Class	Index Number	Name
23S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2024
Preliminary Examination

PHYSICS, Higher 2 **9749/03**

Paper 3 Longer Structured Questions **11th September 2024**
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section **A**
Answer **all** questions.

Section **B**
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/ 15
2	/ 6
3	/ 6
4	/ 8
5	/ 7
6	/ 10
7	/ 8
Section B	
8	/ 20
9	/ 20
Total	/ 80

This document consists of **26** printed pages including this page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\varphi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/^{\circ}\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$

decay constant $\lambda = \frac{\ln 2}{t_{1/2}}$

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

1 **(a)** The Earth spins on its axis with a period of one day.

(i) Show that the angular velocity of a point on the Earth's surface is 7.27×10^{-5} rad s^{-1}.

[1]

(ii) Calculate the centripetal acceleration of a point on the Earth's equator. The radius of the Earth's equator is 6.38×10^{6} m.

centripetal acceleration = ... m s^{-2} [2]

(b) The acceleration of free fall g at the equator is not equal to the acceleration of free fall at the poles. Explain

(i) why they are different,

....

....

....

.... [2]

(ii) why the difference is small.

....

....

....

....

.... [2]

(c) **(i)** State Newton's law of gravitation.

....

....[1]

(ii) The mass M of the Earth may be considered to be concentrated at its centre. The radius of the Earth is R. Derive, in terms of M and R, the equation relating the Earth's gravitational field strength g to the gravitational constant G.

Explain your working.

[2]

(d) **(i)** Calculate how far a satellite needs to be from the centre of the Earth for its angular velocity to be equal to the angular velocity of the Earth.

distance =............................m [3]

(ii) State two circumstances under which a satellite at this distance will be a geostationary satellite.

1. ....

....

2. ....

.... [2]

2 The first law of thermodynamics, when applied to a system, can be expressed as:

$$\Delta U = q + w$$

where ΔU is the increase in internal energy of the system,
q is the heat supplied to the system and
w is the work done on the system.

State and explain, in terms of the first law of thermodynamics, the change, if any, in the internal energy

(a) of the water in an ice cube when ice melts, at atmospheric pressure, to form a liquid without any change of temperature,

....

....

....

....[3]

(b) of the gas in a tyre when the tyre bursts so that the gas suddenly increases in volume. Assume that the gas is ideal.

....

....

....

....[3]

3 **(a)** Explain qualitatively how molecular movement causes the pressure exerted by a gas.

....

....

....

....

....

.... [3]

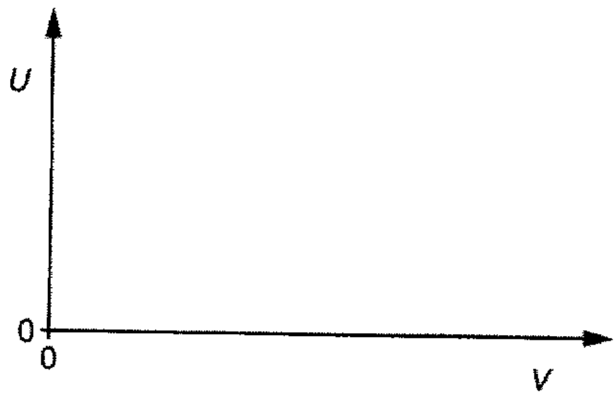
(b) A fixed mass of neon gas has a pressure of 1.02×10^5 Pa and density of 0.900 kg m^{-3}. Neon may be assumed to be an ideal gas.

Calculate the root-mean-square speed of neon atoms.

speed = ... m s^{-1} [2]

(c) The density of the neon gas in **(b)** is now varied, keeping its pressure constant.

On Fig. 3.1, sketch the variation with volume V of the internal energy U of the gas.



[1]

Fig. 3.1

4 A tube, closed at one end, has a uniform area of cross-section. The tube contains some sand so that the tube floats upright in a liquid, as shown in Fig. 4.1

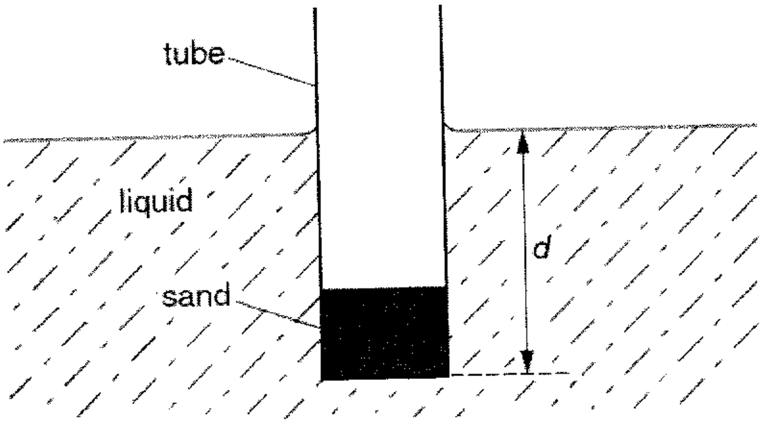


Fig. 4.1

When the tube is at rest, the depth d of immersion of the base of the tube is 16 cm. The tube is displaced vertically and then released.

The variation with time t of the depth d of the base of the tube is shown in Fig. 4.2.

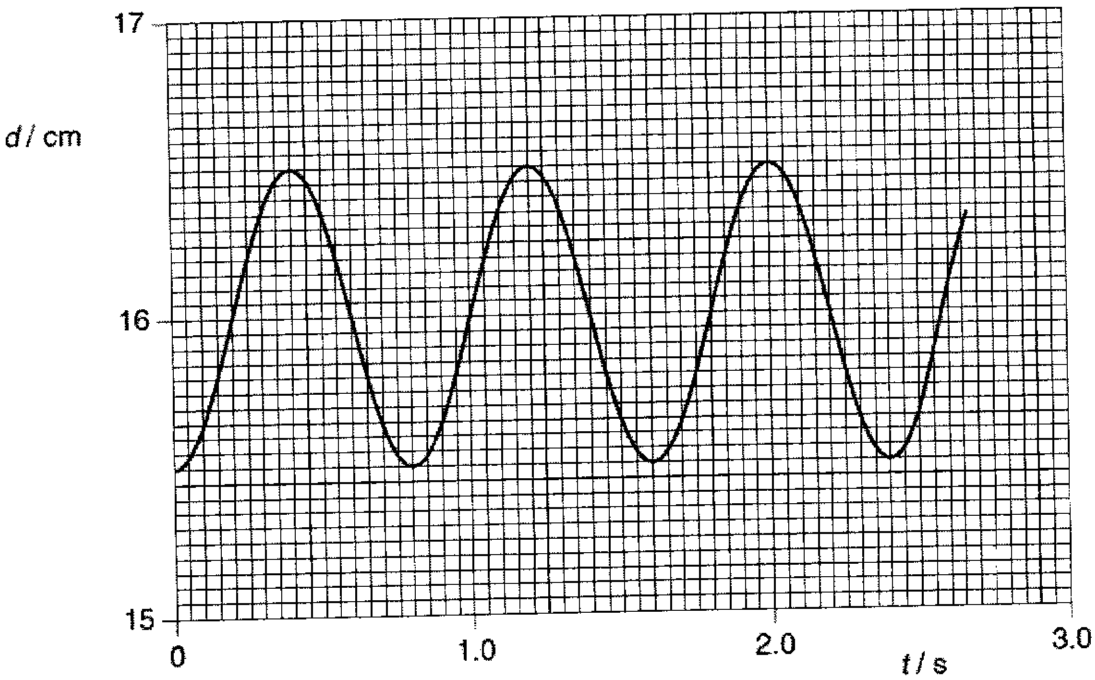


Fig. 4.2

(a) Use Fig. 4.2 to determine, for the oscillations of the tube, the amplitude.

amplitude = ... cm [1]

(b) **(i)** Calculate the vertical speed of the tube at a point where the depth *d* is 16.2 cm.

speed = ... cm s^{-1} [3]

(ii) State **one** other depth *d* where the speed will be equal to that calculated in **(i)**.

d = ... cm [1]

(c) The liquid in **(b)** is now cooled so that, although the density is unchanged, there is friction between the liquid and the tube as it oscillates. Having been displaced, the tube completes approximately 10 oscillations before coming to rest.

On Fig. 4.2, draw a line to show the variation with time *t* of depth *d* for the first 2.5 s of the motion.

[3]

5 (a) A beam of vertically polarised light is incident normally on a polarising filter, as shown in Fig. 5.1.

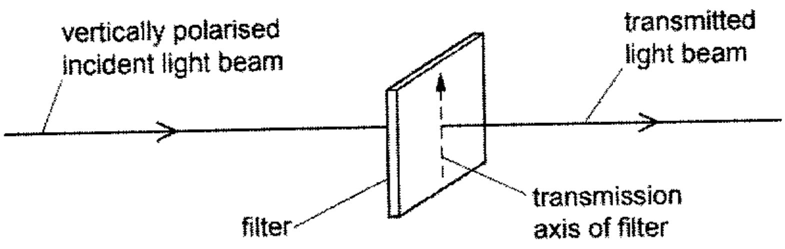
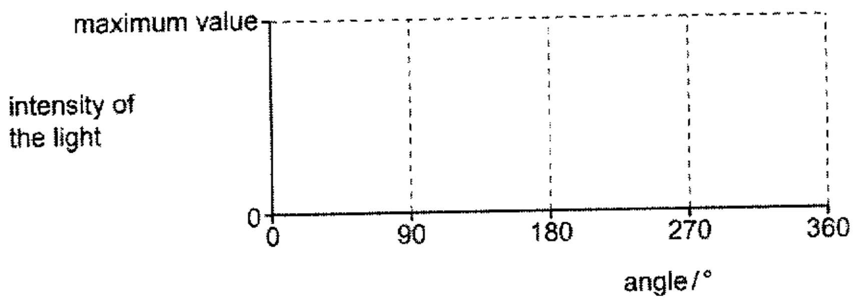


Fig. 5.1

(i) The transmission axis of the filter is initially vertical. The filter is then rotated through an angle of 360° while the plane of the filter remains perpendicular to the beam.

On Fig. 5.2, sketch a graph to show the variation of the intensity of the light in the transmitted beam with the angle through which the transmission axis is rotated.



[2]

Fig. 5.2

(ii) The intensity of the light in the incident beam is 7.6 W m^{-2}. When the transmission axis of the filter is at angle θ to the vertical, the light intensity of the transmitted beam is 4.2 W m^{-2}.

Calculate angle θ.

θ = ...° [1]

(b) State what is meant by the diffraction of a wave.

....

....

.... [1]

(c) A beam of light of wavelength 4.3×10^{-7} m is incident normally on a diffraction grating in air, as shown in Fig. 5.3.

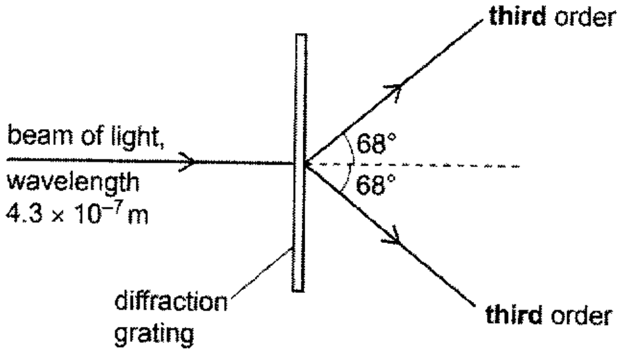


Fig. 5.3 (not to scale)

The **third**-order diffraction maximum of the light is at an angle of 68° to the direction of the incident light beam.

Determine a different wavelength of visible light that will also produce a diffraction maximum at an angle of 68°.

wavelength = ... m [3]

6 (a) The graphs on Fig. 6.1 show how the resistance of a metal resistor **R** and a thermistor **T** varies when the temperature changes.

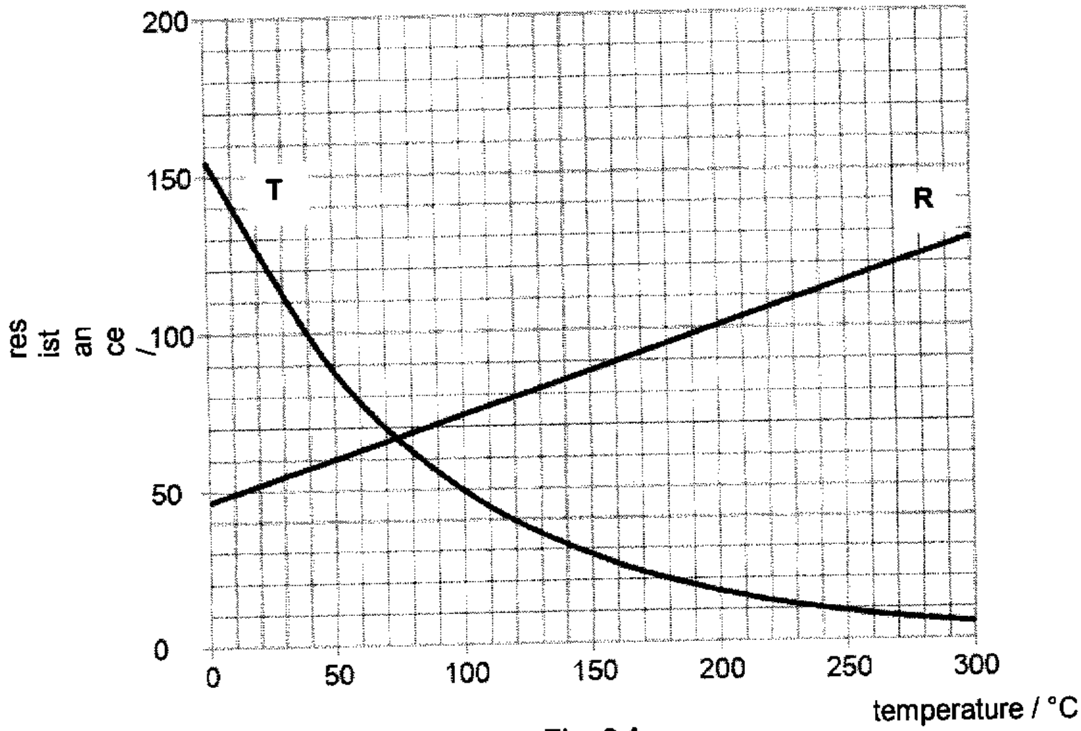


Fig. 6.1

The metal resistor **R** and the thermistor **T** are connected in series as shown in Fig. 6.2 together with a battery of negligible internal resistance. **R** and **T** are kept at the same temperature as each other.

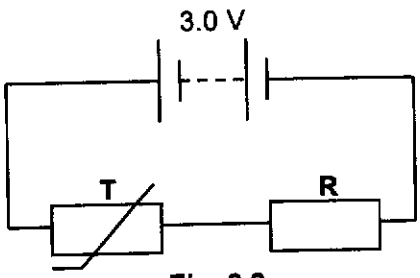


Fig. 6.2

(i) Determine the current in the circuit shown in Fig 6.2 when the resistance of **R** is twice that of **T**.

current = ... A [2]

[Turn Over

(ii) Describe how the effective resistance of the circuit in Fig 6.2 changes as temperature increases from 0 °C to 75 °C.

....

.... [1]

(iii) Determine the potential difference across **T** when the temperature is at 30 °C.

potential difference = ... V [2]

(b) Fig. 6.3 shows a circuit containing five identical lamps A, B, C, D and E. The circuit also contains three switches S_1, S_2 and S_3.

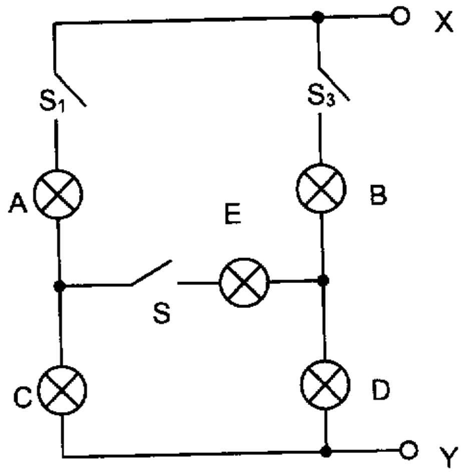


Fig. 6.3

One of the lamps is faulty. In order to detect the fault, an ohm-meter (a meter that measures resistance) is connected between terminals X and Y. When measuring resistance, the ohm-meter causes negligible current in the circuit.

Table 6.1 shows the readings of the ohm-meter for different switch positions. The resistance of the non-faulty lamps can be assumed to be constant.

switch			ohm-meter reading / Ω
S_1	S_2	S_3	
open	open	open	∞
closed	open	open	30.0
closed	closed	open	30.0
closed	closed	closed	15.0

Table 6.1

(i) Identify the faulty lamp, and the nature of the fault.

faulty lamp = ...[1]

nature of fault = ...[1]

(ii) State the resistance of one of the non-faulty lamps, as measured using the ohm-meter.

resistance = ...Ω [1]

(iii) After replacing the faulty lamp in the circuit in Fig. 6.3 with a similar working lamp, the ohm-meter is connected between terminals X and Y.

On Table 6.2, complete the readings of the ohm-meter for different switch positions.

switch			ohm-meter reading / Ω
S_1	S_2	S_3	
open	open	open	∞
closed	open	open	
closed	closed	open	
closed	closed	closed	

Table 6.2

[2]

7 Two small spherical charged particles P and Q may be assumed to be point charges located at their centres. The particles are in vacuum.

Particle P is fixed in position. Particle Q is moved along the line joining the two charges, as shown in Fig. 7.1.

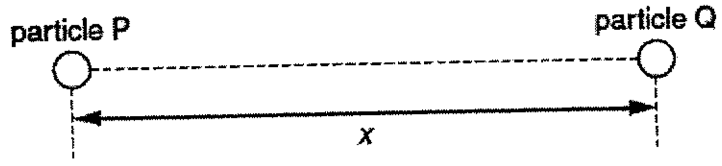


Fig. 7.1

The variation with separation x of the electric potential energy Ep of particle Q is shown in Fig. 7.2.

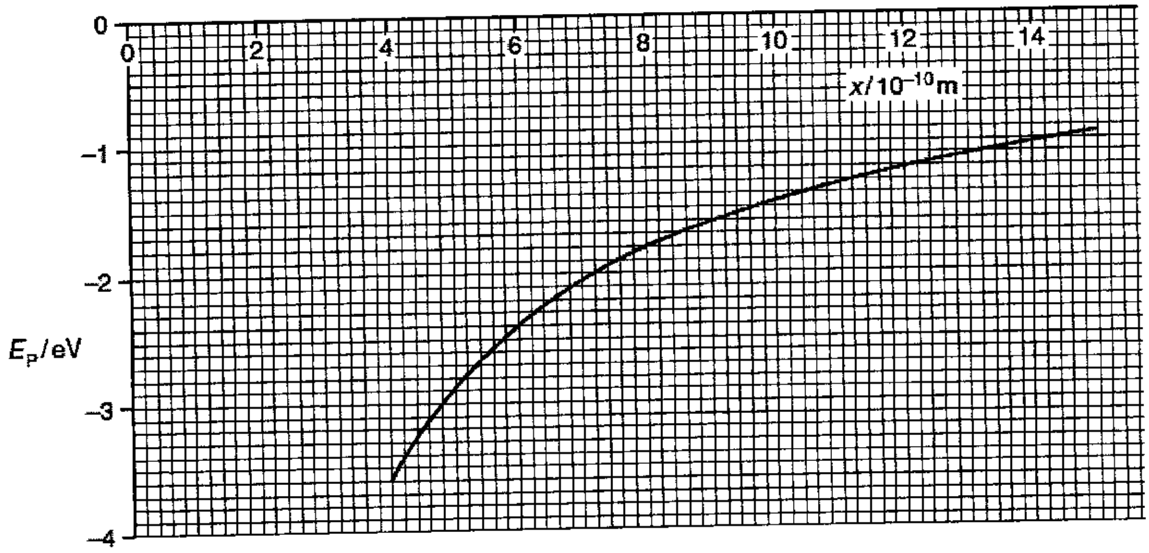


Fig. 7.2

(a) Deduce that the force on particle Q is proportional to the gradient of the curve of Fig. 7.2.

....

....

....

....

.... [2]

(b) By reference to Fig. 7.2, state and explain

(i) whether the two charges have the same, or opposite sign,

....

....

.... [2]

(ii) the effect, if any, on the shape of the graph of doubling the charge on particle P.

....

....

.... [2]

(c) Using Fig. 7.2, determine the separation of the particles at the point where particle Q has electric potential energy equal to -5.1 eV.

separation = ... m [2]

Section B

Answer **one** question from this Section in the spaces provided.

8 **(a)** Explain how an electric field and a magnetic field may be used for the velocity selection of charged particles. You may draw a diagram if you wish.

....

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....

....

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....

....

....[4]

(b) A simple generator consists of a coil with a large number of turns that rotates at a constant rate in a uniform magnetic field, as shown in Fig. 8.1.

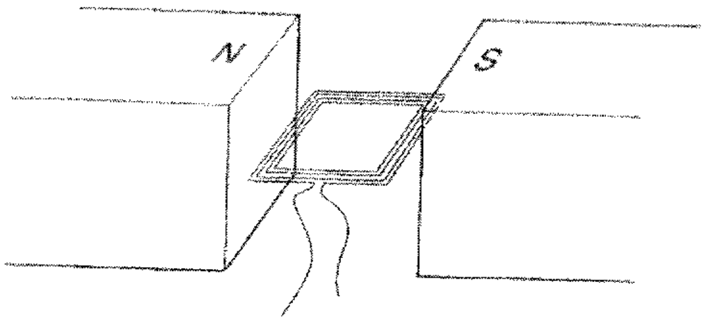


Fig. 8.1

(i) Explain why an e.m.f. is generated when the coil rotates.

....

....

....

....[2]

(ii) State two factors that affect the magnitude of the maximum e.m.f.

1. ....

2. ....

[2]

(iii) Explain briefly, in words, why the e.m.f. is sinusoidal.

....

....

....

....[2]

(c) A rectangular coil of dimensions 30 cm by 24 cm has 15 turns. A uniform magnetic field of flux density 0.018 T is at right-angles to the plane of the coil.

The magnetic field is kept constant for 2.0 s and then reduced to zero over a time of 4.0 s, as shown in Fig. 8.2.

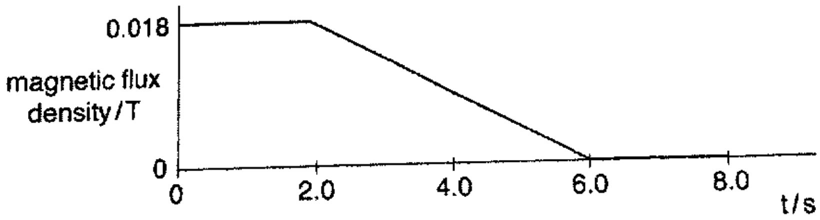
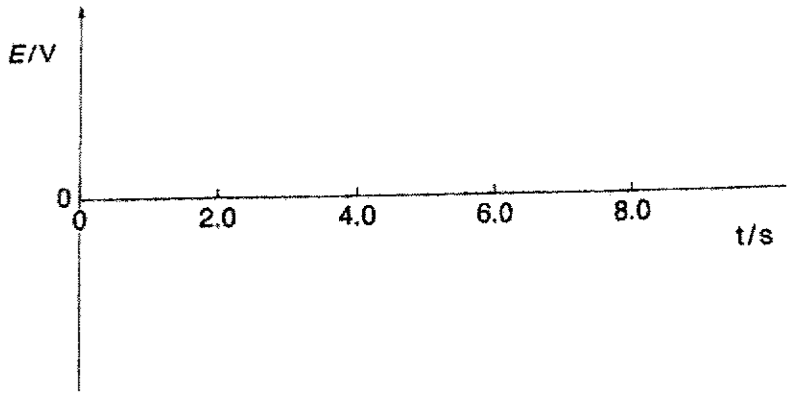


Fig. 8.2

(i) Calculate the magnitude of the induced e.m.f. between 2.0 and 6.0 s.

e.m.f. .... V [2]

(ii) On Fig. 8.3, sketch a graph to show the variation with time of the e.m.f. *E* induced in the coil.



[2]

Fig. 8.3

(d) Fig. 8.4 shows the top view of a train, travelling on a flat ground heading due east at $30.0\ m\ s^{-1}$. **CD** is a horizontal metal axle of the train which is 1.5 m long. Assume the resistance of the axle is 0.400 Ω and resistance of the other parts of the train is negligible.

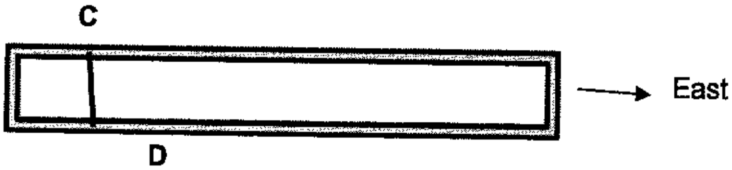


Fig. 8.4

The Earth's magnetic field strength is 6.0×10^{-5} T and acts downwards at 65^0 to the horizontal.

(i) Calculate the rate at which thermal energy is being generated in the axle.

rate = ... W [4]

(ii) State and explain which end of the axle **CD** is at a higher potential.

....

....

....

....[2]

9 **(a)** A beam of light of intensity 160 W m^{-2} is incident normally on a plane mirror, as shown in Fig. 9.1. The momentum of each photon in the beam is 9.5×10^{-28} N s.

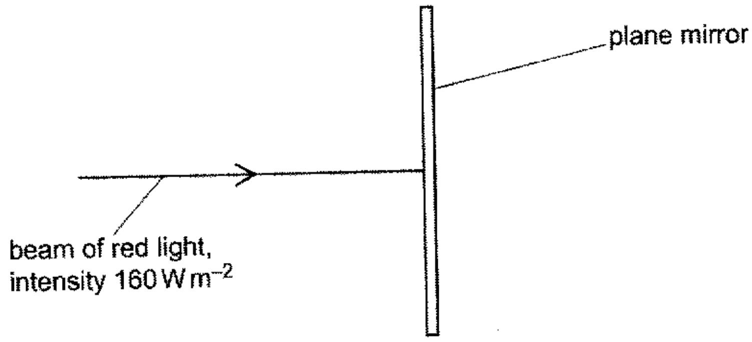


Fig. 9.1

All the light is reflected in the opposite direction to its original path by the mirror of cross-sectional area 2.5×10^{-2} cm^2. The number of photons incident on the mirror per unit time is 1.4×10^{15} s^{-1}.

(i) State what is meant by a photon.

....

....

[2]

(ii) Calculate the photon's de Broglie wavelength and determine its colour in the visible light spectrum.

wavelength = ... nm [1]

colour = ... [1]

(iii) Determine the pressure exerted by the light beam on the mirror.

pressure = ... Pa [2]

(b) Ultraviolet radiation of constant power is incident, in a vacuum, on a metal surface. Photoelectrons are observed to be emitted in the process.

The frequency of ultraviolet radiation is now increased.

State and explain the effect of this change on:

(i) the maximum kinetic energy of the photoelectrons

....

....

.... [2]

(ii) the rate of emission of photoelectrons.

....

....

.... [2]

(c) Fig. 9.2 shows a glass tube in which electrons are accelerated through a high p.d. to form a beam that is incident on a thin graphite crystal.

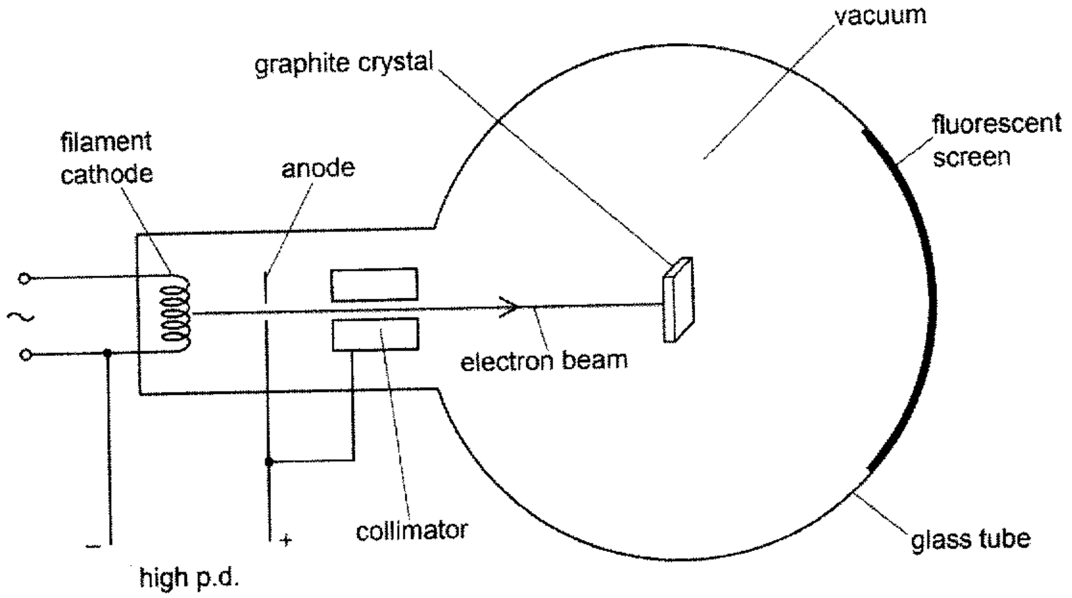


Fig. 9.2

After passing through the graphite crystal, the electrons reach the fluorescent screen. The screen glows where the electrons strike it.

Fig. 9.3 shows the fluorescent screen viewed end-on, from the right-hand side of Fig. 9.2.

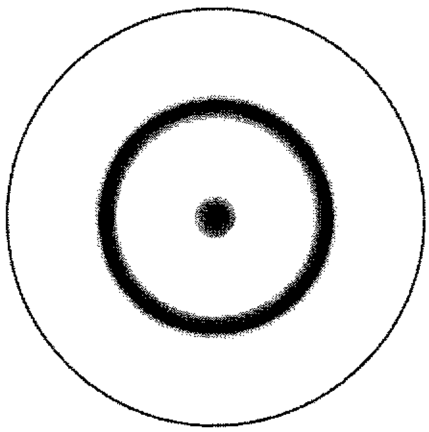


Fig. 9.3

(i) State the name of the phenomenon demonstrated by the pattern shown in Fig. 9.3.

.... [1]

(ii) Explain what can be concluded from the pattern in Fig. 9.3 about the nature of electrons.

....

....

.... [2]

(d) A beam of white light passes through a cloud of cool gas. The spectrum of the transmitted light is viewed and contains several dark lines.

Explain why these dark lines occur.

....

....

....

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....

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.... [4]

(e) Some energy levels for the electron in an isolated hydrogen atom are illustrated in Fig. 9.4.

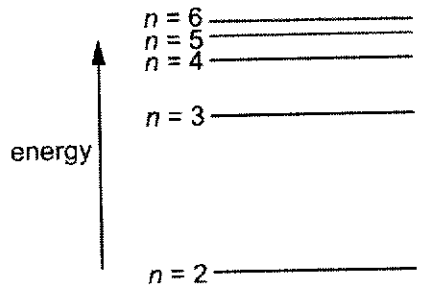


Fig. 9.4

Table 9.1 shows the wavelengths of photons that are emitted in the transitions to $n = 2$ from the other energy levels shown in Fig. 9.4.

wavelength / nm
412
435
488
658

Table 9.1

The energy associated with the energy level $n = 2$ is -3.40 eV.

Calculate the energy, in J, of energy level $n = 3$.

energy = ... J [3]

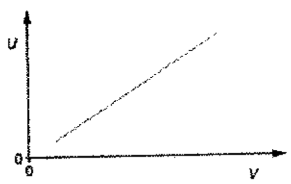
[End of Paper]

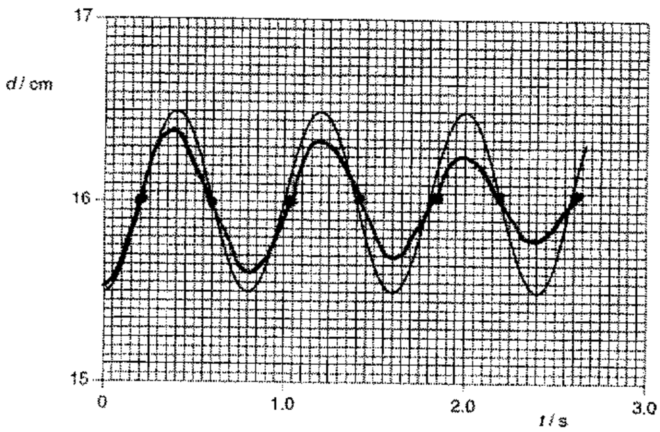
JC2 Prelim (H2 Physics) Paper 3 Solutions

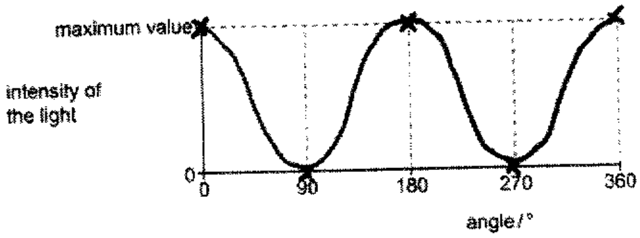
1 (a)(i)	Period of Earth, T = 24 x 3600 s (= 86 400 s) Angular velocity ω = $2\pi/T$ = 7.27×10^{-5} rad s^{-1} (shown)	[1]
(a)(ii)	a = rω^2 = (6.38×10^6) x [Ans in (b) (i)]^2 = 0.0337 m s^{-2}	[1] [1- ecf]
(b)(i)	• There is circular motion at the equator but not at the poles, • At the equator, part of the gravitational force is used to provide the centripetal force (required to keep any mass located there in circular motion, centripetal force is provided by the gravitational force of Earth) (Hence only the remaining part of the gravitational force is available to provide the acceleration of free fall.) Or • Gravi force of Earth = $(mg + ma_c)_{equa}$ = $(mg + ma_c)_{pole}$. [1] • Since $a_{c\ at\ pole} = 0$, $g_{pole} > g_{equa}$, ie g is different for the 2 locations[1] Note: g = acceleration of free fall as defined by the question not gravitational field strength. Be careful in use of symbols.	[1] [1]
(b)(ii)	• Value of *g*, at the pole is 9.81 m s^{-2} • Since centripetal acceleration at equator (in b(ii)) is 0.0337 m s^{-2} , compared to 9.81 m s^{-2}, the difference in g at these 2 locations is small.	[1] [1]
(c)(i)	The gravitational force of attraction between two point masses is proportional to the product of their masses and inversely proportional to the square of their separation.	[1]
(c) (ii)	(By Newton's law), Gravitational force on a (point) mass *m* at Earth's surface, $F = \frac{GMm}{R^2}$ Since field strength *g* is the gravitational force per unit mass at that point, $g = F/m = \frac{GM}{R^2}$	[1] [1]
(d)(i)	•{ Since the gravitational force provides the centripetal force, } $\frac{GMm}{r^2} = mr\omega^2$ {where r = dist of satellite fr Earth's centre}	[1]

	($\therefore r^3 = GM/\omega^2$, not assessed) – (1)	
	•From **(c)**, $GM = gR^2$ – (2) { R = Earth's radius }	[1]
	(2) into (1): ($r^3 = gR^2/\omega^2$, not assessed)	
	•Substituting, $r = 4.23 \times 10^7$ m {$g = 9.81$ m s^{-2}, $R = 6.38 \times 10^6$ m, $\omega = 7.27 \times 10^{-5}$ rad s^{-1}}	[1]
(d)(ii)	1. Satellite lies on the equatorial plane of the earth	[1]
	2. Satellite rotates/revolves from west to east or, following the Earth's rotation	[1]

2(a)	Volume decreases ; hence w is positive (or small volume change so w is 0)	[1]
	As the ice changes state, heat must have been supplied; hence q is positive.	[1]
	internal energy increases	[1]
(b)	gas expands/increase in volume with work done by gas (against atmosphere) or w is negative	[1]
	the sudden increase leaves little time/no time for thermal energy to enter and leave the gas or q = 0	[1]
	internal energy decreases	[1]

3(a)	molecule(s) rebound from wall of vessel / hits walls/ collide	[1]
	change in momentum gives rise to impulse / force	[1]
	average change in momentum/impulse gives rise to the average (constant) pressure/force.	[1]
(b)	$p = 1/3\ \rho <c^2>$ $1.02 \times 10^5 = 1/3 \times 0.900 \times <c^2>$ $<c^2> = 3.4 \times 10^5$ $c_{rms} = 580$ m s^{-1}	[1] [1]
(c)	Straight line with positive gradient Line passing through origin (can never reduce the volume to zero thus the graph need not be shown passing through the origin)  	[1]

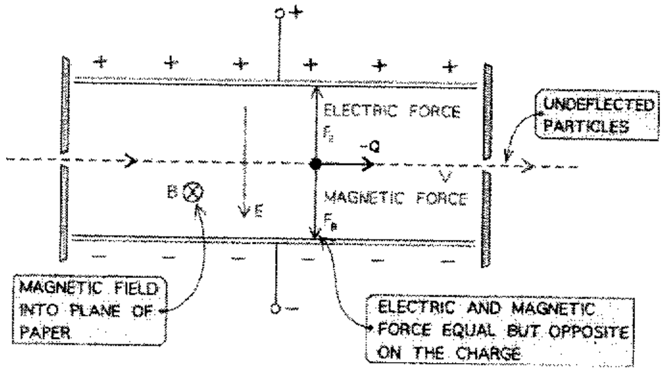
4(a)	amplitude = 0.50 cm	[1]
b(i)	T = 0.8 s $\omega = 2\pi / T$ = 7.85 rad s^{-1} $v = \omega \sqrt{(x_0^2 - x^2)}$ $= 7.85 \times \sqrt{(\{0.5 \times 10^{-2}\}^2 - \{0.2 \times 10^{-2}\}^2)}$ = 3.6 cm s^{-1}	[1] [1 – ecf for (a)] [1 – ecf for (a)]
(ii)	d = 15.8 cm	[1]
(c)	• same period { Accept: small increase in period) • (For same period) : displacement of damped oscillator is always smaller than that on Fig.4.2 (ignore first T/4) • peak decreases (exponentially) with time 	[1] [1] [1]

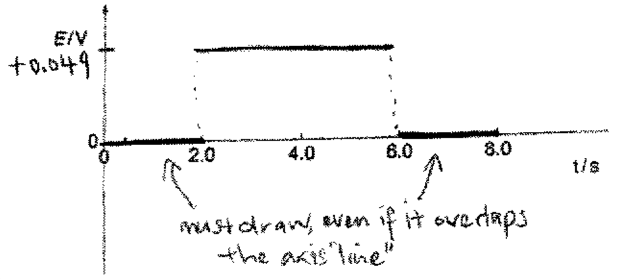
5 (a)(i)	light intensity has maximum value at 0°, 180°, 360° and zero intensity at 90°, 270° 'sinusoidally-shaped' curve of constant amplitude 	[1] [1]
(a)(ii)	$I = I_0 \cos^2\Theta$ $4.2 = 7.6 \cos^2\Theta$ $\Theta = 42°$	[1]
(b)	wave passes (through) an opening/gap/aperture or, wave passes (by / through / around) an obstacle/edge wave spreads (into geometrical shadow)	[1]
(c)	$n\lambda = d \sin\Theta$ $d = (3 \times 4.3 \times 10^{-7}) / \sin 68°$ $= 1.4 \times 10^{-6}$ m $1.4 \times 10^{-6} \times \sin 68° = 2\lambda$ or, $3 \times 4.3 \times 10^{-7} = 2\lambda$ $\lambda = 6.5 \times 10^{-7}$ m	[1] [1] [1]

6(a)(i)	From the graph, R = 80 Ω, T = 40 Ω at 120°C $E = I R_T$ $3.0 = I (80 + 40)$ $I = 25 \times 10^{-3}$ A = 0.025 A	[1] [1]
(ii)	(When the temperature increases from 0 oC to 75 oC, magnitude of RATE of Increase of resistance of R is smaller than the magnitude of RATE of Decrease of resistance of T.} {Compare their gradients} Thus, effective resistance decreases at a decreasing rate with respect to temperature.	[1]
(iii)	From graph at 30 °C, resistance of R = 55 ∧ and resistance of T = 110 ∧ By potential divider rule, p.d. across T = (R_T / R_{total}) x 3.0 V = (110/110+55) X 3.0 = 2	[1] [1]
(b) (i)	faulty lamp: lamp E nature of fault: lamp fused/ fuse melt/broken filament	[1] [1]
(ii)	Resistance of one non-faulty lamp = 30.0 / 2 = 15.0	[1]
(iii)	see table below	- 1 mark for each mistake

switch S_1	S_2	S_3	ohm-meter reading / Ω
open	open	open	∞
closed	open	open	30.0
closed	closed	open	25.0
closed	closed	closed	15.0

7(a)	Since F = - dEp/dx & dEp/dx is the gradient of graph. Hence force is proportional to the gradient of the curve.	[1] [1]
(b)(i)	Since all values of E_p are negative (Fig 7.2), & $E_P = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$ E_p is negative only if the 2 pt charges are of opposite sign. or F = -dE_p/dx Since dE_p/dx is positive, (fr Fig 7.2), F is negative. Since a negative F indicates an attractive force between the charges, the charges are of opposite sign.	[1] [1]
(ii)	When Q_p is doubled: Since $E_P = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$, E_p is doubled at every x. Thus gradient would be doubled/increased/become steeper. or, since F = Q_pQ_Q / (4□Σ_0x^2), F is doubled for every x. & F = - gradient of graph, gradient is doubled at every x.	[1] [1]
(c)	$E_p = \frac{(charge\ of\ P)(charge\ of\ Q)}{4\pi\varepsilon_0 r}$ Since (charge of P) x (charge of Q) = constant E_p 1/r E_p = - 3.6 eV at $x = 4 \times 10^{-10}$ m E_p = - 5.1 eV at x = r 3.6/5.1 = r / 4 x 10^{-10} r = 2.82 x 10^{-10} m	[1] [1]

8 (a)(i)	 1 mark for each of 4 pts: 1. Correct directions of uniform E & uniform B fields for a charge particle of a stated sign 2. Correct directions of electric force F_E & magnetic force F_B (they are in opposite directions) 3. Stated $F_E = F_B$ (mag) (to be undeflected & hence exit slit S_3 & be selected) 4. ie $B\,q\,v = q\,E$ { essential } ® $v = \frac{E}{B}$ { essential }	[4]
(b)(i)	• As coil rotates, there is a change in flux (linkage) • due to a change in the area of the coil perpendicular to B field By Faraday's law, an emf is induced (when there is a change in flux linking the coil)	[1] [1]
(ii)	{ For a coil rotating in a B field, instantaneous E = NBAω cos ωt. Hence max emf = NBAω } Any 2 of 4: number of turns, (magnetic) flux density, area of coil & angular velocity/speed of rotation	[2]
(iii)	1. Flux varies sinusoidally with time or, ϕ = BAcosθ where θ = angle between *B* and normal to plane of the coil. 2. By Faraday's law/since induced emf E is equal/proportional to the rate of change of flux linkage, ie Emf = $\frac{d(N\phi)}{dt}$ = NBAω sinθ.	[1] [1]
(c)(i)	E = $\frac{d(N\phi)}{dt}$ = N [$B_i - B_f$] A ÷ Δt = 15 [0.018 – 0] (30 x10^{-2}) x (24 x 10^{-2}) ÷ { 6.0 s – 2.0 s } = 4.86 x 10^{-3} = 4.9 x 10^{-2} V	[1] [1]

(ii)	• From 0- 2.0 s, 6.0 – 8.0 s: horizontal line at zero V • From 2.0 – 6.0 s: horizontal line at +0.049 V, value of "0.049 V" (or 0.50 V) indicated on E- axis (ecf) 	[1] [1]
(d)(i)	Emf induced across axle, V = $(B \sin \theta) Lv$ { straight rod } $= (6.0 \times 10^{-5}) \sin 65^0 \times 1.5 \times 30.0$ $= 2.45 \times 10^{-3}$ V Rate = V^2/ R $= (2.45 \times 10^{-3})^2 / 0.400$ { ecf for V } $= 1.50 \times 10^{-5}$ W	 [1] [1] [1] [1]
(ii)	By Fleming's Left Hand Rule, the electrons in the axle are deflected by a force towards D, making D the end with a negative potential. Hence C is at a higher potential, or, By Lenz's law, the (induced) current in CD must flow in such a direction as to oppose the (rightward) motion of the rod; (hence with LEFT Thumb (induced force) pointing to left), by Fleming's LHR, the (induced) current will flow from D to C. Since rod is an emf source, C is at a higher potential.	[1] [1] [1] [1]

9(a)(i)	discrete/ packet / quantum_of energy of electromagnetic radiation	[1] [1]
(a)(ii)	wavelength = $(6.63 \times 10^{-34}) / (9.5 \times 10^{-28}) = 700 \times 10^{-9}$ m so red	[1] [1]
(a)(iii)	pressure = force / area force = rate of change of momentum $= 2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}$ pressure = $(2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}) / (2.5 \times 10^{-6})$ $= 1.1 \times 10^{-6}$ Pa	 [1] [1]
(b)(i)	greater photon energy (hf) and same work function (Φ) so by $hf = \Phi + KE_{max}$ maximum kinetic energy is increased	[1] [1]
(b)(ii)	By I = Nhf/At or $P = N(hf)/t$, greater photon energy (and same power) so lower number of photons (per unit time) each electron absorbs/interacts with one photon so lower rate of emission	[1] [1]
(c)(i)	(Electron) diffraction	[1]
(ii)	Diffraction is a wave phenomenon electron can behave as a wave / have wave-like property	[1] [1]
(d)	• photon absorbed (by electron) and electron excited • photon energy equal to difference in (energy of two) discrete energy levels • photon energy relates to a single wavelength / single frequency • electron de-excites and emits photon in any direction (only some reach the screen)	[1] [1] [1] [1]
(e)	$\frac{hc}{\lambda} = \Delta E$ ⊗E = $E_3 - E_2$ $\frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{658 \times 10^{-9}} = E_3 - (-3.40 \times 1.6 \times 10^{-19})$ {As $E_3 - E_2$ is the lowest energy of all the transitions down to E_2, thus ⊗E = hc/L corresponds to that of the longest wavelength} $E_1 = -2.42 \times 10^{-19}$ J	 [1 mk per eqn side] [1]

End of solutions