

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

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

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

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

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

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

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

$$Ft = \Delta(mv)$$

$$E = hf$$

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

$$hf = E_2 - E_1$$

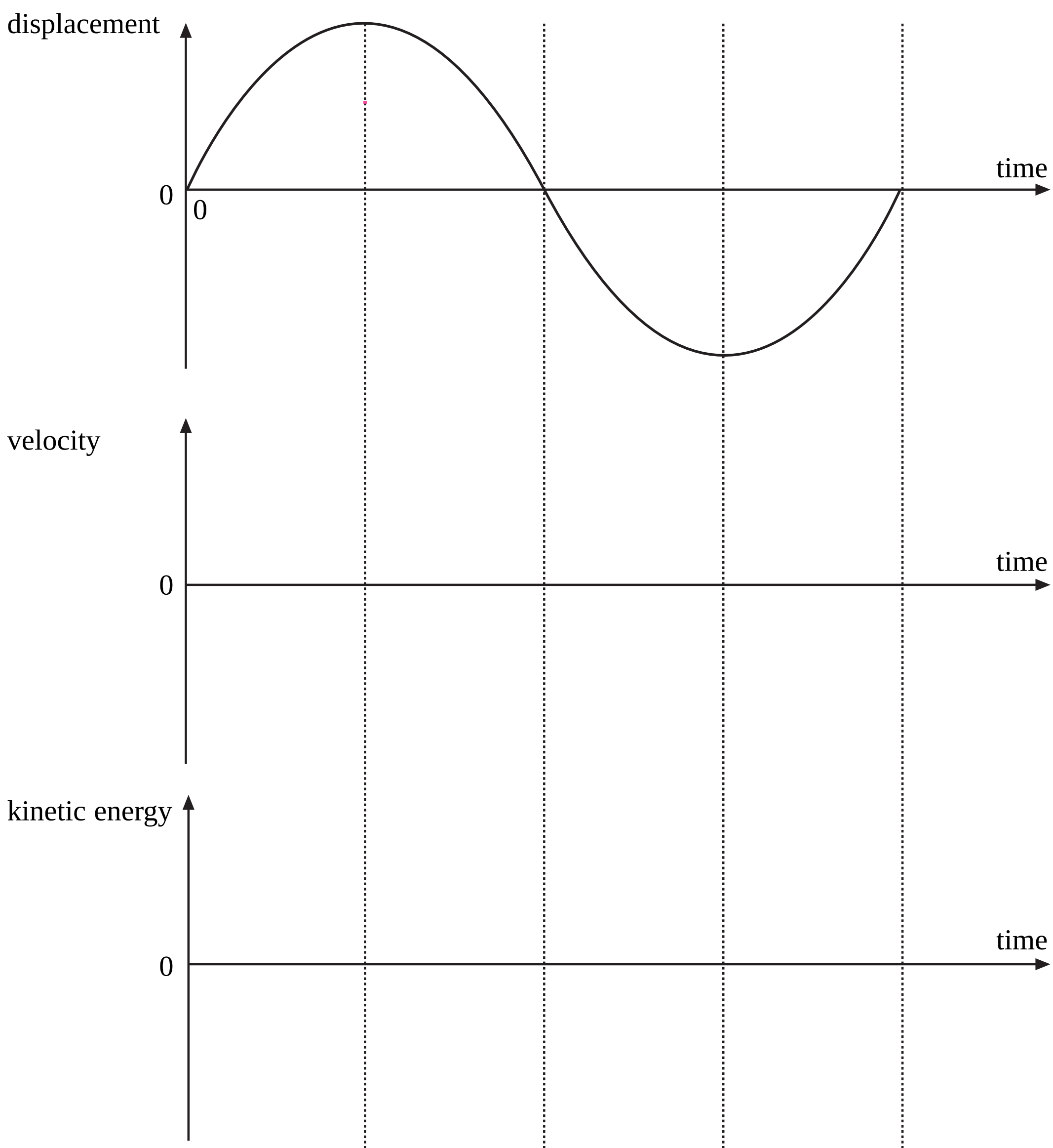
$$\lambda = \frac{h}{mv}$$

(iv) A lorry and its contents have a total mass of 5300 kg. The spring constant of the supporting spring k is $1.9 \times 10^5\,\text{N m}^{-1}$. The frequency of oscillation of the platform with the lorry resting on it is 0.91 Hz.

Calculate the mass of the platform.

(3 marks)

(b) The graph below shows how the displacement of the platform varies with time over one cycle. Sketch on the axes provided graphs of velocity against time and kinetic energy against time for the motion of the platform.



(5 marks)

QUESTION 1 CONTINUES ON THE NEXT PAGE

(c) The driver is required to turn off the vehicle engine whilst the measurement is taking place.

The driver of the lorry in part (a)(iv) fails to do this and slowly increases the frequency of vibration of his vehicle from 0.5 Hz to about 4 Hz whilst the measurement is in progress and the platform is free to move. Describe and explain how the amplitude and frequency of the platform vary as this frequency increase occurs. You should use a sketch graph to support your answer.

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(4 marks)

16

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

2 In a power station, water is heated in a boiler to create steam. This steam is passed through a turbine before being cooled by river water to condense it back into the liquid state. The cooled water is then pumped back to the boiler for re-use.

(a) The cooling water enters the condenser at 16 °C and is returned to the river at 40 °C. Every second, 35×10^3 kg of water are removed from the river.

Calculate the power required to heat this water.

Specific heat capacity of water, c, = 4200 J kg^{-1}K^{-1}

(2 marks)

(b) Assume that all the energy transferred by the river water came from steam changing to water without a change in temperature.

Calculate the mass of steam passing through the turbine per second.

Specific latent heat of vaporisation of water = 2.4×10^6 J kg^{-1}

(2 marks)

(c) The turbine is linked to a generator that produces 800 MW of electrical power.
Calculate the efficiency of conversion of the internal energy of the steam into electrical energy.

(2 marks)

6

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

3 **Figure 2** shows the rotor-blade arrangement used in a model helicopter. Each of the blades is 0.55m long with a uniform cross-sectional area of $3.5 \times 10^{-4}\,m^2$ and negligible mass. An end-cap of mass 1.5 kg is attached to the end of each blade.

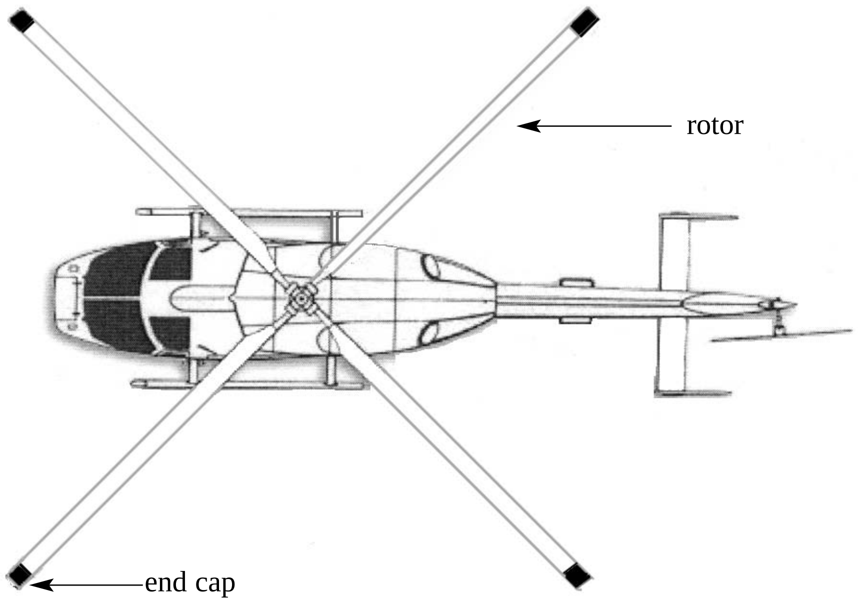

Figure 2

(a) (i) Show that there is a force of about 7 kN acting on each end-cap when the blades rotate at 15 revolutions per second.

(3 marks)

(ii) State the direction in which the force acts on the end-cap.

....

(1 mark)

(iii) Show that this force leads to a longitudinal stress in the blade of about 20 MPa.

(2 marks)

(iv) Calculate the change in length of the blade as a result of its rotation.

Young modulus of the blade material = 6.0×10^{10} Pa

(2 marks)

(v) Calculate the total strain energy stored in **one** of the blades due to its extension.

(2 marks)

(b) The model helicopter can be made to hover above a point on the ground by directing the air from the rotors vertically downwards at speed v.

(i) Show that the change in momentum of the air each second is $A\rho v^2$, where A is the area swept out by the blades in one revolution and ρ is the density of air.

(2 marks)

(ii) The model helicopter has a weight of 900 N. Calculate the speed of the air downwards when the helicopter has no vertical motion.

Density of air = $1.3\,\mathrm{kg\,m^{-3}}$

(3 marks)

15

Total for this question: *14 marks*

4 A pressure pad used to count customers entering a shop consists of two parallel metal plates separated by a rubber sheet. **Figure 3** shows the pad and the electrical connections to it. When a customer steps on the pad, the sheet is compressed and changes in the circuit are detected by an electronic counter.

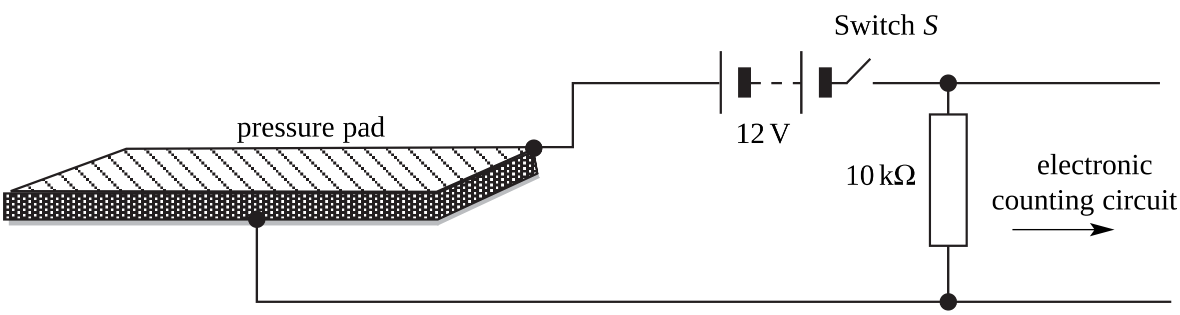

Figure 3

(a) The dimensions of the metal plates and the rubber sheet are 0.35 m by 0.45 m. The rubber sheet is initially 3.0×10^{-3} m thick with a relative permittivity of 6.0.

(i) Calculate the capacitance of the pressure pad.

Permittivity of free space = 8.9×10^{-12} F m^{-1}

(2 marks)

(ii) The resistor has a value of 10 kΩ and the power supply has an emf of 12 V and negligible internal resistance. Calculate the initial current when the switch is closed.

(2 marks)

(iii) Calculate the time constant, *T*, for the circuit.

(1 mark)

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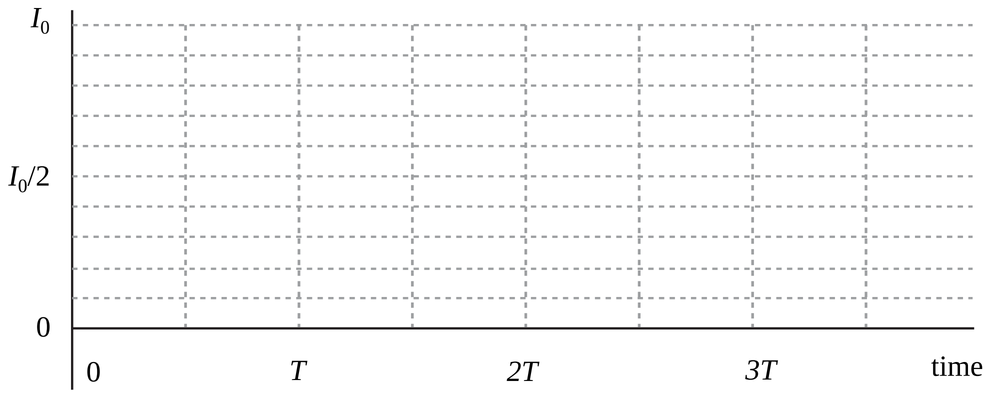
(iv) Sketch a graph showing the variation of current through the resistor with time after switch S is closed.

initial current



(3 marks)

(b) When a customer steps on the pad the separation of the plates decreases. State and explain how the current changes in the circuit as the customer steps on the pad.

Two of the 6 marks in this question are available for the quality of your written communication.

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(6 marks)

14

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

5 **Figure 4** shows how the maximum kinetic energy of electrons emitted from the cathode of a photoelectric cell varies with the frequency of the incident radiation.

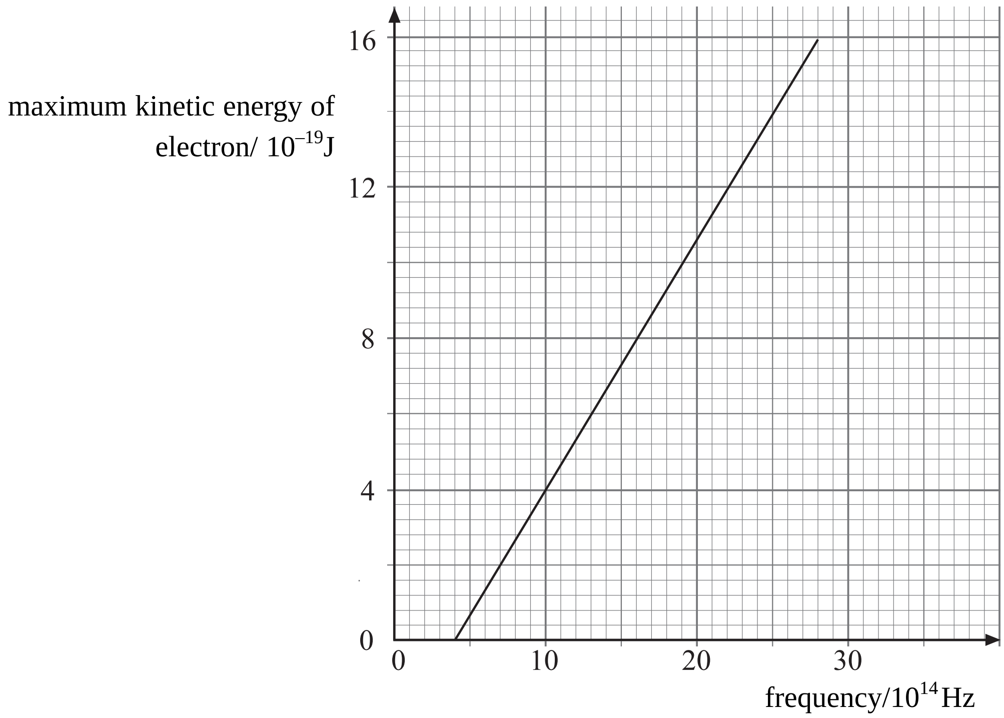

Figure 4

(a) Calculate the maximum wavelength of electromagnetic radiation that can release photoelectrons from the cathode surface.

Speed of electromagnetic radiation in a vacuum = $3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

(3 marks)

(b) Another photoelectric cell uses a different metal for the photocathode. This metal requires twice the minimum energy for electron release compared to the metal in the first cell.

(i) Draw a line on **Figure 4** to show the graph you would expect to obtain for this second cell.
(1 mark)

(ii) Explain your answer with reference to the Einstein photoelectric equation.

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(2 marks)

6

Total for this question: *5 marks*

6 **Figure 5** shows electrons being fired at a polycrystalline graphite target in a vacuum. The electrons are emitted from a heated cathode and pass through an accelerating p.d. The inside surface on the far side of the chamber is coated with fluorescent material that emits light when the electrons release their energy to it.

Mass of electron $m_e = 9.1 \times 10^{-31}$ kg
Planck constant $h = 6.6 \times 10^{-34}$ Js

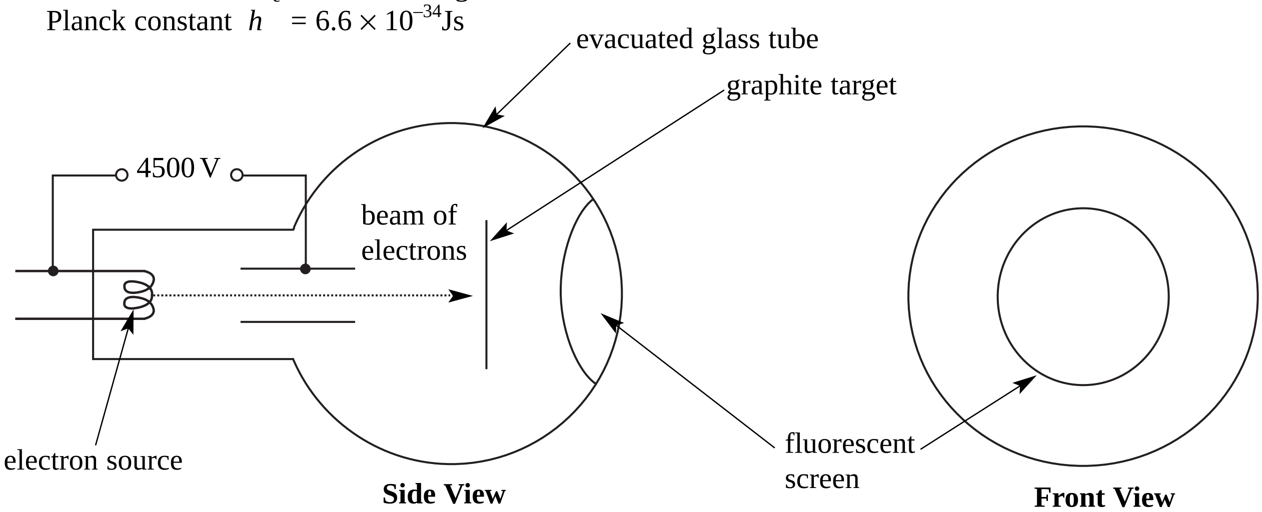

Figure 5

(a) The electrons travel at a speed of 4.0×10^7 m s^{-1}. Calculate their de Broglie wavelength.

(1 mark)

(b) Sketch on the **front view** of the fluorescent screen shown in **Figure 5** the pattern of light you would expect to see emitted by the fluorescent material.

Explain why this pattern suggests that electrons have wave-like properties.

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(2 marks)

(c) Explain **one** aspect of the experiment that suggests that electrons have particle-like properties.

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(2 marks)

5

Total for this question: ***13 marks***

7 Some liquids in open bottles deteriorate with exposure to the air. **Figure 6** shows one device used to reduce this deterioration. It consists of a rubber valve that is inserted into the neck of the bottle together with a pump that is used to remove some of the air in the bottle through this rubber valve. On a *quick* up-stroke of the pump, air enters the pump chamber from the bottle. On the down-stroke the rubber valve closes and the air in the chamber is expelled to the atmosphere through another valve (not shown) in the handle.

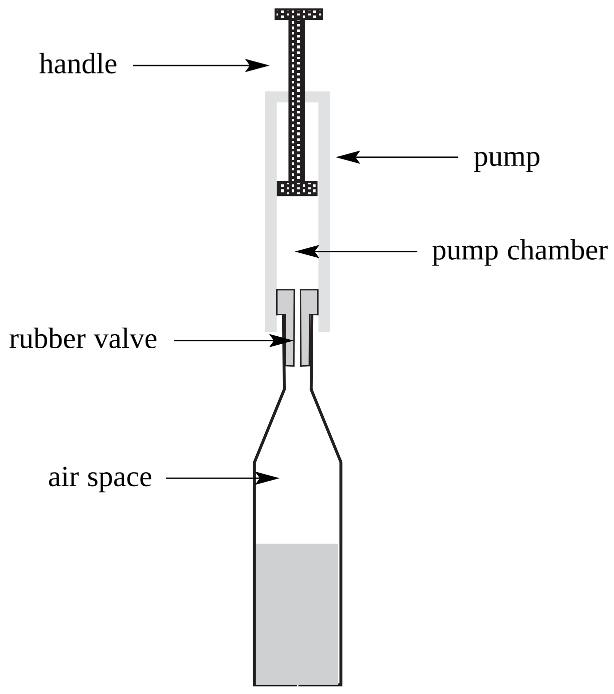

Figure 6

(a) (i) There is $3.5 \times 10^{-4}\,m^3$ of air space in the bottle and the volume of the pump chamber changes from zero at the beginning of the up-stroke to $6.5 \times 10^{-5}\,m^3$ at the end of up-stroke. The initial pressure of the air in the bottle is that of the atmosphere with a value of 99 kPa.

Assuming that the process is isothermal, calculate the pressure in the bottle after one up-stroke of the pump.

(3 marks)

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(ii) State why it is unlikely that the process is isothermal.

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(1 mark)

(b) Calculate the number of moles of air originally in the air space in the bottle at a temperature of 18 °C.

Universal gas constant = 8.3 J mol^{-1} K^{-1}

(2 marks)

(c) Explain how the kinetic theory model of an ideal gas predicts the existence of a gas pressure inside the bottle. Go on to explain why this pressure decreases when some of the air is removed from the bottle.

Two of the 7 marks in this question are available for the quality of your written communication.

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(7 marks)

13

END OF QUESTIONS