SYDNEY GRAMMAR SCHOOL

TRIAL EXAMINATION 2024

FORM VI PHYSICS

Candidate No:

General Instructions

- Working Time: 3 hours (+ 5min Reading Time)
- Write using black pen

Structure of Paper & Instructions

- Section I Multiple Choice (20 marks). Spend 30 minutes on this section.
- Section II Parts A-D (80 marks). Spend 2 hours and 30 minutes on this section.

Total marks: 100

Wednesday 21 August 8:40am

Checklist

Each boy should have the following:

- ☐ Examination Paper (includes)
  - Examination sections
  - Extra Writing sheets
  - Data/Formula sheets
  - Multiple-Choice Answer Sheet

ED, SRW, ILM, PCK MIC: ILM

Exam Instructions

- Remove the centre staple and hand in all parts of the examination in a neat bundle in its original order. Do not insert parts into other parts.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.
  - Each detachable part A-D of Section II has additional writing space to use for that part.
  - Further additional writing paper can be given on request.

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SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 A transformer has 2000 turns in its primary winding and 60 turns in its secondary. If the voltage input to the transformer is 240 V, the voltage output is:

(A) 0.25 V

(B) 7.2 V

(C) 33 V

(D) 8000 V

2 In an experiment to investigate the structure of matter, alpha particles were fired into gold foil. About 1 in 8000 particles bounced back at a large angle.

Which conclusion can be drawn from this observation?

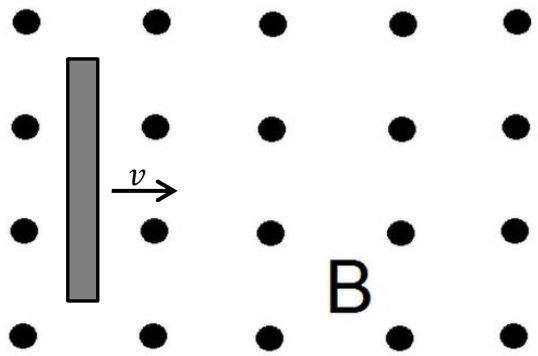
(A) The atomic nucleus contains protons and neutrons.

(B) Electrons orbit the atomic nucleus.

(C) The atomic nucleus is at the centre of the atom.

(D) The atomic nucleus occupies a very small fraction of the volume of the atom.

3 A conductive bar travels at constant velocity v through a magnetic field B pointing out of the page. Whilst this movement occurs, which region of the bar will become negatively charged?



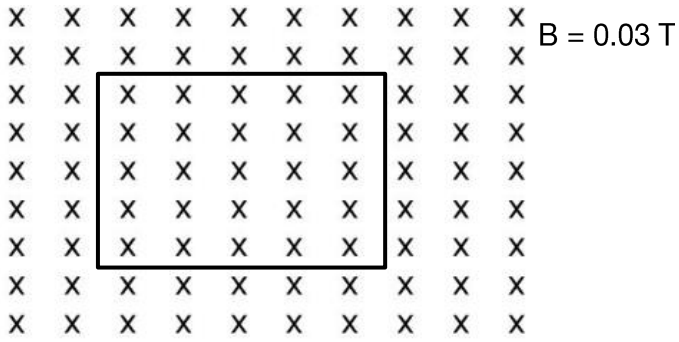
(A) The left-hand side

(B) The right-hand side

(C) The top (up the page)

(D) The bottom (down the page)

4 A rectangular coil with sides of length 0.04 m and 0.06 m is placed in a uniform magnetic field B of strength 0.03 T so that the plane of the coil is perpendicular to the field direction, as shown.



The magnetic flux through the coil is

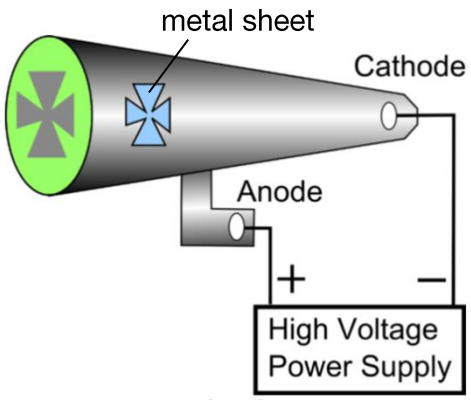
(A) 3.6×10^{-5} Wb

(B) 7.2×10^{-5} Wb

(C) 3.6×10^{-1} Wb

(D) 7.2×10^{-1} Wb

5 The diagram below shows an experiment performed with a high voltage across an evacuated tube.



The observation of a sharp-edged shadow on the end of the tube suggests that

(A) particles are blocked by a sheet of metal.

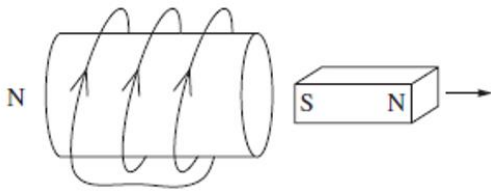
(B) particles diffract around the edges of a sheet of metal.

(C) negative particles travel from the anode to the cathode.

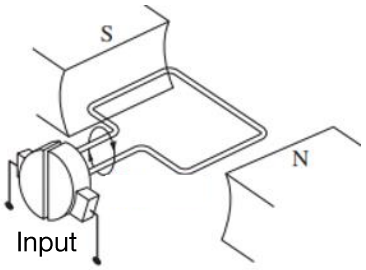
(D) positive particles travel from the cathode to the anode.

6 Which of the following diagrams depicts a dc generator?

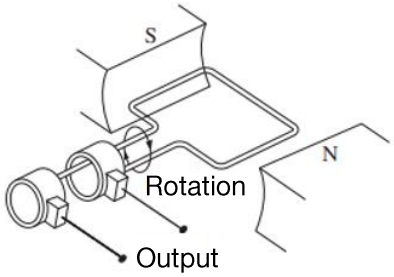
(A)



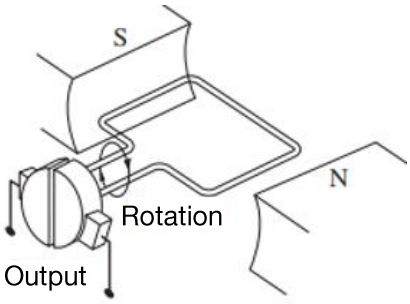
(B)



(C)



(D)



7 Which of the following was a contribution of James Clerk Maxwell to our understanding of the nature of light?

(A) Unification of the laws of electricity and magnetism

(B) Observation of the existence of radio waves

(C) Observation that electric and magnetic fields are always at right angles to each other

(D) Observation that the speed of light is a constant

8 The surface gravity of a planet is g. What would be the new value of the surface gravity if both the mass and radius of the planet were halved?

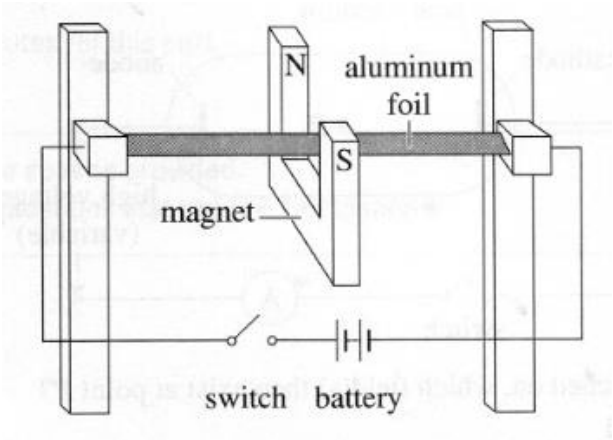
(A) $\frac{g}{4}$

(B) $\frac{g}{2}$

(C) g

(D) $2g$

9 A thin piece of aluminium foil is connected by a conducting wire to a switch and battery as shown. The foil is placed between the poles of a magnet, as shown.



When the switch is closed, the aluminium foil will move

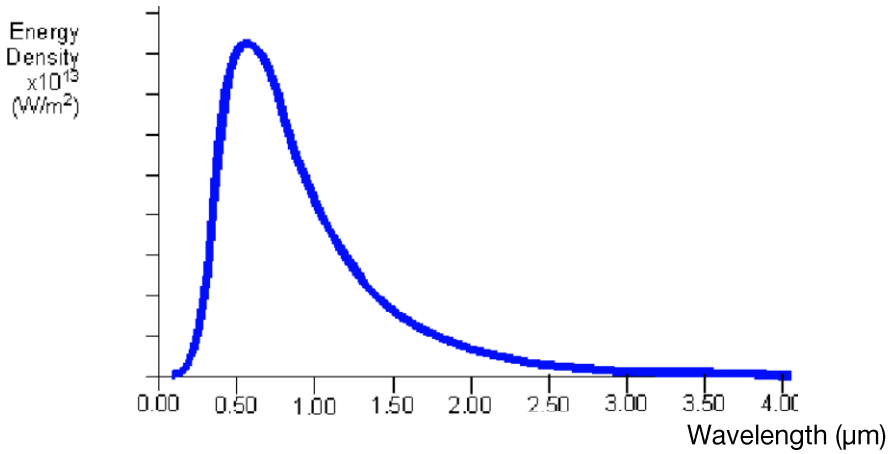
(A) downwards.

(B) upwards.

(C) towards the north pole of the magnet.

(D) towards the south pole of the magnet.

10 A blackbody curve is shown in the diagram below.



The temperature of the blackbody is closest to

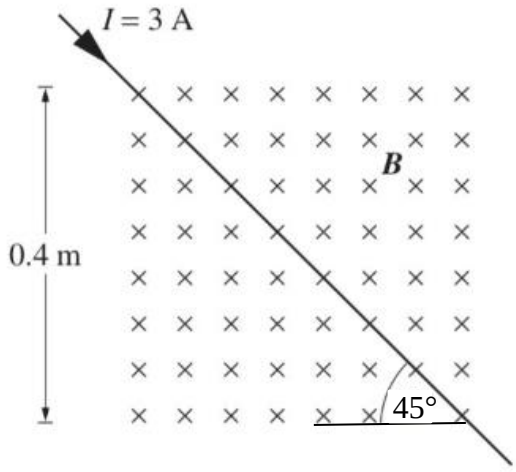
(A) 0.0058 K

(B) 5800 K

(C) 5800°C

(D) 8×10^{13} K

11 A current-carrying wire passes through a square region of magnetic field, magnitude 2.0 T, as shown in the diagram below. The magnetic field is directed into the page.



What is the magnitude of the magnetic force on the conductor?

(A) 0.68 N

(B) 1.7 N

(C) 2.4 N

(D) 3.4 N

12 Polarisation could not be explained in terms of a wave theory of light until which development?

(A) Einstein proposed a photon model of light

(B) Most scientists abandoned the particle model of light

(C) Light was understood to be a transverse wave

(D) Light was understood to be a longitudinal wave

13 One of the largest conventional bombs ever made is the MOAB with a yield of 11 tonnes of TNT. If 1 tonne of TNT produces 4.2×10^9 J of energy, the amount of mass lost in this explosion is

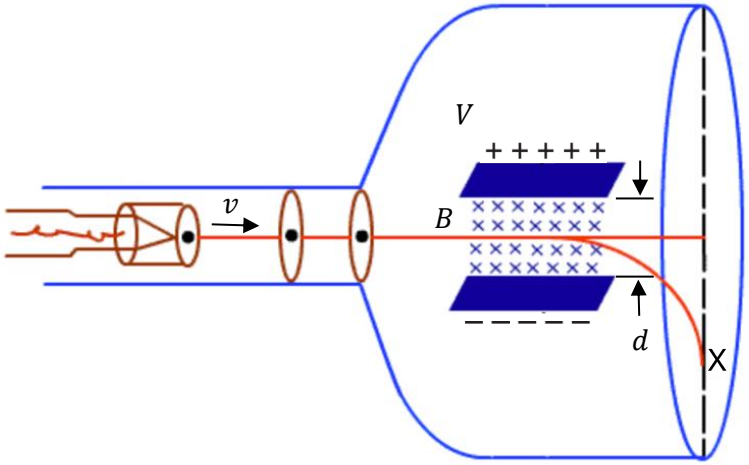
(A) 4.67×10^{-8} kg

(B) 5.13×10^{-7} kg

(C) 14.0 kg

(D) 154 kg

14 The diagram below shows an electron travelling at speed v within a magnetic field B. The charged plates have a voltage V across them and are separated by a distance d. The quantities B, V and d are set so that the electron passes through undeflected.



Which of the following adjustments could lead to the electron arriving at X?

(A) Decrease V

(B) Decrease B

(C) Decrease v

(D) Decrease d

15 When a projectile reaches its maximum height it is travelling at speed u. When it hits the ground, its speed is $2u$.

At what angle does it hit the ground?

(A) 30° below the horizontal

(B) 45° below the horizontal

(C) 60° below the horizontal

(D) 63° below the horizontal

16 The maximum speed that a car can go around a circular turn with a constant radius is 80 kmh^{-1} without skidding. What is the maximum speed of a truck in the same corner with 5 times the mass and 3 times the sideways frictional force?

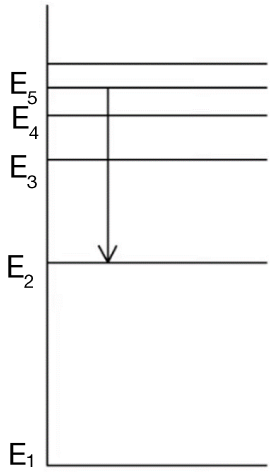
(A) 48 kmh^{-1}

(B) 62 kmh^{-1}

(C) 103 kmh^{-1}

(D) 133 kmh^{-1}

17 The diagram below shows electron energy levels within an atom.



The transition E_5 to E_2 causes the emission of infrared radiation.

A transition that could cause the emission of ultraviolet radiation would be

(A) E_4 to E_2

(B) E_4 to E_3

(C) E_5 to E_1

(D) E_5 to E_4

18 A metal with a work function Φ emits electrons with a kinetic energy of K when light of wavelength λ is shone on it.

What is the new kinetic energy of the emitted electrons if the wavelength of the light is halved?

(A) $2K$

(B) $\mathrm{K} - \Phi$

(C) $2\mathrm{K} - \Phi$

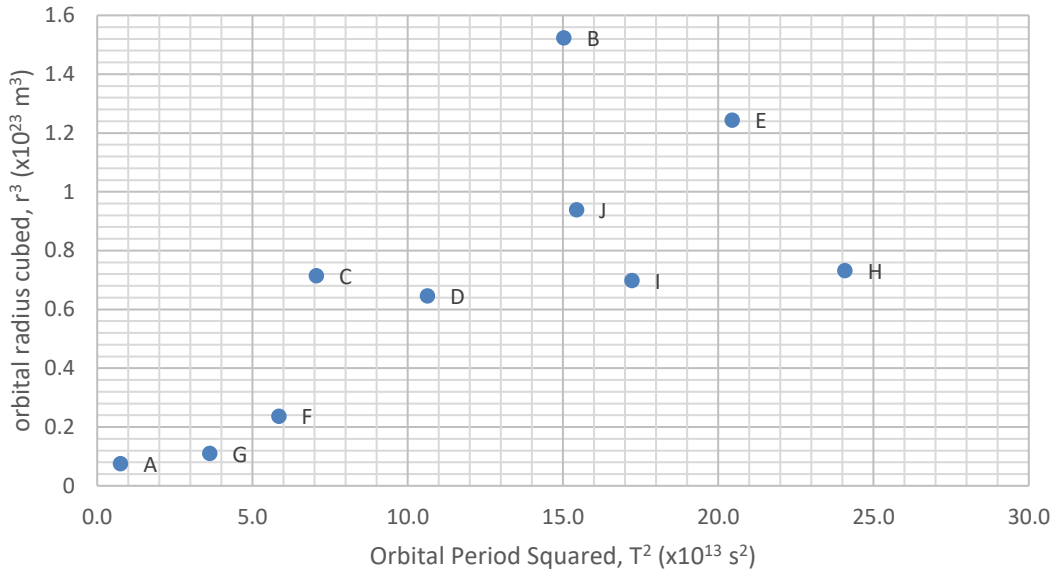
(D) $2\mathrm{K} + \Phi$

19 A Blu-ray video disk has a diameter of 0.12 m and rotates at 810 rpm (or 13.5 rotations per second) when it is playing.

Select the correct option for the angular velocity ω and the centripetal acceleration a_c of a point at the edge of the disk.

	Angular Velocity, ω (rad s^{-1})	Centripetal Acceleration, a_c (m s^{-2})
(A)	27	216
(B)	27	432
(C)	85	432
(D)	85	863

20 In a distant solar system there are 5 exoplanets with 10 moons in total orbiting around them. The orbital radius and orbital periods for all these moons (labelled A-J) are in the diagram below.



Which groups of moons are orbiting the same planet?

(A) Moons A, C, G

(B) Moons B, C, G

(C) Moons D, E, J

(D) Moons F, G, H

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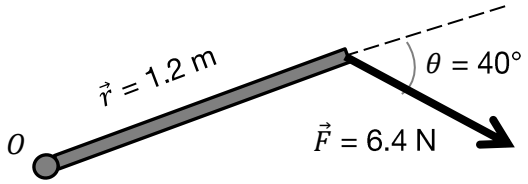
SECTION II: Part A (20 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (2 marks) **Marks**

Determine the magnitude and direction of the torque around the axis O.



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Question 22 (2 marks)

Determine the wavelength produced by the transition of an electron in a hydrogen atom from the n = 3 to the n = 1 energy level.

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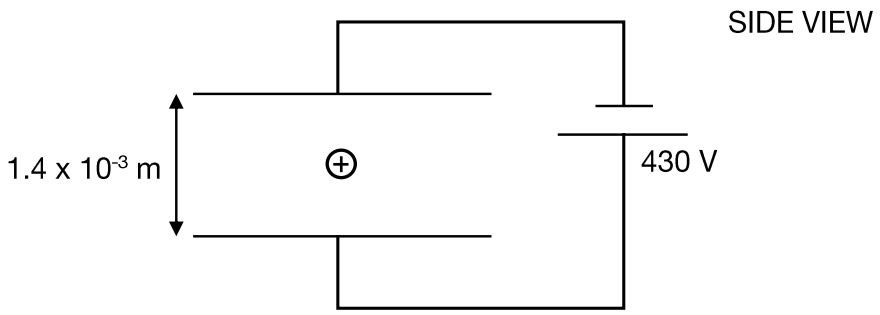
Question 23 (3 marks) **Marks**

The diagram below shows two parallel, charged metal plates in a vacuum. A small ball with a charge of $+4.0 \times 10^{-6}$ C is placed between the plates.



When the ball is released, it remains stationary. Determine:

(a) the electric field strength between the plates.

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(b) the mass of the ball.

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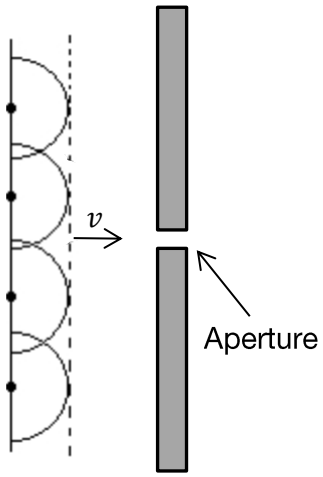
Question 24 (3 marks) **Marks**

The diagram illustrates the construction Huygens created to model how light propagates through space.



Describe how this model can be used to explain how light behaves when it passes through a narrow aperture.

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Question 25 (2 marks) **Marks**

A proton with a velocity of v = 3.0 x 10^6 ms^{-1} enters a region with a uniform magnetic field of 2.0 T directed into the page, as shown.

Calculate the radius of the proton's path in the magnetic field.

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Question 26 (4 marks) **Marks**

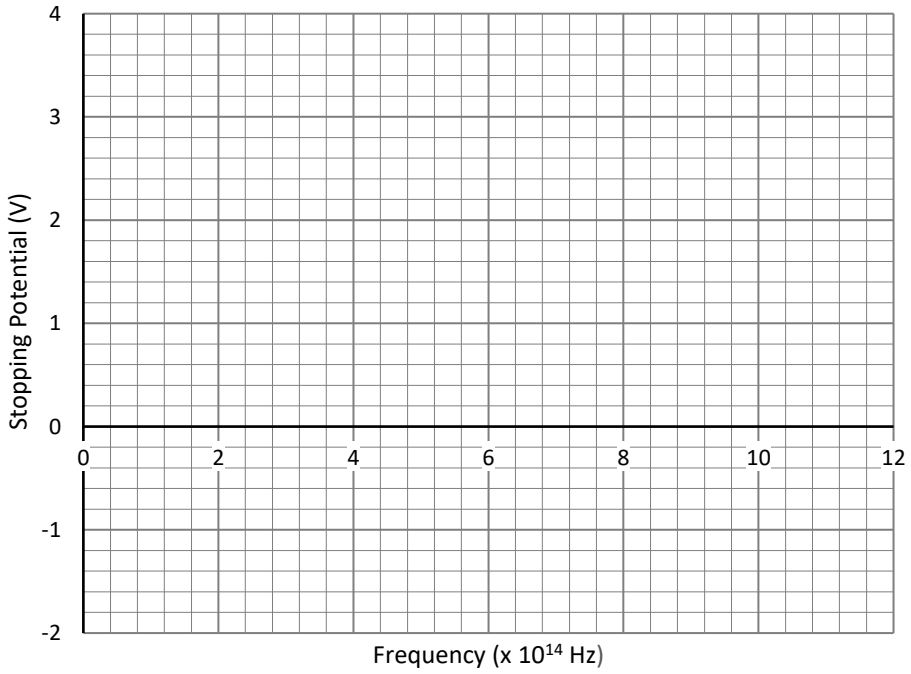
For a particular cathode material in a photoelectric experiment the stopping potentials were measured as a function of the wavelength of light shone on the cathode.

(a) Complete the table by calculating the frequency of the light.

Stopping Potential (V)	Wavelength ($\times 10^{-7}$ m)	Frequency ($\times 10^{14}$ Hz)
1.0	6.0	
2.0	4.0	
3.0	3.0	

1

(b) On the graph paper below, plot a graph of Stopping Potential versus Frequency. Draw a line of best fit.



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(c) Use your graph to determine the work function of the metal.

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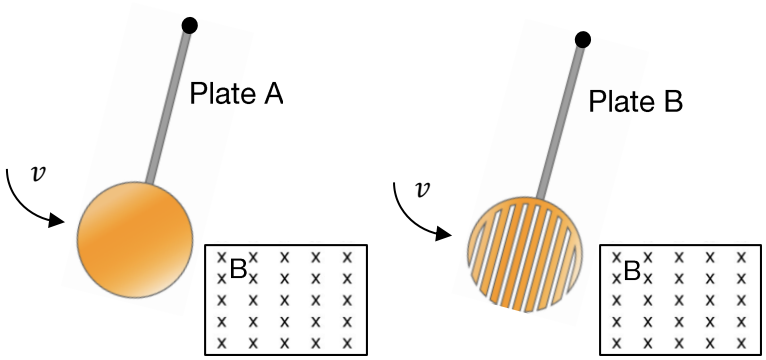
Question 27 (4 marks) **Marks**

Electromagnetic braking can be demonstrated by swinging two metal plates inside a strong magnetic field, as shown below.



In which of Plates A and B would the electromagnetic braking effect be stronger? Justify your answer.

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Part A extra writing space

If you use this space, clearly indicate which question you are answering.

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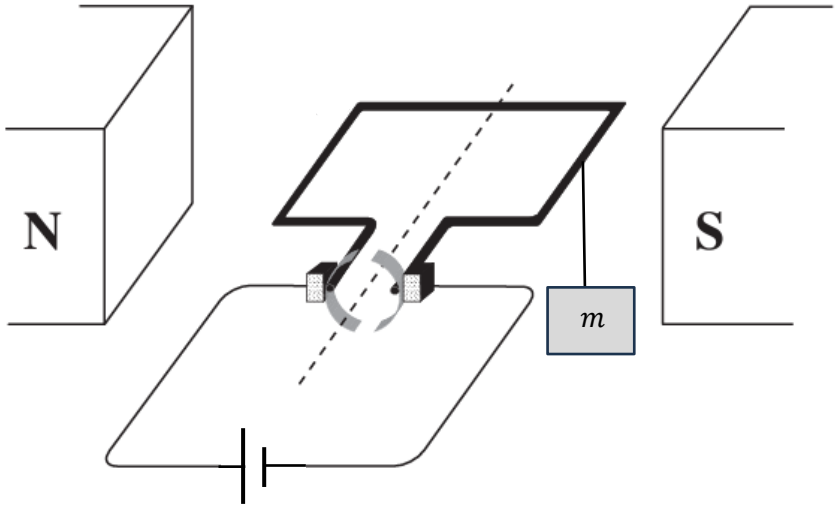
SECTION II: Part B (21 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 28 (3 marks) **Marks**

A square coil of side 0.10 m with 40 turns that has a current of 0.30 A flowing through it is inside a magnetic field of uniform magnitude 2.0 T, as shown below. A mass m is hung from the right-hand side of the coil.



(a) Determine the magnitude of the torque on the coil **before** the mass m is added.

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(b) When the mass m is hung from the right-hand side of the coil, determine the value of m necessary to stop the coil from turning.

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Question 29 (4 marks) **Marks**

Crystallography is a tool for studying the structure of materials that uses x-rays with a wavelength of around 1.0×10^{-10} m, about the same as the spacing between atoms.

(a) Determine the energy of an x-ray photon that has a wavelength of 1.0×10^{-10} m.

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(b) Because they have a wave nature, neutrons can also be used for this technique. Determine the kinetic energy of a neutron that has a de Broglie wavelength of 1.0×10^{-10} m.

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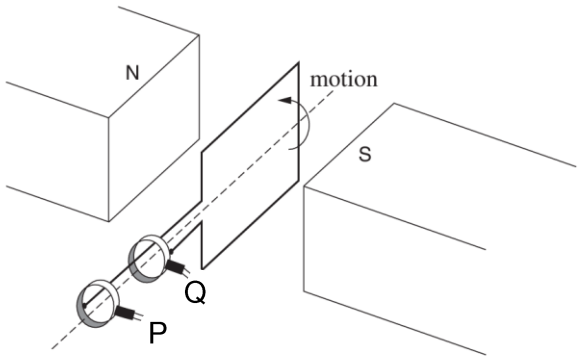
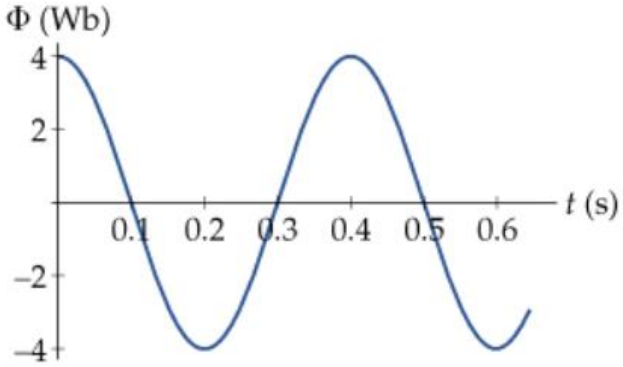
Question 30 (4 marks) **Marks**

The flux though a single coil of an AC generator is shown below.





(a) Identify one time when the induced EMF will be zero according to the above graph.

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(b) If the generator consists of 60 coils, estimate from the above graph the magnitude of the average EMF generated over the first 0.2 s.

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(c) At t = 0.1 s, which of P and Q would be the positive terminal?

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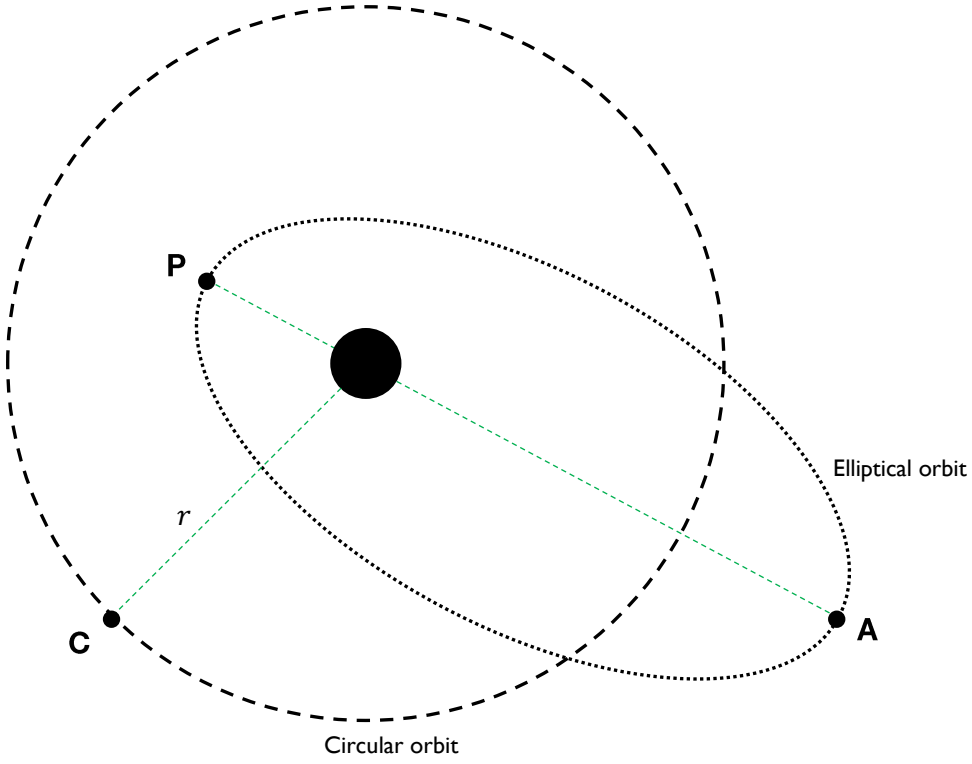
Question 31 (6 marks) **Marks**

The diagram below shows two satellites in orbit around the Earth. One orbit is circular, and the other is elliptical. Both satellites have the same total energy.



(a) If the gravitational potential energy of the satellite is U, show that the kinetic energy, K, of the satellite in a circular orbit is $K = -\frac{U}{2}$, and that therefore the total energy $E = \frac{U}{2}$.

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Question 31 continued on next page.

Question 31 continued **Marks**

(b) Compare the work done by gravity on each of the satellites over the course of one orbit.

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Question 32 (4 marks) **Marks**

Discuss limitations of Rutherford's model of the atom, and how modifications of the atomic model introduced by Bohr and de Broglie addressed the limitations.

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Part B extra writing space

If you use this space, clearly indicate which question you are answering.

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SECTION II: Part C (21 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 33 (4 marks) **Marks**

Around a planet called Pax, a satellite has an orbital velocity of 1400 ms^{-1} at a constant orbital radius of 5.5×10^7 m.

(a) Calculate the mass of Pax.

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(b) Determine the escape velocity from Pax at the position of the satellite.

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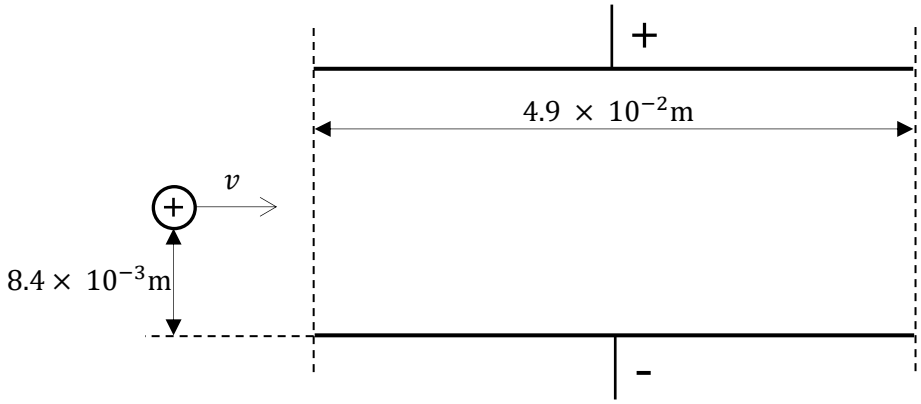
Question 34 (6 marks) **Marks**

In the diagram below, a uniform electric field of strength 2.7×10^4 N C^{-1} exists between two metal plates. A proton enters the electric field mid-way between the plates, travelling at speed v parallel to the plates, as shown.



(a) Determine the minimum speed v that the proton must have to pass through the plates without hitting them.

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(b) Discuss the similarities and differences between the motion of charged particles in uniform electric fields and the motion of masses in uniform gravitational fields.

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Question 35 (4 marks) **Marks**

A pion is a subatomic particle with a half-life of $2.6 \times 10^{-8} s$ when at rest. When pions are accelerated to a very high speed, v, in a particle accelerator, the half-life increases to $4.2 \times 10^{-7} \text{s}$, as measured by an observer in the control room of the accelerator.

(a) Determine the velocity v of the pions in the accelerator.

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(b) Determine the average distance a pion travelling at this speed would move in its lifetime, according to the observer in the control room.

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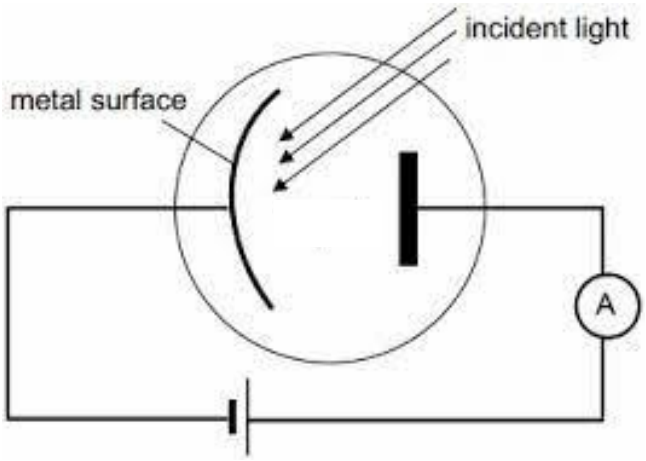
Question 36 (3 marks) **Marks**

Light is incident upon a piece of metal in a vacuum tube, as shown. If the frequency of the light is above a certain value, called the threshold frequency, a current is detected in the ammeter.



Explain this observation in terms of Einstein's model of light.

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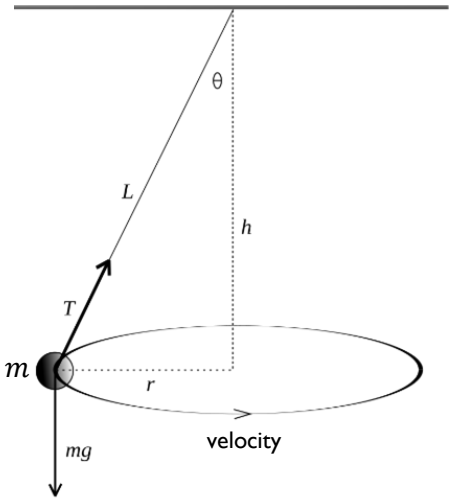
Question 37 (4 marks) **Marks**

The diagram below shows a mass, m, being swung in a horizontal circle on a string of length L.



As the mass is rotated faster the angle to the vertical, θ, changes.

Analyse the forces on the mass to explain why the vertical angle changes as the speed of the rotating mass is increased.

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Part C extra writing space

If you use this space, clearly indicate which question you are answering.

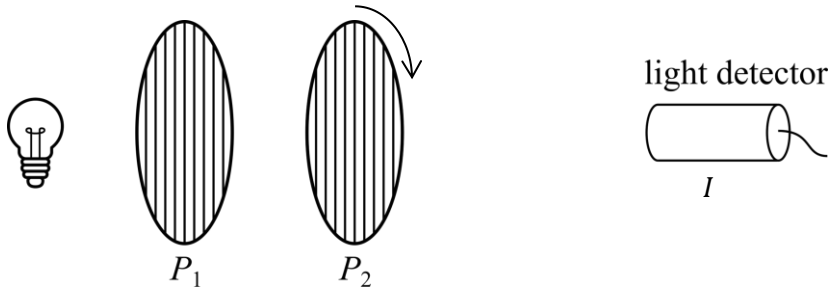
SECTION II: Part D (18 Marks)

CANDIDATE NUMBER							

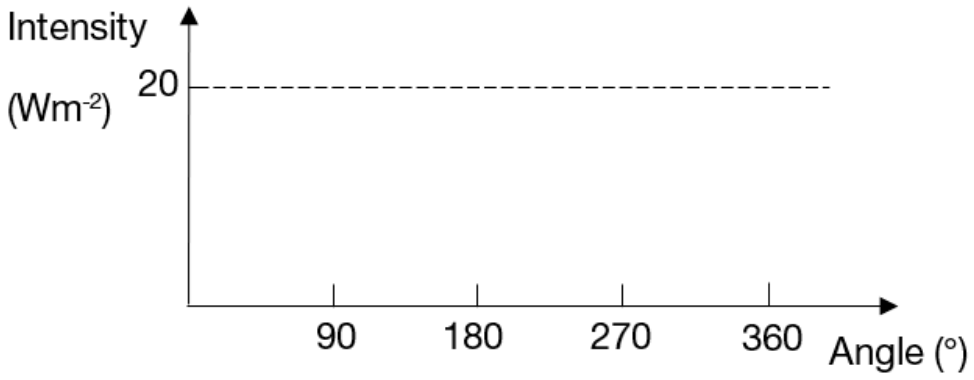
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 38 (4 marks) **Marks**

Two ideal polarising filters are placed in a row, as shown. Initially the polarising axis of each filter is vertical. Unpolarised light from a globe is incident on P_1, and the light has intensity of I = 20 Wm^{-2} after it passes through the polarisers.



(a) Polariser P_2 is then rotated through one complete rotation. Sketch the detected intensity I vs angle on the axes below. (You do not need to add any numbers to the graph.)



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(b) Determine the value of I when polariser P_2 is set to 55° from the vertical.

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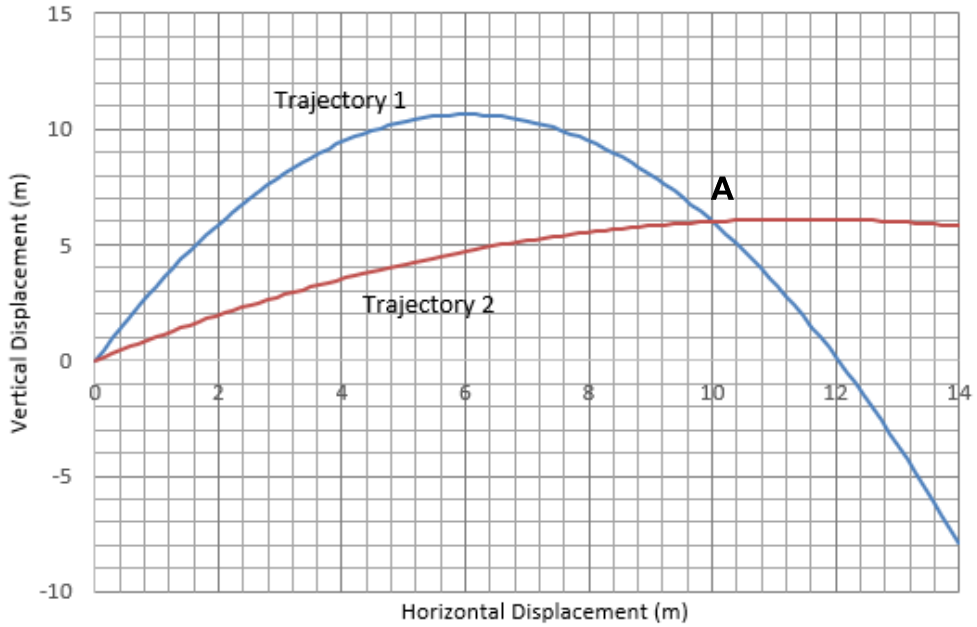
Question 39 (5 marks) **Marks**

Two projectiles are fired simultaneously at the same launch speed of 15 ms^{-1} from two different angles. Their trajectories, 1 and 2, are shown in the graph below. At point A, both trajectories have a horizontal displacement of 10 m, and a vertical displacement of 6.0 m.



(a) The maximum height that that trajectory 1 reaches is 10.6 m. Determine the launch angle of trajectory 1.

.....

.....

..... **2**

(b) Trajectory 2 is launched at an angle of 46.8°. Determine its speed at point A.

.....

.....

.....

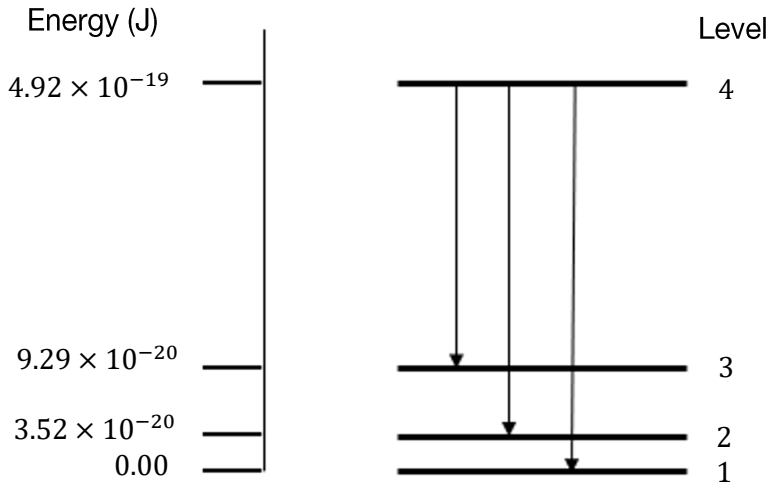
.....

.....

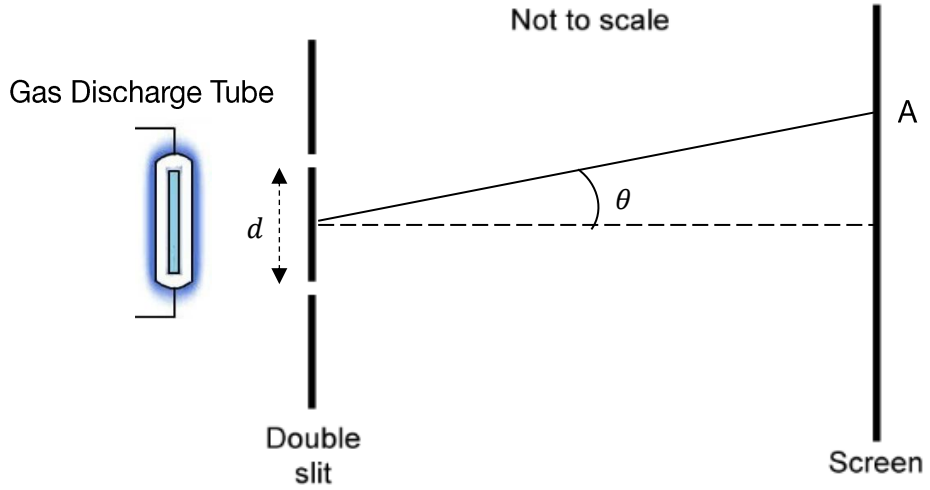
..... **3**

Question 40 (9 marks) **Marks**

The simplified electron energy diagram below shows the relative energies of electrons of an unknown element in a discharge tube, producing three different wavelengths of visible light.



When the light was shone through two narrow slits a distance $d = 1.0 \times 10^{-5} m$ apart and projected onto a screen, the first-order maximum for one of the wavelengths was seen at point A, θ = 2.32° degrees from the centre line, as shown below.



Analyse the processes occurring in the discharge tube and at the double slit to determine which transition created the light that formed the bright fringe at point A. Your analysis should include both qualitative and quantitative information.

.....

.....

.....

.....

Question 40 continued on next page.

Question 40 continued **Marks**

9

END OF EXAMINATION

Part D extra writing space

If you use this space, clearly indicate which question you are answering.

Part D extra writing space

If you use this space, clearly indicate which question you are answering.

Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	$340\ \text{m s}^{-1}$
Earth's gravitational acceleration, g	$9.8\ \text{m s}^{-2}$
Speed of light, c	$3.00 \times 10^{8}\ \text{m s}^{-1}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12}\ \text{A}^2\,\text{s}^4\,\text{kg}^{-1}\,\text{m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}\ \text{N A}^{-2}$
Universal gravitational constant, G	$6.67 \times 10^{-11}\ \text{N m}^2\,\text{kg}^{-2}$
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^{6} m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	$1.097 \times 10^{7}\ \text{m}^{-1}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5\ \text{MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3}\ \text{kg m}^{-3}$
Specific heat capacity of water	$4.18 \times 10^{3}\ \text{J kg}^{-1}\,\text{K}^{-1}$
Wien's displacement constant, b	$2.898 \times 10^{-3}\ \text{m K}$

FORMULAE SHEET

Motion, forces and gravity

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

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

$$\Delta U = mg\Delta h$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\sum \frac{1}{2}mv_{\text{before}}^2 = \sum \frac{1}{2}mv_{\text{after}}^2$$

$$\Delta \vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$\omega = \frac{\Delta \theta}{t}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$v = \frac{2\pi r}{T}$$

$$U = -\frac{GMm}{r}$$

$$v = u + at$$

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$W = F_{||}s = Fs\cos\theta$$

$$K = \frac{1}{2}mv^2$$

$$P = F_{||}v = Fv\cos\theta$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$a_{\text{c}} = \frac{v^2}{r}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$F = \frac{GMm}{r^2}$$

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

Waves and thermodynamics

$$v = f\lambda$$

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

$$d\sin\theta = m\lambda$$

$$n_{\text{x}} = \frac{c}{v_{\text{x}}}$$

$$I = I_{\text{max}}\cos^2\theta$$

$$Q = mc\Delta T$$

$$f_{\text{beat}} = \left| f_2 - f_1 \right|$$

$$f' = f\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\sin\theta_{\text{c}} = \frac{n_2}{n_1}$$

$$I_1r_1^2 = I_2r_2^2$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

Electricity and magnetism

$$E = \frac{V}{d}$$

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{||}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\vec{F} = q\vec{E}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_p I_p = V_s I_s$$

Quantum, special relativity and nuclear

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

$$K_{max} = hf - \phi$$

$$\lambda_{max} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}$$

$$p_v = \frac{m_0 v}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$$

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

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

2024
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Section I - Multiple Choice

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: $2 + 4 =$ (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.

correct

A ⊗ B ⊗ C ○ D ○

1.	A○	B○	C○	D○		**11.**	A○	B○	C○	D○
2.	A○	B○	C○	D○		**12.**	A○	B○	C○	D○
3.	A○	B○	C○	D○		**13.**	A○	B○	C○	D○
4.	A○	B○	C○	D○		**14.**	A○	B○	C○	D○
5.	A○	B○	C○	D○		**15.**	A○	B○	C○	D○
6.	A○	B○	C○	D○		**16.**	A○	B○	C○	D○
7.	A○	B○	C○	D○		**17.**	A○	B○	C○	D○
8.	A○	B○	C○	D○		**18.**	A○	B○	C○	D○
9.	A○	B○	C○	D○		**19.**	A○	B○	C○	D○
10.	A○	B○	C○	D○		**20.**	A○	B○	C○	D○

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SYDNEY GRAMMAR SCHOOL

TRIAL EXAMINATION 2024

FORM VI PHYSICS

CRIB

General Instructions

- Working Time: 3 hours (+ 5min Reading Time)
- Write using black pen

Structure of Paper & Instructions

- Section I Multiple Choice (20 marks). Spend 30 minutes on this section.
- Section II Parts A-D (80 marks). Spend 2 hours and 30 minutes on this section.

Total marks: 100

Wednesday 21 August 8:40am

Checklist

Each boy should have the following:

- ☐ Examination Paper (includes)
  - Examination sections
  - Extra Writing sheets
  - Data/Formula sheets
  - Multiple-Choice Answer Sheet

ED, SRW, ILM, PCK MIC: ILM

Exam Instructions

- Remove the centre staple and hand in all parts of the examination in a neat bundle in its original order. Do not insert parts into other parts.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.
  - Each detachable part A-D of Section II has additional writing space to use for that part.
  - Further additional writing paper can be given on request.

Multiple Choice Breakdown

		A	B	C	D
1	B	0%	96%	0%	4%
2	D	0%	0%	0%	100%
3	C	1%	1%	68%	30%
4	B	0%	100%	0%	0%
5	A	90%	8%	3%	0%
6	D	0%	8%	6%	86%
7	A	81%	1%	10%	8%
8	D	4%	8%	8%	81%
9	A	90%	8%	1%	1%
10	B	1%	95%	4%	0%
11	D	0%	9%	18%	73%
12	C	4%	3%	88%	5%
13	B	30%	64%	1%	5%
14	A	92%	3%	4%	1%
15	C	4%	8%	84%	4%
16	B	16%	73%	8%	4%
17	C	3%	6%	81%	10%
18	D	6%	0%	16%	78%
19	C	1%	5%	78%	16%
20	C	3%	1%	94%	3%

SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 A transformer has 2000 turns in its primary winding and 60 turns in its secondary. If the voltage input to the transformer is 240 V, the voltage output is:

(A) 0.25 V

(B) 7.2 V

(C) 33 V

(D) 8000 V

2 In an experiment to investigate the structure of matter, alpha particles were fired into gold foil. About 1 in 8000 particles bounced back at a large angle.

Which conclusion can be drawn from this observation?

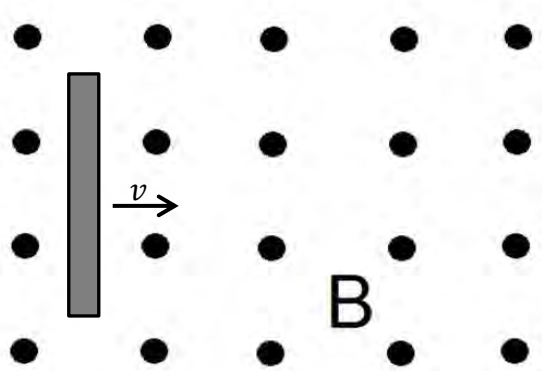
(A) The atomic nucleus contains protons and neutrons.

(B) Electrons orbit the atomic nucleus.

(C) The atomic nucleus is at the centre of the atom.

(D) The atomic nucleus occupies a very small fraction of the volume of the atom.

3 A conductive bar travels at constant velocity v through a magnetic field B pointing out of the page. Whilst this movement occurs, which region of the bar will become negatively charged?



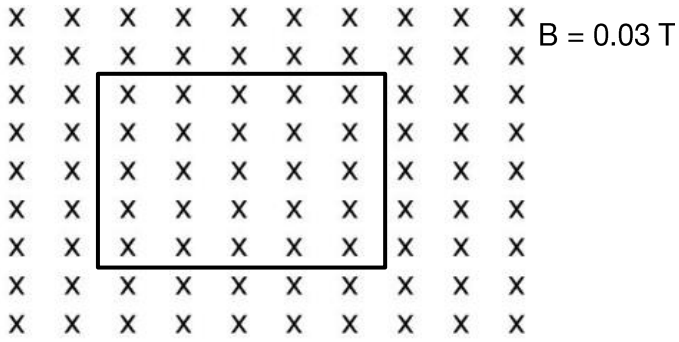
(A) The left-hand side

(B) The right-hand side

(C) The top (up the page)

(D) The bottom (down the page)

4 A rectangular coil with sides of length 0.04 m and 0.06 m is placed in a uniform magnetic field B of strength 0.03 T so that the plane of the coil is perpendicular to the field direction, as shown.



The magnetic flux through the coil is

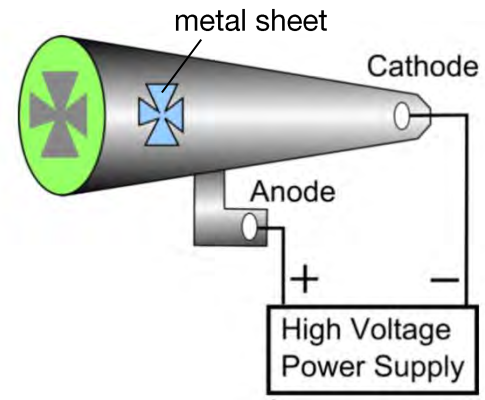
(A) 3.6×10^{-5} Wb

(B) 7.2×10^{-5} Wb

(C) 3.6×10^{-1} Wb

(D) 7.2×10^{-1} Wb

5 The diagram below shows an experiment performed with a high voltage across an evacuated tube.



The observation of a sharp-edged shadow on the end of the tube suggests that

(A) particles are blocked by a sheet of metal.

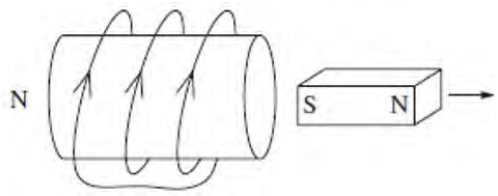
(B) particles diffract around the edges of a sheet of metal.

(C) negative particles travel from the anode to the cathode.

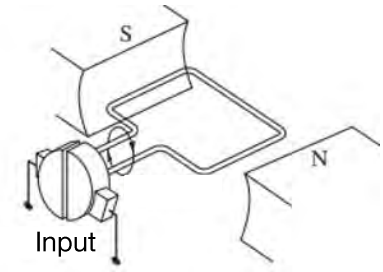
(D) positive particles travel from the cathode to the anode.

6 Which of the following diagrams depicts a dc generator?

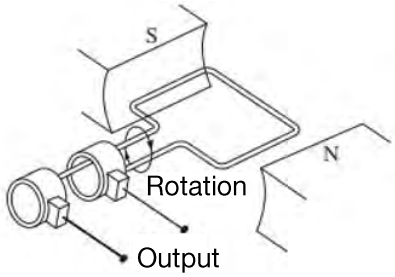
(A)



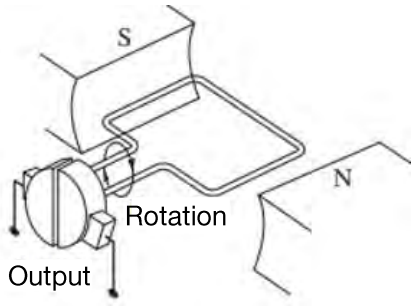
(B)



(C)



(D)



7 Which of the following was a contribution of James Clerk Maxwell to our understanding of the nature of light?

(A) Unification of the laws of electricity and magnetism

(B) Observation of the existence of radio waves

(C) Observation that electric and magnetic fields are always at right angles to each other

(D) Observation that the speed of light is a constant

8 The surface gravity of a planet is g. What would be the new value of the surface gravity if both the mass and radius of the planet were halved?

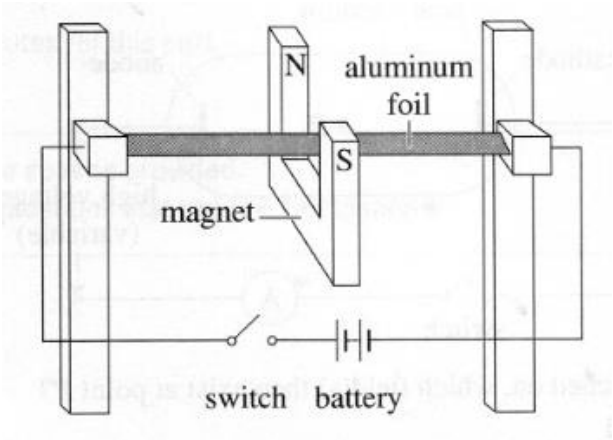
(A) $\frac{g}{4}$

(B) $\frac{g}{2}$

(C) g

(D) $2g$

9 A thin piece of aluminium foil is connected by a conducting wire to a switch and battery as shown. The foil is placed between the poles of a magnet, as shown.



When the switch is closed, the aluminium foil will move

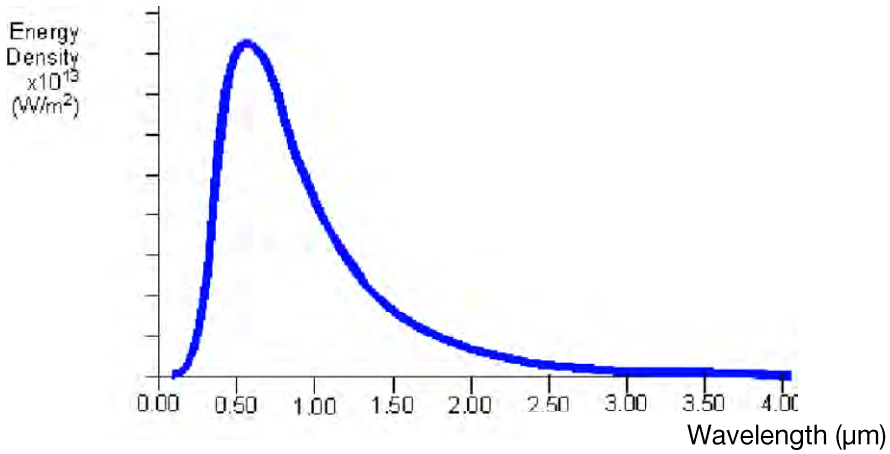
(A) downwards.

(B) upwards.

(C) towards the north pole of the magnet.

(D) towards the south pole of the magnet.

10 A blackbody curve is shown in the diagram below.



The temperature of the blackbody is closest to

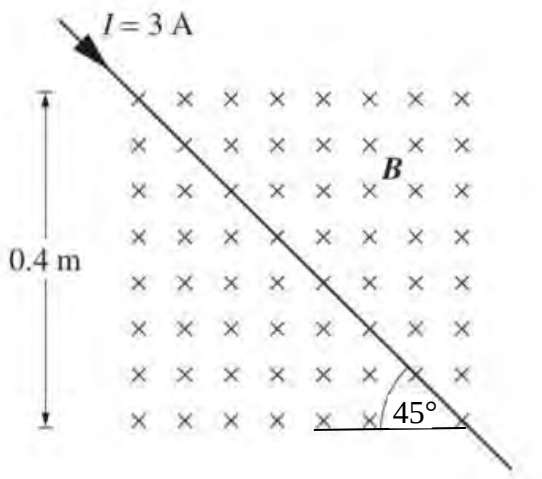
(A) 0.0058 K

(B) 5800 K

(C) 5800°C

(D) 8×10^{13} K

11 A current-carrying wire passes through a square region of magnetic field, magnitude 2.0 T, as shown in the diagram below. The magnetic field is directed into the page.



What is the magnitude of the magnetic force on the conductor?

(A) 0.68 N

(B) 1.7 N

(C) 2.4 N

(D) 3.4 N

12 Polarisation could not be explained in terms of a wave theory of light until which development?

(A) Einstein proposed a photon model of light

(B) Most scientists abandoned the particle model of light

(C) Light was understood to be a transverse wave

(D) Light was understood to be a longitudinal wave

13 One of the largest conventional bombs ever made is the MOAB with a yield of 11 tonnes of TNT. If 1 tonne of TNT produces 4.2×10^9 J of energy, the amount of mass lost in this explosion is

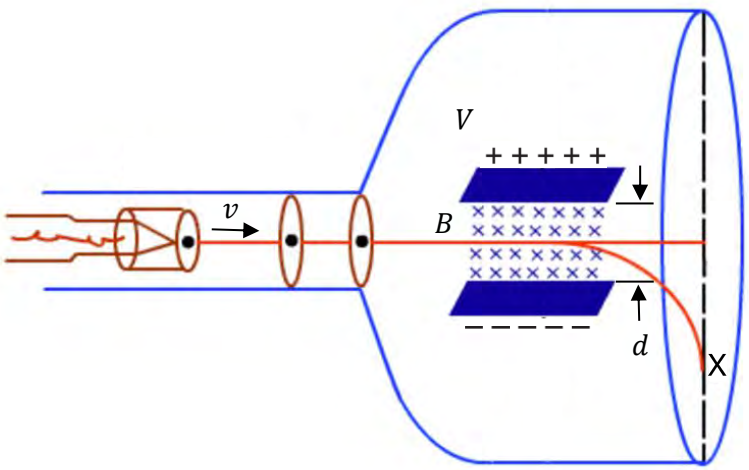
(A) 4.67×10^{-8} kg

(B) 5.13×10^{-7} kg

(C) 14.0 kg

(D) 154 kg

14 The diagram below shows an electron travelling at speed v within a magnetic field B. The charged plates have a voltage V across them and are separated by a distance d. The quantities B, V and d are set so that the electron passes through undeflected.



Which of the following adjustments could lead to the electron arriving at X?

(A) Decrease V

(B) Decrease B

(C) Decrease v

(D) Decrease d

15 When a projectile reaches its maximum height it is travelling at speed u. When it hits the ground, its speed is $2u$.

At what angle does it hit the ground?

(A) 30° below the horizontal

(B) 45° below the horizontal

(C) 60° below the horizontal

(D) 63° below the horizontal

16 The maximum speed that a car can go around a circular turn with a constant radius is 80 kmh^{-1} without skidding. What is the maximum speed of a truck in the same corner with 5 times the mass and 3 times the sideways frictional force?

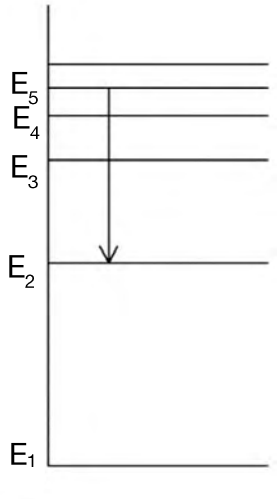
(A) 48 kmh^{-1}

(B) 62 kmh^{-1}

(C) 103 kmh^{-1}

(D) 133 kmh^{-1}

17 The diagram below shows electron energy levels within an atom.



The transition E_5 to E_2 causes the emission of infrared radiation.

A transition that could cause the emission of ultraviolet radiation would be

(A) E_4 to E_2

(B) E_4 to E_3

(C) E_5 to E_1

(D) E_5 to E_4

18 A metal with a work function Φ emits electrons with a kinetic energy of K when light of wavelength λ is shone on it.

What is the new kinetic energy of the emitted electrons if the wavelength of the light is halved?

(A) $2K$

(B) $\mathrm{K} - \Phi$

(C) $2\mathrm{K} - \Phi$

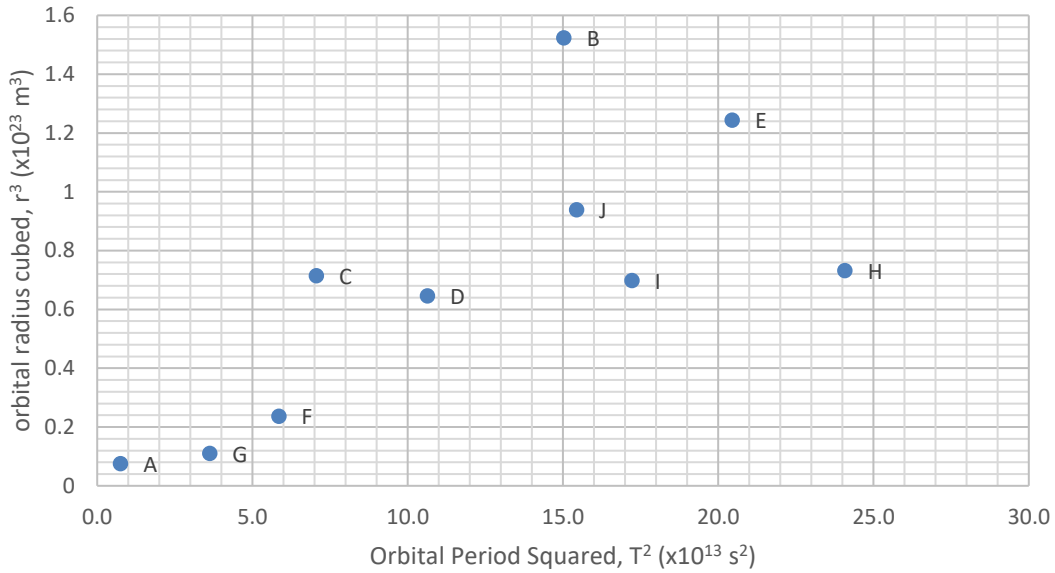
(D) $2\mathrm{K} + \Phi$

19 A Blu-ray video disk has a diameter of 0.12 m and rotates at 810 rpm (or 13.5 rotations per second) when it is playing.

Select the correct option for the angular velocity ω and the centripetal acceleration a_c of a point at the edge of the disk.

	Angular Velocity, ω (rad s^{-1})	Centripetal Acceleration, a_c (m s^{-2})
(A)	27	216
(B)	27	432
(C)	85	432
(D)	85	863

20 In a distant solar system there are 5 exoplanets with 10 moons in total orbiting around them. The orbital radius and orbital periods for all these moons (labelled A-J) are in the diagram below.



Which groups of moons are orbiting the same planet?

(A) Moons A, C, G

(B) Moons B, C, G

(C) Moons D, E, J

(D) Moons F, G, H

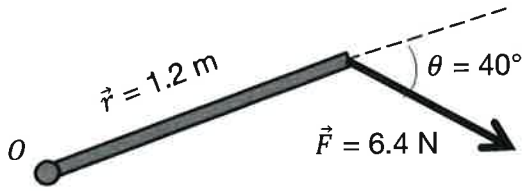
SECTION II: Part A (20 Marks)

			S	R	W			
CANDIDATE NUMBER								

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (2 marks) **Marks**

Determine the magnitude and direction of the torque around the axis O.



$\tau = rF_\perp = 1.2 \times 6.4 \times \sin 40°$

$= 4.94$ N.m clockwise (1) (1)

2

Question 22 (2 marks)

Determine the wavelength produced by the transition of an electron in a hydrogen atom from the n = 3 to the n = 1 energy level.

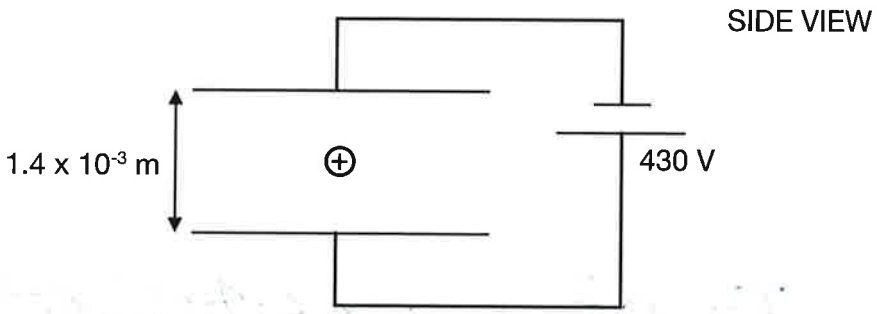
$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$ (1)

$\lambda = 102.6$ nm

2

Question 23 (3 marks) **Marks**

The diagram below shows two parallel, charged metal plates in a vacuum. A small ball with a charge of $+4.0 \times 10^{-6}$ C is placed between the plates.



When the ball is released, it remains stationary. Determine:

(a) the electric field strength between the plates.

$E = \frac{V}{d} = \frac{430 \text{ Volts}}{1.4 \times 10^{-3} \text{ m}} = 3.1 \times 10^{5} \text{ Vm}^{-1}$ **1**

(b) the mass of the ball.

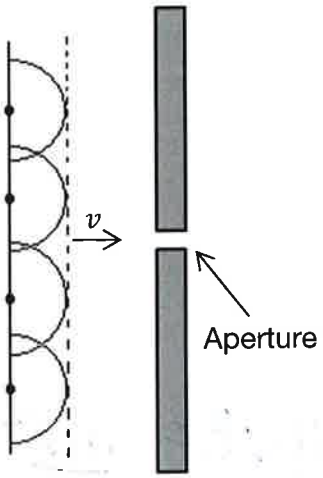
$Eq = mg$

$\therefore m = \frac{Eq}{g} = \frac{3.07 \times 10^{5} \times 4 \times 10^{-6}}{9.8}$

$= 0.125 \text{ kg}$ **2**

Question 24 (3 marks) **Marks**

The diagram illustrates the construction Huygens created to model how light propagates through space.

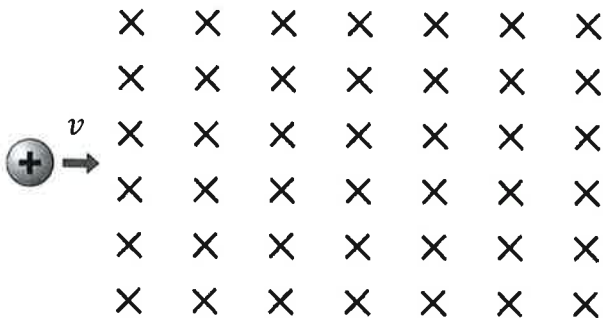


Describe how this model can be used to explain how light behaves when it passes through a narrow aperture.

① Every point on a wave is a soure of semi-circular wavelets.
① A successive wavefront is the superposition/tangent of these wavelets
① At the aperture only a limited number of close points can generate wavelets producing a semi circular diffraction pattern. 3

Question 25 (2 marks) **Marks**

A proton with a velocity of v = 3.0 x 10^6 ms^{-1} enters a region with a uniform magnetic field of 2.0 T directed into the page, as shown.



Calculate the radius of the proton's path in the magnetic field.

$qvB = \frac{mv^2}{r}$ (1)

$r = \frac{mv}{qB} = 0.0157\ m$ (1)

2

Question 26 (4 marks) **Marks**

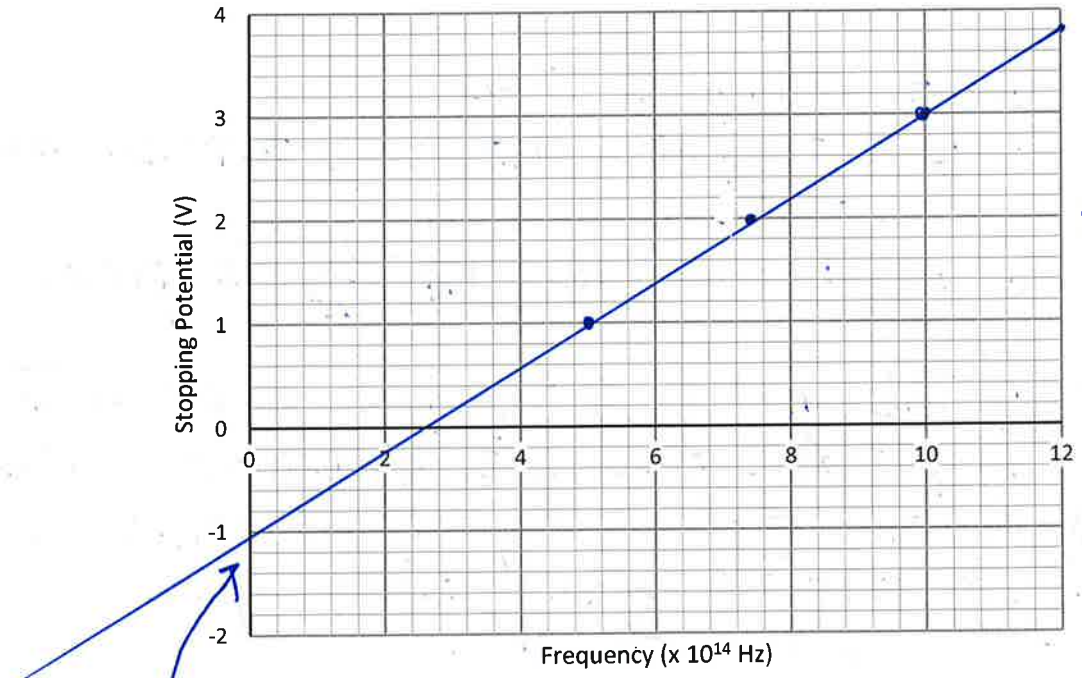
For a particular cathode material in a photoelectric experiment the stopping potentials were measured as a function of the wavelength of light shone on the cathode.

(a) Complete the table by calculating the frequency of the light.

Stopping Potential (V)	Wavelength ($\times 10^{-7}$ m)	Frequency ($\times 10^{14}$ Hz)
1.0	6.0	5
2.0	4.0	7
3.0	3.0	10

1

(b) On the graph paper below, plot a graph of Stopping Potential versus Frequency. Draw a line of best fit.



(1) points
(1) line

2

(c) Use your graph to determine the work function of the metal.

1eV or 1.6×10^{-19} J

.....

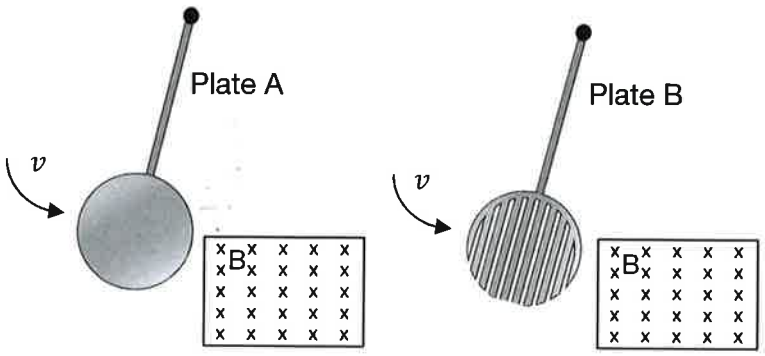
.....

1

(1) Answer
(1) Unit.

Question 27 (4 marks) **Marks**

Electromagnetic braking can be demonstrated by swinging two metal plates inside a strong magnetic field, as shown below.



In which of Plates A and B would the electromagnetic braking effect be stronger? Justify your answer.

① A braking is stronger
① As both plates enter field there is a change in flux.
① By Faraday's law $\mathcal{E}_{MF} = \frac{\Delta\Phi}{\Delta t}$ is produced.
* ① This induced voltage produces a current only in plate A as B has slits stopping the current. The direction of these currents by Lenz's law is such that the external Field applies a force slowing the disc. 4

* Some boys said that this was an area effect. I accepted their answer even though I think this is not quite correct. If the slits were very thin then the surface area would be the same but the braking would be negligible.

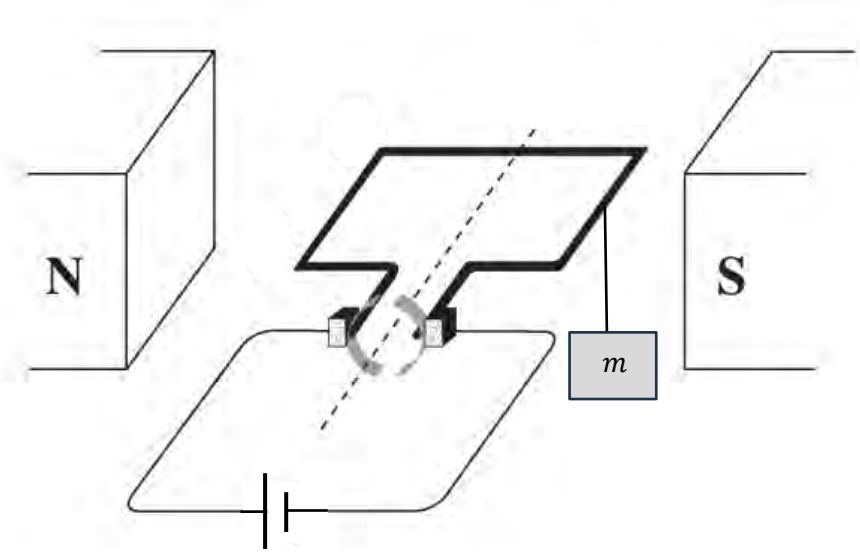
SECTION II: Part B (21 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 28 (3 marks) **Marks**

A square coil of side 0.10 m with 40 turns that has a current of 0.30 A flowing through it is inside a magnetic field of uniform magnitude 2.0 T, as shown below. A mass m is hung from the right-hand side of the coil.



(a) Determine the magnitude of the torque on the coil **before** the mass m is added.

$\tau = nBIA\sin\theta = 40 \times 2 \times 0.3 \times (0.1)^2 \times \sin 90$

$= 0.24\ Nm$ **1**

(b) When the mass m is hung from the right-hand side of the coil, determine the value of m necessary to stop the coil from turning.

$\tau_m = \tau_g$

$0.24 = rF\sin\theta$

$0.24 = 0.05 \times m \times 9.8 \times \sin 90$

$m = 0.49\ kg$ **2**

Question 29 (4 marks) **Marks**

Crystallography is a tool for studying the structure of materials that uses x-rays with a wavelength of around 1.0×10^{-10} m, about the same as the spacing between atoms.

(a) Determine the energy of an x-ray photon that has a wavelength of 1.0×10^{-10} m. **1**

$E = hf = \frac{hv}{\lambda}$

$= \frac{(6.626 \times 10^{-34}) \times (3 \times 10^{8})}{1 \times 10^{-10}}$

$= 1.99 \times 10^{-15}$ J

(b) Because they have a wave nature, neutrons can also be used for this technique. Determine the kinetic energy of a neutron that has a de Broglie wavelength of 1.0×10^{-10} m. **3**

$\lambda = \frac{h}{mv}$ $v = \frac{h}{m\lambda}$ (1)

$= \frac{6.626 \times 10^{-34}}{(1.675 \times 10^{-27}) \times (1 \times 10^{-10})}$

$= 3.956 \times 10^{3}$ ms^{-1} (1)

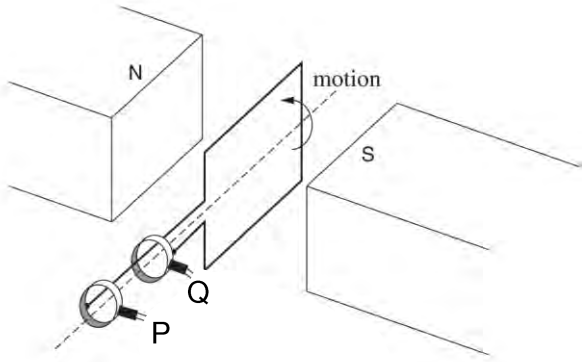
$KE = \frac{1}{2}mv^2$

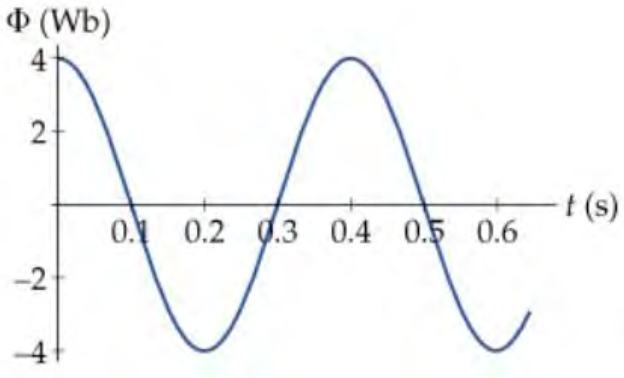
$= \frac{1}{2} \times (1.675 \times 10^{-27}) \times (3.956 \times 10^{3})$

$= 1.3 \times 10^{-20}$ J (1)

Question 30 (4 marks) **Marks**

The flux though a single coil of an AC generator is shown below.





(a) Identify one time when the induced EMF will be zero according to the above graph.

0, 0.2, 0.4, 0.6 **1**

(b) If the generator consists of 60 coils, estimate from the above graph the magnitude of the average EMF generated over the first 0.2 s.

$\mathcal{E} = -N\frac{\Delta\phi}{\Delta t}$ $\Delta\phi = 8$

$= \frac{60 \times 8}{0.2}$

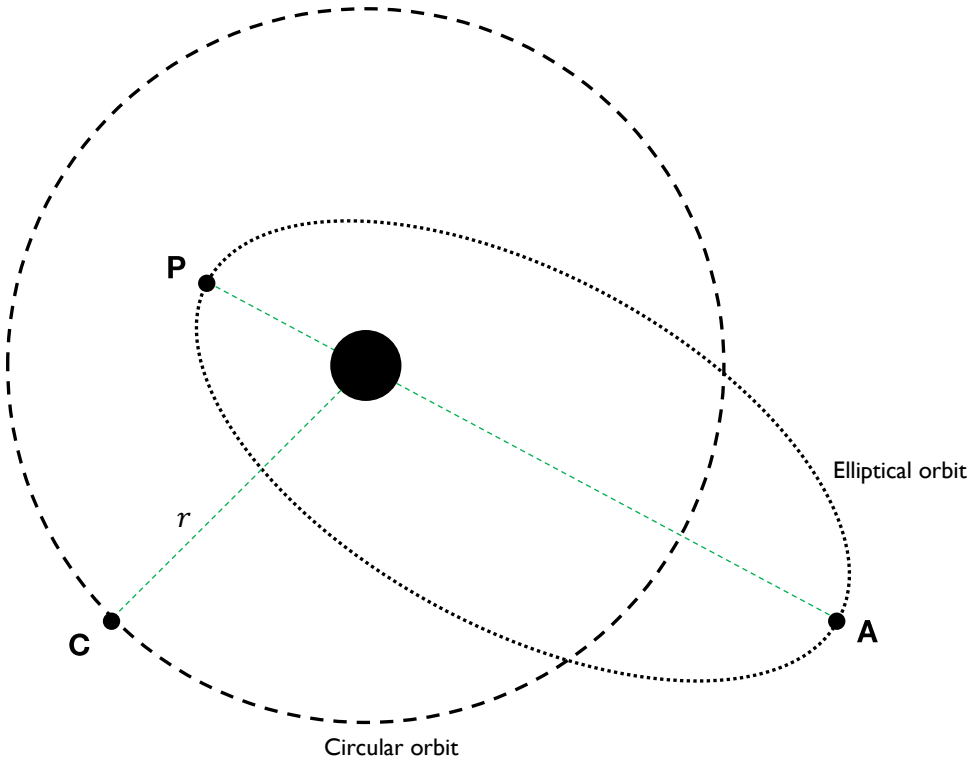
$= 2400V$ **2**

(c) At t = 0.1 s, which of P and Q would be the positive terminal?

P **1**

Question 31 (6 marks) **Marks**

The diagram below shows two satellites in orbit around the Earth. One orbit is circular, and the other is elliptical. Both satellites have the same total energy.



(a) If the gravitational potential energy of the satellite is U, show that the kinetic energy, K, of the satellite in a circular orbit is $K = -\frac{U}{2}$, and that therefore the total energy $E = \frac{U}{2}$.

For circular orbits $F_c = F_g$

$\frac{mv^2}{r} = \frac{GMm}{r^2}$

eq.1 $v^2 = \frac{GM}{r}$ (1)

eq.2 $KE = \frac{1}{2}mv^2$ sub (1) into (2)

$= \frac{1}{2}m\left(\frac{GM}{r}\right)$

$= \frac{1}{2} \times \frac{GMm}{r}$

$= \frac{1}{2} \times (-U)$

$= -\frac{U}{2}$ (1)

$E = U + KE$

$= U - \frac{U}{2}$

$= \frac{U}{2}$ (1)

3

Question 31 continued on next page.

Question 31 continued **Marks**

Important!

(b) Compare the work done by gravity on each of the satellites over the course of one orbit.

(1) For circular orbits, no work done by gravity

(1) For elliptical orbits, work done by gravity is not zero.

(1) Specifies: - positive work when moving towards Earth.
- Negative work when moving away from Earth. **3**

Question 32 (4 marks) **Marks**

Discuss limitations of Rutherford's model of the atom, and how modifications of the atomic model introduced by Bohr and de Broglie addressed the limitations.

2 marks - Identifies two limitations of the Rutherford model

1 mark - Describes Bohr's modification to Rutherford's model (linked to limitation)

1 mark - Describes de Broglie's modification to Rutherford's/Bohr's model (linked to limitation)

4

SECTION II: Part C (21 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 33 (4 marks) **Marks**

Around a planet called Pax, a satellite has an orbital velocity of 1400 ms^{-1} at a constant orbital radius of 5.5×10^7 m.

(a) Calculate the mass of Pax.

Method 1 $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $v_{orbit} = \sqrt{\frac{GM}{r}}$ (1) derive or know relationship not on formula sheet } equation must be written in working to get mark

$M = \frac{rv^2}{G} = \frac{5.5 \times 10^7 \times (1400)^2}{6.67 \times 10^{-11}}$

$= 1.62 \times 10^{24}$ kg (1) correct answer

(can also use $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ and $\frac{2\pi r}{T} = v$, $T = 2.47 \times 10^5$ s) **2**

(0 marks if equation is incorrect)

(b) Determine the escape velocity from Pax at the position of the satellite.

$K = 0 - U$, $\frac{1}{2}mv_e^2 = \frac{GMm}{r}$ $v_e = \sqrt{\frac{2GM}{r}} = \sqrt{2}\, v_{orbit}$

(1) derive or know eq. not on formula sheet $= \sqrt{2}\ 1400 m/s$

$= 1979.9 m/s$

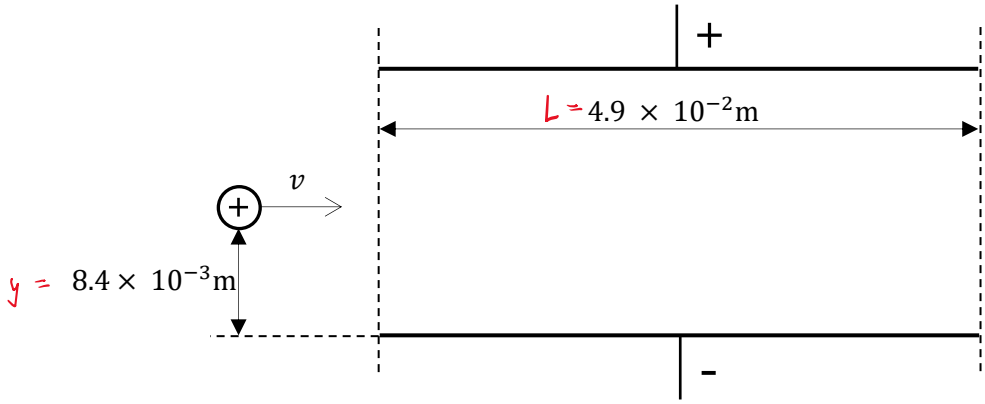
long way $v_e = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2\pi(6.67 \times 10^{-11})(1.62 \times 10^{24})}{5.5 \times 10^7}}$

$= 1980$ m/s (1) correct answer **2**

0 - equation incorrect

Question 34 (6 marks) **Marks**

In the diagram below, a uniform electric field of strength 2.7×10^4 N C^{-1} exists between two metal plates. A proton enters the electric field mid-way between the plates, travelling at speed v parallel to the plates, as shown.



No indication this is vertical so gravity should not be included

(a) Determine the minimum speed v that the proton must have to pass through the plates without hitting them.

time of flight $t = \frac{L}{v}$, $y = \frac{1}{2}a_y t^2$, $F = qE = ma_y$, $a_y = \frac{q}{m}E$

for a proton $q = 1.602 \times 10^{-19}$ C, $m = 1.673 \times 10^{-27}$ kg

method 1

$a_y = \frac{q}{m}E = \frac{1.602 \times 10^{-19} \times 2.7 \times 10^4}{1.673 \times 10^{-27}} = 2.54 \times 10^{12}$ m/s^2

$t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2 \times 8.4 \times 10^{-3}}{2.54 \times 10^{12}}} = 8.06 \times 10^{-9}$ s

$v = \frac{L}{t} = \frac{4.9 \times 10^{-2}}{8.06 \times 10^{-8}} = 6.08 \times 10^5$ m/s -1

a_y found 1
t found 1

method 2

$y = \frac{1}{2}\left(\frac{q}{m}E\right)\left(\frac{L}{v}\right)^2$, $v^2 = \frac{qEL^2}{2my}$

$v = L\sqrt{\frac{qE}{2my}}$

$v = (4.9 \times 10^{-2})\sqrt{\frac{(1.602 \times 10^{-19})(2.7 \times 10^4)}{2(1.67 \times 10^{-27})(8.4 \times 10^{-3})}}$

$= 6.08 \times 10^5$ m/s -1

or 607,864 m/s

3

(b) Discuss the similarities and differences between the motion of charged particles in uniform electric fields and the motion of masses in uniform gravitational fields.

Sample Answer

Translation: Outline how the motion in different uniform fields (constant magnitude and direction) are similar and different in shape and what they depend upon

The shape of the motion depends on the acceleration due to force created by the field (magnitude and direction).
Assume motion is compared using the same initial velocity
Since both uniform electric fields and uniform gravitational fields have constant accelerations (and forces) in only one direction both will create similar parabolic paths.
The shape of the parabolic motion changes because of the differences in the forces.
The gravitational force ($\vec{W} = m\vec{g}$) acts on mass and creates a constant acceleration ($\vec{a} = \vec{g}$) which means that the motion depends only on the gravitational field strength regardless of mass.
Whereas the electric force ($\vec{F} = q\vec{E}$) acts on charge and the acceleration ($\vec{a} = q\vec{E}/m$) depends on the mass, charge and charge polarity and electric field strength. Because charge polarity can be positive or negative the direction of acceleration can be in the direction of the field (for positive charges) or the opposite direction to the field (for a negative charge)

Continued next page

Continues on next page

–3

Question 35 (4 marks) **Marks**

A pion is a subatomic particle with a half-life of 2.6×10^{-8}s when at rest. When pions are accelerated to a very high speed, v, in a particle accelerator, the half-life increases to 4.2×10^{-7}s, as measured by an observer in the control room of the accelerator.

(a) Determine the velocity v of the pions in the accelerator.

$t_v = \frac{t_0}{\sqrt{1-(\frac{v}{c})^2}} \rightarrow (\frac{t_0}{t_v})^2 = 1-(\frac{v}{c})^2 \rightarrow (\frac{v}{c})^2 = 1-(\frac{t_0}{t_v})^2$ $\frac{v}{c} = \sqrt{1-(\frac{t_0}{t_v})} = \sqrt{1-(\frac{2.6\times10^{-8}}{4.2\times10^{-7}})^2} =$

$\frac{v}{c} = 0.9980821$ correct to 3 sig figs

or $v = 299\,424\,618$ m/s

this cannot be rounded to 3.0×10^8 m/s as $v \neq c$ **2**

(b) Determine the average distance a pion travelling at this speed would move in its lifetime, according to the observer in the control room.

half-life = lifetime as above

not lifetime = 2× half-life.

$d = vt_v = (299\,424\,618)(4.2\times10^{-7}) = 1.26\times10^2 = 125.8$ m

method ✓ not using 3.0×10^8 m/s ✗ correct time ✓

therefore full working must be shown **2**

Question34b continued

Table comparing factors that will determine/affect the motion

	Comparison	Motion of charged particles in uniform electric fields ($\vec{E}$)	Motion of masses in uniform gravitational fields ($\vec{g}$)
T	Path shape in uniform field	The motion has a parabolic shape because of constant acceleration in one direction	The motion has a parabolic shape because of constant acceleration in one direction
A	Acceleration magnitude (affects motion/parabolic shape)	$a = \frac{qE}{m}$ Acceleration depends on charge and mass and electric field strength.	$a = g$ Acceleration depends on gravitational field strength only and is constant for all masses and is not affected by charge.
D	Direction of acceleration (affects orientation of motion/parabola relative to field)	Acceleration is in the direction of the field for positive charges and in the opposite direction for negative charges	Acceleration is always parallel to the field in the same direction as the field.

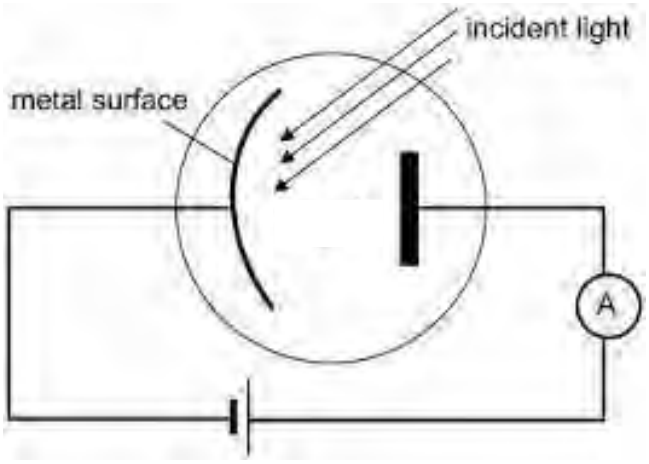
Criteria	Mark
Analyses and compares all 3 factors that affect motion in uniform fields • T, A, D labelled above	3
• 2 of above	2
• 1 of above • OR relevant information	1

Notes:

- The comparison is made of the motion in each field and the factors that affect it. Comparing forces without linking it to how motion is affected were not considered complete.
- To earn a mark requires a qualitative or quantitative comparison in both fields.
- The question specifies uniform fields – so motion in radial fields is not counted (circular motion in orbits or forces between pairs of masses or charges)
- Answers with charges moving to positive/negative plates or the centre of the Earth are not relating the motion relative to the field as asked.
- No orientation of fields is given in question so horizontal/vertical directions are meaningless. Describe motion parallel/perpendicular to field direction.
- Fields do not attract or repel, they are vectors. Force directions depend on the direction of the field.

Question 36 (3 marks) **Marks**

Light is incident upon a piece of metal in a vacuum tube, as shown. If the frequency of the light is above a certain value, called the threshold frequency, a current is detected in the ammeter.



Explain this observation in terms of Einstein's model of light.

Observation being explained – The frequencies of light higher than threshold frequency creates a measurable current

A fully correct answer should contain the following key elements.

(E) According to Einstein's Model, incoming light is made of photons with energy related to their frequency ($E = hf$) and when it hits an electron in a metal it gives all its energy to it.

(W) Only if the photon has an energy greater the workfunction $hf > \Phi$ is an electron released from the metal. This minimum photon energy corresponds to a specific threshold frequency $f_o = \frac{\Phi}{h}$ where the 'workfunction' is the amount of energy needed to remove an electron from the metal or specifically the work done against electrostatic attraction.

(C) The electrons emitted from the metal move through the vacuum tube (with kinetic energy $K_{max} = hf - \Phi$) create a measurable current observed on the ammeter in circuit. If the frequency of light is below the threshold frequency then no electrons are emitted and no current is measured

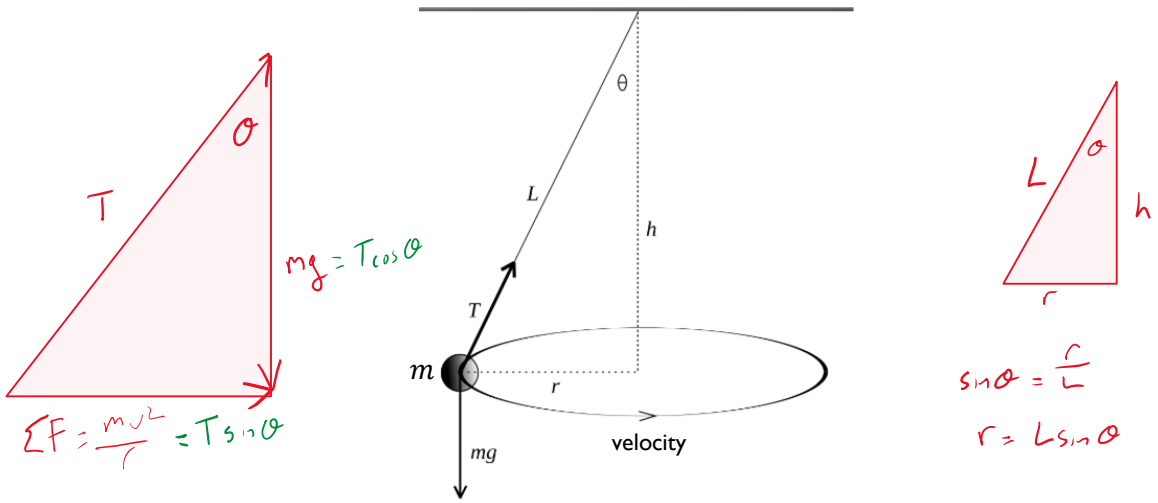
Criteria	Mark
• Contains all elements o E – outlines Einstein's model of photons with energy $E = hf$ that is given to the electrons in the metal. o W – a description of the workfunction and how this creates a threshold frequency, mathematically, from Einstein's model. o C – how a current is read at the ammeter from the ejection of electrons with kinetic energy. • AND response is a clear explanation of how current is detected using Einstein's model	3
• Two of the elements E,W,C	2
• One of the elements E,W,C • OR Relevant information to question	1

Note:
Better answers are clearer about what Einstein's model is and its equations and incorporating this into their explanation of the observation

3

Question 37 (4 marks) **Marks**

The diagram below shows a mass, m, being swung in a horizontal circle on a string of length L.



As the mass is rotated faster the angle to the vertical, θ, changes.

Analyse the forces on the mass to explain why the vertical angle changes as the speed of the rotating mass is increased.

To show definitive relationships an equation has to be derived that directly relates angle and speed with no other changing dependent variables

By analysing forces $\tan\theta = \left(\frac{mv^2}{r}\right) \div mg = \frac{v^2}{rg}$

relates velocity to angle $v^2 = rg\tan\theta$

but r changes $r = L\sin\theta$ so $v^2 = Lg\sin\theta\tan\theta$ L, g are constant so v^2 depends only on $(\tan\theta\sin\theta)$

as v^2 increases $\sin\theta\tan\theta$ must also increase, which it does at $\theta \to 90°$ as $\{\sin\theta \to 1$ as $\theta \to 90°$, $\tan\theta \to \infty$ as $\theta \to 90°\}$

The main complication that many did not account for when answering this question is that the equations $F_c = \frac{mv^2}{r}$ has variable speed and variable radius, and $v^2 = gr\tan\theta$ has variable radius and variable angle.
The two variables in each of these equations are also not independent.
Therefore, statements or assumptions that "*as velocity is increasing then centripetal force is increasing*" cannot be made without further justification. Many failed to see the direct relationship between radius and angle $r = L\sin\theta$ ($0° < \theta < 90°$).

Many methods were used to answer so marking was based on matching the following standard for each mark.	**Mark**
• Has a force vector sum diagram AND • Derives a direct comparison between the velocity and angle $v^2 = gL\sin\theta\tan\theta$ AND • Fully accounts for how the angle must increase if the velocity increases in logical steps with no incorrect, or unjustified, statements and assumptions	4
• Has a force vector sum diagram AND • Derives $v^2 = gr\tan\theta$ AND • Has made unjustified statements or invalid assumptions but has made some significant correct logical steps to account for the variable radius's effect on centripetal force and angle.	3
• Has a force vector sum diagram AND • Derives $v^2 = gr\tan\theta$ or related component forces in force diagram AND • Has made unjustified statements or invalid assumptions OR has not accounted for how the changing radius affects centripetal force or angle.	2
• Relevant information	1

Note:

- Explanations cannot be just mathematical; words are needed explain the steps and justifications you are using to fully answer the question of why angle must increase as velocity is increased.
- If you are using mathematical arguments or physics arguments, then you will be judged on the correctness of your steps and if they are making any assumptions or skipping steps (i.e. stating that $\tan\theta$ is increasing then θ is increasing) of your mathematical statements.

4

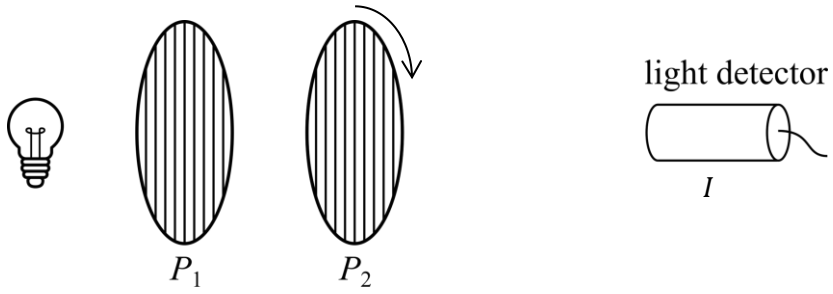
SECTION II: Part D (18 Marks)

CANDIDATE NUMBER							

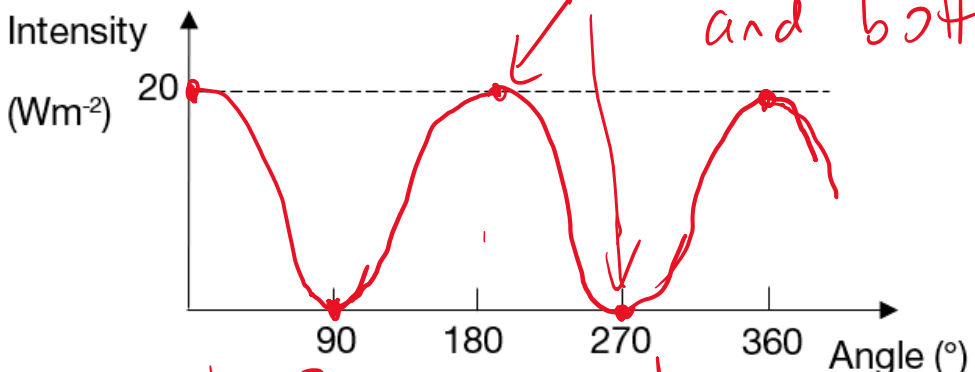
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 38 (4 marks) **Marks**

Two ideal polarising filters are placed in a row, as shown. Initially the polarising axis of each filter is vertical. Unpolarised light from a globe is incident on P_1, and the light has intensity of I = 20 Wm^{-2} after it passes through the polarisers.



(a) Polariser P_2 is then rotated through one complete rotation. Sketch the detected intensity I vs angle on the axes below. (You do not need to add any numbers to the graph.)



Must level off at top and bottom

1 mark for correct maxima + minima
1 mark for correct shape

2

(b) Determine the value of I when polariser P_2 is set to 55° from the vertical.

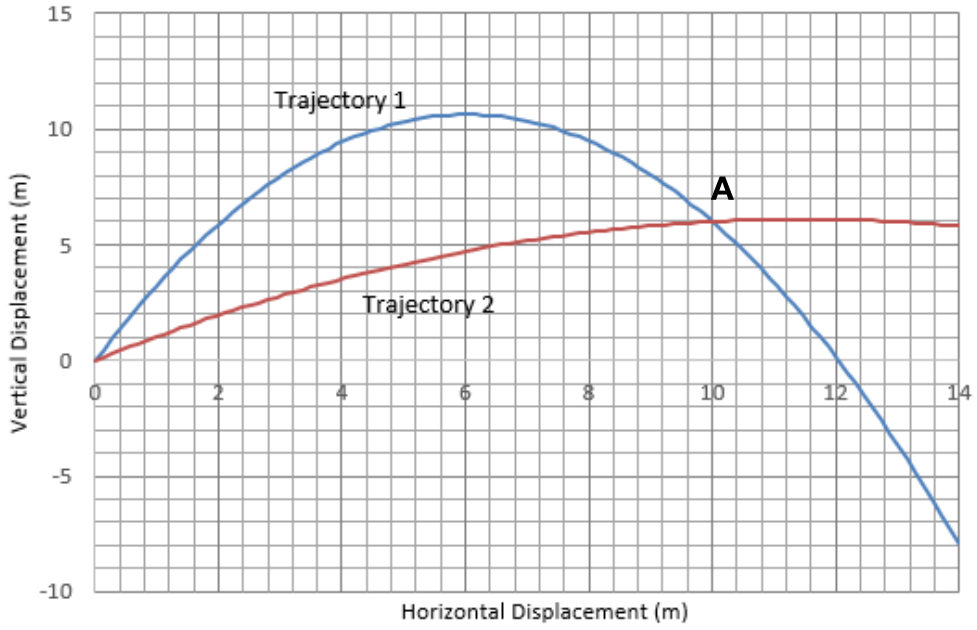
$I = 20 \cos^2 55$
$= 6.58$ Wm^{-2}

(If a) and b) both have max = 10, only 1 mark lost.)

2

Question 39 (5 marks) **Marks**

Two projectiles are fired simultaneously at the same launch speed of 15 ms^{-1} from two different angles. Their trajectories, 1 and 2, are shown in the graph below. At point A, both trajectories have a horizontal displacement of 10 m, and a vertical displacement of 6.0 m.



(a) The maximum height that that trajectory 1 reaches is 10.6 m. Determine the launch angle of trajectory 1.

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

$0 = u_y^2 - 19.6 \times 10.6$, $u_y = 14.4\ ms^{-1}$

$\theta = \sin^{-1}\frac{14.4}{15} = 73.9°$ **2**

(b) Trajectory 2 is launched at an angle of 46.8°. Determine its speed at point A.

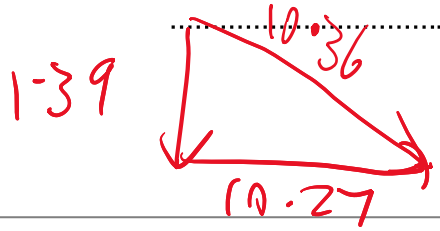
$u_y = 10.93$, $u_x = 10.27$

$t = \frac{10}{10.27} = 0.974\ s$

$v_y = u_y - gt = 10.93 - 9.8 \times 0.974$

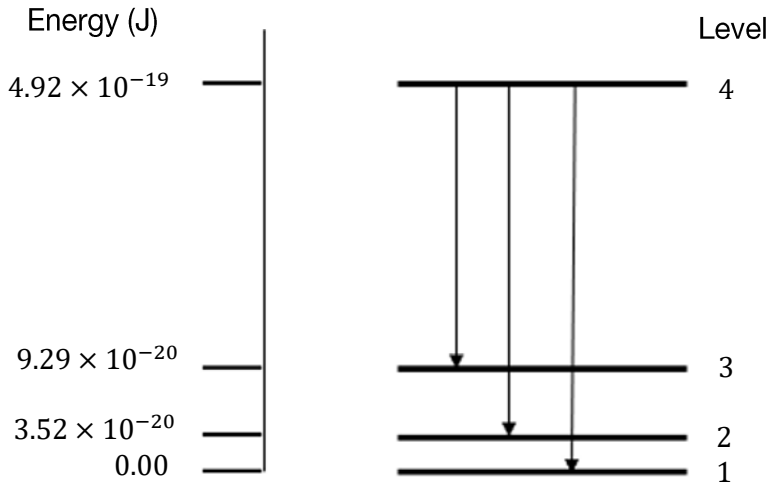
$= 1.39\ ms^{-1}$

$V = 10.36\ ms^{-1}$ **3**

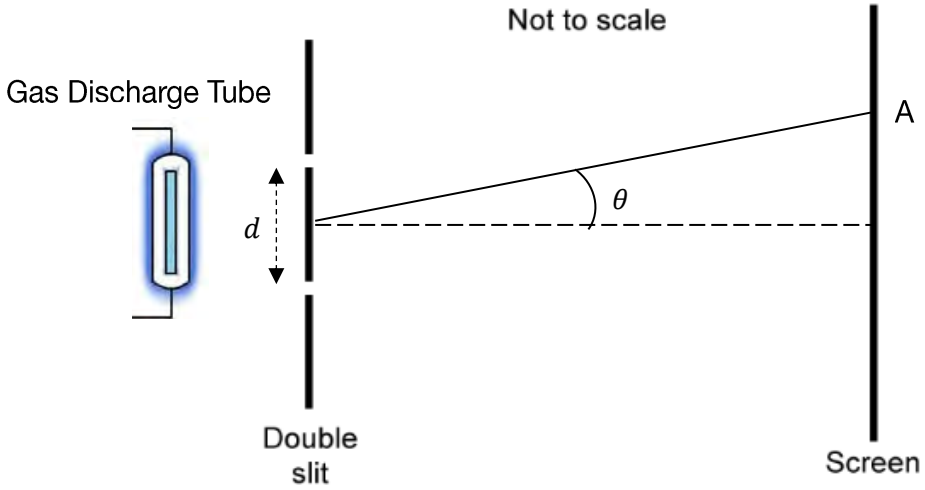


Question 40 (9 marks) **Marks**

The simplified electron energy diagram below shows the relative energies of electrons of an unknown element in a discharge tube, producing three different wavelengths of visible light.



When the light was shone through two narrow slits a distance $d = 1.0 \times 10^{-5} m$ apart and projected onto a screen, the first-order maximum for one of the wavelengths was seen at point A, θ = 2.32° degrees from the centre line, as shown below.



Analyse the processes occurring in the discharge tube and at the double slit to determine which transition created the light that formed the bright fringe at point A. Your analysis should include both qualitative and quantitative information.

$m\lambda = d \sin\theta$

$\lambda = 1 \times 10^{-5} \sin 2.32 = 404\,nm$

Question 40 continued on next page.

Question 40 continued **Marks**

Possible calculations for atom:
E change 4→1 = 4.92×10^{-19} J (or others.)
$f = E/h = 7.425 \times 10^{14}$ Hz "
$\lambda = c/f = 405$ nm "
• Transition 4→1 caused fringe at A.

Processes:
- electron jumps from higher to lower energy level
- it emits a photon (discrete packet of energy.)
- change in energy of electron = photon energy = hf (conservation of energy.)
- at double slit, superposition of light waves causes interference pattern.
- constructive interference creates maxima (bright spots.)

Criteria	Mark
• Calculation of double slit wavelength, electron energy change, photon frequency and wavelength • AND comprehensive analysis of processes in atom and at double slit • AND identification of transition 4 to 1	9
• Calculations of wavelength, energy and frequency • AND thorough analysis of at least one process	7-8
• Calculations of wavelength, energy and frequency • AND some analysis of processes	5-6
• Calculation of wavelength, frequency and energy • AND/OR some analysis of processes	3-4
• Some calculation • OR some description of process	2
• Relevant information	1

Notes:
This question required calculation to arrive at conclusion that transition 4 --> 1 caused bright fringe. It also required qualitative analysis of processes, which for this question means a description of each process and some explanation.
The least successful descriptions used vague, waffling sentences rather than simple specific details. For example, the phrase: "this wavelength is associated with the transition from level 4 to 1" is vague and doesn't actually describe what is happening. Instead, say "The electron jumps from energy level 4 to level 1 and emits a photon whose energy is equal to the energy lost by the electron." Also, a number of students said "the electron emits a wavelength." A wavelength is not an object, it is a property possessed by some objects.
It was a good idea to use a diagram showing the electron jumping levels with a photon coming out, but please label the diagram or it's just a bunch of circles and squiggles.
Students who got 8 had generally failed to use the term photon (or equivalent) and just talked about the electron emitting light, or "the energy of the light," etc.

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