NESA STUDENT NUMBER

2020

Year 12 Physics

Trial Examination

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen.
- Draw diagrams using pencil.
- Calculators approved by NESA may be used.
- A data sheet, formulae sheet and Periodic Table are provided.

Total marks: 100

Section 1 – Multiple Choice — **20 marks**
- Attempt Questions 1–20

Section 2A – Written Response — **20 marks**
- Attempt Questions 21–25

Section 2B – Written Response — **40 marks**
- Attempt Questions 26–32

Section 2C – Written Response — **20 marks**
- Attempt Questions 33–36

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S1

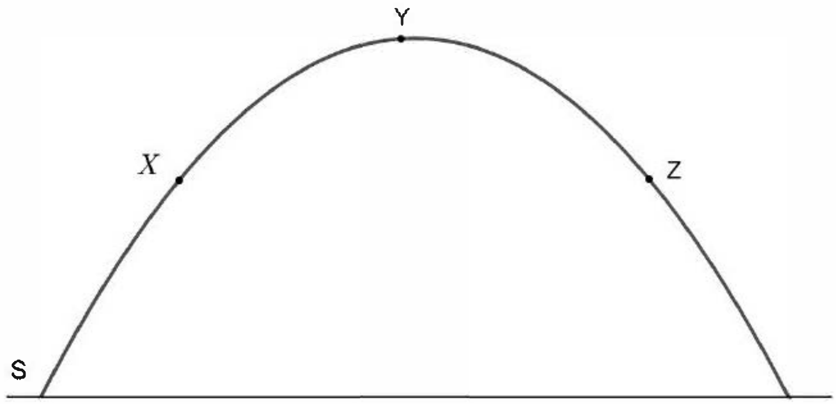
Section I

20 marks

- Attempt Questions 1–20.
- Use the multiple-choice answer sheet at the back of Section 2A for Questions 1–20.

Question 1 (1 mark)

A ball is thrown from S at an angle to the horizontal as shown in the diagram below:



X, Y and Z are different points along the ball's trajectory.

Which of the following best represent the velocity and acceleration of the ball?

	Velocity			Acceleration		
	X	Y	Z	X	Y	Z
(A)	↑	zero	↓	↓	zero	↓
(B)	↗	→	↘	↑	zero	↓
(C)	↗	→	↘	↓	↓	↓
(D)	↗	→	↘	↗	zero	↘

Question 2 (1 mark)

Which of the following does not affect the speed velocity of a satellite?

(A) The mass of the planet it orbits.

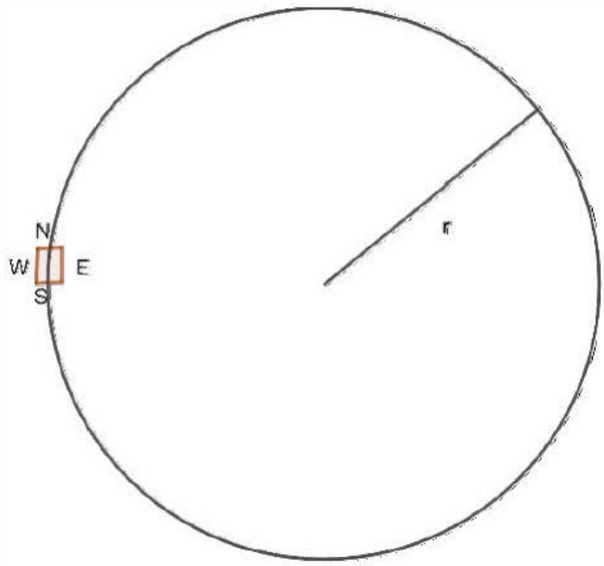
(B) The gravitational force of the planet.

(C) The mass of the satellite.

(D) The satellite's altitude.

Question 3 (1 mark)

Consider a car of mass m travelling with a constant velocity *v* around a corner of radius *r* as shown below:



Which of the following statements best describes the net force on the car when it is at the position shown above?

(A) There is no net force on the car as it is moving with uniform circular motion.

(B) The net force depends on the *v*, *m*, and *r* and is directed towards the centre

(C) The net force depends on the *v*, *m*, and *r* and is directed towards the west.

(D) The net force will be the sum of the centripetal force and the gravitational force acting on the car.

Question 4 (1 mark)

The speed of an electric motor which has no load is limited by the:

(A) current that can flow through the motor's coils.

(B) area of the motor's coils.

(C) resistance in the motor's coils.

(D) back EMF produced in the motor.

Question 5 (1 mark)

The soft iron core of a transformer is usually laminated.

What is the main purpose of this lamination?

(A) To reduce eddy currents in the core.

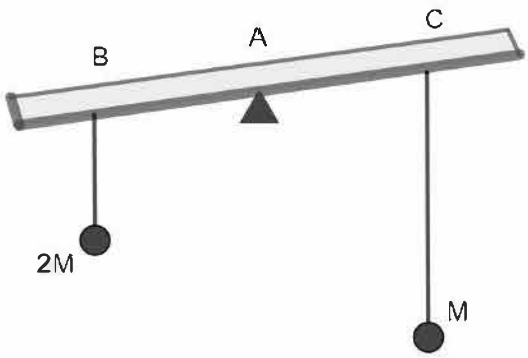
(B) To increase the permeability of the core.

(C) To reduce the electrical resistance of the core.

(D) To reduce the flux linkage of the two coils through the core.

Question 6 (1 mark)

Consider the two masses suspended in a lever system as shown below:



When released, the lighter mass (M) accelerates downwards. Assume that the strings are essentially weightless and the system is free to turn around the fulcrum.

Given that AB = R_1 and AC = R_2, what can be said about the lengths R_1 and R_2?

(A) $R_2 > 2R_1$

(B) $R_2 < 2R_1$

(C) $R_2 = 2R_1$

(D) $R_2 < R_1$

Question 7 (1 mark)

A low earth orbit satellite (LEO) experienced a gravitational force F_g. Its altitude is doubled to reduce orbital decay.

What effect would this have on the force of gravity acting on the satellite?

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

(B) $\frac{F_g}{1.1}$

(C) $2F_g$

(D) $4F_g$

NESA STUDENT NUMBER

Question 8 (1 mark)

The following nuclear equations describe four different transmutation reactions involving the isotope uranium-235.

The transmutation that currently occurs naturally on Earth is:

(A) ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{236}_{92}\mathrm{U}$ + energy

(B) ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{144}_{54}\mathrm{Xe} + {}^{90}_{38}\mathrm{Sr} + 2{}^{1}_{0}n$ + energy

(C) ${}^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$ + energy

(D) ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}n \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3{}^{1}_{0}n$ + energy

Question 9 (1 mark)

A black body radiates maximum intensity at a wavelength of 7.00×10^{-7} m, when the temperature of the body is 4140 K.

If the temperature of the body is increased by 1000 K, the maximum intensity would be observed at approximately:

(A) 4.65×10^{-7} m

(B) 5.65×10^{-7} m

(C) 6.00×10^{-7} m

(D) 2.90×10^{-6} m

Question 10 (1 mark)

The work function of aluminium is 4.08 eV.

Determine the wavelength of the light needed to eject an electron from the surface of aluminium.

(A) 6.54×10^{-19} m

(B) 9.86×10^{14} m

(C) 2.96×10^{23} m

(D) 3.04×10^{-7} m

Question 11 (1 mark)

Two physics students are conducting experiments to test Newton's second law of motion.

Each student is in a windowless railway carriage. Carriage **A** is moving at a constant velocity of 0.75c while carriage **B** is moving at 20 m s^{-1} and slowing down.

Which one of the following best describes the likely results of their experiments?

(A) Only the experiment in carriage **A** confirms Newton's second law of motion.

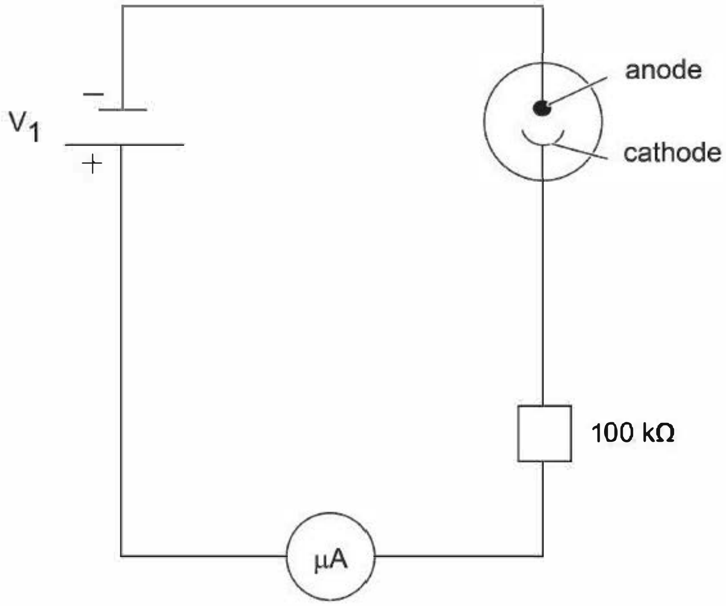
(B) Only the experiment in carriage **B** confirms Newton's second law of motion.

(C) Neither experiment confirms Newton's second law of motion.

(D) Both experiments confirm Newton's second law of motion.

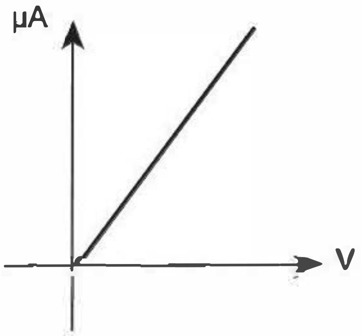
Question 12 (1 mark)

The following is a circuit diagram of a photoelectric effect apparatus.

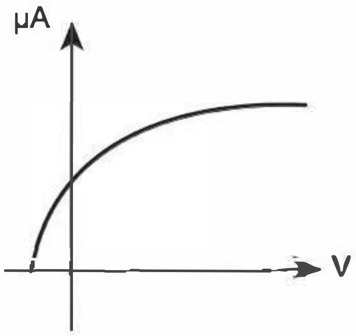


Which of the following graphs shows how the current through the photocell varies as the applied voltage V_1 is changed?

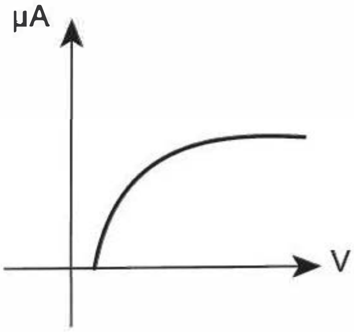
(A)



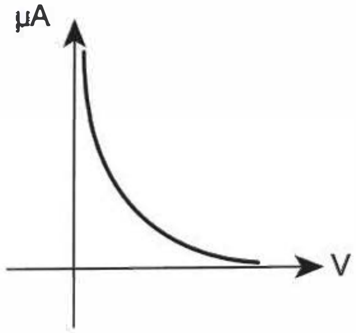
(B)



(C)



(D)



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Question 13 (1 mark)

When a muon meets an antimuon (its antiparticle with the same mass), both particles are annihilated and two photons (gamma rays) are formed. If the two particles are essentially stationary, the two emitted photons are observed to have a total energy of 3.38×10^{-11} J.

Using this data, which one of the following is closest to the mass of a single muon?

(A) 3.76×10^{-28} kg

(B) 1.88×10^{-28} kg

(C) 1.13×10^{-19} kg

(D) 5.64×10^{-19} kg

Question 14 (1 mark)

The Davisson-Germer experiment provided evidence to support:

(A) the accepted value of the charge of the electron.

(B) the particle nature of the electron.

(C) the wave nature of the electron.

(D) the presence of a compact, positively charged nucleus in the centre of an atom.

Question 15 (1 mark)

The main contribution of Erwin Schrödinger to physics is best described as:

(A) postulating that particles can behave as waves.

(B) postulating that waves can behave as particles.

(C) explaining the wavelengths of the emission lines in the spectrum of hydrogen.

(D) describing the likelihood of finding an electron in a certain position.

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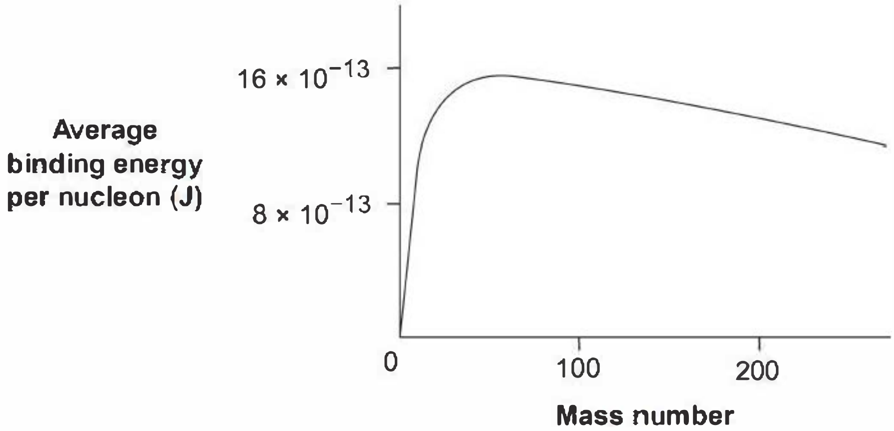
Question 16 (1 mark)

The graph below shows how average binding energy per nucleon varies with the mass number of the nuclide.



From the graph it can be concluded that:

(A) light hydrogen (mass number of 1) is the most stable element in the Universe.

(B) a nucleus with a mass number of 50 is more stable than a nucleus with a mass number of 200.

(C) a nucleus with a mass number of 200 is more stable than a nucleus with a mass number of 50.

(D) nuclides with a mass number of less than 50 release energy by undergoing nuclear fission.

Question 17 (1 mark)

The ratio of primary turns to secondary turns for a transformer is 5:2.

The primary coil of the transformer draws a current of 0.25 A from a 200 V alternating current supply. The current in the secondary coil is 0.50 A.

What is the efficiency of the transformer?

(A) 20%

(B) 50%

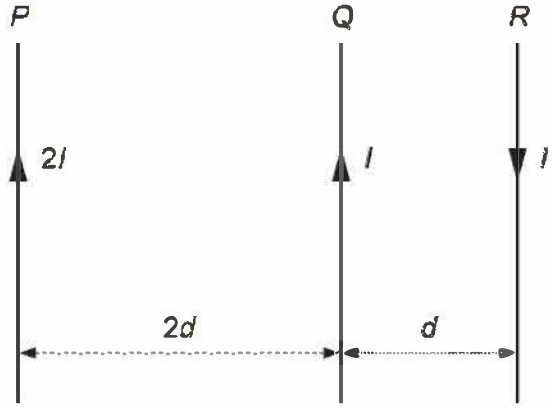
(C) 80%

(D) 100%

Question 18 (1 mark)

P, *Q* and *R* are straight, current-carrying conductors of equal length *L*.

- Conductor *P* carries a current of 2*I* amperes while conductors *Q* and *R* carry *I* amperes of current.
- Conductors *P* and *R* are fixed in place.
- *Q* is placed 2*d* metres from *P* and *d* metres from *R*.

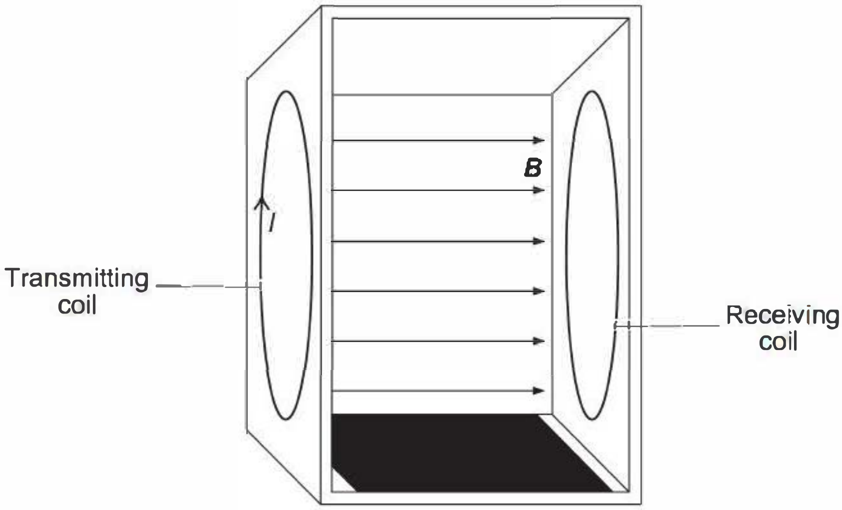


Given that $k = \frac{\mu_0}{2\pi}$, the magnitude and direction of the net force acting on *Q* is:

	Magnitude of force (N)	Direction
(A)	$\frac{2kI^2L}{d}$	To the left
(B)	$\frac{3kI^2L}{2d}$	To the left
(C)	$\frac{2kI^2L}{d}$	To the right
(D)	$\frac{3kI^2L}{2d}$	To the right

Question 19 (1 mark)

A simplified diagram of an airport security gate is shown below.



The transmitting coil on the left-hand side of the security gate produces a magnetic field as a result of a varying current.

The receiving coil of radius 50 cm consists of 35 turns experiences an induced emf of magnitude 28.5 mV.

What is the rate at which magnetic flux density changes inside receiving coil required to induce the stated emf?

(A) 1.04×10^{-3} Wb s^{-1}

(B) 1.81×10^{-3} Wb s^{-1}

(C) 3.63×10^{-3} Wb s^{-1}

(D) 5.18×10^{-4} Wb s^{-1}

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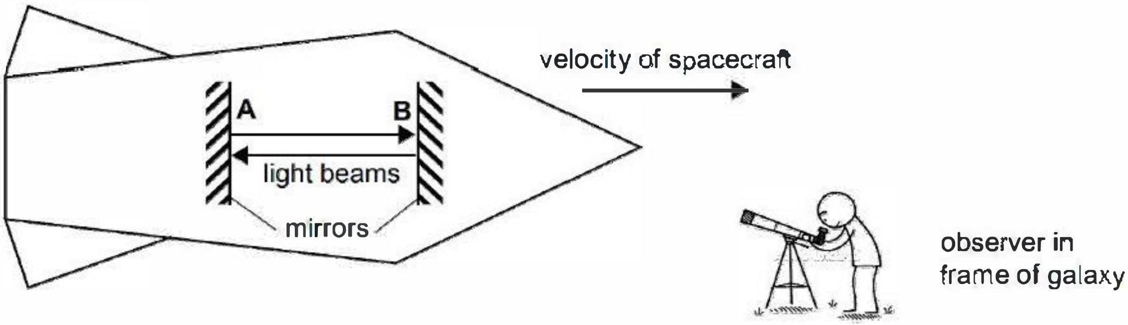
Question 20 (1 mark)

An astronaut takes a clock in her spacecraft. The clock was built using two mirrors between which a pulse of light is repeatedly reflected. It is known that the proper length between the two mirrors is 5.00 m and the spacecraft's velocity is 0.60c relative to our galaxy in the direction **AB**.



One period of this clock is the time taken for light to travel from **A** to **B** and back to **A**.

According to an observer in the frame of our galaxy, the period of this clock is closest to:

(A) 13 ns

(B) 21 ns

(C) 27 ns

(D) 42 ns

END OF SECTION 1

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S2A

2020

Year 12 Physics

Trial Examination

Section 2A (20 marks)

Questions 21–25

- Write using a black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

NESA STUDENT NUMBER

Marks

Question 21 (5 marks)

In an indoor soccer match, whenever the ball touches the ceiling of the court following a goal kick from the goalkeeper it is considered a foul.

The ceiling of the court is 10 m high, and the keeper always kicks the ball at a speed of 20 m s^{-1}.

(a) What should be the maximum angle the keeper kicks the ball so that a foul is not committed? **3**

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(b) Find the velocity of the ball 2.0 s after being kicked by the goalkeeper, assuming it is kicked at 20 m s^{-1} at the angle found in part (a) above. **2**

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NESA STUDENT NUMBER

Marks

Question 22 (3 marks)

A car, with mass m and turning a corner on a flat road describes an arc of a circle with a radius of r metres. The friction of the road is just enough for the car to turn at v km h^{-1}. **3**

Suppose that the car suddenly encounters an oil spill on the road that halves the surface friction.

What is the maximum velocity the car can turn without skidding?

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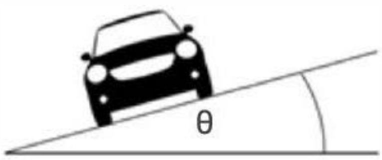
Question 23 (2 marks)

A banked curved road has a radius of 50 m and the recommended maximum speed of 40 km h^{-1}. **2**



By drawing a labelled vector diagram of the forces involved in the space provided, determine the angle at which the road is banked if the tyres exert no sideways force.

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NESA STUDENT NUMBER

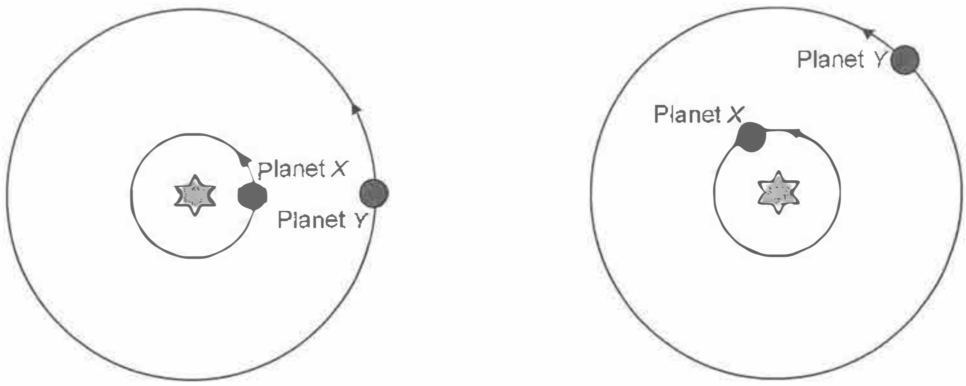
Marks

Question 24 (3 marks)

Two planets **X** and **Y** travel anticlockwise in circular orbits about a star, as seen in the diagram. The radii of the orbits **X** and **Y** are in the ratio 2:5. **3**

The planets are shown below at a time interval of 5 years. Initially they were aligned, making a straight line with the star. Five years later, planet **X** has rotated through 120°, as shown in the diagram.

Initial position of planets **Position of the planets 5 years later**



Determine how long it takes planet **Y** to orbit the star.

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Marks

Question 25 (7 marks)

Discuss the importance of Newton's law of universal gravitation and Kepler's Third Law in understanding and calculating the motion of satellites around Earth. 7

END OF SECTION 2A

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S2B

2020

Year 12 Physics

Trial Examination

Section 2B (40 marks)

Questions 26–32

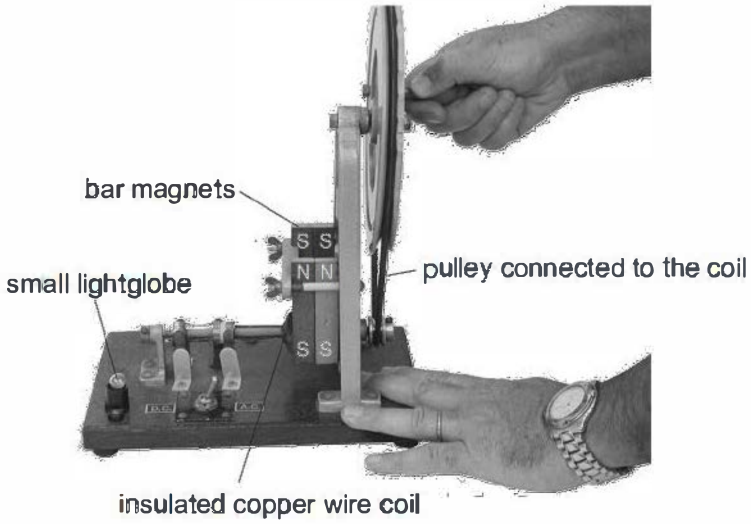
- Write using a black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

NESA STUDENT NUMBER

Marks

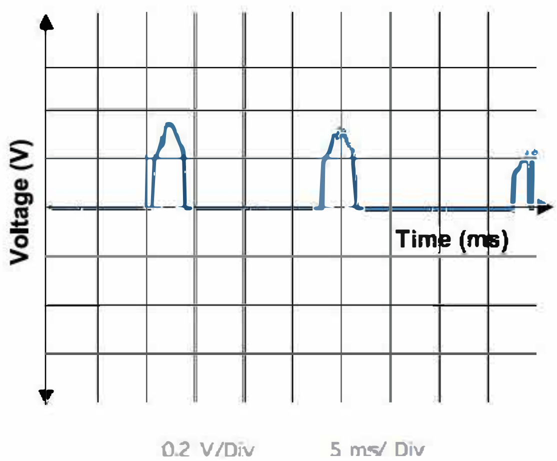
Question 26 (4 marks)

A hand generator shown in the photograph below. Often these hand generators can be set to generate either AC or DC current as they contain a slip-ring commutator and a split-ring commutator.

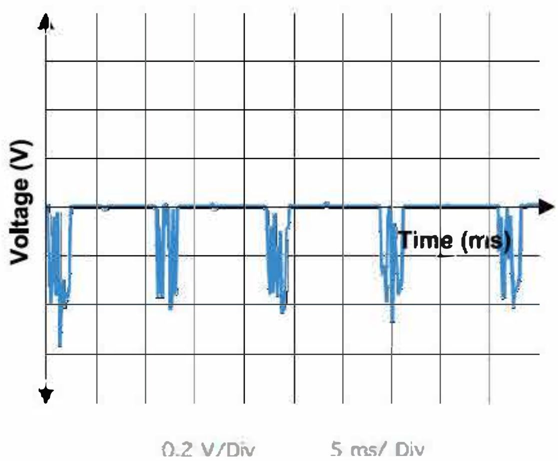


Two students turned the hand generator whilst it was connected to a cathode ray oscilloscope. The following displays recorded for each student.

Student A



Student B



Question continues on the next page

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Marks

(a) Determine whether the split-ring commutator or the slip-ring commutator was used by each student. Justify your answer. **2**

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(b) Account for the differences in the two displays shown for Student A and Student B. **2**

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NESA STUDENT NUMBER

Marks

Question 27 (6 marks)

An experiment was performed in which the lifetime (T) of a high-speed tau lepton was measured, in the laboratory frame of reference, as a function of its velocity, v.

The following data was obtained.

Velocity of tau lepton, v ($\times 10^8$ m s^{-1})	$\dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$	**Lifetime in laboratory frame of reference, T** ($\times 10^{-13}$ s)
1.00	1.06	3.08
1.50	1.15	3.35
2.00	1.34	3.89
2.50		5.25
2.75	2.50	7.26

(a) Determine the missing value to complete the table. **1**

(b) Plot a graph of T versus $\dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$ on the grid below. **3**

Question continues on the next page

Marks

(c) Using the graph, determine the lifetime of the tau lepton in its rest frame. **2**

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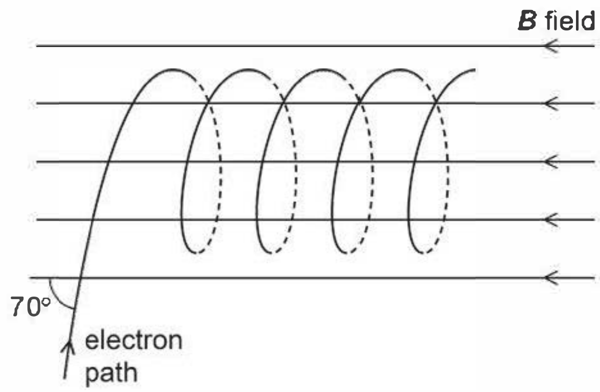
Question 28 (8 marks)

An electron travelling at 8.0×10^6 m s^{-1} enters a uniform magnetic field, at an angle of 70° to the field. The electron moves in a helical path as shown in the diagram below.



(a) Calculate the component of the electron's initial velocity that is perpendicular to the magnetic field. **1**

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(b) Calculate the component of the electron's initial velocity that is parallel to the magnetic field. **1**

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(c) Outline why the electron moves in the helical path. **1**

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Question continues on the next page

NESA STUDENT NUMBER

Marks

(d) Given that the magnetic flux density of the field is 0.015 T, calculate the radius of the loop of the helical path. **2**

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(e) Calculate the distance between two adjacent loops in the helical path. **3**

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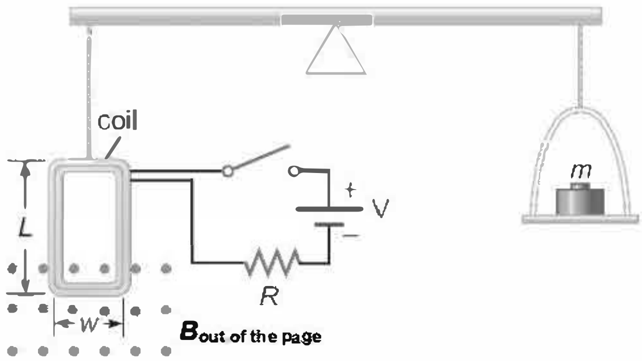
NESA STUDENT NUMBER

Marks

Question 29 (4 marks)

A student was to use the following apparatus to measure the magnetic flux density, ***B***, of a magnet.



The student made the following notes:

- The left-hand and right-hand sides of the balance are equidistant from the fulcrum.
- The rectangular coil of wire consisted of *N* turns has a width *w* and length *L* and has a mass ***M***.
- The coil is attached to one arm of a balance and is suspended between the poles of a magnet. The magnetic field is uniform and perpendicular to the plane of the coil.
- The system is first balanced when the current in the coil is zero.
- When the switch is closed and the coil carries a current *I*, a mass *m* must be added to the right side to balance the system. Once the system is balanced, the magnetic flux density of a magnet can be determined.

(a) Derive an expression for the magnitude of the magnetic flux density, ***B***. **3**

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(b) Why is the result in part (a) independent of the length of the coil? **1**

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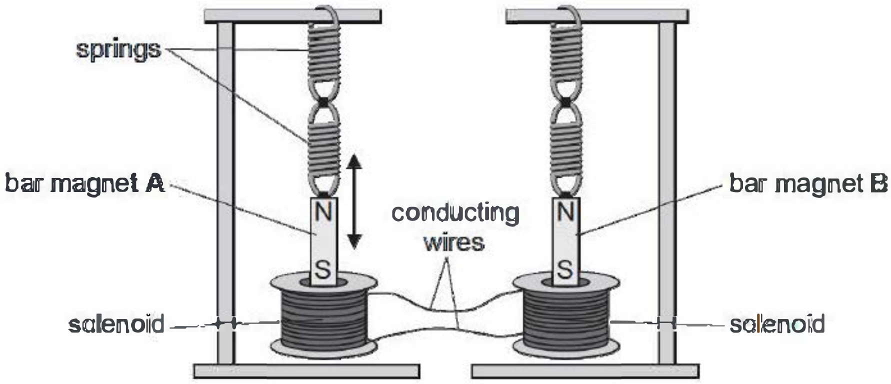
NESA STUDENT NUMBER

Marks

Question 30 (4 marks)

Two identical bar magnets are suspended from identical springs, with the south pole of each magnet inside a solenoid as shown in the diagram below. The two coils are connected together with conducting wires. **4**



Magnet **A** is displaced so that it oscillates vertically with the south pole of magnet **A** moving into and out of the coil of wire. As this motion continues, magnet **B** starts to oscillate vertically. The amplitude of oscillation of magnet **B** increases over time.

Using physics principles, account for the increase in amplitude of oscillation of magnet **B** over time.

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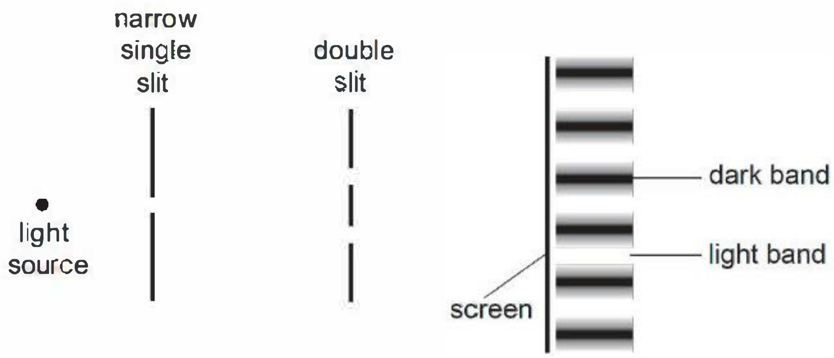
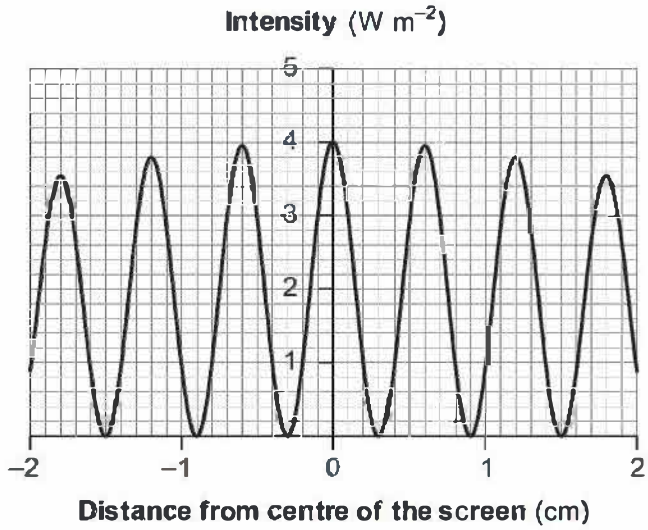
Marks

Question 31 (7 marks)

The diagram shows a monochromatic light source of wavelength λ, slits and a screen arranged for an experiment on light. Light and dark bands form on the screen.



The distance from the double slit to the screen is 3.2 m and the separation of the two slits is 0.39 mm. The graph shows how the intensity of the light on the screen varies with distance from the centre of the screen.



(a) Determine the wavelength of the light. **2**

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Question continues on the next page

Marks

(b) The red light is replaced by blue light. **2**

Predict what (if anything) will happen to the separation of the bright fringes on the screen. Justify your answer.

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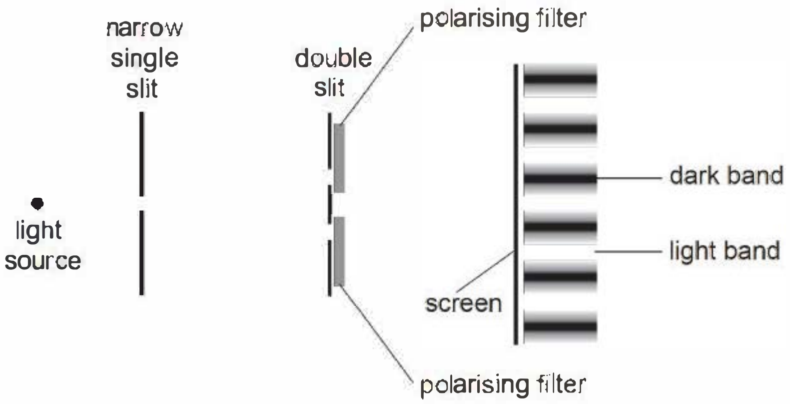
(c) Polarising filters are placed relative to the slits as shown. When the planes of the polarising filters are parallel to the slits, the pattern of light and dark bands is still seen as shown below. **3**



If one polarising filter is rotated through 90°, there are no dark bands and the screen is illuminated evenly.

Explain why there are no dark bands when one filter has a plane of polarisation that is 90° to that of the other filter.

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Marks

Question 32 (7 marks)

In the 19th and 20th centuries, our understanding of the nature of light has changed as debates regarding its wave and particle nature were challenged by experimental observations. **7**

Use this as an example to explain how scientists test and validate models.

END OF SECTION 2B

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S2C

2020

Year 12 Physics

Trial Examination

Section 2C (20 marks)

Questions 33–36

- Write using a black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

Marks

Question 33 (5 marks)

In 1897, J.J. Thomson experimentally measured the charge to mass ratio of the electron. **5**

Use an annotated diagram to describe how Thomson's experiment can be performed.

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Marks

Question 34 (8 marks)

In 1913, Neils Bohr proposed a model of the hydrogen atom that explained the formation of spectral lines.

(a) Describe Bohr's model of the atom and explain how it accounted for the formation of spectral lines. **4**

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(b) Outline two shortcomings of Bohr's atomic model. **2**

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(c) Calculate the wavelength of the violet H-delta emission line, produced from an electron transition from the sixth to the second energy level in the hydrogen atom. **2**

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NESA STUDENT NUMBER

Marks

Question 35 (3 marks)

An atom of carbon-12 contains 6 protons and 6 neutrons in its nucleus. The mass of a carbon-12 atom is 12.000 atomic mass units. **3**

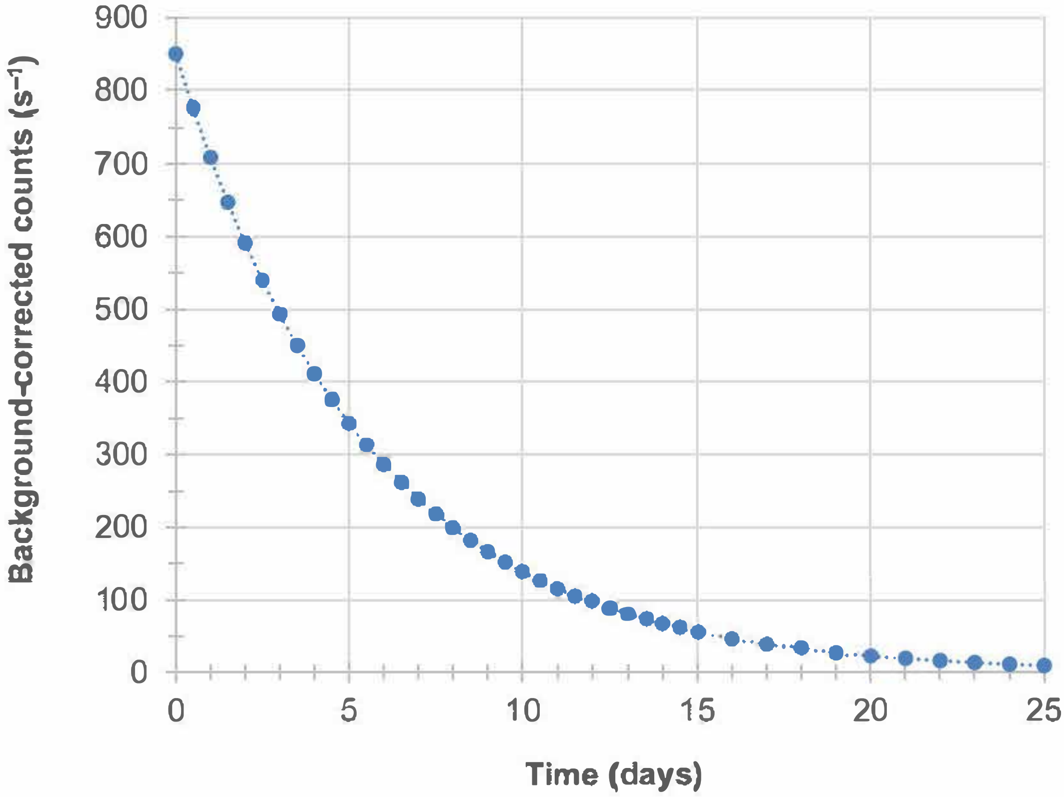
Calculate the mass defect of one carbon-12 atom. Quote your answer in atomic mass units (u) and assume that the mass of the electrons is negligible.

NESA STUDENT NUMBER

Marks

Question 36 (4 marks)

The following graph shows the decay of an unknown radioactive isotope.



(a) Use the graph to determine to find the decay constant (λ) of the isotope in s^{-1}. Show all working. **3**

....

....

....

....

....

(b) Further experiments identified the isotope to be an alpha emitter, forming the daughter nuclide polonium-218. **1**

Write a nuclear equation for the decay of this isotope.

....

....

END OF SECTION 2C

Normanhurst Boys High School

2020 Year 12 Physics Trial Examination

Marking Responses, Sample Answers & Notes from the Marker

S1

Section 1
Multiple Choice

Question	A	B	C	D
1				
2				
3				
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11				
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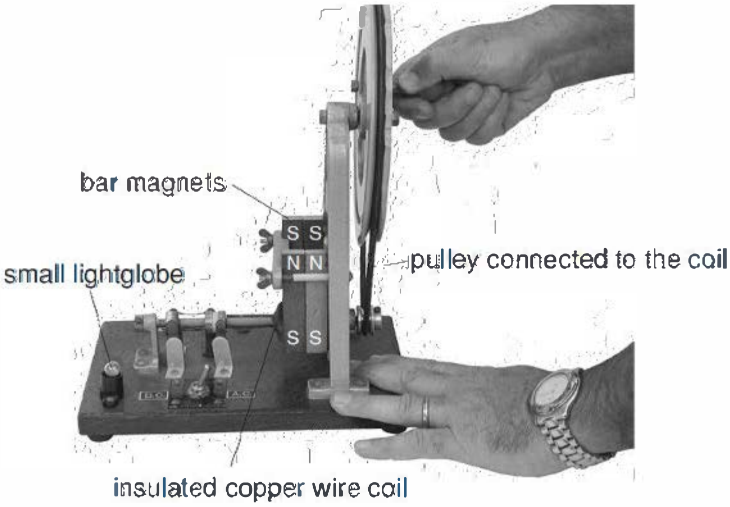
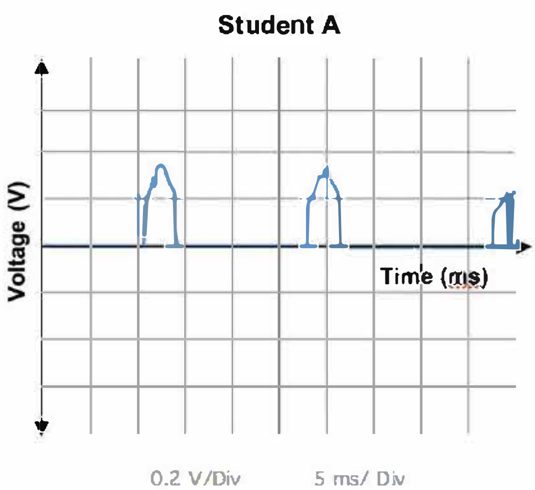
Section 2B (40 marks)
Written Response

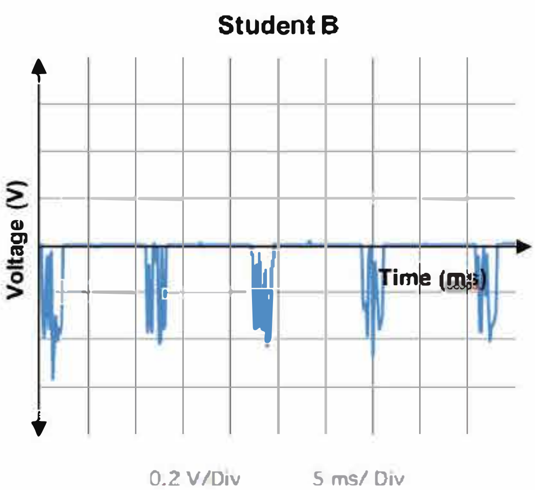
Question 26 (4 marks)

A hand generator shown in the photograph below. Often these hand generators can be set to generate either AC or DC current as they contain a slip-ring commutator and a split-ring commutator.



Two students turned the hand generator whilst it was connected to a cathode ray oscilloscope. The following displays are recorded for each student.





(a) **Determine** whether the split-ring commutator or the slip-ring commutator was used by each student. **Justify** your answer. **2**

(b) **Account** for the differences in the two displays shown for Student A and Student B. **2**

Question 26(a)

Marking Criteria	Marks
• States that a split-ring commutator was used for both students A and B. • Provides appropriate justification in terms of changing the direction of the current every half turn to keep current and emf in one direction.	2
• States that a split-ring commutator was used for both students A and B. OR • Provides some relevant interpretation of the CRO output.	1

Sample Response

A split-ring commutator was used by both students A and B as it changes the direction of the current through the coil every half turn so that the coil continues rotating in the same direction. This is evident in both outputs as the emf induced occurs in one direction only.

Notes from the Marker

- Better responses identified that a split-ring commutator was used and provided an interpretation of the graph in relation to the function of the split-ring commutator.
- Many weaker responses mentioned that both used different commutators or misinterpreted the positive and negative emf as being DC and AC.
- Useful resource: https://www.animations.physics.unsw.edu.au/jw/electricmotors.html.
- **Average** = 0.68/2

Question 26(b)

Marking Criteria	Marks
• Provides TWO reasons to account for the differences in emf output for students A and B.	2
• Provides ONE reason to account for the differences in emf output for students A and B.	1

Sample Response

The differences between the two outputs occur as a result of:

- Students A and B have rotated the pulley in opposite directions with the polarity of the magnets kept constant in both cases. This results in the emf being induced in opposite directions as per Lenz's law.

OR

- Students A and B have rotated the pulley in the same direction but have switched the polarity of the magnets. This results in the emf being induced in opposite directions as per Lenz's law.
- Student B has rotated the pulley at a faster rate as compared to student A. By Faraday's law:

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

the faster rate of change in flux caused by faster rotation of the pulley would induce a larger emf as evidenced by the differing magnitudes of the maximum emf produced in each case.

Notes from the Marker

- Most students were able to identify ONE difference to account for the different outputs.
- Students are reminded to read the question carefully and address pluralised aspects.

"Account for the **differences** in the two displays shown for Student A and Student B."

At least two differences would need to be addressed.

- Students are reminded to use physics principles where appropriate to support their responses.
- **Average** = 1.18/2

Question 27 (6 marks)

An experiment was performed in which the lifetime (T) of a high-speed tau lepton was measured, in the laboratory frame of reference, as a function of its velocity, v.

The following data was obtained.

Velocity of tau lepton, v ($\times 10^8$ m s^{-1})	$\dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$	**Lifetime in laboratory frame of reference, T** ($\times 10^{-13}$ s)
1.00	1.06	3.08
1.50	1.15	3.35
2.00	1.34	3.89
2.50	**1.81**	5.25
2.75	2.50	7.26

(a) Determine the missing value to complete the table. **1**

(b) Plot a graph of T versus on the grid below. **3**

(c) Using the graph, determine the lifetime of the tau lepton in its rest frame. **2**

Question 27(a)

Marking Criteria	**Mark**
• Correctly states the missing value in the table (1.81).	1

Sample Response

See above.

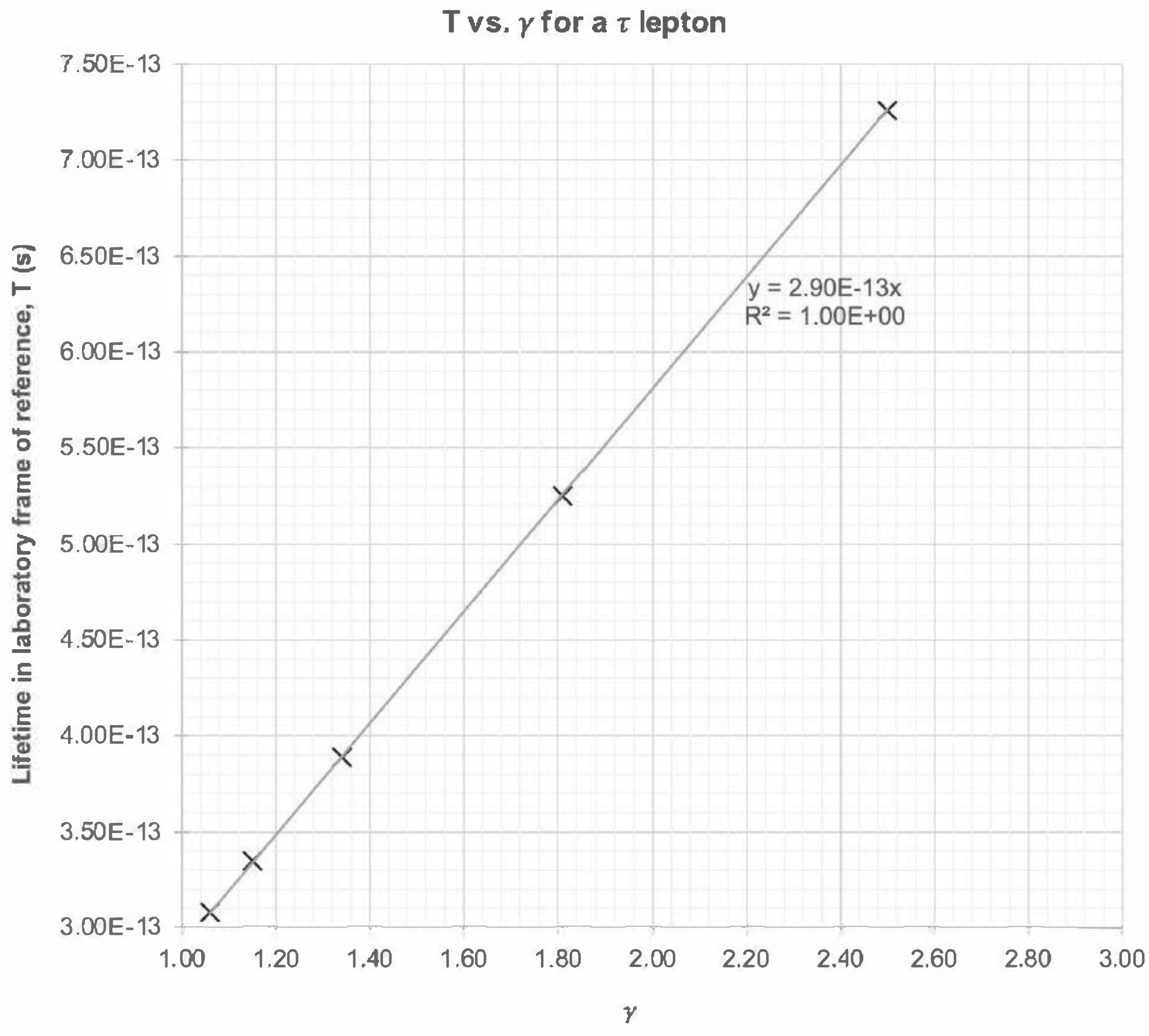
Notes from the Marker

- Most students were able to correctly calculate the missing value.
- Ensure that values are stated to the same number of decimal places in a column of a table.
- **Average** = 0.97/1

Question 27(b)

Marking Criteria	Marks
• Constructs a graph with: ○ an appropriate line-of-best-fit. ○ accurately plotted points using crosses. ○ correct axes labelled with units and appropriate scaling of axes. ○ at least 75% of the given space occupied.	3
• Constructs a graph that contains THREE of the features mentioned above.	2
• Constructs a graph that contains TWO of the features mentioned above.	1

Sample Response



Notes from the Marker

- Most students were able to draw an appropriate graph.
- Students are reminded to use an appropriate scale so that the graph occupies a significant portion of the provided grid.
- **Average** = 2.12/3

Question 27(c)

Marking Criteria	Marks
• Correctly calculates the rest lifetime of the tau lepton using the graph with appropriate units.	2
• Calculates the rest lifetime of the tau lepton using the graph but makes ONE error.	1

Sample Response

The lifetime of the tau lepton can be deduced by using:

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$t_0 = t\sqrt{1 - \frac{v^2}{c^2}}$$

The above expression is equivalent to the gradient of the line.

Using the graph and two data points:

$$m = \frac{(7.1 - 3.6) \times 10^{-13}}{2.45 - 1.25}$$

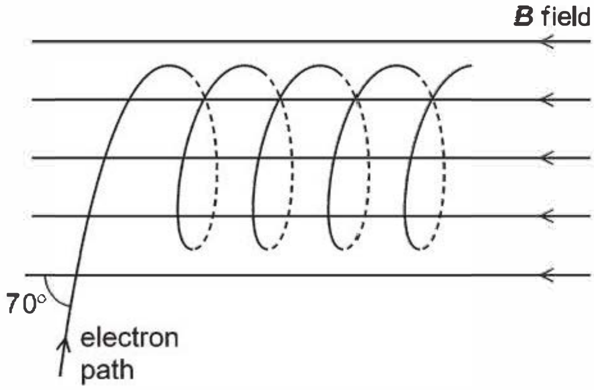
$$= 2.92 \times 10^{-13}\ \text{s}$$

Notes from the Marker

- Students are reminded to show working by indicating the points used in the calculation of the gradient of a line by using two points which are not data points that lie on the best fit that are well spaced apart to minimise the effects of uncertainties in reading points off the graph.
- Some students who tried to use extrapolation were unsuccessful as they tried to do this when $\gamma = 0$ when $\gamma = 1$ when v = 0 m s^{-1}. Those who did use the case where $\gamma = 1$, did this inaccurately due to the limitations involved with the scaling of the graph.
- Some students made careless errors by forgetting the $\times 10^{-13}$ s in their calculation and are reminded that this needs to be included in their working out.
- **Average** = 0.70/1

Question 28 (8 marks)

An electron travelling at 8.0×10^6 m s^{-1} enters a uniform magnetic field, at an angle of 70° to the field. The electron moves in a helical path as shown in the diagram below.



(a)	Calculate the component of the electron's initial velocity that is perpendicular to the magnetic field.	**1**
(b)	Calculate the component of the electron's initial velocity that is parallel to the magnetic field.	**1**
(c)	Outline why the electron moves in the helical path.	**1**
(d)	Given that the magnetic flux density of the field is 0.015 T, calculate the radius of the loop of the helical path.	**2**
(e)	Calculate the distance between two adjacent loops in the helical path.	**3**

Question 28(a)

Marking Criteria	Mark
• Correctly calculates the component of the electron's initial velocity that is perpendicular to the magnetic field.	1

Sample Response

$$v_{\perp} = v\sin\theta$$
$$= 8.0 \times 10^6 \times \sin 70°$$
$$= 7.5 \times 10^6 \text{ m s}^{-1}$$

Notes from the Marker

- Most students were able to correctly calculate the velocity component perpendicular to the magnetic field.
- Students are reminded to draw a vector diagram and to resolve vectors into components to assist in their interpretation of the question.
- **Average** = 0.86/1

Question 28(b)

Marking Criteria	Mark
• Correctly calculates the component of the electron's initial velocity that is parallel to the magnetic field.	1

Sample Response

$$v_{\parallel} = v\cos\theta$$

$$= 8.0 \times 10^{6} \times \cos 70°$$

$$= 2.7 \times 10^{6}\ \text{m s}^{-1}$$

Notes from the Marker

- Most students were able to correctly calculate the velocity component parallel to the magnetic field.
- Students are reminded to draw a vector diagram and to resolve vectors into components to assist in their interpretation of the question.
- **Average** = 0.89/1

Question 28(c)

Marking Criteria	Mark
• Relates the helical path to acceleration/force experienced perpendicular to the field and the constant velocity parallel to the field.	1

Sample Response

The electron will undergo uniform circular motion perpendicular to the field due to the magnetic force and moves at a constant velocity parallel to the field as it experiences no force in this direction. The combination of these motions results in a helical trajectory.

Notes from the Marker

- Better responses were able to correctly account for the circular loops produced as a result of the magnetic force due to $v_{\perp}$ providing the centripetal force and relate the horizontal motion due to the component of the $v_{//}$ to the magnetic field. The vector sum of the two velocity vectors results in the helical motion of the electron.
- Weaker responses generally only accounted for the circular motion of the electron.
- **Average** = 0.62/1

Question 28(d)

Marking Criteria	Marks
• Correctly calculates the radius of the loop by equating the centripetal force with the magnetic force.	2
• Calculates the radius of the loop but makes ONE error.	1

Sample Response

The charge experiences uniform circular motion perpendicular to the field due to the magnetic force.

Hence:

$$F_c = F_B$$

$$\frac{mv_{\perp}^{2}}{r} = qv_{\perp}B$$

$$\frac{9.109\times 10^{-31}\times \left(7.5\times 10^{6}\right)^{2}}{r} = 1.602\times 10^{-19}\times 7.5\times 10^{6}\times 0.015$$

$$r = \frac{9.109\times 10^{-31}\times 7.5\times 10^{6}}{1.602\times 10^{-19}\times 0.015}$$

$$= 2.8\times 10^{-3}\ \text{m}$$

Notes from the Marker

- Better responses were able to structure their calculations by stating the conditions required for uniform circular motion to occur as a result of the constant magnetic force experienced by the electron and used $v_{\perp}$ in their calculation.
- Weaker responses substituted v and tried to unsuccessfully to substitute $\theta = 70°$ into $qvB\sin\theta$ for their calculation.
- **Average** = 1.45/2

Question 27(e)

Marking Criteria	Marks
• Correctly calculates the distance between two loops by determining the: ○ length of the path taken by the charge ● time taken by calculating period using $v_\perp$ ○ distance between two loops using $v_{//}$	3
• Calculates the distance between two loops with ONE error.	2
• Calculates the distance between two loops with TWO errors.	1

Sample Response

Since the charge is travelling in a circular path perpendicular to the magnetic field:

$$v_\perp = \frac{s}{t}$$

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

$$7.5\times 10^6 = \frac{2\pi\times 2.8\times 10^3}{T}$$

$$T = \frac{2\pi\times 2.8\times 10^3}{7.5\times 10^6}$$

$$= 2.3\times 10^{-9}\ \text{s}$$

Hence, the distance of two loops can be described by:

$$v_\parallel = \frac{s}{t}$$

$$2.7\times 10^6 = \frac{s}{2.3\times 10^{-9}}$$

$$s = 2.7\times 10^6\times 2.3\times 10^{-9}$$

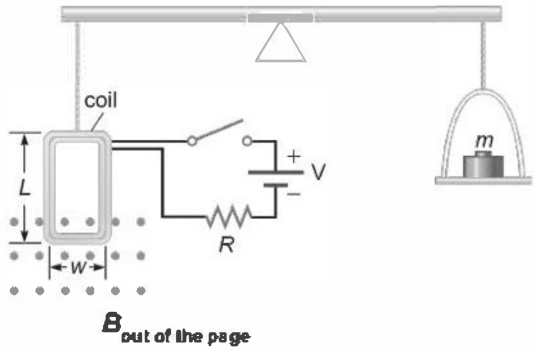
$$= 6.2\times 10^{-3}\ \text{m}$$

Notes from the Marker

- Better responses were able to use the appropriate velocity components in each part of the calculation and were able to demonstrate a logical approach through clearly structuring their working out.
- Weaker responses used the incorrect components of velocity and failed to relate their knowledge of motion of charged particles in uniform magnetic fields and uniform circular motion to calculate the relevant quantities.
- **Average** = 1.69/3

Question 29 (4 marks)

A student was to use the following apparatus to measure the magnetic flux density, ***B***, of a magnet.



The student made the following notes:

- The left-hand and right-hand sides of the balance are equidistant from the fulcrum.
- The rectangular coil of wire consisting of N turns has a width w and length L and has a mass M.
- The coil is attached to one arm of a balance and is suspended between the poles of a magnet. The magnetic field is uniform and perpendicular to the plane of the coil.
- The system is first balanced when the current in the coil is zero.
- When the switch is closed and the coil carries a current I, a mass m must be added to the right side to balance the system. Once the system is balanced, the magnetic flux density of a magnet can be determined.

(a) Derive an expression for the magnitude of the magnetic flux density, ***B***. **3**

(b) Why is the result in part (a) independent of the length of the coil? **1**

Question 29(a)

Marking Criteria	Marks
• Correctly derives the relationship with appropriate logic.	3
• Partially derives the relationship by showing some correct steps or reasoning.	2
• Provides some relevant information.	1

Sample Response

When the current is on, the rectangular coil experiences a force. In order for no motion to occur about the fulcrum, the magnitudes of the torques must be equal:

$$\tau_{anticlockwise} = \tau_{clockwise}$$

$$F_B d = F_g d$$

$$NBIw\sin\theta d = mgd$$

$$B = \frac{mg}{NIw} \text{ (since } \sin 90^\circ = 1)$$

Notes from the Marker

- Better responses were able to derive the relationship by clearly and logically stating assumptions made in their derivation and had evidently read the stimulus carefully.
- Weaker responses confused M and m and made careless mistakes such as not noting that the coil consisted of N turns.
- **Average** = 1.68/3

Question 29(b)

Marking Criteria	Mark
• Outlines appropriate reasoning to account for the independence of the length of the coil in the derived equation from (a).	1

Sample Response

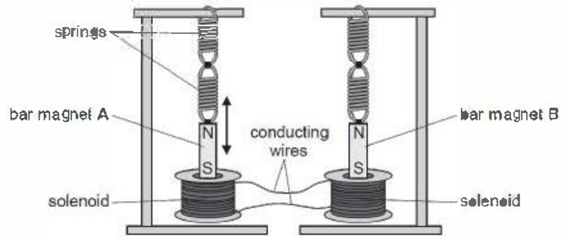
The result in (a) is independent of *L* as the two sides experience equal but opposing forces on the coil, thus leading to a net force of zero on the coil in the horizontal direction and hence provides no forces which would contribute to torque about the fulcrum.

Notes from the Marker

- Better responses were able to explain why L was not included with reference to forces and annotated the stimulus provided.
- Weaker responses stated that L was not in the magnetic field and this was not a correct interpretation of the stimulus.
- **Average** = 0.45/1

Question 30 (4 marks)

Two identical bar magnets are suspended from identical springs, with the south pole of each magnet inside a solenoid as shown in the diagram below. The two coils are connected together with conducting wires. **4**



Magnet **A** is displaced so that it oscillates vertically with the south pole of magnet **A** moving into and out of the coil of wire. As this motion continues, magnet **B** starts to oscillate vertically. The amplitude of oscillation of magnet **B** increases over time.

Using physics principles, account for the increase in amplitude of oscillation of magnet **B** over time.

Marking Criteria	Marks
• Account for the increasing amplitude of magnet B with reference to the: ○ movement of bar magnet A and B and the induced emf and current with specific analysis using Lenz's and Faraday's law in a closed loop ○ force experienced by bar magnet B as a result of the induced current • change in flux created as a result of the movement of magnet B ○ resonance occurring due to the same period/frequency of the springs and their subsequent changes in flux.	4
• Account for the increasing amplitude of magnet B with reference to THREE of the above features	3
• Account for the increasing amplitude of magnet B with reference to TWO of the above features.	2
• Provides some relevant information.	1

Sample Response

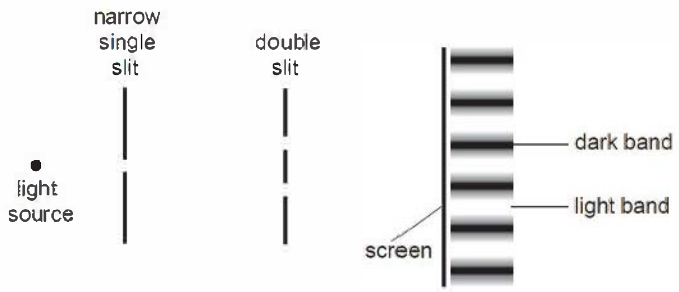
As magnet A moves downwards, the solenoid experiences an increase in magnetic flux linkage. By Faraday's law, the change in magnetic flux linkage induces an emf in the solenoid directly below magnet A. Using Lenz's law, it can be deduced that this occurs in an anticlockwise direction as viewed from above due to the approaching south pole. As the solenoids are linked in a closed loop, the induced emf causes an anticlockwise current in both solenoids. The current in the second coil causes a repulsive force to act on magnet B, driving magnet B into oscillation. This results in magnet B causing a change in flux in the solenoid directly below it, thus causing changes in the magnetic flux, inducing an emf and hence current in the closed loop. Because both mass-spring systems have the same period/frequency, resonance occurs and magnet B will oscillate with increasing amplitude.

Notes from the Marker

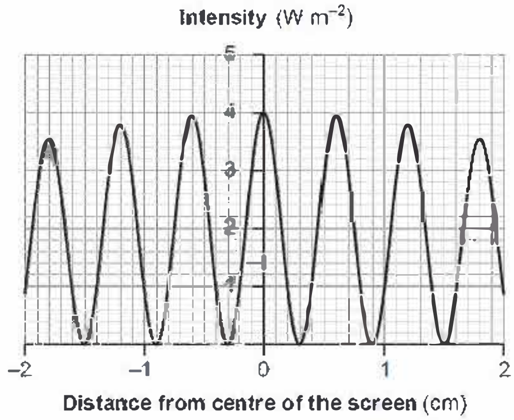
- Better responses were able to synthesise Lenz's and Faraday's laws with reference to force and resonance to interpret why magnet B will increase its amplitude of oscillation and specifically engaged with the stimulus. These were written in a logical and coherent manner.
- Weaker responses did not specifically engage with the stimulus and were broad and vague.
- Link: https://serc.carleton.edu/introgeo/demonstrations/examples/48755.html
- **Average** = 2.09/4

Question 31 (7 marks)

The diagram shows a monochromatic light source of wavelength λ, slits and a screen arranged for an experiment on light. Light and dark bands form on the screen.



The distance from the double slit to the screen is 3.2 m and the separation of the two slits is 0.39 mm. The graph shows how the intensity of the light on the screen varies with distance from the centre of the screen.

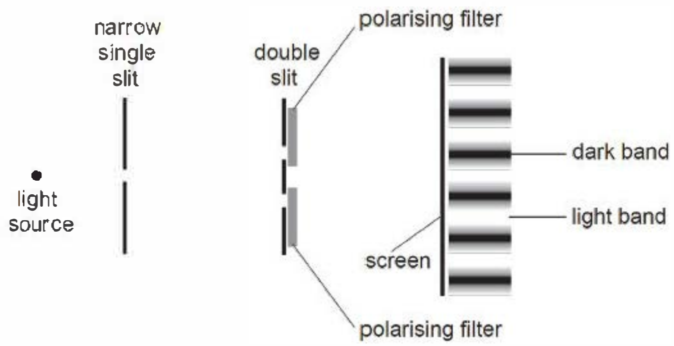


(a) Determine the wavelength of the light. **2**

(b) The red light is replaced by blue light. **2**

Predict what (if anything) will happen to the separation of the bright fringes on the screen. Justify your answer.

(c) Polarising filters are placed relative to the slits as shown. When the planes of the polarising filters are parallel to the slits, the pattern of light and dark bands is still seen as shown below. **3**



If one polarising filter is rotated through 90°, there are no dark bands and the screen is illuminated evenly.

Explain why there are no dark bands when one filter has a plane of polarisation that is 90° to that of the other filter.

Question 31(a)

Marking Criteria	Marks
• Correctly calculates the wavelength of light.	2
• Calculates the wavelength of light with ONE error.	1

Sample Response

For m = 1:

$$x = \frac{\lambda L}{d}$$

$$0.39 \times 10^{-3} = \frac{\lambda \times 3.2}{0.6 \times 10^{-2}}$$

$$\lambda = 731 \text{ nm}$$

Notes from the Marker

- Better responses were able to calculate the wavelength using all of the information given in the question.
- Weaker responses demonstrated a lack of understanding of the formulae involved for the double slit experiment.
- **Average** = 1.06/2

Question 31(b)

Marking Criteria	Marks
• States that blue light has a shorter wavelength than red light and deduces that the fringe spacing will decrease. • Uses a elevant formula to justify response to show that wavelength is directly proportional to fringe spacing.	2
• States that blue light has a shorter wavelength than red light and deduces that the fringe spacing will decrease.	1

Sample Response

Blue light has a shorter wavelength as compared to red light. Hence, by using the formula:

$$x = \frac{\lambda L}{d}$$

where x is the fringe spacing and λ is the wavelength of light, x is directly proportional to λ and hence the distance between bright fringes will decrease.

Notes from the Marker

- Better responses were able to relate and use appropriate formula/formulae to deduce the impact of changing the wavelength. Students are reminded to use appropriate terminology to describe the relationship between variables.
- **Average** = 1.14/2

Question 31(c)

Marking Criteria	Marks
• Accounts for the observation with reference to THREE of the following features: ○ Identifies the nature of the light emerging from the single slit ● Correctly relates the orientation of the filters to the plane of polarisation of the light. ○ Relates the inability for the waves to interfere due to differing planes of polarisation to the observation.	3
• Partially accounts for the observation with reference to some of the above features.	2
• Provides some relevant information.	1

Sample Response

When light passes through the narrow single slit, the light becomes coherent. When this light encounters the double slit, two situations will arise based on the orientation of the light relative to the slits:

- The plane of polarisation of the light source that is parallel to the filter and slit will allow light to be transmitted through.
- The filter on the other slit will absorb light in the plane of polarisation that is perpendicular to the filter and lead to no light being transmitted.

As the light emerging from the two slits after passing through the filters are not in the same plane, they are unable to undergo interference. Hence, destructive interference does not occur to create areas containing dark bands.

Notes from the Marker

- Better responses were able to calculate the wavelength using all of the information given in the question.
- Weaker responses demonstrated a lack of understanding of the formulae involved for the double slit experiment.
- **Average** = 1.89/2

Question 32 (7 marks)

In the 19th and 20th centuries, our understanding of the nature of light has changed as debates regarding its wave and particle nature were challenged by experimental observations. **7**

Use this as an example to explain how scientists test and validate models.

Criteria	Marks
• Describes models of light over time with extensive reference to how evidence over time has facilitated changes in our understanding of the nature of light. • Makes reference to ALL of the following: Newton's model, Huygens' model, Young's double slit experiment, Planck's interpretation of the UV catastrophe, observations from the photoelectric effect and Einstein's wave-particle duality interpretation of light. • Relates changes in understanding of light to explain how evidence is used to validate, refine or refute models over time. • Response is written in a coherent, logical and sequential manner.	6-7
• Describes models of light over time with reference to how evidence over time has facilitated changes in our understanding of light. • Makes reference to MOST of the following: Newton's model, Huygens' model, Young's double slit experiment, Planck's interpretation of the UV catastrophe, observations from the photoelectric effect and Einstein's wave-particle duality interpretation of light. • Relates changes in understanding of light to explain how evidence is used to validate, refine or refute models over time. • Response is written in a coherent, logical and sequential manner.	4-5
• Describes models of light over time with some reference to how evidence over time has facilitated changes in our understanding of light. • Makes reference to SOME of the following: Newton's model, Huygens' model, Young's double slit experiment, Planck's interpretation of the UV catastrophe, observations from the photoelectric effect and Einstein's wave-particle duality interpretation of light.	2-3
• Provides some relevant information.	1

In the 19th century, there were two competing views of the model of light. Isaac Newton's particle model of light described light made of corpuscles which varied in size depending on the colour of the light. Huygens' model described light as being a wave. Whilst both models offered explanations for light phenomena such as reflection and refraction, no conclusive evidence was available until Young's double slit experiment showed that light diffracts when passing through a slit. This was evident in the interference patterns produced which are consistent with wave nature of light. This supported Huygens' wave model of light and thus Newton's particle model was invalidated and replaced with the classical wave model.

In the 19th century, experiments involving blackbody radiation were done and were unable to be accounted for by the classical wave model. Attempts using the Rayleigh-Jean law were unsuccessful as it had predicted that hotter objects would keep radiating energy indefinitely towards the ultraviolet end of the EM spectrum. Planck's approach of quantisation where different wavelengths were radiated as discrete packets of energy in differing amounts was able to match the experimental curve and thus demonstrated that the classical model was insufficient.

Furthermore, the photo-electric effect was observed and was not able to be explained using the classical model of light. The photo-electric effect is the emission of electrons from a metal when light above a certain frequency is incident upon the metal. A classical model would suggest that intensity, not frequency, is related to electron ejection. Also, electron emission was almost spontaneous, where the classical wave model would predict that emission should occur after some time so as to allow energy to build up.

In 1905, Albert Einstein was able to explain the photo-electric effect by using a particle model of light, where light was made up of packets of energy called photons. These photons would collide with electrons and would eject the electrons if they possessed enough energy, where energy is proportional to frequency.

The new evidence supported the particle model of light but since a wave model was appropriate to describe other light phenomena, such as diffraction, a new particle-wave model was adopted. This model indicates that light can behave as both a particle and a wave depending on the scenario. Thus, over time the emergence of new evidence regarding the nature of light has forced the scientific community to continually reassess the model of light.

Notes from the Marker

- Better responses were able to use the changes in the wave and particle models of light as a means of explaining the role of evidence in the validation of models and integrated this well. Specific details regarding models and how observations and evidence supported or refuted them were required to clearly address the question. These responses were evidently planned and showed a logical progression.
- Weaker responses did not provide enough detail or ignored the stimulus and simply addressed the question as a “changes in the understanding of light over time” type of question.
- **Average** = 4.11/7

S2C	**Section 2C (20 marks)** Written Response

Marks

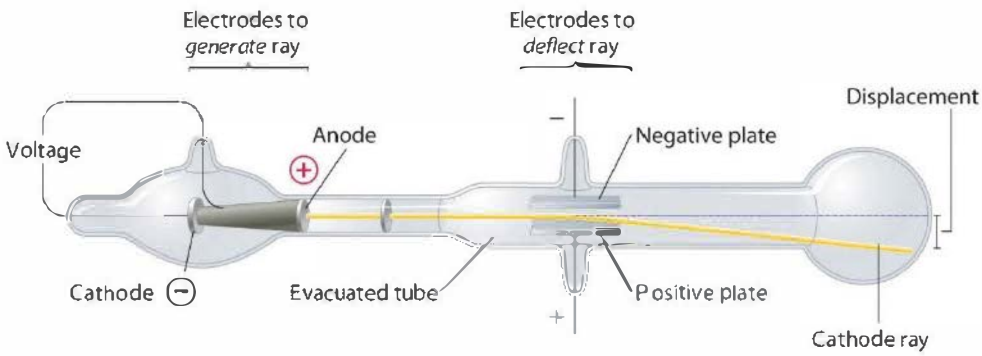
Question 33 (5 marks)

In 1897, J.J. Thomson experimentally measured the charge to mass ratio of the electron. **5**

Use an annotated diagram to describe how Thomson's experiment can be performed.

Answer:

Thomson measured the mass-to-charge ratio of the cathode rays by measuring how they were deflected by a magnetic field (path became circular) and compared this with the deflection in an electric field. To determine the magnetic deflection, he placed the discharge tube between the poles of a large electromagnet. He then equated the electric and magnetic fields to algebraically solve for the charge-to-mass ratio, $q/m = E/B^2r$, using the observable quantities measured from his experimental set-up, namely E, B, and r, the radius of the circular path.



Marking Scale:

- Detailed annotated diagram, showing at least the direction of cathode rays, and orientation of electric and magnetic fields (2 marks)
- Diagram with some relevant information (1 mark)

- Detailed description of Thomson's experiment, using appropriate equations to show that the q/m ratio depends on OBSERVABLE quantities, namely E, B and r (radius of circular path);

  $q/m = E/B^2r$ (3 marks)

- Detailed description using appropriate equations to show how the q/m ratio depends on the quantities E, B and v (not measurable), OR an adequate description with equation as above (2 marks)

- Qualitative answer only giving general description of experiment (1 mark)

Marks

Question 34 (8 marks)

In 1913, Neils Bohr proposed a model of the hydrogen atom that explained the formation of spectral lines.

(a) Describe Bohr's model of the atom and explain how it accounted for the formation of spectral lines. **4**

- Sample answer:

Bohr modified Rutherford's atom to have electron(s) orbiting the nucleus in discrete energy levels, i.e the energy levels are quantised. Each level had a specific value of quantised angular momentum and the electrons within each energy level did not radiate electromagnetic radiation (EMR).

Energy was either absorbed or emitted from the atom when electrons moved between energy levels. If electrons jumped down towards the ground state, a photon was emitted with an energy, $\Delta E = hf = |E_f - E_i|$.

Electrons would jump only to a higher orbit only by absorbing a photon with the exact energy corresponding to an energy difference between levels.

Marking Scheme:

- Detailed answer describing Bohr's model (using his postulates) AND describing how the model accounted for BOTH emission and absorption lines) (4 marks)
- Answer with less detail on Bohr's model OR a detailed answer that only described the formation of spectral lines in general (3 marks)
- Answer with less detail on Bohr's model AND a general description of spectral line formation (2 marks)
- Provides some relevant information (1 mark)

(b) Outline two shortcomings of Bohr's atomic model. **2**

Brief outline of two of the following shortcomings (1 mark each):

- Model only works for hydrogen or hydrogen-like ions;
- Model couldn't explain observed intensities of spectral lines;
- Model doesn't account for presence of hyperfine spectral lines;
- Model cannot account for the splitting of lines in a strong magnetic field (Zeeman effect);
- Model cannot explain why, following Maxwell, EMR is not radiated away, collapsing the atom;
- model is an ad-hoc mixture of classical and quantum physics.

(c) Calculate the wavelength of the violet H-delta emission line, produced from an electron transition from the sixth to the second energy level in the hydrogen atom. **2**

$1/\lambda = 1.097 x 10^{-7} \times (1/2^2 - 1/6^2)$

$1/\lambda = 1.097 x 10^{-7} \times (1/2^4 - 1/36)$

--> λ = 4.10 x 10^{-7} m

Correctly uses Rydberg equation to calculate λ = 4.10 x 10^{-7} m or 410 nm (2 marks)

Incorrect application of formula, or answer has substitution/calculation error (1 mark)

Marks

Question 35 (3 marks)

An atom of carbon-12 contains 6 protons and 6 neutrons in its nucleus. The mass of a carbon-12 atom is 12.000 atomic mass units. **3**

Calculate the mass defect of one carbon-12 atom. Quote your answer in atomic mass units (u) and assume that the mass of the electrons is negligible.

Mass of ^{12}C atom = 12.000 u = 1.9932×10^{26} kg

Mass of individual nucleons = $6 \times 1.675 \times 10^{-27}$ kg + $6 \times 1.673 \times 10^{-27}$ kg = 2.0088×10^{-26} kg

Mass defect = mass of nucleons – atomic mass of ^{12}C = 1.56×10^{-28} kg = 0.09392 u (4 sig .fig.)

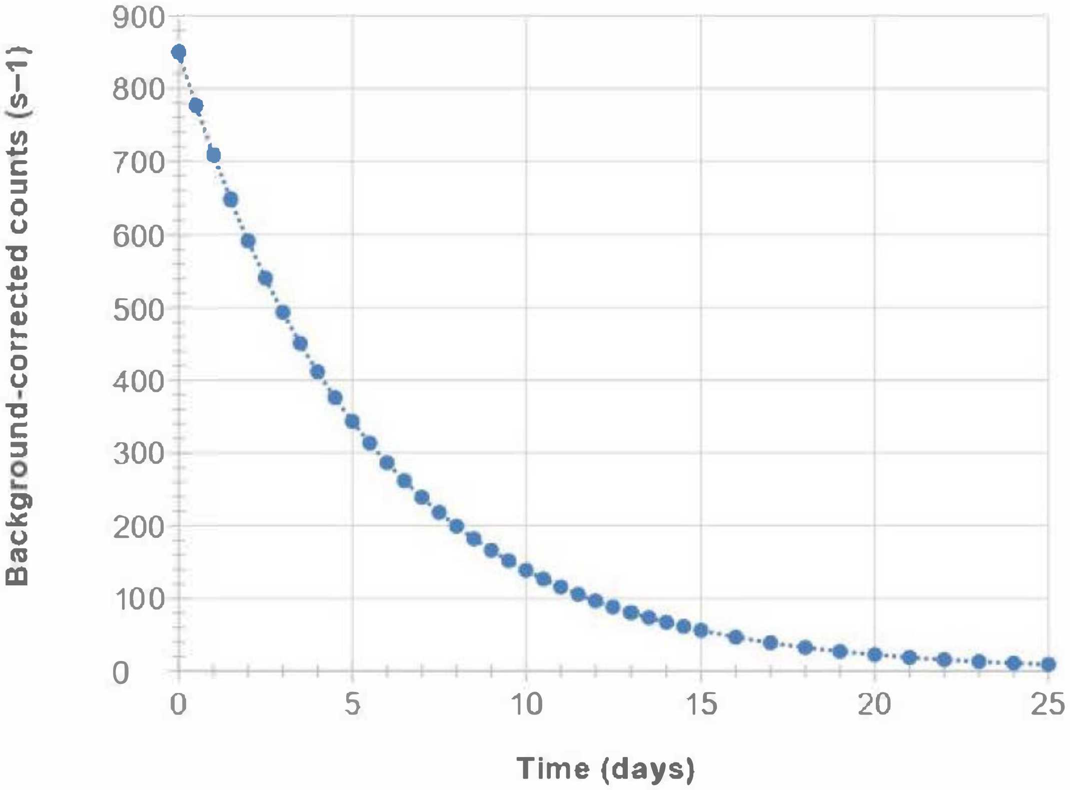
Thankfully, this question was NOT marked for sig figs. Student answers ranged from 2 to 10 significant figures!

- Correct answer with full working (3 marks)
- Mass defect given in kg, OR correct approach with calculation/substitution error (2 marks)
- Some relevant information (1 mark)

Marks

Question 36 (4 marks)

The following graph shows the decay of an unknown radioactive isotope.



(a) Use the graph to determine to find the decay constant (λ) of the isotope in s^{-1}. Show all working. 3

From graph, $T_{1/2} = 3.8 \pm 0.3$ d

$T_{1/2} = 328320$ sec

$\lambda = \ln(2) / T_{1/2} = 0.693 / 328320$

$\lambda = 2.1 \times 10^{-6}\ s^{-1}$

Correct answer with working (3 marks)

Correct working, but with answer in day^{-1} (2 marks)

Some appropriate working (1 mark)

(b) Further experiments identified the isotope to be an alpha emitter, forming the daughter nuclide polonium-218. 1

Write a nuclear equation for the decay of this isotope.

86222*Rn* 84218*Po* + 24*He* + energy