Student Number								

2023 **HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION**

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, formula sheet and Periodic Table are provided

Total marks: 100

Section I – 20 marks

- Attempt questions 1 – 20
- Allow about 35 minutes for this section

Section II – 80 marks

- Attempt questions 21 – 34
- 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 on page 11 for Questions 1 – 20

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1 The Standard Model of matter states that protons are not considered to be fundamental particles because:

(A) protons may spontaneously decay into other particles.

(B) fundamental particles have no charge.

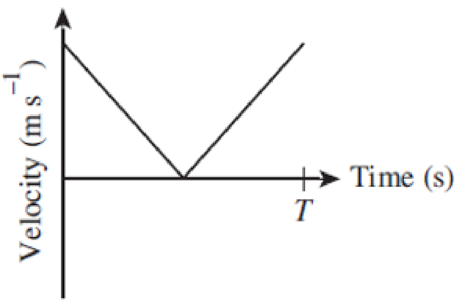
(C) protons can be broken apart in particle accelerators.

(D) protons are a member of the Boson family of particles.

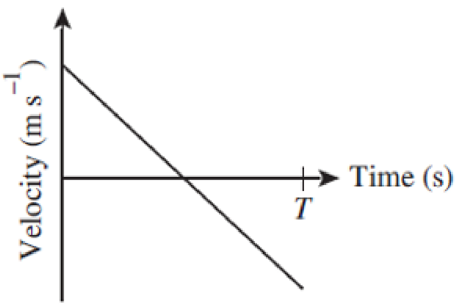
2 A tennis player launches a tennis ball vertically upwards. At time T, the tennis player catches the ball when it returns to its starting position.

Which of the following graphs shows the tennis ball's velocity over time?

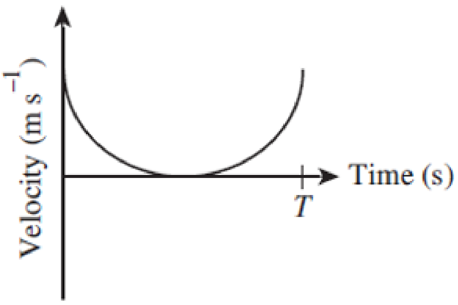
A.



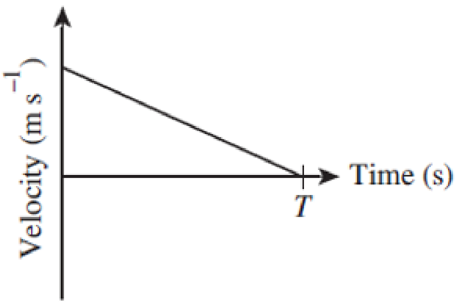
B.



C.



D.



3 Students plotted the radiation of stars against their wavelengths.

If a star has a surface temperature of 4000 K, what is the maximum wavelength of the radiation emitted by the star?

(A) 0.725×10^{-7} m

(B) 7.25×10^{-6} m

(C) 725×10^{-7} m

(D) 725 nm

4 Which of the following statements is true regarding the observations of two people, one traveling at 99.9% of the speed of light, and one stationary?

(A) Both people will observe time to be passing at the normal rate in their frame of reference.

(B) The person traveling at 99.9% of the speed of light will observe their time to be passing slower.

(C) The stationary person will observe their time to be passing slower.

(D) Both people will observe time to be passing slower in their frame of reference.

5 Which of the following statements about AC induction motors is correct?

(A) There is no current produced in induction motors.

(B) Induction motors need slip rings to operate.

(C) The magnetic field rotates faster than the rotor.

(D) The rotor rotates faster than the magnetic field.

6 A muon is an elementary particle similar to the electron, with an electric charge of -1e but with a much greater mass. A muon and an electron are travelling at the same speed.

Which row gives the particle with the greater kinetic energy and the particle with the longer de Broglie wavelength?

	Greater kinetic energy	**Longer de Broglie wavelength**
(A)	muon	muon
(B)	muon	electron
(C)	electron	muon
(D)	electron	electron

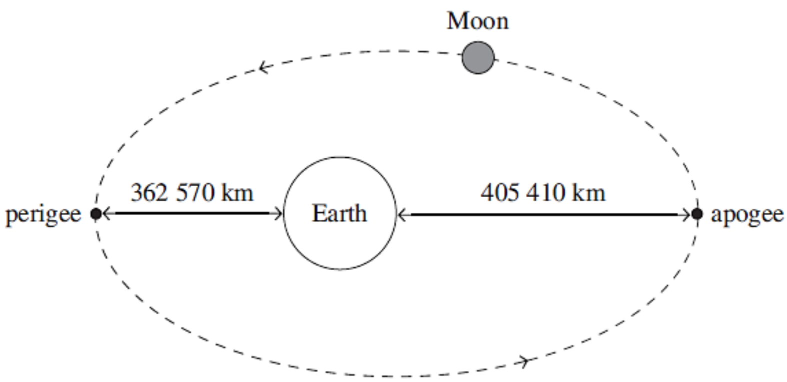
7 In a Physics class, students conduct three experiments in which they observe various light sources through a spectroscope.

- Experiment 1 uses an incandescent lamp.
- Experiment 2 uses a sodium lamp.
- Experiment 3 uses an incandescent lamp and passed the light through sodium vapour.

Which row of the table identifies what the students would observe through the spectroscope in each experiment?

	Experiment 1	***Experiment 2***	***Experiment 3***
(A)	continuous spectrum of colours	two yellow lines on a dark background	fully colours background with two black lines
(B)	continuous spectrum of colours	fully colours background with two black lines	two yellow lines on a dark background
(C)	two yellow lines on a dark background	full spectrum of colours	fully colours background with two black lines
(D)	fully colours background with two black lines	two yellow lines on a dark background	full spectrum of colours

8 The diagram shows the perigee and apogee of the moon – two points in the moon's elliptical orbit around Earth.



Which of the following statements is correct?

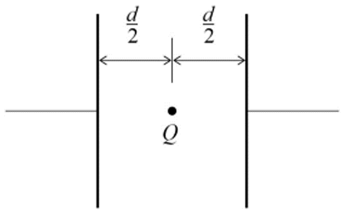
(A) When the moon reaches the apogee, its gravitational potential energy as well as its kinetic energy will be at minimum. It will move at a low velocity.

(B) When the moon reaches the apogee, its gravitational potential energy as well as its kinetic energy will be at maximum. It will move at a high velocity.

(C) When the moon reaches the perigee, its gravitational potential energy will be at a minimum and its kinetic energy will be at a maximum. It will move at a high velocity.

(D) When the moon reaches the perigee, its gravitational potential energy will be at a maximum and its kinetic energy will be at a minimum. It will move at a low velocity.

9 Two parallel plates separated by a distance d have a potential difference V across them. A particle with charge Q is placed midway between the plates.



What is the magnitude of the electrostatic force acting on the particle?

(A) zero

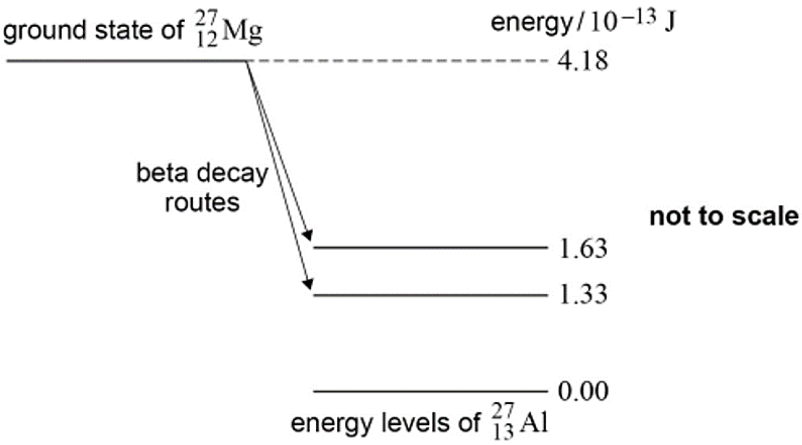
(B) $\frac{QV}{2d}$

(C) $\frac{QV}{d}$

(D) $\frac{2QV}{d}$

10 $^{27}_{12}Mg$ can decay by beta minus emission to one of two possible excited states of $^{27m}_{13}Al$. Both excited states decay by emission of a gamma photon directly to the ground state.

The diagram below shows the energy levels and two routes for the beta decay.



One route results in the emission of a gamma photon with a higher frequency than the other photon.

What is the kinetic energy for the beta particle emitted in this route?

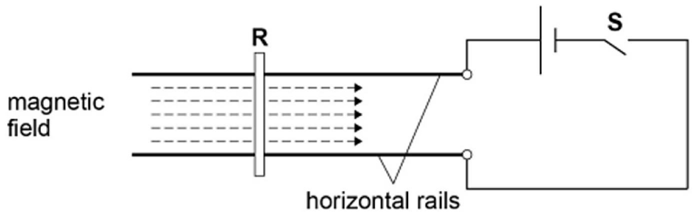
(A) 1.33×10^{-13} J

(B) 1.63×10^{-13} J

(C) 2.55×10^{-13} J

(D) 2.85×10^{-13} J

11 A short copper rod **R** is placed on a pair of thick horizontal parallel copper rails. A horizontal magnetic field exists in the direction shown by the dashed arrows. The diagram shows the apparatus when viewed from directly above.



When switch **S** is closed, **R** will tend to:

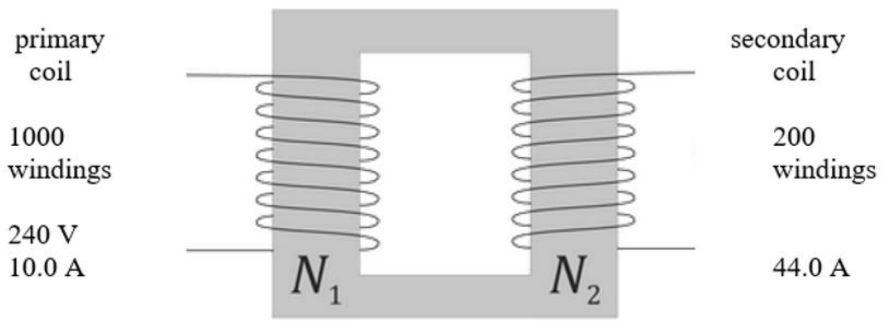
(A) Lift upwards away from the rails.

(B) Move to the left.

(C) Move to the right.

(D) Be pressed downwards onto the rails.

12 A transformer has 1000 windings on the primary coil and 200 windings on the secondary coil.



The primary voltage is 240 V, with a primary current of 10.0 A.

The secondary current is 44.0 A.

What is the efficiency and type of this transformer?

	Efficiency	**Type**
(A)	23%	step-up
(B)	44%	step-up
(C)	20%	step-down
(D)	88%	step-down

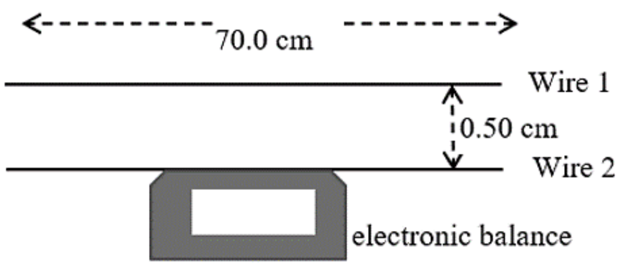
13 For a planet orbiting a single star, which factors determine the planet's orbital period?

(A) mass of planet; mass of star; radius of orbit
(B) mass of star; radius of orbit
(C) speed of planet; radius of orbit
(D) mass of star; mass of planet

Use the following information for Questions **14** and **15**.

An investigation was performed with the aim of measuring the value of the magnetic permeability constant, μ_0.

Two wires, both of length 70.0 cm were arranged horizontally, with one wire above the other, as shown in the diagram below. The bottom wire is resting on an electronic balance.



When a current of 25.5 A flows through both wires, the reading on the electronic balance changes by 0.500 g.

14 What is the value of μ_0 as determined by this investigation?

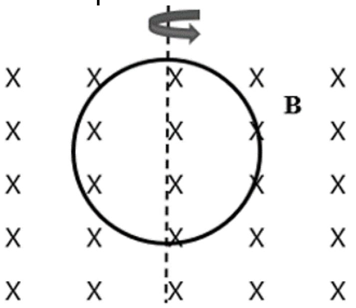
(A) 3.4×10^{-7}
(B) 1.7×10^{-7}
(C) 3.4×10^{-4}
(D) 1.7×10^{-4}

15 Which measurement made in the above investigation has the greatest relative error?

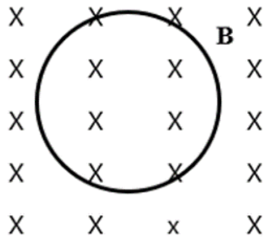
(A) length of the wires
(B) separation of the wires
(C) current in wires
(D) change in the reading of the electronic balance

16 In the diagrams below the loops are initially all the same size and the magnetic field B is the same.

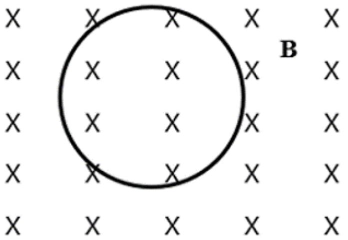
(S) The loop is rotated 90° in 2.0 s.



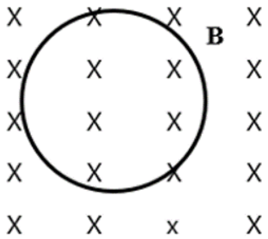
(T) The magnetic field is reduced to zero in 4.0 s



(U) The loop's radius doubles in 2.0 s.



(V) The direction of the magnetic field is reversed in 2.0 s.



In which situation would the average induced EMF around the loop be the greatest?

(A) S

(B) T

(C) U

(D) V

17 Which statement correctly matches Malus' Law?

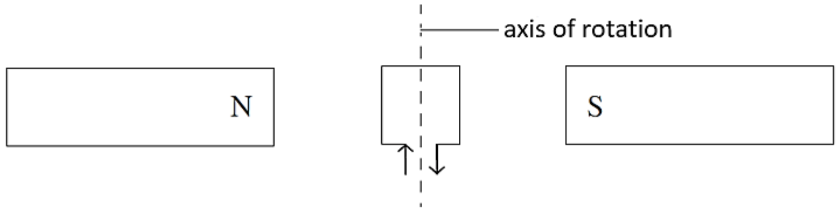
(A) The intensity of polarised light entering an analyser is directly proportional to the cosine squared of the angle between the polariser and the analyser.

(B) The intensity of polarised light entering an analyser is inversely proportional to the cosine squared of the angle between the polariser and the analyser.

(C) The intensity of non-polarised light entering an analyser is directly proportional to the cosine squared of the angle between the polariser and the analyser.

(D) The intensity of a non-polarised light entering an analyser is inversely proportional to the cosine squared of the angle between the polariser and the analyser.

18 A rectangular coil has a dimensions 3.0 cm × 4.0 cm and carries a current of 15.0 mA in a uniform magnetic field of 3.0 T. The coil has 20 turns of wire and is free to rotate about the axis as shown.



If the coil is rotated by 25°, what is the torque acting on the coil?

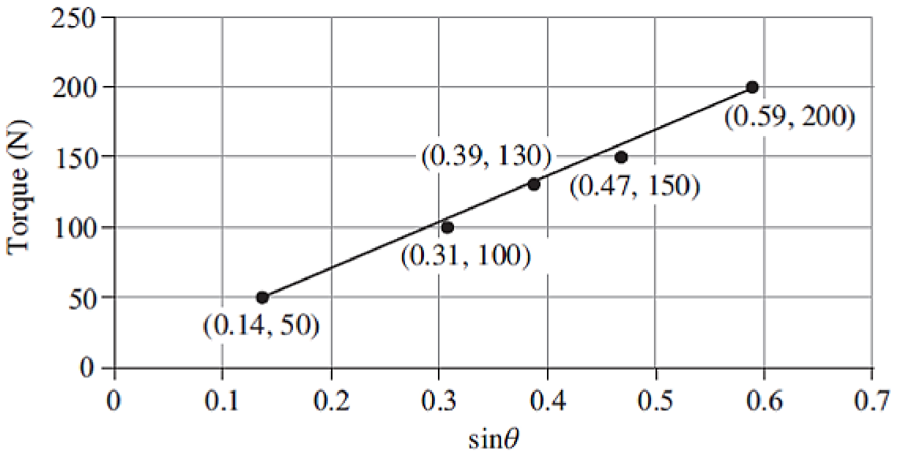
(A) 9.79×10^{-4} Nm clockwise

(B) 9.79×10^{-4} Nm anticlockwise

(C) 4.56×10^{-4} Nm clockwise

(D) 4.56×10^{-4} Nm anticlockwise

19 An engineer turns a nut by applying a constant force to a 25.00 cm spanner. They applied this force at different angles and measured the torque. The graph shows the data collected by the engineer.



What is the magnitude of the force applied to the nut?

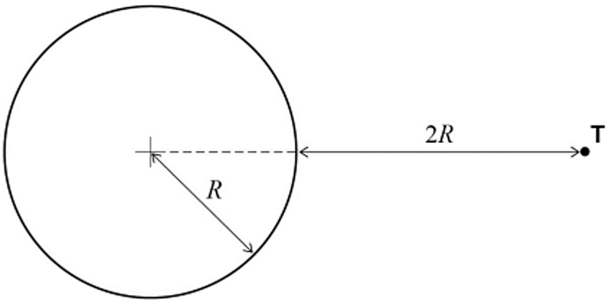
(A) 14.8 N

(B) 84.8 N

(C) 339 N

(D) 1333 N

20 An isolated spherical conductor is charged.
The conductor has a radius R and an electric potential V. The electric field strength at its surface is E.



Point **T** is a distance $2R$ from the surface.

What are the electric field strength and electric potential at **T**?

	Electric field strength	**Electric potential**
(A)	$\frac{E}{2}$	$\frac{V}{4}$
(B)	$\frac{E}{9}$	$\frac{V}{3}$
(C)	$\frac{E}{4}$	$\frac{V}{2}$
(D)	$\frac{E}{9}$	$\frac{V}{9}$

End of Section I

Student Number								

2023 **HSC TRIAL EXAMINATION**

PHYSICS

Section I – Multiple Choice Answer Sheet

Instructions for answering questions in Section I:

- Complete you answers in either blue or black pen
- Multiple choice

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

Sample 1: 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.

A ○ **B** ○ **C** ~~●~~ **D** ~~●~~

correct

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

Student Number								
Section I /20								
Section II /80								
Total /100								

Physics
Section II

80 marks
Attempt Questions 21 – 34
Allow about 2 hours 25 minutes for this section

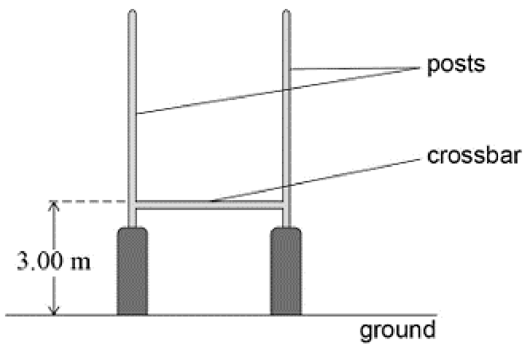
Instructions

- Write your student number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations
- Extra writing paper is available, please raise your hand to request more paper. If you use extra paper, clearly indicate your student number and which question you are answering.

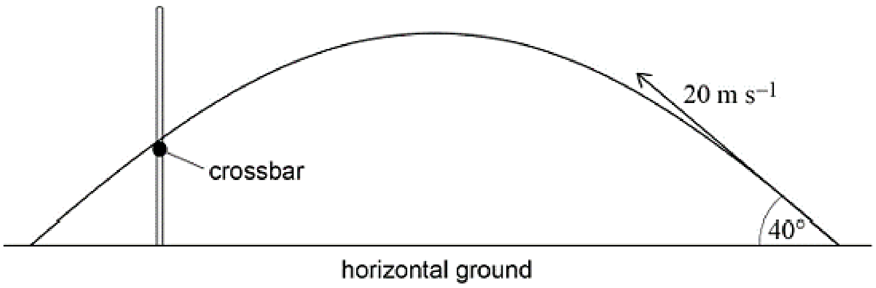
Please turn over

Question 21 (5 marks)

The diagram below shows the H-shaped posts used in a game of rugby.



The path of a ball that is kicked and just passes over the crossbar is shown below.



The initial velocity of the ball is 20.0 ms^{-1} at an angle of 40.0° to the ground.
The top of the crossbar is 3.00 m above the horizontal ground.
Ignore the effect of air resistance and treat the ball as a simple projectile.

(a) Determine the minimum velocity of the ball in flight. **1**

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(b) The ball just passes over the cross bar at a time t after it is kicked. Find t. **2**

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Question 21 continues on the following page

Question 21 (continued)

(c) Another attempt is made to kick the ball over the crossbar. It was kicked at the same angle with the same initial velocity as the first attempt.
This kick is made from a horizontal distance of 38 m from the posts.

Determine whether the ball can pass over the crossbar. Show working. **2**

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End of Question 21
Question 22 is on the following page

Question 22 (8 marks)

The Global Positioning System (GPS) uses satellites to support navigation on Earth.

One GPS satellite is in a circular orbit at a height h above the surface of the Earth.
The Earth has mass M and radius R.

(a) Use $\omega = \frac{2\pi}{T}$ to show that the angular speed, ω, of the satellite is given by: **2**

$$\omega = \sqrt{\frac{GM}{(R+h)^3}}$$

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(b) Calculate the orbital period of the satellite when h equals 2.02×10^7 m. **2**

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Question 22 continues on the following page

Question 22 (continued)

(c) The satellite has a mass of 1630 kg.

Calculate the gravitational potential energy of the satellite when in the orbit in part **(b)**. **2**

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(d) A different satellite is in a higher circular orbit.

Explain how the linear speed of this satellite compares with the linear speed of the satellite in part (a). **2**

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End of Question 22
Question 23 is on the following page

Question 23 (6 marks)

A 1300 kg car makes a turn on a circular bend of road at a speed of 80 km/h. The bend is not banked and has a radius of 40 m.

(a) What is the magnitude of the centripetal force required for the car to make this turn? **2**

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(b) Calculate the magnitude of the centripetal force exerted by the road on the car if the bend were banked at an angle of 8°. **4**
Support your answer with a diagram that identifies the relevant forces and vector components.

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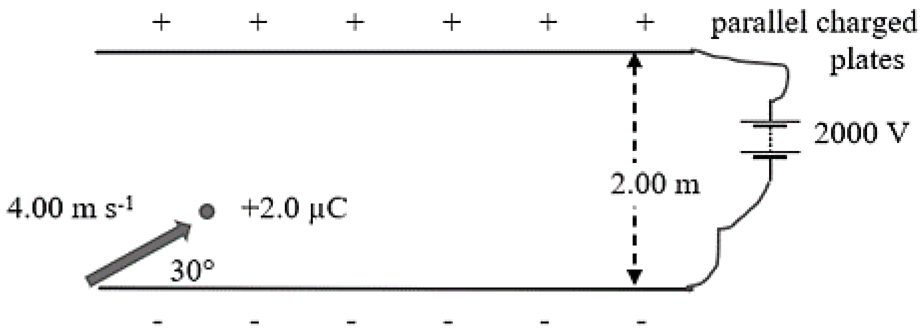
Question 24 (6 marks)

A small particle with mass 5.0 mg and a charge of +2.0 μC is shot at an angle of 30° and initial speed 4.00 ms^{-1} into a large gravity-free region between two parallel charged plates 2.0 m apart, as shown below.



(a) Find the acceleration of the charged particle within the gravity-free region. **3**

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(b) How far along from its launch position will the charged particle hit the negative plate? **3**

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Question 25 (5 marks)

Rutherford's atomic model placed all the positive charge and most of the mass of an atom in the nucleus. It could not account for the existence of isotopes, where atoms of the same element differ in mass.

Outline the way in which the discovery of the particle responsible for this variation in mass was made and explain why the discovery came so much later. **5**

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Question 26 (7 marks)

(a) Using an example of a proton moving at 500 kms^{-1}, show that its wavelength is too short to detect using present-day technology. **3**

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(b) Outline the experimental evidence that led to the development of the formula used to calculate the wavelength of de Broglie's matter waves. **4**

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Question 27 (3 marks)

A technique used to turn pure silicon-28 into a type of material used in semiconductors is to bombard the pure silicon-28 with neutrons from a nuclear reactor.

Using appropriate equations, show how the capture of a neutron by a silicon-28 nucleus can result in the transmutation of silicon nuclei into phosphorous by beta decay. **3**

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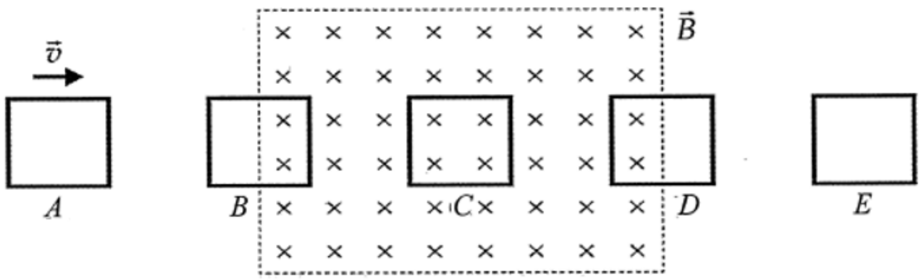
Question 28 (5 marks)

A square coil of wire of 10 turns with a cross-sectional area of 1.6×10^{-3} m^2 passes at a constant speed into, through and out of a magnetic field of magnitude 2.0×10^{-2} T.
The coil takes 0.40 s to go from position A to position B. The distance between each coil position equals the length of coil side.



(a) Calculate the emf induced in this coil as it enters the field. **2**

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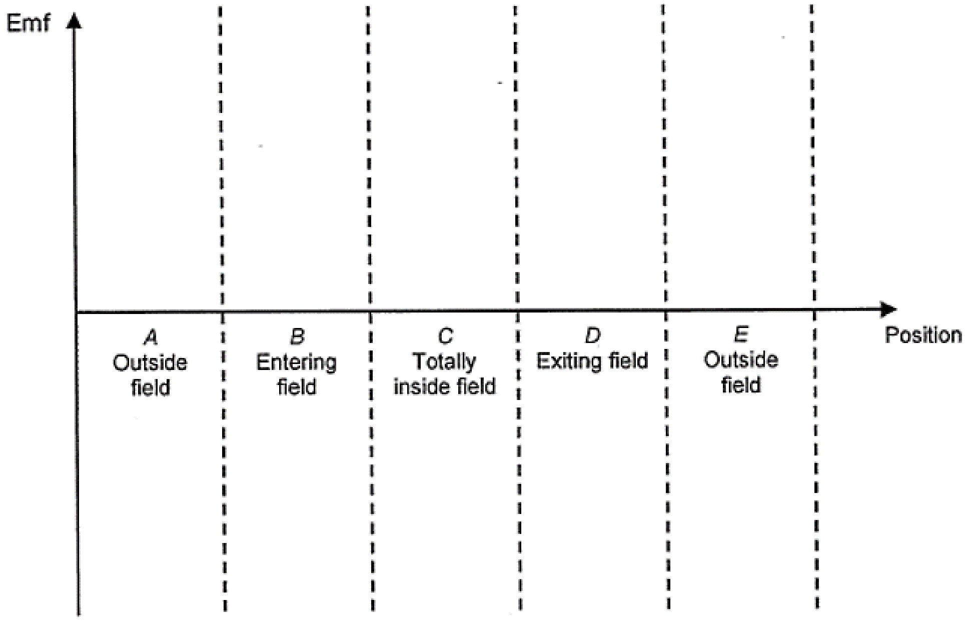
Question 28 continues on the following page

Question 28 (continued)

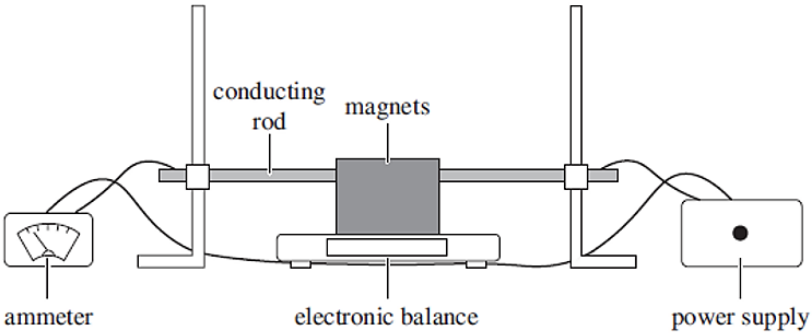
(b) Complete the diagram below to show the magnitude and direction of the induced emf in the coil as it moves through the 5 labelled positions. **3**
Do not include values on the axes.



End of question 28
Question 29 is on the following page

Question 29 (7 marks)

A group of students were conducting an experiment and set up a current balance.



The conducting rod was positioned between two magnets, perpendicular to the magnetic field. 60 cm of the conducting rod is within the magnetic field. The balance was initially set at zero. When the students changed the current flowing though the apparatus, the readings on the balance changed due to the force acting up or down.

The students steadily increased the current, which was measured using the ammeter, and recorded the mass displayed on the balance. They then used the measured current and mass to calculate the force acting on the magnets. Their results are shown in the table.

Current (A)	*Mass (kg)*	*Force (N)*
1.1	-0.55×10^{-3}	5.61×10^{-4}
2.1	-1.02×10^{-3}	1.04×10^{-4}
2.9	-1.43×10^{-3}	1.46×10^{-4}
3.6	-1.86×10^{-3}	1.90×10^{-4}
4.3	-2.15×10^{-3}	2.19×10^{-4}

(a) Plot a graph of force versus current. Include a line-of-best-fit. **3**

(b) Identify the relationship between force and current shown in the graph from part (a) and state TWO assumptions that must be made for this relationship to exist. **2**

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(c) Calculate the gradient of the graph from part (a) and use the gradient to determine the strength of the magnetic field. **2**
In your response, include any relevant equation(s).

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End of Question 29
Question 30 is on the following page

Question 30 (4 marks)

The Standard Model identifies bosons as responsible for all the force interactions we observe.

Outline the role of bosons in our universe. **4**

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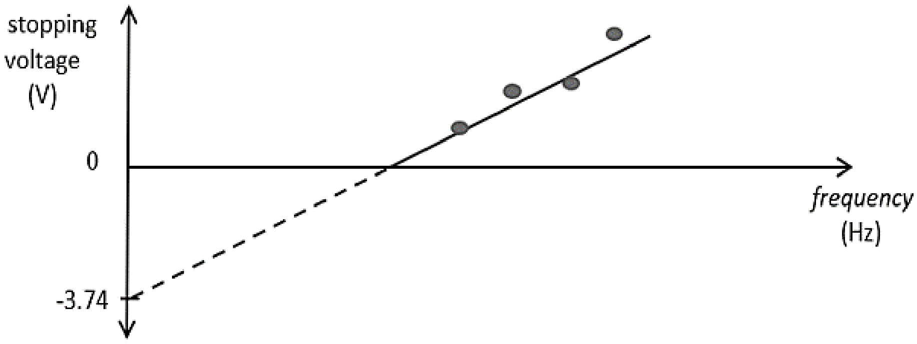
End of Question 30
Question 35 is on the following page

Question 31 (7 marks)

Students performed an investigation to observe the photoelectric effect using a zinc cathode. The results were plotted on a set of axes as shown below and extrapolated to the y-axis where the line of best fit intersects at -3.74 V.



(a) Calculate the threshold frequency of the zinc cathode. **2**

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(b) The investigation is repeated after replacing the zinc cathode by a different metal known to have a greater work function. The new results were plotted in the same manner.
Draw a line of best fit on the graph above to show how the results will vary.

2

Question 31 continues on the following page

Question 31 (continued)

(c) In the investigation, the students noticed that the photoelectrons did not all have the same velocities despite all receiving the same frequency of incident light.

Account for this observation. **3**

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End of Question 31

Question 32 is on the following page

Question 32 (3 marks)

A pair of detectors is set up to measure the intensity of a parallel beam of unstable particles. In the reference frame of the laboratory, the detectors are separated by a distance of 45 m. The speed of the particles in the beam is $0.97c$.

The intensity of the beam at the second detector is 12.5% of the intensity at the first detector.

Calculate the half-life of the particles in the reference frame in which they are at rest. **3**

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End of Question 32
Question 33 is on the following page

Question 33 (8 marks)

(a) In 1864, James Maxwell developed equations to describe the interaction of electric and magnetic fields and suggested that light was an electromagnetic wave.

Outline why his work was challenged by physicists of his day and explain the eventual solution in Einstein's Theory of Special Relativity. **6**

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Question 33 continues on the following page

Question 33 (continued)

(b) Describe one experimental evidence supporting Einstein's Theory of Special Relativity. **2**

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End of Question 33
Question 34 is on the following page

Question 34 (6 marks)

A student has three discs: a Blu-ray disc, a DVD and a CD. The reflective coating from the discs is removed so that they act as diffraction gratings. The discs have different slit separation.

The student also has two laser pointers A and B that emit different colours of visible light.

The tables below show information about the discs and the laser pointers.

Disc	**Slit separation (μm)**
Blu-ray disc	0.32
DVD	0.74
CD	1.60

Laser pointer	**Wavelength of light emitted (nm)**
A	445
B	636

(a) Deduce the combination of disc and laser pointer that will produce the greatest possible number of interference maxima. **2**

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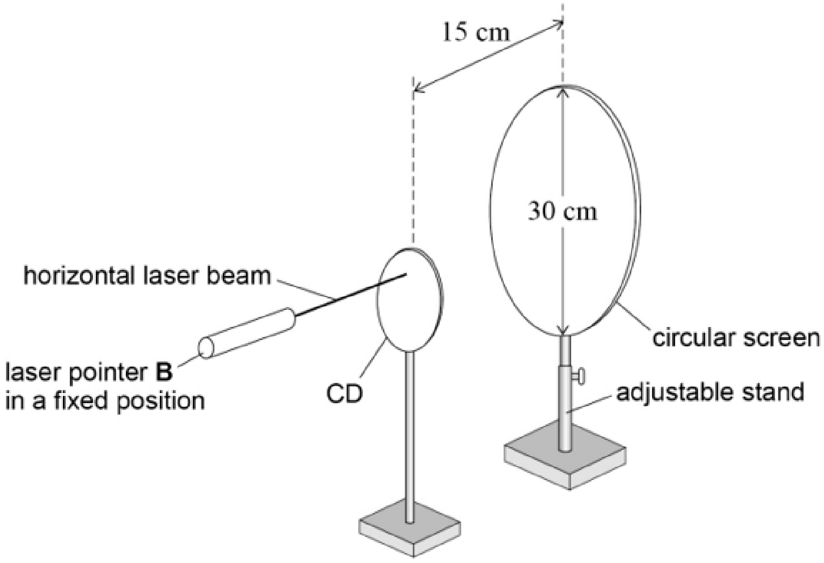
Question 34 continues on the following page

Question 34 (continued)

(b) The student uses the CD and laser pointer B as shown below. A diffraction pattern is produced vertically on the screen. Laser pointer B and the CD are in fixed positions. The laser beam is horizontal and incident normally (i.e. at 90°) on the CD. The height of the screen can be adjusted.



The screen has a diameter of 30 cm and is positioned behind the CD at a fixed horizontal distance of 15 cm.
The student plans to adjust the height of the screen until the greatest number of bright spots is observed, without changing the distance from the CD to the circular screen.

Determine the greatest number of bright spots that can be observed on the screen. **4**

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End of Section II

End of Examination

Extra Writing Space

Student Number								

2023 **HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION**

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, formula sheet and Periodic Table are provided

Total marks: 100

Section I – 20 marks

- Attempt questions 1 – 20
- Allow about 35 minutes for this section

Section II – 80 marks

- Attempt questions 21 – 34
- 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 The Standard Model of matter states that protons are not considered to be fundamental particles because:

(A) protons may spontaneously decay into other particles.

(B) fundamental particles have no charge.

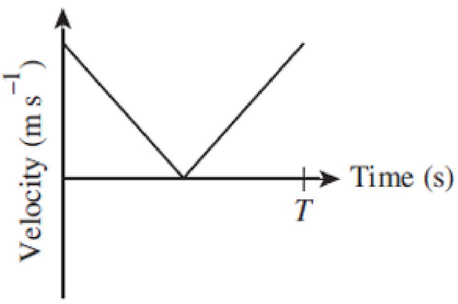
(C) protons can be broken apart in particle accelerators.

(D) protons are a member of the Boson family of particles.

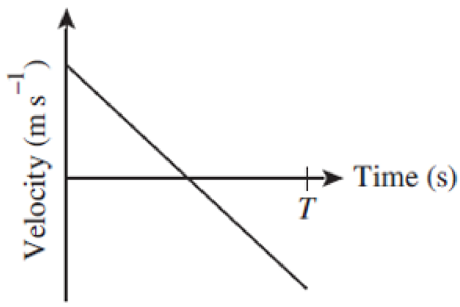
2 A tennis player launches a tennis ball vertically upwards. At time T, the tennis player catches the ball when it returns to its starting position.

Which of the following graphs shows the tennis ball's velocity over time? B

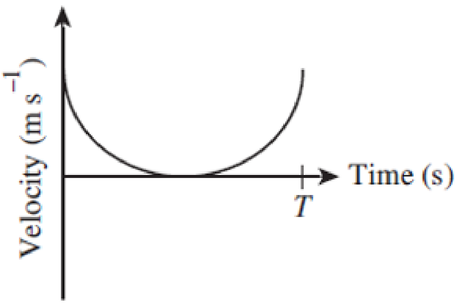
A.



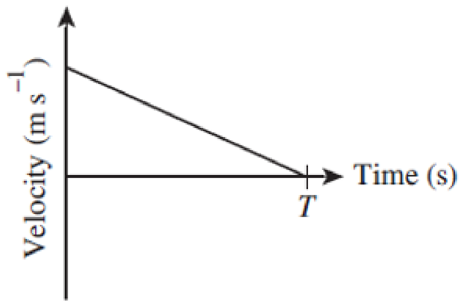
B.



C.



D.



3 Students plotted the radiation of stars against their wavelengths.

If a star has a surface temperature of 4000 K, what is the maximum wavelength of the radiation emitted by the star?

(A) 0.725×10^{-7} m

(B) 7.25×10^{-6} m

(C) 725×10^{-7} m

(D) 725 nm

4 Which of the following statements is true regarding the observations of two people, one traveling at 99.9% of the speed of light, and one stationary?

(A) Both people will observe time to be passing at the normal rate in their frame of reference.

(B) The person traveling at 99.9% of the speed of light will observe their time to be passing slower.

(C) The stationary person will observe their time to be passing slower.

(D) Both people will observe time to be passing slower in their frame of reference.

5 Which of the following statements about AC induction motors is correct?

(A) There is no current produced in induction motors.

(B) Induction motors need slip rings to operate.

(C) The magnetic field rotates faster than the rotor.

(D) The rotor rotates faster than the magnetic field.

6 A muon is an elementary particle similar to the electron, with an electric charge of $-1e$ but with a much greater mass. A muon and an electron are travelling at the same speed.

Which row gives the particle with the greater kinetic energy and the particle with the longer de Broglie wavelength?

	Greater kinetic energy	**Longer de Broglie wavelength**
(A)	muon	muon
(B)	muon	electron
(C)	electron	muon
(D)	electron	electron

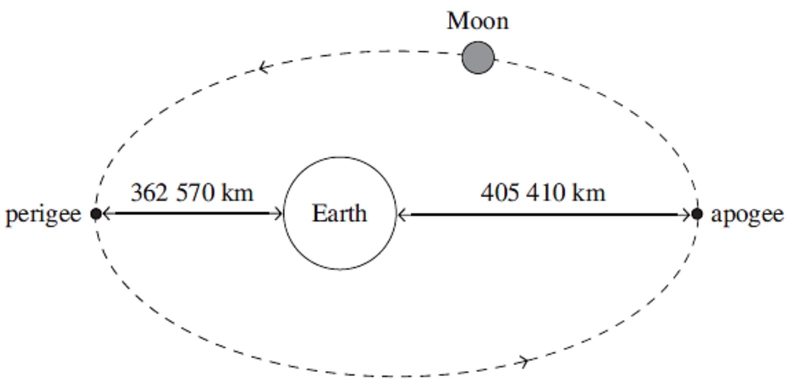
7 In a Physics class, students conduct three experiments in which they observe various light sources through a spectroscope.

- Experiment 1 uses an incandescent lamp.
- Experiment 2 uses a sodium lamp.
- Experiment 3 uses an incandescent lamp and passed the light through sodium vapour.

Which row of the table identifies what the students would observe through the spectroscope in each experiment?

	Experiment 1	***Experiment 2***	***Experiment 3***
(A)	continuous spectrum of colours	two yellow lines on a dark background	fully colours background with two black lines
(B)	continuous spectrum of colours	fully colours background with two black lines	two yellow lines on a dark background
(C)	two yellow lines on a dark background	full spectrum of colours	fully colours background with two black lines
(D)	fully colours background with two black lines	two yellow lines on a dark background	full spectrum of colours

8 The diagram shows the perigee and apogee of the Moon – two points in the Moon's elliptical orbit around Earth.



Which of the following statements is correct?

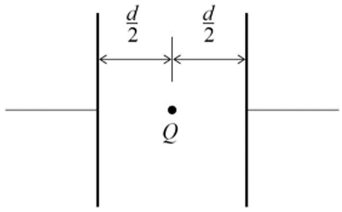
(A) When the Moon reaches the apogee, its gravitational potential energy as well as its kinetic energy will be at minimum. It will move at a low velocity.

(B) When the Moon reaches the apogee, its gravitational potential energy as well as its kinetic energy will be at maximum. It will move at a high velocity.

(C) When the Moon reaches the perigee, its gravitational potential energy will be at a minimum and its kinetic energy will be at a maximum. It will move at a high velocity.

(D) When the Moon reaches the perigee, its gravitational potential energy will be at a maximum and its kinetic energy will be at a minimum. It will move at a low velocity.

9 Two parallel plates separated by a distance d have a potential difference V across them. A particle with charge Q is placed midway between the plates.



What is the magnitude of the electrostatic force acting on the particle?

(A) zero

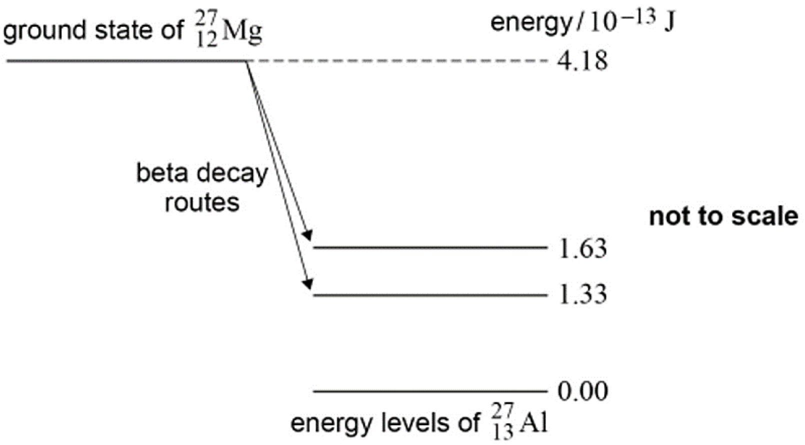
(B) $\frac{QV}{2d}$

(C) $\frac{QV}{d}$

(D) $\frac{2QV}{d}$

10 ${}^{27}_{12}Mg$ can decay by beta minus emission to one of two possible excited states of ${}^{27m}_{13}Al$. Both excited states decay by emission of a gamma photon directly to the ground state.

The diagram below shows the energy levels and two routes for the beta decay.



One route results in the emission of a gamma photon with a higher frequency than the other photon.

What is the kinetic energy for the beta particle emitted in this route?

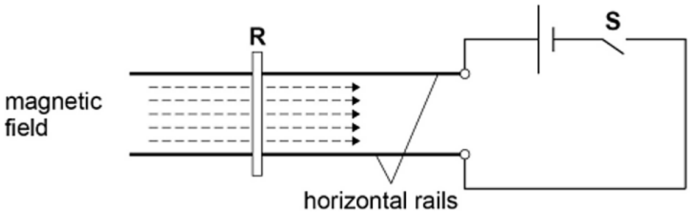
(A) 1.33×10^{-13} J

(B) 1.63×10^{-13} J

(C) 2.55×10^{-13} J

(D) 2.85×10^{-13} J

11 A short copper rod **R** is placed on a pair of thick horizontal parallel copper rails. A horizontal magnetic field exists in the direction shown by the dashed arrows. The diagram shows the apparatus when viewed from directly above.



When switch **S** is closed, **R** will tend to:

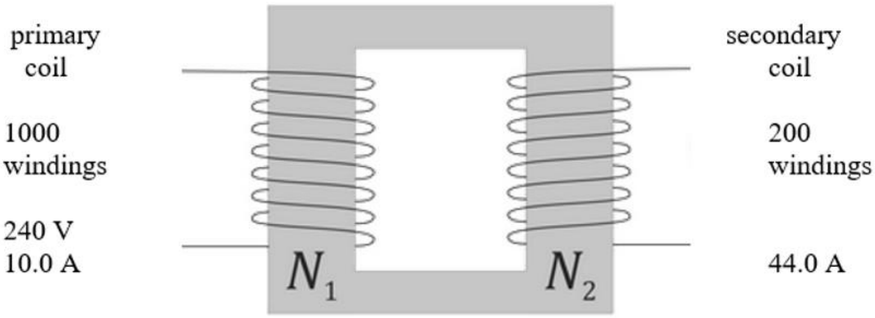
(A) lift upwards away from the rails.

(B) move to the left.

(C) move to the right.

(D) be pressed downwards onto the rails.

12 A transformer has 1000 windings on the primary coil and 200 windings on the secondary coil.



The primary voltage is 240 V, with a primary current of 10.0 A.

The secondary current is 44.0 A.

What is the efficiency and type of this transformer?

	Efficiency	Type
(A)	23%	step-up
(B)	44%	step-up
(C)	20%	step-down
(D)	88%	step-down

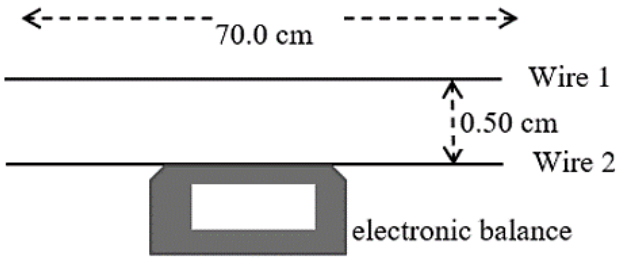
13 For a planet orbiting a single star, which factors determine the planet's orbital period?

(A) mass of planet; mass of star; radius of orbit
(B) mass of star; radius of orbit
(C) speed of planet; radius of orbit
(D) mass of star; mass of planet

Use the following information for Questions **14** and **15**.

An investigation was performed with the aim of measuring the value of the magnetic permeability constant, μ_0.

Two wires, both of length 70.0 cm were arranged horizontally, with one wire above the other, as shown in the diagram below. The bottom wire is resting on an electronic balance.



When a current of 25.5 A flows through both wires, the reading on the electronic balance changes by 0.500 g.

14 What is the value of μ_0 as determined by this investigation?

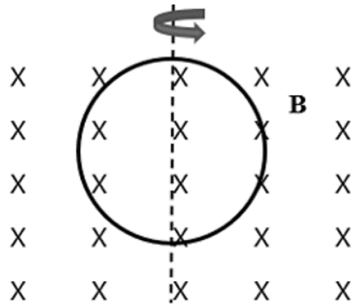
(A) 3.4×10^{-7}
(B) 1.7×10^{-7}
(C) 3.4×10^{-4}
(D) 1.7×10^{-4}

15 Which measurement made in the above investigation has the greatest relative error?

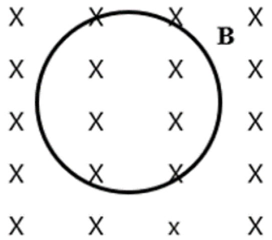
(A) length of the wires
(B) separation of the wires
(C) current in wires
(D) change in the reading of the electronic balance

16 In the diagrams below the loops are initially all the same size and the magnetic field B is the same. Find the expression for $\Delta\Phi$ using either ΔA or ΔB, then divide it by Δt to find the expression for ε in each situation.

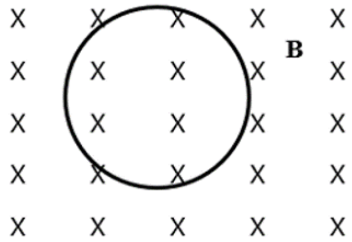
(S) The loop is rotated 90° in 2.0 s. $\varepsilon = \frac{1}{2}BA$



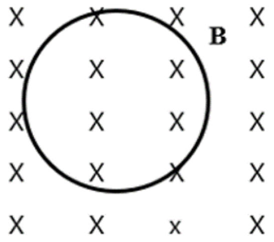
(T) The magnetic field is reduced to zero in 4.0 s. $\varepsilon = \frac{1}{4}BA$



(U) The loop's radius doubles in 2.0 s. $\varepsilon = \frac{3}{2}BA$



(V) The direction of the magnetic field is reversed in 2.0 s. $\varepsilon = BA$



In which situation would the average induced EMF around the loop be the greatest?

(A) S

(B) T

(C) U

(D) V

17 Which statement correctly matches Malus' Law?

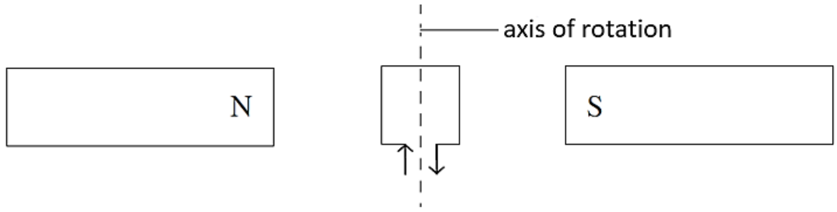
(A) The intensity of polarised light entering an analyser is directly proportional to the cosine squared of the angle between the polariser and the analyser.

(B) The intensity of polarised light entering an analyser is inversely proportional to the cosine squared of the angle between the polariser and the analyser.

(C) The intensity of non-polarised light entering an analyser is directly proportional to the cosine squared of the angle between the polariser and the analyser.

(D) The intensity of a non-polarised light entering an analyser is inversely proportional to the cosine squared of the angle between the polariser and the analyser.

18 A rectangular coil has a dimensions 3.0 cm × 4.0 cm and carries a current of 15.0 mA in a uniform magnetic field of 3.0 T. The coil has 20 turns of wire and is free to rotate about the axis as shown.



If the coil is rotated by 25°, what is the torque acting on the coil?

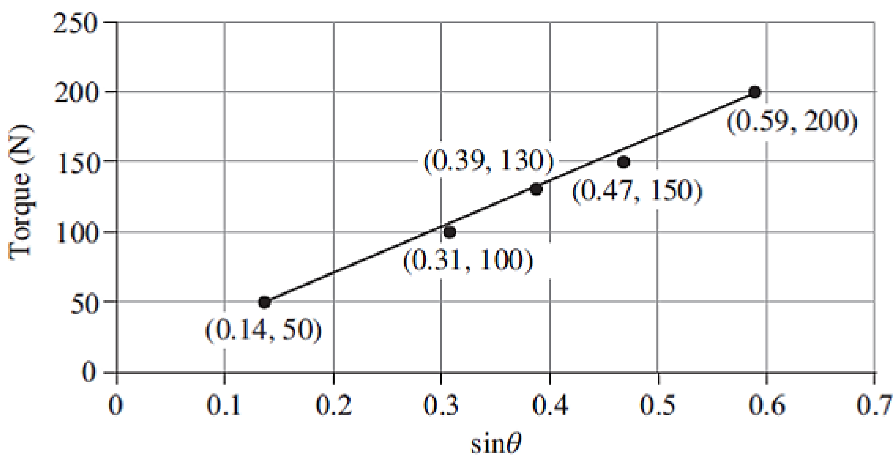
(A) 9.79×10^{-4} Nm clockwise

(B) 9.79×10^{-4} Nm anticlockwise

(C) 4.56×10^{-4} Nm clockwise

(D) 4.56×10^{-4} Nm anticlockwise

19 An engineer turns a nut by applying a constant force to a 25.00 cm spanner. They applied this force at different angles and measured the torque. The graph shows the data collected by the engineer.



What is the magnitude of the force applied to the nut?

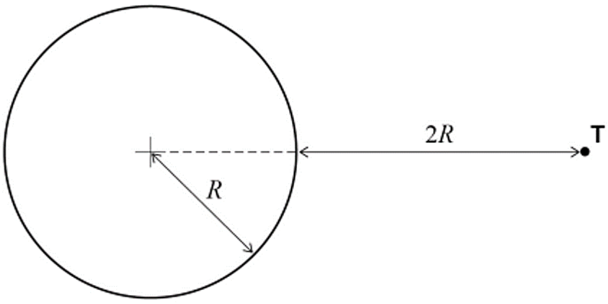
(A) 14.8 N

(B) 84.8 N

(C) 339 N

(D) 1333 N

20 An isolated spherical conductor is charged.
The conductor has a radius R and an electric potential V. The electric field strength at its surface is E.



Point **T** is a distance $2R$ from the surface.

What are the electric field strength and electric potential at **T**?

Use $E = \frac{F}{q}$ where $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$, hence $E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}$ where q_1=charge of conductor.

Use $V = Ed$ to compare the expressions for V.

	Electric field strength	**Electric potential**
(A)	$\frac{E}{2}$	$\frac{V}{4}$
(B)	$\frac{E}{9}$	$\frac{V}{3}$
(C)	$\frac{E}{4}$	$\frac{V}{2}$
(D)	$\frac{E}{9}$	$\frac{V}{9}$

End of Section I

Student Number								

2023 **HSC TRIAL EXAMINATION**

PHYSICS

Section I – Multiple Choice Answer Sheet

Instructions for answering questions in Section I:

- Complete you answers in either blue or black pen
- Multiple choice

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

Sample 1: 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.

A ○ **B** ○ **C** ● **D** ●

correct

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

Student Number								
Section I /20								
Section II /80								
Total /100								

Physics
Section II

80 marks
Attempt Questions 21 – 34
Allow about 2 hours 25 minutes for this section

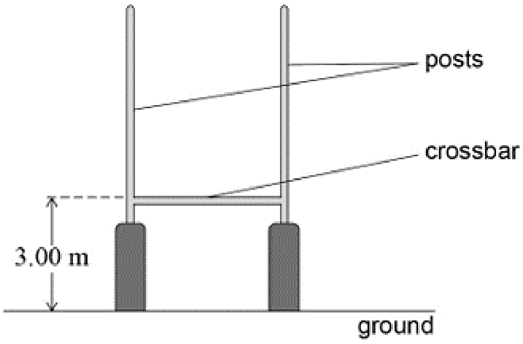
Instructions

- Write your student number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations
- Extra writing paper is available, please raise your hand to request more paper. If you use extra paper, clearly indicate your student number and which question you are answering.

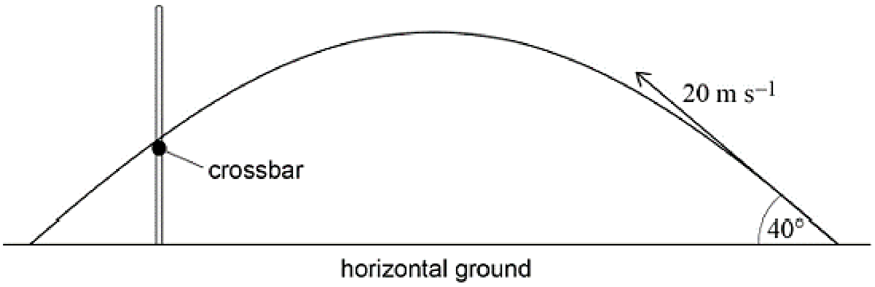
Please turn over

Question 21 (5 marks)

The diagram below shows the H-shaped posts used in a game of rugby.



The path of a ball that is kicked and just passes over the crossbar is shown below.



The initial velocity of the ball is 20.0 ms^{-1} at an angle of 40.0° to the ground.
The top of the crossbar is 3.00 m above the horizontal ground.
Ignore the effect of air resistance and treat the ball as a simple projectile.

(a) Determine the minimum velocity of the ball in flight. **1**

Marking Criteria	Marks
• Correct calculation for the horizontal component of the initial velocity	1

Minimum velocity = horizontal component of the initial velocity at maximum height.

$$v_{min} = v\cos 40° = 15.3\ \text{ms}^{-1}$$

(b) The ball just passes over the cross bar at a time t after it is kicked.
Find t. **2**

Marking Criteria	Marks
• Correct use of kinematic equation(s) AND • Correct calculation for the time taken to reach the crossbar	2
• As above but with an error	2

Find t when $s = 3$.

$$v^2 = u^2 + 2as$$
$$v^2 = (20\sin 40°)^2 + 2(-9.8)(3)$$
$$v = -10.32$$

$$v = u + at$$
$$t = \frac{v - u}{a}$$
$$t = 2.36 \text{ s}$$

OR

$$s_y = u_y t + \frac{1}{2} a_y t^2$$
$$3 = 20 \sin 30\, t + \frac{1}{2} 9.8 t^2$$

Using quadratic equation formula:
t = 0.2589 s or 2.36 s
Since the ball goes further away when crossing the bar so the later time of 2.36 s is correct.

(c) Another attempt is made to kick the ball over the crossbar. It was kicked at the same angle with the same initial velocity as the first attempt.
This kick is made from a horizontal distance of 38 m from the posts.

Determine whether the ball can pass over the crossbar. Show working. **2**

Marking Criteria	Marks
• Correct use of equation AND • States that the ball cannot pass over the crossbar	**2**
• As above but with an error	**1**

$s = vt = (20 \cos 40°)\,(2.36) = 36.3$ m
Since the ball was kicked further away than the original distance to the post, the ball won't pass over the cross bar.

OR

$$s_x = u_x t$$
$$38 = (20 \cos 40°)\,(t)$$
$$t = 2.48s$$
$$s_y = u_y t + \frac{1}{2} a_y t^2$$
$$s_y = (20 \sin 40° \times 2.48) + \left(\frac{1}{2} \times -9.8 \times 2.48^2\right)$$
$$s_y = 1.7m$$

1.7 m is lower than 3 m so it won't pass over the ball.

Question 22 (8 marks)

The Global Positioning System (GPS) uses satellites to support navigation on Earth.

One GPS satellite is in a circular orbit at a height h above the surface of the Earth. The Earth has mass M and radius R.

(a) Use $\omega = \frac{2\pi}{T}$ to show that the angular speed, ω, of the satellite is given by:

$$\omega = \sqrt{\frac{GM}{(R+h)^3}}$$

2

Marking Criteria	Marks
• Correct use of two F equations AND • Derivation of the equation given in the question OR • Correct use of the Kepler's third law equation AND • Derivation of the equation given in the question	**2**
• Insufficient working out OR • As above but with an error	**1**

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

$$\frac{GMm}{(R+h)^2} = \frac{mv^2}{(R+h)}$$

$$v^2 = \frac{GM}{(R+h)}$$

Since $v = \frac{2\pi r}{T}$ and $\omega = \frac{2\pi}{T}$, $\therefore v = r\omega$.

$$[(R+h)\omega]^2 = \frac{GM}{(R+h)}$$

$$\omega^2 = \frac{GM}{(R+h)^3}$$

$$\omega = \sqrt{\frac{GM}{(R+h)^3}}$$

OR

Using Kepler's third law

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

$$\frac{(r+h)^3}{T^2} = \frac{GM}{4\pi^2}$$

$$\frac{4\pi^2}{T^2} = \frac{GM}{(r+h)^3}$$

$$\omega = \frac{2\pi}{T} = \sqrt{\frac{GM}{(r+h)^3}}$$

(b) Calculate the orbital period of the satellite when h equals 2.02×10^7 m. **2**

Marking Criteria	Marks
• Correct substitution of values into the equation given in (a) AND • Correct calculation of T	2
• As above but with an error	1

$$\omega = \sqrt{\frac{GM}{(R+h)^3}} = \sqrt{\frac{(6.67 \times 10^{-11})(5.97 \times 10^{24})}{(2.02 \times 10^7 + 6.37 \times 10^6)^3}} = 1.46 \times 10^{-4}\ \text{rads}^{-1}$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{1.45 \times 10^{-4}} = 4.31 \times 10^4\ \text{s}$$

(c) The satellite has a mass of 1630 kg.
Calculate the gravitational potential energy of the satellite when in the orbit in part **(b)**. **2**

Marking Criteria	Marks
• Correct substitution of values into the equation given in (a) AND • Correct calculation of U	2
• As above but with an error	1

$$U = -\frac{GMm}{r} = -\frac{(6.67 \times 10^{-11})(5.97 \times 10^{24})(1630)}{2.66 \times 10^7} = -2.44 \times 10^{10}\ \text{J}$$

(d) A different satellite is in a higher circular orbit.
Explain how the linear speed of this satellite compares with the linear speed of the satellite in part **(a)**. **2**

Marking Criteria	Marks
• Correct derivation of relationship between r and v AND • Use of the correct equation for derivation	2
• Insufficient reasoning OR • As above but with an error	1

The centripetal force is provided by the gravitational force so equating these:

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

Get an equation for v, $v = \sqrt{\frac{GM}{r}}$.

In a higher orbit, the linear speed is smaller since, $v = \sqrt{\frac{GM}{r}}$. As shown by this equation, v decreases as r increases in value.

Question 23 (6 marks)

A 1300 kg car makes a turn on a circular bend of road at a speed of 80 km/h. The bend is not banked and has a radius of 40 m.

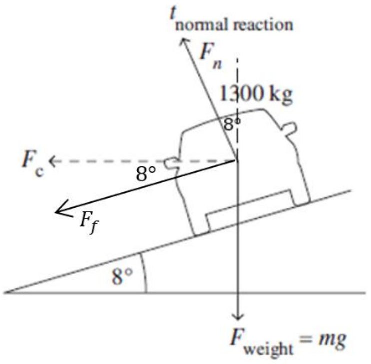
(a) What is the magnitude of the centripetal force required for the car to make this turn? **2**

Marking Criteria	Marks
• Correct substitution of values into the equation for F_c AND • Correct calculation of F_c	2
• As above but with an error	1

$$F_c = \frac{mv^2}{r} = \frac{1300\left(\frac{80}{3.6}\right)^2}{40} = 16049 \text{ N}$$

(b) The car is travelling at the maximum velocity without moving up or down the banked road. By assuming that the force calculated in **(a)** is the maximum frictional force on the wheels by the road, calculate the magnitude of the centripetal force exerted by the road on the car if the bend were banked at an angle of 8°. **4**
Support your answer with a diagram that identifies the relevant forces and vector components.

Marking Criteria	Marks
• Correct diagram showing three forces, F_g, F_N AND F_f • Correct calculation of F_N using F_g • Correct substitution of values into the equation AND • Correct formulation of F_c including the $components\ of$ F_N AND F_f	4
• As above but with an error	1



$$F_N \cos\theta = mg + F_f \sin\theta$$

$$F_N = \frac{mg + F_f \sin\theta}{\cos\theta}$$
$$= \frac{(1300)(9.8) + (16049)(\sin 8°)}{\cos 8°}$$
$$= 15121 \text{ N}$$

$$F_C = F_f \cos\theta + F_N \sin\theta$$
$$= (16049)(\cos 8°) + (15121)(\sin 8°)$$
$$= 17998 \text{ N}$$

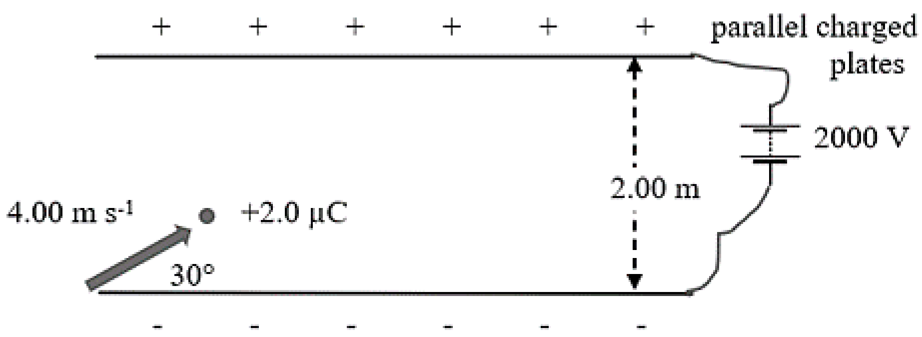
If no F_f, included then -1.

Note: When a car starts the motion, the frictional force will act up the track. As the car speed up, this fractional force decreases and eventually becomes zero when the car reaches the design speed. If the car continues to accelerate, the frictional force will now act downwards because the car will be moving up the track. However, for this question, we can't assume that the car is going at the design speed. When it goes higher than the design speed, the friction will act down the track, causing the car to go inwards helping the centripetal force.

https://www.geogebra.org/m/hpnfxv3b
Click the link above to see which way the frictional force acts at low and high velocities around a banked track. Tick the boxes to show frictional force on the diagram.

Question 24 (6 marks)

A small particle with mass 5.0 mg and a charge of +2.0 μC is shot at an angle of 30° and initial speed 4.00 ms^{-1} into a large gravity-free region between two parallel charged plates 2.0 m apart, as shown below.



(a) Find the acceleration of the charged particle within the gravity-free region. **3**

Marking Criteria	Marks
• Correct steps taken with correct working to obtain correct answer.	3
• As above but with an error	2
• A correct step provided	1

$$F = qE$$

$$F = \frac{qV}{d} \text{ and } F = ma,$$

$$ma = \frac{qV}{d}$$

$$a = \frac{qV}{md}$$

$$= \frac{(2.0 \times 10^{-6})(2000)}{(5.0 \times 10^{-6})(2.00)}$$

$$a = 4.0 \times 10^2 \text{ ms}^{-2} \text{ downwards towards the negative plate}$$

(b) How far along from its launch position will the charged particle hit the negative plate? **3**

Marking Criteria	Marks
• Correct method used to find correct answer (carry-over error OK)	3
• Correct method attempted with error made	2
• A correct step completed towards obtaining an answer	1

$u_y = u\sin\theta$
$u_y = 4.00\sin30°$
$= 2.00 \text{ ms}^{-1}$

$u_x = u\cos\theta$
$u_x = 4.00\cos30°$
$= 3.46 \text{ ms}^{-1}$

Use: $v = u + at$
$-2.00 = 2.00 + (-4.0 \times 10^2 t)$
$400t = 4$
$t = 0.01 \text{ s}$

So: $\Delta x = u_x t$
$= 3.46 \times 0.01$
$= 3.46 \times 10^{-2} \text{ m}$

OR

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

Question 25 (5 marks)

Rutherford's atomic model placed all the positive charge and most of the mass of an atom in the nucleus. It could not account for the existence of isotopes, where atoms of the same element differ in mass.

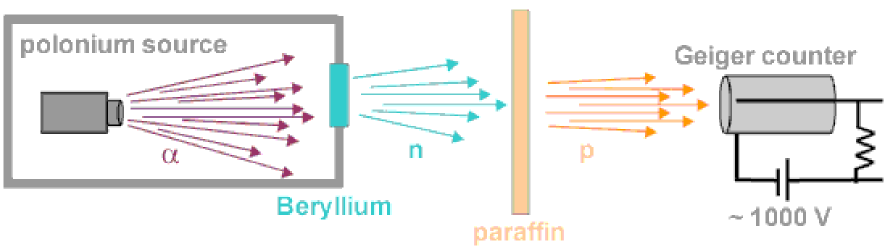
Outline the way in which the discovery of the particle responsible for this variation in mass was made, and explain why the discovery came so much later.

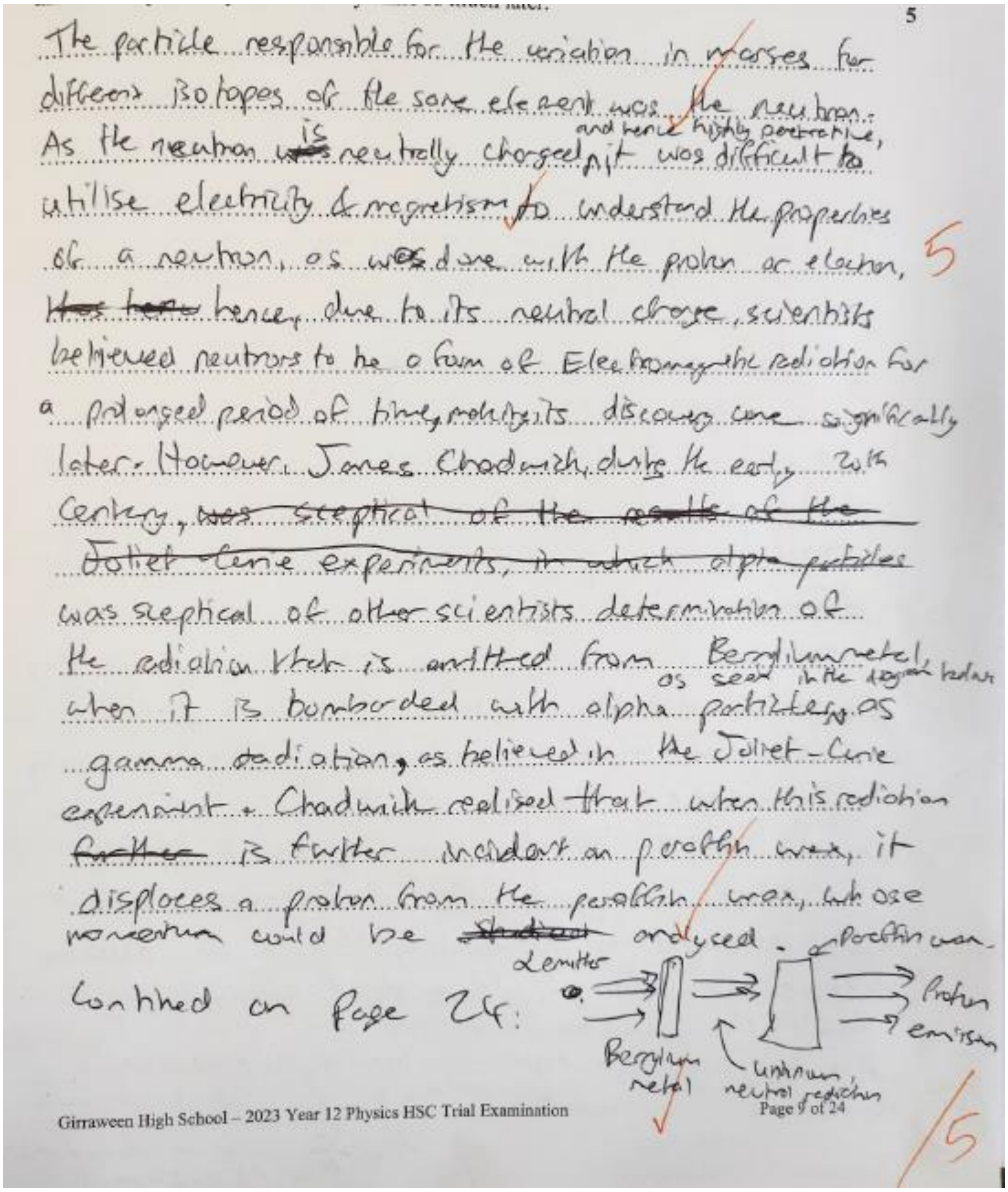
Marking Criteria	Marks
• The experimental set up/method clearly explained using Law of conservation of energy and momentum. • The discovery of the neutron is described clearly in a logical and sequential manner • The neutron is identified as the particle responsible for the existence of isotopes • The nature of the neutron, and how this makes it harder to detect, is clearly linked to why it was discovered later	5
• The discovery of the neutron is described clearly • The neutron is identified as the particle responsible for the existence of isotopes • The nature of the neutron, and how this makes it harder to detect, is linked to why it was discovered later	4
• The discovery of the neutron is outlined • The neutron is identified as the particle responsible for the existence of isotopes	2-3
• The neutron is identified as the particle responsible for the existence of isotopes	1

The neutron, a neutral particle with a mass nearly equal that of the proton, was more difficult to discover because of its weak interaction with matter due to its neutral charge. This resulted in it being discovered much later, after Rutherford had discovered the nucleus but not being able to explain the existence of isotopes.

James Chadwick discovered the neutron by using a source of alpha particles aimed at a beryllium block. A sheet of paraffin wax placed behind the beryllium was observed to emit protons as these can be detected by a Geiger counter (whereas neutrons cannot). By using the conservation of momentum, the particles emitted by the source, and the protons detected by Geiger counter were found to have the similar momentum, however the particles before paraffin were neutral in charge whereas the ones emitted by the paraffin were found to be positively charged.

This investigation confirmed the existence of the neutron.




5

The particle responsible for the variation in masses for different isotopes of the same element was the neutron. As the neutron ~~was~~ is neutrally charged and hence highly penetrative, it was difficult to utilise electricity & magnetism to understand the properties of a neutron, as was done with the proton or electron, ~~this term~~ hence, due to its neutral charge, scientists believed neutrons to be a form of Electromagnetic radiation for a prolonged period of time, making its discovery come significantly later. However, James Chadwick, during the early 20th Century, ~~was sceptical of the results of the Joliet-Curie experiments, in which alpha particles~~ was sceptical of other scientists determination of the radiation that is emitted from Beryllium metal, as seen in the diagram below when it is bombarded with alpha particles, as gamma radiation, as believed in the Joliet-Curie experiment. Chadwick realised that when this radiation ~~further~~ is further incident on paraffin wax, it displaces a proton from the paraffin wax, whose momentum could be ~~studied~~ analysed.

Continued on page 24.

5

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Question 26 (7 marks)

(a) Using an example of a proton moving at 500 kms^{-1}, show that its wavelength is too short to detect using present-day technology. **3**

Marking Criteria	Marks
• Use of correct equation (de Broglie's matter wave equation) • Correct wavelength calculated • Correct unit for λ	3
• Wavelength calculation made with an error • Shortness of wavelength identified	2
• Attempt at wavelength calculation evident	1

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

$$\lambda = \frac{(6.626\times10^{-34})}{(1.673\times10^{-27})(500\times10^{3})}$$

$$\lambda = 7.9 \times 10^{-13}\ \text{m}$$

The wavelength is much smaller than the diameter of an atom and would not be detectable using conventional methods.

Marker's comment:

- Penalty for not writing the unit for the λ calculated
- Incorrect calculation of λ resulting detectable size of λ (-1 mark)

(b) Outline the experimental evidence that led to the development of the formula used to calculate the wavelength of de Broglie's matter waves. **4**

Marking Criteria	Marks
• Correct identification and description of the experiment • Relevant formula is referred to and explained in terms of wave-particle duality • Response is clear, logical and concise	**4**
• Response includes a clear outline of some relevant evidence/observation • Relevant formula is identified	**3**
• Some relevant evidence/observation included • Formula is identified	**2**
• Some relevant evidence/observation included	**1**

As well as being able to give an explanation for Bohr's 1st postulate that electrons can exist in certain "stationary states" without emitting energy and his 3rd postulate that electrons' angular momentum is quantised, de Broglie's matter wave hypothesis was based on observations made by Davisson and Germer's investigation into the diffraction of electrons using a nickel crystal, a phenomenon only possible if the electrons had a wave nature.

Further, electrons used in a double-slit experiment resulted in a diffraction pattern being observed. Measurements taken from these observations confirmed de Broglie's formula that $\lambda = \frac{h}{mv}$, i.e. the wavelength of a particle is Planck's constant div ided by the momentum of the particle. Only particles with very small momentum, such as electrons which have a very small mass, would exhibit detectable wavelengths.

Response could include:
Arthur Compton's observation in an experiment to determine the λ of X-ray: the λ of X-ray was measured to slightly increase caused by electron-recoil which means some of the photon's energy was transferred to electrons, led to de Broglie's investigation of wave-particle duality.

Marker's comment:

- Not mentioning the electrons in slit experiment produced interference pattern similar to that of light (-1 mark)

Question 27 (3 marks)

A technique used to turn pure silicon-28 into a type of material used in semiconductors is to bombard the pure silicon-28 with neutrons from a nuclear reactor.

Using appropriate equations, show how the capture of a neutron by a silicon-28 nucleus can result in the transmutation of silicon nuclei into phosphorous by beta decay.

Marking Criteria	Marks
• All required equations are shown correctly in order	3
• Most required equations are shown	2
• A relevant attempt at a nuclear equation is evident	1

Neutron capture by a silicon-28 nucleus: $^{28}_{14}Si + ^{1}_{0}n \rightarrow ^{29}_{14}Si$

Beta decay of Si-29 to phosphorous: $^{29}_{14}Si \rightarrow ^{29}_{15}P + ^{0}_{-1}e$

No penalty for combining the two equations above in one line:

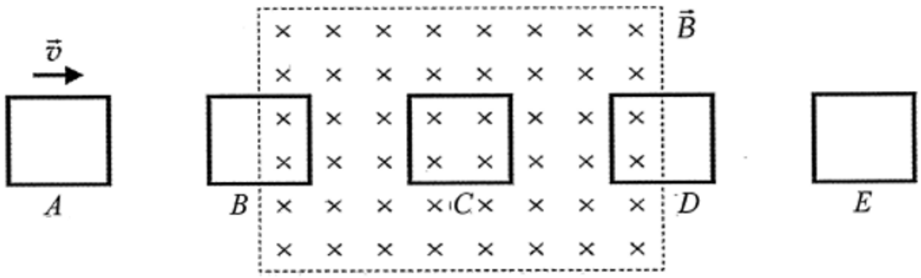
$$^{28}_{14}Si + ^{1}_{0}n \rightarrow ^{29}_{14}Si \rightarrow ^{29}_{15}P + ^{0}_{-1}e$$

Marker's comment:

- Incorrect spots for the mass and the atomic number in the equation (−1 mark)
- Not showing the formation of Si-29 (−1 mark)
- Incorrect symbol for $\bar{v}$ (−1 mark)

Question 28 (5 marks)

A square coil of wire of 10 turns with a cross-sectional area of 1.6×10^{-3} m^2 passes at a constant speed into, through and out of a magnetic field of magnitude 2.0×10^{-2} T. The coil takes 0.40 s to go from position A to position B. The distance between each coil position equals the length of coil side.



(a) Calculate the emf induced in this coil as it enters the field. **2**

Marking Criteria	Marks
• Calculates induced emf correctly	2
• Working out contains one error	1

The coil was moved 0.08 m in 0.4 s.
For the coil to move fully into the magnetic field, it will need to move 0.04 m, so it will take 0.2 s. This is Δt.

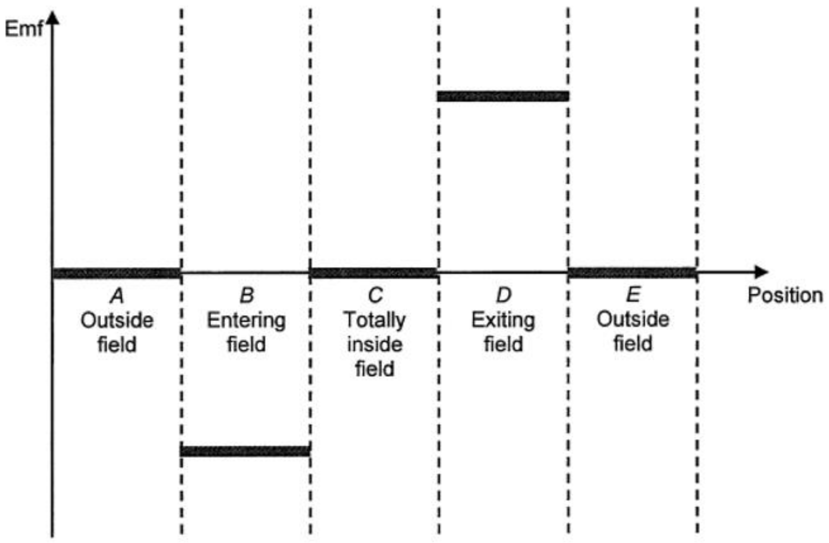
$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = (10)\frac{(2.0\times10^{-2})(1.6\times10^{-3})}{(0.2)} = 1.6\times10^{-3}\ \text{V}$$

Marker's comment:

- Many used $\Delta t = 0.4$ s (received 1 mark)
- Some divided the area by 2 as in the diagram, only half the coil has entered the magnetic field. If so, then 2 cm has entered the field, so $\Delta t = 0.1$ s (received 1 mark)

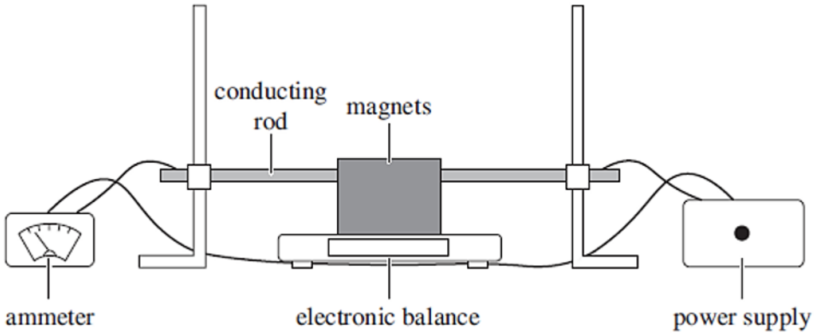
(b) Complete the diagram below to show the magnitude and direction of the induced emf in the coil as it moves through the 5 labelled positions. **3**
Do not include values on the axes.

Marking Criteria	Marks
• Provides graph with constant emf at B in the negative region and D in the positive but they are equally distant to the horizontal axis AND • Emf is zero at A, C and E	3
• Same as above but the Emf at B is in the positive region and that of D is in the negative OR • Emf is zero at A, C and E AND • Provides graph with sloping lines/parabolic curves for Emf at B and D in opposite directions	2
• Emf is zero at A, C and E OR • Provides graph with sloping lines for Emf at B and D in opposite directions	1



Question 29 (7 marks)

A group of students were conducting an experiment and set up a current balance.



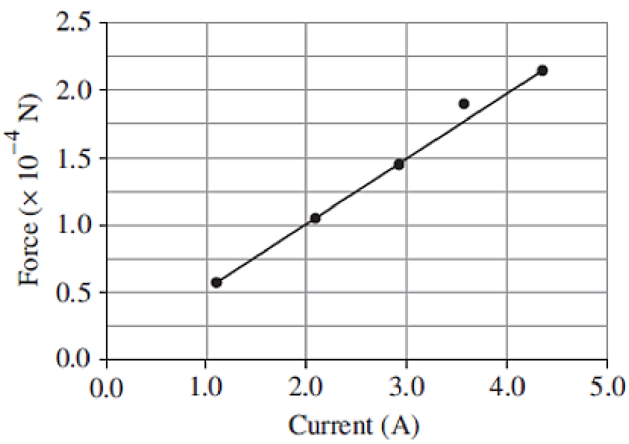
The conducting rod was positioned between two magnets, perpendicular to the magnetic field. 60 cm of the conducting rod is within the magnetic field. The balance was initially set at zero. When the students changed the current flowing though the apparatus, the readings on the balance changed due to the force acting up or down.

The students steadily increased the current, which was measured using the ammeter, and recorded the mass displayed on the balance. They then used the measured current and mass to calculate the force acting on the magnets. Their results are shown in the table.

Current (A)	*Mass (kg)*	*Force (N)*
1.1	-0.55×10^{-3}	5.61×10^{-5}
2.1	-1.02×10^{-3}	1.04×10^{-4}
2.9	-1.43×10^{-3}	1.46×10^{-4}
3.6	-1.86×10^{-3}	1.90×10^{-4}
4.3	-2.15×10^{-3}	2.19×10^{-4}

(a) Plot a graph of force versus current. Include a line-of-best-fit. **3**

Marking Criteria	Marks
• Identifies the y-axis as force and the x-axis as current. AND • Labels the axes, including correct units AND • Plots the data AND • Draws a line of best fit	**3**
• Missing any one or two above	**2 – 1**



(b) Identify the relationship between force and current shown in the graph from part **(a)** and state TWO assumptions that must be made for this relationship to exist. **2**

Marking Criteria	Marks
• Identifies the relationship shown in the graph AND • States two assumptions	**2**
• Missing any one of the two above	**1**

The graph shows that as current increases, there is a proportional increase in the upwards net force acting on the system.
Assumptions made were that the magnetic field and current are kept constant.
(The length of wire within magnetic field is assumed to be constant also accepted.)

Marker's comment:

- No mark for stating that as I increases, F increase
- θ always stays at 90° as it is mentioned in the question

(c) Calculate the gradient of the graph from part (a) and use the gradient to determine the strength of the magnetic field.
In your response, include any relevant equation(s). **2**

$$gradient = \frac{rise}{run} = \frac{(1.5 \times 10^{-4}) - (1.0 \times 10^{-4})}{3.0 - 2.0} = 0.5 \times 10^{-4}$$

$$F = lIB \sin\theta$$

$$\therefore \frac{F}{I} = gradient = lB \sin\theta$$

$$\therefore B = \frac{\frac{F}{I}}{l \sin\theta} = \frac{gradient}{l \sin\theta} = \frac{0.5 \times 10^{-4}}{0.60} = 8.3 \times 10^{-5}\ \text{T}$$

Question 30 (4 marks)

The Standard Model identifies bosons as responsible for all the force interactions we observe.

Outline the role of bosons in our universe.

Marking Criteria	Marks
• Provides information about the THREE fundamental forces, the role of bosons and their corresponding bosons AND the predicted graviton	**4**
• Provides information about the THREE fundamental forces the role of bosons and their corresponding bosons without mentioning about graviton OR • Provides correct information about all of the four fundamental forces without identifying 1 or 2 of the four bosons	**3**
• Provides information about the TWO fundamental forces the role of bosons and their corresponding bosons	**2**
• Identifies bosons as force-carrier particles involved in energy exchange AND • Naming the four bosons	**1**

There are four fundamental forces at work in the universe: the strong force, the weak force, the electromagnetic force, and the gravitational force. Apart from the gravitational force, the forces result from the exchange of force-carrier particles called bosons, sub-atomic particles having an integer spin quantum number.

Particles of matter transfer discrete amounts of energy by exchanging bosons with each other. Each fundamental force has its own corresponding boson – the strong force is carries by the 'gluon', the electromagnetic force is carried by the 'photon', and the 'W and Z bosons' are responsible for the weak force. Although not yet found, the 'graviton' should be the corresponding force-carrying particle of gravity.
Response could include:

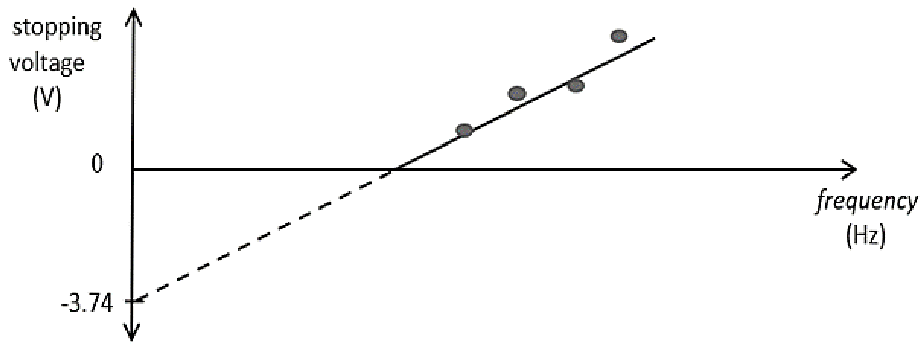
- Types of bosons: gauge/vector bosons & scalar bosons
- Scalar boson (Higg's boson) is the force field that gives the mass

Bosons are known as the force carriers. They can be either gauge bosons or scalar bosons. Gauge-bosons, characterised by their integer (1, 2, 3 ...) ~~@~~ spin, are responsible for the 4 fundamental forces. The photon is responsible for electromagnetic force. ~~the~~ The gluon ~~is responsible~~ gluon is responsible for strong nuclear force, the W+Z bosons are responsible for weak nuclear force and finally, the theoretical 'graviton' is responsible for gravitational forces. These 4 are responsible for allowing the interactions that make up the world. For example the balance of electrostatic and strong force, due to proton and gluons is what keep the nuclei stable. Scalar Bosons, on the other hand, ~~are~~ ~~responsible~~ for ~~the~~ characterised by their 0 spin, are made up currently of only the higgs. The higgs boson is what provides objects with mass. Hence ~~B~~ the reason mass-carrying objects ~~interact~~ can interact is since the higgs boson provides its mass.

Excellent!

Question 31 (7 marks)

Students performed an investigation to observe the photoelectric effect using a zinc cathode. The results were plotted on a set of axes as shown below and extrapolated to the y-axis where the line of best fit intersects at -3.74 V.



(a) Calculate the threshold frequency of the zinc cathode. **2**

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

$K_{max} = 0$ J when $f = f_0$.

$$f_0 = \frac{\emptyset}{h} = \frac{(3.74)(1.602 \times 10^{-19})}{(6.626 \times 10^{-34})} = 9.04 \times 10^{14} \text{ Hz}$$

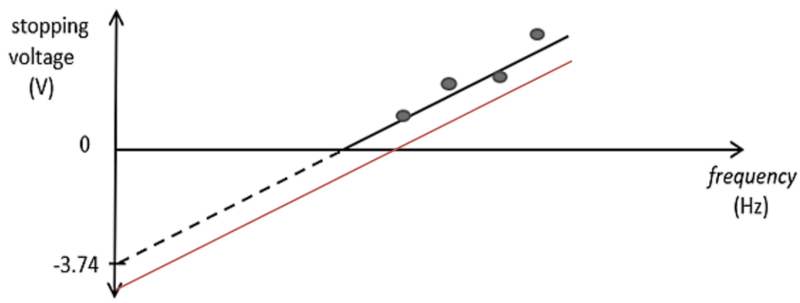
Marker's comment:

- Not converting the work function from V to J (-1 mark)

(b) The investigation is repeated after replacing the zinc cathode by a different metal known to have a greater work function. The new results were plotted in the same manner.
Draw a line of best fit on the graph above to show how the results will vary.

2

Marking Criteria	Marks
• Line drawn is below the original and is parallel to it AND • Line extends to the vertical axis to show that the y-int is lower than the original	2
• Any one of above	1



Marker's comment:

- Line is drawn above the original and is parallel (1 mark)
- Line is not extended to the y-axis (1 mark)

(c) In the investigation, the students noticed that the photoelectrons did not all have the same velocities despite all receiving the same frequency of incident light.
Account for this observation. **3**

Marking Criteria	Marks
• States that the light of the same frequency consists of photons with equal energy which is transferred to the electrons on the metal ($E = hf$) AND • Explains the difference in the amount of energy required to emit electrons from different energy levels of metal atoms OR from different depth of the metal AND • States the source of kinetic energy of photoelectrons	**3**
• Any two of above	**2**
• Any one of above	**1**

As the light of the same frequency consist of photons with equal energy, according to $E = hf$, as the light is incident on the metal surface at cathode, equal amount of energy is transferred from photons to electrons.

Photoelectrons emitted from a cathode can come from different energy levels of the metal atoms. The electrons emitted from lower energy levels will have lower kinetic energy and travel at lower velocities as they require more energy to be ejected from the metal atoms. The kinetic energy of photoelectrons is the remaining energy from the energy transferred from photons and the energy needed to be ejected from the metal atom. Likewise, the electrons emitted from higher energy levels will have higher kinetic energy and travel at higher velocities as they require less energy to be ejected from the metal atoms.

Additionally, electrons ejected from the atoms from deeper layers of the cathode will need to travel through more layers of the material before reaching the surface and they will lose some of their energy due to collisions with other electrons or atoms along the way. Therefore, they will have a lower initial kinetic energy and hence a lower ejection velocity compared to electrons emitted from shallower layers.

Marker's comment:

- Not well answered. General lack of understanding of photoelectric effect
- Common misunderstanding
  1. Photoelectrons have different masses
  2. Photoelectrons have various work functions
  3. Energy given by photons are converted to other types such as heat

As the different metal of a higher work function was used, a higher threshold frequency is required. Since both metal experience the same frequency of incident light, the threshold frequency is not met. In light the frequency (the energy in one photon) of an electron governs the kinetic energy of the electrons. ~~the~~ 3
one photon transfers all its quantised energy ($E=hf$) to one electron. ~~the~~ However, before the photons give its energy to the electrons, it must overcome the work function of the metal cathode. ~~the~~ Since the work function is higher, more energy is needed to overcome this, hence less ~~energy~~ ~~frequency~~ kinetic energy is able to be transfered to

End of Question 31

Question 32 is on the following page

the photoelectrons. ~~i~~ Not all photo photoelectrons
∴ The zinc metal photoelectrons would have higher kinetic energy and hence higher velocity ($K = \frac{1}{2}mv^2$) as its threshold ~~f~~frequency is less than of the different metal.

Question 32 (3 marks)

A pair of detectors is set up to measure the intensity of a parallel beam of unstable particles. In the reference frame of the laboratory, the detectors are separated by a distance of 45 m. The speed of the particles in the beam is $0.97c$.

The intensity of the beam at the second detector is 12.5% of the intensity at the first detector.

Calculate the half-life of the particles in the reference frame in which they are at rest.

In the reference frame in which the particles are at rest,

distance between detectors = $45\sqrt{1-\frac{(0.97c)^2}{c^2}} = 10.9 \text{ m}$

time taken between detectors = $\frac{10.9}{0.97c} = 3.8 \times 10^{-8} \text{ s}$

Since only 12.5% of the intensity at the first detector was detected at the second detector, $3 \times$ half-life have elapsed.

$\therefore$ Half-life $= \frac{3.8\times10^{-8}}{3} = 1.3 \times 10^{-8} \text{ s} = 13 \text{ ns}$

Marker's comment:

- Common incorrect calculation that received 2 marks:

$$t = \frac{d}{s} = \frac{45}{0.97c} = 1.55 \times 10^{-9} \text{ s}$$

$$t_{1/2} = \frac{t}{3} = \frac{1.55 \times 10^{-9}}{3} = 5.15 \times 10^{-8} \text{ s}$$

Where is the relativistic effect?

Question 33 (8 marks)

(a) In 1864, James Maxwell developed equations to describe the interaction of electric and magnetic fields and suggested that light was an electromagnetic wave.

Outline why his work was challenged by physicists of his day and explain the eventual solution in Einstein's Theory of Special Relativity. **6**

Marking Criteria	Marks
• Clearly outlines Maxwell's theory of EMR that it is composed of $\vec{E}$ and $\vec{B}$ propagating perpendicularly, hence no medium is required (**E_M**) • Describes that the speed of EMR determined by Maxwell matched the speed of light, which led to Maxwell to predict that light was a part of EMR (**E_C**) • Clearly states that this posed a problem as all waves and light were thought to need a medium to travel (**E_P**) • Brief description that Michelson-Morley experiment using an interferometer failed to prove the existence of aether (**A**) • States that Einstein's postulate that the speed of light is constant was his solution to reflect the existence of the aether (**P**) • States that in accordance to Einstein's postulate that the speed of light being an absolute, length and time are relative quantities on the motion of the observer (**R**) AND • Response is clear, logical and concise	**1 mark each**

James Maxwell had presented this theory on electromagnetism in the form of mathematical equations describing the interaction of electric and magnetic fields resulting in the propagation of the fields as an electromagnetic wave with a speed identical to the speed of light. He therefore reasoned that light was an electromagnetic wave.

The problem was that waves were thought to need a medium through which they moved. The medium for light waves was called the aether, although experiments to demonstrate the predicted effect of the aether on the motion of light had all been failures, including that done by Michelson and Morley. The experiment was thought to be a failure as it did not show any effect of the aether on the speed of light moving in perpendicular directions. As well, the role of aether could be shown to violate the Galileo's principle of relativity that all uniform motion could not be detected without an outside frame of reference.

Einstein's solution was to reflect the existence of the aether and he stated two postulates.
1. The speed of light in a vacuum is an absolute constant.
2. All inertial frames of references are equivalent, and the principle of relativity holds.

Einstein argues that as a consequence of the speed of light being an absolute, length and time are relative quantities depending on the motion of the observer.

(b) Describe one experimental evidence supporting Einstein's Theory of Special Relativity. **2**

Marking Criteria	Marks
• Describes an experimental measurement indicating time dilations or length contraction occurring	2
• Identifies an experiment	1

Rossi-Hall's muon experiment
Muons are unstable particles formed in Earth's atmosphere and travel at velocities near the speed of light towards Earth's surface. The majority of muons should decay before reaching the surface based on their extremely short half-life, but the number of muons detected at the Earth's surface showed that this was not happening. This is explained by the increase in their half-life time due to time dilation when measured by a stationary observer on Earth.

(Note: must mention that muons travel at relativistic speed)

Hafele-Keating atomic clocks experiment
They took four caesium-beam atomic clocks aboard commercial airliners. They flew twice around the world, first eastward, then westward, and compared the clocks against others that remained at the United States Naval Observatory. When reunited, the three sets of clocks were found to disagree with one another, and their differences were consistent with the predictions of special and general relativity.

Westward flown (against Earth's spin): time dilation (i.e. clock was ahead) +273 ns
Eastward flown (in Earth's spin): time contraction (i.e. clock was behind) −59 ns

Question 34 (6 marks)

A student has three discs: a Blu-ray disc, a DVD and a CD. The reflective coating from the discs is removed so that they act as diffraction gratings. The discs have different slit separation.

The student also has two laser pointers A and B that emit different colours of visible light.

The tables below show information about the discs and the laser pointers.

Disc	Slit separation (μm)
Blu-ray disc	0.32
DVD	0.74
CD	1.60

Laser pointer	Wavelength of light emitted (nm)
A	445
B	636

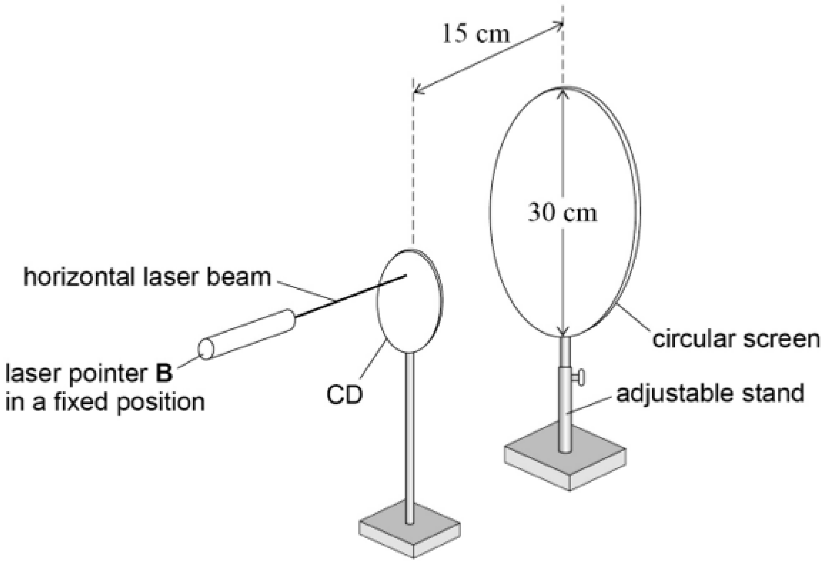
(a) Deduce the combination of disc and laser pointer that will produce the greatest possible number of interference maxima. **2**

Marking Criteria	Marks
• Identifies the correct combination of the disc and laser pointer AND • Deduces the reason	2
• Any one of above	1

Pointer A and CD

To achieve the maximum number of interference maxima θ needs to be the minimum.
At minimum θ, $\sin\theta$ is also at minimum.
Since $d\sin\theta = m\lambda$, $\sin\theta = \frac{m\lambda}{d}$.
Hence the greatest number of maximum is achieved when $\frac{\lambda}{d}$ is at minimum.
Thus, the combination of a shorter wavelength and a longer slit spacing is needed.

(b) The student uses the CD and laser pointer B as shown below. A diffraction pattern is produced vertically on the screen. Laser pointer B and the CD are in fixed positions.
The laser beam is horizontal and incident normally (i.e. at 90°) on the CD.
The height of the screen can be adjusted.



The screen has a diameter of 30 cm and is positioned behind the CD at a fixed horizontal distance of 15 cm.
The student plans to adjust the height of the screen until the greatest number of bright spots is observed, without changing the distance from the CD to the circular screen.

Determine the greatest number of bright spots that can be observed on the screen. **4**

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

For the 1st order maximum: $\theta = \sin^{-1}\left(\frac{636\times10^{-9}}{1.60\times10^{-6}}\right) = 23.4°$

The distance between $m = 0$ and $m = 1$ on the screen:
$\tan\theta = \frac{x_1}{L}$, $x_1 = (\tan 23.4°)(0.15) = 0.065\text{ m} = 6.5$ cm

For the 2nd order maximum: $\theta = \sin^{-1}\left(\frac{2\times(636\times10^{-9})}{1.60\times10^{-6}}\right) = 52.7°$

The distance between $m = 0$ and $m = 2$ on the screen:
$\tan\theta = \frac{x_2}{L}$, $x_1 = (\tan 52.7°)(0.15) = 0.197\text{ m} = 19.7$ cm

As $(x_1 + x_2) < 30$ cm, by adjusting the position of the screen, one of $m = 2$ can be shown.
Therefore, up to 4 bright spots can be observed on the screen.

Marker's comment:

- Bright spots are NOT equally spaced
- $\frac{dy}{L} = m\lambda$ ← this equation is only to be used for small θ
- Most common incorrect answer that received 2 marks:
  Finding m using $d\sin\theta = m\lambda$, with $\theta = 45°$.
  $m = 1.78$, ∴ 3 bright spots
- Finding m with $\theta = 45°$ (1 mark)
- Finding m with $\tan\theta = \frac{0.30}{0.15}$, $\theta = 63.43°$, $m = 2.25$, ∴ 3 bright spots (1 mark)

End of Section II

End of Examination