Sydney Boys High School

NESA Student Number:

Multiple Choice Answer Sheet

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

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

A B C D

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

A B C D

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

correct

A B C D

Start Here ➔

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

Sydney Boys High School

NESA Student Number:

2023	**Trial Exam**

Physics

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 at the back of this paper • SHOW ALL WORKING • Write your student number in ALL of the boxes provided
Total marks: 100	**Section I – Multiple Choice** • 20 marks • Allow about 35 minutes for this section **Section II – Free Response** • 80 marks • Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

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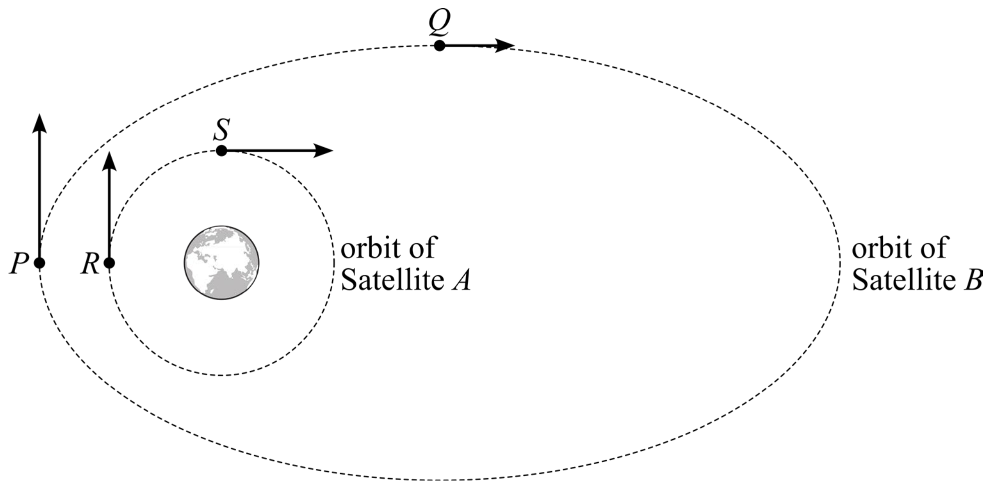
1. A ball is thrown horizontally from the top of a building with speed v, and it hits the ground with a range, R, from the bottom of the building. A second ball is thrown horizontally from the top of the same building with speed $2v$. What is the range of the second ball?

A. R
B. $\sqrt{2}R$
C. $2R$
D. $4R$

2. Two satellites orbit earth, as shown below. Satellite *A* orbits with a circular orbit, whilst Satellite *B* orbits with an elliptical orbit. The velocities at different points of the two satellites are shown by arrows.



Which of the following correctly describes the work done by the gravitational field of Earth on Satellite *A* as it moves from *R* to *S* in its orbit, and the work done by the gravitational field of Earth on Satellite *B* as it moves from *P* to *Q* in its orbit?

	Work done on Satellite A from R to S	*Work done on Satellite B from P to Q*
A.	zero	zero
B.	zero	non-zero
C.	non-zero	zero
D.	non-zero	non-zero

3. Which one of the following best describes a hypothesis?

A. a testable scientific explanation
B. a well-tested scientific explanation
C. a scientific explanation by a famous scientist
D. a widely believed and highly plausible explanation

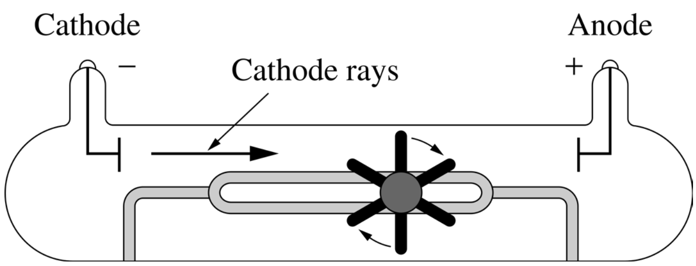
4. Quantised energy levels within atoms can best be explained by

A. electrons behaving as individual particles with varying energies.
B. atoms having specific energy requirements that can only be satisfied by electrons.
C. electrons behaving as waves, with each energy level representing a diffraction pattern.
D. electrons behaving as waves, with only standing waves at particular wavelengths allowed.

5. Actinium-227 can undergo either alpha- or beta-decay. What would be the product nuclei for either of the two modes of radioactive decay?

	Product from alpha-decay of ^{227}Ac	*Product from beta-decay of ^{227}Ac*
A.	^{223}Fr	^{227}Th
B.	^{223}Fr	^{228}Th
C.	^{225}Fr	^{227}Th
D.	^{225}Fr	^{228}Th

6. The cathode ray tube shown below contains a rotating paddle wheel that is free to move. The tube's electrodes are connected to a high-voltage source.

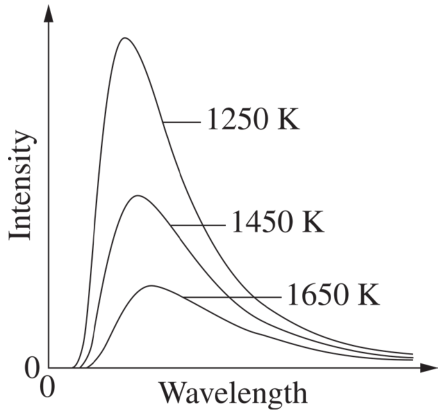


Which of the following statements about cathode rays does this apparatus provide evidence for?

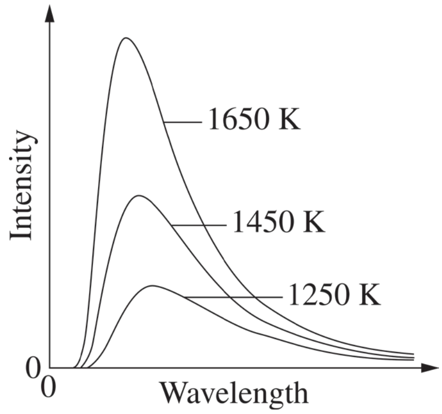
A. Cathode rays travel in straight lines.
B. Cathode rays can only be produced in vacuum tubes.
C. Cathode rays are particles that have momentum.
D. Cathode rays are waves of high frequency and short wavelength.

7. Which graph is consistent with predictions resulting from Planck's hypothesis regarding radiation from hot objects?

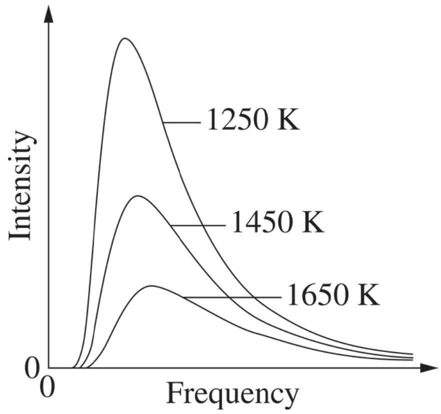
A.



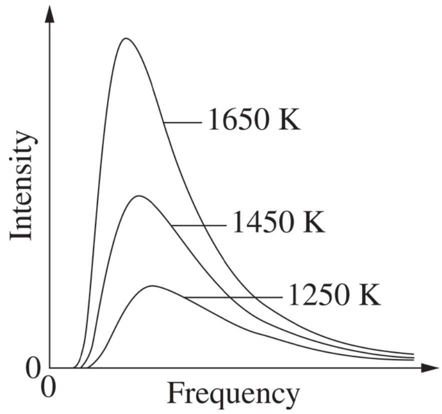
B.



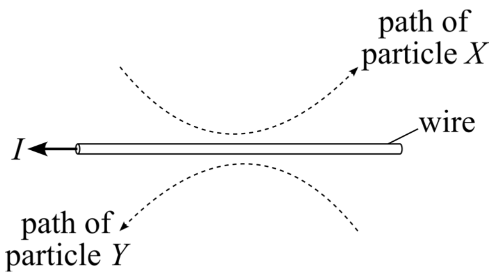
C.



D.



8. At two separate times, two charged particles approach a wire carrying a current-carrying wire and follow the trajectories shown in the diagram below.

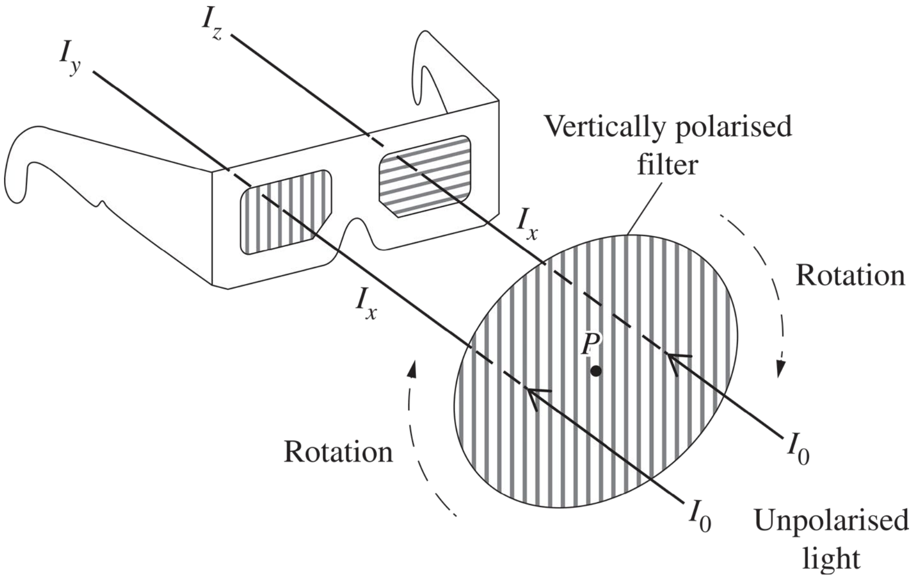


What are the signs of the charges for particles X and Y?

	Charge of particle X	*Charge of particle Y*
A.	Positive	Negative
B.	Positive	Positive
C.	Negative	Negative
D.	Negative	Positive

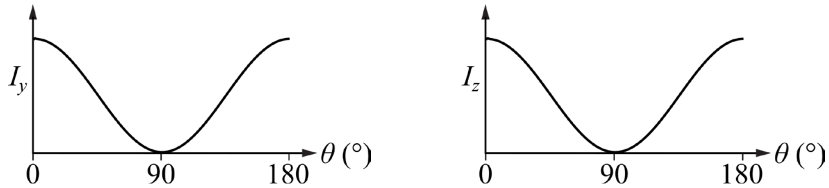
9. Unpolarised light of intensity I_0 is incident upon a vertically polarised filter. The filtered light then passes through a pair of glasses. The glass have polarising filters, with one side polarised vertically and the other horizontally.

The filter undergoes 180° rotation around point P, as shown.

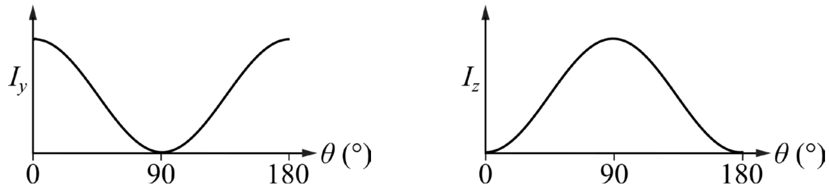


Which of the following correctly compares I_y and I_z during the rotation?

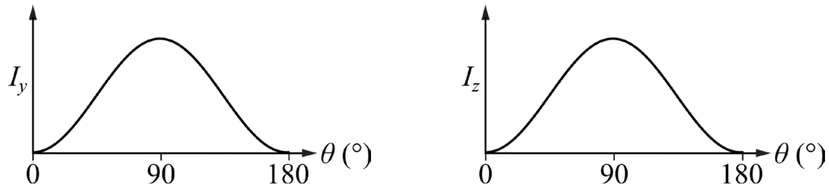
A.



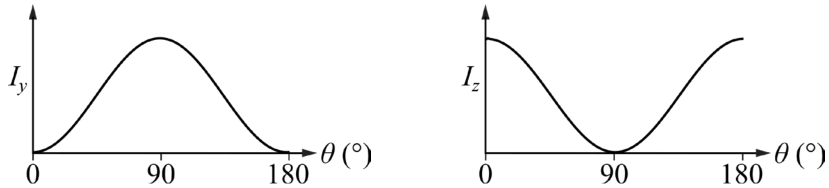
B.



C.



D.



10. JJ Thomson determined the charge/mass ratio of the electron by constructing a device which contained

A. perpendicular magnetic fields.
B. perpendicular electric fields.
C. parallel electric and magnetic fields.
D. perpendicular electric and magnetic fields.

11. Two students, Rob and Jan, measure the current in the same circuit on separate occasions. Rob obtains the following readings: 7.50 mA, 7.21 mA, 7.10 mA and 7.60 mA (average 7.35). Jan obtains the following readings: 7.20 mA, 7.25 mA, 7.31 mA and 7.36 mA (average 7.28). The true value of the current is known to be 7.33 mA.

Which one of the following best describes these two sets of measurements?

A. Both sets of results are equally accurate.
B. Rob's results are more accurate than Jan's results.
C. Both sets of results are equally reliable.
D. Rob's results are more reliable than Jan's results.

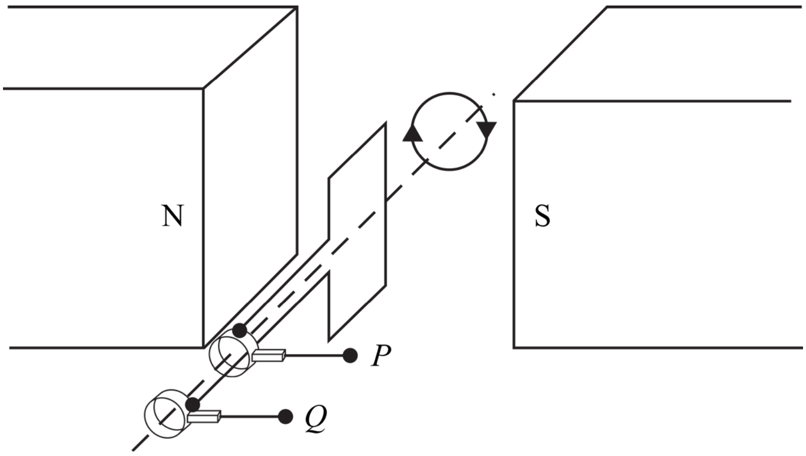
12. Why is an iron core used in a transformer?

A. To reduce the heat generated
B. To separate the magnetic fields
C. To increase the linkage of the flux
D. To limit eddy currents

13. Which of the following is NOT a contribution by Maxwell?

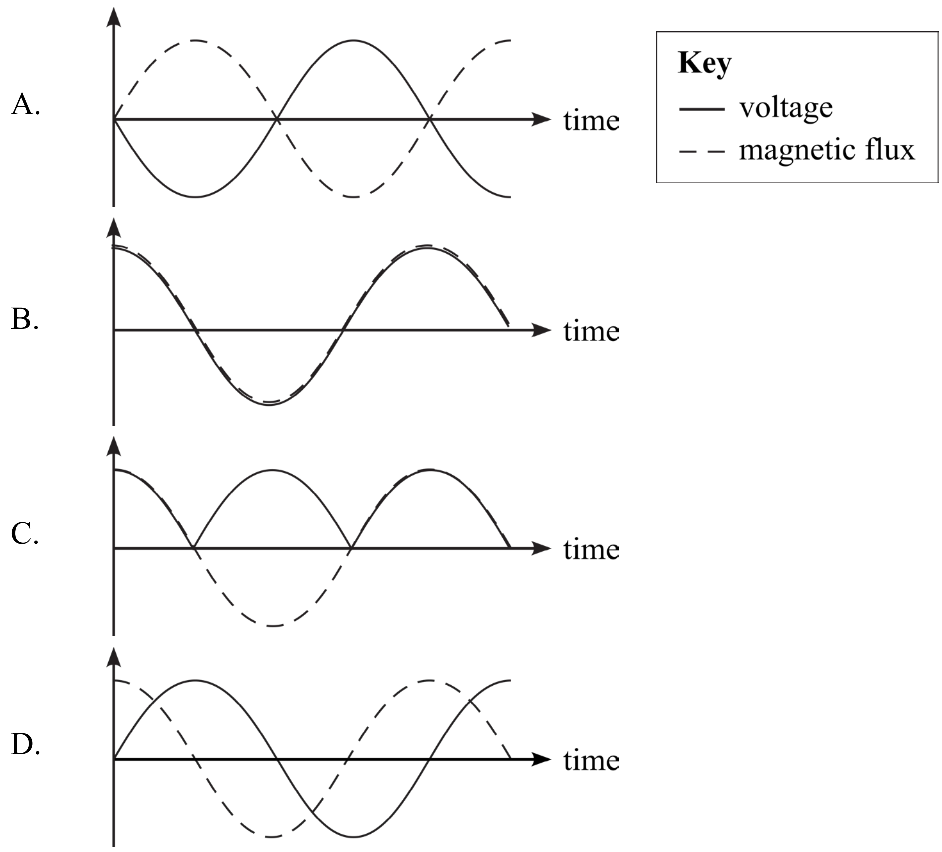
A. Predicting the velocity of electromagnetic radiation
B. Unifying electricity and magnetism
C. Predicting electromagnetic waves
D. Discovery of radio waves

14. An electrical generator is shown in the diagram below. The generator is turning clockwise.

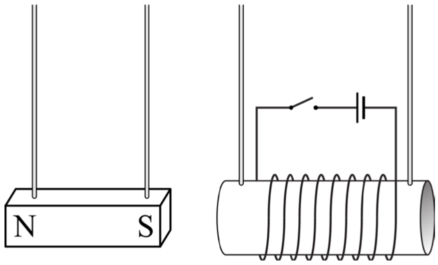


The voltage between P and Q and the magnetic flux through the loop are both graphed as a function of time, with voltage versus time shown as a solid line and magnetic flux versus time shown as a dashed line.

Which one of the following graphs best shows the relationships for this electrical generator?



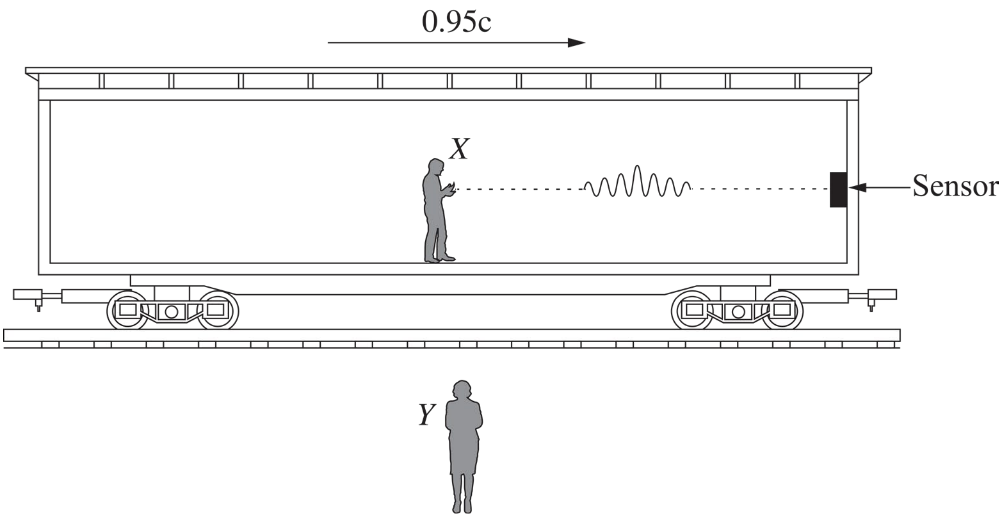
15. A bar magnet and a solenoid are suspended next to each other from a fixed platform, as shown below.



The switch on the solenoid circuit is closed. Which choice below correctly indicates the direction(s) the magnet and solenoid will move immediately after the switch is closed?

	Magnet moves	*Solenoid moves*
A.	right	left
B.	left	right
C.	right	right
D.	left	left

16. In a thought experiment, observer *X* is on a train travelling at a constant velocity of 0.95 *c* relative to the ground. Observer *Y* is standing on the ground outside the train. As observer *X* passes observer *Y*, observer *X* sends a short light pulse towards the sensor.



Which statement about the light pulse is correct as observed by *X* or *Y* in their respective frames of reference?

A. Its velocity observed by Y is 0.05 c.

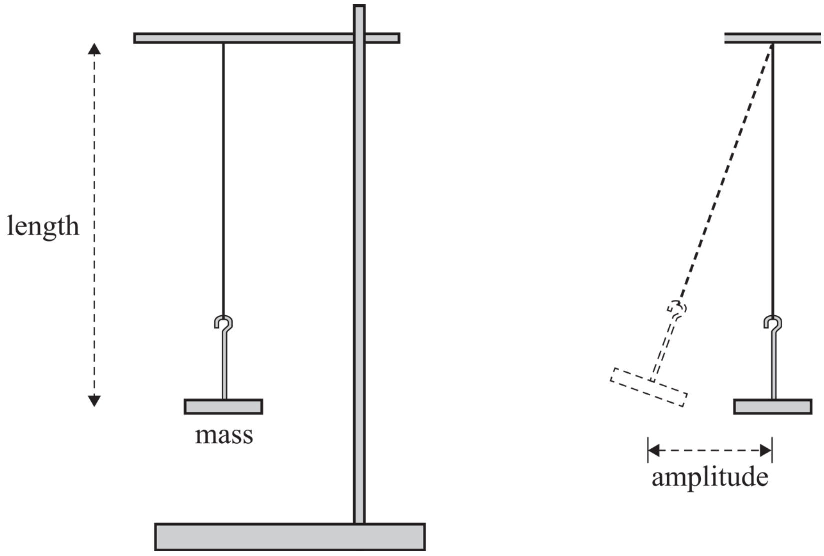
B. *X* sees it travel a shorter distance to the sensor than *Y*.

C. *X* sees it take a longer time to reach the sensor than *Y*.

D. Both *X* and *Y* see it travel the same distance in the same amount of time.

Use the following information to answer Questions 17 and 18.

As part of an experimental investigation, Physics students use a pendulum, as shown below, to indirectly measure the magnitude of Earth's gravitational field at their location.



The students use a constant mass and a constant amplitude of swing, changing only the length of the pendulum and then measuring the time for five oscillations. They obtain four different time readings for four different lengths of the pendulum.

By using the relationship

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where T is the period and l is the length of the pendulum,. The students obtain four values for the magnitude of Earth's gravitational field.

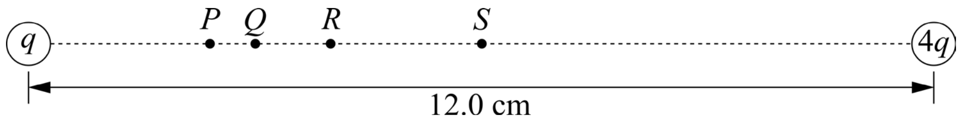
17. Which of the following best identifies the independent, dependent and controlled variables in the students' experimental investigation?

	Independent variable	*Dependent variable*	*Controlled variables*
A.	length	time	mass, amplitude
B.	time	length	mass, amplitude
C.	mass	time	length, amplitude
D.	amplitude	length	time, mass

18. Which one of the following best explains why the students measured the time for five oscillations rather than the time for one oscillation?

A. One oscillation is too quick to see.
B. Five oscillations reduce the effect of air friction.
C. Five oscillations reduce the uncertainty of the measured length.
D. Five oscillations reduce the uncertainty of the measured period.

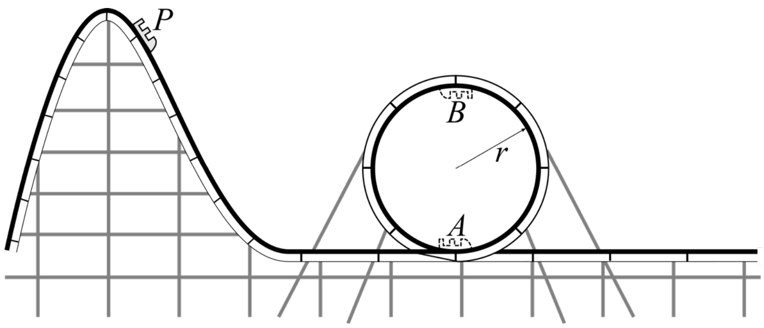
19. Two positive point charges, q and $4q$, are placed 12 cm apart, as shown in the scale diagram below.



At which point along the straight line between the charges q and $4q$ will a null point be found?

A. P
B. Q
C. R
D. S

20. A carriage is rolling down a rollercoaster track under the influence of gravity at point P, as shown in the image below.



The carriage proceeds along the track and around a loop, of radius r, before reaching the end of the rollercoaster track. Ignoring friction, which expression below shows the decrease in speed from u at point A to v point B.

A. $\frac{2gr}{u-v}$
B. $\sqrt{4gr}$
C. $\frac{4gr}{u+v}$
D. $\sqrt{2gr}$

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2023 **Trial Exam**

NESA Student Number:

Physics

Section II Answer Booklet I

80 marks
Attempt Questions
Allow about 2 hours and 25 minutes for this section

Instructions

- Write your NESA Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (4 marks)

Explain refraction using both Huygens' and Newton's theories of light. **4**

Question 22 (4 marks)

A distant exoplanet, Methanos, has a single moon, Propedes.

(a) Compare the force of gravity exerted on Propedes by Methanos with the force of gravity exerted on Methanos by Propedes. **2**

(b) The acceleration due to gravity on Propedes is 2.2 m s^{-2} and on Methanos it is 12.8 m s^{-2}. Quantitatively compare the mass and weight of a 95 kg astronaut on Propedes and on Methanos. **2**

Question 23 (4 marks)

A square coil of conducting wire, 44.0 cm long, is placed in a 2.75 T magnetic field, as shown below in Figure 1. The shape of the coil is uniformly changed to a circular shape in 1.25 ms, as shown in Figure 2.

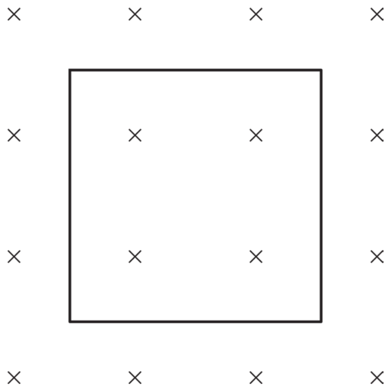
Figure 1

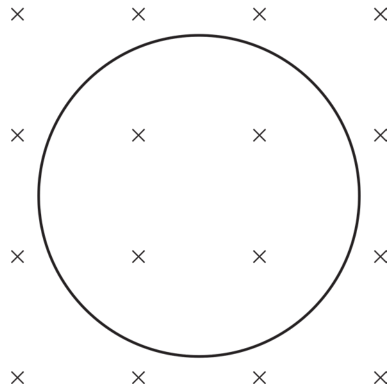
Figure 2

(a) Calculate the magnitude of the average induced EMF. **3**

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(b) Identify the direction of the current that passes through the conducting wire as a result of the induced EMF. **1**

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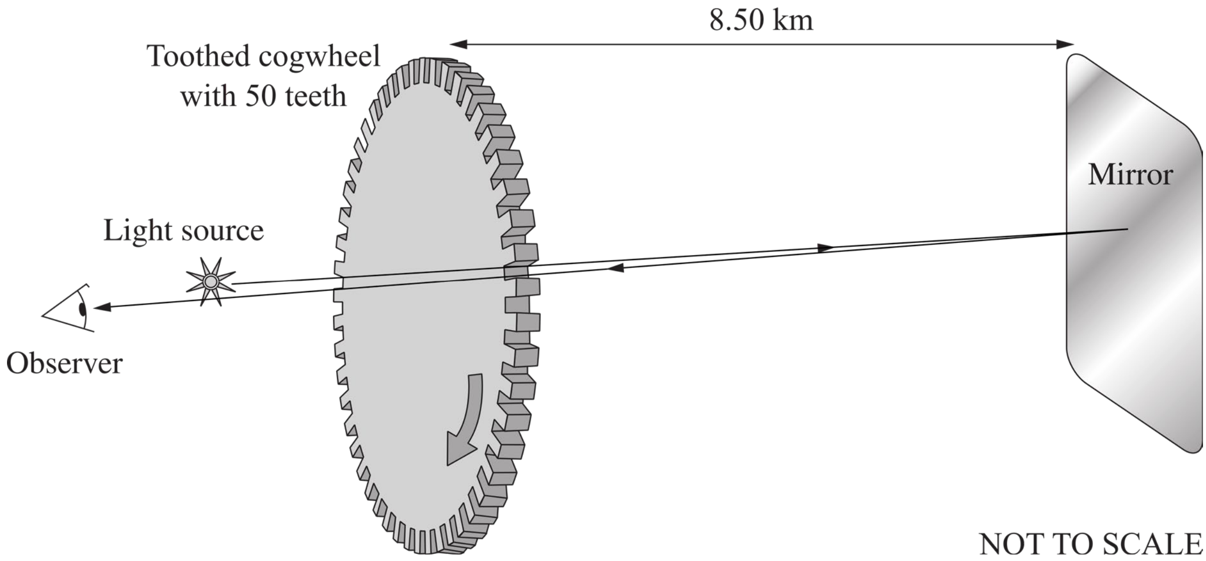
Question 24 (5 marks)

In the 1840s, French physicist, Hippolyte Fizeau performed an experiment to measure the speed of light. He shone an intense light source at a mirror 8.50 km away and broke up the light beam with a rotating cogwheel. He increased the speed of rotation of the wheel until the reflected light beam could no longer be seen returning through the gaps in the cogwheel. **5**

The diagram shows a similar experiment. The cogwheel has 50 teeth and 50 gaps of the same width.



Explain why specific speeds of rotation of the cogwheel will completely block the returning light. Support your answer with calculations.

Booklet II

NESA Student Number:

Question 25 (7 marks)

A polonium-118 atom, at rest, undergoes radioactive decay, with a decay constant of 0.2236 min^{-1}. The masses of the nuclei involved are shown below:

polonium-118	$\rightarrow$	lead-114	+	helium-4
218.00897 u		213.99981 u		4.00260 u

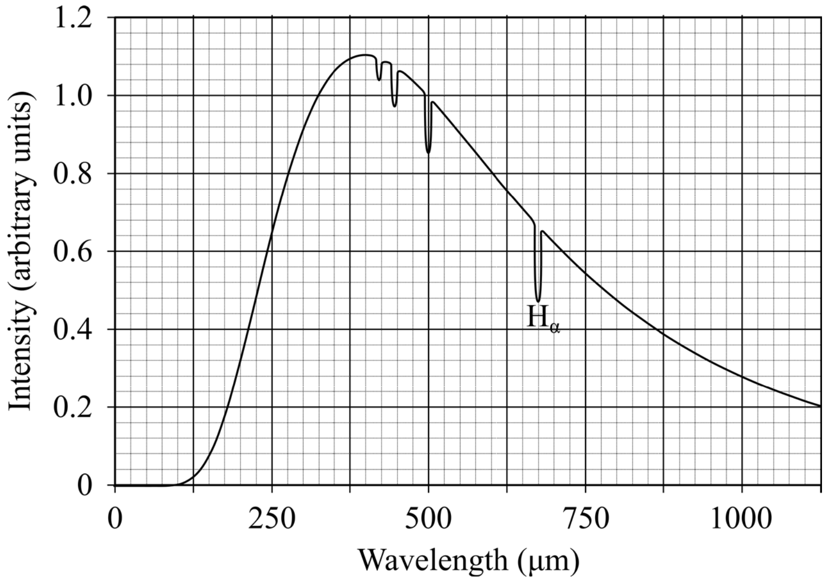
(a) Calculate the energy, in Joules, released by this decay. **3**

(b) Identify whether lead-114 has a higher or lower *binding energy per nucleon*. **1**

(c) If a polonium-118 ion is accelerated in a particle accelerator to 0.99945 c, what will be the decay constant of the radioisotope? **3**

Question 26 (8 marks)

An astronomer measured the spectrum of a distant star using a spectrometer attached to a telescope on Earth. The spectrum is shown below.



The astronomer used the hydrogen absorption dips to analyse the properties of the star.

The first four wavelengths (in decending order) in the Balmer series of the hydrogen spectrum are shown in the table below.

Hydrogen line	H_α	H_β	H_γ	H_δ
Wavelength (nm)	656.3	486.2	434.1	410.2

(a) Calculate the next wavelength, H_ε, in the Balmer series. **2**

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Question 26 continues on page 19

Question 26 (continued)

(b) The H_α absorption peak in the star's spectrum was found to be shifted. It was precisely measured to have a wavelength of 673.2 nm. **3**

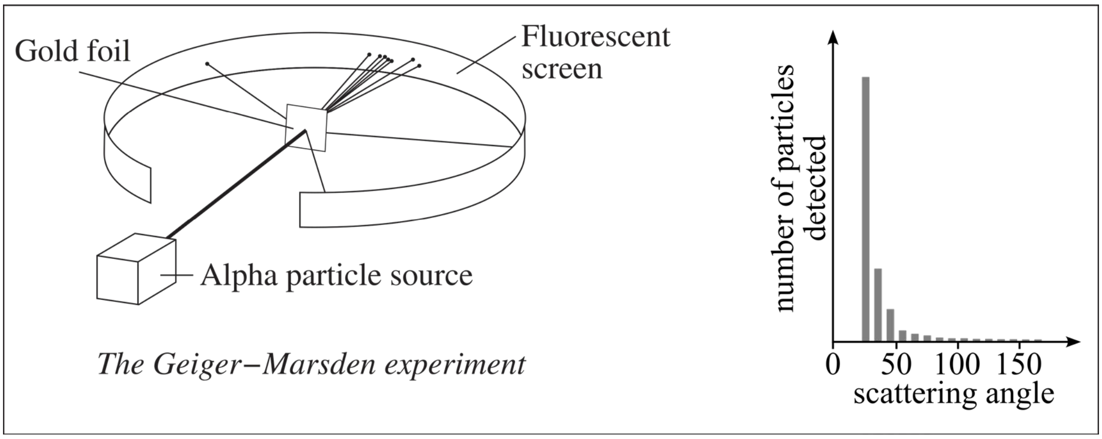
Ignoring the velocity of the Earth, determine the velocity of the star with respect to Earth.

(c) Calculate the surface temperature of the star. **3**

End of Question 26

Question 27 (4 marks)

Geiger and Marsden performed their gold-foil experiment, measuring the number of particles being scattered at different angles. The results are shown below for angles above 30°. **4**



The Geiger−Marsden experiment

Based on these results, Rutherford proposed his model of the atom.

How do features of his model account for all the experimental evidence above?

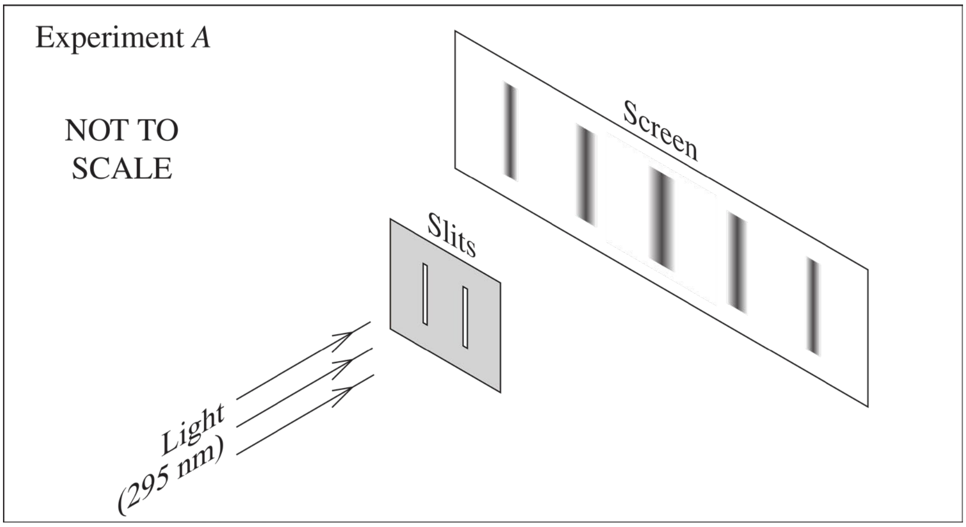
Question 28 (5 marks)

Using examples from special relativity, explain how theories in science are validated in different ways. **5**

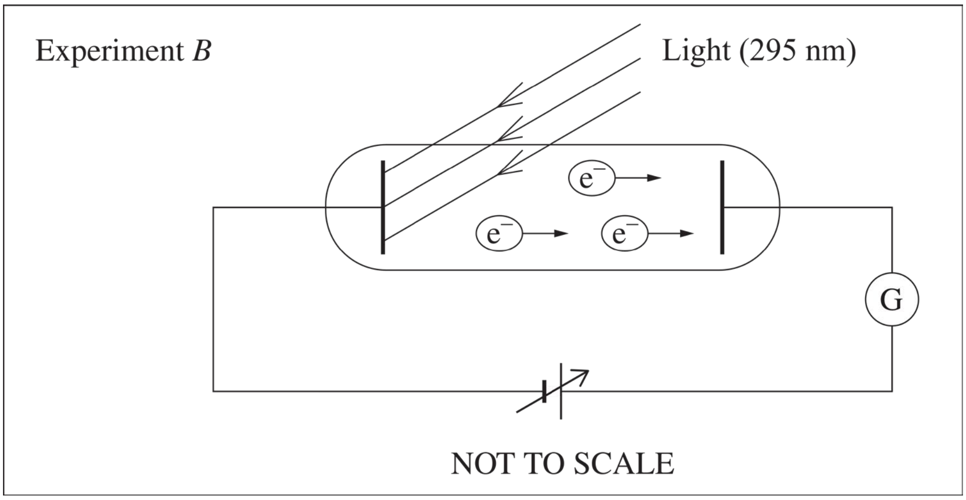
Question 29 (9 marks)

Two experiments are performed with identical light sources having a wavelength of 295 nm. **9**

In experiment *A*, the light is incident on a pair of narrow slits 12 μm apart, producing a pattern on a screen located 2.0 m behind the slits.



In experiment *B*, the light is incident on different metal samples inside an evacuated tube as shown. The kinetic energy of any emitted photoelectrons can be measured.



Some results from experiment B are shown.

Metal sample	*Work function (eV)*	*Galvanometer reading (μA)*
Magnesium	3.7	3.26
Gold	5.1	0.00

Question 29 continues on page 23

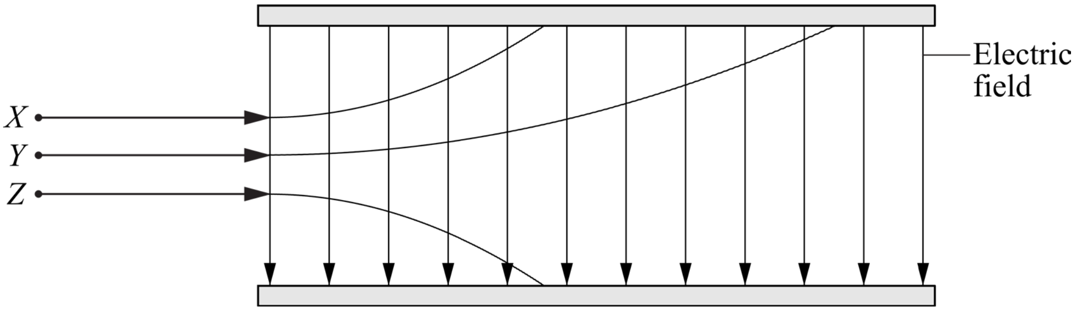
Question 29 (continued)

How do the results from Experiment A and Experiment B support TWO different models of light? In your answer, include a quantitative analysis of each experiment.

End of Question 29

Question 30 (7 marks)

Three charged particles of identical mass, X, Y and Z, and travelling along straight, parallel trajectories, enter a region in which there is a uniform electric field which causes them to follow the paths shown. Assume that the particles do not exert any significant force on each other. **7**



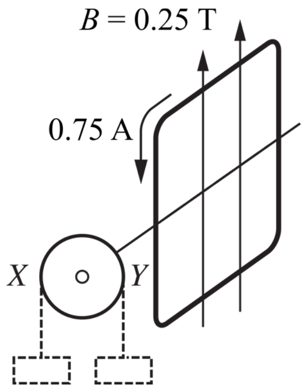
Explain the different paths that the particles follow through the electric field.

Booklet III

NESA Student Number:

Question 31 (5 marks)

A simple motor consists of a flat rectangular coil with 175 turns in a magnetic field, as shown.



The coil carries a current of 0.75 A. The motor drives a pulley of diameter 50 cm, and weights can be hung from either side of the pulley at point X or point Y.

(a) In order to prevent rotation, should a weight be hung at point X or at point Y? Justify your answer. **2**

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(b) If the motor is just stopped by a mass of 0.2 kg, what area does the coil have? **3**

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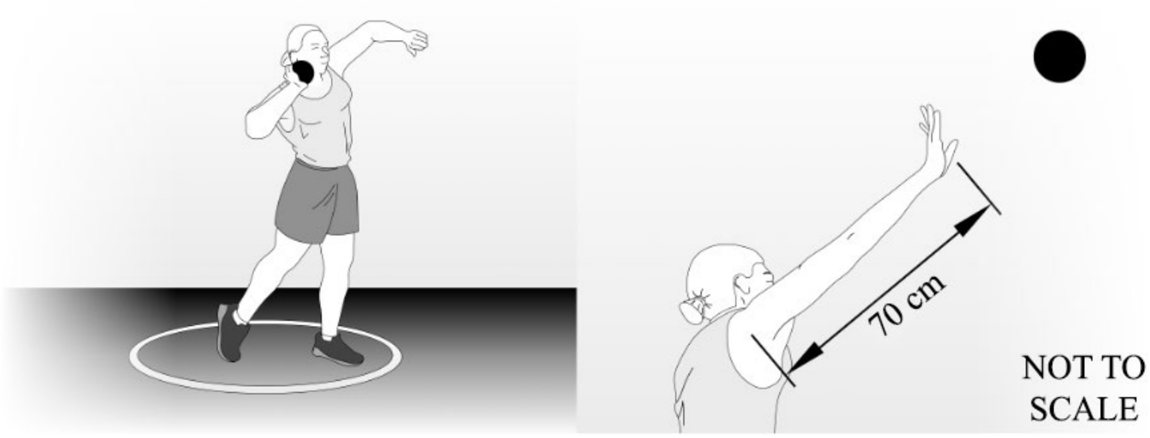
Question 32 (8 marks)

A champion shot put thrower is competing in a competition despite having recently damaged a ligament in her knee. Because of her injury she is forced to throw the shot put from a static position. Therefore, the shotput will only be accelerated across the distance of her extended arm which is 70 cm long.



(a) During her first attempt, she applied a constant force of 432 N throughout the extension of her arm. If the 4.0 kg ball is released at 11.8 m s^{-1}, at what angle did she throw the ball? **4**

Question 32 continues on page 27

Question 32 (continued)

(b) On her second attempt she releases the shot put at an angle of 45° with the same launch velocity as her first attempt in part (a). If she released it from a height of 1.8 m above the ground, determine the range of her throw. **4**

End of Question 32

Question 33 (7 marks)

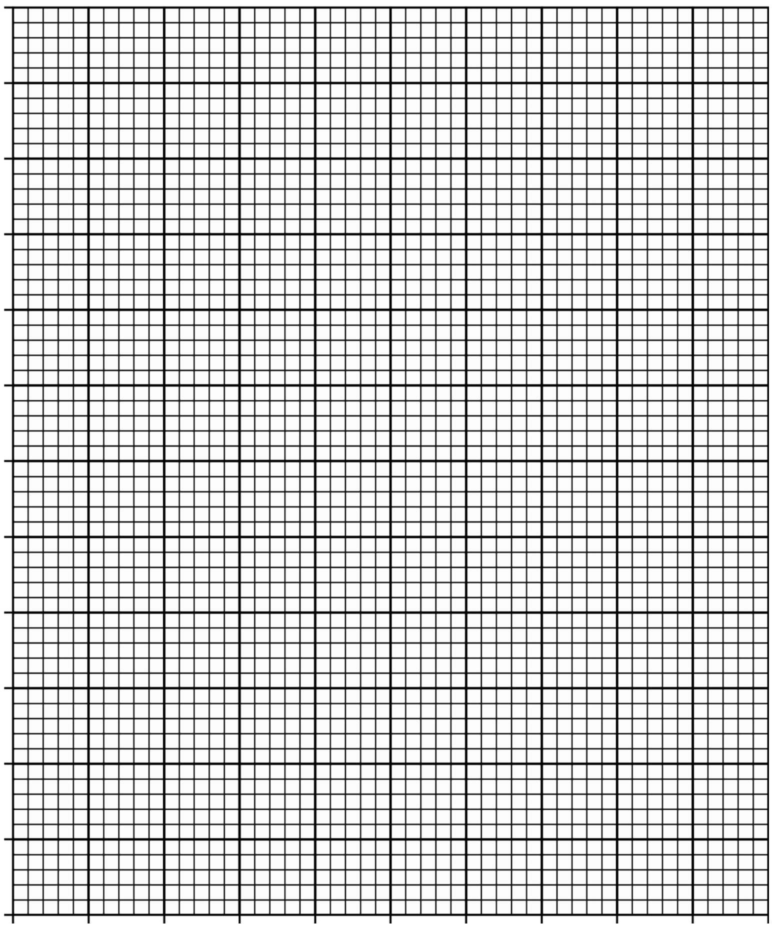
A beam of particles was fired at a metal crystal, resulting in a diffraction pattern on the detector screen.

The speed of the particles was varied, and the diffraction pattern was used to determine the associated wavelengths of the particles.

The following results were obtained. Note, a picometer (pm) is 10^{-12} m.

Particle speed ($\times 10^{6}$ m s^{-1})	*Wavelength (pm)*	*Inverse of the wavelength (pm^{-1})*
1.4	56.3	0.017
2.9	27.2	0.039
4.1	17.2	0.051
6.8	11.6	0.089
7.3	8.5	0.117

(a) Plot the results for *particle speed* and *inverse of the wavelength* on the grid below. **4**



Question 33 continues on page 29

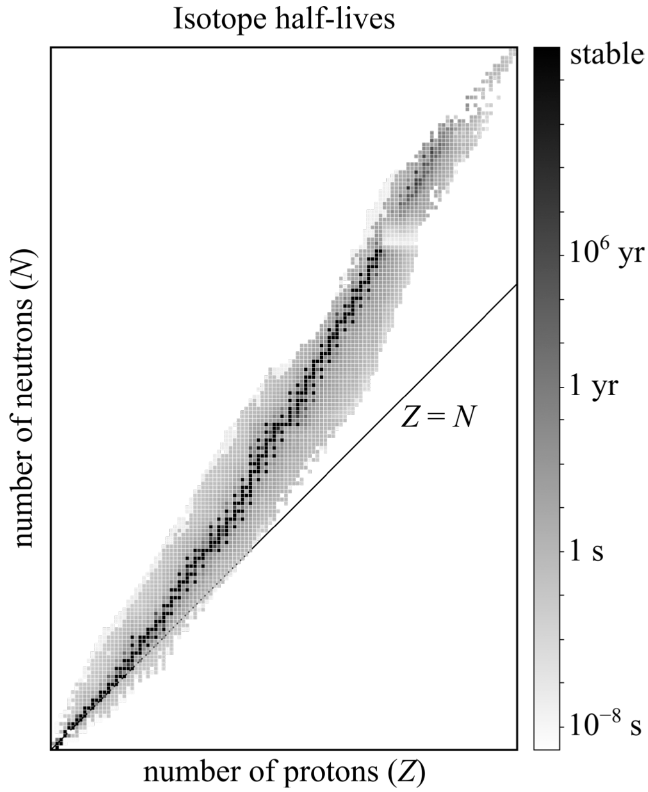
Question 33 (continued)

(b) Use the graph to determine the mass of the particles. **3**

End of Question 33

Question 34 (3 marks)

Outline features of the nuclear force that explains the stability of isotopes illustrated in the diagram below. **3**



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End of exam

Section II extra writing space

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

Section II extra writing space

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

2020 HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

DATA SHEET

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

FORMULAE SHEET

Motion, forces and gravity

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

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

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

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

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

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

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

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

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

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

$$v = u + at$$

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$$v = f\lambda$$

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

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

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

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

$$Q = mc\Delta T$$

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

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

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

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

$$I_1r_1^2 = I_2r_2^2$$

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

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

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

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

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

$$\frac{V_\mathrm{p}}{V_\mathrm{s}} = \frac{N_\mathrm{p}}{N_\mathrm{s}}$$

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

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

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

$$V = IR$$

$$P = VI$$

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

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

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

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

$$V_\mathrm{p} I_\mathrm{p} = V_\mathrm{s} I_\mathrm{s}$$

Quantum, special relativity and nuclear

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

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

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

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_\mathrm{f}^2} - \frac{1}{n_\mathrm{i}^2}\right)$$

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

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

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

$$N_\mathrm{t} = N_0 e^{-\lambda t}$$

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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

Lanthanoids

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

Actinoids

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

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

Sydney Boys High School

NESA Student Number:

Multiple Choice Answer Sheet

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

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

A	B	C	D
○	●	○	○

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

A ● B ~~●~~ C ○ D ○

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

correct

A ~~●~~ B ~~●~~ C ○ D ○

Start Here →

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

Sydney Boys High School

NESA Student Number:

2023 **Trial Exam**

Physics

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 at the back of this paper
- SHOW ALL WORKING
- Write your student number in ALL of the boxes provided

Total marks: 100

Section I – Multiple Choice

- 20 marks
- Allow about 35 minutes for this section

Section II – Free Response

- 80 marks
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

---

1. Answer: C
Given that the balls have no vertical velocity at launch $(u_y = 0)$, the time to fall from the height of the building is given by:
$s_y = u_y t + \frac{1}{2} a_y t^2 = \frac{1}{2} a_y t^2 \quad \rightarrow \quad t = \sqrt{\frac{2s_y}{a_y}}$
which is independent of launch velocity. Therefore, both balls will have the same time-of-flight, and the range is only dependent on the launch velocity, according to:
$s_x = u_x t = vt \quad \rightarrow \quad s_x \propto v$

2. Answer: B
Work done by gravitational field is given by $W = F_{\parallel} s$.
In a circular orbit (Satellite *A*), the gravitational force that provides the centripetal force is always perpendicular to the direction of motion. In addition, the orbital speed is constant. If the kinetic and gravitational potential energies are constant, no work is being done on the satellite Therefore, the work done is zero.
In an elliptical orbit (Satellite *B*), the gravitational force *sometimes* acts perpendicular to the direction of motion (Point *R* and the opposite point of the orbit, furthest away). However, at all other times, the force acts with a component along the orbital trajectory, corresponding to work being done on the satellite. In addition, the speed of the satellite changes throughout the orbit. From Point P to Point Q, the satellite will slow down and the gravitational potential energy increases, indicating that work is being done on the satellite. Therefore, the work is non-zero (negative, more specifically).

3. Answer: A
A hypothesis is a predictive statement, and can be made by anyone. It must be tested in order to confirm its validity, irrespective on how widely it is believed or how plausable it is.

4. Answer: D
The electrons cannot behave like a particle, otherwise they would emit energy due to their centripetal acceleration (according to Maxwell's theory). The specific energy requirements are due to their behavior as a wave under specific conditions (the electron's orbital, sub-orbital, etc.).

5. Answer: A
The alpha decay reaction is ${}^{227}_{89}Ac \rightarrow {}^{223}_{87}Fr + {}^{4}_{2}He$.
The beta decay reaction is ${}^{227}_{89}Ac \rightarrow {}^{227}_{90}Th + {}^{0}_{-1}e + {}^{0}_{0}\nu$.

6. Answer: C
The path of the cathode rays is not visible, so the straightness of their motion cannot be known. Cathode rays can be produced in a gaseous environment. However, they will not travel far in a medium. Finally, electromagnetic waves will not impart sufficient energy to turn the paddle wheel.

7. Answer: B
Blackbody curves will only be shaped like the graphs shown when intensity is plotted against wavelength (plotted against frequency, the curves will have a different shape altogether). The peaks of the curves always increase in intensity and decrease in wavelength with increasing temeprature.

8. Answer: A
Using the right-hand grip rule, the magnetic field around the current will be into the page above the wire and out of the page below the wire.
Using the right-hand palm rule above the wire, fingers point into the page $(\vec{B} = \otimes)$ and palm is facing upwards $(\vec{F} = \uparrow)$, making the thumb point to the right ($\vec{v}_+ = \rightarrow$). Given that the charge is, indeed, moving to the right, then the charge of particle *X* must be positive.
Using the right-hand palm rule below the wire, fingers point out of the page $(\vec{B} = \odot)$ and palm is facing downwards $(\vec{F} = \downarrow)$, making the thumb point to the right ($\vec{v}_+ = \rightarrow$). Given that the particle is actually moving to the left, then the charge of particle *Y* must be negative.

9. Answer: B
Malus' law follows $I = I_{max}\cos^2\theta$. Given that $\cos 0 = 1$, then $\cos^2 0 = 1$. Likewise, as $\cos 90 = 0$, then $\cos^2 90 = 0$.
For I_y, the polarisers start parallel, meaning $\theta = 0$, and the intensity will be a maximum. As the filter rotates, the polarisers will become perpendicular (reducing the intensity to zero) before returning to a maximum at 180°.
For I_y, the polarisers start perpendicular, meaning $\theta = 90$, and the intensity will be zero. As the filter rotates, the polarisers will become parallel (incresing the intensity to maximum) before returning to zero at 180°.

10. Answer: D
JJ Thomson's experiment used perpendicular electric and magnetic fields to act as a speed selector, according to $v = \frac{E}{B}$. This allowed the charge-to-mass ratio to be related to the radius of curvature of the cathode rays when deflected by the magnetic field only, according to $\frac{q}{m} = \frac{v}{rB} = \frac{E}{rB^2}$ (from $qvB = \frac{mv^2}{r}$).

11. Answer: B

	Rob	*Jan*
Error	0.02 A	0.05 A
Range	0.50 A	0.16 A

Clearly, Rob's results are more accurate (a smaller error), whilst Jan's results are more reliable (a smaller range).

12. Answer: C
The use of an iron core is to magnetically link the primary and secondary coils (increasing the flux linkage). *Laminating* the core will reduce the heat generated by eddy currents. But, the use of an iron core will not, in itself, achieve this.

13. Answer: D
Maxwell made the other contributions. However, the discovery of radio waves was due to Hertz (the induction coil sparking experiment).

14. Answer: D

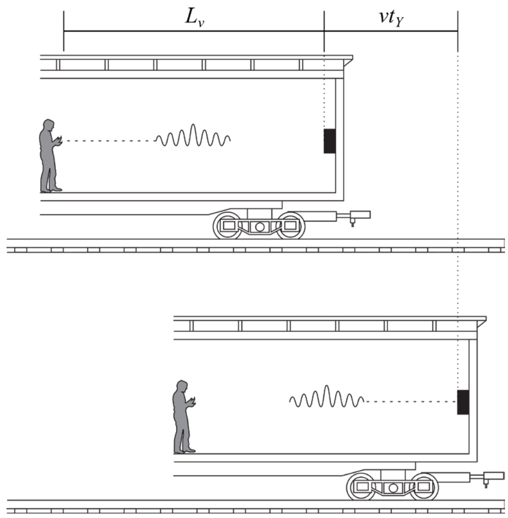
The initial magnetic flux is a maximum, since the area vector is parallel to the field, according to $\Phi = BA\cos\theta$. As the coil rotates, the flux will decrease to zero before increasing to a maximum in the opposite direction (the coil has rotated 180° to make the field pass the other way through the coil).

The voltage is given by the EMF, according to $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$. Thus, the voltage is negatively related to the gradient of the $\Phi - \mathrm{t}$ graph. That is, the voltage is zero when the flux has maximum magnitude (peak or trough), and the voltage is a maximum when the flux passes through the x-axis.

15. Answer: A

When the switch is closed, the circuit will travel to the left in the top wire, above the solenoid. This will lead to an anticlockwise current (whe viewed from the bar magnet) around the solenoid. From the right-hand solenoid rule, this current will lead to a magnetic field to the left through the centre of the solenoid, producing a north pole on the left. As a result, this north pole will attract the south pole of the bar magnet, pulling the bar magnet and solenoid towards each other. Thus, the bar magnet will move to the right (towards the solenoid) and the solenoid will move to the left (towards the bar magnet).

16. Answer: B



From observer X's frame of reference, the train is at rest and the length of the light's path is L_0. Therefore, time taken for the light to reach the sensor is $t_X = \frac{L_0}{c}$.

From observer Y's frame of reference, the train is moving. Therefore, the train carriage will appear to contract. However, the sensor will also be moving away from the light as it travels. The total length that the light's path is $L_v + vt_Y$. Given that light pulse travels at c:

$ct_Y = L_v + vt_Y$

$t_Y = \frac{L_v}{c-v} = \frac{L_0}{\gamma(c-v)} = \frac{L_0}{\gamma c\left(1-\frac{v}{c}\right)} = \frac{1}{\gamma\left(1-\frac{v}{c}\right)}\frac{L_0}{c}$

For $v = 0.95c$, $\gamma = 3.2$ and $t_Y = 6.2\frac{L_0}{c} = 6.2t_X$.

Therefore, X sees the pulse travel a shorter distance in a shorter time.

17. Answer: A

As the question states, the length was changed first (making it the independent variable). Then the time for oscillation, the period, was measured (making it the dependent variable). All other variables must be kept constant.

18. Answer: D

Air friction is unavoidable, but it does not affect the period, as long as the amplitude is low (which applies here, as the appropriate equation is used). Therefore, a decreasing amplitude due to air friction will not affect the results.

Multiple swings is equivalent to repetitions of one swing. As a general rule, repetitions include random errors, including values both above and below the correct value. As a result, averaging leads to progressive cancelling out of random errors, resulting in a final value that has less error.

19. Answer: C

Given that $F = qE$ and $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$. At the null point, the electric fields from the two charges cancel out. Therefore, they must be equal:

$$\frac{q_{left}}{r_{left}^2} = \frac{q_{right}}{r_{right}^2}$$

$$\frac{r_{left}^2}{r_{right}^2} = \left(\frac{r_{left}}{r_{right}}\right)^2 = \frac{q_{left}}{q_{right}}$$

$$\frac{r_{left}}{r_{right}} = \sqrt{\frac{q_{left}}{q_{right}}} = \sqrt{\frac{q}{4q}} = \frac{1}{2}$$

Thus, the null point is half the distance from charge q as it is from $4q$ (a 1:2 ratio). This corresponds to 4 cm from charge q (making it 8 cm from $4q$).

20. Answer: C

From the law of conservation of energy, the total change in energy is zero:

$$\Delta K + \Delta U = 0$$

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

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = -mg\Delta h$$

Given that the change in height between the top of the loop and the bottom is $2r$:

$$\frac{1}{2}v^2 - \frac{1}{2}u^2 = -g(2r)$$

$$u^2 - v^2 = 4gr$$

$$(u - v)(u + v) = 4gr$$

$$u - v = \frac{4gr}{u + v}$$

2023 **Trial Exam**

NESA Student Number:

Physics

Section II Answer Booklet I

80 marks
Attempt Questions
Allow about 2 hours and 25 minutes for this section

Instructions

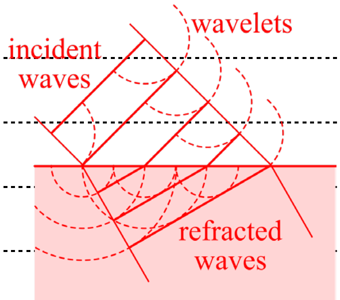
- Write your NESA Student Number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

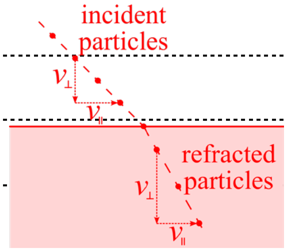
Question 21 (4 marks)

Explain refraction using both Huygens' and Newton's theories of light. **4**

Huygens' theory of light was based on a wave model. Each point on a wave produces wavelets that add to form the new wave. When applied to refraction, the wavelets slow down as they propagate into a denser medium (e.g. water). That is, they form smaller wavelets, as shown in the diagram to the right. When added to form the new waves, the refracted waves bend toward the normal.



Newton's theory of the light is based on a corpuscular model. When the particles approach a denser medium, the higher density of matter particles attract the light corpuscles towards the interface, causing the perpendicular velocity ($v_{\perp}$) to increase whilst the parallel velocity($v_{\parallel}$) remains the same. The overall effect is to cause the net velocity of the corpuscles to bend towards the normal.



✓ identifies Huygens' wave model
✓ correctly relates refraction to speed change
✓ identifies Newton's particle model
✓ relates particle refraction to perpendicular forces in new medium

Question 22 (4 marks)

A distant exoplanet, Methanos, has a single moon, Propedes.

(a) Compare the force of gravity exerted on Propedes by Methanos with the force of gravity exerted on Methanos by Propedes. **2**

The magnitude of gravitational forces is the same for both but the direction of gravitational force is opposite.

✓ clearly states that magnitudes are the same
✓ clearly states that directions are opposite

(b) The acceleration due to gravity on Propedes is 2.2 m s^{-2} and on Methanos it is 12.8 m s^{-2}. Quantitatively compare the mass and weight of a 95 kg astronaut on Propedes and on Methanos. **2**

	Propedes	*Methanos*
Weight (N)	$F_g = mg = 95 \times 2.2 = 209$	$F_g = mg = 95 \times 12.8 = 1216$
Mass (kg)	95	

✓ states that the masses are the same for both and gives the value (95kg)
✓ clearly calculates the 2 weight forces and states that they are different

Question 23 (4 marks)

A square coil of conducting wire, 44.0 cm long, is placed in a 2.75 T magnetic field, as shown below in Figure 1. The shape of the coil is uniformly changed to a circular shape in 1.25 ms, as shown in Figure 2.

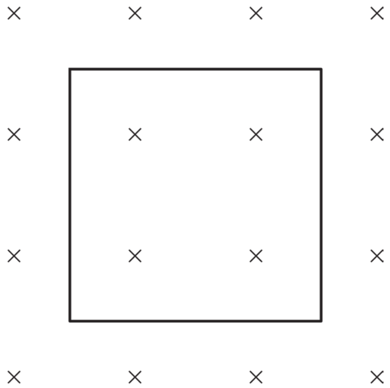


Figure 1

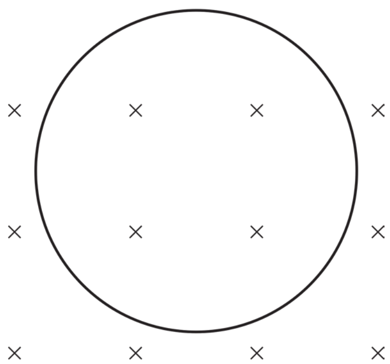


Figure 2

(a) Calculate the magnitude of the average induced EMF. **3**

From length of 44.0 cm, square has sides $l = \frac{44}{4} = 11.0\ cm = 0.110\ m$

The area of the square is $A = 0.110 \times 0.110 = 0.0121\ m^2$

Given the circumference is $C = 2\pi r$, then the radius is:

$$r = \frac{C}{2\pi} = \frac{44}{2\pi} = 7.0028\ cm = 0.070028\ m$$

The area of the circle is $A = \pi r^2 = \pi \times 0.070028^2 = 154.06\ cm^2 = 0.015406\ m^2$

$\varepsilon = -N\frac{\Delta\phi}{\Delta t} = -N\frac{B\Delta A}{\Delta t} = -1 \times \frac{2.75\times(0.0154-0.0121)}{1.25\times10^{-3}} = -7.26\ V$

The induced EMF is 7.26 V.

✓ some correct working towards answer
✓ correctly calculates change in area (0.003306) or ΔΦ (0.00909)
✓ correctly relates ΔA to ε

* if ε = 116 V then 2 marks

(b) Identify the direction of the current that passes through the conducting wire as a result of the induced EMF. **1**

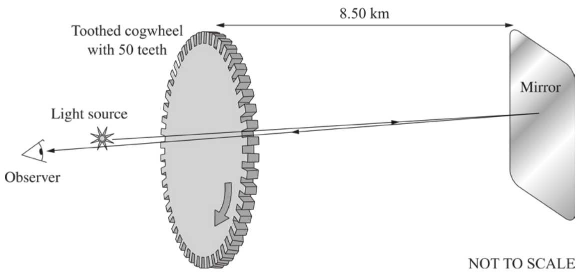
The flux through the loop is increasing into the page. Therefore, the induced current will be produce a flux out of the page, meaning the current is directed anticlockwise.

✓ correct direction (anticlockwise)

Question 24 (5 marks)

In the 1840s, French physicist, Hippolyte Fizeau performed an experiment to measure the speed of light. He shone an intense light source at a mirror 8.50 km away and broke up the light beam with a rotating cogwheel. He increased the speed of rotation of the wheel until the reflected light beam could no longer be seen returning through the gaps in the cogwheel. **5**

The diagram shows a similar experiment. The cogwheel has 50 teeth and 50 gaps of the same width.



Explain why specific speeds of rotation of the cogwheel will completely block the returning light. Support your answer with calculations.

At low rotational speeds, the light passes through a gap in the cog wheel, travels on to the mirror and reflects, before returning through the same gap and on to the Observer. In this way, the light source can be seen. As the angular velocity of the cog wheel increases, the time that the gap in the cog wheel lines up between the light source and the mirror decreases. However, the time taken for the light to travel from the cog wheel to the mirror and back remains constant:

$$v = \frac{s}{t} \rightarrow t = \frac{s}{v} = \frac{8.50\times10^3\times2}{3.00\times10^8} = 5.67\times10^{-5}\ \text{s} = 56.7\ \mu\text{s}$$

If the rotational velocity of the cog wheel exceeds a certain magnitude, the cog wheel rotates so that, in the time the light to travel from the cog wheel to the mirror and back, the tooth adjacent to the gap blocks the light's return. Given that there are 50 teeth and 50 gaps, the minimum rotational velocity to block the light is:

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{\frac{2\pi}{50+50}}{5.67\times10^{-5}} = 1108.8 = 1110\ \text{rad s}^{-1}$$

Therefore, the Observer will not see the light beam when the angular velocity of the cog wheel is odd-integer multiples (3, 5, 7, etc.) of 1110 rad s^{-1}, due to the alternation of gaps and teeth.

- ✓ provides some relevant information
- ✓ relates rotation to interruption of light by tooth
- ✓ calculates *time-of-flight* for light
- ✓ calculates *angular velocity* of cog wheel
- ✓ justifies specific multiples of *angular velocity*

2 marks if give ω = 176.47 rev/s

Max mark with no calcs = 2

Must attempt substitution and answer to be a calculation

Can't have units of angular velocity as m s^{-1}.

Read the question!!!!!!

Booklet II

NESA Student Number:

Question 25 (7 marks)

A polonium-118 atom, at rest, undergoes radioactive decay, with a decay constant of 0.2236 min^{-1}. The masses of the nuclei involved are shown below:

polonium-118	$\rightarrow$	lead-114	+	helium-4
218.00897 u		213.99981 u		4.00260 u

(a) Calculate the energy, in Joules, released by this decay. **3**

$m_{defect} = m_{reactants} - m_{products} = 218.00897 - (213.99981 - 4.00260)$

$= 0.00657\ u$

$= 0.00657 \times 1.661 \times 10^{-27} = 1.09 \times 10^{-29}$ kg

$E = mc^2 = 1.09 \times 10^{-29} \times (3.00 \times 10^8)^2 = 9.82 \times 10^{-13}$ J

OR

$E = 0.00657 \times 931.5 = 6.12$ MeV

$= 6.12 \times 1.602 \times 10^{-19} = 9.80 \times 10^{-13}$ J

✓ some correct working towards answer
✓ correct calculation of change in *mass*
✓ corretly relates *mass defect* to *energy*

(b) Identify whether lead-114 has a higher or lower *binding energy per nucleon*. **1**

Since the radioactive decay is spontaneous, the products must be more stable than the parent nucleus, and lead-114 must have a higher binding energy per nucleon.

✓ correct answer (higher)

(c) If a polonium-118 ion is accelerated in a particle accelerator to 0.99945 c, what will be the decay constant of the radioisotope? **3**

Since $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ $\left(\text{i.e. } \lambda \propto \frac{1}{t}\right)$ and $t_v = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma t_0$ (i.e. $t \propto \gamma$), then $\lambda \propto \gamma$. That is:

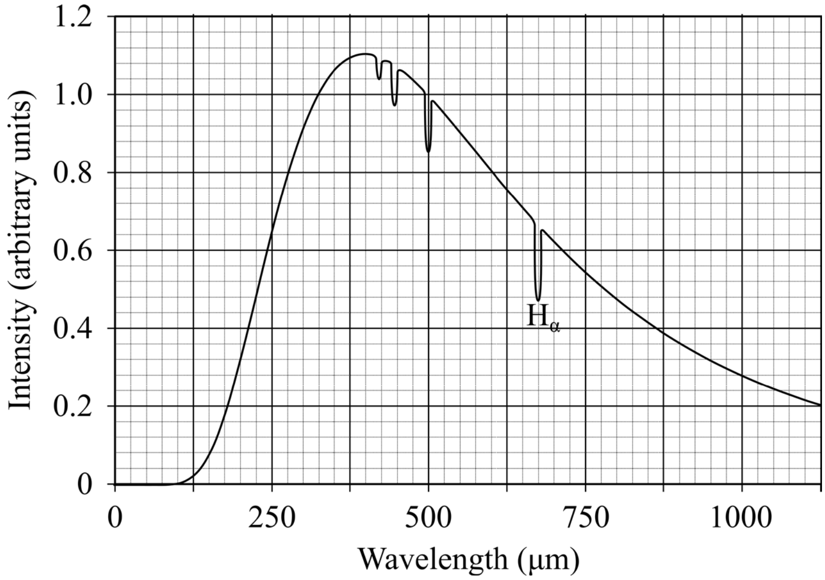
$\lambda_v = \frac{1}{\gamma}\lambda_0 = \lambda_0\sqrt{1-\frac{v^2}{c^2}} = 0.2236 \times \sqrt{1 - 0.9945^2} =$

$0.007415\ \text{min}^{-1}$ *or* $0.00012358\ s^{-1}$

✓ some correct working towards answer
✓ correct calculation of magnitude of γ
✓ correct application of γ ($\lambda \propto \gamma$) & answer with correct untis

Question 26 (8 marks)

An astronomer measured the spectrum of a distant star using a spectrometer attached to a telescope on Earth. The spectrum is shown below.



The astronomer used the hydrogen absorption dips to analyse the properties of the star.

The first four wavelengths (in decending order) in the Balmer series of the hydrogen spectrum are shown in the table below.

Hydrogen line	H_α	H_β	H_γ	H_δ
Wavelength (nm)	656.3	486.2	434.1	410.2
transitions:	3→2	4→2	5→2	6→2

(a) Calculate the next wavelength, H_ε, in the Balmer series. **2**

The next wavelength is due to the electron transition 7→2:

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = 1.097 \times 10^7 \times \left(\frac{1}{2^2} - \frac{1}{7^2}\right) = 2.519 \times 10^6 \text{ m}^{-1}$

$\lambda = \frac{1}{2.519 \times 10^6} = 3.970 \times 10^{-7} \text{ m} = 397.0 \text{ nm}$

✓ correct transition ($n = 7 \rightarrow 2$)
✓ correct calculation of wavelength (with units)

Question 24 continues on page 13

Question 24 (continued)

(b) The Hα absorption peak in the star's spectrum was found to be shifted. It was precisely measured to have a wavelength of 673.2 nm. **3**

Ignoring the velocity of the Earth, determine the velocity of the star with respect to Earth.

Since $c = f\lambda$ and $f' = f\frac{(v_{wave}+v_{observer})}{(v_{wave}-v_{source})}$:

$\lambda' = \lambda\frac{(v_{wave}-v_{source})}{(v_{wave}+v_{observer})} = \lambda\frac{v_{wave}-v_{source}}{v_{wave}}$ (since $v_{observer} = v_{Earth} = 0$)

$\lambda' v_{wave} = \lambda(v_{wave} - v_{source}) = \lambda v_{wave} - \lambda v_{source}$

$\lambda v_{source} = \lambda v_{wave} - \lambda' v_{wave} = v_{wave}(\lambda - \lambda')$

$v_{source} = v_{wave}\frac{\lambda-\lambda'}{\lambda} = 3.00 \times 10^8 \times \frac{656.3-673.2}{656.3} = -7.71 \times 10^6 \text{ m s}^{-1}$

The star is moving 7.71×10^6 m s^{-1} away from Earth.

✓ some correct working towards answer
✓ correct speed
✓ correct direction

(c) Calculate the surface temperature of the star. **3**

Given that the peak wavelength is also Doppler shifted:

$\lambda = \lambda'\frac{v_{wave}}{v_{wave}-v_{source}} = 400 \times \frac{3.00\times10^8}{3.00\times10^8-(-7.71\times10^6)} = 390.0 \text{ nm}$

From $\lambda_{peak} = \frac{b}{T}$:

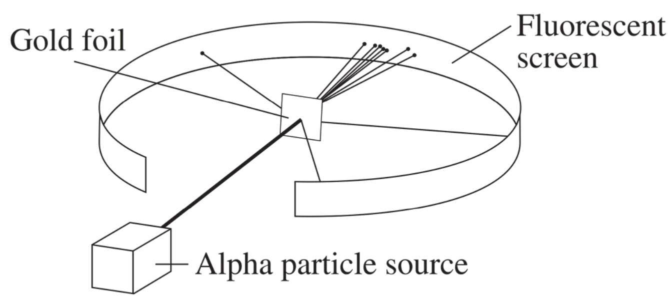
$T = \frac{b}{\lambda_{peak}} = \frac{2.898\times10^{-3}}{390.0\times10^{-9}} = 7431 \text{ K}$

✓ correct λ_{peak} read from graph
✓ correctly relates λ_{peak} to T
✓ accounts for Doppler shift

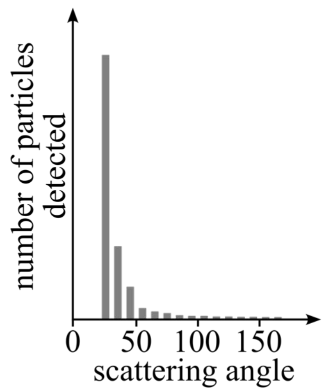
End of Question 24

Question 27 (4 marks)

Geiger and Marsden performed their gold-foil experiment, measuring the number of particles being scattered at different angles. The results are shown below for angles above 30°. **4**



The Geiger–Marsden experiment



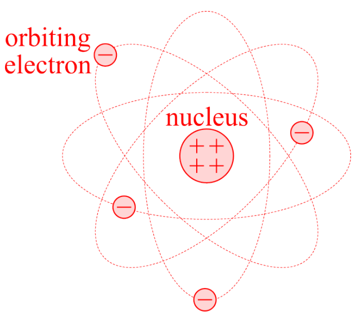
Based on these results, Rutherford proposed his model of the atom.

How do features of his model account for all the experimental evidence above?

Rutherford's model of the atom had a positive, dense nucleus (containing almost all of the mass of the atom) with the electrons orbiting the nucleus at a distance much greater than the size of the nucleus. As a result, the atom is mostly (>99%) made up of empty space. His model is illustrated in the diagram below.

The fact that the atom was mostly empty space explains why almost all of the alpha particles passed straight through the gold foil. The alpha particles are not affected by the orbiting electrons, since they have a mass much less than that of the alpha particles. Thus, most alpha particles pass between the gold nuclei and, thus, experience negligible to no deflection force.

A small fraction of the alpha particles were scattered at large angles, some deflected back towards the alpha radiation source. This is due to the dense, positively charged nucleus electrostatically repelling the positively charged alpha particles. The large relative mass of the gold nuclei effectively repelled alpha particles that passed close enough to the nucleus, such that the alpha particles could be deflected at large scattering angles.



✓ provides some relevant information
✓ describes detail model of atom
✓ relates empty space to most particles passing straight through
✓ relates dense, positive nucleus to high-angle deflections

Question 28 (5 marks)

Using examples from special relativity, explain how theories in science are validated in different ways. **5**

Scientific theories are validated through the scientific method. That is, they are tested by using the theory to make a prediction, performing an experiment to test that prediction, and analysing the results to determine whether they support the theory.

Einstein's theory of Special Relativity was validated through a number of experiments:

Frisch-Smith experiment: The decay time of stationary muons at high altitude was used to predict how many would be detected at sea level. Special relativity predicted a much higher number than expected by the stationary half-life. This was found to be the case, with a greater number of muons detected at sea level than predicted by Newtonian motion.

Particle accelerator experiments: Lithium ions were accelerated to approximately one-third the speed of light in a particle accelerator. The orbiting electrons were then excited so as to transitions between orbits. The times taken for these electron-orbit transitions was found to be longer than those measured in stationary electrons in the lab.

In this way, the two experiments obtained results that agreed with those predicted by Special Relativity (in this case, time dilation), thereby validating the theory.

- ✓ provides some relevant information
- ✓ describes features of the scientific method
- ✓ relates *special relativity* to feature(s) of the scientific method
- ✓ uses one relevant example with the appropriate detail
- ✓ uses other relevant example(s) the appropriate detail
    - o last mark lost if two relevant examples provided, but lacking in detail

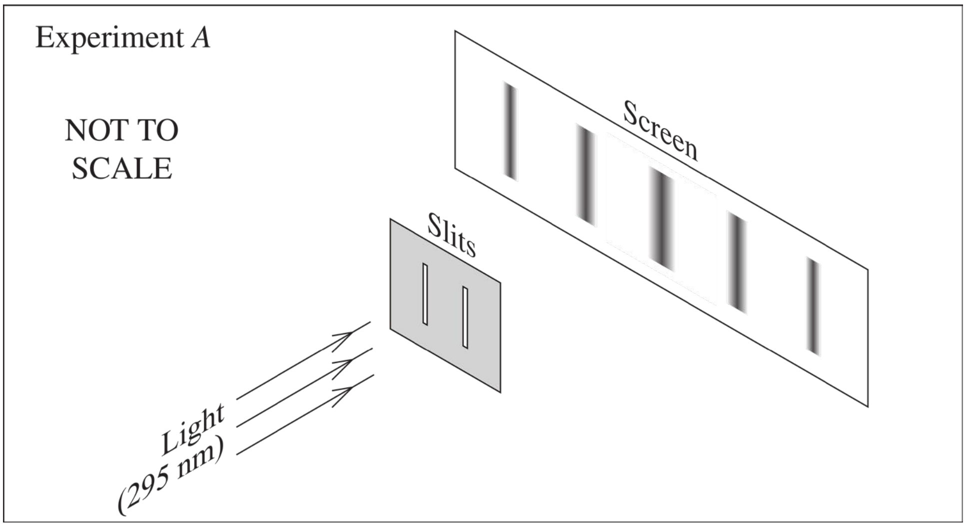
Marker's notes

- thought experiments are NOT valid! Einstien used them to develop SR
- Michelson Moreley preceded the development of Special Relativity, so it cannot be used to validate it
- need to link what SR predicts with results observed, not just state the phenomenon.

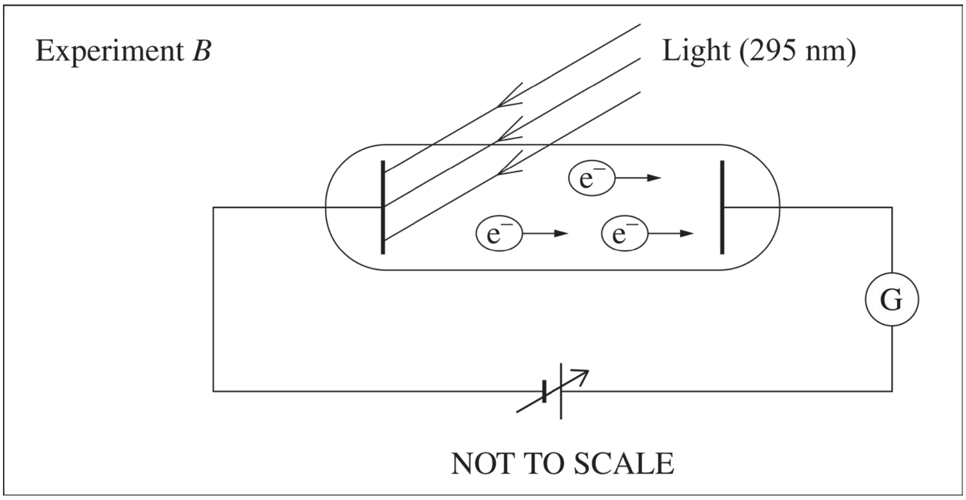
Question 29 (9 marks)

Two experiments are performed with identical light sources having a wavelength of 295 nm. **9**

In experiment *A*, the light is incident on a pair of narrow slits 12 μm apart, producing a pattern on a screen located 2.0 m behind the slits.



In experiment *B*, the light is incident on different metal samples inside an evacuated tube as shown. The kinetic energy of any emitted photoelectrons can be measured.



Some results from experiment B are shown.

Metal sample	*Work function (eV)*	*Galvanometer reading (μA)*
Magnesium	3.7	3.26
Gold	5.1	0.00

Question 22 continues on page 17

Question 22 (continued)

How do the results from Experiment A and Experiment B support TWO different models of light? In your answer, include a quantitative analysis of each experiment.

In Experiment A, the pattern of alternating light and dark bands is called a diffraction pattern. The spacing of the bands, Δx, can be calculated from $d \sin\theta = m\lambda$. From the small-angle approximation ($\sin\theta \approx \tan\theta \approx \theta$ for $\theta \ll 1$):

$$\Delta x \approx \frac{m\lambda L}{d} = \frac{1 \times 295 \times 10^{-9} \times 2.0}{12 \times 10^{-6}} \approx 0.0492 \text{ m} \approx 4.9 \text{ cm}$$

This pattern results from waves passing through two slits and alternately undergoing constructive (bright) and destructive (dark) interference as they reach different points on the screen. Since diffraction and interference can only occur with waves, this result supports the wave model of light.

In Experient B, the photoelectric effect is being demonstrated. In the photoelectric effect, electrons are emitted from the surface of a metal when light of sufficient energy is incident upon the surface. This experiment supports the particle model of light because the emission and kinetic energy of electrons is only dependent on the frequency of the light, and not intensity nor time. In this experiment, the energy of the photons is:

$$E = hf = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3.00 \times 10^{8}}{295 \times 10^{-9}} = 6.738 \times 10^{-19} \text{ J} = \frac{6.738 \times 10^{-19}}{1.602 \times 10^{-19}} = 4.2 \text{ eV}$$

Thus, the light has insufficient energy to overcome the large work function of gold (5.1 eV), and electrons will not be emitted. As a result, no electrons will be transmitted through the circuit and the photocurrent through the Galvanometer will be zero.

On the other hand, the energy of the light is greater than the work function of magnesium (3.7 eV), resulting in the emission of electrons from the surface of the magnesium with a maximum kinetic energy given by $K_{max} = hf - \phi = 4.2 - 3.7 = 0.5$ eV. Therefore, the photoelectrons will continue through the circuit and register a current in the galvanometer. From the current reading, the number of electrons reaching the electrode is:

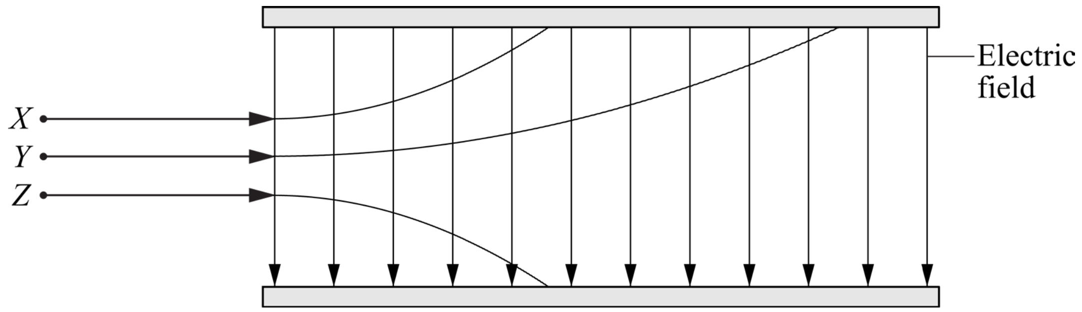
$$I = \frac{nq}{t} \rightarrow \frac{n}{t} = \frac{I}{q} = \frac{3.26 \times 10^{-6}}{1.602 \times 10^{-19}} = 2.03 \times 10^{13} \text{ electrons per second}$$

notes:
* Exp B is not evidence for Newton's model (photons are not corpuscles)
* need to relate photon energy to emitted electrons, not just current

- ✓ identifies Experient A supports wave model
- ✓ describes formation of diffraction pattern
- ✓ relates wave model to diffraction pattern
- ✓ calculation of distance between bands
- ✓ identifies Experient B supports particle model
- ✓ relates particle model to photoelectric effect
- ✓ appropriate calculation related to photoelectric effect
- ✓ relates energy of light to no photoelectric effect in Mg
- ✓ relates energy of light to photoelectric effect in Au

Question 30 (7 marks)

Three charged particles of identical mass, X, Y and Z, and travelling along straight, parallel trajectories, enter a region in which there is a uniform electric field which causes them to follow the paths shown. Assume that the particles do not exert any significant force on each other. **7**



Explain the different paths that the particles follow through the electric field.

Charged particles follow parabolic trajectories in uniform electric fields because they experience a constant acceleration along the orientation of the field lines, but zero acceleration perpendicular to the field lines. In this case, the force acting on the charges is given by $F = qE$. This force will result in an acceleration along the field lines, according to $a = \frac{F}{m} = \frac{qE}{m}$. From uniform linear acceleration, this will result in a time-of-flight of $t = \sqrt{\frac{2s_y}{a}} = \sqrt{\frac{2s_y m}{qE}}$. Thus, the distance travelled by the charged particle before reaching an electric plate is $s_x = v\sqrt{\frac{2s_y m}{qE}}$. Given that the masses of the particles and the field strength are the same, then $s_x \propto v\sqrt{\frac{s_y}{q}}$.

From the vector form of $\vec{F} = q\vec{E}$, both particles X and Y are negatively charged, since they deflect in the opposite direction to the direction of the electric field. However, the longer range of particle Y indicates that it has a smaller negative charge or higher initial velocity that particle X. Even taking into account the closer proximity of particle X to the electric plate, particle Y has a shallower parabolic trajectory.

Particle Z has the same shaped path and same range as particle X, but reflected vertically (that is, downwards). Thus, particle Z must have a positive charge and a similar $\frac{v}{\sqrt{q}}$ ratio to particle X.

notes:
* this is not a magnetic field (don't use $F = qvB$)
* this is also not circular motion (don't us $F = \frac{mv^2}{r}$)
* there are no Coulombic forces between charges

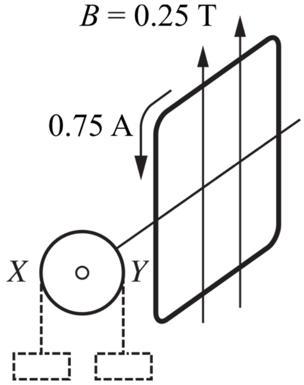
✓ provides some relevant information
✓ identifies X & Y as negatively charged
✓ identifies Z as oppositely charged to X & Y
✓ relates direction of deflection to direction of field
✓ relates magnitude of charge to path
✓ relates intial velocity to path
✓ extension of answer (use of mathematical models/ explain parabolic trajectory)

Booklet III

NESA Student Number:

Question 31 (5 marks)

A simple motor consists of a flat rectangular coil with 175 turns in a magnetic field, as shown.



The coil carries a current of 0.75 A. The motor drives a pulley of diameter 50 cm, and weights can be hung from either side of the pulley at point *X* or point *Y*.

(a) In order to prevent rotation, should a weight be hung at point *X* or at point *Y*? Justify your answer. **2**

From the right hand palm rule, the top side of the loop will experience a force to the left, turning the coil anticlockwise. A weight must be placed at Y to oppose this torque.

✓ correct location
✓ valid justification

note: if you did not describe the rotation of the coil and instead said that the motor moved left or right, then you did not receive the mark for justification

(b) If the motor is just stopped by a mass of 0.2 kg, what area does the coil have? **3**

If the torques balance:

$\tau_g = \tau_B$

$F_g r = mgr = nIAB \sin\theta$

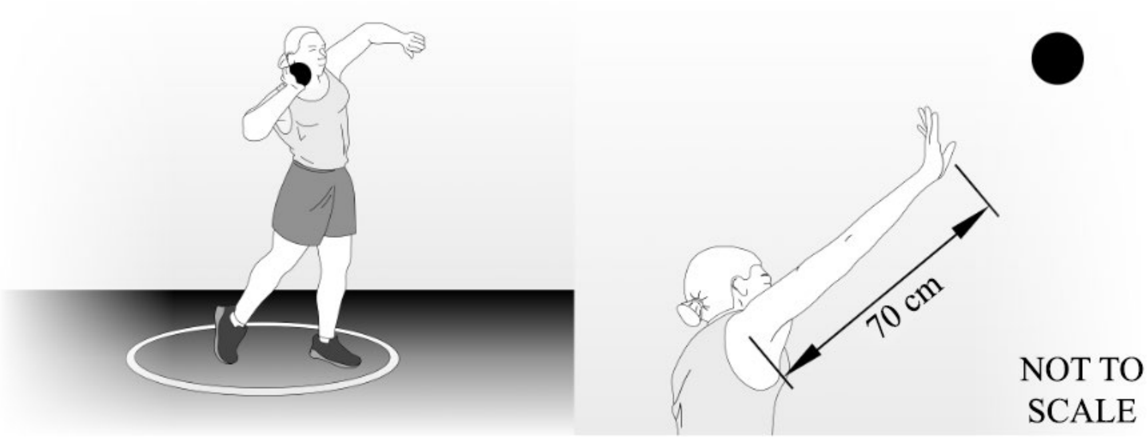
Given that the area vector of the coil is perpendicular to the coil, $\theta = 90°$ and $\sin 90 = 1$:

$A = \frac{mgr}{nIB} = \frac{0.2 \times 9.8 \times 0.25}{175 \times 0.75 \times 0.25} = 0.01493 = 0.015 \text{ m}^2$

✓ identifies $\tau_g = \tau_B$
✓ provides correct calculation steps
✓ correct answer & units

Question 32 (8 marks)

A champion shot put thrower is competing in a competition despite having recently damaged a ligament in her knee. Because of her injury she is forced to throw the shot put from a static position. Therefore, the shotput will only be accelerated across the distance of her extended arm which is 70 cm long.



(a) During her first attempt, she applied a constant force of 423 N throughout the extension of her arm. If the 4.0 kg ball is released at 11.8 m s^{-1}, at what angle did she throw the ball? **4**

WORK APPROACH:

The work done by the thrower is used to increase the kinetic energy of the ball **and** to increase the gravitational potential energy of the shot put:

$W = \Delta K + \Delta U$

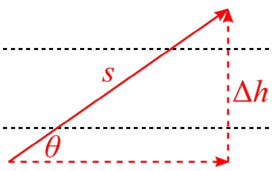
$W = Fs = 432 \times 0.70 = 302.7$ J

$\Delta K = \frac{1}{2}mv^2 = \frac{1}{2} \times 4.0 \times 11.8^2 = 278.5$ J

$\Delta U = W - \Delta K = 302.7 - 278.5 = 23.9$ J

This change in gravitational potential energy corresponds to in heigh increase of:

$\Delta U = mg\Delta h \ \rightarrow \ \Delta h = \frac{\Delta U}{mg} = \frac{23.9}{4.0 \times 9.8} = 0.610$ m



From trigonometry:

$\sin\theta = \frac{\Delta h}{s} \ \rightarrow \ \theta = \sin^{-1}\frac{\Delta h}{s} = \sin^{-1}\frac{0.610}{0.70} = 39.9 = 60.6 = 61°$

✓ provides some relevant information OR attempts to calculate W
✓ calculates correct W
✓ calculates correct ΔK
✓ correct answer & units

notes: * no mark was provided for "relevant information" if $W = Fs\cos\theta$ is used and θ is implied to be the angle of elevation.
* in order to gain 2 marks for the calculation of work the numerical value of work MUST be stated in answer.

SUVAT APPROACH:

The net force F_{net} acting on the shot is due to the shot putter's applied force F_{app} and the force due to gravity F_g:

$F_{x(net)} = F\cos\theta = 432\cos\theta$

$F_{y(net)} = F\sin\theta - mg = 432\sin\theta - 4.0\times 9.8 = 432\sin\theta - 39.2$

$a_{x(net)} = \frac{F_{x(net)}}{m} = \frac{432\cos\theta}{4.0} = 108\cos\theta$

$a_{y(net)} = \frac{F_{y(net)}}{m} = \frac{432\sin\theta - 39.2}{4.0} = 108\sin\theta - 9.8$

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

$a_{net} = \frac{v^2 - u^2}{2s} = \frac{11.8^2 - 0^2}{2\times 0.700} = 99.46\ \mathrm{m\ s^{-2}}$

$a_{net}^2 = a_{x(net)}^2 + a_{y(net)}^2$

$99.46^2 = (108\cos\theta)^2 + (108\sin\theta - 9.8)^2$

$9892.3 = 11664\cos^2\theta + 11664\sin^2\theta - 2116.8\sin\theta + 96.04$

$\quad = 11664(\cos^2\theta + \sin^2\theta) - 2116.8\sin\theta + 96.04$

$\quad = 11664 - 2116.8\sin\theta + 96.04$

$\sin\theta = \frac{11664 + 96.04 - 9892.3}{2116.8} = 0.8823$

$\theta = \sin^{-1} 0.8823 = 61.9 = 62°$

✓ provides some relevant information OR attempts to calculate F_{net}
✓ calculates correct a_{net}
✓ ✓ correct answer & units

note: a SUVAT approach could not be taken simply in the line of the putter's arm as this does not take into account the force of gravity acting downwards on the put as she applies her force

Question 23 continues on page 22

Question 23 (continued)

(b) On her second attempt she releases the shot put at an angle of 45° with the same launch velocity as her first attempt in part (a). If she released it from a height of 1.8 m above the ground, determine the range of her throw. **4**

From the launch angle and speed:

$u_x = u\cos\theta = 11.8 \times \cos 45 = 8.344\text{ m s}^{-1}$

$u_y = u\sin\theta = 11.8 \times \sin 45 = 8.344\text{ m s}^{-1}$

Time to peak height is: $v_y = u_y + a_y t_1 \ \rightarrow t_1 = \frac{v_y - u_y}{a_y} = \frac{0 - 8.344}{-9.8} = 0.851\text{ s}$

Thus, the peak heigh is

$v_y^2 = u_y^2 + 2a_y s_y \ \rightarrow s_y = \frac{v_y^2 - u_y^2}{2a_y} = \frac{0^2 - 8.344^2}{2\times -9.8} = 3.55\text{ m above launch}$

$= 3.55 + 1.8 = 5.35\text{ m total}$

Time from peak height to the ground is:

$s_y = u_y t_2 + \frac{1}{2}a_y t_2^2 = \frac{1}{2}a_y t_2^2$ (since, at peak height, $u_y = 0$)

$t_2 = \sqrt{\frac{2s_y}{a_y}} = \sqrt{\frac{2\times -5.35}{-9.8}} = 1.045\text{ s}$

Therefore, total flight time is $t = t_1 + t_2 = 0.851 + 1.045 = 1.896\text{ s}$

Range is, thus, $s_x = u_x t = 8.344 \times 1.896 = 15.8\text{ m}$

✓ provides some relevant information
✓ makes some calculation steps towards an answer
✓ calculates time(s) OR range at $s_y = 0$
✓ correct answer & units

notes: * an alternative method can be used utilising the quadratic formula to calculate time
* student most often lost marks due to the directionality of their vectors [if a was made $+ve$ then s would be $+ve$ and u should have been made $-ve$]

End of Question 23

Question 33 (7 marks)

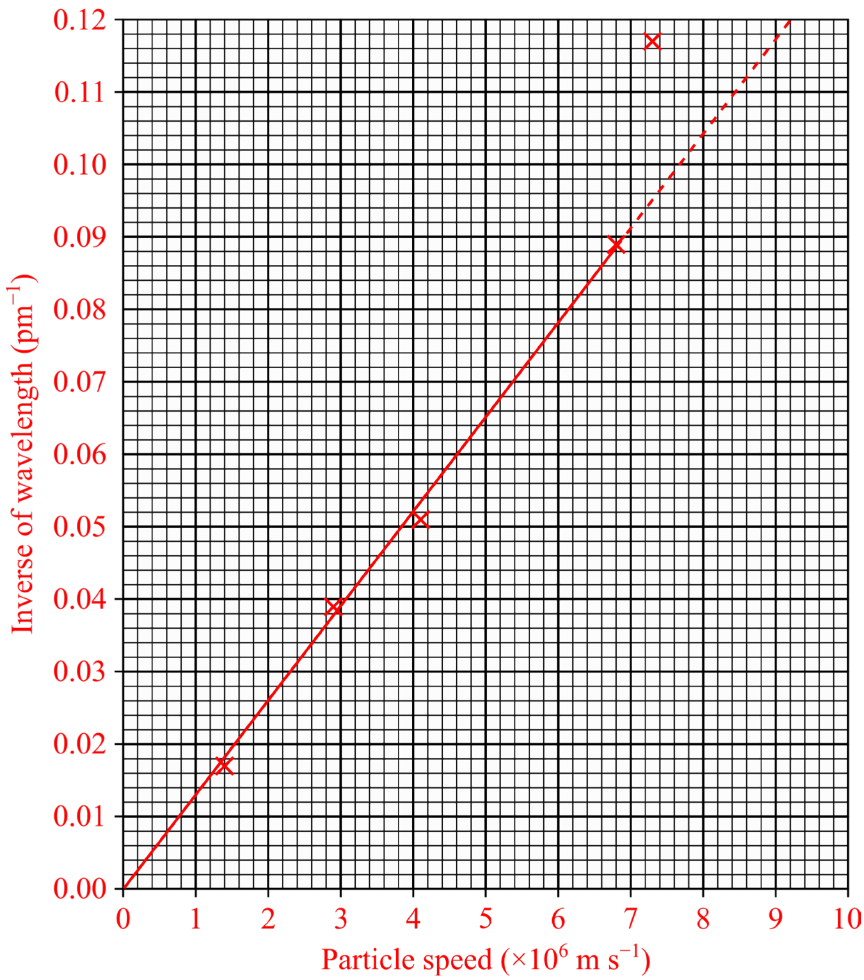
A beam of particles was fired at a metal crystal, resulting in a diffraction pattern on the detector screen.

The speed of the particles was varied, and the diffraction pattern was used to determine the associated wavelengths of the particles.

The following results were obtained. Note, a picometer (pm) is 10^{-12} m.

Particle speed ($\times 10^6$ m s^{-1})	*Wavelength (pm)*	*Inverse of the wavelength (pm^{-1})*
1.4	56.3	0.017
2.9	27.2	0.039
4.1	17.2	0.051
6.8	11.6	0.089
7.3	8.5	0.117

(a) Plot the results for *particle speed* and *inverse of the wavelength* on the grid below. **4**



note: if the y-axis unit was expressed in m, it should have had a positive exponent ($\text{pm}^{-1} = (10^{-12})^{-1} = 10^{12}\ m$)

✓ correctly arranged axes (*speed* on *x*-axis)
✓ correctly labelled axes (with units)
✓ corretly plotted data points with appropriate symbols
✓ appropriate LOBF (ignoring outlier)

Question 30 (continued)

(b) Use the graph to determine the mass of the particles. **3**

From the graph:

$gradient = \frac{rise}{run} = \frac{\frac{1}{\lambda}}{v} = \frac{1}{v\lambda} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(0.086-0.026)\times 10^{12}}{(6.6-2.0)\times 10^{6}} = 13043\ \text{s m}^{-2}$

From de Broglie's hypothesis:

$\lambda = \frac{h}{mv} \rightarrow \frac{m}{h} = \frac{1}{v\lambda} = gradient$

$m = h \times gradient = 6.626 \times 10^{-34} \times 13043 = 8.64 \times 10^{-30}\ \text{kg}$

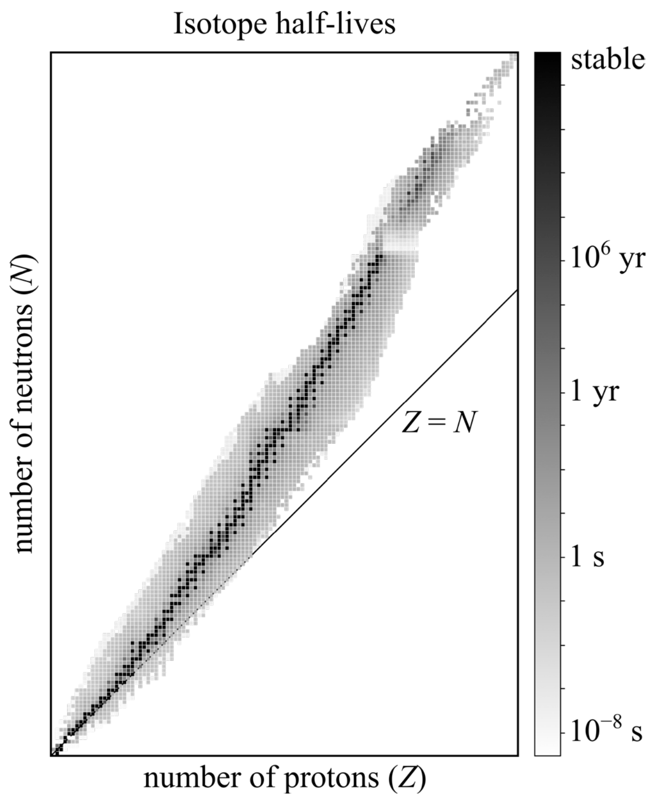
✓ makes a valid calculation
✓ substitutes from LOBF
✓ correct answer & units

notes: * a lot of students forgot to include the unit prefix powers in their calculations
* a maximum of 2 marks was awarded if points chosen to calculate gradient came from the data table and DID NOT fall on their LOBF

End of Question 30

Question 34 (3 marks)

Outline features of the nuclear force that explains the stability of isotopes illustrated in the diagram below. **3**

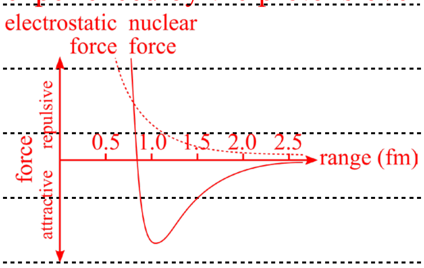


The stablity of a nucleus is related to the nuclear forces responsible for holding it together.

When considering the mass, size and distance of the protons and neutrons, the force of gravity is negligible.

The nuclear force, which is a strongly attractive force between the distances of 0.8 − 2.5 fm, is a significantly larger force than the repulsive Coulomb force experienced by the protons over this same distance as shown in the sketch graph.

The nuclear force is charge independent and is experienced by both protons and neutrons. At distances smaller than 0.8 fm the nuclear force becomes repulsive.



✓ 1 mark each for THREE valid features of the **nuclear force**

notes: * this This question did NOT ask to explain the band of stability or nuclear decay
* answers could include the shown graph; better responses then referred to their sketched graph
* 1 mark was awarded if an answer identified that the nuclear force and the Coulomb force were acting
* 2 marks were awarded if an answer made clear the relationship between the Coulomb and nuclear force