NESA STUDENT NUMBER

2021

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 **45 marks**

- Attempt Questions 21–26

Section 2B – Written Response **25 marks**

- Attempt Questions 27–31

Section 2C – Written Response **10 marks**

- Attempt Questions 32–33

NESA STUDENT NUMBER

S1

Section 1

20 marks

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

Question 1 (1 mark)

A stone of mass *m* is thrown upward at a 25° to the horizontal.

At the instant the stone reaches its highest point, why is the vertical component of the velocity zero?

(A) The acceleration of the stone at that instant is zero.

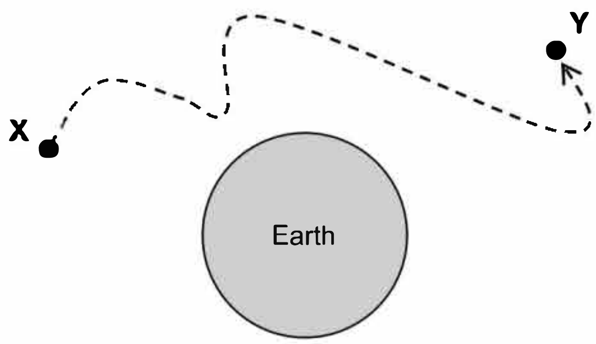
(B) The net force acting upon the stone at that instant has magnitude *mg*.

(C) The stone's kinetic energy has been converted to gravitational potential energy.

(D) The stone has no net force acting on it at the highest point.

Question 2 (1 mark)

A spacecraft travels from point **X** to point **Y** in the Earth's gravitational field along the path shown.



Which of the following is equal to the work done by gravitational force on the spacecraft along the given path?

(A) The change in gravitational potential energy between points **X** and **Y**.

(B) The change in kinetic energy between points **X** and **Y**.

(C) The change in total mechanical energy between points **X** and **Y**.

(D) No work is done by the gravitational force between points **X** and **Y**.

Question 3 (1 mark)

Which of the following quantities does NOT affect the magnitude of the escape velocity?

(A) The mass of the planet.

(B) The mass of the object being projected.

(C) The radius of the planet.

(D) The universal gravitational constant.

NESA STUDENT NUMBER

Question 4 (1 mark)

When a white light is passed through a gas:

(A) all the light is absorbed by the gas.

(B) an emission spectrum is produced.

(C) an absorption spectrum is produced.

(D) electrons are energised and produce light.

Question 5 (1 mark)

What is the meaning of the term redshift in astronomical studies?

(A) The time when a star moves from the main sequence to be a red giant.

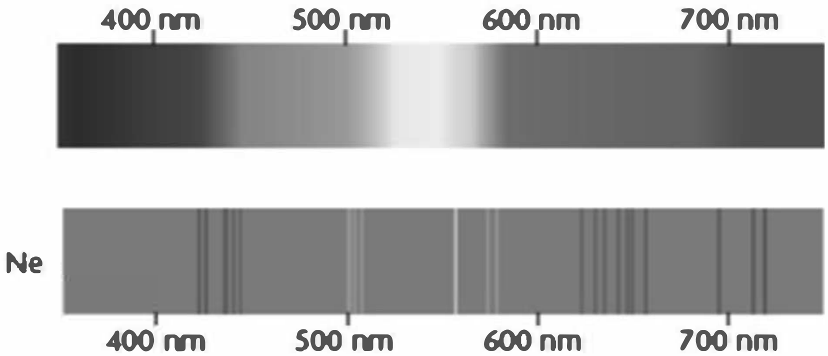
(B) The increase in wavelength of the light from a distant galaxy moving away from Earth.

(C) The red filter used by astronomers to analyse the light from the distant stars.

(D) The increase in frequency of the light from a distant galaxy moving away from us.

Question 6 (1 mark)

In the emission spectrum of neon (Ne) shown, which lines represent the highest energy light?



(A) The lines near 400 nm.

(B) The lines near 500 nm.

(C) The lines near 600 nm.

(D) The lines near 700 nm.

Question 7 (1 mark)

A FM radio station transmits at a frequency of 102.8 MHz.

What is the energy of each photon emitted by the transmitter?

(A) 6.446×10^{-42} J

(B) 6.812×10^{-26} J

(C) 2.918 J

(D) 3.084×10^{16} J

NESA STUDENT NUMBER

Question 8 (1 mark)

The life cycle of a star after the protostar period depends on the size or mass of the star.

A particular star is the same size as the Sun.

What is the order of stages, after the protostar, in the life cycle of this star?

(A) Main sequence, red supergiant, white dwarf, black dwarf.

(B) Main sequence, red giant, black dwarf, white dwarf.

(C) Main sequence, red supergiant, black dwarf, white dwarf.

(D) Main sequence, red giant, white dwarf, black dwarf.

Question 9 (1 mark)

Which of the following best describes the properties of a red giant and a white dwarf relative to Sun?

(A)

Property	Red Giant	White Dwarf
Surface temperature relative to Sun	Lower	Higher
Luminosity relative to Sun	Higher	Lower

(B)

Property	Red Giant	White Dwarf
Surface temperature relative to Sun	Lower	Lower
Luminosity relative to Sun	Higher	Higher

(C)

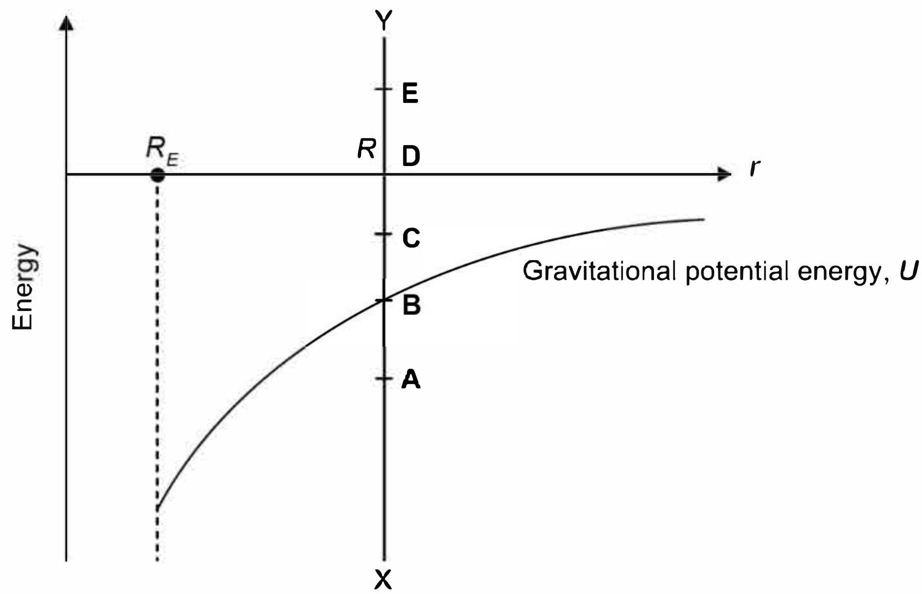
Property	Red Giant	White Dwarf
Surface temperature relative to Sun	Higher	Lower
Luminosity relative to Sun	Higher	Lower

(D)

Property	Red Giant	White Dwarf
Surface temperature relative to Sun	Higher	Lower
Luminosity relative to Sun	Lower	Higher

Question 10 (1 mark)

The following graph shows the relationship between the gravitational potential energy of a mass *m* depends on *r*.



The mass is projected vertically upwards from the Earth's surface, R_E. At a certain distance *R* from the centre of the Earth, the total energy of the body may be represented by a point on the line XY.

Five points, **A**, **B**, **C**, **D** and **E** have been marked on this line.

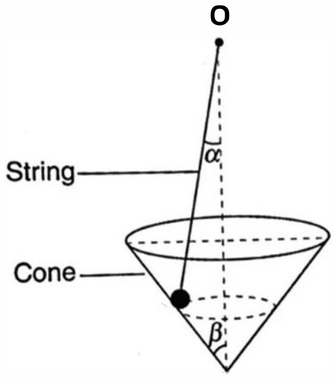
Which rows correctly identifies point(s) which could represent the total energy of the mass represented by the following scenarios?

	The mass is at the top of its trajectory	The mass is falling towards the Earth
(A)	A	C
(B)	B	C
(C)	A	D & E
(D)	B	D & E

NESA STUDENT NUMBER

Question 11 (1 mark)

A mass at the end of a string is suspended from a fixed-point **O**. The mass is in contact with the cone and moves in a horizontal circle on the inside of a cone at a constant speed.



If the tension in the string is T and the normal force by the cone is N, which of the following gives the centripetal force on the bob?

(A) $T\cos\alpha + N\sin\beta$

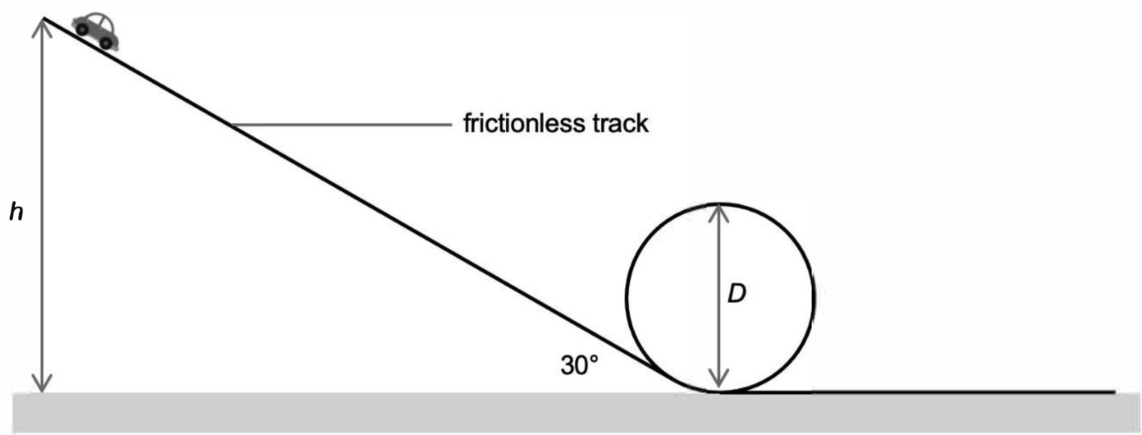
(B) $T\cos\alpha - N\sin\beta$

(C) $T\sin\alpha + N\cos\beta$

(D) $T\sin\alpha - N\cos\beta$

Question 12 (1 mark)

A toy car is released from rest at a height h on a frictionless track.



The car goes around the circular loop of diameter D without leaving the track.

What is the minimum possible value of the height ***h*** required for the car to remain on the track while going around the loop?

(A) $5D/4$

(B) $3D/2$

(C) $2D$

(D) $5D/2$

NESA STUDENT NUMBER

Question 13 (1 mark)

Unpolarised light of intensity I_0 is incident on two ideal polarising sheets on top of each other. Initially the planes of polarisation of the sheets are perpendicular.

What must be the angle between the direction of the sheets if the intensity of the transmitted light is one third the maximum intensity of the incident beam?

(A) 55°

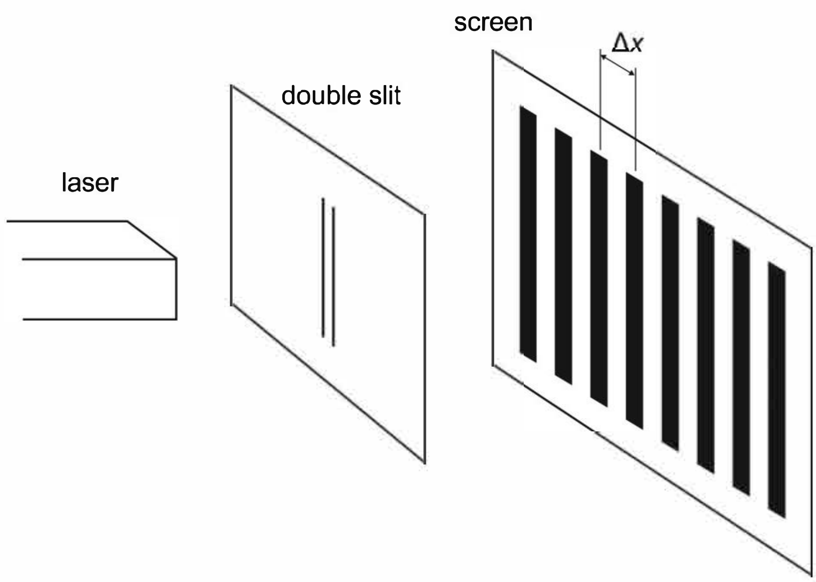
(B) 45°

(C) 35°

(D) 25°

Question 14 (1 mark)

The set-up for Young's double slit experiment is shown below. The pattern of bright and dark bands is observed on the screen.



Which one of the following actions will increase the distance, Δx, between the dark bands in this double slit interference pattern?

(A) Decreasing the slit width.

(B) Decreasing the distance of separation between the slits.

(C) Decreasing the distance between the slit and the screen.

(D) Decreasing the wavelength of the light.

Question 15 (1 mark)

An astronaut set out in a spaceship from Earth orbit to travel to a distant star I our galaxy. The spaceship travelled at a speed of $0.80c$. When the spaceship reached the star, the on-board clock showed the astronaut that the journey took 10 years.

An identical clock remained on Earth. What time had elapsed on this clock when seen from the astronaut's spaceship?

(A) 3.6 years

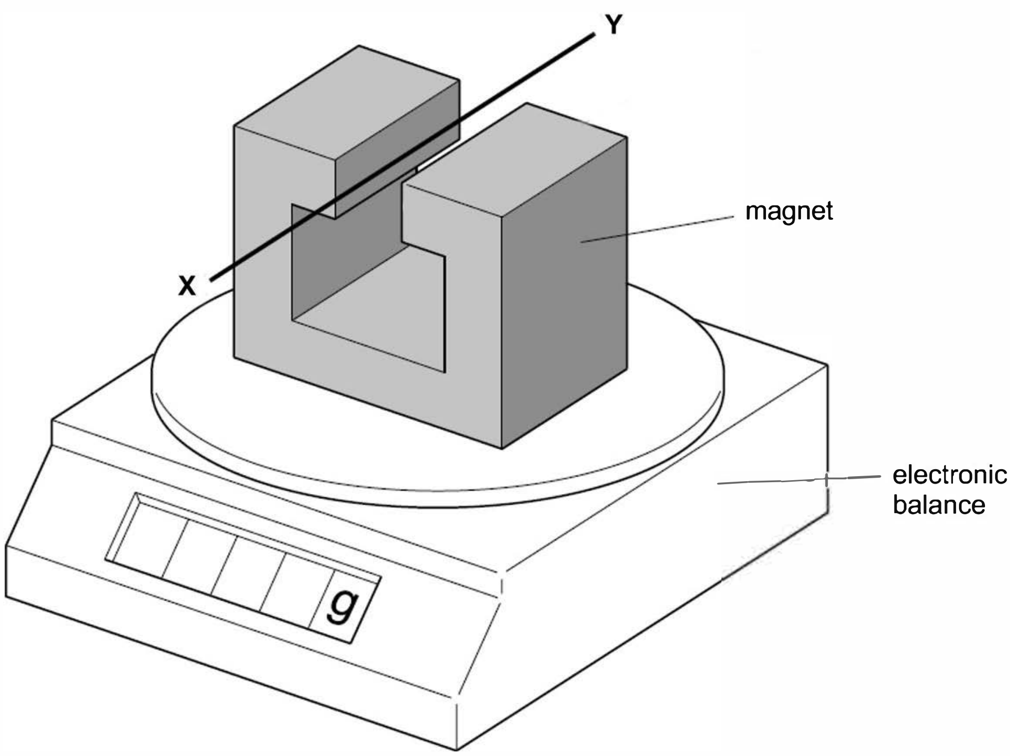
(B) 6.0 years

(C) 10.0 years

(D) 16.7 years

Question 16 (1 mark)

A horseshoe magnet rests on an electronic balance with a wire situated between the poles of the magnet.



With no current in the wire, the reading on the balance is 142.0 g.

With a current of 2.0 A in the wire in the direction **XY**, the reading on the balance changes to 144.6 g.

What is the reading on the balance, when there is a current of 3.0 A in the wire in the direction **YX**?

(A) 138.1 g

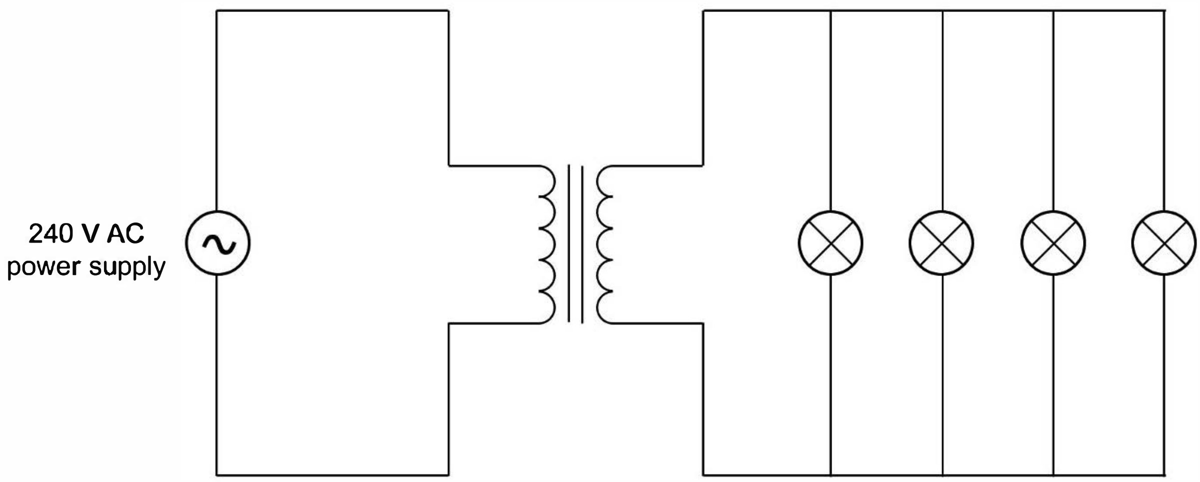
(B) 140.7 g

(C) 145.9 g

(D) 148.5 g

Question 17 (1 mark)

The primary coil of a transformer is connected to a 240 V AC power supply. Four identical lamps are connected to the secondary coil as shown below.



The lamps are rated 12 V and 24 W and are operating at normal brightness.

If the transformer is not 100% efficient, what could be the possible value of the current that can be drawn from the power supply?

(A) 0.10 A

(B) 0.20 A

(C) 0.40 A

(D) 0.45 A

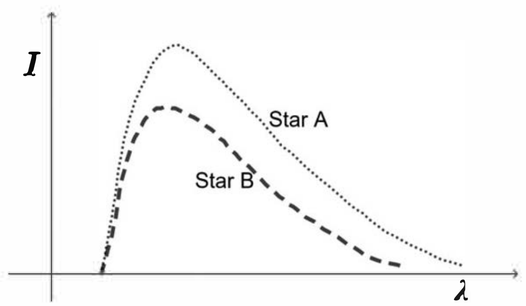
Question 18 (1 mark)

All stars emit radiation as black bodies. The radiation curves of Intensity versus wavelength are plotted for two stars, Star **A** and Star **B**.

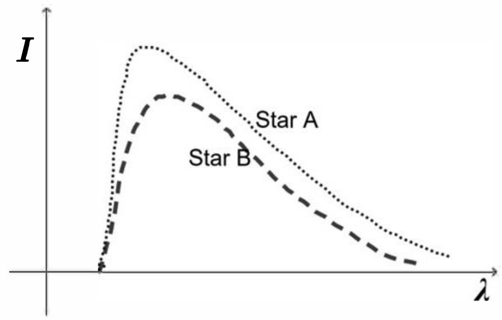
The surface temperature of Star **A** is lower than the surface temperature of Star **B**.

Which of the following graphs represents the distribution of radiation by Stars **A** and **B**?

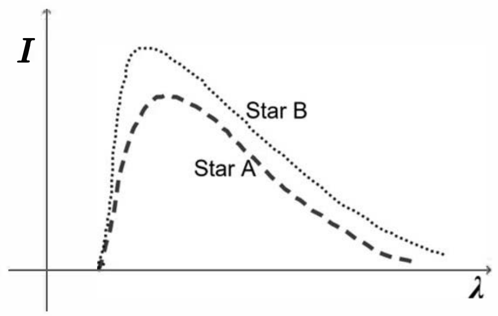
(A)



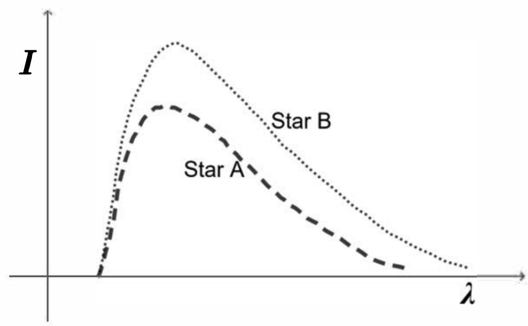
(B)



(C)



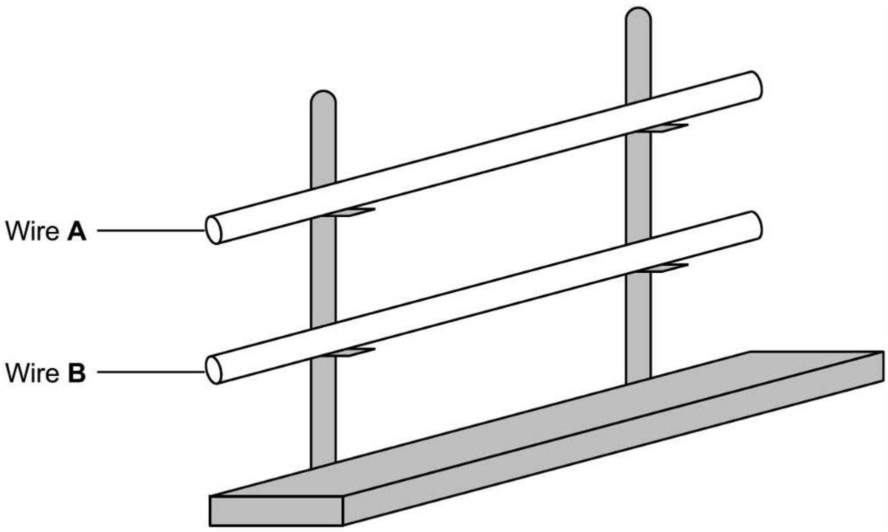
(D)



NESA STUDENT NUMBER

Question 19 (1 mark)

Two wires, **A** and **B** are arranged as shown in the diagram below. Wire **A** is free to move vertically while the wire **B** is fixed.



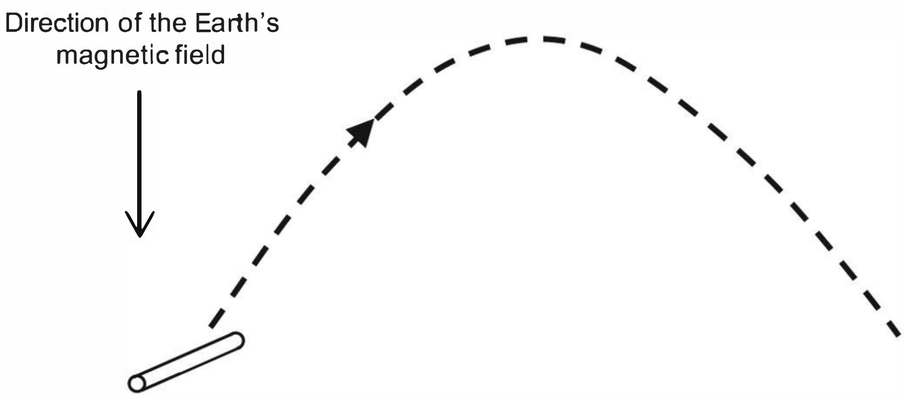
Both wires carry equal currents of 100 A and both have a mass per unit length of 20.0 g m^{-1}.

Determine the height which the wire **A** is above wire **B** and the relative directions of the currents.

	Height of wire A above wire B	Relative directions of the currents
(A)	0.0102 m	Same direction
(B)	0.102 m	Same direction
(C)	0.0102 m	Opposite directions
(D)	0.102 m	Opposite directions

Question 20 (1 mark)

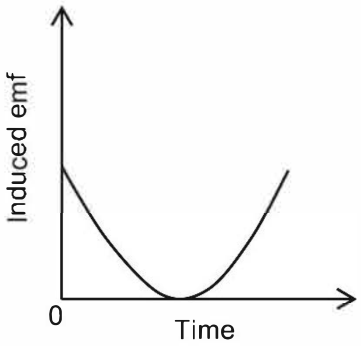
A metal rod is thrown in the air and acts as a projectile. Whilst in motion, the metal rod's long axis remains perpendicular to the Earth's magnetic field.



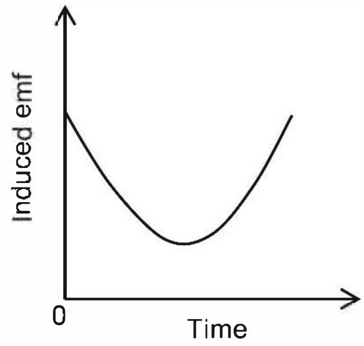
Assume that air resistance is negligible, the Earth's magnetic field is pointing downwards and is uniform throughout the rod's trajectory.

Which of the following graphs show the variation of the emf induced between both ends of the rod with time?

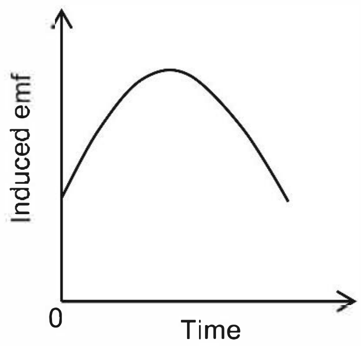
(A)



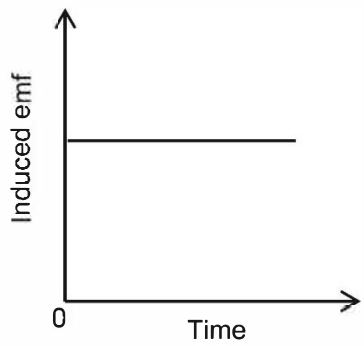
(B)



(C)



(D)



END OF SECTION 1

NESA STUDENT NUMBER

S2A

2021

Year 12 Physics

Trial Examination

Section 2A (45 marks)

Questions 21–26

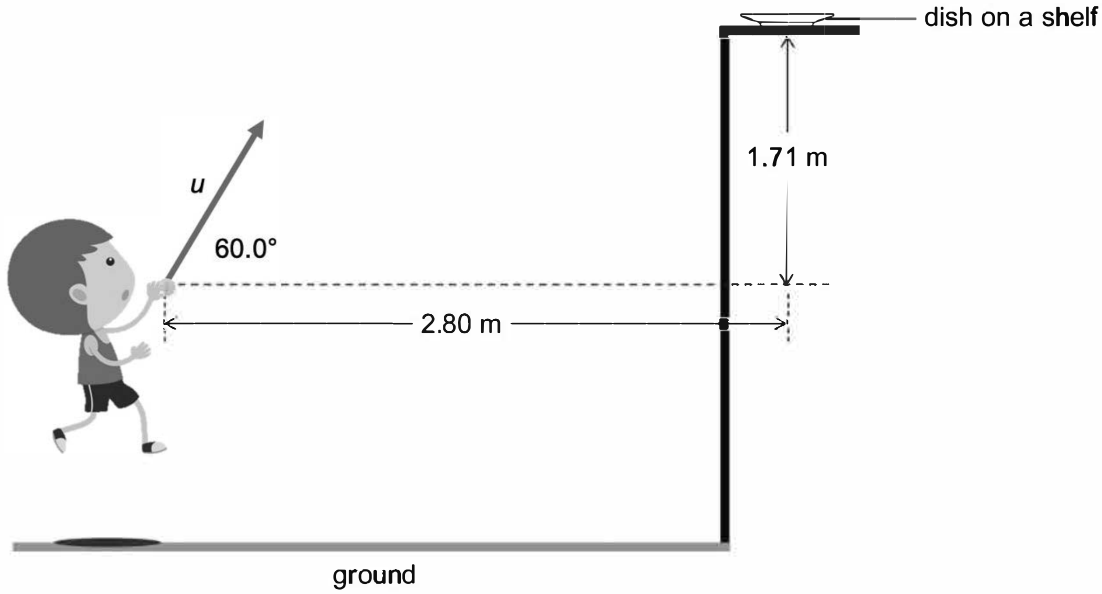
- Write using a black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

NESA STUDENT NUMBER

Marks

Question 21 (6 marks)

A game at a festival involves tossing a coin into a small dish mounted on a shelf. If the person can flick a coin into the small dish, they win a prize.



Aidan flicks the coin with an initial speed of u m s^{-1} at an angle of 60.0° to the horizontal.

When the coin leaves his hand, the horizontal distance between the coin and the dish is 2.80 m and the vertical distance from his hand to the dish is 1.71 m.

(a) Calculate the initial speed, u, required for Aidan to win a prize. **4**

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Question 21 continues on the next page

Marks

(b) Daniel suggests that if he flicks the coin so that the initial speed it greater, the coin will reach the dish more quickly and they can win prizes more efficiently. **2**

Explain why this is not the case and propose an additional change that would make his suggestion work.

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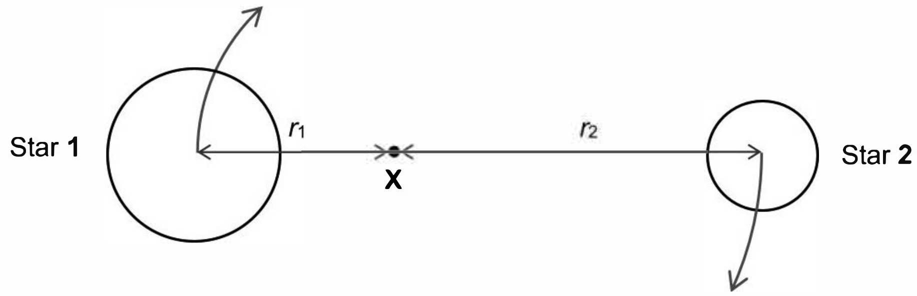
NESA STUDENT NUMBER

Marks

Question 22 (7 marks)

A binary star system consists of two stars, Star **1** and Star **2**, which orbit a fixed-point **X** as shown in the figure below.



NOT TO SCALE

Star **1** has a mass of M_1 and a circular orbit of radius r_1 about **X** while Star **2** has a mass of M_2 and a circular orbit of radius r_2 about **X**. Both stars have the same angular speed of 4.98×10^{-8} rad s^{-1} about **X**.

(a) Explain why the centripetal force acting on both Stars **1** and **2** is the same. **2**

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(b) The distance of separation between the centres of the stars is 2.8×10^8 km. **3**

Given that Star **1** is three times heavier than Star **2**, calculate r_1.

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Question 22 continues on the next page

NESA STUDENT NUMBER

Marks

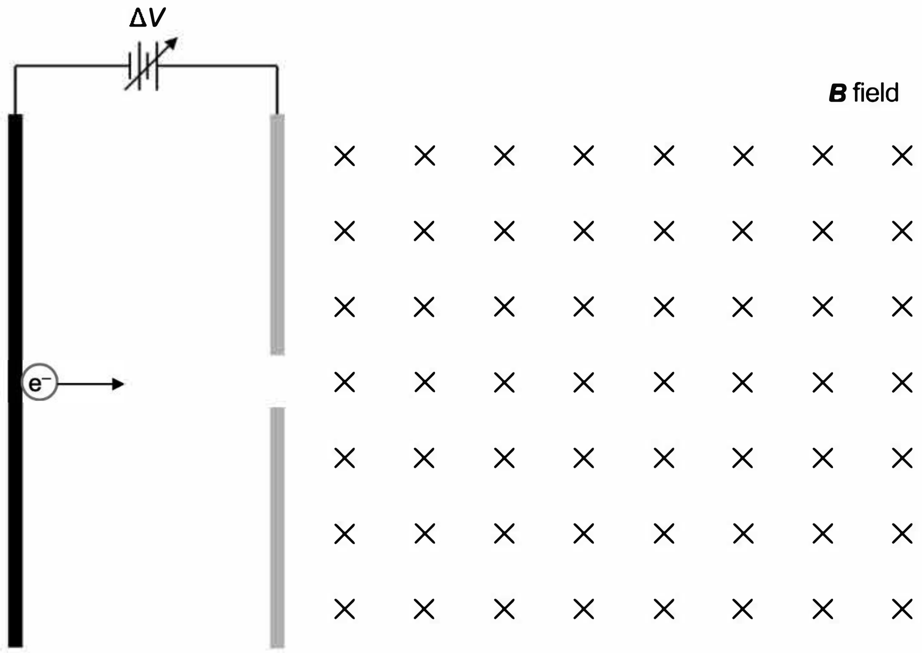
(c) Calculate the mass of Star **2**. **2**

NESA STUDENT NUMBER

Marks

Question 23 (11 marks)

A beam of electrons is accelerated across the space between two parallel plates and passes through a small opening. After passing through the opening, the electrons enter a uniform magnetic field as shown in the diagram below.



The potential difference between the plates is varied, as shown in the table below.

Potential difference (V)	Magnetic field (mT)	
60.0	2.62	
70.0	2.78	
100.0	3.39	
110.0	3.54	
120.0	3.78	
140.0	3.99	

For each potential difference, the magnetic field is varied in order to cause the beam to strike one of the grey plates at a distance of 0.020 m from the opening.

(a) Derive an expression for the speed of a charged particle as it passes through the small opening. **2**

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Question 23 continues on the next page

Marks

(b) Describe the path of the electrons after they enter the uniform magnetic field as shown in the diagram above. **2**

(c) The charge-to-mass ratio is defined as the charge of a particle divided by its mass and is measured in coulombs per kilogram. **1**

Determine the quantities that should be graphed to yield a straight line to calculate the mass-to-charge ratio of an electron by completing the table on the previous page.

(d) Plot the relevant data from (c) on the grid provided and draw a line of best fit. **3**

Question 23 continues on the next page

NESA STUDENT NUMBER

Marks

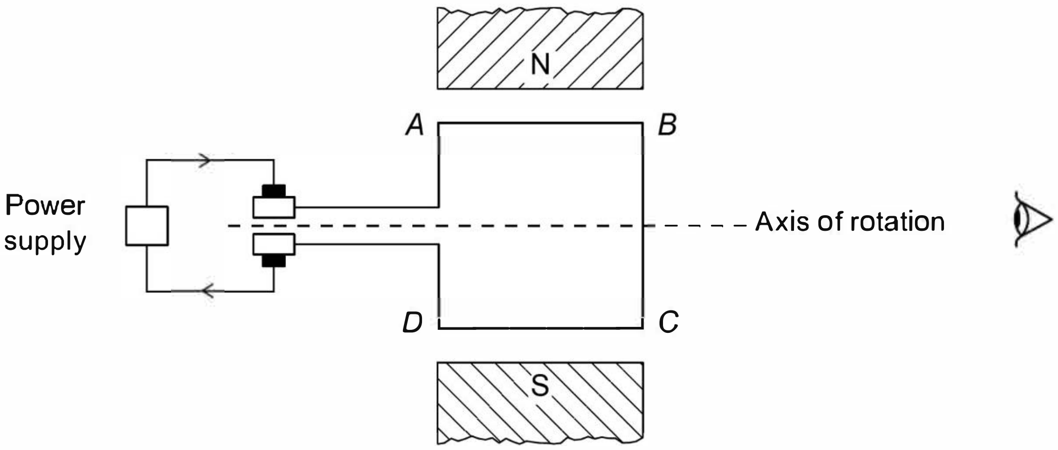
(e) Using the line of best fit, calculate the charge-to-mass ratio of an electron. **3**

NESA STUDENT NUMBER

Marks

Question 24 (8 marks)

A simple DC motor is connected to a 6.00 V battery. The armature of the motor has a resistance of 4.00 Ω and consists of 40 turns. It rotates within an external magnetic field produced by radial magnets of strength 150×10^{-3} T.



It was noted that the current initially was 1.50 A but decreased to constant value of 0.35 A when no load was attached to the motor.

(a) Identify the direction of rotation of the motor as viewed from the eye and outline how this rotation is maintained during the operation of the motor. **2**

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(b) The sides perpendicular to the magnetic field each experience a force of magnitude 2.10 N when the current became constant. **2**

Determine the length of sides AB and CD.

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Question 24 continues on the next page

NESA STUDENT NUMBER

Marks

(c) In addition to the changes in current noted previously, the students also noted that the potential difference across the armature of the motor was less than 6.00 V. **4**

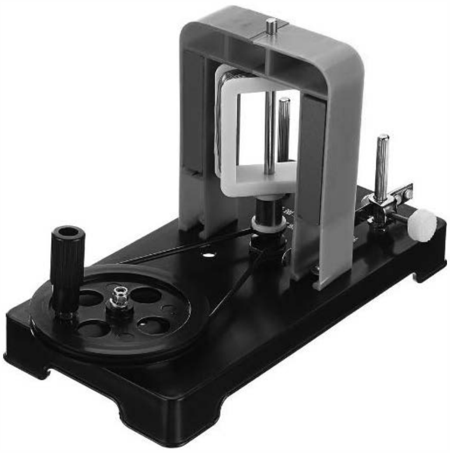
With the aid of calculations, account for the changes in the current and voltage across the armature and its significance to the law of conservation of energy.

NESA STUDENT NUMBER

Marks

Question 25 (6 marks)

A group of keen Physics students wanted to investigate the function of an AC generator as shown in the image below.



The students noted that it had 150 turns of wire in the 6.00 cm wide square coil and was placed in a magnetic field of strength 1.85×10^2 mT. They then connected a digital voltmeter and a motor to the handle to which rotated it at 240 rpm.

(a) Show that the maximum emf, ε_{max}, can be described using the equation: **3**

$$\varepsilon_{max} = 2\pi f NBA$$

where ε_{max} is maximum emf, f is frequency, N is the number of turns in the coil, B is the strength of the external magnetic field and A is the area of the coil.

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(b) Calculate the maximum emf produced by the generator using the above conditions. **1**

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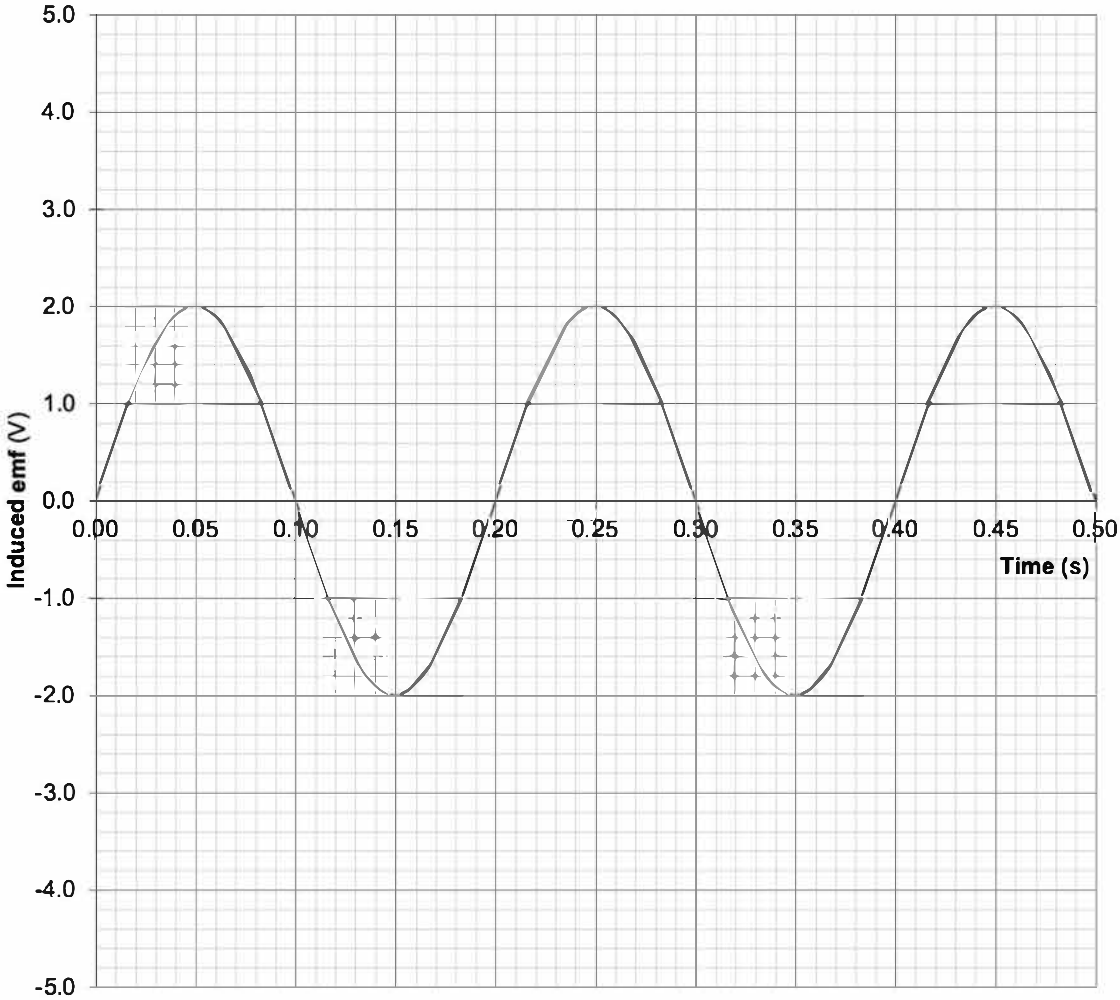
Question 25 continues on the next page

NESA STUDENT NUMBER

Marks

(c) The students then built their own DC generator and tested it out by turning it at a constant speed. An induced emf versus time graph for this test is shown below. **2**

On the axes below, sketch the output that is likely when the speed of rotation is doubled.



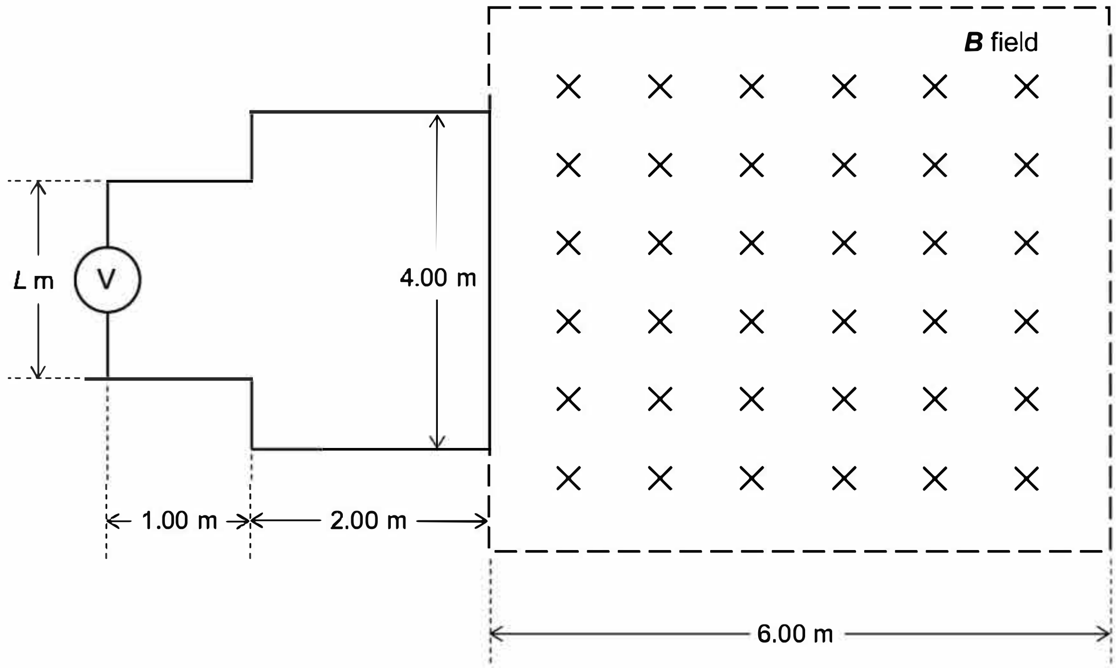
NESA STUDENT NUMBER

Marks

Question 26 (6 marks)

Owen builds a metal frame and slides it at a constant velocity of 0.500 m s^{-1} across a uniform magnetic field (to the right). He then connected a voltmeter to the metal frame.

At time t = 0.0 s, the metal frame is at the position as shown below.



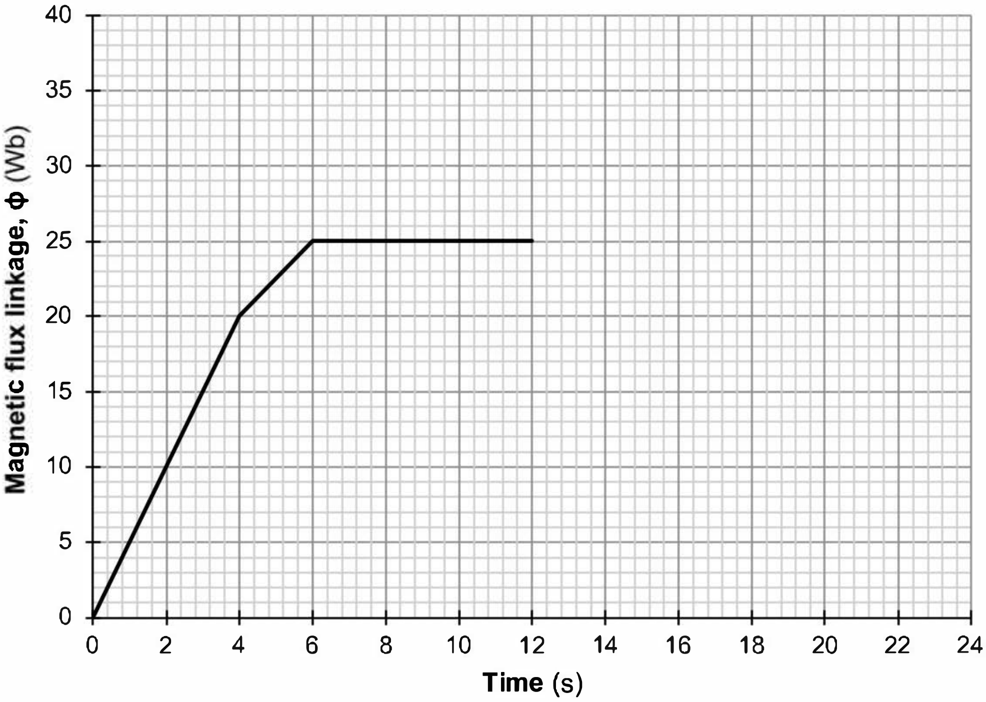
NOT TO SCALE

Question 26 continues on the next page

NESA STUDENT NUMBER

Marks

(a) The changes in magnetic flux linkage ϕ through the metal frame from the time it enters the magnetic field to t = 12.0 s is shown in the graph below. **2**



Calculate the value of the length, *L*.

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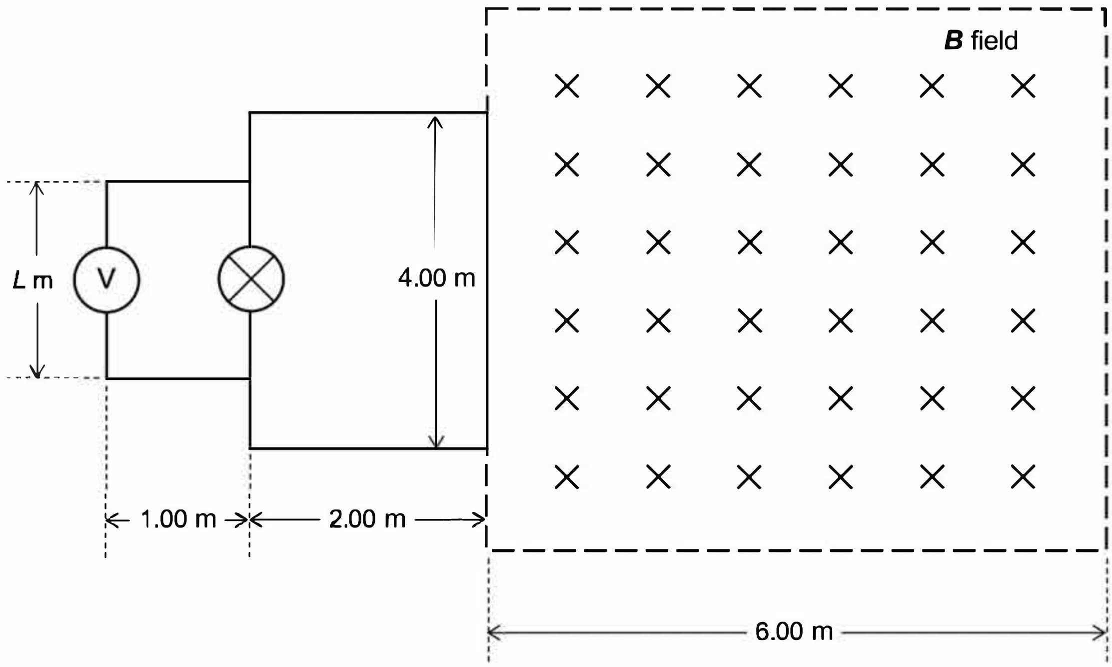
(b) Complete the graph by drawing the changes in ϕ through the metal frame from t = 12.0 s to the time the entire metal frame leaves the magnetic field. **2**

Question 26 continues on the next page

Marks

(c) Edward then connected a light bulb across two points of the metal frame as shown below. **3**



He then repeats the experiment with the metal frame at the same initial velocity of 0.500 m s^{-1} to the right.

Edward noted that an external force needed to be applied to the metal frame when it entered and left the magnetic field so that it would move across at constant speed.

Explain the above observation.

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END OF SECTION 2A

NESA STUDENT NUMBER

S2B

2021

Year 12 Physics

Trial Examination

Section 2B (25 marks)

Questions 27–31

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

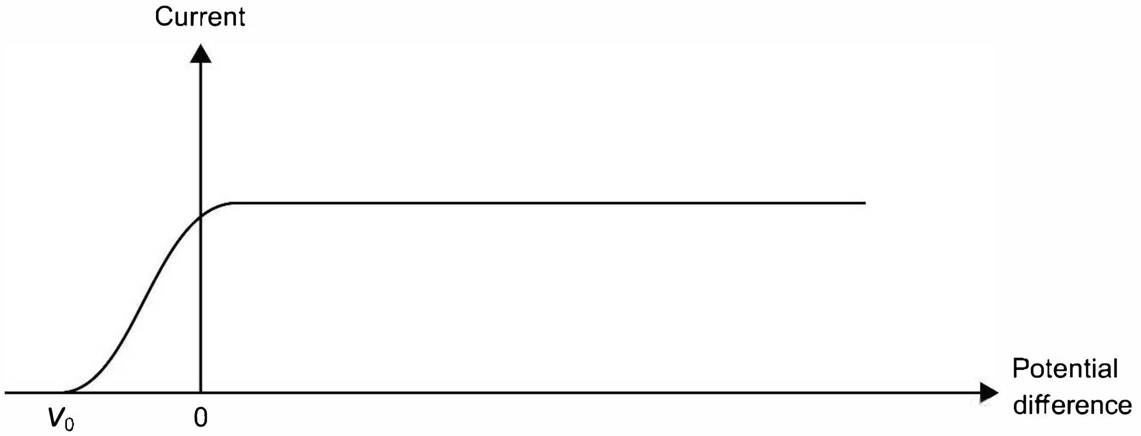
NESA STUDENT NUMBER

Marks

Question 27 (3 marks)

Blue light of frequency 6.25×10^{14} Hz is shone onto the sodium photocathode of a photocell.

The graph of the photoelectric current versus potential difference is shown below.



(a) The threshold frequency for sodium is 5.50×10^{14} Hz. **2**

Calculate the stopping potential, V_0, when blue light of frequency 6.25×10^{14} Hz is shone onto the sodium photocathode of this photocell.

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(b) On the figure above, sketch the curve expected if the light is changed to ultraviolet with a lower intensity than the original. **1**

NESA STUDENT NUMBER

Marks

Question 28 (4 marks)

Discuss the significance of Maxwell's contribution to the development of our current understanding of the nature of light. **4**

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NESA STUDENT NUMBER

Marks

Question 29 (5 marks)

After its initial launch, the Juno probe travelled around Earth and then entered Jupiter's atmosphere.

The probe reached a maximum velocity of 7.36×10^4 m s^{-1} as it went past the Earth at a height of 559 km above the surface.

(a) Using appropriate calculations, show that the probe was able to move away from the Earth and not be captured in orbit around it. **3**

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(b) The Juno probe was launched from Earth and entered Jupiter's orbit, having a trip of 1796 days. It had an average velocity of 7.15×10^4 m s^{-1}. **2**

Assuming there was no effect from gravitational fields, calculate the time difference between the two clocks, one based in the probe and the other in the laboratory on Earth.

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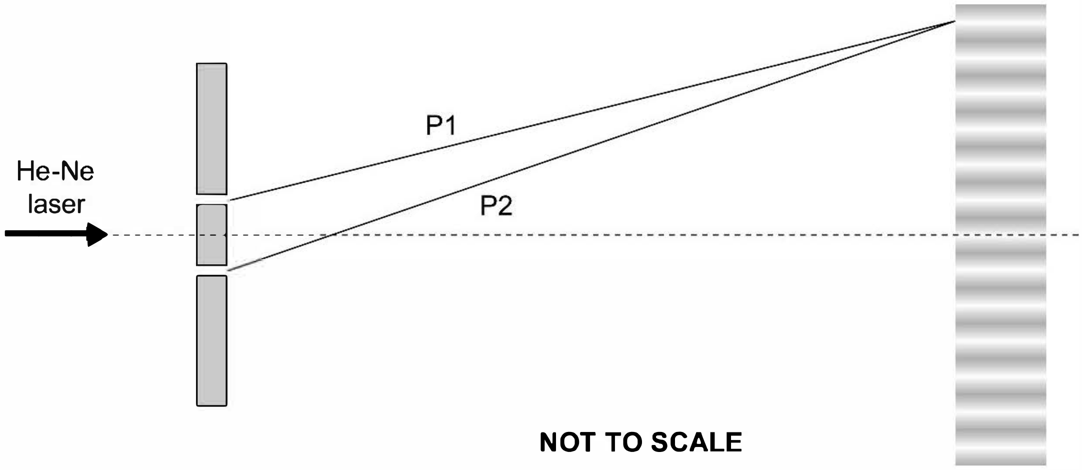
Marks

Question 30 (6 marks)

A He-Ne laser of wavelength 632 nm directs the monochromatic beam onto a set of two parallel slits.

A pattern from these slits has been projected onto a distant wall as seen below.



NOT TO SCALE

(a) Explain the formation of the bright and dark regions in terms of the wave-like nature of light. **2**

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(b) The teacher asks each student to estimate the difference between the length of the lines P1 and P2, which are the lines between the centre of each slit and the 6^{th} bright spot. **2**

Calculate the difference in length between P1 and P2.

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Question 30 continues on the next page

NESA STUDENT NUMBER

Marks

(c) Monochromatic light is now replaced with white light. **2**

Does this result in any changes in the pattern of the bands on the screen? Justify your answer.

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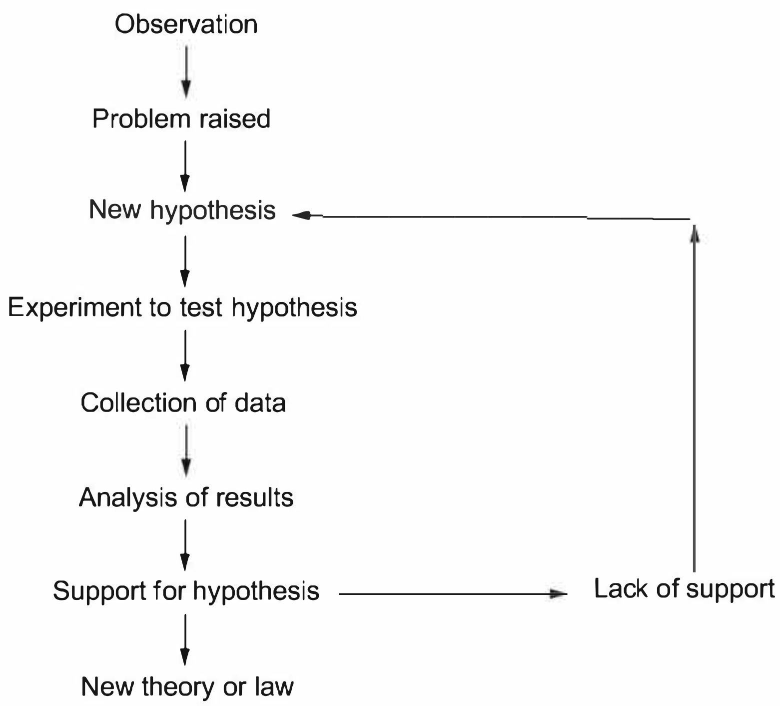
Question 31 (7 marks)

The following flowchart represents a model of scientific method used to show the relationship between theory and the evidence supporting it.



Question 31 continues on the next page

NESA STUDENT NUMBER

Marks

(a) Evaluate the role of thought experiments in the development of our current understanding of length and time. **3**

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(b) Describe two pieces of experimental evidence that support the above-mentioned concepts of length and time. **4**

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END OF SECTION 2B

NESA STUDENT NUMBER

S2C

2021

Year 12 Physics

Trial Examination

Section 2C (10 marks)

Questions 32–33

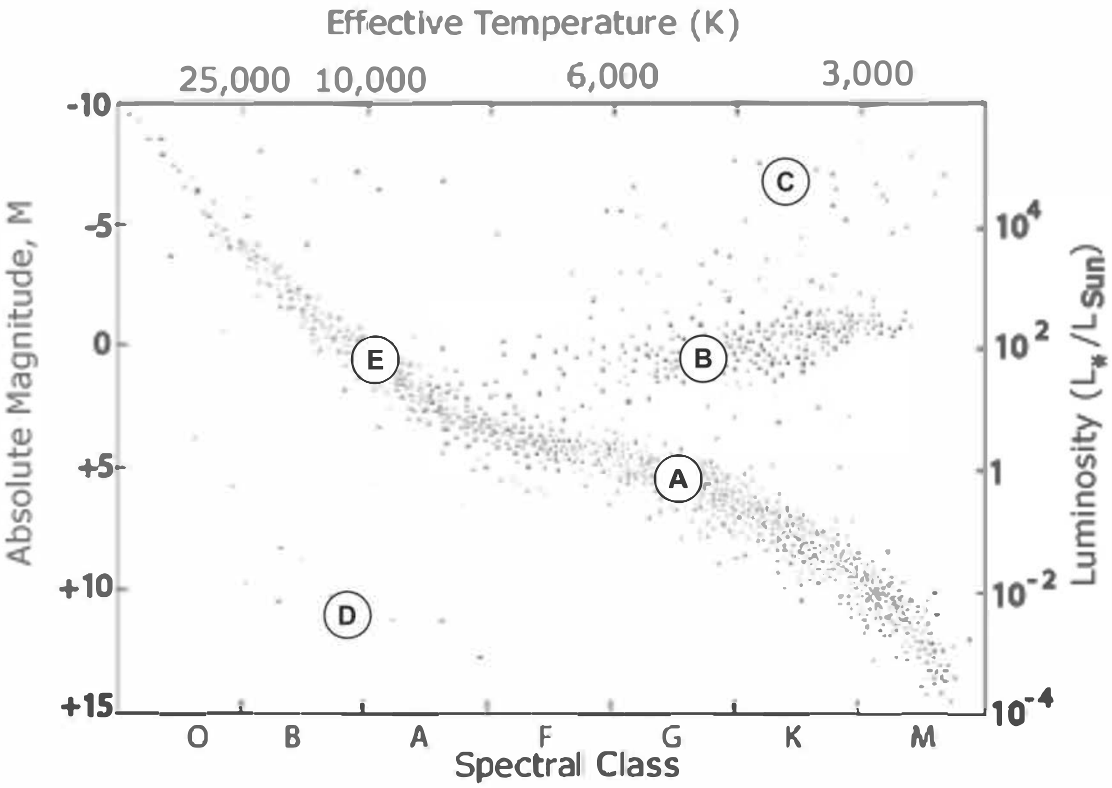
- Write using a black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

NESA STUDENT NUMBER

Marks

Question 32 (5 marks)

Consider the following Hertzsprung-Russell diagram with stars **A**, **B**, **C**, **D** and **E** labelled below.



(a) Identify the stars that will evolve into white dwarf. **1**

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(b) Outline the two nuclear reactions that are occurring in Star **B**. **1**

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Question 32 continues on the next page

Marks

(c) Energy can be produced in Stars **A** and **E** by two nuclear processes: the proton-proton chain and CNO cycle.

(i) Compare the two nuclear processes. **2**

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(ii) Explain which feature of a star determines the dominance of one of the above reactions in a star. **1**

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NESA STUDENT NUMBER

Marks

Question 33 (5 marks)

Astronomers combine mathematical models with observations to develop theories to describe the evolution of the observable universe. The Big Bang theory is the prevailing cosmological model that explains origin and subsequent large-scale expansion of the universe. **5**

Describe how the careful observation of the electromagnetic radiation from various sources gave evidence in support of the Big Bang Theory.

END OF SECTION 2C

END OF TRIAL EXAMINATION

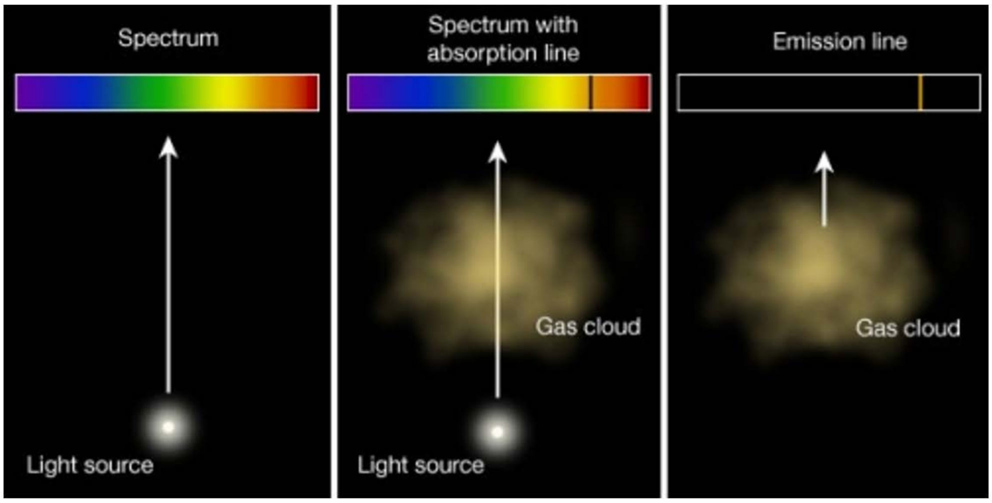
Normanhurst Boys High School

2021 HSC Physics Mock Trial Examination

Marking Guidelines, Sample Answers and Notes from the Markers

S1

Section 1 (10 marks)

Question	Correct Answer	Explanation
1	C	The transformation of kinetic energy into gravitational potential energy is the reason why the vertical velocity will be decreased at the peak.
2	A	Work done by a conservative force (i.e. a force where the work done is independent of path) results in a change in its associated potential energy.
3	B	Since escape velocity is defined as the minimum velocity required by a mass to rise vertically and just escape the gravitational field of a planet (E = 0). Hence: $E = K + U$ $0 = \frac{1}{2}mv^2 - \frac{GMm}{r}$ $\frac{1}{2}mv^2 = \frac{GMm}{r}$ $v_{esc} = \sqrt{\frac{2GM}{r}}$ where the escape velocity is independent of the mass of the object.
4	C	The following summarises the spectra produced in different scenarios: 
5	B	If an object such as a star was moving away from us (or indeed us from it, it is only the relative motion that is important) then the spectral lines would appear to shift towards the longer wavelength or redder part of the spectrum. Such a shift is termed a redshift. The amount of the shift would depend on the relative velocity between source and observer. The greater the recession velocity, the greater the shift in the lines.

6 A

Since:

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

where the energy of a photon is inversely proportional to the wavelength, the highest energy light shown in the spectra must have the lowest wavelengths (i.e. the lines near the 400 nm).

7 B

To calculate the energy of the photon:

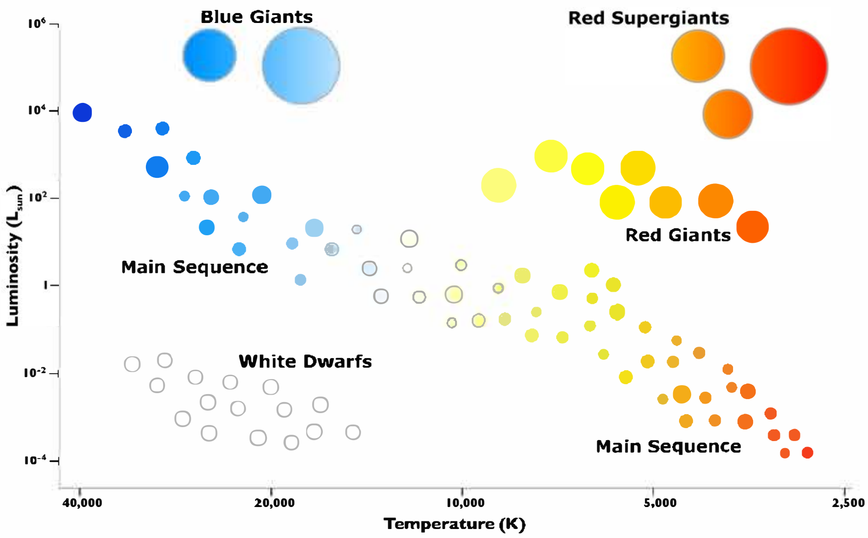
$$E = hf$$
$$= 6.626 \times 10^{-34} \times 102.8 \times 10^{6}$$
$$= 6.812 \times 10^{-26} \text{ J}$$

8 D

A useful resource to show the difference in stellar evolutionary stages for stars of different masses can be found using the following link.

https://cdn.kastatic.org/KA-share/BigHistory/KU3.0.9_Life_Cycle_of_Stars.pdf

9 A



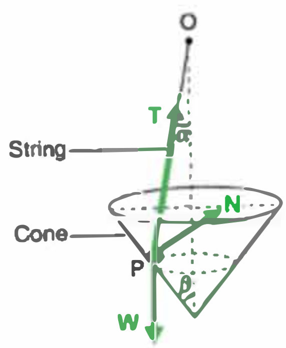
10 B

If the body is momentarily at rest at the top of its trajectory, then its kinetic energy will be zero. Hence, its total energy is entirely gravitational potential energy. Therefore, the total energy is represented by point B.

If the body is falling towards Earth, its kinetic energy is non-zero and so the total energy will be greater than the gravitational potential energy. However, as the body does not escape from Earth, its total energy is negative as it is still a bound system. Hence, the total energy is represented by point C.

11 C

Consider the horizontal components of the forces.



12 A

For the car to remain on track, the normal contact force should be more than zero. To find the minimum possible height, the normal contact force should be at least zero.

The forces acting on the car at the top of the loop:

$$mg + N = \frac{mv^2}{\left(\frac{D}{2}\right)}$$

When N goes to zero:

$$mg = \frac{mv^2}{\left(\frac{D}{2}\right)}$$

$$v = \sqrt{\frac{gD}{2}}$$

By the law of conservation of energy:

$$\begin{aligned} mgh &= mgD + \frac{1}{2}mv^2 \\ &= mgD + \frac{1}{2}m\left(\sqrt{\frac{gD}{2}}\right)^2 \\ &= mgD + \frac{mgD}{4} \\ &= \frac{5mgD}{4} \\ h &= \frac{5D}{4} \end{aligned}$$

13 C

Since the light is initially unpolarised, after passing through one polarising sheet, the intensity will drop by 50%.

Hence, by applying Malus' law:

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

$$\frac{1}{3}I_0 = \frac{1}{2}I_0\cos^2\theta$$

$$\cos^2\theta = \frac{2}{3}$$

$$\begin{aligned} \theta &= \cos^{-1}\left(\sqrt{\frac{2}{3}}\right) \\ &= 35° \end{aligned}$$

14 B

From the formula to analyse Young's double slit experiment, it can be seen that the slit separation is inversely proportional to distance between dark bands. Hence if slit separation is decreased, the distance between dark bands will increase.

15 D

Using the time dilation formula:

$$\begin{aligned} t &= \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \\ &= \frac{10}{\sqrt{1 - \frac{(0.80c)^2}{c^2}}} \\ &= 16.7 \text{ years} \end{aligned}$$

16	A	Force on XY is equal and opposite to the force exerted on magnet (Newton's 3rd law) Force on XY, F = BIl Without current, balance is measuring the mass of the magnet which is 142.0 g. With 2.0 A in XY, force on magnet causes an increase in mass by: 144.6 – 142.0 = 2.6 g With 3.0 A in YX, force on magnet causes a decrease in mass by: 142.0 – ((2.6/2) × 3) = 138.1 g
17	D	Using the assumption that the transformer is ideal and that the current will split in a parallel circuit: $$V_p I_p = V_s I_s$$ $$240 \times I_p = 12 \times (2.0 \times 4)$$ $$I_p = \frac{12 \times (2.0 \times 4)}{240}$$ $$= 0.40 \text{ A}$$ However, as the transformer is not ideal, the power input must be greater than the useful power output in order to enable the globes to function optimally. Hence, the primary current must be greater than 0.40 A.
18	C	Since Star A is cooler than Star B: • Star A's peak wavelength will be lower than that of Star B • Star A will emit less energy than Star B as indicated by the area enclosed by the graph and the horizontal axis.
19	C	Since the wire is suspended, the magnitude of the magnetic force due to the other wire must balance the weight force of the wire: Note: The diagram shows supports next to wire A, which probably shouldn't be there as wire A should be able to move both up and down. $$\frac{F_B}{L} = \frac{mg}{L}$$ $$\frac{\mu_0 I^2}{2\pi r} = \left(\frac{m}{L}\right) g$$ $$\frac{4\pi \times 10^{-7} \times 100^2}{2\pi r} = 0.020 \times 9.8$$ $$r = 0.0102 \text{ m}$$ In order for there to be a repulsive force, the currents must flow in the opposite direction relative to each other.
20	D	The horizontal component of the velocity of a projectile is constant. As a result, the rate of change of flux linkage is constant and hence, by Faraday's law, the emf induced across the two ends of the wire will be constant.

Normanhurst Boys High School

2021 Year 12 Physics Trial Examination

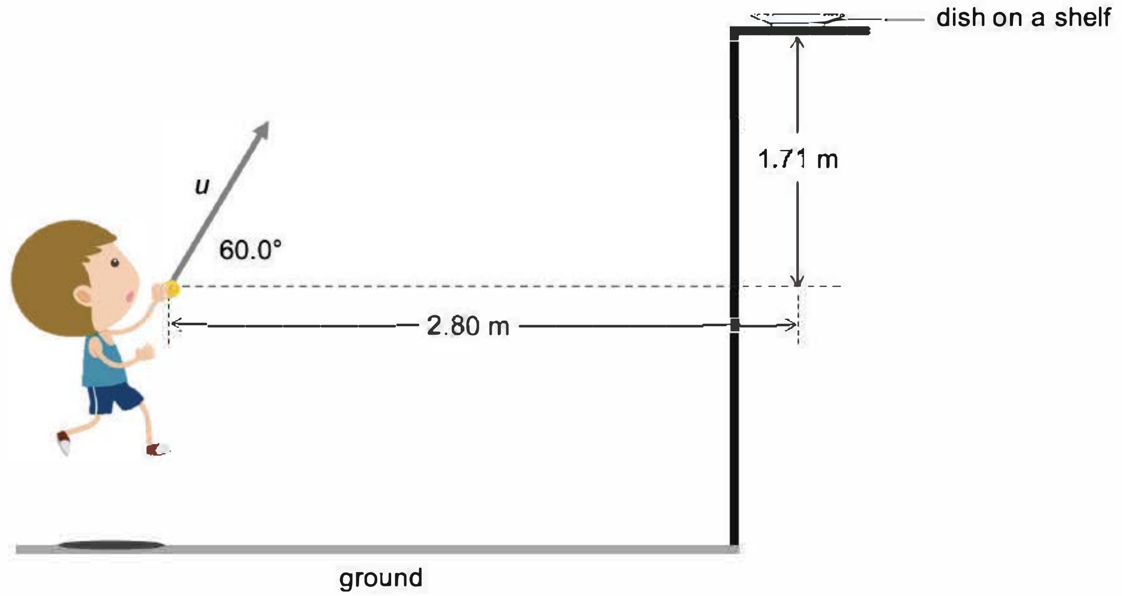
Marking Responses, Sample Answers & Notes from the Marker

S2A

Section 2A (45 marks)
Written Response

Question 21 (6 marks)

A game at a festival involves tossing a coin into a small dish mounted on a shelf. If the person can flick a coin into the small dish, they win a prize.



Aidan flicks the coin with an initial speed of u m s^{-1} at an angle of 60.0° to the horizontal.

When the coin leaves his hand, the horizontal distance between the coin and the dish is 2.80 m and the vertical distance from his hand to the dish is 1.71 m.

(a) Calculate the initial speed, u, required for Aidan to win a prize. **4**

(b) Daniel suggests that if he flicks the coin so that the initial speed is greater, the coin will reach the dish more quickly and they can win prizes more efficiently. **2**

Explain why this is not the case and propose an additional change that would make his suggestion work.

Question 21(a)

Marking Criteria	Marks
• Correctly calculates the initial velocity with FOUR of the following features: ○ derives correct expressions for horizontal and vertical components of launch velocity of the coin. ○ derives correct expression for time of flight using the horizontal displacement ○ derives correct expression for time of flight using the vertical displacement ○ substitutes into the derived equation	4
• Calculates the initial velocity with THREE of the following features.	3
• Partially calculates the initial velocity with TWO of the following features.	2
• Derives correct expressions for horizontal and vertical components of launch velocity of the coin.	1

Sample Response

The horizontal (u_x) and vertical (u_y) components of the launch velocity of coin can be given by:

$$u_x = u\cos 60.0°$$

$$= \frac{1}{2}u \text{ m s}^{-1}$$

$$u_y = u\sin 60.0°$$

$$= \frac{\sqrt{3}}{2}u \text{ m s}^{-1}$$

The time taken for the coin to reach the plate can be given by:

$$s_x = u_x t$$

$$2.80 = \frac{1}{2}ut$$

$$t = \frac{5.60}{u} \text{ s} \ldots \boxed{1}$$

$$s_y = u_y t + \frac{1}{2}a_y t^2$$

$$1.71 = \frac{\sqrt{3}}{2}ut + \frac{1}{2}(-9.8)t^2$$

$$1.71 = \frac{\sqrt{3}}{2}ut - 4.9t^2$$

$$4.9t^2 - \frac{\sqrt{3}}{2}ut + 1.71 = 0 \ldots \boxed{2}$$

Substitute **1** in **2**:

$$4.9t^2 - \frac{\sqrt{3}}{2}ut + 1.71 = 0$$

$$4.9t\left(\frac{5.60}{u}\right)^2 - \frac{\sqrt{3}}{2}u\left(\frac{5.60}{u}\right) + 1.71 = 0$$

$$u = 7.00 \text{ m s}^{-1} \ (u > 0)$$

Notes from the Marker

- Better responses ...
- Weaker responses ...

Question 21(b)

Marking Criteria	Marks
• Explains why the statement is incorrect using an equation AND proposes a modification to the statement to make it plausible for the coin to reach the plate.	2
• Briefly outlines why the statement is incorrect OR proposes a modification to the statement to make it plausible for the coin to reach the plate.	1

Sample Response

The statement is incorrect as increasing the initial speed would result in a larger horizontal component of the initial velocity.

$$s_x = u_x t$$
$$= ut\cos\theta$$

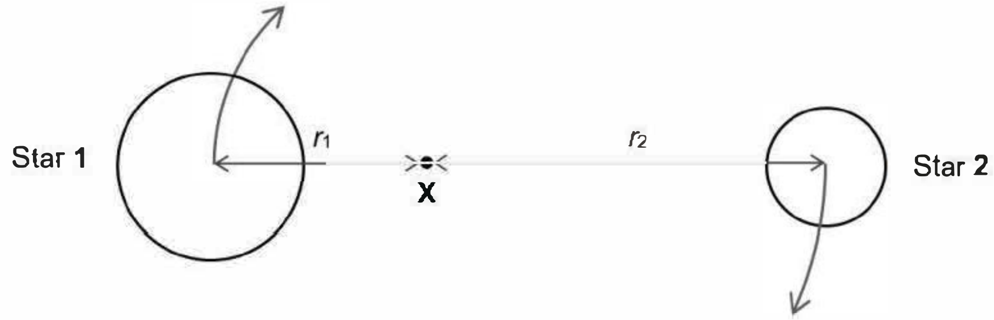
Since the range is directly proportional to the horizontal component of the initial velocity, this would lead to the coin flying past the plate. In order for this to work, an additional change of increasing the launch angle relative to the horizontal helps reduce the range as the cosine of the launch angle would reduce and hence reduce to the range so that the coin lands in the plate.

Notes from the Marker

- Better responses ...
- Weaker responses ...

Question 22 (7 marks)

A binary star system consists of two stars, Star **1** and Star **2**, which orbit a fixed-point **X** as shown in the figure below.



NOT TO SCALE

Star **1** has a mass of M_1 and a circular orbit of radius r_1 about **X** while Star **2** has a mass of M_2 and a circular orbit of radius r_2 about **X**. Both stars have the same angular speed of 4.98×10^{-8} rad s^{-1} about **X**.

(a) Explain why the centripetal force acting on both Stars **1** and **2** is the same. **2**

(b) The distance of separation between the centres of the stars is 2.8×10^{8} km. **3**

Given that Star **1** is three times heavier than Star **2**, calculate r_1.

(c) Calculate the mass of Star **2**. **2**

Question 22(a)

Marking Criteria	Marks
• Relates the centripetal force acting on both Stars 1 and 2 to gravitational force AND Newton's third law.	2
• Relates the centripetal force acting on both Stars 1 and 2 to gravitational force OR Newton's third law.	1

Sample Response

The centripetal force acting on both stars is the same since the centripetal force is supplied by the gravitational force acting on each of the stars. These gravitational forces have the same magnitude as a consequence of Newton's third law.

Question 22(b)

Marking Criteria	Marks
• Correctly calculates r_1 with units by: ○ equating the centripetal force in terms of mass and angular velocity ○ relating r_1 and r_2 using an appropriate expression ○ relating M_1 and M_2 using the given information.	3
• Calculates r_1 incorrectly as the result of ONE error.	2
• Partially makes progress towards calculating r_1 with TWO errors.	1

Sample Response

Since the centripetal force acting on each star is equal in magnitude:

$$F_{c,1} = F_{c,2}$$

$$\frac{M_1 v_1^2}{r_1} = \frac{M_2 v_2^2}{r_2}$$

$$M_1 r_1 \omega^2 = M_2 r_2 \omega^2$$

$$M_1 r_1 \omega^2 = M_2\left(2.8\times 10^{11} - r_2\right)\omega^2$$

$$\frac{M_1}{M_2} = \frac{2.8\times 10^{11} - r_1}{r_1}$$

$$\frac{3M_2}{M_2} = \frac{2.8\times 10^{11} - r_1}{r_1}$$

$$3 = \frac{2.8\times 10^{11} - r_1}{r_1}$$

$$3r_1 = 2.8\times 10^{11} - r_1$$

$$4r_1 = 2.8\times 10^{11}$$

$$r_1 = 7.0\times 10^{10}\ \text{m}$$

Question 22(c)

Marking Criteria	Marks
• Correctly calculates the mass of Star **2.**	2
• Calculates the mass of Star **2** but makes ONE error.	1

Sample Response

Since the gravitational force provides the centripetal force:

$$F_{c,1}=F_g$$

$$M_1 r_1 \omega^2=\frac{GM_1M_2}{(r_1+r_2)^2}$$

$$r_1\omega^2=\frac{GM_2}{(r_1+r_2)^2}$$

$$7.0\times 10^{10}\times (4.98\times 10^{-8})^2=\frac{6.67\times 10^{-11}\times M_2}{2.8\times 10^{11}}$$

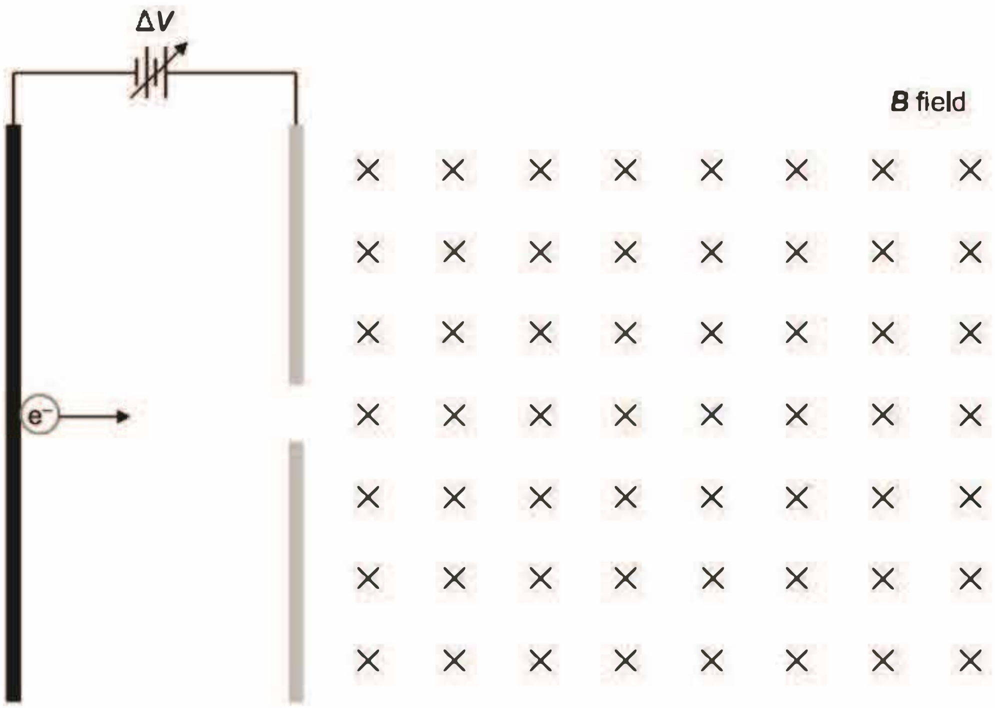
$$M_2=\frac{7.0\times 10^{10}\times (4.98\times 10^{-8})^2\times 2.8\times 10^{11}}{6.67\times 10^{-11}}$$

$$M_2=2.0\times 10^{29}\ \text{kg}$$

Alternative answers may also use Kepler's third law.

Question 23 (11 marks)

A beam of electrons is accelerated across the space between two parallel plates and passes through a small opening. After passing through the opening, the electrons enter a uniform magnetic field as shown in the diagram below.



The potential difference between the plates is varied, as shown in the table below.

Potential difference (V)	Magnetic field (mT)	B^2 ($\times 10^{-6}$ T)
60.0	2.62	6.86
70.0	2.78	7.73
100.0	3.39	11.49
110.0	3.54	12.53
120.0	3.78	14.29
140.0	3.99	15.92

For each potential difference, the magnetic field is varied in order to cause the beam to strike one of the grey plates at a distance of 0.020 m from the opening.

(a) Derive an expression for the speed of a charged particle as it passes through the small opening. **2**

(b) Describe the path of the electrons after they enter the uniform magnetic field as shown in the diagram above. **2**

(c) The charge-to-mass ratio is defined as the charge of a particle divided by its mass and is measured in coulombs per kilogram. **1**

Determine the quantities that should be graphed to yield a straight line to calculate the mass-to-charge ratio of an electron by completing the table on the previous page.

(d) Plot the relevant data from (c) on the grid provided and draw a line of best fit. **3**

(e) Using the line of best fit, calculate the charge-to-mass ratio of an electron. **3**

Question 23(a)

Marking Criteria	Marks
• Correctly derives the relationship with appropriate logic by relating work done to changes in kinetic energy as a result of an applied potential difference.	2
• Partially derives the relationship by relating work done to changes in kinetic energy as a result of an applied potential difference.	1

Sample Response

The change in kinetic energy of the electron is due to the change in electric potential energy:

$$\Delta K = -\Delta U$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = -q\Delta V$$

Since the electron is accelerated from rest, u = 0 m s^{-1}:

$$\frac{1}{2}mv^2 = -q(0 - V)$$

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

$$v = \sqrt{\frac{2qV}{m}} \dots \boxed{1}$$

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. These responses related potential difference to the kinetic energy of the electron.
- Weaker responses showed only partially reasoned derivations or misinterpreted the question by deducing the velocity of the electron due to the effect of a uniform magnetic field.

Question 23(b)

Marking Criteria	Marks
• Describes the path of the electron as a result of the magnetic field and the portion of the plate which the electron will hit.	2
• Provides some relevant information.	1

Sample Response

The electron will experience a centripetal force due to the magnetic force within the magnetic field initially directed downwards as determined using the left hand rule. The electron will then move in a semi-circular path as the force is perpendicular to its velocity and strike the lower portion of the grey plate, 0.020 m below the opening.

Notes from the Marker

- Better responses were able to provide details of the path of the electron and had demonstrated evidence of reading the stimulus material provided.
- Weaker responses did not engage with the stimulus or provided vague descriptions.

Question 23(c)

Marking Criteria	Mark
• Identifies the appropriate variable on each axis.	1

Sample Response

Since the centripetal force is supplied by the magnetic force experienced by the electron in the uniform magnetic field:

$$F_c = F_B$$

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

$$\frac{m}{qr}v = B \ldots \boxed{2}$$

Substitute **1** (from part (a)) in **2**:

$$\frac{m}{qr}\sqrt{\frac{2qV}{r}} = B$$

$$\frac{2qmV}{q^2r^2} = B^2$$

$$B^2 = \frac{2m}{qr^2}V$$

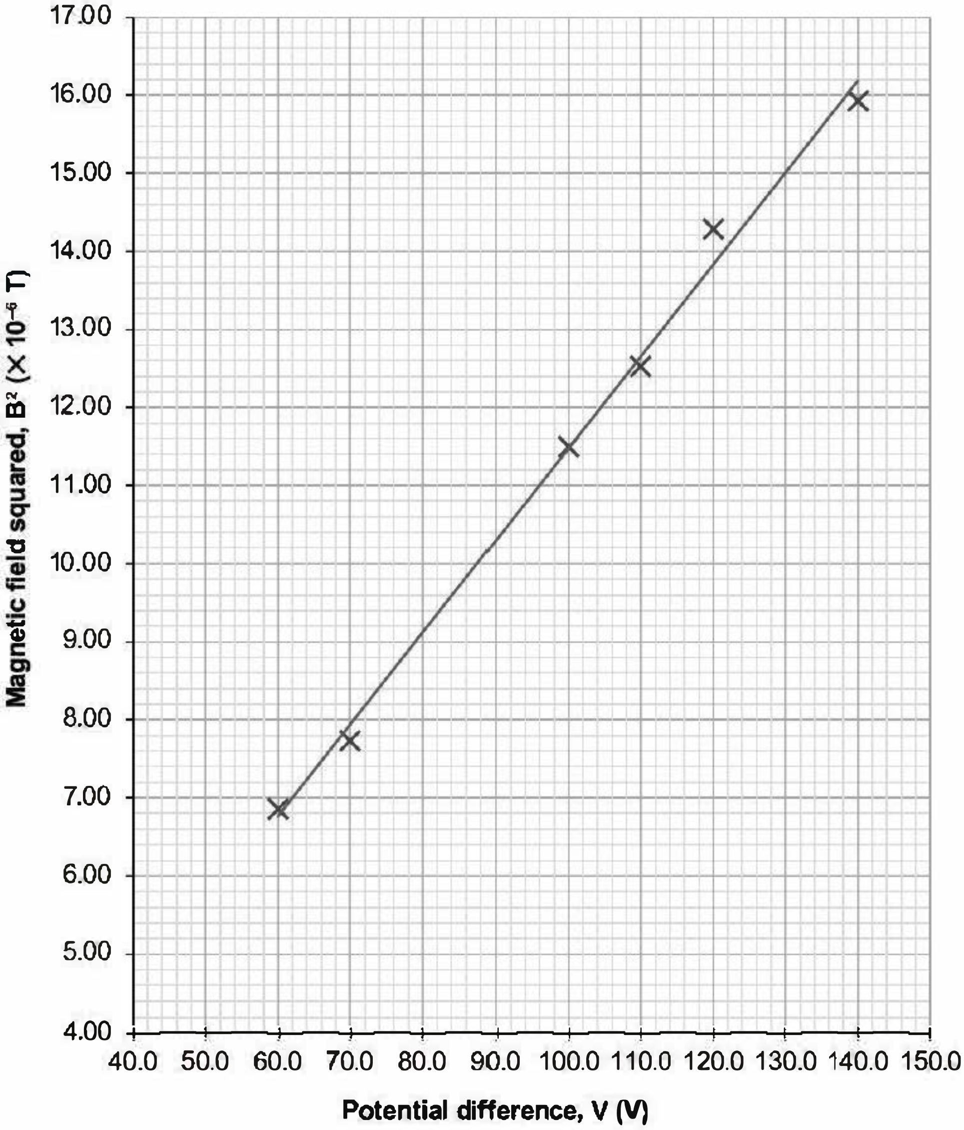
Therefore, B^2 should be plotted on the vertical axis and V on the horizontal axis to yield the mass to charge ratio as part of the gradient.

Notes from the Marker

- Better responses were able to derive the relationship further and to linearise this equation by expressing it in y = mx form.
- Weaker responses showed only partially reasoned derivations or failed to understand which quantities would be variable and which would be constant.

Question 23(d)

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



Notes from the Marker

- Better responses were able to correctly plot the linearised form of the equation and incorporate an appropriate scale. Most responses that were successful were able to plot an appropriate line of best fit for the plotted data.
- Weaker responses generally produced graphs which were not appropriate and did not show evidence of linearisation.

Question 23(e)

Marking Criteria	Marks
• Determines the charge to mass ratio of an electron with THREE of the following features: ○ uses two indicated and well-spaced points which are not data points to calculate gradient ○ equates the gradient to the appropriate expression ○ substitutes correct values into the equation formed and states appropriate units for the calculated value	3
• Partially calculates the charge to mass ratio of an electron with TWO of the above features.	2
• Provides some relevant information.	1

Sample Response

The gradient of the line is given by:

$$\text{slope} = \frac{(15.0 - 7.0) \times 10^{-6}}{130.0 - 62.0}$$

$$= 1.176470588 \times 10^{-7}\ \mathrm{T^2V^{-1}}$$

Since:

$$\text{slope} = \frac{2m}{qr^2}$$

$$\frac{q}{m} = \frac{2}{r^2 \times \text{slope}}$$

$$= \frac{2}{0.10^2 \times 1.176470588 \times 10^{-7}}$$

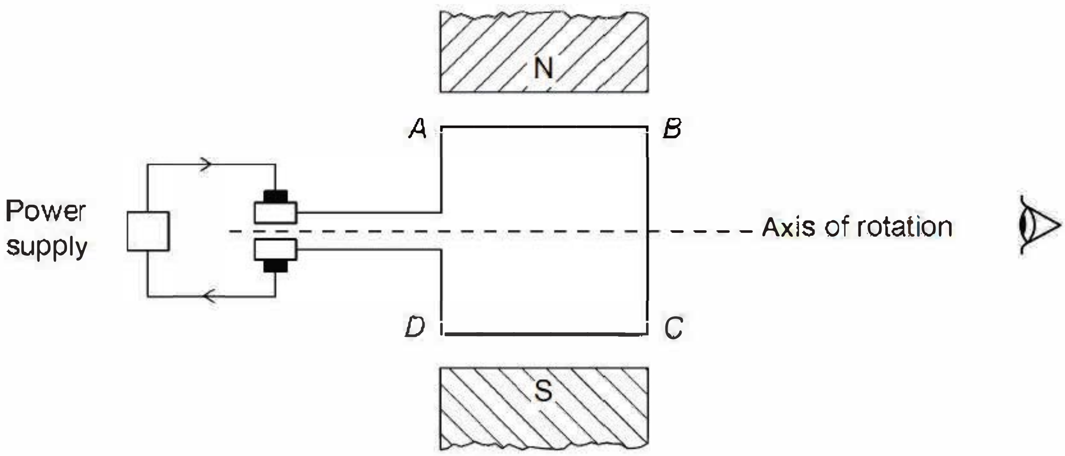
$$= 1.7 \times 10^{11}\ \mathrm{C\,kg^{-1}}$$

Notes from the Marker

- Better responses were able to demonstrate their ability to relate the gradient of the line to the equation derived previously and to manipulate it to determine the charge to mass ratio of an electron.
- 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.

Question 24 (8 marks)

A simple DC motor is connected to a 6.00 V battery. The armature of the motor has a resistance of 4.00 Ω and consists of 40 turns. It rotates within an external magnetic field produced by radial magnets of strength 150×10^{-3} T.



It was noted that the current initially was 1.50 A but decreased to constant value of 0.35 A when no load was attached to the motor.

(a) Identify the direction of rotation of the motor as viewed from the eye and outline how this rotation is maintained during the operation of the motor. **2**

(b) The sides perpendicular to the magnetic field each experience a force of magnitude 2.10 N initially when the motor was turned on. **2**

Determine the length of sides AB and CD.

(c) In addition to the changes in current noted previously, the students also noted that the potential difference across the armature of the motor was less than 6.00 V. **4**

With the aid of calculations, account for the changes in the current and voltage across the armature and its significance to the law of conservation of energy.

Question 24(a)

Marking Criteria	Marks
• Identifies that the direction of rotation is clockwise AND explains about how rotation is maintained.	2
• Identifies that the direction of rotation is clockwise OR outlines details about how rotation is maintained.	1

Sample Response

The direction of rotation is clockwise as viewed from the eye. This direction of rotation is maintained during the operation of the DC motor through the use of a split-ring commutator which reverses the direction of current at vertical positions every half cycle by changing the contact of each half of the split ring commutator with the brushes. This allows the force and hence the torque acting on the two sides of the coil which are perpendicular to the magnetic field to change direction every half revolution at the vertical positions, consequently allowing the coil of the DC motor to spin continuously.

Notes from the Marker

- Most responses were able to identify the direction of rotation.
- Better responses were able to explain the role of the split-ring commutator with reference to the structure of a DC motor and current through explicitly making links.
- Weaker responses merely stated that the direction of current was reversed every half turn and did not provide any further elaboration.

Question 24(b)

Marking Criteria	Marks
• Correctly calculates the length of sides AB and CD.	2
• Calculates the length of sides AB and CD but makes ONE error.	1

Sample Response

Sides AB and CD experience a force due to the motor effect given by:

$$F = nIl_{\perp}B$$

$$F = nIlB\sin\theta$$

$$2.10 = 40 \times 0.35 \times l \times 150 \times 10^{-3} \times \sin 90^{\circ}$$

$$l = \frac{2.10}{40 \times 1.50 \times 150 \times 10^{-3} \times \sin 90^{\circ}}$$

$$= 0.23 \text{ m}$$

Notes from the Marker

- Better responses ...
- Weaker responses ...

Question 24(c)

Marking Criteria	Marks
• Provides an extensive explanation of the observations made for the DC motor by including the following FOUR features: ○ accounting for the effect of the supply emf and its relation to the initial current measured ○ relating Lenz's law, Faraday's law and Ohm's law to the changes in voltage and current observed to the Law of Conservation of Energy ○ accounting for the need of a small current for the non-ideal DC motor to continue spinning at its maximum rotational speed ○ includes supporting equations and calculations to justify aspects of the response.	4
• Provides an explanation of the observations made for the DC motor by including THREE of the above features.	3
• Provides a partial explanation of the observations made for the DC motor by including TWO of the above features.	2
• Provides some relevant information.	1

Sample Response

When the motor is initially turned on, the supply emf of 6.00 V will cause a current of 1.50 A to flow through the coils of the armature. However, as the armature begins to rotate, a potential difference (back emf) will be induced across the terminals of the motor created as a result of the changing magnetic flux passing through the coils within the motor as predicted by Faraday's law. As the speed of rotation of the motor increases, the magnitude of the back emf as they are directly proportional.

$$\varepsilon_{back} = -\frac{\Delta\Phi}{\Delta t}$$

This potential difference (back emf) will oppose the supply emf as stated by Lenz's law as a means of opposing the change in flux experienced by the coils. Since the current flowing through is directly proportional to the net emf, where net emf = supply emf – back emf, the current flowing through the coils will decrease as net emf decreases. This is evidenced in the following calculation and accounts for the drops in voltage and current observed:

$$V = IR$$

$$\varepsilon_{supply} - \varepsilon_{back} = IR$$

$$6.00 - \varepsilon_{back} = 0.35 \times 4.00$$

$$\varepsilon_{back} = (0.35 \times 4.00) - 6.00$$

$$= -4.6 \text{ V}$$

If this did not happen and instead the net emf increased, this would be a violation of the law of conservation of energy as it would aid the supply emf, leading to the coil continually increasing its speed, thus creating more kinetic energy.

As the residual current remains constant at 0.35 A, the motor will spin at maximum rotational speed. This residual current is required to overcome any friction within the motor and any voltage drop due to losses such as resistive heating. As the motor is not ideal, the power loss can be quantified:

$$P_{loss} = I^2 R$$

$$= 0.35^2 \times 4.00$$

$$= 0.49 \text{ W}$$

Notes from the Marker

- Better responses were able to relate the observations in the stimulus material and use it to explain the operation of the DC motor with reference to appropriate Physics principles. Calculations were included in these responses which were used to clarify aspects of the non-ideal DC motor.
- Weaker responses provided basic details about back emf and did not provide evidence of engagement with the stimulus material.

Question 25 (6 marks)

A group of keen Physics students wanted to investigate the function of an AC generator as shown in the image below.

The students noted that it had 150 turns of wire in the 6.00 cm wide square coil and was placed in a magnetic field of strength 1.85×10^2 mT. They then connected a digital voltmeter and a motor to the handle to which rotated it at 240 rpm.

(a) Show that the maximum emf, ε_{max}, can be described using the equation: **3**

$$\varepsilon_{max} = 2\pi f N B A$$

where ε_{max} is maximum emf, f is frequency, N is the number of turns in the coil, B is the strength of the external magnetic field and A is the area of the coil.

(b) Calculate the maximum emf produced by the generator using the above conditions. **1**

(c) The students then built their own AC generator and tested it out by turning it at a constant speed. An induced emf versus time graph for this test is shown below. **2**

On the axes below, sketch the output that is likely when the speed of rotation is doubled.

Question 25(a)

Marking Criteria	Marks
• Provides a complete derivation of the formula with assumptions stated.	3
• Provides a partial derivation of the formula without assumptions stated.	2
• Provides some relevant information.	1

Sample Response

The emf, ε, due to the motion of a wire in the **B** field is:

$$\varepsilon = BLv\sin\theta$$

The emf, ε, due to the motion of the sides perpendicular to the **B** field containing *N* coils is:

$$\begin{aligned}\varepsilon &= 2NBLv\sin\theta \\ &= 2NBL\left(\frac{L}{2}\times\omega\right)\sin(\omega t) \\ &= NBL^2\omega\sin(\omega t) \\ &= NBA\omega\sin(\omega t) \\ &= NBA(2\pi f)\sin(\omega t) \\ &= 2\pi fNBA\sin(\omega t)\end{aligned}$$

Since maximum emf, ε_{max}, occurs when sin(ωt) = 1:

$$\varepsilon_{max} = 2\pi fNBA$$

Notes from the Marker

- Better responses were able to note that the changes were occurring as a result of changes in the angle of the area vector in relation to the magnetic field lines. Any other logical responses were accepted.
- Weaker responses incorrectly assumed that a changing area or magnetic field strength or that changes in time could be replaced with frequency to generate the induced emf.

Question 25(b)

Marking Criteria	Mark
• Correctly calculates the maximum emf produced using the provided equation.	1

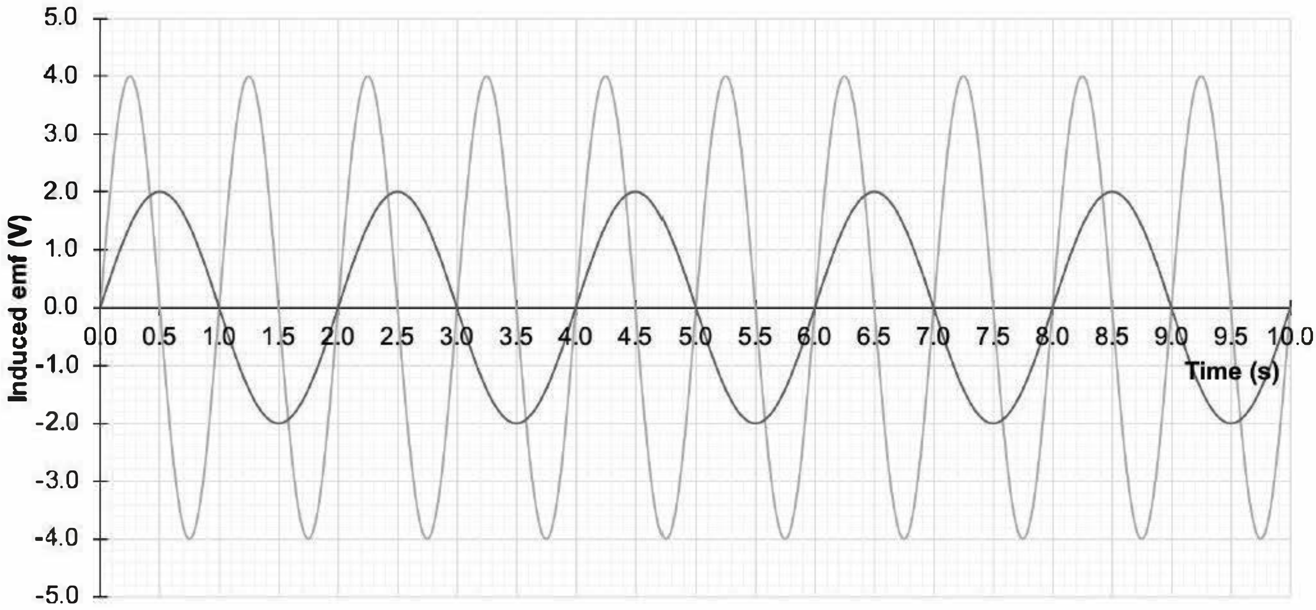
Sample Response

$$\begin{aligned}\varepsilon_{max} &= 2\pi fNBA \\ &= 2\pi\times\frac{240}{60}\times 150\times 1.85\times 10^{-1}\times 0.0600^2 \\ &= 2.51\ \text{V}\end{aligned}$$

Question 25(c)

Marking Criteria	Marks
• Correctly sketches the output of induced emf versus time when the speed of rotation is doubled by showing TWO of the following features: ○ doubles the maximum induced emf ○ doubles the frequency	2
• Partially accounts for the speed of rotation doubling by showing ONE of the above features.	1

Sample Response



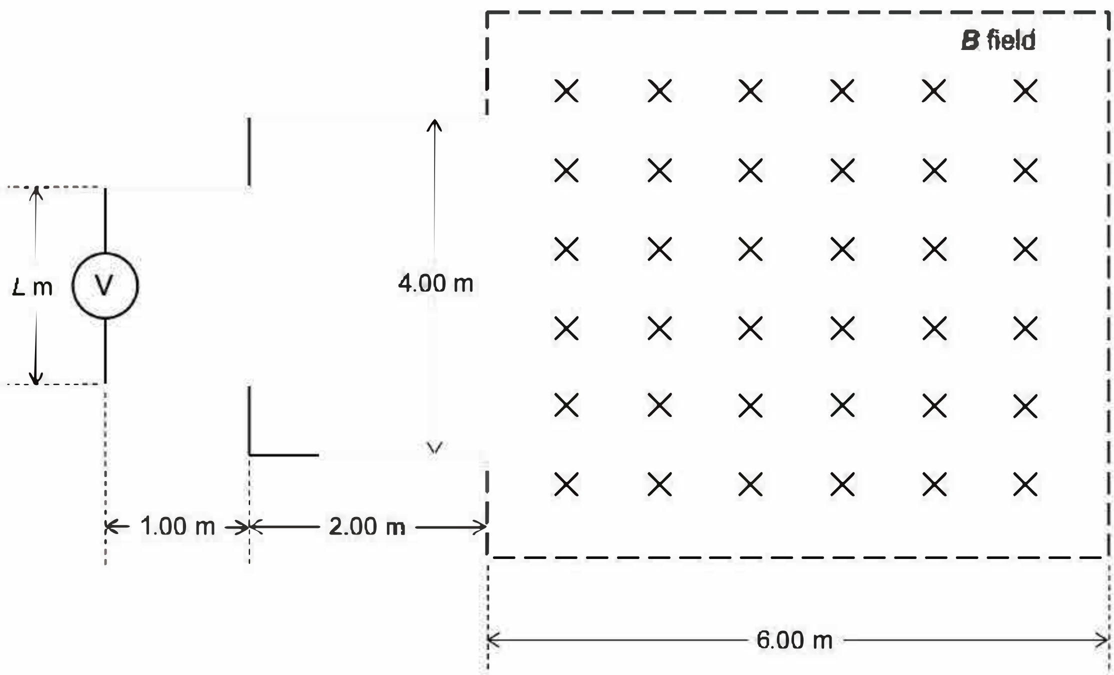
Notes from the Marker

- Better responses were able to relate the doubling of the speed of rotation to Faraday's law and hence the changes in the maximum induced emf as well as the frequency of change in emf with respect to time.
- Weaker responses partially accounted for the change by doubling the maximum induced emf only.

Question 26 (7 marks)

Owen builds a metal frame and slides it at a constant velocity of 0.500 m s^{-1} across a uniform magnetic field (to the right). He then connected a voltmeter to the metal frame.

At time t = 0.0 s, the metal frame is at the position as shown below.



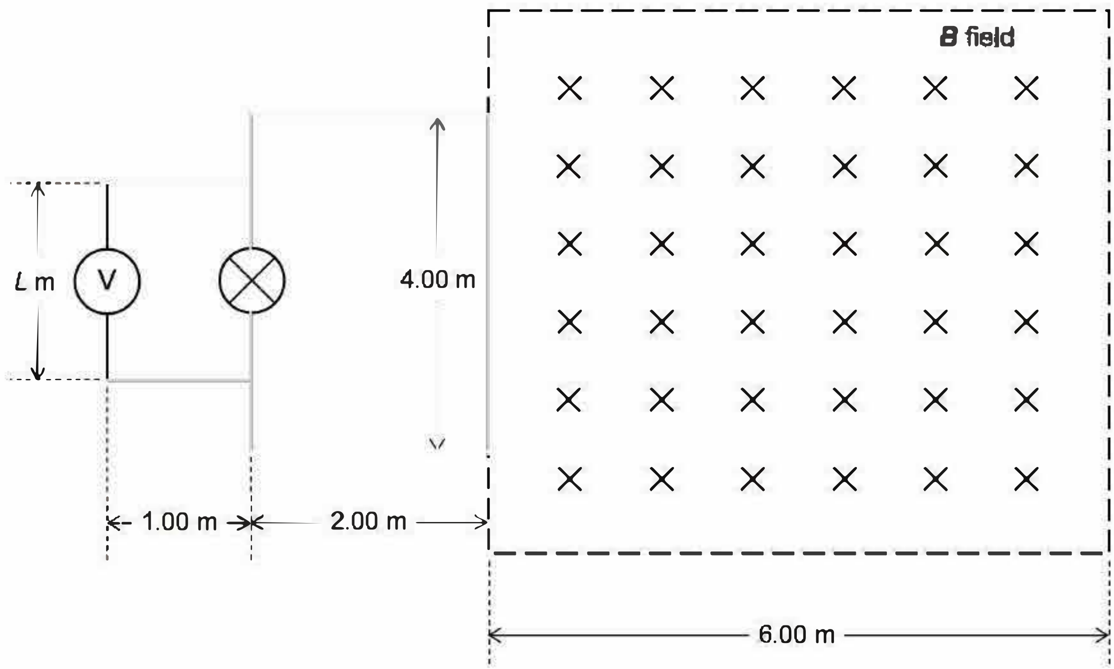
NOT TO SCALE

(a) The changes in magnetic flux linkage ϕ through the metal frame from the time it enters the magnetic field to t = 12.0 s is shown in the graph below. **2**

Calculate the value of the length, L.

(b) Complete the graph by drawing the changes in ϕ through the metal frame from t = 12.0 s to the time the entire metal frame leaves the magnetic field. **2**

(c) Edward then connected a light bulb across two points of the metal frame as shown below. **3**



He then repeats the experiment with the metal frame at the same initial velocity of 0.500 m s^{-1} to the right.

Edward noted that an external force needed to be applied to the metal frame when it entered and left the magnetic field so that it would move across at constant speed.

Explain the above observation.

Question 26(a)

Marking Criteria	Marks
• Correctly calculates the length, *L* with appropriate calculations.	2
• Calculates the length, L with ONE mistake in the calculation. OR • States the correct value of the length, *L*.	1

Sample Response

$\Phi_1 = BA_1$

$20 = B \times (4.00 \times 2.00)$

$B = 2.5$ T into the page

Since B is constant:

$\Phi_2 = BA_2$

$5 = 2.5 \times (L \times 1.00)$

$L = 2$ m

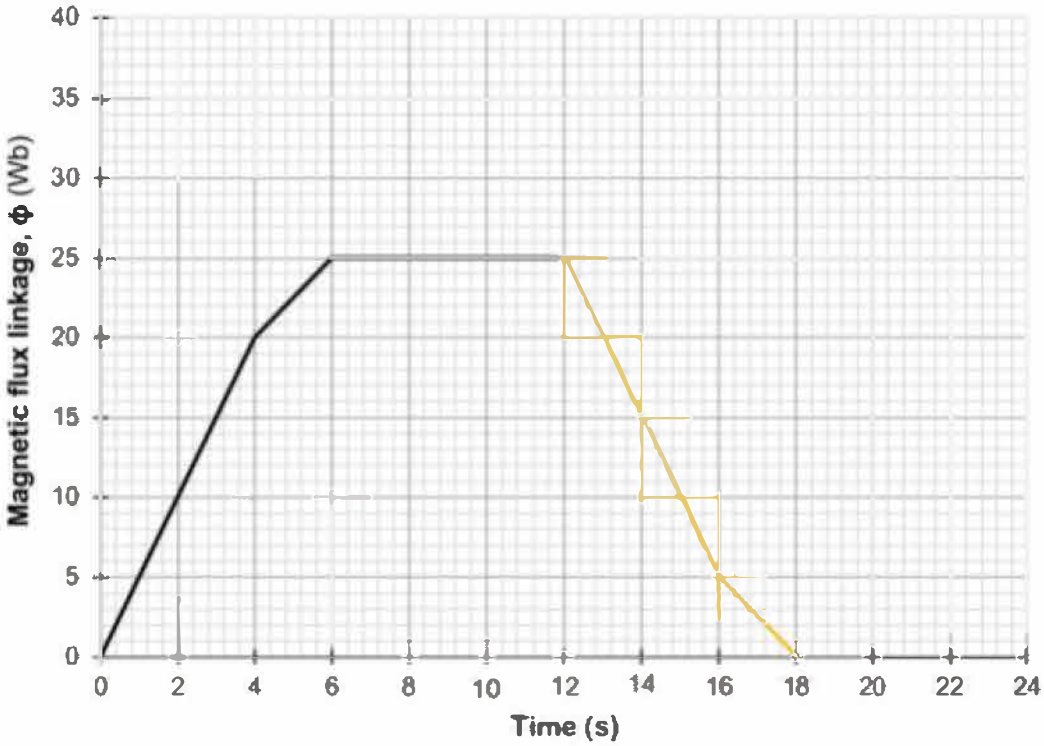
Notes from the Marker

- Better responses were able to recognise that the magnetic fiield density was constant and thus the magnetic flux linkage was dependent on the area enclosed by that portion of the loop.
- Weaker responses did not engage with the stimulus material or incorrectly tried to relate the gradient of the line to calculate *L*.

Question 26(b)

Marking Criteria	Marks
• Correctly shows the TWO changes in magnetic flux linkage at the correct times.	2
• Shows the TWO changes in magnetic flux linkage at the incorrect times.	1

Sample Response



Notes from the Marker

- Better responses were able to recognise that since the frame is moving at a velocity of 0.500 m s^{-1} to the right, by t = 12 s the right edge of the frame would reach the end of the region of constant magnetic field. Hence, after t = 12 s, the changes in magnetic flux linkage would mirror the changes that occurred when the frame entered the magnetic field.
- Weaker responses incorrectly:
  - related the velocity of the frame and hence showed a longer portion of time that showed no change in magnetic flux linkage, or;
  - showed the change in magnetic smaller portion of the metal frame occurring before that larger portion of the metal frame.

Question 26(c)

Marking Criteria	Marks
• Writes a response which extensively accounts for the observation with the ALL of following features: ○ relates the changes in magnetic flux linkage to an induced emf in relation to Faraday's law ○ explains the role of the light bulb in providing a closed circuit and relates the direction of induced emf and current to Lenz's law ○ explains that the induced current will produce a force when interacting with the external magnetic field ○ relates the need for a greater applied force in the opposite direction will need to be applied when the frame enters and leaves the magnetic field to a net force of zero in order to maintain a constant velocity	3
• Writes a response which mostly accounts for the observation with MOST of the above features.	2
• Provides some relevant information.	1

Sample Response

When the metal frame enters the magnetic field from t = 0 s to t = 6 s, it experiences an increase in magnetic flux linkage. By Faraday's Law, an induced emf is set up in the frame. Since the light bulb and metal frame provides a closed conducting path, by Lenz's Law and Ohm's law (V = IR), an induced current will flow in the frame in an anticlockwise direction that sets up a magnetic field that opposes the change which is the motion of the metal frame. This will produce a magnetic force on the frame to the left to slow it down. In order for the frame to move at a constant speed of 0.500 m s^{-1}, an additional external force to the right must be applied such that the resultant force on the frame is zero.

Whilst fully in the field between t = 6 s and t = 12 s, no additional applied force needs to be applied as the metal frame does not experience a change in magnetic flux linkage.

However, when the metal frame leaves the magnetic field, it will experience a decrease in magnetic flux linkage and thus by the aforementioned principles, an anticlockwise current will be set up to oppose the motion of the frame and again, an additional external force to the right must be applied such that the resultant force on the frame is zero to maintain its motion from t = 12 s to t = 18 s until the metal frame is completely removed from the magnetic field.

Notes from the Marker

- Better responses were able to specifically relate changes in magnetic flux linkage and were able to relate these changes to the stimulus provided with application of appropriate Physics principles.
- Weaker responses wrote non-specific responses which did not strongly relate to the stimulus material. Most responses addressed the need for a force when the metal frame entered the magnetic field but not when the metal frame left the magnetic field.

NESA STUDENT NUMBER

S2B

2021

Year 12 Physics

Trial Examination

Section 2B (25 marks)

Questions 27–31

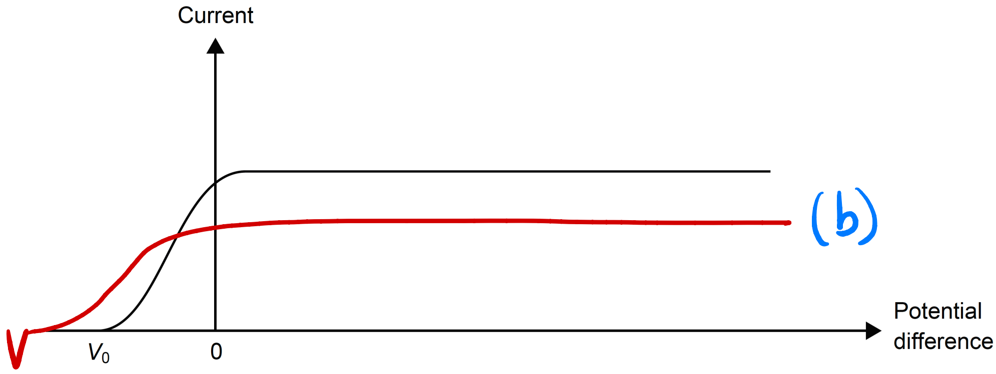
- Write using a black pen.
- Draw diagrams using pencil.
- Show all relevant working in questions involving calculations.
- NESA approved calculators may be used.

Marks

Question 27 (3 marks)

Blue light of frequency 6.25×10^{14} Hz is shone onto the sodium photocathode of a photocell.

The graph of the photoelectric current versus potential difference is shown below.



(a) The threshold frequency for sodium is 5.50×10^{14} Hz. **2**

Calculate the stopping potential, V_0, when blue light of frequency 6.25×10^{14} Hz is shone onto the sodium photocathode of this photocell.

$E_{k(max)} = hf - \phi = hf - hf_0$

$= 6.626\times10^{-34}(6.25 - 5.50)\times10^{14} = 4.9695\times10^{-20}$ J

$E_{k(max)} = qV_0 = 4.9695\times10^{-20}$ J

$V_0 = \dfrac{4.9695\times10^{-20}}{1.602\times10^{-19}} = 0.31$ eV

$V_0 = 0.310$ V

Question 27(a)

Marking Criteria	**Marks**
• Correct calculation of stopping potential with steps of working shown.	2
• Correct calculation of KE and stopping potential not attempted. **OR** • Incorrect calculation of stopping potential	1

(b) On the figure above, sketch the curve expected if the light is changed to ultraviolet with a lower intensity than the original. **1**

Question 27(b)

Marking Criteria	**Marks**
• Lower value of stopping potential marked **AND** • Curve with a lower value of maximum current shown.	1

Marks

Question 28 (4 marks)

Discuss the significance of Maxwell's contribution to the development of our current understanding of the nature of light. **4**

Sample Responses

1.

Marks

Question 28 (4 marks)

Discuss the significance of Maxwell's contribution to the development of our current understanding of the nature of light. 4

4/4

Maxwell's work on unifying electricity and magnetism, allowed us to understand that light waves are Electromagnetic waves, and exist across a spectrum. He did this through his discovery that light waves are mutually inducing electric and magnetic fields, with an accelerating charge producing a changing electric field, by Ampere's law producing a magnetic field and by Faraday's law an electric field, leading him to discover that light waves can propagate forever, through this and that there speed can be calculated by

$v=f\lambda$ and that $c=\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$. This provided the framework for future experiments determining parts of the EM spectrum and methods to measure the speed of light. When Maxwell's findings were supported by Young's Double slit experiment, this allowed a greater understanding of the nature of light as EM waves displaying wave ~~particles dual~~ features. Before Einstein's photon theory, building from those and the photoelectric effect.

2. Question 28 (4 marks)

4/4

Discuss the significance of Maxwell's contribution to the development of our current understanding of the nature of light.

- Maxwell unified the > 20 equations for electricity & magnetism into 4 simple equations, unifying the 2 fields into one field of electromagnetism:

① Gauss' Law of static E fields: the electric flux of the total charge enclosed by a sphere: charges can produce electric fields; Coulomb's Law: $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$ is a special case of this

② Gauss' Law of static B fields: Total magnetic flux enclosing any object = 0, as B-field lines form closed loops with no definite start or end ⇒ there is no such thing as a magnetic monopole

③ Faraday's Law: A change in flux induces a proportional emf ($\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$)

④ Ampere-Maxwell Law: ~~A change~~ A change in electric flux or a current can induce a magnetic field.

These eqns contributed to the our current understanding of light:

From ③ and ④, it can be seen that a changing B field produces a changing E field, which produces a changing B field, ... ∴ he described light as sinusoidally varying E- and B-fields in phase, ⊥ to each other & wave velocity.

- then he showed that they were self-propagating and could travel through the vacuum of space.
- he applied mathematics to find $v = \frac{E}{B} = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3.0 \times 10^8$ m/s in a vacuum.
- ~~he~~ from his 4th equation, he showed that they could be produced by accelerating charges.

⇒ ∴ he showed that the electromagnetic wave was transverse.

- he showed that they could exist at a range of λs and fs, but with fixed $v = c$, which conformed to $c = f\lambda$.

- ∴ Maxwell made a significant contribution to developing our understanding of the nature of light, as his work, ~~...~~ along with Einstein's later quantum model, lead to our current understanding of light in wave-particle duality.

- this wave model was later experimentally shown to explain wave behaviours such as refraction, reflection, diffraction, dispersion, interference & polarisation.

Question 28

Marking Criteria	Marks
• Describes **in detail** Maxwell's contribution to the development of our current understanding of the nature of light, **including**, • His **equations** and their **significance** • **Constancy** of the speed of light • **Lead up** of his contributions to the experiments done by Hertz, Einstein, Young to **further improve/develop** our current understanding of the nature of light.	4
• Describes **in detail** Maxwell's contribution to the development of our current understanding of the nature of light, **including – ANY 2 from the following** • His **equations** and their **significance** • **Constancy** of the speed of light • **Lead up** of his contributions to the experiments done by Hertz, Einstein, Young to **further improve/develop** our current understanding of the nature of light.	3
• Describes **in some detail** Maxwell's contribution to the development of our current understanding of the nature of light, **including – Any 2 of the following** • His **equations** and their **significance** • **Constancy** of the speed of light • **Lead up** of his contributions to the experiments done by Hertz, Einstein, Young to **further improve/develop** our current understanding of the nature of light.	2
• Describes Maxwell's contribution to the development of our current understanding of the nature of light, **including – Any 1 of the following** • His **equations** and their **significance** • **Constancy** of the speed of light • **Lead up** of his contributions to the experiments done by Hertz, Einstein, Young to **further improve/develop** our current understanding of the nature of light.	1

Marks

Question 29 (5 marks)

After its initial launch, the Juno probe travelled around Earth and then entered Jupiter's atmosphere.

The probe reached a maximum velocity of 7.36×10^4 m s^{-1} as it went past the Earth at a height of 559 km above the surface.

(a) Using appropriate calculations, show that the probe was able to move away from the Earth and not be captured in orbit around it. **3**

For the probe to escape Earth, $\Delta K + \Delta U = 0$ (LOCE)

$$\left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2\right) + \left(-GMm\left(\frac{1}{r_f} - \frac{1}{r_i}\right)\right) = 0$$

$v_f = 0$, $r_f = \infty$, $v_i = V_e$, $r_i = 5.59\times10^5 + 6.37\times10^6 = 6.929\times10^6$ m

$\therefore V_e = 1.07\times10^4$ ms^{-1} (escape velocity)

As $v_{max} > V_e$, the probe escapes Earth.

Question 29(a)

Marking Criteria	**Marks**
• Clearly and **correctly** used [redacted] the above method[redacted], shown all calculations **AND** concluded that the probe escapes Earth.	3
• Uses [redacted] the above method[redacted] **AND** correctly/incorrectly calculates the [redacted]/escape velocity	2
• Attempts to calculate [redacted]/escape velocity **AND** shows some relevant detail.	1

(b) The Juno probe was launched from Earth and entered Jupiter's orbit, having a trip of 1796 days. It had an average velocity of 7.15×10^4 m s^{-1}. **2**

Assuming there was no effect from gravitational fields, calculate the time difference between the two clocks, one based in the probe and the other in the laboratory on Earth.

$t_0 = 1796$ days (Jupiter)

$v = 7.15 \times 10^4$ m s^{-1}

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1796}{\sqrt{1 - \left(\frac{7.15 \times 10^4}{3 \times 10^8}\right)^2}} = 1796.000051 \text{ days (Earth)}$$

$$\text{Difference in time} = t - t_0 = 0.000051 \text{ days} = 4.41 \text{ s}$$

Question 29(b)

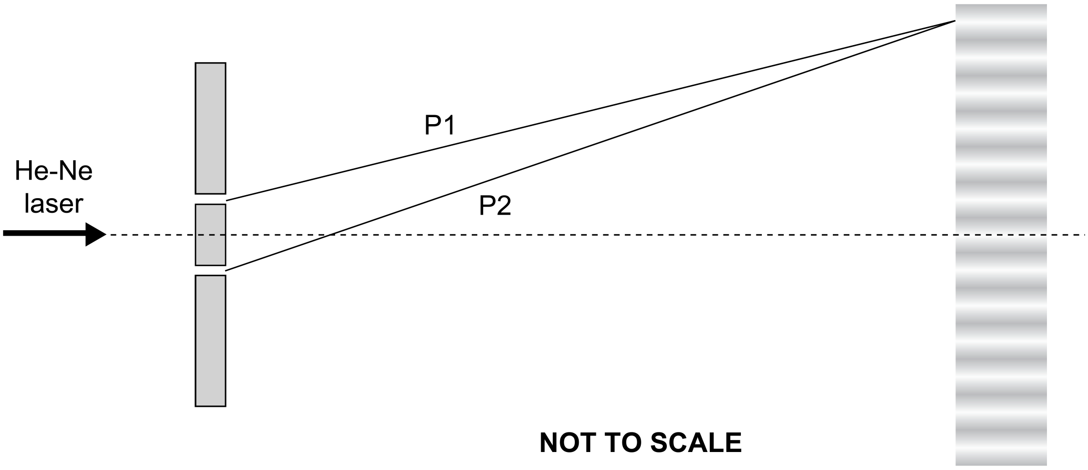
Marking Criteria	Marks
• Clearly and correctly calculates the time difference.	2
• Identifies the time dilation equation and shows some relevant working.	1

Marks

Question 30 (6 marks)

A He-Ne laser of wavelength 632 nm directs the monochromatic beam onto a set of two parallel slits.

A pattern from these slits has been projected onto a distant wall as seen below.



(a) Explain the formation of the bright and dark regions in terms of the wave-like nature of light. **2**

It is an interference pattern where bright bands result from constructive interference (or path difference = 0, 1λ, 2λ, 3λ....) and dark bands from destructive interference (or path difference = $\frac{\lambda}{2}$, $\frac{3\lambda}{2}$, $\frac{5\lambda}{2}$ .....)

Question 30(a)

Marking Criteria	Marks
• Correctly explains the complete interference pattern.	2
• Explains either constructive/destructive interference pattern.	1

(b) The teacher asks each student to estimate the difference between the length of the lines P1 and P2, which are the lines between the centre of each slit and the 6th bright spot. **2**

Calculate the difference in length between P1 and P2.

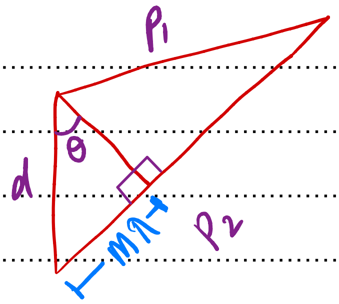
path difference $= m\lambda = d\sin\theta$

6th bright band $\therefore m=6$

$\therefore$ p.d. $= 6 \times 632 \times 10^{-9}$ m

p.d. $= 3.79 \times 10^{-6}$ m

$= 3.79$ μm



Question 30(b)

Marking Criteria	**Marks**
• Correctly calculates the path difference.	2
• Identifies m = 6 **OR** incorrect calculation **OR** provides some relevant detail.	1

(c) Monochromatic light is now replaced with white light. **2**

Does this result in any changes in the pattern of the bands on the screen? Justify your answer.

Yes.

White light is made of a combination of all colours of the spectrum.

As $d\sin\theta = m\lambda$, and for small angles, $\sin\theta \approx \tan\theta \approx \theta = \frac{x}{L}$; $d\frac{x}{L} = m\lambda \Rightarrow x = \frac{m\lambda L}{d}$

If all other variables are constant, $x \propto \lambda$

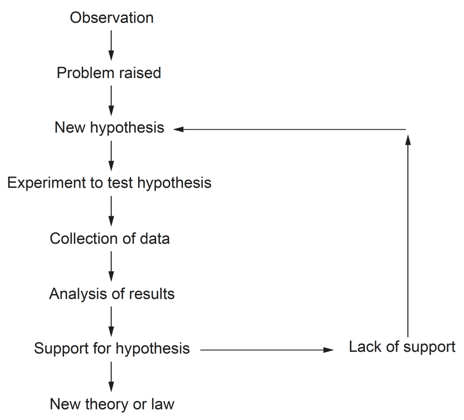
There will be a series of bright and dark bands with varying brightness. Violet is closest to central maximum and is the brightest. Red is the furthest away and is the least bright.

Question 30 (c)

Marking Criteria	Marks
• Clearly explains the changes in the interference pattern including the varying brightness.	2
• Identifies the varying brightness/ dispersion/ link between bands wavelengths and brightness.	1

Question 31 (7 marks)

The following flowchart represents a model of scientific method used to show the relationship between theory and the evidence supporting it.



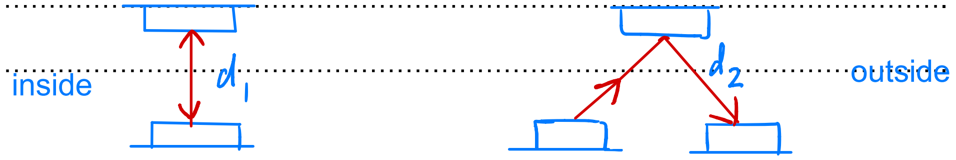
(a) Evaluate the role of thought experiments in the development of our current understanding of length and time. **3**

Thought experiments have significantly contributed to the current understanding of length and time. Earlier it was believed that length and time are absolute. However, Einstein came up with his theory of special relativity and hypothesised that the speed of light was constant and so length and time must change. He then conducted a thought experiment such as:

Light shone from both mirrors reaches simultaneously for the person inside the carriage. But, for the observer on the platform, the carriage has moved right, $d_2 > d_1$ **or** $c_1 t_1 < c_2 t_2$.

As **c is constant,** $t_1 < t_2$ which means that the observer on the platform observes light from source 2 is emitted after the light from source 1.

These thought experiments when analysed showed that time and length varied and were not absolute. This further led to the concepts of length contraction and time dilation.



Question 31(a)

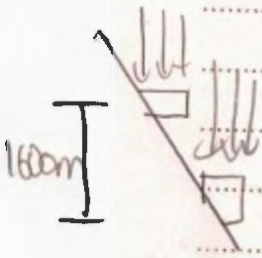
Marking Criteria	Marks
• Clearly evaluates the role of thought experiments using an example to address the question.	3
• Evaluates the role of thought experiments OR uses an example to address the question.	2
• Provides some relevant detail.	1

(b) Describe two pieces of experimental evidence that support the above-mentioned concepts of length and time. **4**

Sample Responses

1.

• Cosmic-Origin Muons: Muons are subatomic particle produced in the upper atmosphere, travelling at speeds close to speed of light, eg. $v \approx 0.998c$.



In 1941, Rossi & Hall measured the relative intensity of the muon flux between two detectors 1600m vertically apart in Colorado. They measured this value as ~~for~~ 88.3%.

In ~~conventional~~ classical mechanics, muons would take $t = \frac{d}{v} = \frac{1600}{0.998 \times 3 \times 10^8} = 5.34 \times 10^{-6}$ s to travel 1600m.

However, the mean lifetime of a muon is $2.2\mu s$ so the relative intensity ~~loss~~ should be $\frac{N_t}{N_0} = e^{-t/t_{lifetime}} = e^{-5.34/2.2} \doteqdot 8.8\%$

which was not observed.

END OF SECTION 2B

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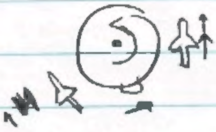
31) b) This could be explained via special relativity, as the muons travel at relativistic speeds.

In the frame of reference of an observer, the mean lifetime of a muon is $t = \frac{2.2\mu s}{\sqrt{1-0.998^2}} = 34.80\mu s$, which is greater than the time taken to travel 1600m. ✓

Using $\frac{N_t}{N_0} = e^{-t/t_{mean}} = e^{-5.34/34.80} \doteq 86\%$ which closely matches the observed value, and hence provides evidence for special relativity. ✓

• 2: ✓ Hafele-Keating's Experiment: Hafele & Keating ~~placed~~ had 3 pairs of caesium atomic clocks. One they placed in the U.S. Naval Observatory (USNO), another on an eastward bound commercial airliner, and ~~a~~ the final on a westward bound one. Relative to an earth centred inertial frame,

ECI



$v_{eastward} > v_{USNO} > v_{westward}$. Hence by time dilation the time in the frame of reference of the clocks should be $t_0 = t\sqrt{1-v^2/c^2}$ where t is earth centred inertial frame. Hence $t_{eastward} < t_{USNO} < t_{westward}$.

~~Th~~ The data collected by Hafele-Keating measured

~~t_{USNO}~~ $t_{eastward} - t_{USNO} = -40ns$

$t_{westward} - t_{USNO} = +270ns$

which provided experimental confirmation for special relativity ~~the the~~ via time dilation. ✓

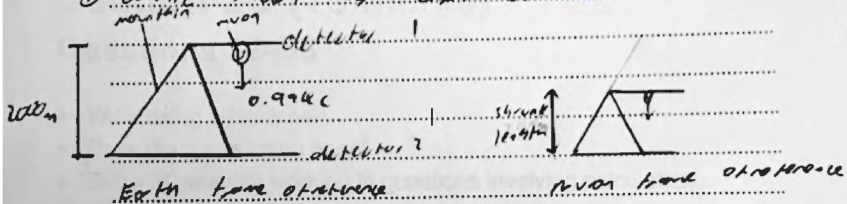
Thus, through the collected experiment evidence and analysis, the hypothesis of special relativity was confirmed and thus so too the theory of special relativity. ✓

2.

(b) Describe two pieces of experimental evidence that support the above-mentioned concepts of length and time. **4**

When Einstein hypothesised the above theory, support for hypothesis was obtained

① Cosmic Muon origin experiment



accordingly, as muons were timed from detector 1 to 2, they observed length to contract via $l = l_0\sqrt{1-\frac{v^2}{c^2}}$

$= 2000\sqrt{1-\frac{0.994^2c^2}{c^2}} \approx 656m$

END OF SECTION 2B

$= 219m$, giving evidence for length contraction

Hence, while it was classically believed ~~only~~ < 5% of muons would reach detector 2 due to them decaying with half-life = 2.2μs, more than 75% did as they observed > 75% did, as in muon's frame of reference, $t = \frac{2.2\mu s}{\sqrt{1-0.994^2}}$ = 20μs half-life

as well as the muons observing shortened length

 cont'd. back

contd
b) This opposed classical belief that length and time were absolutes and gave rise to time-dilation and length contraction effects

Moreover ② Hafele-Keating Experiment

Four synchronised clocks on Earth (high precision atomic clocks) were flown twice around the Earth on high speed jets, 2 flown eastward, 2 flown westward and compared to clock stationary on Earth. The one flying eastward had 60ns less pass on it and the one westward had 270ns more pass on it when compared to stationary clock. This was consistent with Einstein's theory of time-dilation as the eastward moving clocked moved with Earth's rotation and hence should experience the most time dilation, while the one flying westward flew against Earths rotation and should hence experience the least time-dilation.

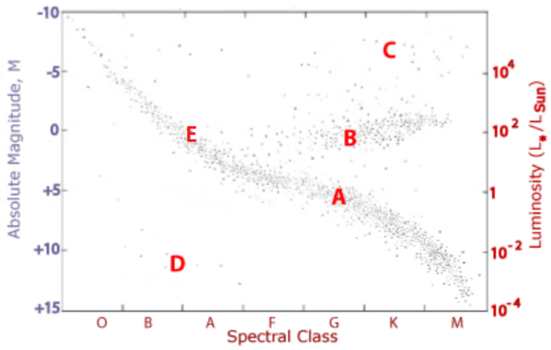
These experimental evidence supported Einstein's hypothesis and thus led to a new theory flow as seen in flowchart

Question 31 (b)

Marking Criteria	Marks
• Correctly states 2 evidence that support **both** length and time. **AND** • Correctly describes in detail the above 2 evidence that support **both** length and time.	4
• Correctly states 2 evidence that support **both** length and time. **AND** • Correctly describes in detail only **ONE** evidence that supports length **OR** time. **AND** Briefly describes the other evidence.	3
• Correctly states 1 evidence that support length **OR** time. **AND** Correctly describes in detail only **ONE** evidence that supports length **OR** time. **OR** • Briefly describes **both** evidence that support length and time	2
• Correctly states 2 evidence that supports **both** length and time. **OR** • Briefly describes **ONE** evidence that supports length **OR** time.	1

END OF SECTION 2B

Question 32 (5 marks)



a. Identify the stars that will evolve into white dwarf. **1**

Stars A and B

b. Outline the two nuclear reactions that are occurring in Star B. **2**

Star B is a Red Giant. There are two reactions that occur in this stage:

Hydrogen Shell burning: it involves fusion of hydrogen in a shell around star's helium core. The helium produced sinks into the core.

Helium fusion in the core: In the core, helium nuclei fuse together to form heavier nuclei.

2 marks	Identification and some relevant description of each nuclear reaction
1 mark	Identification of both types of reactions or description of just one of the reactions

c. Energy can be produced in Star A and Star E by two nuclear processes- named Proton- Proton chain and CNO cycle. Compare these two processes. **2**

The mass of a main sequence star will determine which of the two nuclear processes will dominate in the star. The higher mass stars have higher core temperature due to higher gravitational force. This allows CNO cycle to dominate.

In both Proton-Proton chain and CNO cycle, four hydrogen nuclei fuse together into a helium-4 nucleus. However, in the CNO cycle, carbon-12 nuclei act as nuclear catalysts. These Carbon-12 nuclei facilitate the reaction but are not changed by it. In proton-proton chain there is no such catalyst.

2 marks	Describes the similarities and differences between two reactions including the reason that will cause one reaction to dominate over the other.
1 Mark	Describes the similarity or difference

Question 33 (5 marks)

Astronomers combine mathematical models with observations to develop theories to describe the evolution of the observable universe. **The Big Bang theory** is the prevailing cosmological model that explains origin and subsequent large-scale expansion of the universe.

Describe how the careful observation of the electromagnetic radiation from various sources gave evidence in support of the Big Bang Theory.

Expected: a clear description of the observation of red-shift of light from galaxies together with either an appreciation of its significance in terms of an expanding universe or some detail about the process. This should lead to a brief description about how this supported the Big Bang theory. This should then be coupled with an understanding of the significance of another observation; cosmic microwave background radiation.
Following points to be included:

- observation of visible light led to discovery of red -shift.
- red-shift means lower frequency / longer wavelength
- red-shift was greatest for the most distant galaxies - galaxies are moving away from each other
- red-shift means universe is expanding
- distances to galaxies could be determined

Big Bang and Steady State theories were proposed and both theories could explain red -shift

- CMBR detected in radio telescopes
- space telescopes (such as COBE) gave more detail of CMBR
- CMBR is residual radiation (6) - only Big Bang could explain CMBR

1-2	a limited description of either red -shift or CMBR, e.g. light from galaxies was red -shifted OR Red -shift is evidence for Big bang. • the answer communicates ideas using simple language and uses limited scientific terminology
3-4	a description giving full detail of either red -shift or CMBR OR some detail of both red -shift and CMBR, e.g. light was seen to be shifted towards a longer wavelength. This means that the galaxies are moving away from each other. • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately
5	a detailed description of how both red -shift and CMBR give supporting evidence for the Big Bang theory, e.g. light was seen to be shifted towards a longer wavelength. This means that the galaxies are moving away from each other so the Universe must be expanding. This is evidence for the Big Bang theory. Cosmic Background Radiation coming from all directions provides further evidence for the Big Bang. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately

End of Examination.