SYDNEY GRAMMAR SCHOOL

2019
TRIAL EXAMINATION

PHYSICS

Form VI

STRUCTURE OF PAPER

SECTION I Pages 3-12

Multiple Choice 20 marks

Allow about 30 minutes for this section

SECTION II Pages 13-36

Parts A-E 80 marks

Allow about 2 hours and 30 minutes for this section

EXAMINATION

DATE:	Fri 16th August 8.40 AM
DURATION:	3 hours (+5min reading)
MARKS:	100

CHECKLIST

Each boy should have the following:

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

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the examination in a neat bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATE SECTION.
- There is a Data/Formula sheet included at the end of the paper as well as additional extra writing paper.
- Responses requiring more writing space should be clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.

Authors: PCK, MRW, ILM, DGB, SRW, AAH Master in charge: PCK

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SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

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1 A photon of light with 8.3×10^{-19} J of energy has a wavelength closest to:

(A) 2.4×10^{-7} m

(B) 5.2 m

(C) 4.2×10^{6} m

(D) 1.3×10^{15} m

2 A projectile is fired with a speed of 100 m s^{-1} at an angle of 60° above the horizontal. The speed of the projectile at maximum height is:

(A) 0 m s^{-1}

(B) 50 m s^{-1}

(C) 87 m s^{-1}

(D) 100 m s^{-1}

3 The largest moon of Neptune, Triton, has a mass of 2.14×10^{22} kg, and a radius of 1.35×10^{6} m. The gravitational field strength at its surface is:

(A) 0.783 m s^{-2}

(B) 1.06 m s^{-2}

(C) 2.38 m s^{-2}

(D) 11.7 m s^{-2}

4 At what stage is the torque acting on a DC motor coil a maximum?

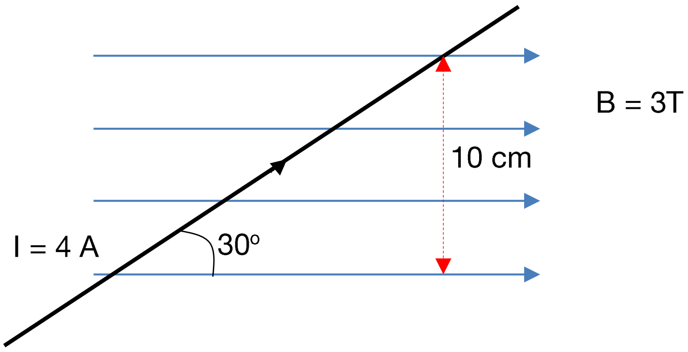
(A) When the forces acting on each side of the coil act in the same direction.

(B) When the coil is rotating at its maximum speed.

(C) When the plane of the coil is perpendicular to the external magnetic field.

(D) When the plane of the coil is parallel to the external magnetic field.

5 A current carrying wire is placed in a uniform magnetic field as shown in the following diagram.



The magnitude of the magnetic force acting on the wire is:

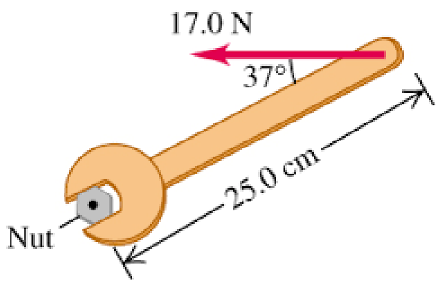
(A) 0 N

(B) 1.2 N

(C) 2.4 N

(D) 120 N

6 Determine the torque acting on the wrench below.



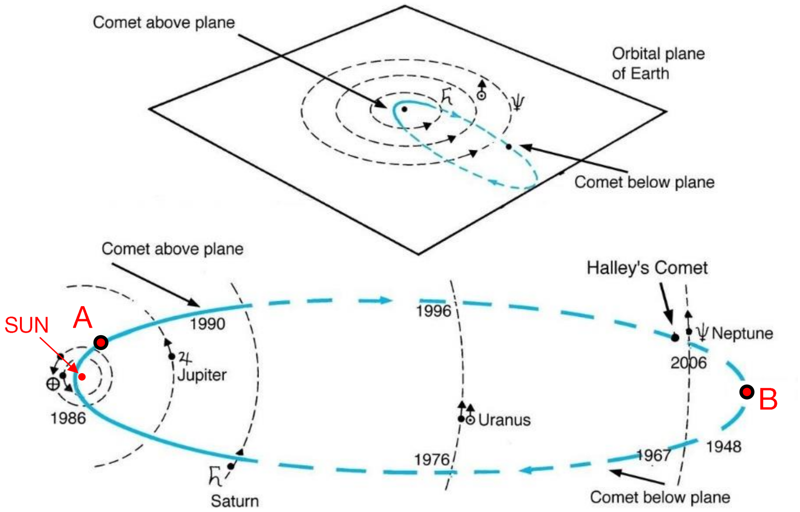
(A) 17sin(37°) x 25

(B) 17 x 25

(C) 17cos(37°) x 0.25

(D) 17sin(37°) x 0.25

7 The diagram below shows the orbit of Halley's comet around the Sun.



The *total energy* of the comet at any point is defined as the sum of its kinetic energy and gravitational potential energy at that point.

Which of the following statements is true about the orbit of the comet?

(A) Both the kinetic energy and the total energy are constant throughout the orbit.

(B) The kinetic energy at A is greater than the kinetic energy at B, but the total energy is constant throughout the orbit.

(C) The kinetic energy at A is less than the kinetic energy at B, but the total energy is constant throughout the orbit.

(D) The kinetic energy is constant throughout the orbit, but the total energy is lower at A than at B.

8 A washing machine's blades have a period of T seconds. What must the period be to triple the centripetal acceleration of a point on the blades?

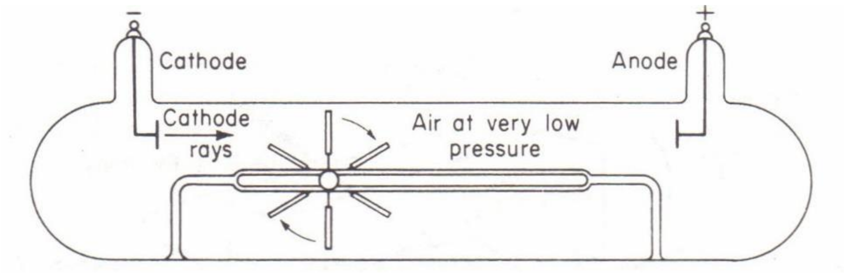
(A) $\frac{T}{3}$

(B) $\frac{T}{\sqrt{3}}$

(C) $\sqrt{3}T$

(D) $3T$

9 When a paddle-wheel was placed in a cathode ray tube, cathode rays were able to rotate the paddle wheel.



From this observation scientists were able to conclude:

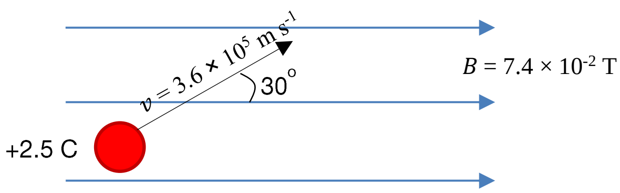
(A) cathode rays have momentum.

(B) cathode rays are positively charged.

(C) cathode rays are photons.

(D) cathode rays are not deflected by electric fields.

10 In the diagram below, a +2.5 C charge is travelling at a speed of 3.6×10^5 m s^{-1} at an angle of 30° to a magnetic field of strength 7.4×10^{-2} T.



The magnitude of the magnetic force experienced by the charge is:

(A) 2.7×10^4 N

(B) 3.3×10^4 N

(C) 5.8×10^4 N

(D) 6.7×10^4 N

11 Which of the following is necessary for the operation of an AC induction motor?

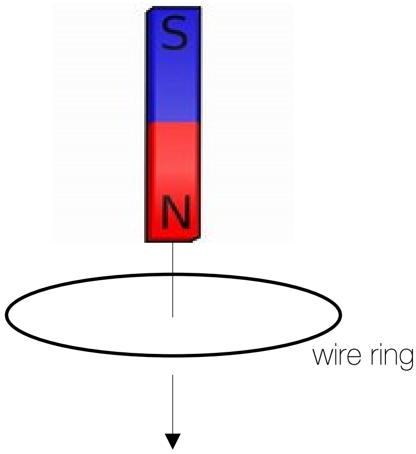
(A) A commutator connected to the rotor and the electromagnets creating the magnetic field.

(B) A permanent magnet in the rotor.

(C) A rotating magnetic field applied to the rotor.

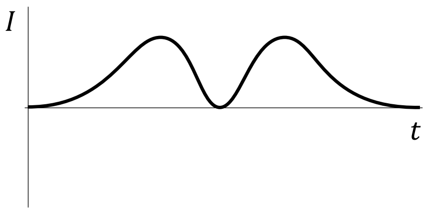
(D) Split rings to connect current to the rotor.

12 A bar magnet is lowered at constant speed through a wire ring, as shown in the diagram.

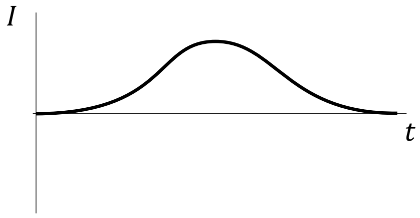


Which of the following graphs best represents the variation of the current induced in the ring, I, with time, t?

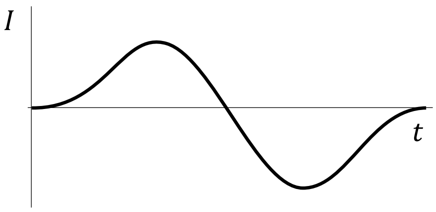
(A)



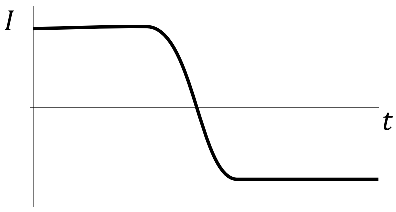
(B)



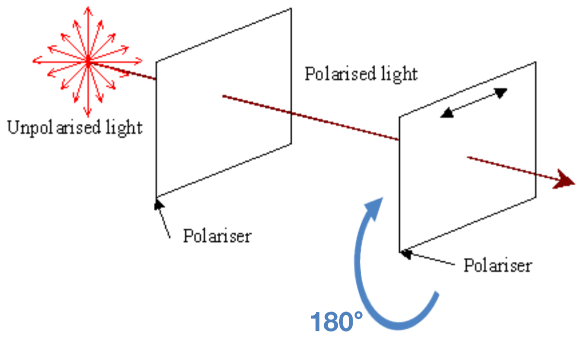
(C)



(D)

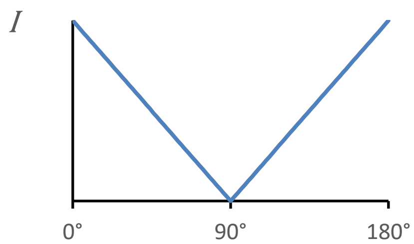


13 An experiment is performed to measure the intensity of light transmitted through 2 polarising sheets. The initial orientation of the polarisers to each other is unknown.

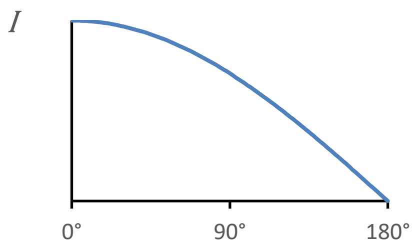


Which of the following graphs would represent how the intensity could change as the second polariser is rotated 180°?

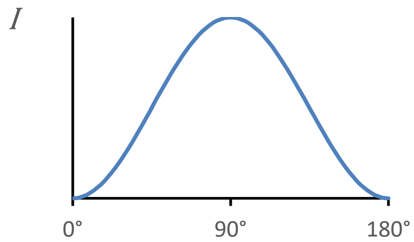
(A)



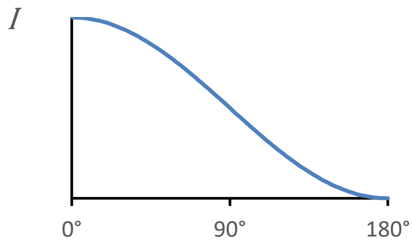
(B)



(C)



(D)



14 An incandescent lamp (acting as a black-body) is behind a cool gas. How will this affect the spectrum observed on the other side of the gas?

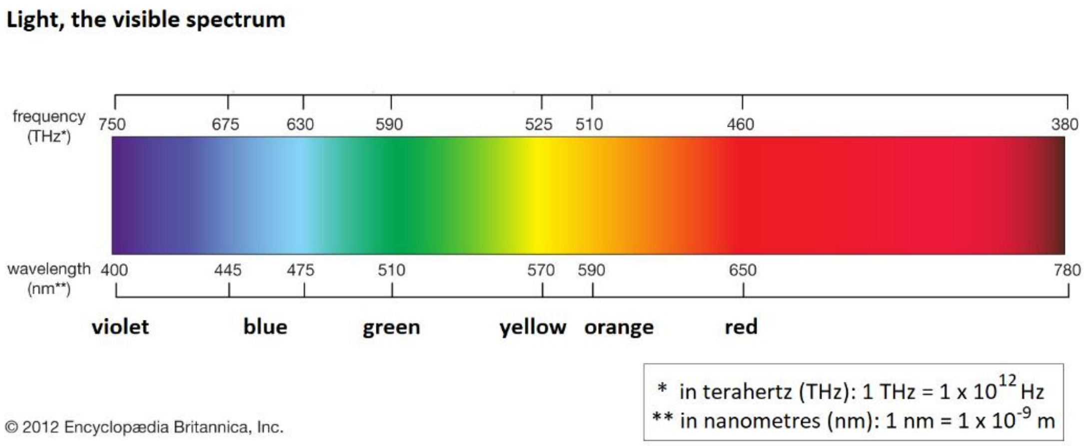
(A) Dark lines would appear in the spectrum.

(B) Bright lines would appear in the spectrum.

(C) The spectrum would be continuous.

(D) The spectrum would be blue-shifted.

15 The star CX-234 can be considered an ideal black body. It has a (surface) temperature of about 6400 K. Using the diagram below and any relevant calculations, determine the colour CX-234 is most likely to have in the night sky.



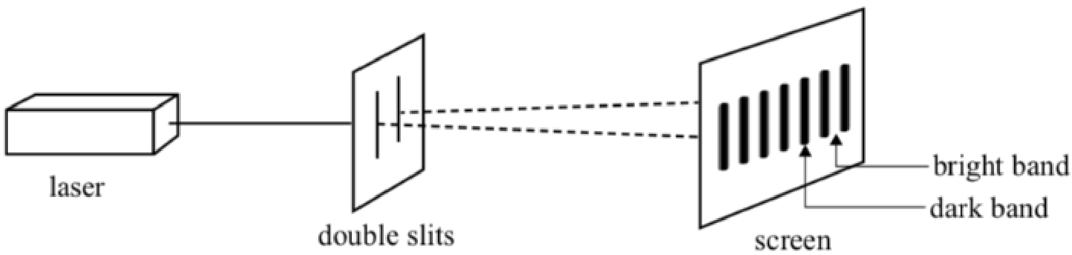
(A) Red

(B) Yellow

(C) Blue

(D) Invisible to the human eye (ultraviolet)

16 Light from a green laser passes through a double-slit arrangement, as seen below. An interference pattern is observed on the screen.



Which of the following actions would increase the spacing between the bands?

(A) Increasing the separation of the laser and the double slits.

(B) Decreasing the distance between the double slits and the screen.

(C) Changing from a green laser to a blue laser.

(D) Changing from a green laser to a red laser.

17 A spacecraft is observed from Earth to take 5 years to travel from Earth to Proxima Centauri. A clock in the ship only measures the journey to have taken 2.55 years.

What is the velocity of the spacecraft?

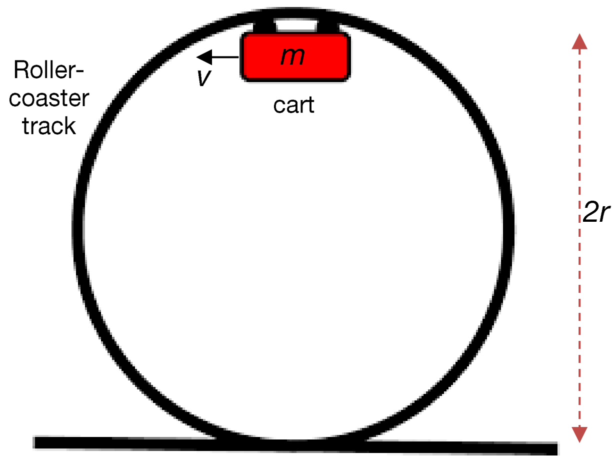
(A) 0.70 c.

(B) 0.71 c.

(C) 0.74 c.

(D) 0.86 c.

18 A roller coaster cart of mass m is moving on a looped track of radius r. In the following diagram the cart is at the top of the loop and is moving at velocity v.



There are two forces on the cart in this position.

If

W is the magnitude of the cart's Weight force, and
N is the magnitude of the Normal force (the force of the track on the cart),

then which of the following equations is true?

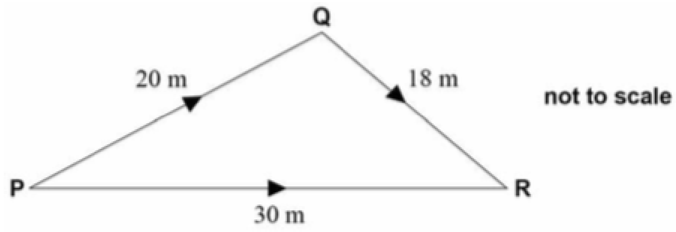
(A) $N = \frac{mv^2}{r}$

(B) $W = \frac{mv^2}{r}$

(C) $N + W = \frac{mv^2}{r}$

(D) $N - W = \frac{mv^2}{r}$

19 In the diagram below, P is a source of radio waves of frequency 75 MHz. The waves travel to R by two paths, P → Q → R and P → R.



What is the path length difference between the two waves at R in terms of the wavelength λ of the waves?

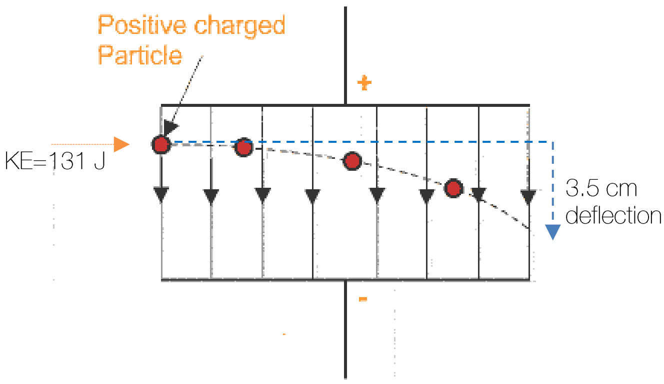
(A) λ

(B) 2λ

(C) 4λ

(D) 8λ

20 A positive 1.2 C charge with a kinetic energy of 131 J enters an electric field of 1400 N C^{-1} between two charged metal plates at right angles to the field as shown in the diagram. The charge has been deflected vertically by 3.5 cm (0.035 m) by the time it leaves the plates.



The kinetic energy of the charge as it leaves the plates is closest to:

(A) 58.8 J

(B) 72.2 J

(C) 180 J

(D) 190 J

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SECTION II: Part A (22 Marks)

CANDIDATE NUMBER							

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

Question 21 (6 marks) **Marks**

The planet Mercury has a mass of 3.30×10^{23} kg and a radius of 2.44×10^{6} m.

(a) Calculate the escape velocity at the surface of Mercury. **3**

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(b) For a spacecraft with a mass of 1.40×10^{3} kg, calculate the change in gravitational potential energy moving the spacecraft from the surface of Mercury to a radius of 4.94×10^{6} m. **3**

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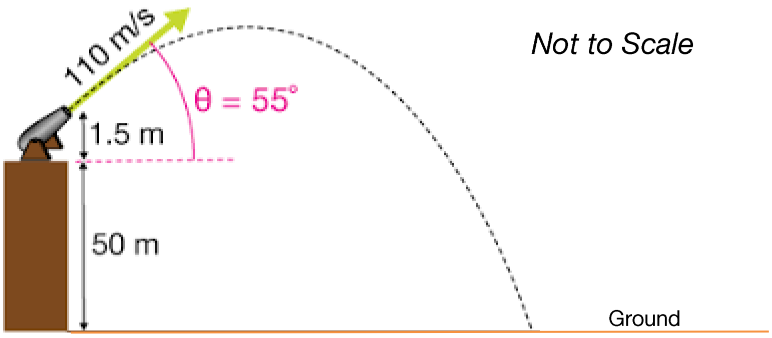
Question 22 (9 marks) **Marks**

A canon fires a projectile from the top of a cliff as shown below.



(a) Determine the magnitude of the initial vertical velocity of the projectile. **1**

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(b) Determine the maximum height of the projectile above its launch height. **2**

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(c) Determine the time of flight of the projectile. **2**

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Question 22 continued on next page.

Question 22 continued **Marks**

(d) Determine the range of the projectile. **2**

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(e) Determine the angle to the horizontal at which the projectile strikes the ground. **2**

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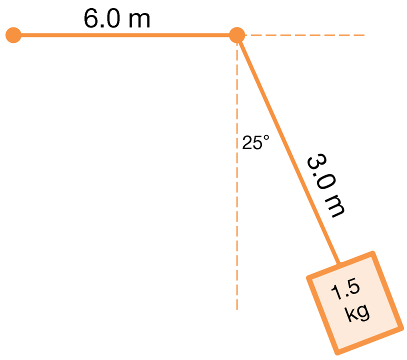
Question 23 (3 marks) **Marks**

An amusement park ride consists of a rotating platform of radius 6.0 m with bucket seats of mass 1.5 kg attached to the edge of the platform by cables 3.0 m long. When the ride rotates at its operating speed, the angle of the seats to the vertical is 25°.



Determine the linear speed of the seats. **3**

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Question 24 (4 marks) **Marks**

Outline the requirements necessary for a satellite to orbit the Earth in a geostationary orbit. Include any relevant calculations in your answer.

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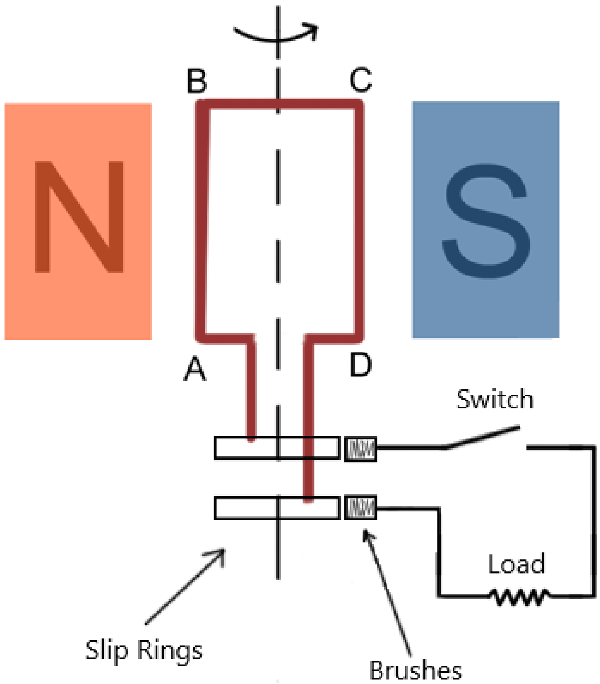
SECTION II: Part B (18 Marks)

CANDIDATE NUMBER							

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

Question 25 (4 marks) **Marks**

A coil is rotated by hand in a magnetic field as depicted below. At the moment pictured, side AB is moving out of the page and side CD is moving into the page.



(a) In the moment pictured and when the switch is closed, what is the direction of the induced current in the coil, ABCD or DCBA? **1**

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(b) Only while the switch is closed is an opposing torque felt when turning the coil. Explain this observation. **3**

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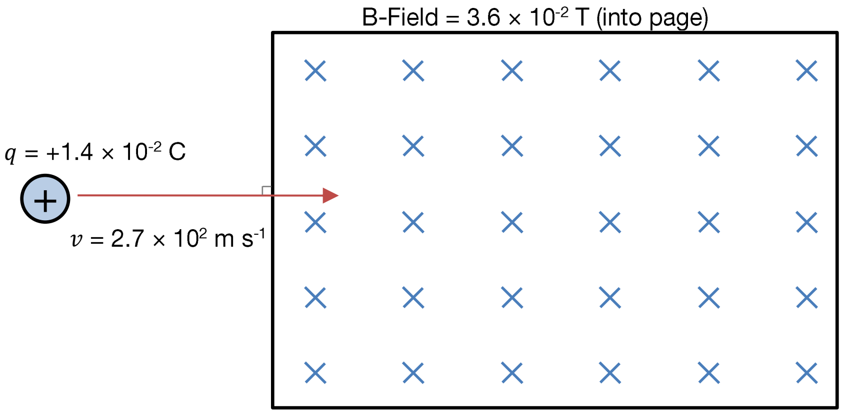
Question 26 (9 marks) **Marks**

In the diagram below, a particle of mass 2.4×10^{-7} kg and charge $+1.4 \times 10^{-2}$ C, travelling at a speed of 2.7×10^{2} m s^{-1}, enters a magnetic field of 3.6×10^{-2} T as shown.



(a) Determine the force acting on the particle at the instant it enters the magnetic field. **2**

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(b) While moving in the magnetic field, the particle performs uniform circular motion. Calculate the radius of the circular path travelled. **2**

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Question 26 continued on next page.

Question 26 continued **Marks**

(c) Discuss the similarities and differences between the motion of

- charged particles in uniform electric fields,
- charged particles in uniform magnetic fields, and
- masses in uniform gravitational fields.

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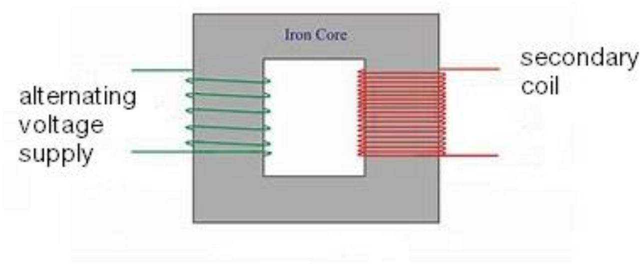
Question 27 (5 marks) **Marks**

A transformer consists of a primary coil and a secondary coil electrically insulated from each other but wound on the same soft iron core. The diagram shows a simple transformer not drawn to scale.



(a) Use Faraday's Law to briefly explain how an emf is generated in the secondary coil. **2**

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(b) Explain how eddy currents in the core can be reduced to increase the efficiency of the transformer. **2**

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(c) An ideal step-down transformer connected to a 240 V alternating current supply is needed to supply 12 V to a low voltage lighting system.

If the secondary coil has 100 turns, then how many turns are needed in the primary coil for the transformer to work correctly? **1**

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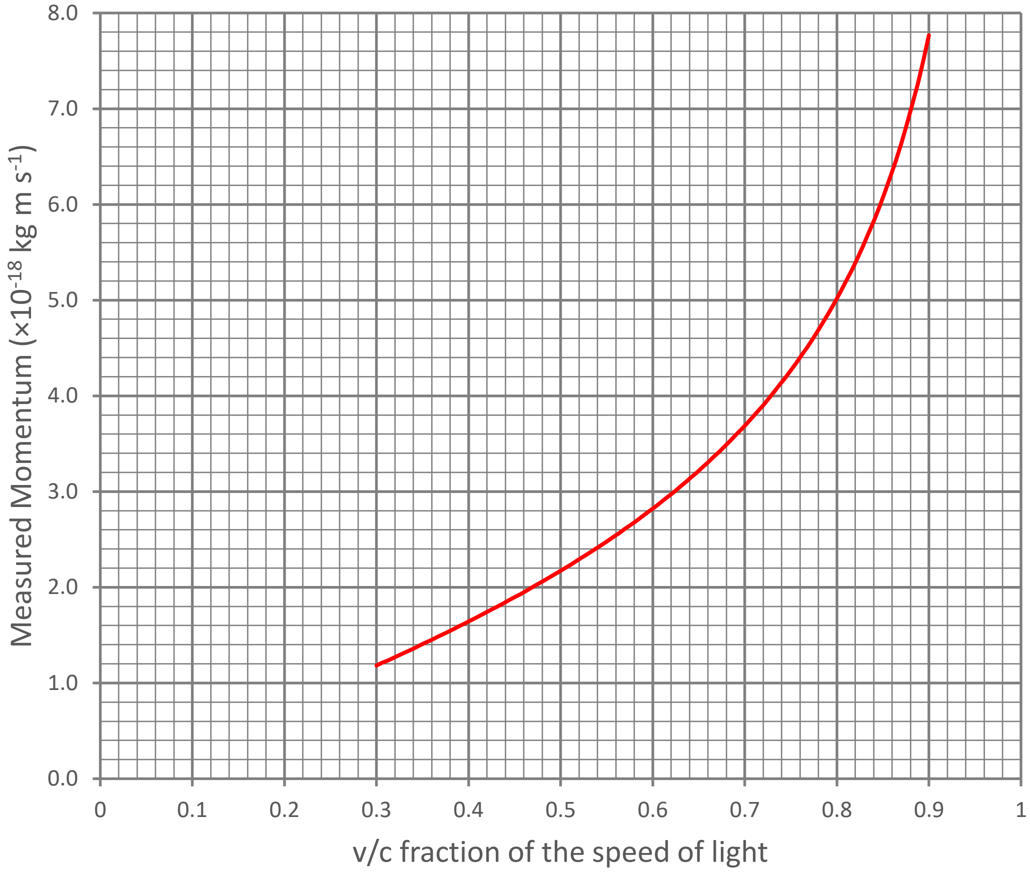
SECTION II: Part C (20 Marks)

CANDIDATE NUMBER							

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

Question 28 (3 marks) **Marks**

Physicists use a particle accelerator to measure the momentum of a newly discovered particle (named Ω_{cb}^{0}) at different velocities. This data is recorded in the graph below.



(a) Determine the velocity of the particle when its momentum is 3.3×10^{-18} kg m s^{-1}.

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(b) Use the graph, or otherwise, to calculate the rest mass of this Ω_{cb}^{0} particle.

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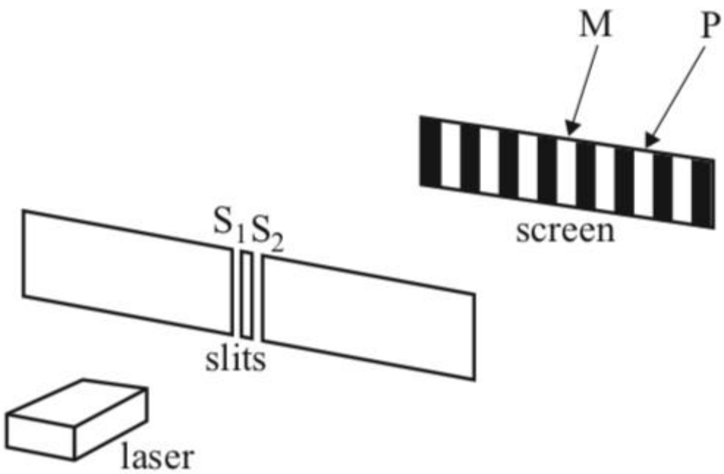
Question 29 (7 marks) **Marks**

A barrier with two narrow slits S_1 and S_2 which are 0.2 mm apart is placed as shown in the path of laser light of wavelength 532 nm. An interference pattern is observed. The point M on the screen is at the centre of the interference pattern. There is a bright band at point P on the screen. It is the second bright band to the right of M, as shown.



(a) Outline the meaning of the term diffraction and explain why it is essential for the interference pattern in this experiment. **2**

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(b) Explain why there will be a bright fringe on the screen at point M. **2**

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Question 29 continued on next page.

Question 29 continued **Marks**

(c) Calculate the angle of the band at point P from the central axis. **3**

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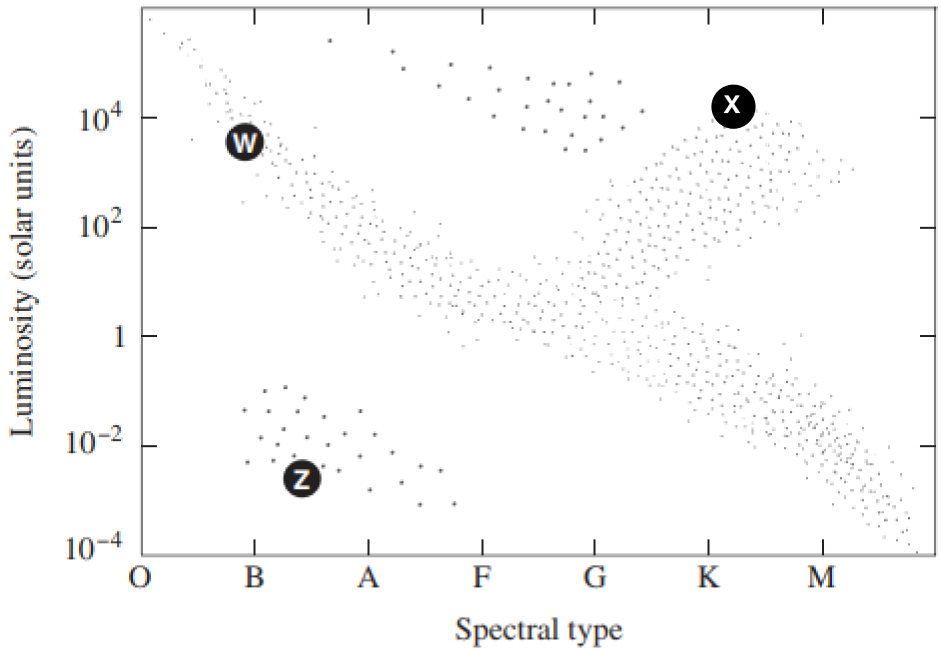
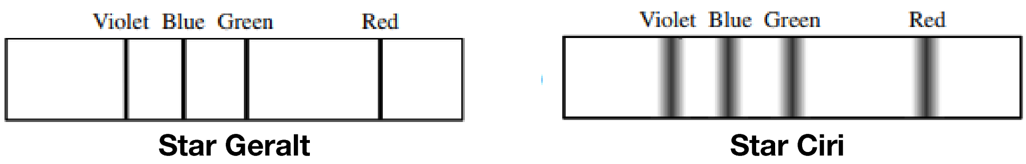
Question 30 (6 marks) **Marks**

Two stars, Geralt and Ciri, have similar temperatures and are located at positions W and Z on the Hertzsprung-Russell diagram shown below.



Spectra were taken of the two stars and are shown below.



(a) Identify which of the two stars could occupy position Z. Justify your answer. **2**

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Question 30 continued on next page.

Question 30 continued **Marks**

(b) Compare the diameter of a star at position W to that of a star at position X. Justify your answer.

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(c) Identify which star(s), would have the proton-proton fusion chain reaction occurring in the core.

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(d) Star W has a luminosity of 1.91×10^{30} W. This means that it is emitting 1.91×10^{30} joules of energy each second.

How much mass is star W losing each second to produce this energy?

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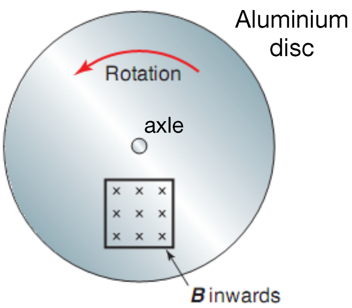
Question 31 (4 marks)

When one side of a spinning aluminium disc was placed into a perpendicular magnetic field, it was observed to quickly come to rest.



Explain the process which brings the spinning disc to rest. **4**

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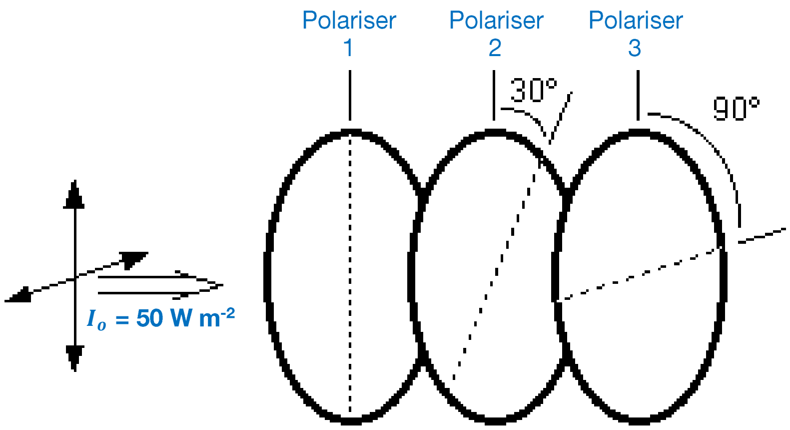
SECTION II: Part D (10 Marks)

CANDIDATE NUMBER							

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

Question 32 (4 marks) **Marks**

Unpolarised light with an intensity of 50 W m^{-2} is incident on a series of three polarising sheets. The polarising plane of the first is vertical, the second is at 30° to the vertical, and the third is horizontal.



(a) What intensity of light passes through Polariser 1?

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(b) What intensity of light passes through Polariser 3?

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(c) Polariser 2 is now removed. What intensity of light now passes through Polariser 3?

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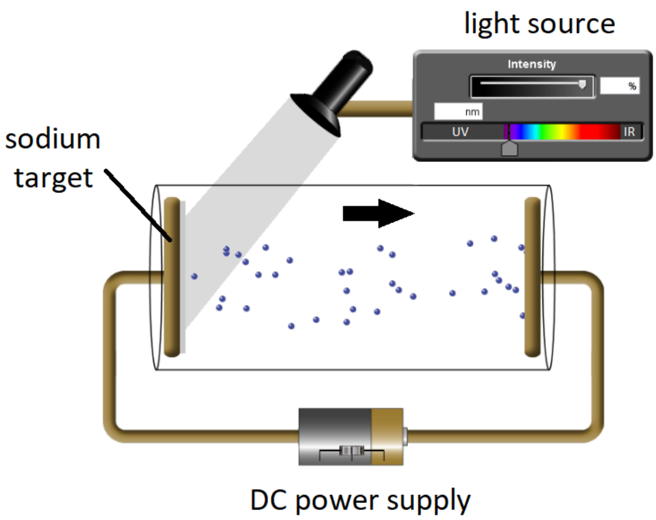
Question 33 (6 marks) **Marks**

The diagram below shows a simulation of the photoelectric effect. As violet light is shone on the sodium target (which has a workfunction of 2.3 eV), electrons leave the sodium and move to the right, reaching the opposite plate and causing a small current to flow in the circuit.



Two experiments are then performed.

In both experiments the photocurrent and the maximum kinetic energy of the photoelectrons are measured.

Experiment 1:

While violet light (420 nm) shines onto the sodium target, its intensity is varied from low to high.

Experiment 2:

Keeping the intensity of light at a constant high level, the wavelength of light is increased from 420 nm to 700 nm.

Question 33 continued on next page.

Question 33 continued **Marks**

Predict and explain the results of both experiments with reference to Einstein's model of light. **6**

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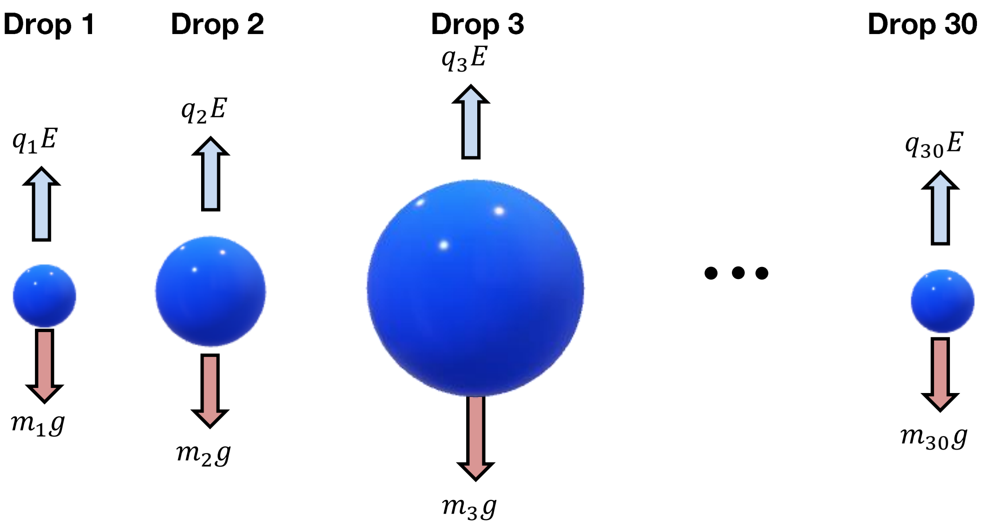
SECTION II: Part E (10 Marks)

CANDIDATE NUMBER							

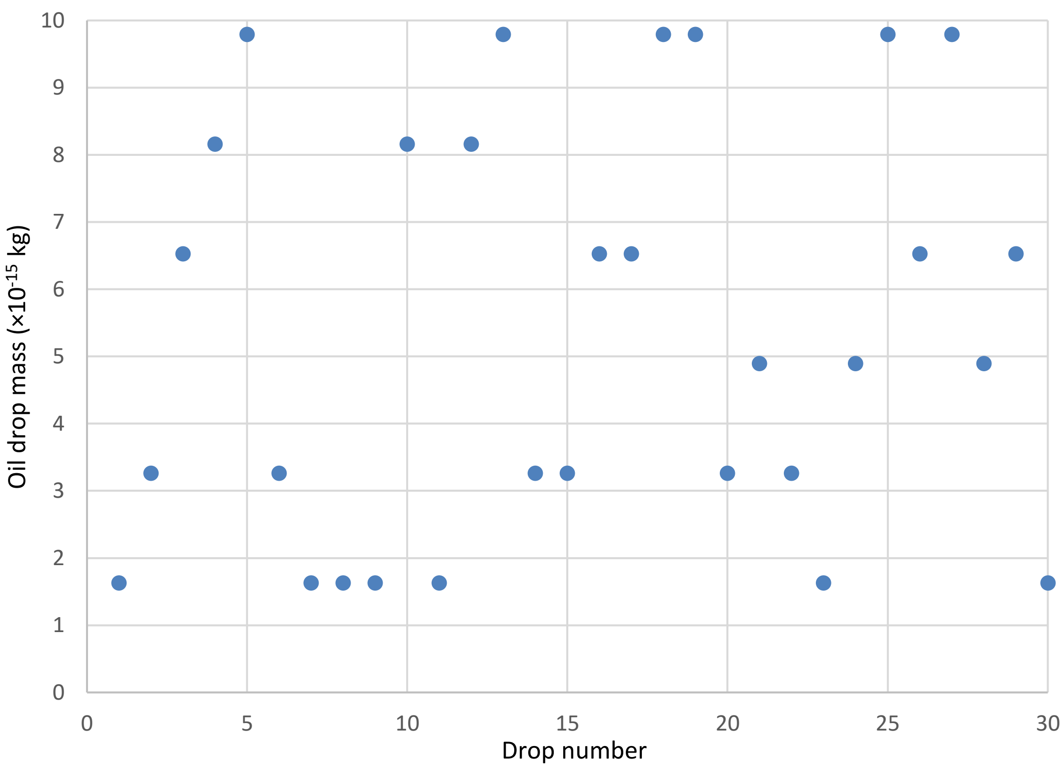
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 34 (4 marks) **Marks**

In an experiment similar to Millikan's oil drop experiment, thousands of oil drops of various masses are bombarded with x-rays giving them different amounts of charge. When placed in a uniform electric field, only 30 of the oil drops became stationary. For these oil drops, the upward electrostatic force balanced the weight force ($qE = mg$).



The mass of each of these oil drops was recorded in the following graph.



Question 34 continued on next page.

Question 34 continued **Marks**

(a) Account for the pattern of this recorded data.

.... **2**

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(b) Using the data provided, estimate the electric field strength used in this experiment, stating any assumptions you make.

.... **2**

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Question 35 (6 marks) **Marks**

Referring to the work of Thomson and Rutherford in atomic physics, discuss how scientists use experimental observations and physical principles to improve scientific models. **6**

HIGHER SCHOOL CERTIFICATE
EXAMINATION

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 m s^{-1}
Earth's gravitational acceleration, g	9.8 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	$4.18 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Wein's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$v = u + at$

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

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

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

$\Delta U = mg\Delta h$

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

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

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

$\sum\frac{1}{2}mv^2_{before} = \sum\frac{1}{2}mv^2_{after}$

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

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

$a_c = \frac{v^2}{r}$

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

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

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

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

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

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

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

Waves and thermodynamics

$v = f\lambda$

$f_{beat} = |f_2 - f_1|$

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

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

$d\sin\theta = m\lambda$

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

$n_x = \frac{c}{v_x}$

$\sin\theta_c = \frac{n_2}{n_1}$

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

$I_1r_1^2 = I_2r_2^2$

$Q = mc\Delta T$

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

FORMULAE SHEET (continued)

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

$$B = \frac{\mu_0 N I}{L}$$

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

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

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

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

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

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

$$V = IR$$

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

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

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

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

$$V_p I_p = V_s I_s$$

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

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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

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

LAUS DEO

CANDIDATE NUMBER

2019

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 ○

Start Here →

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 ○

SYDNEY GRAMMAR SCHOOL

2019
TRIAL EXAMINATION

PHYSICS CRIB

Form VI

STRUCTURE OF PAPER

SECTION I Pages 3-12

Multiple Choice 20 marks

Allow about 30 minutes for this section

SECTION II Pages 13-36

Parts A-E 80 marks

Allow about 2 hours and 30 minutes for this section

EXAMINATION

DATE: Fri 16th August 8.40 AM

DURATION: 3 hours (+5min reading)

MARKS: 100

CHECKLIST

Each boy should have the following:

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

EXAM INSTRUCTIONS

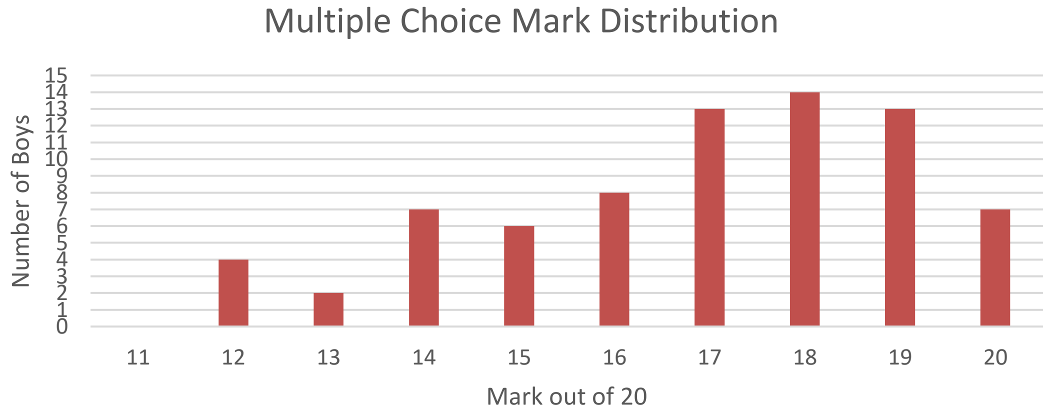
- Remove the centre staple and hand in all parts of the examination in a neat bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATE SECTION.
- There is a Data/Formula sheet included at the end of the paper as well as additional extra writing paper.
- Responses requiring more writing space should be clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.

Authors: PCK, MRW, ILM, DGB, SRW, AAH Master in charge: PCK

Form Average for Multiple Choice

16.9/20

Question	Answer	A	B	C	D
1	**A**	99%	0%	0%	1%
2	**B**	3%	96%	0%	1%
3	**A**	97%	1%	0%	1%
4	**D**	0%	0%	30%	70%
5	**B**	0%	88%	5%	5%
6	**D**	0%	0%	5%	93%
7	**B**	1%	81%	14%	3%
8	**B**	9%	78%	11%	0%
9	**A**	99%	1%	0%	0%
10	**B**	0%	93%	5%	1%
11	**C**	14%	7%	74%	5%
12	**C**	12%	9%	70%	8%
13	**C**	19%	1%	69%	11%
14	**A**	86%	7%	5%	1%
15	**C**	4%	3%	89%	4%
16	**D**	3%	4%	7%	86%
17	**D**	4%	1%	7%	88%
18	**C**	0%	7%	88%	5%
19	**B**	1%	85%	5%	8%
20	**D**	9%	16%	16%	58%



SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 A photon of light with 8.3×10^{-19} J of energy has a wavelength closest to:

(A) 2.4×10^{-7} m

(B) 5.2 m

(C) 4.2×10^{6} m

(D) 1.3×10^{15} m

2 A projectile is fired with a speed of 100 m s^{-1} at an angle of 60° above the horizontal. The speed of the projectile at maximum height is:

(A) 0 m s^{-1}

(B) 50 m s^{-1}

(C) 87 m s^{-1}

(D) 100 m s^{-1}

3 The largest moon of Neptune, Triton, has a mass of 2.14×10^{22} kg, and a radius of 1.35×10^{6} m. The gravitational field strength at its surface is:

(A) 0.783 m s^{-2}

(B) 1.06 m s^{-2}

(C) 2.38 m s^{-2}

(D) 11.7 m s^{-2}

4 At what stage is the torque acting on a DC motor coil a maximum?

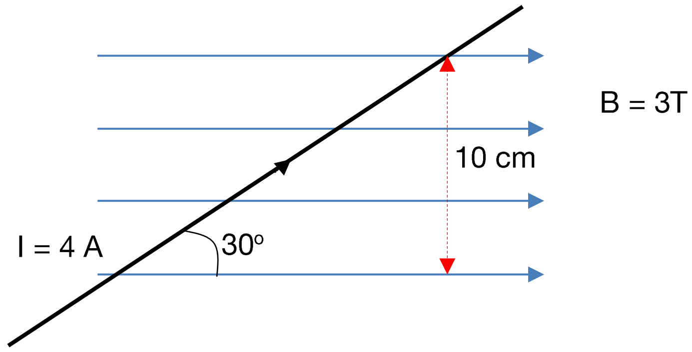
(A) When the forces acting on each side of the coil act in the same direction.

(B) When the coil is rotating at its maximum speed.

(C) When the plane of the coil is perpendicular to the external magnetic field.

(D) When the plane of the coil is parallel to the external magnetic field.

5 A current carrying wire is placed in a uniform magnetic field as shown in the following diagram.



The magnitude of the magnetic force acting on the wire is:

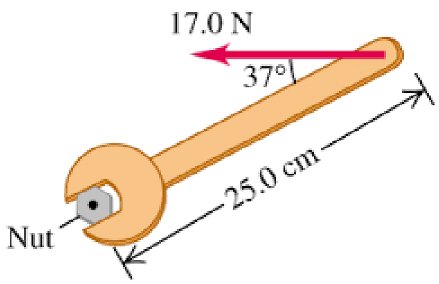
(A) 0 N

(B) 1.2 N

(C) 2.4 N

(D) 120 N

6 Determine the torque acting on the wrench below.



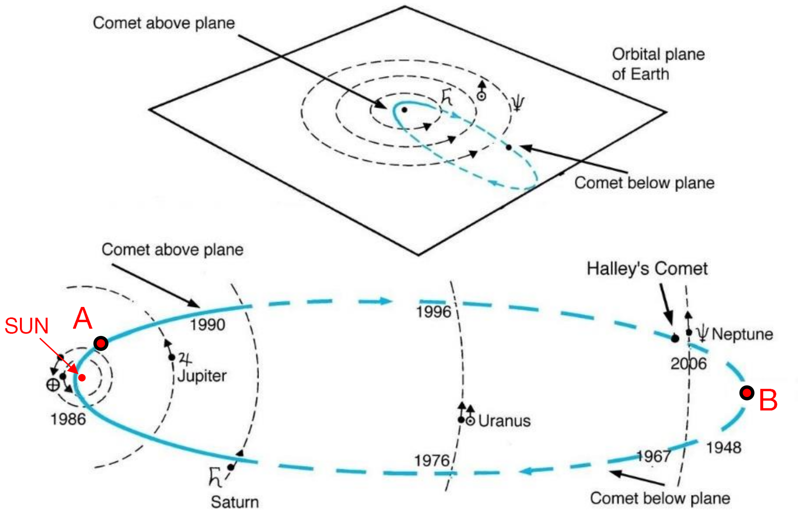
(A) 17sin(37°) x 25

(B) 17 x 25

(C) 17cos(37°) x 0.25

(D) 17sin(37°) x 0.25

7 The diagram below shows the orbit of Halley's comet around the Sun.



The *total energy* of the comet at any point is defined as the sum of its kinetic energy and gravitational potential energy at that point.

Which of the following statements is true about the orbit of the comet?

(A) Both the kinetic energy and the total energy are constant throughout the orbit.

(B) The kinetic energy at A is greater than the kinetic energy at B, but the total energy is constant throughout the orbit.

(C) The kinetic energy at A is less than the kinetic energy at B, but the total energy is constant throughout the orbit.

(D) The kinetic energy is constant throughout the orbit, but the total energy is lower at A than at B.

8 A washing machine's blades have a period of T seconds. What must the period be to triple the centripetal acceleration of a point on the blades?

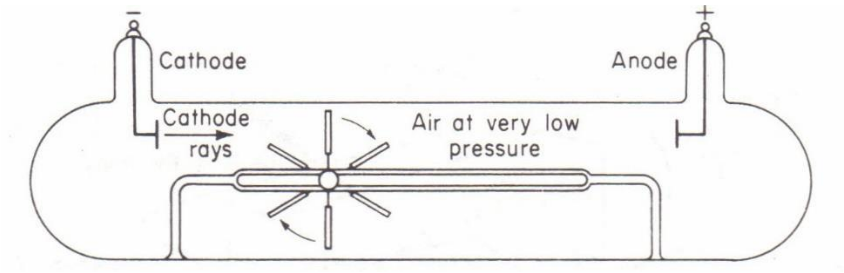
(A) $\frac{T}{3}$

(B) $\frac{T}{\sqrt{3}}$

(C) $\sqrt{3}T$

(D) $3T$

9 When a paddle-wheel was placed in a cathode ray tube, cathode rays were able to rotate the paddle wheel.



From this observation scientists were able to conclude:

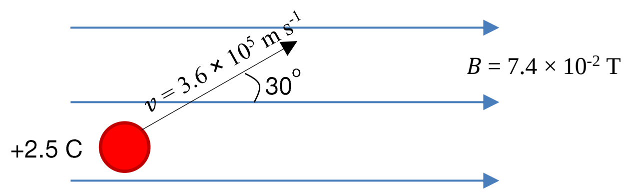
(A) cathode rays have momentum.

(B) cathode rays are positively charged.

(C) cathode rays are photons.

(D) cathode rays are not deflected by electric fields.

10 In the diagram below, a +2.5 C charge is travelling at a speed of 3.6×10^5 m s^{-1} at an angle of 30° to a magnetic field of strength 7.4×10^{-2} T.



The magnitude of the magnetic force experienced by the charge is:

(A) 2.7×10^4 N

(B) 3.3×10^4 N

(C) 5.8×10^4 N

(D) 6.7×10^4 N

11 Which of the following is necessary for the operation of an AC induction motor?

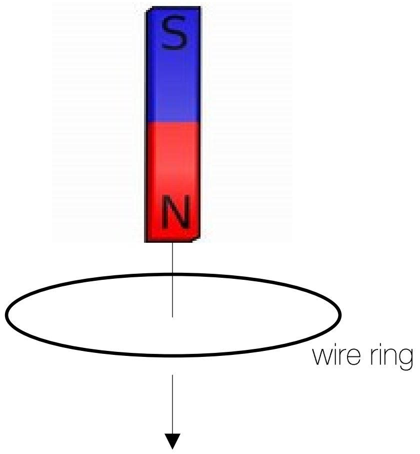
(A) A commutator connected to the rotor and the electromagnets creating the magnetic field.

(B) A permanent magnet in the rotor.

(C) A rotating magnetic field applied to the rotor.

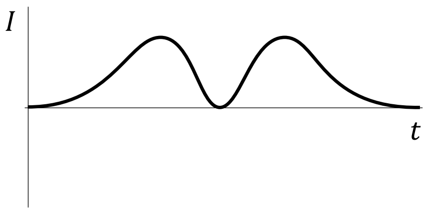
(D) Split rings to connect current to the rotor.

12 A bar magnet is lowered at constant speed through a wire ring, as shown in the diagram.

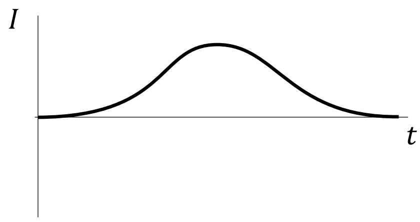


Which of the following graphs best represents the variation of the current induced in the ring, I, with time, t?

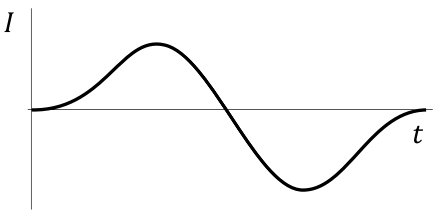
(A)



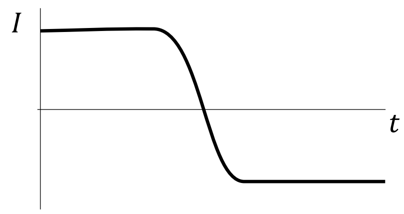
(B)



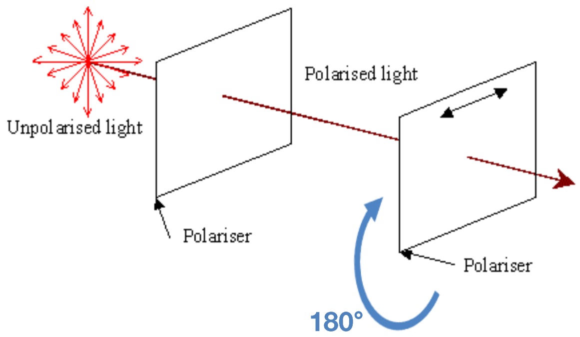
(C)



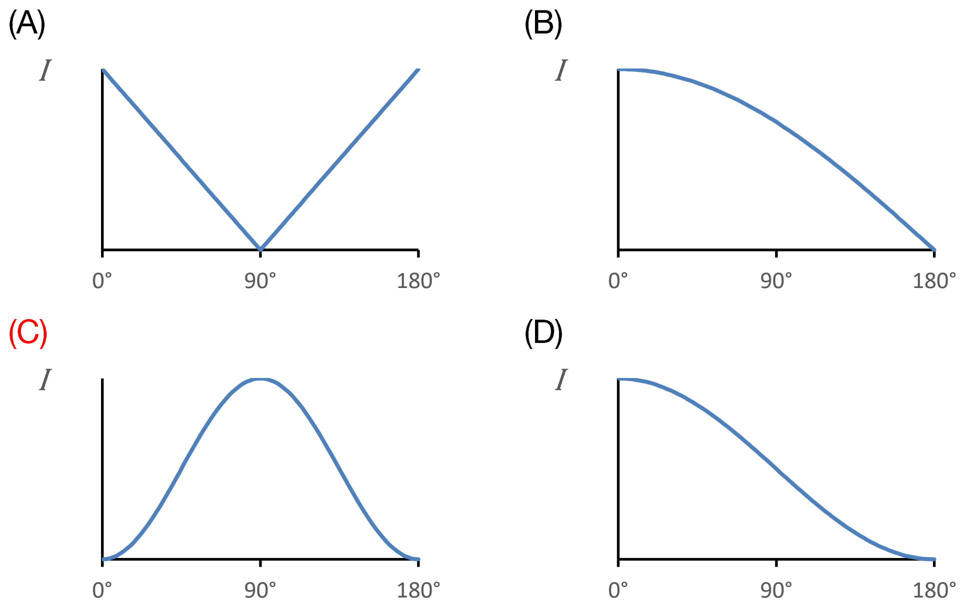
(D)



13 An experiment is performed to measure the intensity of light transmitted through 2 polarising sheets. The initial orientation of the polarisers to each other is unknown.



Which of the following graphs would represent how the intensity could change as the second polariser is rotated 180°?



14 An incandescent lamp (acting as a black-body) is behind a cool gas. How will this affect the spectrum observed on the other side of the gas?

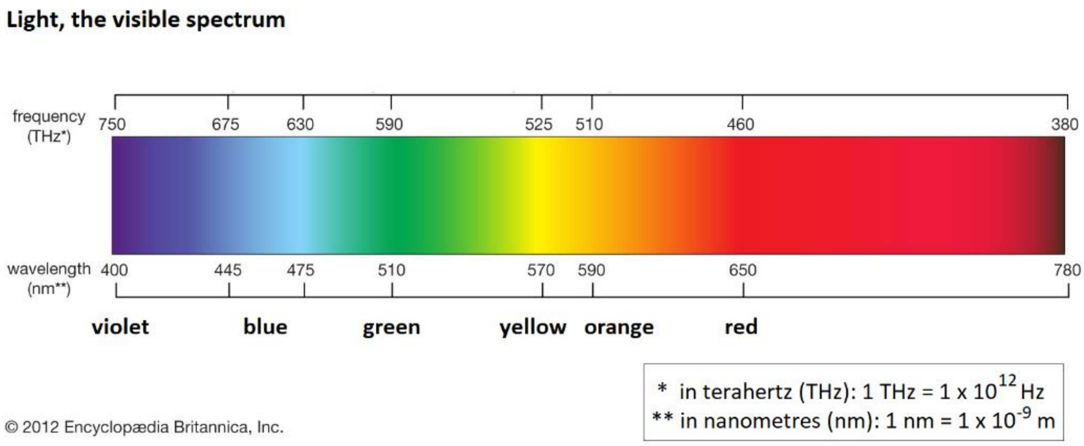
(A) Dark lines would appear in the spectrum.

(B) Bright lines would appear in the spectrum.

(C) The spectrum would be continuous.

(D) The spectrum would be blue-shifted.

15 The star CX-234 can be considered an ideal black body. It has a (surface) temperature of about 6400 K. Using the diagram below and any relevant calculations, determine the colour CX-234 is most likely to have in the night sky.



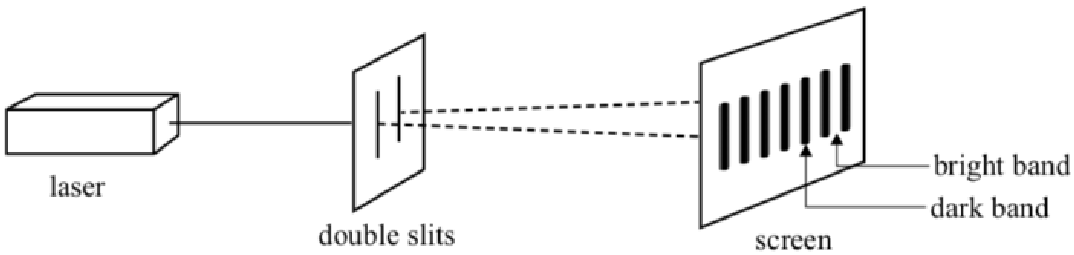
(A) Red

(B) Yellow

(C) Blue

(D) Invisible to the human eye (ultraviolet)

16 Light from a green laser passes through a double-slit arrangement, as seen below. An interference pattern is observed on the screen.



Which of the following actions would increase the spacing between the bands?

(A) Increasing the separation of the laser and the double slits.

(B) Decreasing the distance between the double slits and the screen.

(C) Changing from a green laser to a blue laser.

(D) Changing from a green laser to a red laser.

17 A spacecraft is observed from Earth to take 5 years to travel from Earth to Proxima Centauri. A clock in the ship only measures the journey to have taken 2.55 years.

What is the velocity of the spacecraft?

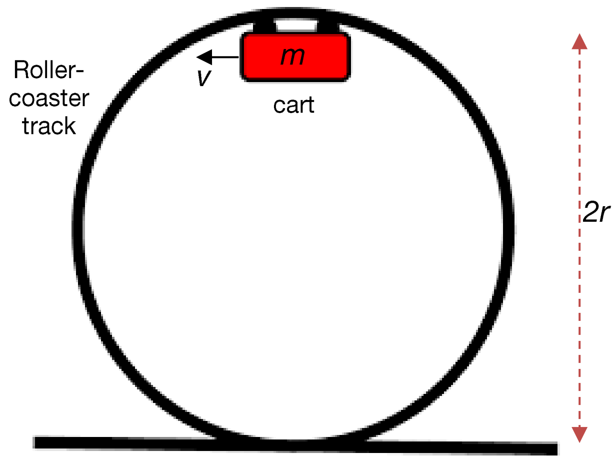
(A) 0.70 c.

(B) 0.71 c.

(C) 0.74 c.

(D) 0.86 c.

18 A roller coaster cart of mass m is moving on a looped track of radius r. In the following diagram the cart is at the top of the loop and is moving at velocity v.



There are two forces on the cart in this position.

If

W is the magnitude of the cart's Weight force, and

N is the magnitude of the Normal force (the force of the track on the cart),

then which of the following equations is true?

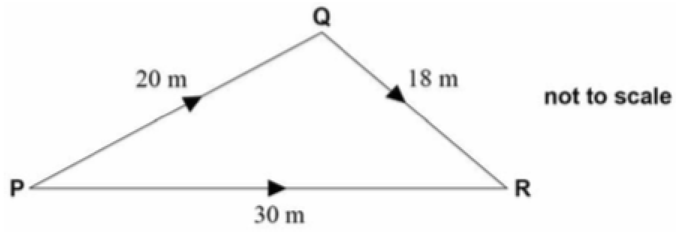
(A) $N = \frac{mv^2}{r}$

(B) $W = \frac{mv^2}{r}$

(C) $N + W = \frac{mv^2}{r}$

(D) $N - W = \frac{mv^2}{r}$

19 In the diagram below, P is a source of radio waves of frequency 75 MHz. The waves travel to R by two paths, P → Q → R and P → R.



What is the path length difference between the two waves at R in terms of the wavelength λ of the waves?

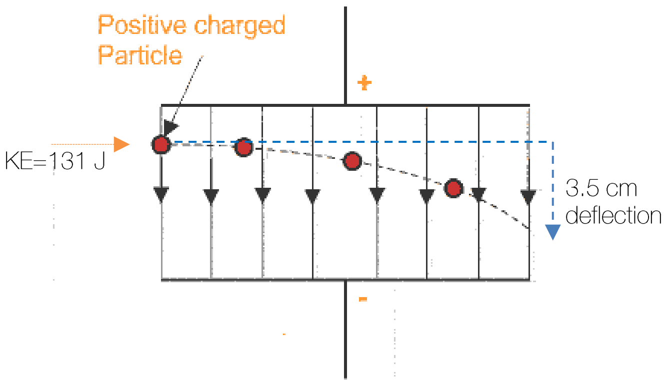
(A) λ

(B) 2λ

(C) 4λ

(D) 8λ

20 A positive 1.2 C charge with a kinetic energy of 131 J enters an electric field of 1400 N C^{-1} between two charged metal plates at right angles to the field as shown in the diagram. The charge has been deflected vertically by 3.5 cm (0.035 m) by the time it leaves the plates.



The kinetic energy of the charge as it leaves the plates is closest to:

(A) 58.8 J

(B) 72.2 J

(C) 180 J

(D) 190 J

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SRW

SECTION II: Part A (22 Marks)

CANDIDATE NUMBER							

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

Question 21 (6 marks) **Marks**

The planet Mercury has a mass of 3.30×10^{23} kg and a radius of 2.44×10^{6} m.

(a) Calculate the escape velocity at the surface of Mercury. 3

(1) $v = \sqrt{\frac{2GM}{r}}$

(1) $= \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 3.3 \times 10^{23}}{2.44 \times 10^{6}}}$

(1) $= 4.25 \times 10^{3}$ m/s

Max (2) if used $v = \sqrt{\frac{GM}{r}}$ orbital velocity!

(b) For a spacecraft with a mass of 1.40×10^{3} kg, calculate the change in gravitational potential energy moving the spacecraft from the surface of Mercury to a radius of 4.94×10^{6} m. 3

$E_i = -\frac{GMm}{r_i} = -1.26 \times 10^{10}$ J (1)

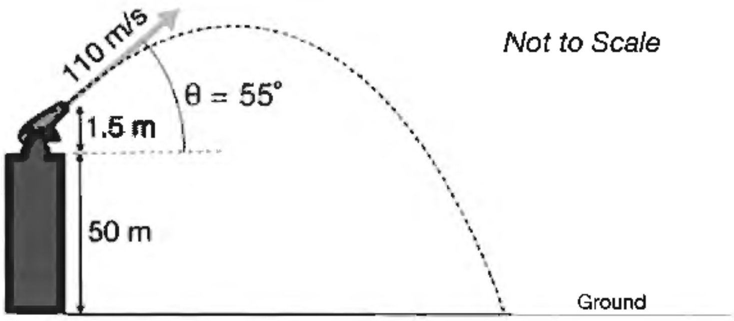
$E_f = -\frac{GMm}{r_f} = -6.24 \times 10^{9}$ J (1)

Note $r_f = 4.94 \times 10^{6}$ m

$\Delta E = E_f - E_i = 6.39 \times 10^{9}$ J (1)

Question 22 (9 marks) **Marks**

A canon fires a projectile from the top of a cliff as shown below.



(a) Determine the magnitude of the initial vertical velocity of the projectile. **1**

110 sin55 = 90.1 m/s (1)

(b) Determine the maximum height of the projectile above its launch height. **2**

$v^2 = u^2 + 2as$ = 414m (1)

$s = -\frac{(110\sin 55)^2}{2 \times 9.8}$ (1)

(c) Determine the time of flight of the projectile. **2**

$-51.5 = 110\sin 55\, t - 4.9t^2$ (1)

t = 18.94 sec (1)

Question 22 continued on next page.

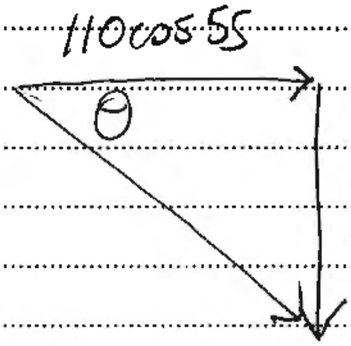
Question 22 continued **Marks**

(d) Determine the range of the projectile. **2**

$R = 110\cos 55 \times t$ (1)

$= 1195$ (1)

(e) Determine the angle to the horizontal at which the projectile strikes the ground. **2**

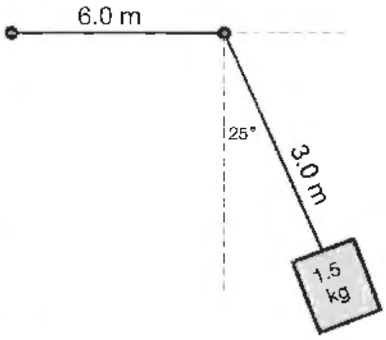


95.51 m/s (1)

$\theta = 56.6^\circ$ (1)

Question 23 (3 marks) **Marks**

An amusement park ride consists of a rotating platform of radius 6.0 m with bucket seats of mass 1.5 kg attached to the edge of the platform by cables 3.0 m long. When the ride rotates at its operating speed, the angle of the seats to the vertical is 25°.



Determine the linear speed of the seats. 3

$r = 6 + 3\sin 25 = 7.27\,m$ (1)

$T\cos 25 = mg$
$T\sin 25 = \frac{mv^2}{r}$ } (1) sensible working

$v = \sqrt{r \times 9.8 \times \tan 25}$ (1)
$= 5.76\ m/s$

Marked very generously!

Question 24 (4 marks) **Marks**

Outline the requirements necessary for a satellite to orbit the Earth in a geostationary orbit. Include any relevant calculations in your answer. 4

Must have!!

(1) $T = 24$ hrs (1)

(1) $r = \sqrt[3]{\frac{GM}{4\pi^2}T^2} = 4.23 \times 10^4$ km (1)

+ any 2 of these:

(1) Equatorial

(1) Travel to the East

(1) $v = \sqrt{\frac{GM}{r}} = 3100$ m/s

(1) Circular orbit

(1) Remains at the same point above Earth's surface

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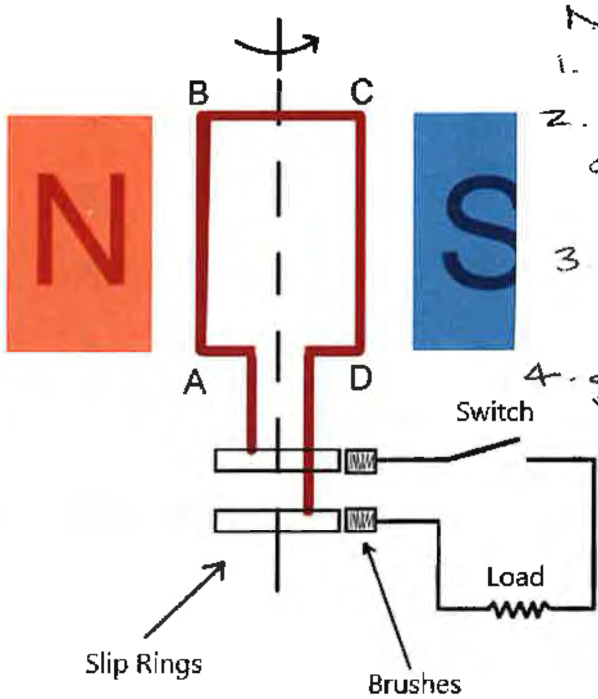
SECTION II: Part B (18 Marks)

CANDIDATE NUMBER

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

Question 25 (4 marks) **Marks**

A coil is rotated by hand in a magnetic field as depicted below. At the moment pictured, side AB is moving out of the page and side CD is moving into the page.



Notes:
1. emf's do not flow
2. extra effort is not due to overcoming "back emf"
3. In Lenz's Law, "force opposes the motion" not the emf or current
4. do not use the word "resistance" when you mean "force"

(a) In the moment pictured and when the switch is closed, what is the direction of the induced current in the coil, ABCD or DCBA? 1

ABCD / clockwise ✓ ① mk

(b) Only while the switch is closed is an opposing torque felt when turning the coil. Explain this observation.

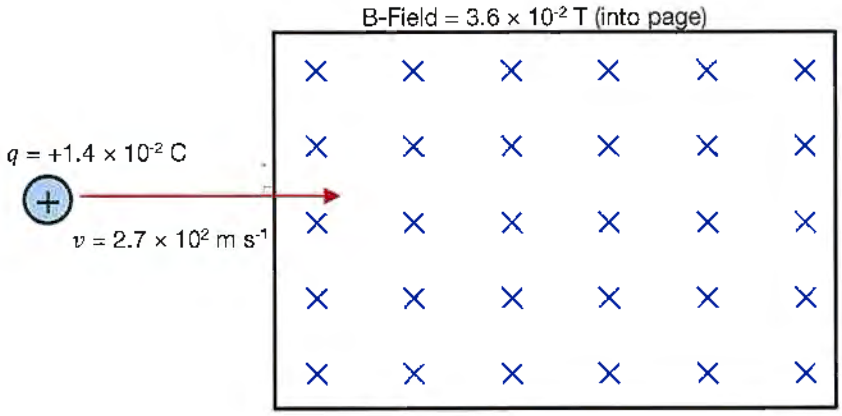
✓① I = induced current flows when switch closed
= no induced current flows when switch open
✓① L = correct statement of Lenz's Law i.e. direction of induced current produces a magnetic field that interacts with the external field in such a way that provides a
✓① F = force that opposes the motion of the coil

OR when switch closed, current flows ∴ more work needed to produce this energy ∴ more force necessary as W = Fr.

To obtain full marks, answers needed to refer to the physical principles involved and were logical and coherent and expressed in correct terminology.

Question 26 (9 marks) **Marks**

In the diagram below, a particle of mass 2.4×10^{-7} kg and charge $+1.4 \times 10^{-2}$ C, travelling at a speed of 2.7×10^{2} m s^{-1}, enters a magnetic field of 3.6×10^{-2} T as shown.



(a) Determine the force acting on the particle at the instant it enters the magnetic field. **2**

$F_M = B|q|v\sin\theta$ ✓ ①mk correct substitution

$= 3.6\times10^{-2} \times 1.4\times10^{-2} \times 2.7\times10^{2} \times \sin 90^{\circ}$

$= 0.1361$ N

✓①mk for direction

perpendicular to velocity or

upwards.

(b) While moving in the magnetic field, the particle performs uniform circular motion. Calculate the radius of the circular path travelled. **2**

$F_{centripetal} = F_{motor}$ −1 mk for any mistake.

$mv^2/r = qvB\sin\theta$ ✓①mk

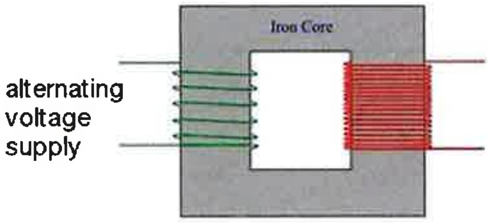
$r = mv/qB = \dfrac{2.4\times10^{-7} \times 2.7\times10^{2}}{1.4\times10^{-2} \times 3.6\times10^{-2}}$

$= 0.13$ m. ✓ ①mk

Question 26 continued on next page.

Question 27 (5 marks) **Marks**

A transformer consists of a primary coil and a secondary coil electrically insulated from each other but wound on the same soft iron core. The diagram shows a simple transformer not drawn to scale.



(a) Use Faraday's Law to briefly explain how an emf is generated in the secondary coil. **2**

✓ ① mk. { Statement of Faraday's Law. emf = $-N\Delta\phi/\Delta t$

✓ ① mk { applied to transformer alternating voltage produced an changing magnetic field in primary which creates a $\Delta\phi$ in secondary coil.

(b) Explain how eddy currents in the core can be reduced to increase the efficiency of the transformer. **2**

How ✓ ① mk Laminate the iron core or use ferrite materials in the core

Explanation ✓ ① mk. minimises eddy currents reducing the power loss due to ohmic heating ($P = I^2R$)

✗ any wrong statement −1 mk

(c) An ideal step-down transformer connected to a 240 V alternating current supply is needed to supply 12 V to a low voltage lighting system.

If the secondary coil has 100 turns, then how many turns are needed in the primary coil for the transformer to work correctly? **1**

$V_p/V_s = n_p/n_s$

$240/12 = n_p/100$

$n_p = 2000$ ✓ ① mk correct answer. or correct substitution

Trial Physics Examination 2019

Question 26 (c) CRIB
Marking Scheme

The question concerns "the similarities and differences between the **motion** of" charged particles in three types of fields. The answer must explicitly address a comparison of trajectories in **UNIFORM** fields, identifying a similarity in two (parabolic path in both E fields and G fields) and a difference (circular path in B field).

The question asks "**discuss** the similarities and differences". The focus of the answer must be on:

- Describing the shape of the path based on correctly identifying the force and how it effects the components of the velocity.
- What type of particle is affected in each field?
- What factors affect the size of the force?
- What is the direction of the force?
- Explicitly demonstrating the similarities and differences for each motion.

Mark	Criteria
4-5*	For an answer containing all of the following: A good discussion of the **similarities and differences** of the motion of each particle in the three types of fields. **Correct shape** for the motion of each particle in the three types of uniform fields. A good explanation for the shape of the motion based on the direction of the force and the factors which affect the size of the force A cohesive, logically sequenced answer using correct physical terminology.
2-3*	For an answer containing most of the following: A discussion of the **similarities and differences** of the motion of each particle in the three types of fields. **Correct shape** for the motion of each particle in the three types of uniform fields. An explanation for the shape of the motion based on the direction of the force and the factors which affect the size of the force
1	For an answer containing a correct statement about the motion.

**In each band, better answers received higher marks*

Note 1

Common features of better answers included:

- Describing the shapes (trajectories) of the motion produced for all three situations.
  Note: The trajectory of a charged particle in a uniform gravitational field is parabolic or linear depending on the angle between the field and the initial velocity. The shape would be circular in a non-uniform radial field.

- Direction of the force must be explicitly stated – not in generalised terms. Same direction as the field, same or opposite to the field depending **on the sign of the** charge, perpendicular to both the velocity and field direction and depends on the **sign of the** charge. If said "depends on the charge" without clarification is too vague. Answering in terms of force directions and their affect on the velocity rather than equating the direction of acceleration as the direction of motion unless (u = 0)
- What factors affect the size of the charge depends on. Best answered with the use of correct equations.
- *Explicitly* relating cause and effect; e.g. relating the affect of the force on the motion to clearly demonstrate path taken.
- Using equations to help explanations.
- Taking the opportunity to demonstrate a thorough understanding of the similiarites and differences in the paths for all three situtions, in the context of a well-structured answer.

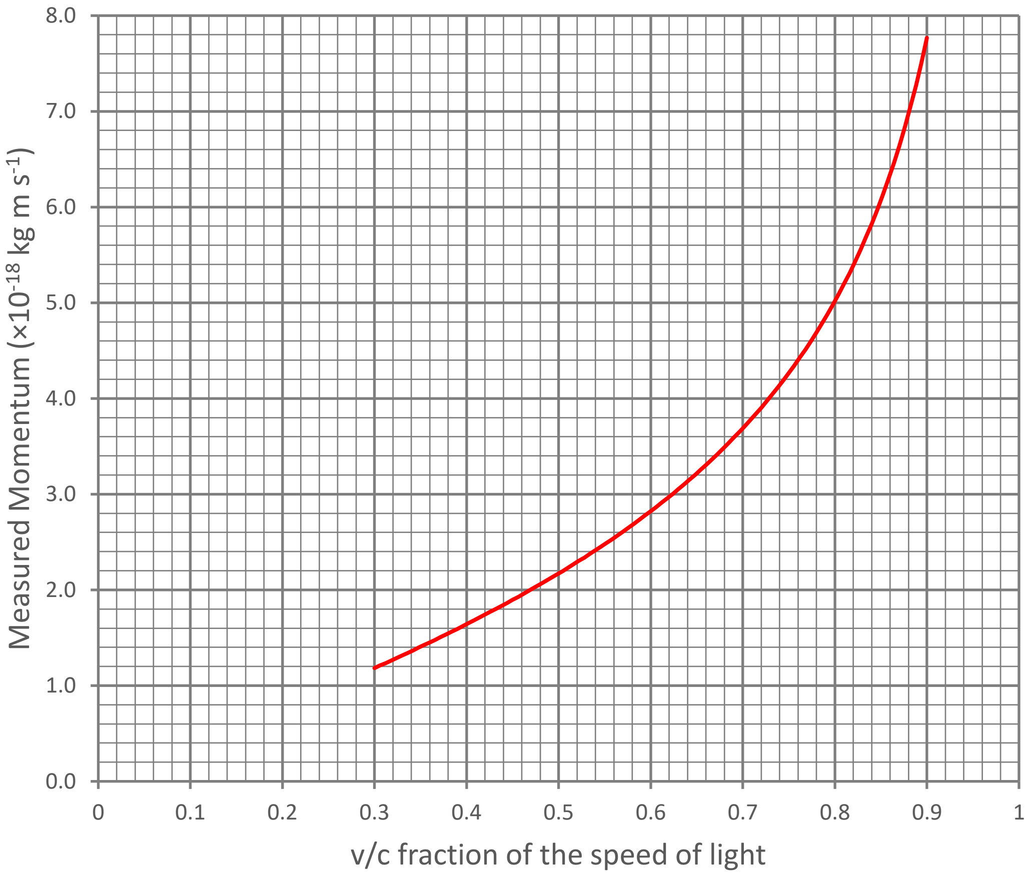
SECTION II: Part C (20 Marks)

CANDIDATE NUMBER

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

Question 28 (3 marks) **Marks**

Physicists use a particle accelerator to measure the momentum of a newly discovered particle (named Ω_{cb}^{0}) at different velocities. This data is recorded in the graph below.



(a) Determine the velocity of the particle when its momentum is 3.3×10^{-18} kg m s^{-1}.

v = 0.66c , OR v = 1.98×10^{8} ms^{-1}
(Accept 0.65c – 0.67c) **1**

(b) Use the graph, or otherwise, to calculate the rest mass of this Ω_{cb}^{0} particle.

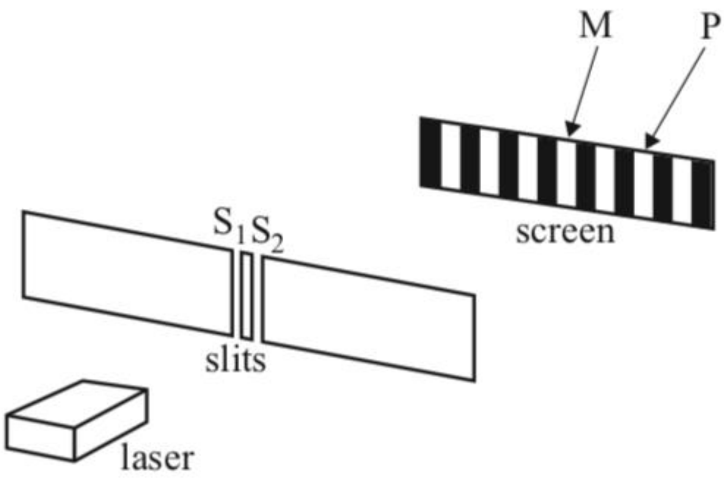
$p = \frac{m_0 v}{\sqrt{1-\frac{v^2}{c^2}}}$ So $3.3 \times 10^{-18} = \frac{m_0 \times 1.98\times10^{8}}{\sqrt{1-0.66^2}}$ So $m_0 = \frac{3.3\times10^{-18} \times 0.75}{1.98\times10^{8}}$ **2**

$$m_0 = 1.25 \times 10^{-26} kg$$

Criteria	Mark
• Substitution into correct equation (relativistic momentum), correct answer	2
• Incorrect calculation using correct equation OR • Correct calculation using relevant equation (ordinary momentum)	1

Question 29 (7 marks) **Marks**

A barrier with two narrow slits S_1 and S_2 which are 0.2 mm apart is placed as shown in the path of laser light of wavelength 532 nm. An interference pattern is observed. The point M on the screen is at the centre of the interference pattern. There is a bright band at point P on the screen. It is the second bright band to the right of M, as shown.



(a) Outline the meaning of the term diffraction and explain why it is essential for the interference pattern in this experiment. **2**

Sample answer:
Diffraction is the spreading out of a wave when it passes through an aperture. It is necessary to produce parts of the interference pattern that are not in direct line with the slits.

Criteria	Mark
• Outlines diffraction as spreading of light after passing through slits OR as the fact that each slit acts as point source • Explains that diffraction is necessary to get pattern that is not in line with slits, OR so that diffracted waves from each slit can combine (as if from 2 point sources), OR so that waves from the slits can interact with each other as they coincide on screen	**2**
• One of above	**1**

Note: Some students confused diffraction with refraction.

(b) Explain why there will be a bright fringe on the screen at point M. **2**

Sample answer:

Point M is an equal distance from each slit. Laser light in phase at the two slits will also be in phase at M, so will produce constructive interference resulting in a bright patch.

Criteria	Mark
• States that point M is equal distance from each slit • Links equal path length to constructive interference	2
• One of above	1

Note: Students attempting to use equation as explanation needed to say that the bright fringes occur at angles given by equation, and that central point is m = 0 which corresponds to θ =0 as a bright spot.

Question 29 continued on next page.

Question 29 continued

Marks

(c) Calculate the angle of the band at point P from the central axis. **3**

Sample Answer:

m = 2, ie second bright fringe from centre.

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

$$2 \times 532 \times 10^{-9} = 0.2 \times 10^{-3} \sin\theta$$

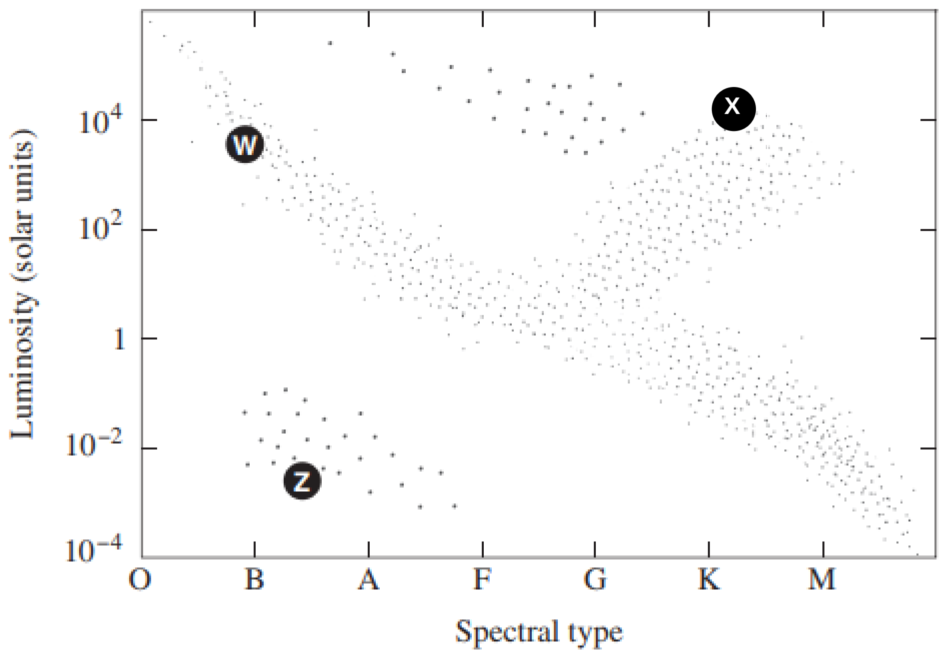
$$\theta = sin^{-1}\left(\frac{2 \times 532 \times 10^{-9}}{0.2 \times 10^{-3}}\right) = sin^{-1} 0.00532 = 0.30°$$

Criteria	Mark
• Correct substitution into double slit equation, correct answer	3
• As above but unit conversion error or wrong fringe number	2
• Correct equation	1

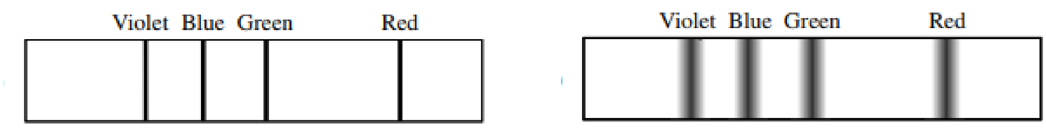
Note:
A few students thought it was m = 3 fringe, but the central fringe is m = 0, so point P was m = 2.

Question 30 (6 marks) **Marks**

Two stars, Geralt and Ciri, have similar temperatures and are located at positions W and Z on the Hertzsprung-Russell diagram shown below.



Spectra were taken of the two stars and are shown below.



Star Geralt **Star Ciri**

(a) Identify which of the two stars could occupy position Z. Justify your answer. **2**

Answer:
The star at Z is a white dwarf and so must have a much denser atmosphere than the main sequence star at W. That would produce pressure broadening of spectral lines. Thus only Ciri could occupy position Z.

Criteria	Mark
• Star at Z is white dwarf, so must have much denser atmosphere. • Only Ciri shows line broadening, which would be due to pressure broadening, so Ciri is at Z	**2**
• Identifies Ciri at Z but with wrong or no reason OR • Identifies a reason for line broadening	**1**

Note:
Talking about Doppler broadening was worth 1 mark.

Question 30 continued on next page.

Question 30 continued **Marks**

(b) Compare the diameter of a star at position W to that of a star at position X. Justify your answer. **2**

Answer:
W and Z stars have similar luminosity but W is much hotter. Therefore X must have greater surface area, hence larger diameter.

Criteria	Mark
• Identifies stars at X as larger • Reason: W and Z stars have similar luminosity, but W is much hotter. Therefore X must have greater surface area, hence larger diameter	**2**
• Identifies stars at X as larger OR • Identifies X as red giant	**1**

Note:
I accepted the argument that all red giants must be larger than all main sequence stars, but it had to be explicitly stated as a general rule. Qualifiers such as "red giants tend to be larger than main sequence" or specifics such as "It is a red giant so it's bigger" were not enough for 2 marks.

(c) Identify which star(s), would have the proton-proton fusion chain reaction occurring in the core. **1**

Answer:
Star W (only main sequence star)

(d) Star W has a luminosity of 1.91×10^{30} W. This means that it is emitting 1.91×10^{30} joules of energy each second. **1**

Answer:

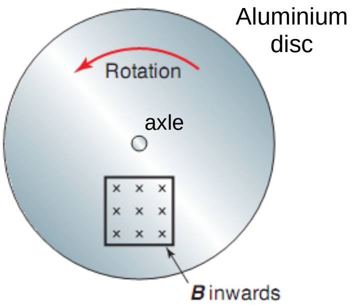
$$E = mc^2$$

$$m = \frac{E}{c^2} = \frac{1.91 \times 10^{30}}{(3.0 \times 10^8)^2} = 2.12 \times 10^{13}\ kg$$

Note:
Why is changing the subject of a simple equation so hard??

Question 31 (4 marks)

When one side of a spinning aluminium disc was placed into a perpendicular magnetic field, it was observed to quickly come to rest.



Explain the process which brings the spinning disc to rest. **4**

Sample Answer:

- As the disc spins, areas of it are entering B field while other areas are leaving.
- In these areas, where magnetic flux is changing, emf is induced by Faraday's Law.
- Since the disc is conductive metal, the emf creates eddy currents.
- By Lenz's Law, the direction of the current will be to create a magnetic field that opposes the change in flux.
- The current combines with the external B field by the motor effect to produce a retarding force that slows the disc.

Criteria	Mark
• Links the concepts of: movement, leading to change in flux, causing induced emf (Faraday,) hence current (in conductor,) which acts in direction such that its induced B field opposes change (Lenz,) then current and external field create retarding force (which is motor effect but I didn't insist on label).	4
• As above but with one step in chain of logic missing	3
• Two correct facts	2
• One correct fact	1

Notes:

- The pattern of HSC marking is that first mark is extremely easy to get, but each successive mark extra becomes harder. I have followed that pattern here.
- I didn't take "by Ohm's Law" as sufficient reason why emf leads to current. Ohm's Law can just as well be used to explain why current doesn't flow in an open circuit – it says nothing about what the value of R is.
- It wasn't enough to say that induced magnetic field opposes change in flux, therefore slowing happens. Some students said induced B field makes disc attracted to magnet which slows the disc. Answers should link B fields perpendicular to page to a force in the plane of the page. A diagram (or annotation on given diagram) was helpful here.

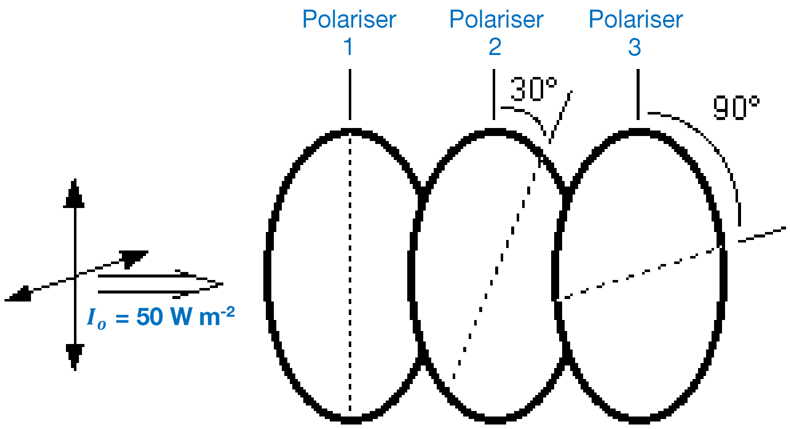
SECTION II: Part D (10 Marks**)**

CRIB - AAH

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

Question 32 (4 marks) **Marks**

Unpolarised light with an intensity of 50 W m^{-2} is incident on a series of three polarising sheets. The polarising plane of the first is vertical, the second is at 30° to the vertical, and the third is horizontal.



(a) What intensity of light passes through Polariser 1?

$I = \frac{I_o}{2}$ = **25 Wm^{-2}** (1 Mark)

(b) What intensity of light passes through Polariser 3? **2**

$I = 25.cos^2 30.cos^2 60$ = **4.7 Wm^{-2}** (2 Mark)

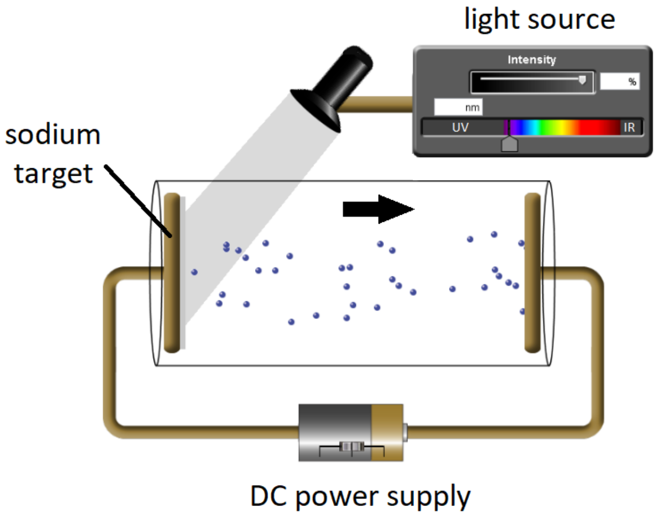
(1 Mark for getting one of these angles wrong)

(c) Polariser 2 is now removed. What intensity of light now passes through Polariser 3? **1**

$I = 25.cos^2 90$ = **0 Wm^{-2}** (1 Mark)

Question 33 (6 marks) **Marks**

The diagram below shows a simulation of the photoelectric effect. As violet light is shone on the sodium target (which has a workfunction of 2.3 eV), electrons leave the sodium and move to the right, reaching the opposite plate and causing a small current to flow in the circuit.



Two experiments are then performed.

In both experiments the photocurrent and the maximum kinetic energy of the photoelectrons are measured.

Experiment 1:

While violet light (420 nm) shines onto the sodium target, its intensity is varied from low to high.

Experiment 2:

Keeping the intensity of light at a constant high level, the wavelength of light is increased from 420 nm to 700 nm.

Question 33 continued on next page.

Question 33 continued **Marks**

Predict and explain the results of both experiments with reference to Einstein's model of light.

6

Marking Scheme

Mark	Answer Includes the Following Points:
5-6*	A good outline of the photon model of light. A correct set of predictions. A good explanation for all predictions made. Incorporates a quantitative analysis into the explanation.
3-4*	A reasonable outline of the photon model of light. A set of correct predictions Some correct explanation for the predictions made.
2	A reasonable outline of the photon model of light, *or* A reasonable set of predictions
1	Some relevant prediction, *or* Some correct statement about the photon model of light.

****In each band, better answers received higher marks***

Note 1
Common features of better answers included:
- Outlining the photon model of light explicitly (usually at the beginning of the answer).
- Using the numerical information, e.g. to determine the threshold wavelength of Sodium.
- Answering in terms of wavelength (as the questions asks) rather than frequency.
- *Explicitly* relating cause and effect; e.g. relating the number of electrons released to the photocurrent; stating that the intensity of light is proportional to the number of photons.
- Using equations to help explanations; e.g. $KE=hc/\lambda - \phi$.
- Taking the opportunity to demonstrate a thorough understanding of the photon model of light, and the photoelectric effect, in the context of a well-structured answer.

Note 2
The effect of increasing wavelength on the photocurrent is actually quite complicated. In part, the prediction depends on the interpretation of the word 'intensity'.

Most answers assumed that keeping the intensity constant meant keeping the number of photons constant. Others recognised that, as intensity relates to power, increasing the wavelength actually *increases* the number of photons.

(Either way, the exact effect on the photocurrent is not obvious. For example, it will also depend on the number of electrons emitted at less than the maximum kinetic energy, and how this number diminishes as the kinetic energy of the photons is reduced.)

As long as the answer made an attempt to address kinetic energy and photocurrent for both experiments, and was consistent with the assumptions made, either of these approaches was accepted.

Sample Answer

Einstein's model of light (the photon model) states that:

- Light is composed of particles called photons.
- The energy of a photon is given by the equation $E=hc/\lambda$
- The intensity of a light source is proportional to the number of photons.

When photons of sufficient energy strike a metal surface, each photon liberates a single *photoelectron* – the photoelectric effect.

The maximum energy of the photoelectrons is given by the equation $KE=hc/\lambda - \phi$, where ϕ is the *work function* of the metal - the minimum energy required to liberate electrons from it.

Sodium has a work function of 2.3 eV, which equals 2.3 x $1.6\text{x}10^{-19}$ = $3.68\text{x}10^{-19}$ J.
A photon with this energy has a wavelength of $6.63\text{x}10^{-34}$ x $3\text{x}10^{8}$ / $3.68\text{x}10^{-19}$ = <u>540 nm</u> (which makes the *threshold frequency* $5.55\text{x}10^{14}$ Hz).

Experiment 1

Prediction:
As the intensity of the light is increased, the photocurrent increases proportionally.
The kinetic energy of the photoelectrons is unchanged.

Explanation:
Increasing the intensity of the light increases the number of photons, which therefore increases the number of photoelectrons and therefore the current.
The energy of the photons remains the same and therefore the maximum energy of the photoelectrons is constant.

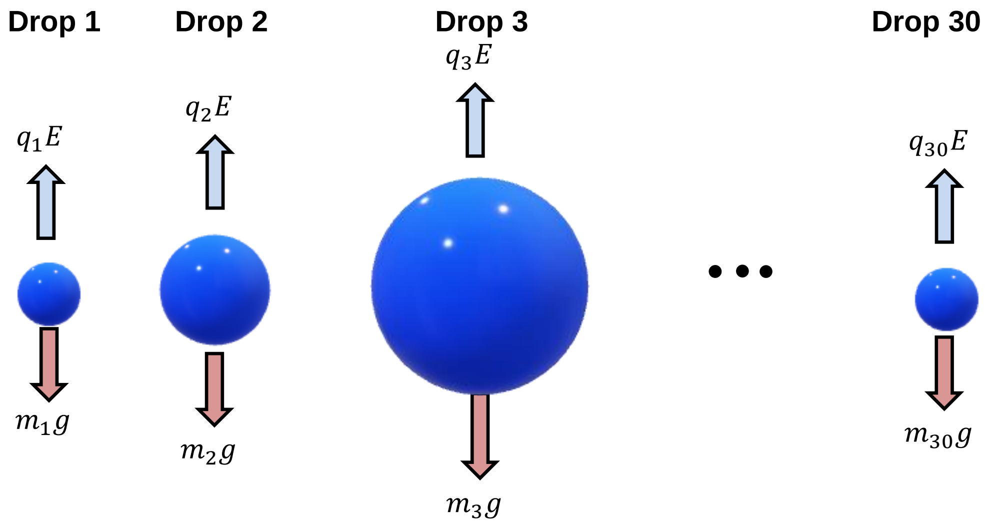
Experiment 2

Prediction:
As the wavelength of light is increased, the maximum kinetic energy of the photoelectrons decreases, reaching zero when the wavelength reaches 540 nm.
As the wavelength passes 540 nm, the photocurrent drops suddenly to (and remains at) zero.

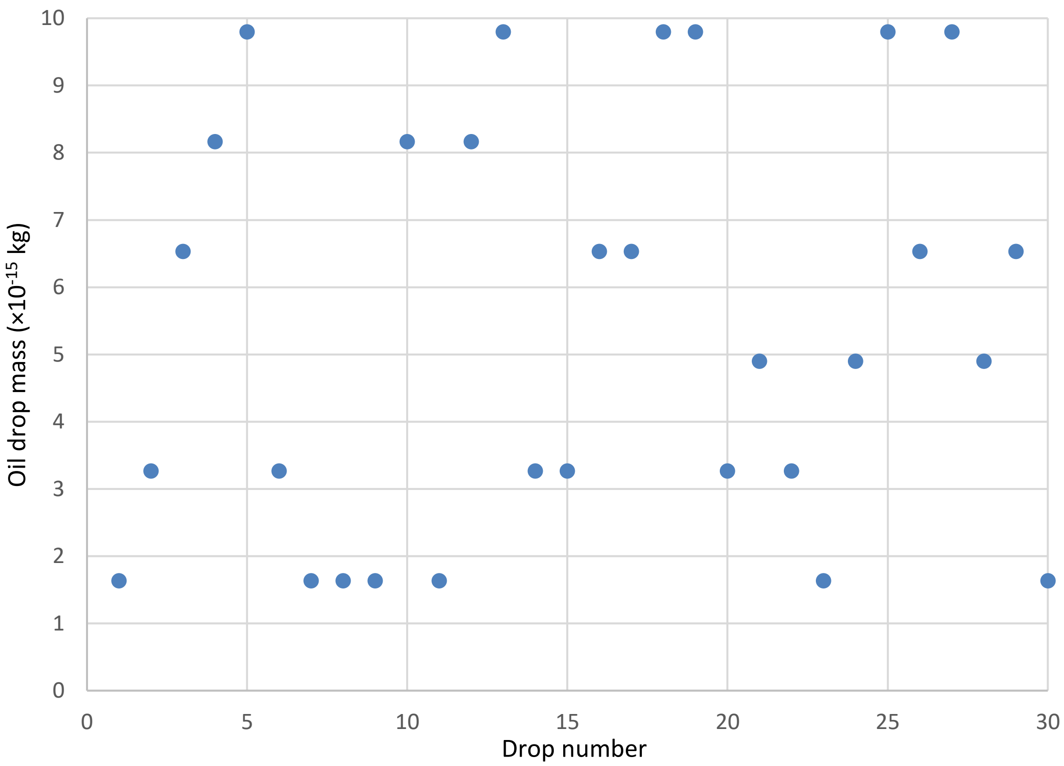
Explanation:
Increasing the wavelength of the light decreases the energy of the photons, which therefore decreases the kinetic energy of the photoelectrons.
When the wavelength passes 540 nm, the energy of the photons becomes less than the work function of Sodium. No more photoelectrons are emitted, and the current therefore drops to zero.

Question 34 (4 marks) **Marks**

In an experiment similar to Millikan's oil drop experiment, thousands of oil drops of various masses are bombarded with x-rays giving them different amounts of charge. When placed in a uniform electric field, only 30 of the oil drops became stationary. For these oil drops, the upward electrostatic force balanced the weight force ($qE = mg$).



The mass of each of these oil drops was recorded in the following graph.



Question 34 continued on next page.

Question 34 continued

Marks

(a) Account for the pattern of this recorded data.

2

The recorded data shows that only certain masses of oil drops have balanced forces and are multiples of a base mass. This base mass is much larger than the mass of atoms and must therefore be due to the upward electric force only has discrete values (since $qE = mg$ and E and g are constant). This would be because oil drops can only have a charge that is multiples of the charge of an electron.

The pattern of discrete masses is because there are different numbers of electrons on each drop creating discrete changes in the electric force. To levitate this force must be balanced by an equivalent discrete weight force.

Criteria	Mark
Identifies and describes pattern of discrete masses (multiples identified). This must be an observation from graph, not just previous knowledge of Millikan's experiment	1
Correct inference that the charge can only occur in multiples of the fixed amount. Must explain using balanced forces. The inference must be linked to pattern observation, not just stated as a conclusion. Answer must explain why only certain masses have forces balanced	1

Commentary

- A common mistake was thinking that the oil masses are changing by the mass of an electron.
- Many answers state that charge/mass must be constant without establishing why.

(b) Using the data provided, estimate the electric field strength used in this experiment, stating any assumptions you make.

2

These are the masses that can be read from the graph..
1.6×10^{-15}, 3.3×10^{-15}, 4.9×10^{-15}, 6.5×10^{-15}, 8.2×10^{-15}, 9.8×10^{-15}

Assumption
That the smallest oil drop mass has only the charge of 1 electron.

If $qE = mg$ then $E = \frac{mg}{q} = \frac{(1.6\times10^{-15})(9.8)}{(1.6\times10^{-19})}$ = 98,000 $N{\cdot}C^{-1}$

The other mass values can be used so long as it is recognised that the charge is a multiple of the charge on an electron.

Criteria	Mark
Correct mass measured from graph. Stating assumption that this must be the lowest mass that matches the charge of a single electron.	1
Correct estimate of approx. 100,000 V/m (variance allowed, so long as calculation correct)	1

Question 35 (6 marks) **Marks**

Referring to the work of Thomson and Rutherford in atomic physics, discuss how scientists use experimental observations and physical principles to improve scientific models.

Models are constructed to explain observations and create further predictions of behaviour. Thomson and Rutherford performed experiments whose observations (via experimental measurements and conclusions) they used to create models of the atoms that would explain their results.

Marks were awarded for how the answer was structured, with the appropriate level of detail, to address all aspects of the question that had been asked.

It is expected that answers would outline the experiments (the work of Thomson and Rutherford) and include physical principles (i.e. the physics they used) and their conclusions and observations. These observations and conclusions should then be explicitly linked to the features of their models of the atom that they constructed to consolidate and explain these observations. Answers should show how the model of the atom improved as new evidence was obtained from further experimental evidence.

Thomson's Experiment

Description of experiment (labelled diagram would help)

Thomson passed a cathode ray between perpendicular electric and magnetic fields, this created opposing forces $F = qE$ and $F = qvB$ that could both deflect the ray vertically. These could be adjusted until there was no deflection (Null method). This condition allowed him to calculate the velocity of the cathode rays ($v = E/B$).

If the electric field was then turned off, then the ray was deflected in a circular arc whose radius of curvature could be measured. This allowed the calculation of the charge to mass ratio of the particles in the cathode ray.

$$\frac{mv^2}{r} = qvB \text{ and } \frac{q}{m} = \frac{v}{rB} = \frac{E}{rB^2}$$

Observations/Conclusions

1. Cathode rays deflected by E-fields and B-fields as expected by theory as if they are negatively charged particles.
2. Charge/mass of cathode rays measured (q/m = 1.8×10^{11} C·kg^{-1}).
3. q/m ratio was far greater (1800 times) than a small element like a hydrogen ion (proton). Since the atom is neutral, Thomson said it suggested that the charge could be similar to that of other positively charged objects known at the time, which implied that the electrons mass was very small. (Millikan's later measurement of the charge of an electron confirmed the low mass)
4. q/m ratio independent on cathode material and gas in tube (therefore was in all atoms)
5. Cathode rays must be sub-atomic and come from inside all types of atom. It is a part of all atoms (sub-atomic)

Thomson's plum pudding model (these features should be linked to his observations)

From these measurements and observations Thomson proposes that the atom is a positively charged diffuse ball 'pudding' with negative electron 'plums' distributed throughout (labelled diagram helpful). This introduces the first sub-atomic particle to the atom. Its mass suggests a small size that fits many inside the atom. There must be a positive charge to balance it. The electrons must be able to 'escape' when a voltage is applied to become cathode rays.

Rutherford's Experiment

Description of experiment (labelled diagram would help)

Rutherford (with Geiger and Marsden) used radium to send alpha particles at a thin gold sheet. The deflection of the alpha particles could be measured at different angles when they made a movable small flash on a phosphorous screen (ZnS).

Observations

- Most alpha particles passed through undeflected.
- Some had small deflections.
- 1 in 8,000 deflected back more than 90˚ (this is the commonly cited value; the Pearson textbook rounds it to 10,000)

Physics used in experiment to measure the size of the nucleus

Rutherford used the physics of elastic collisions between the positive alpha particles and a small positive nucleus (electrostatic repulsion by coulomb's law). By analysing the amount of deflection at each angle he was able to determine the size of the nucleus that would cause this and found it to be 1/10000th the size of the atom.

Rutherford's 'solar system' or 'planetary' model

Features (labelled diagram helpful)

- Central small positive nucleus with most of the mass (its composition of protons and neutron still not understood)
- Orbiting electrons with the electrostatic force as the centripetal force $\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2} = \frac{mv^2}{r}$.

  (Rutherford knew accelerating electrons emit radiation and should spiral into the nucleus but did not have any additional evidence at the time to refine his model further. His model could only be based on the evidence that he had. Niels Bohr later creates his own model to help account for this)
- Rutherford's model of the atom improves on Thomson by giving more detail about the positive charge being in a nucleus and that the electrons (having much smaller mass) were orbiting it like planets around the sun (and not just electrostatically stuck to the positive nucleus). These electrons are moving in empty space but still give the atom its size (repelling electrons from other nearby atoms)
-

How it matches observations

- This model of the atom is mostly empty space, which explains why most of the alpha particles were undeflected.
- Only a small positive nucleus 1/10,000 the size of the atom, with most of the mass of the atom, would explain why any some were deflected and only 1 in 8000 deflected backwards.
- Thomson's diffuse positive charge would have only created smaller deflections as the alpha particles pass through and none backwards.

Criteria	Mark
Includes a comprehensive description of the experimental observations and applicable physics of their experiments AND Provides direct links between the observations and the development of the features of each model of the atom AND Describes all the features of the Thomson's and Rutherford's model of the atom	6
Includes a good description of both observations and applicable physics of their experiments AND Provides some links between the observations and the features of the model of the atom AND Describes all the features of the Thomson's and Rutherford's model of the atom.	5
Includes a good description of both observations and applicable physics of their experiments AND Identifies features of the Thomson's and Rutherford's model of the atom	4
Includes some description of observations OR applicable physics of their experiments AND Identifies the features of the Thomson's and Rutherford's model of the atom	3
Includes a basic description of the experimental observations/applicable physics/model for both Thomson and/or Rutherford	2
Includes some relevant detail description of the experimental observations/applicable physics/model for either Thomson and Rutherford	1

Comments

- The models are formed from evidence, not proposed first then experiment made to prove/disprove. As new evidence (experimental results) is created, features of previous models are refined and improved.
- There is much confusion about the work that preceded Thomson and what was already established before he started his work. Cathode rays were already known (specifically Crookes and Perrin) to be negative had mass and could be deflected by magnetic fields (though some German scientists disputed that this made them particles for a long time). Experimentally there had been difficulty deflecting cathode rays with electric fields. It was Thomson who realised that this was because the tubes needed to be at lower pressure, and when he managed to deflect them by electric fields they did so like negative charges. He is credited with discovering the electron because his measurement of the unique charge/mass ratio definitively indicated this was a new particle, previously unknown. In this context, it is only his experiment measuring the q/m ration that needs to be described.