SYDNEY GRAMMAR SCHOOL

2020
TRIAL EXAMINATION
PHYSICS
Form VI

STRUCTURE OF PAPER

SECTION I

Multiple Choice 20 marks

Allow about 30 minutes for this section

SECTION II

Parts A-D 80 marks

Allow about 2 hours and 30 minutes for this section

EXAMINATION

DATE:	Thu 13th August 8.39 AM
DURATION:	3 hours (+5min reading)
MARKS:	100

CHECKLIST

Each boy should have the following:

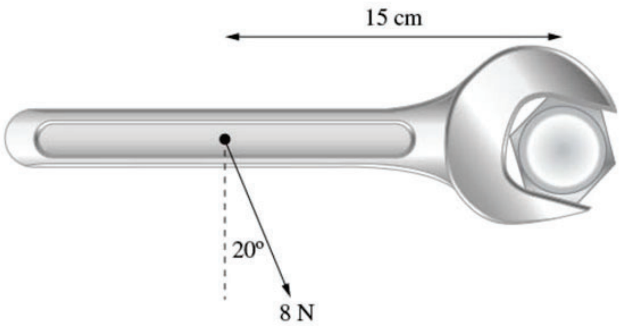
- Examination Paper (including)
  - Examination sections
  - Extra Writing sheets
  - Data/Formula sheets
  - Multiple-Choice Answer Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the examination in a neat bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should be clearly be marked **CONTINUED.** When the response is continued on extra writing paper it should clearly indicate the question number.
  - Each detachable part A-D of Section II has additional writing space.
  - Further additional writing paper is included at the end of the paper.
- There is a Data/Formula sheet included at the end of the paper.

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

1 A spanner is being used to tighten a bolt as shown.



The torque being applied to the bolt by the spanner is:

(A) 0.41 N m

(B) 1.1 N m

(C) 1.2 N m

(D) 120 N m

2 The mass of the Sun is 2.0×10^{30} kg and the distance between the Sun and the Earth is 1.5×10^{11} m. What is the gravitational force exerted by the Sun on the Earth?

(A) 3.6×10^{22} N

(B) 1.2×10^{28} N

(C) 5.3×10^{33} N

(D) 8.0×10^{43} N

3 Two planets orbit a distant star. Planet A orbits at distance r and has period T. Planet B orbits at distance $\frac{r}{4}$. What will be the period of Planet B?

(A) $\mathrm{T}/8$

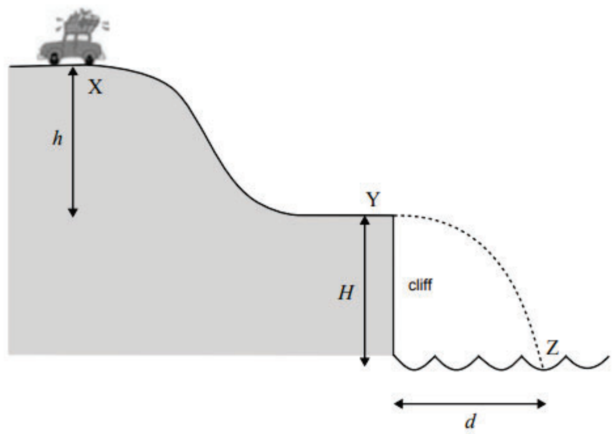
(B) $T/2$

(C) $2T$

(D) $8T$

Use the following information to answer questions 4 and 5

A car is stationary on top of a hill at X, h metres above the top of a cliff. The brakes are released and the car starts to roll down the hill to point Y, where it is projected horizontally off a cliff of height H, and lands at point Z, a distance d from the base of the cliff. Ignore friction and air resistance.



4 Which of the expressions below gives the speed of the car at point Y?

(A) $\sqrt{2gh}$

(B) $\sqrt{2gH}$

(C) $\sqrt{2g(h+H)}$

(D) $\sqrt{2g(H-h)}$

5 Which of the statements below is correct?

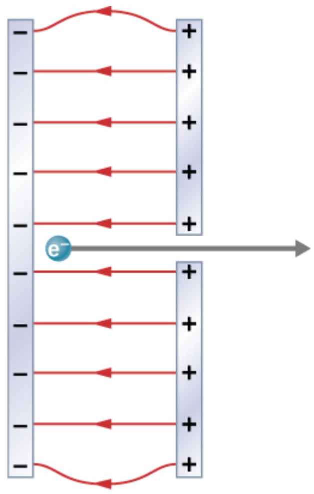
(A) The magnitude of the horizontal component of the velocity of the car at Z is less than the speed at Y.

(B) The magnitude of the horizontal component of the velocity of the car at Z is equal to the speed at Y.

(C) The magnitude of the horizontal component of the velocity of the car at Z is greater than the speed at Y.

(D) The magnitude of the horizontal component of the velocity of the car at Z depends on the height of the cliff.

6 An electron is accelerated from rest to a speed of 3.2×10^6 m s^{-1} between two parallel plates with a uniform electric field as shown.



What voltage is required between the two plates for this to occur?

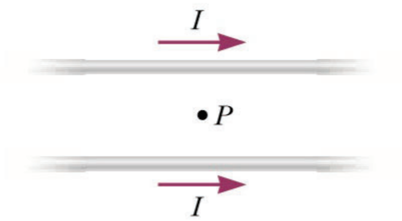
(A) 9.1×10^{-6} V

(B) 29 V

(C) 58 V

(D) 320 V

7 Two long parallel wires carry equal currents I in the same direction as shown below.



It is true to say that the magnetic field at P (midpoint between the wires) is:

(A) Zero.

(B) Directed out of the page.

(C) Directed into the page.

(D) Directed towards the right.

8 A charged particle is fired into a region of space where the electric field is zero. It moves in a straight line. Can you therefore conclude that the magnetic field is zero?

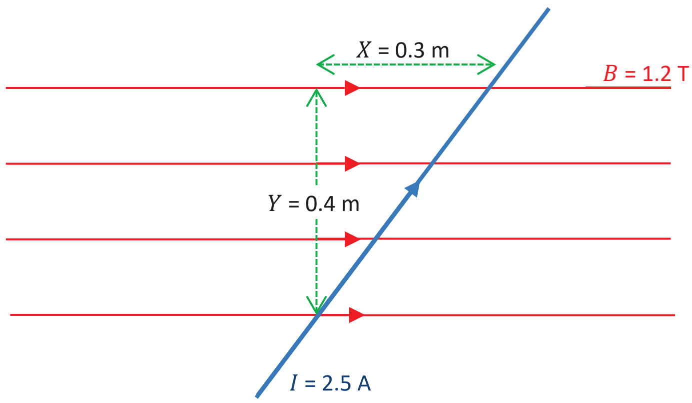
(A) Yes; you can.

(B) No; the field may be perpendicular to the particle's velocity.

(C) No; the field may be parallel to the particle's velocity.

(D) Yes; if the charge is positive.

9 A current carrying wire of $I = 2.5$ A is in a uniform magnetic field of strength $B = 1.2$ T for a horizontal distance of $X = 0.3$ m and a vertical distance of $Y = 0.4$ m as depicted below.



What is the magnitude of the force on the wire?

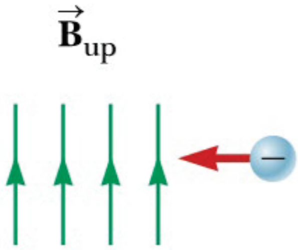
(A) 0.75 N

(B) 0.90 N

(C) 1.2 N

(D) 1.5 N

10 An electron enters a magnetic field as shown below. Determine the direction of the force on the electron.



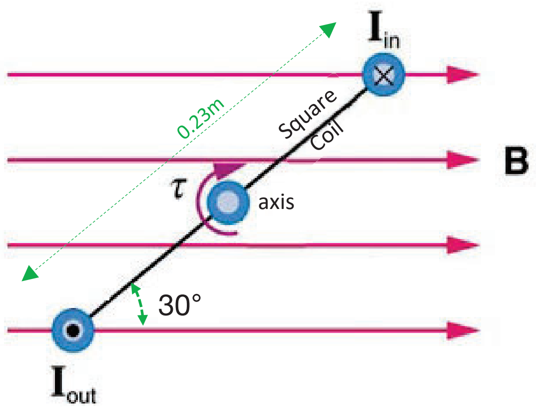
(A) Up the page

(B) Down the page

(C) Into the page

(D) Out of the page

11 The diagram below shows the coil of a DC motor at one part of its rotation.



The square coil consists of 8 turns of wire, and has dimensions 0.23 x 0.23 m. A current of I = 2.75 A flows through it. The external magnetic field is B = 1.50 T

Calculate the magnitude of the torque, τ, on the coil at the angle shown.

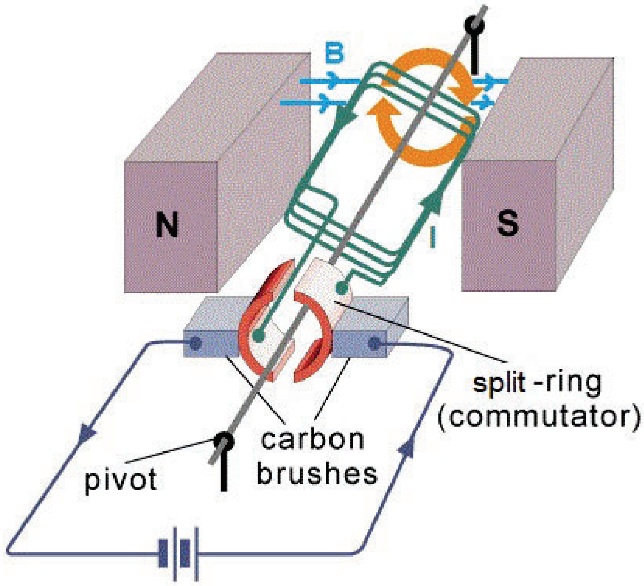
(A) 0.11 N m

(B) 0.87 N m

(C) 1.5 N m

(D) 1.7 N m

12 Identify the device shown in the diagram below:



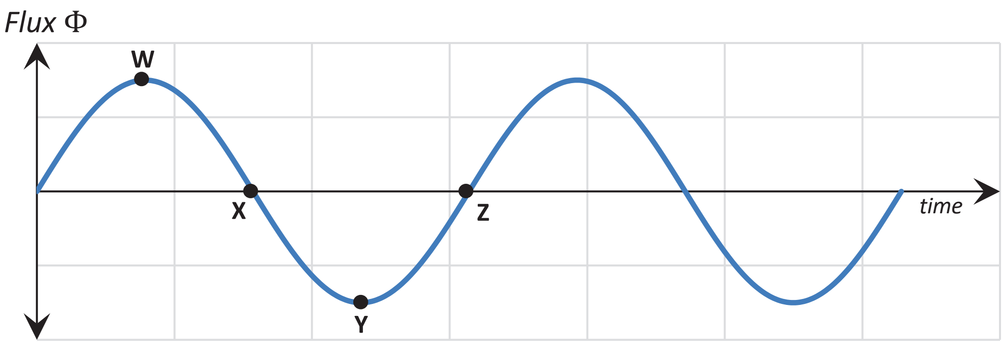
(A) AC Motor

(B) DC Motor

(C) AC Generator

(D) DC Generator

13 The diagram below shows the magnetic flux through the coil of an AC generator as it rotates:



At which point(s) in the rotation is the magnitude of the induced voltage greatest?

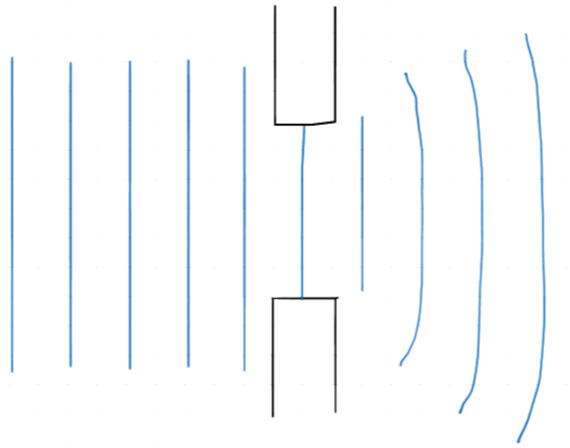
(A) W only

(B) X only

(C) W and Z

(D) X and Z

14 The diagram below shows the behaviour of a wave when it passes through a gap.



How would the wave pattern change if the size of the gap was narrowed?

(A) The angular spread of the waves would increase.

(B) The angular spread of the waves would decrease.

(C) The angular spread of the waves would increase, and the wavelength of the wave would decrease.

(D) The angular spread of the waves would decrease, and the wavelength would increase.

15 Stars A and B are main sequence stars with the same composition. Star A has 10 times more mass than Star B. Which of the following comparisons is correct?

	Star A		Star B	
(A)	Higher luminosity	Longer lifespan	Smaller radius	Higher Surface temperature
(B)	Higher luminosity	Shorter lifespan	Smaller radius	Lower Surface temperature
(C)	Lower luminosity	Shorter lifespan	Smaller radius	Lower Surface temperature
(D)	Lower luminosity	Longer lifespan	Larger radius	Higher Surface temperature

16 What is the momentum of a proton moving close to the speed of light at a velocity of 2.6×10^{8} m s^{-1}?

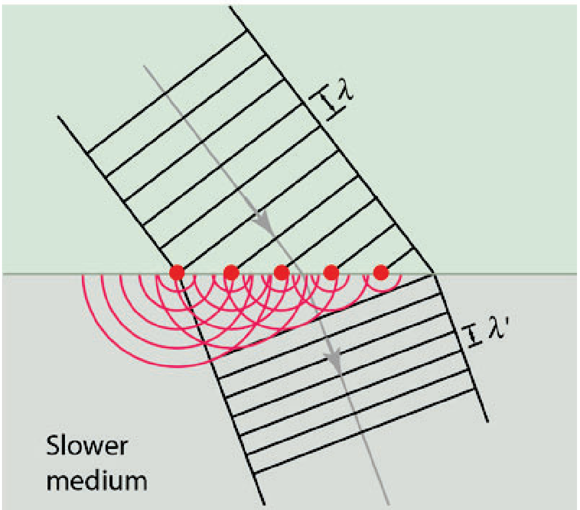
(A) 4.3×10^{-19} kg m s^{-1}

(B) 8.7×10^{-19} kg m s^{-1}

(C) 1.2×10^{-18} kg m s^{-1}

(D) 1.7×10^{-18} kg m s^{-1}

17 The diagram below shows an explanation for the refraction of light from air to glass using the concept of *wavelets*. In this explanation, the speed of light in glass must be slower than in air.



Identify the scientist responsible for proposing this model of light.

(A) James Clerk Maxwell

(B) Max Planck

(C) Isaac Newton

(D) Christian Huygens

18 Millikan measured the charge on an electron by balancing forces on charged oil drops. What were these forces?

(A) Gravitational and Magnetic

(B) Electric and Magnetic

(C) Gravitational and Electric

(D) Electric, Magnetic and Gravitational

19 In the Geiger-Marsden experiment, which is the most correct description of an observation they made?

(A) Most alpha particles were absorbed.

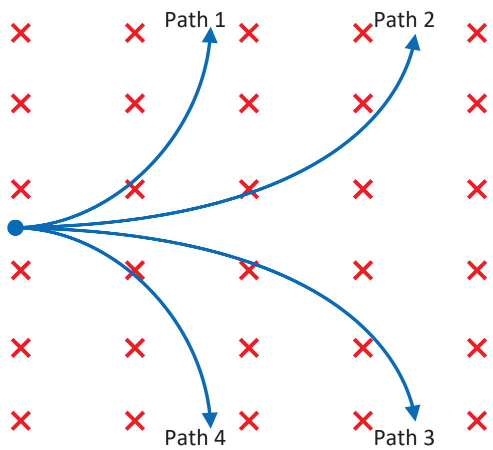
(B) Most alpha particles were reflected back.

(C) Most alpha particles were deflected by large angles.

(D) Most alpha particles were undeflected and passed straight through.

20 By analysing the motion of cathode rays in magnetic fields Thomson discovered the electron by determining that the charge/mass ratio for electrons was much greater than for a particle like a proton.

The diagram shows the possible paths of charged particles entering a magnetic field at the same velocity.



Identify which path would be the mostly likely for each particle.

	Proton	Electron
(A)	1	3
(B)	2	1
(C)	3	2
(D)	2	4

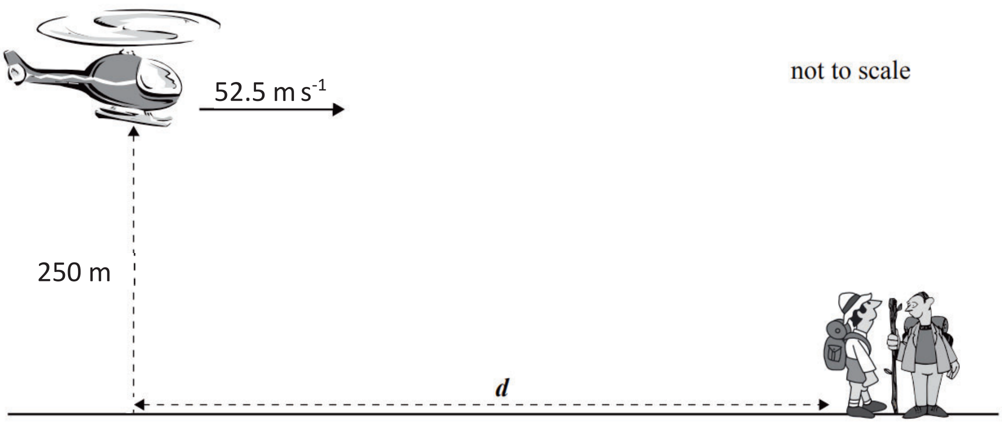
SECTION II: Part A (20 Marks)

CANDIDATE NUMBER							

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

Question 21 (4 marks) **Marks**

A helicopter is to drop a rescue pack to a group of hikers. The helicopter is flying at a horizontal speed of 52.5 m s^{-1} at a constant height of 250 m above the ground.

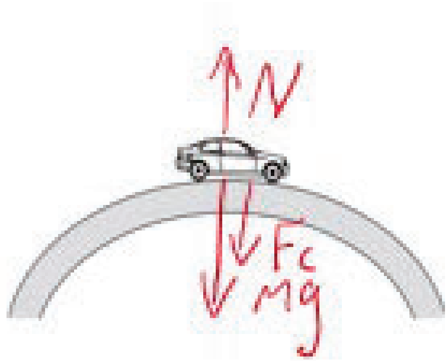


(a) For the rescue package to land beside the hikers, at what distance d from the hikers should the package be released from the plane? **2**

(b) What will be the speed of the package as it hits the ground? **2**

Question 22 (4 marks) **Marks**

A man of mass m was driving his car at a constant speed v over a hump-backed bridge that is circular in shape with radius r, as shown. His fancy new car has a feature in the driver's seat where it acts as a set of scales and lets him observe his weight in the dash screen.

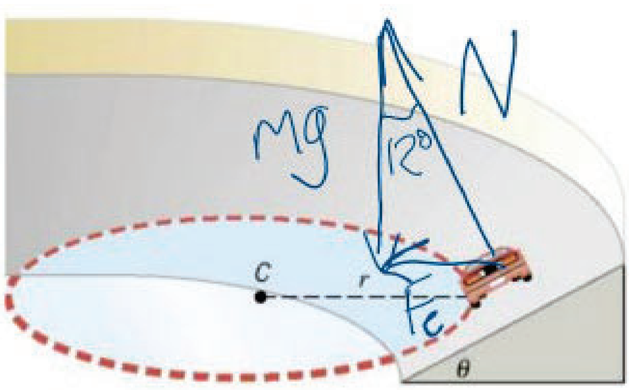


He noticed that the reading on the scales decreased as he passed over the top of the bridge. He claimed later to a friend that if he could have travelled fast enough, the scales would have registered zero. **4**

Assess this man's statement.

Question 23 (5 marks) Marks

A car of mass $m = 1100$ kg is travelling in a horizontal circular path with radius $r = 40$ m on a banked track at a speed of $v = 5\ \text{m s}^{-1}$, as shown below. The angle of the slope is $\theta = 12°$.



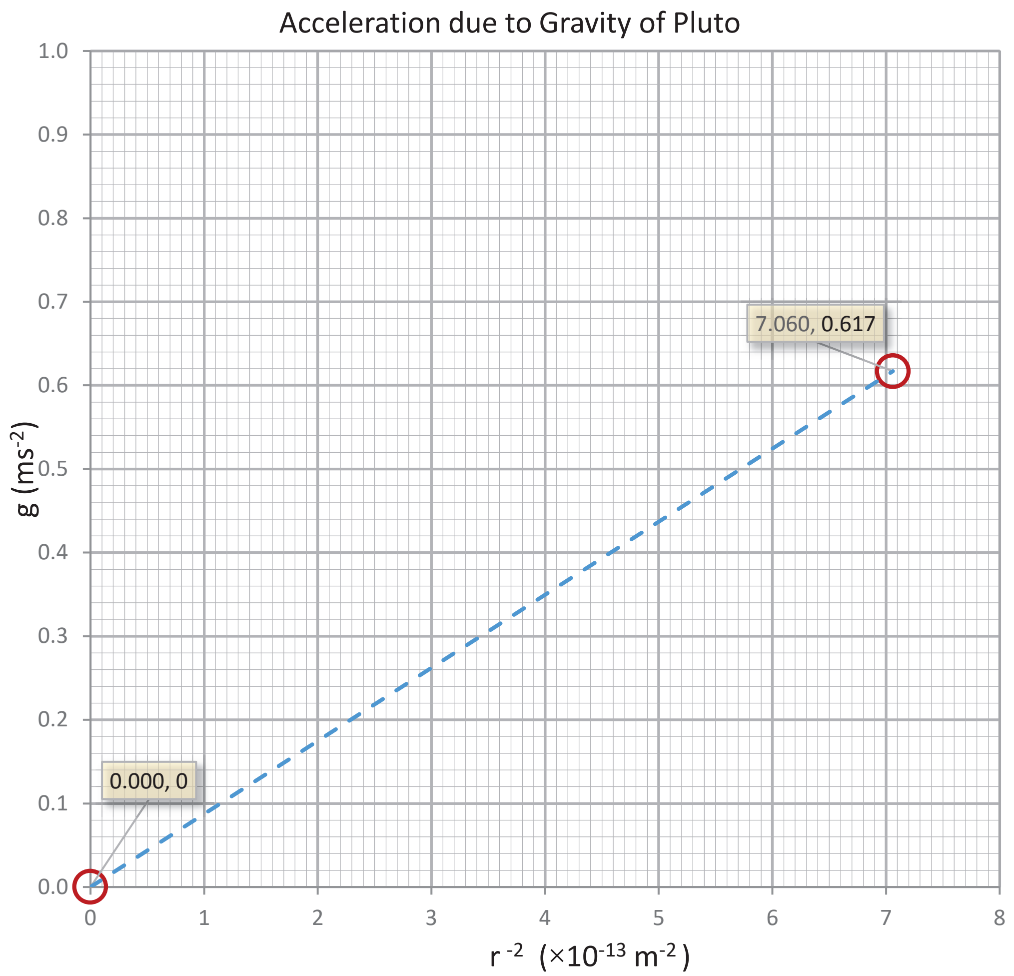
(a) Determine the period of the car around the track. **1**

(b) Determine the angular frequency of the car. **1**

(c) The car increases its speed until it can continue in the circular path without the assistance of friction. Determine this new speed. **3**

Question 24 (7 marks) **Marks**

The graph below shows the acceleration due to gravity, g, near the planet Pluto vs $\frac{1}{r^2}$ where r is the distance from the centre of Pluto.



(a) From the graph, determine the value of gravity g at a distance of 3.0 x 10^6 m from the centre of Pluto.

(b) Use the graph to calculate the mass M_P of Pluto.

2

Predict whether or not this lump of ice will fall back down to the surface of Pluto. (ignore any possible effects of atmospheric drag). Justify your answer with calculations.

3

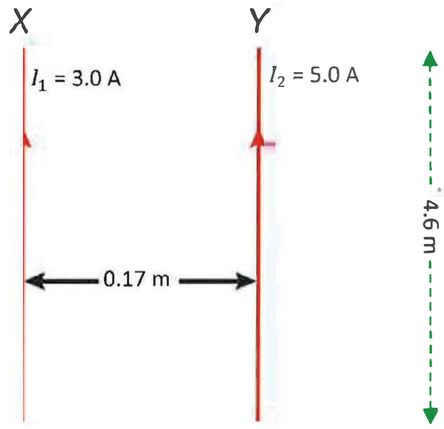
SECTION II: Part B (20 Marks)

CANDIDATE NUMBER

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

Question 25 (4 marks) **Marks**

Two current-carrying wires I_1 = 3.0 A and I_2 = 5.0 A are a distance 0.17 m apart and are parallel to each other for a length of 4.6 m.

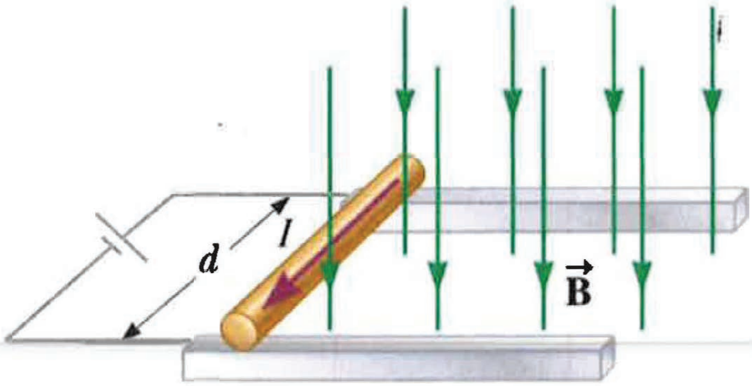


(a) Determine the magnitude and direction of the force on wire Y caused by wire X. **2**

(b) Determine the magnitude of the magnetic field strength on wire Y caused by wire X . **2**

Question 26 (2 marks) **Marks**

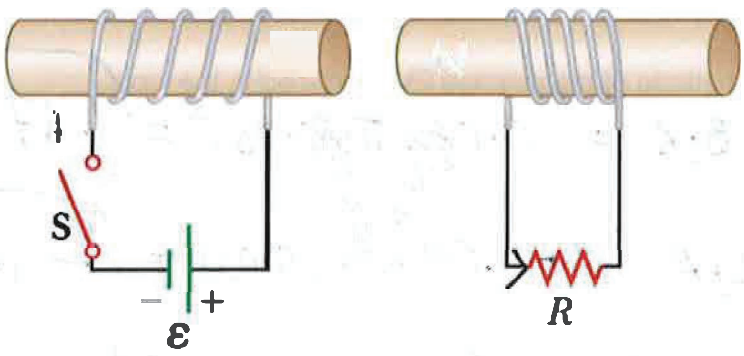
A rod of mass 0.72 kg rests on two parallel rails that are $d = 12.0$ cm apart and $L = 7.4$ m long. The rod carries a current of $I = 48$ A in the direction shown and slides along the frictionless rails. A uniform magnetic field of magnitude $B = 0.24$ T is directed perpendicular to the rod and the rails.



What is the initial acceleration of the rod ~~when the power is turned~~ on 2

Question 27 (4 marks) **Marks**

Two coils are placed near each other as shown below. The coil on the left is connected to a battery and a switch, and the coil on the right is connected to a resistor R.



Identify and explain the direction (left, right or zero) of the current in the resistor:

(a) just after switch S is closed. **2**

(b) after the switch has been closed for several seconds. **2**

Question 28 (3 marks) **Marks**

A circular loop of wire with a radius of 0.030 m is in a uniform magnetic field of magnitude 0.060 T. The plane of the loop is perpendicular to the direction of the magnetic field. In a time interval of 0.35 s, the magnetic field changes at a constant rate to the opposite direction with a magnitude of 0.040 T.

Determine the magnitude of the average EMF induced in the loop **3**

Question 29 (4 marks) **Marks**

A step-down ideal transformer is used inside a DVD player connected to a 240 V household power supply. The ratio of turns in the transformer is 1:13 and when in use the current in the primary coil of the transformer is 0.020 A.

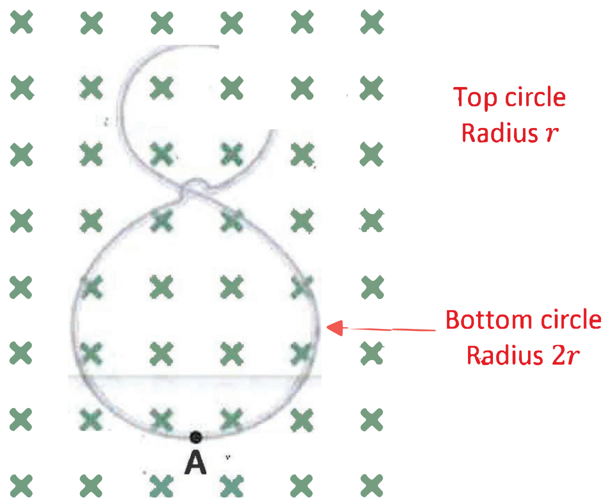
(a) Determine the current in the secondary. **1**

(b) Determine the power delivered to the DVD player from the transformer. **1**

(c) Describe one effect in a real transformer that would reduce its efficiency. **2**

Question 30 (3 marks) **Marks**

A piece of wire with an insulated coating is shaped into a figure eight which we can model as two circles, where the radius of the smaller top circle is half that of the larger circle as shown below.



A uniform magnetic field is applied perpendicular to the plane of the two circles, in the direction shown. The magnetic field is increasing at a constant rate.

If the emf induced in the top circle is 1 Volt, then:

(a) determine the magnitude ~~of the total emf~~ induced in the entire loop. 2

(b) determine the direction of the force on the current induced in the wire at point A due to the external magnetic field. 1

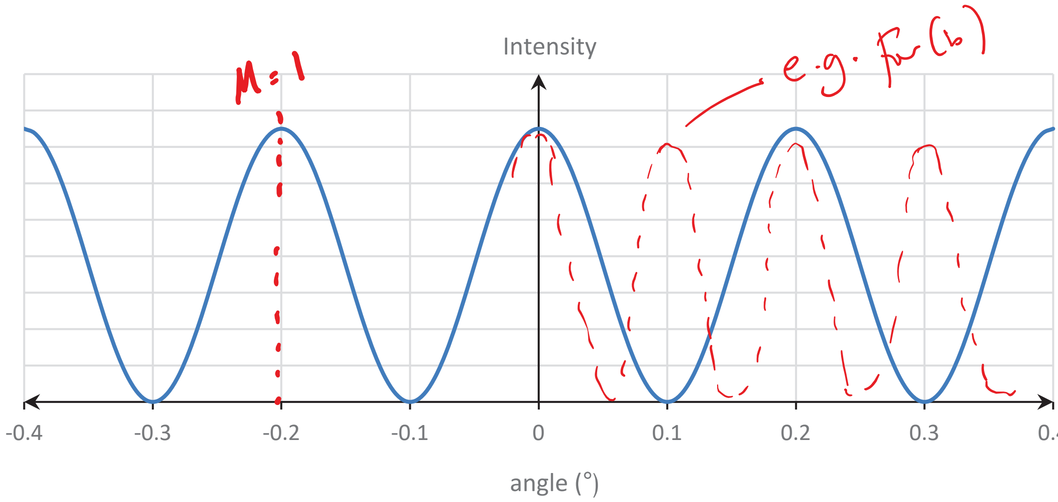
SECTION II: Part C (20 Marks**)**

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

CANDIDATE NUMBER

Question 31 (4 marks) **Marks**

In the diagram below, an interference pattern is created on a screen by the use of a laser passing through a pair of narrow slits, 2.0×10^{-4} m apart.

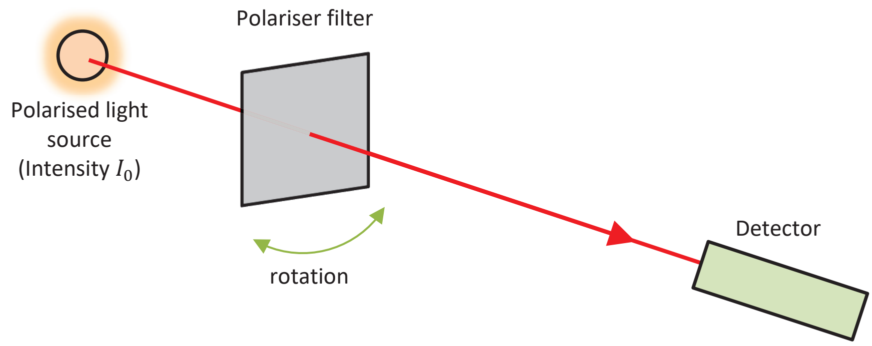


(a) Using the information given, determine the wavelength of the light used in this experiment. **2**

(b) Draw on the above diagram the effect of repeating this experiment if the slits are further apart. **2**

Question 32 (5 marks) **Marks**

A student performs an experiment into polarisation of light using the equipment shown below.



The student begins with a polarised light source of intensity I_0. They adjust the polarising filter until the maximum amount of light passes though it, and set this angle equal to zero. Then, they adjust the angle of the filter relative to this, and record the amount of light that passes through. Their data is recorded in the table below.

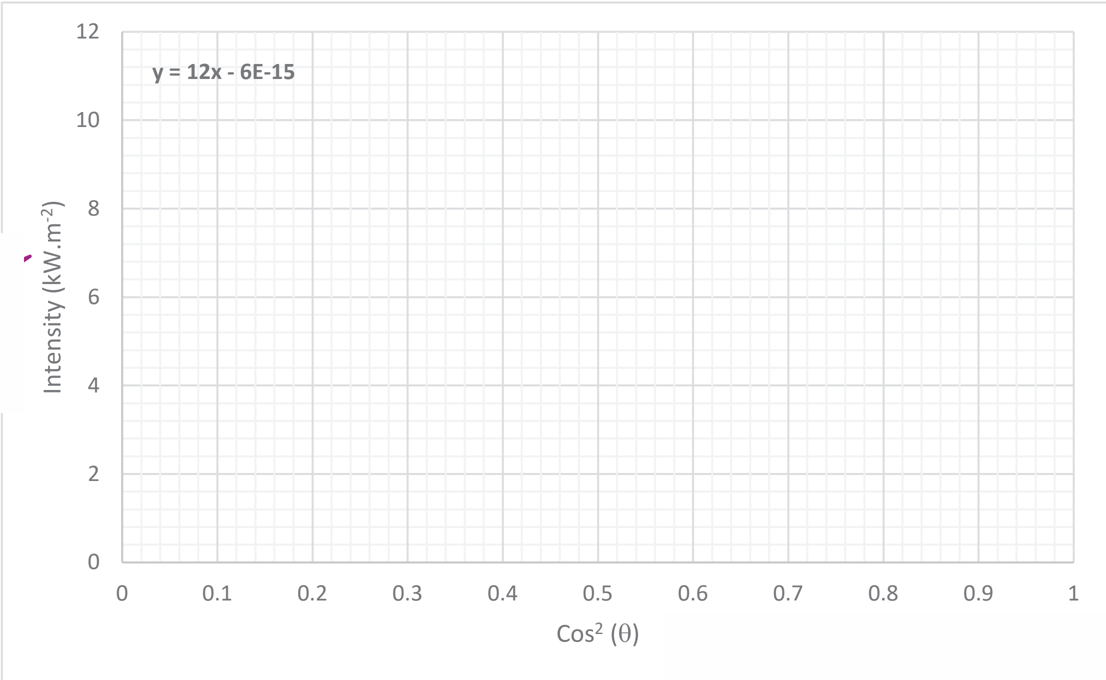
Angle (°)	**Intensity** (kW m^{-2})		
15	11.19		
30	8.99		
45	5.97		
60	2.97		
75	0.78		

The student hypothesises that their results will support Malus's Law.

(a) By plotting a suitable graph, assess whether or not the student's data supports their hypothesis.

Two extra blank columns have been added to the data table in case you wish to perform any calculations.

Question 32 continued on next page.



4

(b) Estimate the original intensity of the light source, I_0.

1

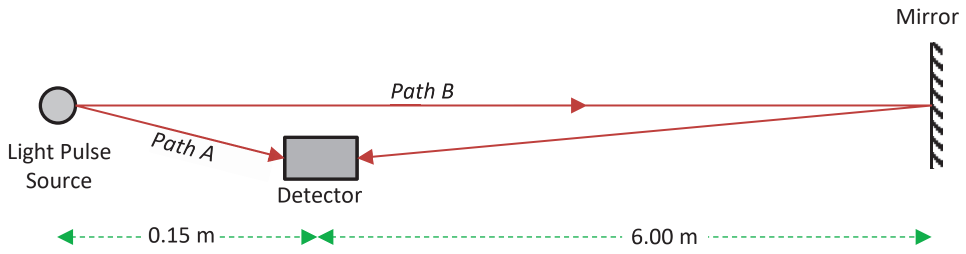
Question 33 (4 marks) **Marks**

In 1865 Maxwell James Clerk Maxwell published "*A Dynamical Theory of the Electromagnetic Field*"

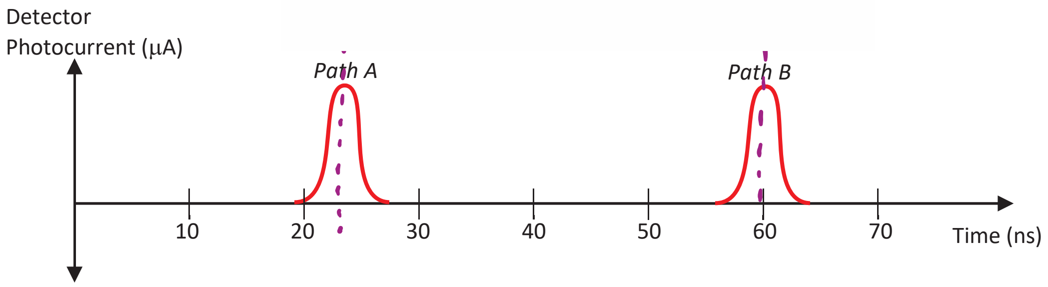
Outline the contribution of James Clerk Maxwell to our understanding of light. **4**

Question 34 (2 marks) **Marks**

The experiment below is set up to measure the speed of light. As shown in the diagram, a light source creates a pulse of light which travels in two paths to a detector, one directly, and the other to a mirror that reflects the light back to the detector. The diagram is not to scale, and the paths of the light can be considered approximately parallel.



The detector is a photocell that converts the light into a photocurrent. The photocell can only record received signals, so there is no way to know on the graph when the pulse was sent. After the detector was set to record, the times at which the light from each path are received are shown in the graph below.



Estimate the speed of light obtained by this method.

Question 35 (5 marks) **Marks**

"The Physics that explains the operation of the induction motor is the same Physics that explains back emf in DC Motors." 5

With reference to the operation of both DC motors and induction motors, justify this statement.

SECTION II: Part D (20 Marks)

CANDIDATE NUMBER							

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

Question 36 (2 marks) **Marks**

A spacecraft is travelling at 0.87c between Earth and Teegarden's Star, a distance of 12.51 lightyears from Earth's frame of reference.

Calculate the distance of the journey in the spacecraft's frame of reference.

2

Question 37 (3 marks)

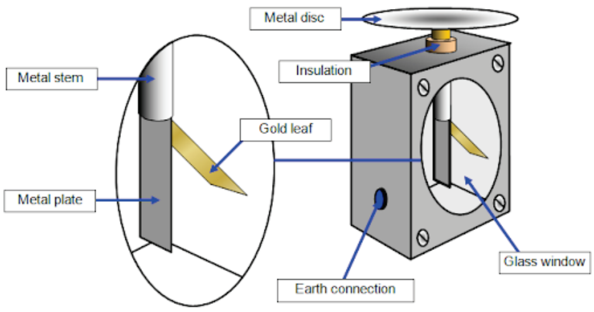
A muon is an elementary particle which decays into an electron. When at rest the decay time of a muon is 2.2 μs, but when observed moving at a relativistic velocity its decay time is measured as 8.8 μs.

Explain how these muons provide evidence for Einstein's theory of special relativity and hence calculate the speed of the muons.

3

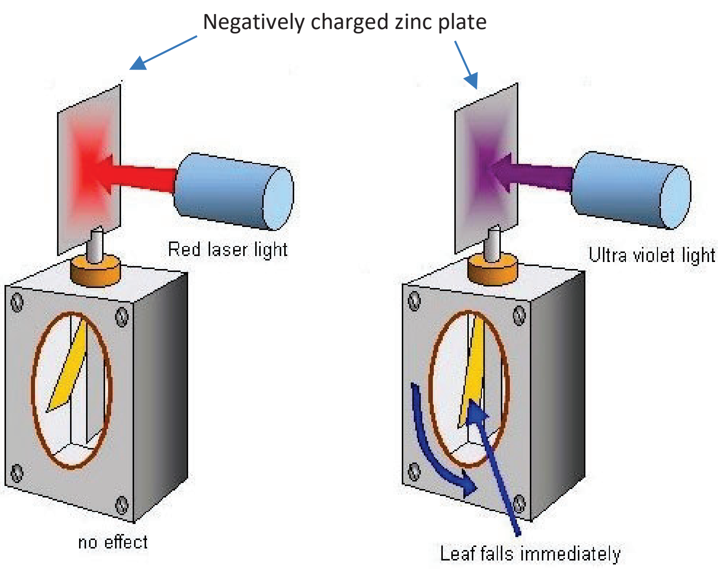
Question 38 (4 marks) **Marks**

A leaf electroscope is a device for measuring electrostatic charge. When an electroscope has a net charge on it the movable gold leaf swings outwards as it is repelled electrostatically from the stationary metal plate which contains the same charge.



A zinc plate is attached to the top of the electroscope and the electroscope is given a net negative charge; this puts the gold leaf is in an outward position. Two different coloured lights are shone on it separately.

As illustrated below, when red light is shone onto the zinc plate the gold leaf remains stationary and does not fall. When ultraviolet light is shone on the zinc plate, then the gold leaf falls immediately.



Question 38 continued on next page.

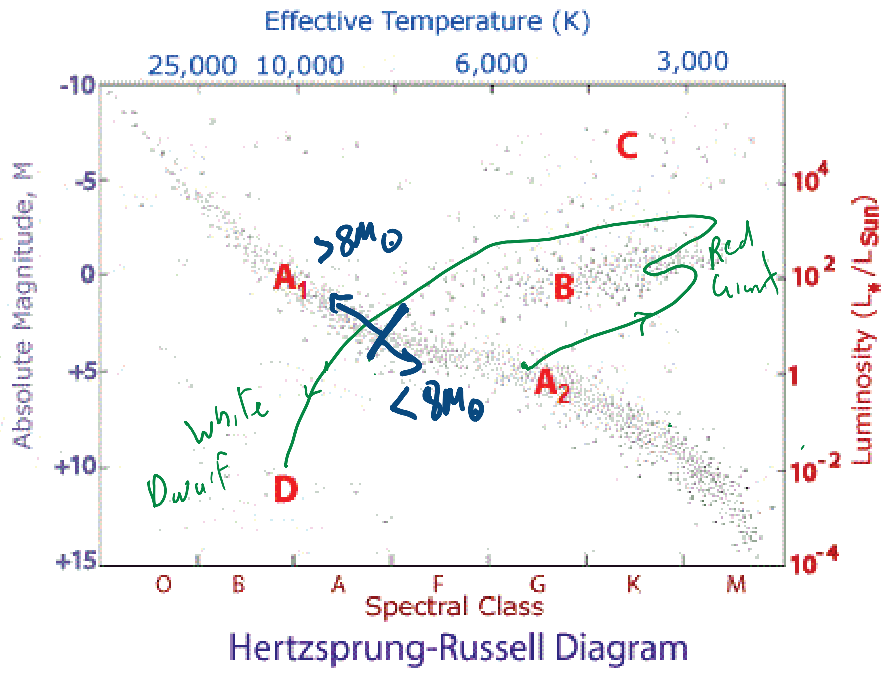
Question 38 continued **Marks**

Explain the behaviour of the different coloured lights on the negatively charged electroscope.

4

Question 39 (5 marks) **Marks**

The following is a HR diagram with several groups of stars labelled.



(a) In the following table contains possible fusion reactions that can occur in stars.

p-p hydrogen fusion	CNO hydrogen fusion
$^1H + {}^1H \rightarrow {}^2H + e^+ + \nu_e$ $^2H + {}^1H \rightarrow {}^3He + \gamma$ $^3He + {}^3He \rightarrow {}^4He + 2\,{}^1H$	$^{12}C + {}^1H \rightarrow {}^{13}N + \gamma$ $^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$ $^{13}C + {}^1H \rightarrow {}^{14}N + \gamma$ $^{14}N + {}^1H \rightarrow {}^{15}O + \gamma$ $^{15}O \rightarrow {}^{15}N + e^+ + \nu_e$ $^{15}N + {}^1H \rightarrow {}^{12}C + {}^4He$

Identify the region(s) where the following predominately occur in the core:

i. p-p hydrogen fusion

1

ii. CNO hydrogen fusion

1

Question 39 continued on next page.

(b) For a star starting in region A2, describe its movement in the HR diagram as it ages, linking this to the changes that are occurring inside it. **3**

Question 40 (6 marks) **Marks**

Explain how the properties of stars can be determined from their spectra. **6**

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CRIB
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STRUCTURE OF PAPER

SECTION I

Multiple Choice 20 marks

Allow about 30 minutes for this section

SECTION II

Parts A-D 80 marks

Allow about 2 hours and 30 minutes for this section

EXAMINATION

DATE: Thu 13th August 8.39 AM

DURATION: 3 hours (+5min reading)

MARKS: 100

CHECKLIST

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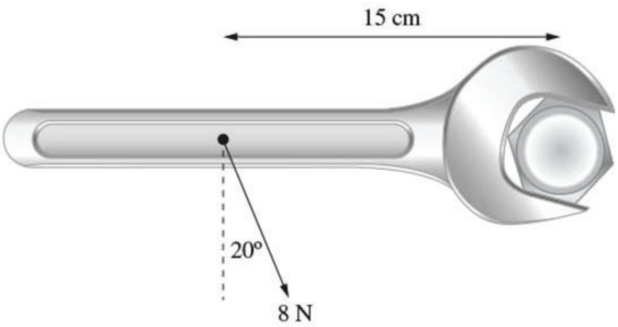
- Remove the centre staple and hand in all parts of the examination in a neat bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should be clearly be marked **CONTINUED.** When the response is continued on extra writing paper it should clearly indicate the question number.
  - Each detachable part A-D of Section II has additional writing space.
  - Further additional writing paper is included at the end of the paper.
- There is a Data/Formula sheet included at the end of the paper.

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

Answers for Multiple Choice

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

1 A spanner is being used to tighten a bolt as shown.



The torque being applied to the bolt by the spanner is:

(A) 0.41 N m

(B) 1.1 N m

(C) 1.2 N m

(D) 120 N m

2 The mass of the Sun is 2.0×10^{30} kg and the distance between the Sun and the Earth is 1.5×10^{11} m. What is the gravitational force exerted by the Sun on the Earth?

(A) 3.6×10^{22} N

(B) 1.2×10^{28} N

(C) 5.3×10^{33} N

(D) 8.0×10^{43} N

3 Two planets orbit a distant star. Planet A orbits at distance r and has period T. Planet B orbits at distance $\frac{r}{4}$. What will be the period of Planet B?

(A) $T/8$

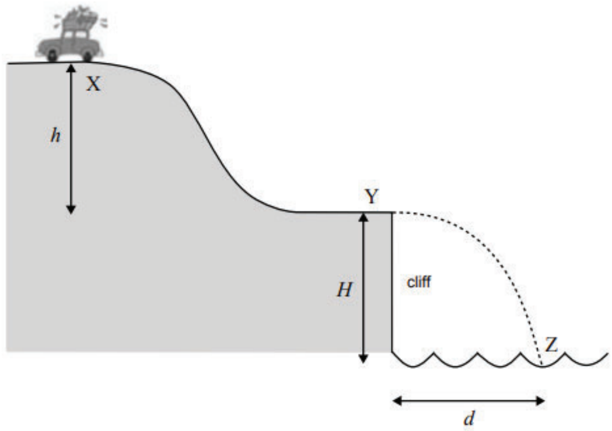
(B) $T/2$

(C) $2T$

(D) $8T$

Use the following information to answer questions 4 and 5

A car is stationary on top of a hill at X, h metres above the top of a cliff. The brakes are released and the car starts to roll down the hill to point Y, where it is projected horizontally off a cliff of height H, and lands at point Z, a distance d from the base of the cliff. Ignore friction and air resistance.



4 Which of the expressions below gives the speed of the car at point Y?

(A) $\sqrt{2gh}$

(B) $\sqrt{2gH}$

(C) $\sqrt{2g(h+H)}$

(D) $\sqrt{2g(H-h)}$

5 Which of the statements below is correct?

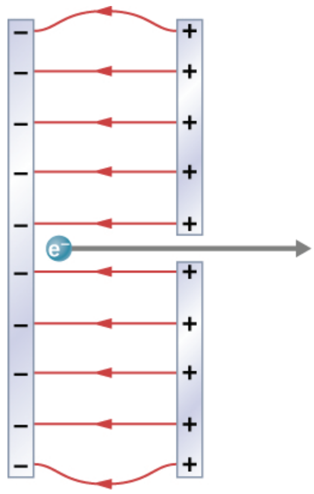
(A) The magnitude of the horizontal component of the velocity of the car at Z is less than the speed at Y.

(B) The magnitude of the horizontal component of the velocity of the car at Z is equal to the speed at Y.

(C) The magnitude of the horizontal component of the velocity of the car at Z is greater than the speed at Y.

(D) The magnitude of the horizontal component of the velocity of the car at Z depends on the height of the cliff.

6 An electron is accelerated from rest to a speed of 3.2×10^{6} m s^{-1} between two parallel plates with a uniform electric field as shown.



What voltage is required between the two plates for this to occur?

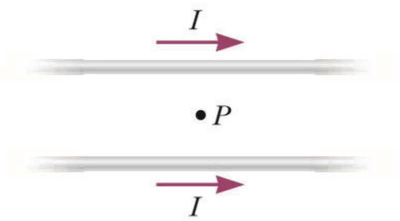
(A) 9.1×10^{-6} V

(B) 29 V

(C) 58 V

(D) 320 V

7 Two long parallel wires carry equal currents I in the same direction as shown below.



It is true to say that the magnetic field at P (midpoint between the wires) is:

(A) Zero.

(B) Directed out of the page.

(C) Directed into the page.

(D) Directed towards the right.

8 A charged particle is fired into a region of space where the electric field is zero. It moves in a straight line. Can you therefore conclude that the magnetic field is zero?

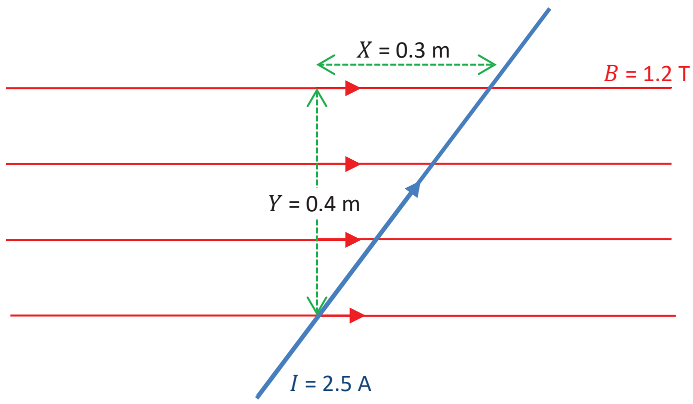
(A) Yes; you can.

(B) No; the field may be perpendicular to the particle's velocity.

(C) No; the field may be parallel to the particle's velocity.

(D) Yes; if the charge is positive.

9 A current carrying wire of $I = 2.5$ A is in a uniform magnetic field of strength $B = 1.2$ T for a horizontal distance of $X = 0.3$ m and a vertical distance of $Y = 0.4$ m as depicted below.



What is the magnitude of the force on the wire?

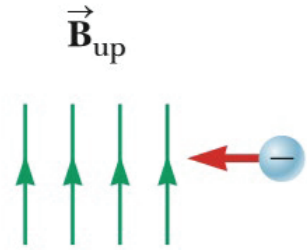
(A) 0.75 N

(B) 0.90 N

(C) 1.2 N

(D) 1.5 N

10 An electron enters a magnetic field as shown below. Determine the direction of the force on the electron.



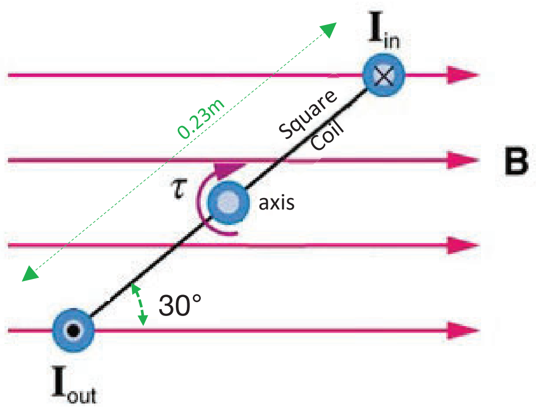
(A) Up the page

(B) Down the page

(C) Into the page

(D) Out of the page

11 The diagram below shows the coil of a DC motor at one part of its rotation.



The square coil consists of 8 turns of wire, and has dimensions 0.23 x 0.23 m. A current of $I = 2.75$ A flows through it. The external magnetic field is $B = 1.50$ T

Calculate the magnitude of the torque, τ, on the coil at the angle shown.

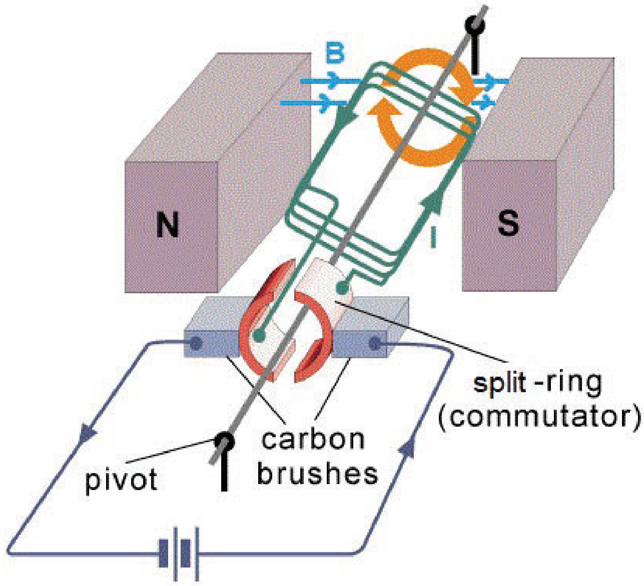
(A) 0.11 N m

(B) 0.87 N m

(C) 1.5 N m

(D) 1.7 N m

12 Identify the device shown in the diagram below:



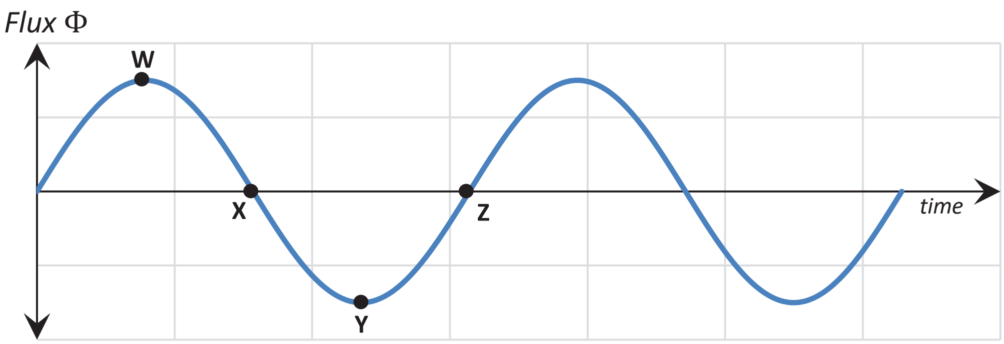
(A) AC Motor

(B) DC Motor

(C) AC Generator

(D) DC Generator

13 The diagram below shows the magnetic flux through the coil of an AC generator as it rotates:



At which point(s) in the rotation is the magnitude of the induced voltage greatest?

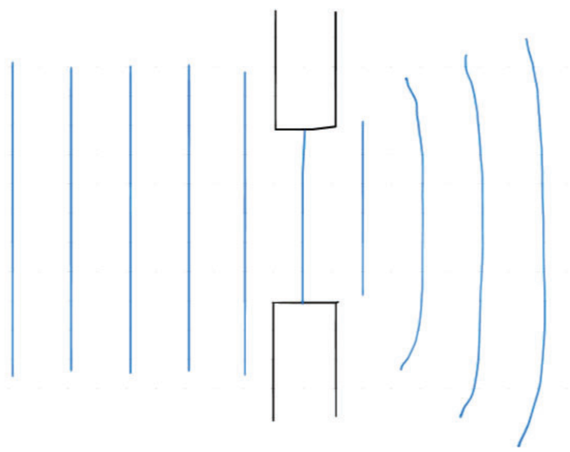
(A) W only

(B) X only

(C) W and Z

(D) X and Z

14 The diagram below shows the behaviour of a wave when it passes through a gap.



How would the wave pattern change if the size of the gap was narrowed?

(A) The angular spread of the waves would increase.

(B) The angular spread of the waves would decrease.

(C) The angular spread of the waves would increase, and the wavelength of the wave would decrease.

(D) The angular spread of the waves would decrease, and the wavelength would increase.

15 Stars A and B are main sequence stars with the same composition. Star A has 10 times more mass than Star B. Which of the following comparisons is correct?

	Star A		Star B	
(A)	Higher luminosity	Longer lifespan	Smaller radius	Higher Surface temperature
(B)	Higher luminosity	Shorter lifespan	Smaller radius	Lower Surface temperature
(C)	Lower luminosity	Shorter lifespan	Smaller radius	Lower Surface temperature
(D)	Lower luminosity	Longer lifespan	Larger radius	Higher Surface temperature

16 What is the momentum of a proton moving close to the speed of light at a velocity of 2.6×10^{8} m s^{-1}?

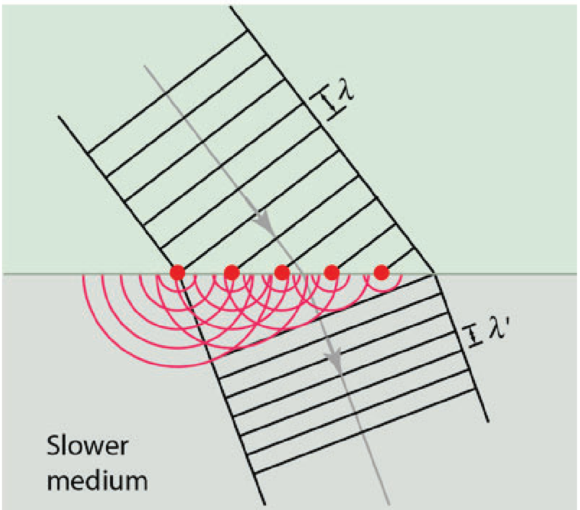
(A) 4.3×10^{-19} kg m s^{-1}

(B) 8.7×10^{-19} kg m s^{-1}

(C) 1.2×10^{-18} kg m s^{-1}

(D) 1.7×10^{-18} kg m s^{-1}

17 The diagram below shows an explanation for the refraction of light from air to glass using the concept of *wavelets*. In this explanation, the speed of light in glass must be slower than in air.



Identify the scientist responsible for proposing this model of light.

(A) James Clerk Maxwell

(B) Max Planck

(C) Isaac Newton

(D) Christian Huygens

18 Millikan measured the charge on an electron by balancing forces on charged oil drops. What were these forces?

(A) Gravitational and Magnetic

(B) Electric and Magnetic

(C) Gravitational and Electric

(D) Electric, Magnetic and Gravitational

19 In the Geiger-Marsden experiment, which is the most correct description of an observation they made?

(A) Most alpha particles were absorbed.

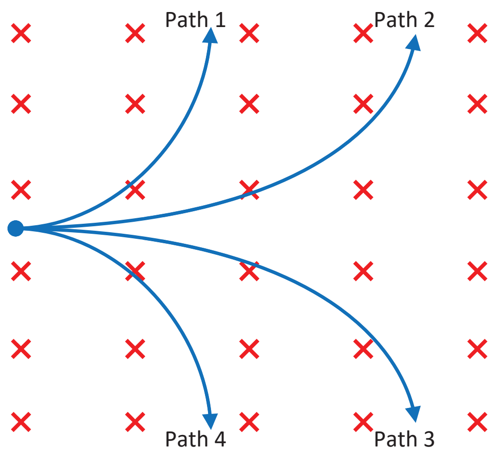
(B) Most alpha particles were reflected back.

(C) Most alpha particles were deflected by large angles.

(D) Most alpha particles were undeflected and passed straight through.

20 By analysing the motion of cathode rays in magnetic fields Thomson discovered the electron by determining that the charge/mass ratio for electrons was much greater than for a particle like a proton.

The diagram shows the possible paths of charged particles entering a magnetic field at the same velocity.



Identify which path would be the mostly likely for each particle.

	Proton	Electron
(A)	1	3
(B)	2	1
(C)	3	2
(D)	2	4

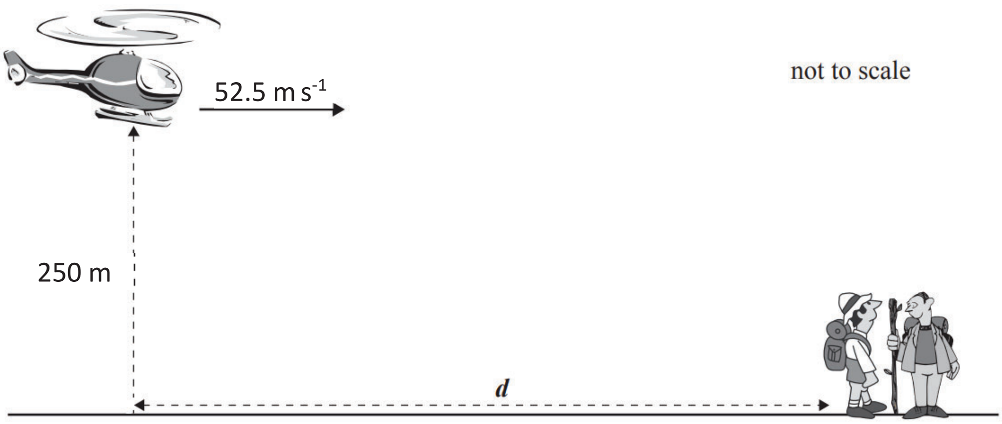
SECTION II: Part A (20 Marks)

CANDIDATE NUMBER

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

Question 21 (4 marks) **Marks**

A helicopter is to drop a rescue pack to a group of hikers. The helicopter is flying at a horizontal speed of 52.5 m s^{-1} at a constant height of 250 m above the ground.



(a) For the rescue package to land beside the hikers, at what distance d from the hikers should the package be released from the plane?

Vertically:

$$-250 = -4.9t^2$$
$$t = 7.14s$$

Horizontally: $d = 52.5 \times 7.14 = 375\ m$

Criteria	Mark
Correct answer (units not considered)	2
Correct time of flight	1

2

(b) What will be the speed of the package as it hits the ground?

Vertical velocity: $v_y^2 = 19.6 \times 250, so\ v = 70\ ms^{-1}$

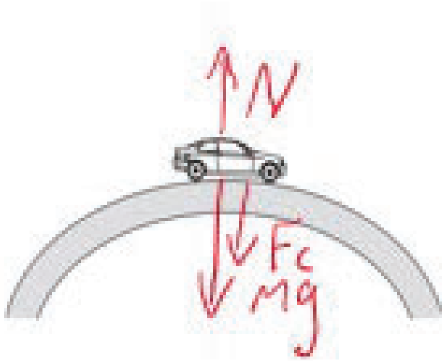
Speed: $v = \sqrt{52.5^2 + 70^2} = 87.5\ ms^{-1}$

Criteria	Mark
Correct answer (units not considered)	2
Only finds vertical velocity	1

2

Question 22 (4 marks) **Marks**

A man of mass m was driving his car at a constant speed v over a hump-backed bridge that is circular in shape with radius r, as shown. His fancy new car has a feature in the driver's seat where it acts as a set of scales and lets him observe his weight in the dash screen.



He noticed that the reading on the scales decreased as he passed over the top of the bridge. He claimed later to a friend that if he could have travelled fast enough, the scales would have registered zero.

Assess this man's statement. 4

The bridge is circular, so the man needs a centripetal force to keep him in contact with the seat. This will be given by the vector sum of his weight force and the normal force.

$$\Sigma F = F_c = \frac{mv^2}{r} = mg - N$$

The scales represent the normal force.

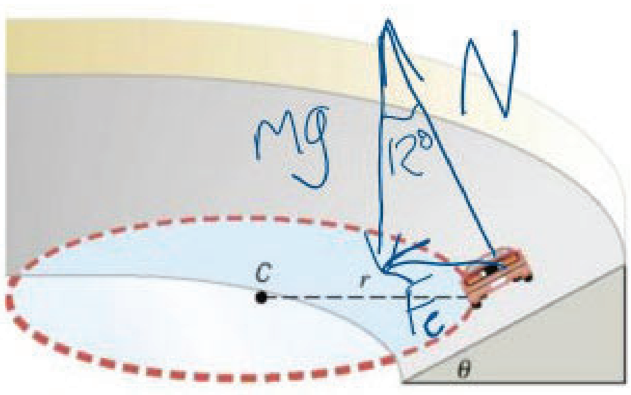
The centripetal force needed to stay on the road increases with speed but weight is fixed so N must decrease. Above $v = \sqrt{gr}$, weight is not enough to supply F_c and so N=0 with car becoming projectile (man and car accelerating downwards at same rate.) This would mean the scales register zero, so the man's statement is correct.

Criteria	Mark
Correct judgement (ie, yes, it is possible) Correctly analyses all forces (W, N, F_c) and their relationship Links feeling of weightlessness with normal force on driver Correctly identifies effect of sufficient speed on normal force	4
Essentially correct but with misconceptions (eg implying weight and F_c are in opposite directions) or omissions (not mentioning normal force.)	3
Correct or consistent judgement and demonstrates some understanding of a relevant force.	2
Correct judgement or any relevant information	1

Note: it was possible to arrive at $v = \sqrt{gr}$ without considering normal force at all but this was not sufficient for full marks as the answer must link the feeling of weightlessness with the normal force on the driver.

Question 23 (5 marks) Marks

A car of mass m = 1100 kg is travelling in a horizontal circular path with radius r = 40 m on a banked track at a speed of v = 5 m s^{-1}, as shown below. The angle of the slope is θ = 12°.



(a) Determine the period of the car around the track.

$$T = \frac{2\pi r}{v} = \frac{80\pi}{5} = 50.3s$$

Criteria	Mark
Correct value for T	1

1

(b) Determine the angular frequency of the car.

$$\omega = 2\pi f = \frac{2\pi}{T} = 0.125\, rad\; s^{-1}$$

Criteria	Mark
Correct value (degrees per second were accepted)	1

1

(c) The car increases its speed until it can continue in the circular path without the assistance of friction. Determine this new speed.

$$F_C = mg\tan 12 = \frac{mv^2}{r}$$
$$m\ cancels, so\ v^2 = gr\tan 12 = 83.3$$
$$v = 9.13\ ms^{-1}$$

Criteria	Mark
Correct answer (units not considered)	3
Correct method but one error in calculation (eg forgets square root)	2
One correct step or equation (eg calculates mg)	1

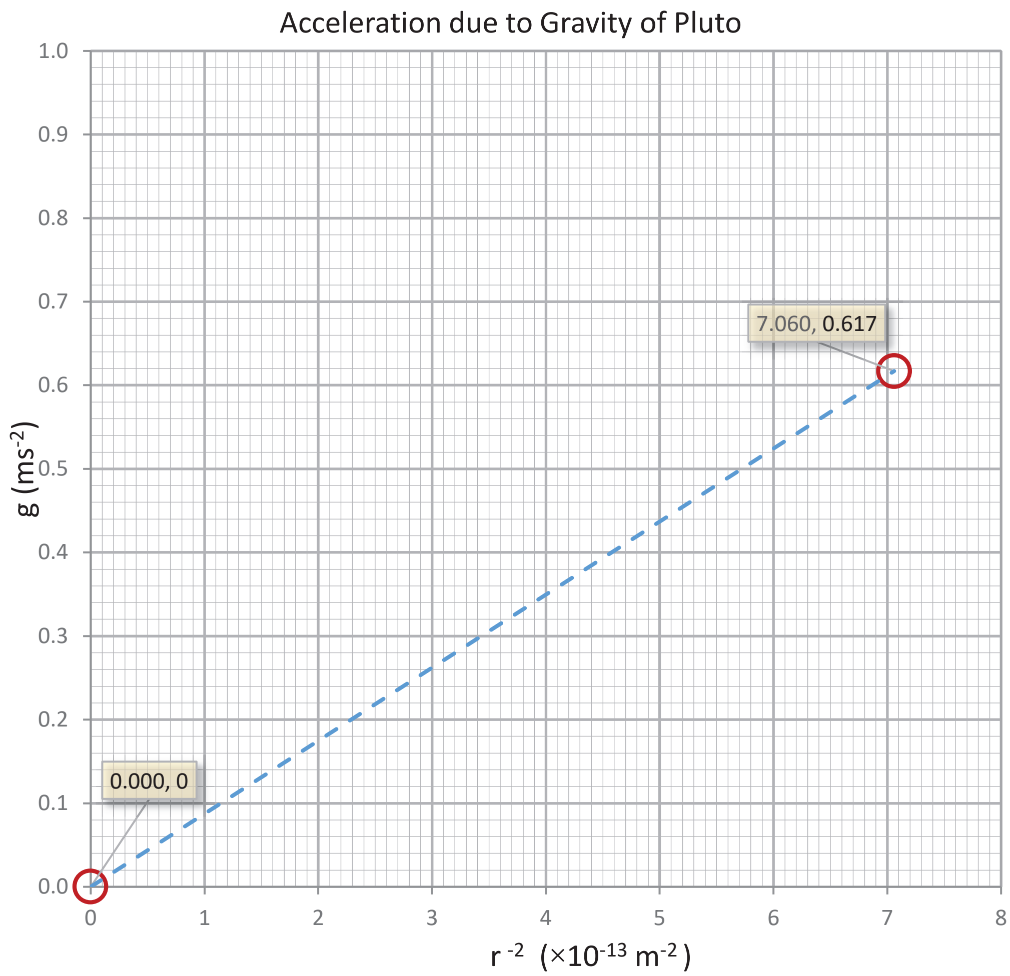
....

....

.... 3

Question 24 (7 marks) **Marks**

The graph below shows the acceleration due to gravity, g, near the planet Pluto vs $\frac{1}{r^2}$ where r is the distance from the centre of Pluto.



(a) From the graph, determine the value of gravity g at a distance of 3.0 x 10^6 m from the centre of Pluto.

$$\frac{1}{r^2} = 1.11 \times 10^{-13}$$

$$g = 0.1\ ms^{-2}$$

(Accept 0.09 – 0.11)

Criteria	Mark
Correct answer (units not considered)	2
Answer not with limits	1

2

Question 24 continued on next page.

(b) Use the graph to calculate the mass M_P of Pluto.

$$g = \frac{GM}{r^2} = grad \times \frac{1}{r^2}$$

$$grad = GM\ , M = \frac{0.617}{7.06 \times 10^{-13} \times 6.67 \times 10^{-11}} = 1.31 \times 10^{22} kg$$

Criteria	Mark
Correct answer (units not considered)	2
One error in calculation (eg incorrect gradient)	1

2

Predict whether or not this lump of ice will fall back down to the surface of Pluto. (ignore any possible effects of atmospheric drag). Justify your answer with calculations.

Ice will escape Pluto if $\frac{1}{2}mv^2 = \frac{GMm}{r}$

Escape velocity $v = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 1.31 \times 10^{22}}{1.19 \times 10^{6}}} = 1205\ ms^{-1}$

Velocity of ice greater than esc. vel. so ice will not fall back down.

Criteria	Mark
Correct prediction with correct reasoning	3
Correct esc vel, or correct prediction with some justification	2
One correct step	1

3

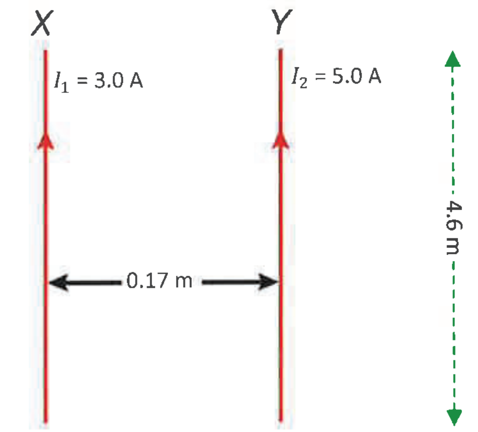
SECTION II: Part B (20 Marks)

CANDIDATE NUMBER

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

Question 25 (4 marks) **Marks**

Two current-carrying wires I_1 = 3.0 A and I_2 = 5.0 A are a distance 0.17 m apart and are parallel to each other for a length of 4.6 m.



(a) Determine the magnitude and direction of the force on wire Y caused by wire X.

$F = \frac{kI_1I_2\ell}{d} = \frac{2\times10^{-7}\times 3\times5\times4.6}{0.17}$

$= \boxed{8.1\times10^{-5}\ N}$ 1

$\boxed{\text{LEFT}}$ 1

2

(b) Determine the magnitude of the magnetic field strength on wire Y caused by wire X.

$B = \boxed{\frac{kI}{r}} = \frac{2\times10^{-7}\times3}{0.17}$ correct answer.

$= \boxed{3.5\times10^{-6}\ T}$

2

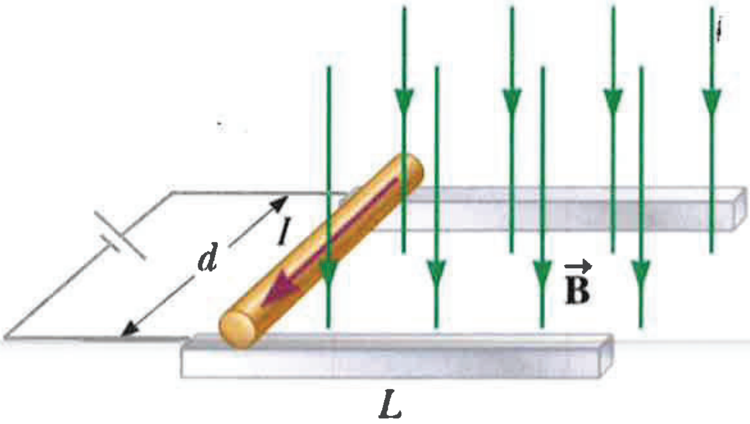
or $B = \frac{F}{IL}$ if you use $I = 3A$ in this formula you are wrong but I gave 1 mark.

5A

i.e $B = 5.9\times10^{-6}\,T$ wrong! 1 mark

Question 26 (2 marks) **Marks**

A rod of mass 0.72 kg rests on two parallel rails that are d = 12.0 cm apart and L = 7.4 m long. The rod carries a current of I = 48 A in the direction shown and slides along the frictionless rails. A uniform magnetic field of magnitude B = 0.24 T is directed perpendicular to the rod and the rails.



What is the initial acceleration of the ~~rod when the power is turned~~ on?

$F = BIL_{\perp} = ma$ 1 mark

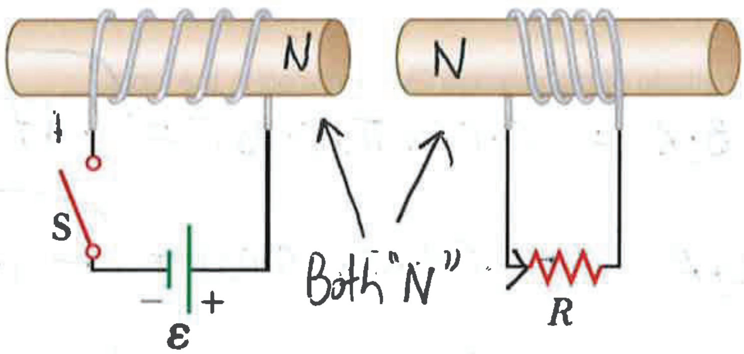
$a = \dfrac{0.24 \times 48 \times 0.12}{0.72}$

$= 1.92\ m/s^2$ right 2

1 mark

Question 27 (4 marks) **Marks**

Two coils are placed near each other as shown below. The coil on the left is connected to a battery and a switch, and the coil on the right is connected to a resistor R.



Identify and explain the direction (left, right or zero) of the current in the resistor:

If you got the wrong direction but you had a good explanation = 1 mark

(a) just after switch S is closed.

Right ① Explanation: Closing the switch creates a N pole on left coil. ①
The change in flux in the right coil produces a N pole (Lenz's law) on the leftside.

2

(b) after the switch has been closed for several seconds.

No change in flux ①
∴ Zero current ①

2

Question 28 (3 marks) **Marks**

A circular loop of wire with a radius of 0.030 m is in a uniform magnetic field of magnitude 0.060 T. The plane of the loop is perpendicular to the direction of the magnetic field. In a time interval of 0.35 s, the magnetic field changes at a constant rate to the opposite direction with a magnitude of 0.040 T.

Determine the magnitude of the average EMF induced in the loop. 3

$\phi_i = B_i A = 0.06 \times \pi \times (0.03)^2 = \boxed{1.7 \times 10^{-4}\ Wb}$ 1

$\phi_f = B_f A = -0.04 \times \pi \times (0.03)^2 = \boxed{-1.13 \times 10^{-4}\ Wb}$ 1

$\therefore \mathcal{E} = \frac{\Delta\phi}{\Delta t} = \frac{(1.7 + 1.13) \times 10^{-4}}{0.35}$

$= \boxed{8 \times 10^{-4}\ V}$ 1

Common error should be +

$\mathcal{E} = \frac{\pi r^2 (0.06 - 0.04)}{0.35}$

$= 1.6 \times 10^{-4}\ V$ 2 marks

Question 29 (4 marks) **Marks**

A step-down ideal transformer is used inside a DVD player connected to a 240 V household power supply. The ratio of turns in the transformer is 1:13 and when in use the current in the primary coil of the transformer is 0.020 A.

(a) Determine the current in the secondary.

$I = 0.02 \times 13$

$= \boxed{0.26\,A}$

1

(b) Determine the power delivered to the DVD player from the transformer.

$P = V_p I_p = 240 \times 0.02$

$= 4.8\,W$

1

(c) Describe one effect in a real transformer that would reduce its efficiency.

Incomplete Flux leakage: Not all the $\vec{B}$ field from primary is channelled into secondary

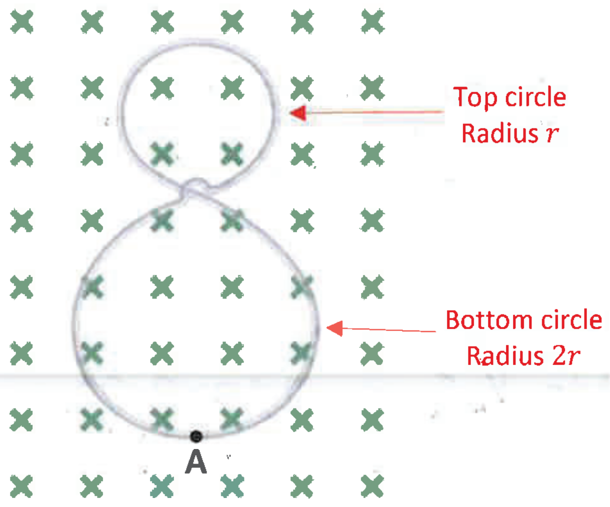
Eddy currents induced in iron core generate heat

Heating of wires due to $P_{ohmic} = I^2R$

2

Question 30 (3 marks) **Marks**

A piece of wire with an insulated coating is shaped into a figure eight which we can model as two circles, where the radius of the smaller top circle is half that of the larger circle as shown below.



A uniform magnetic field is applied perpendicular to the plane of the two circles, in the direction shown. The magnetic field is increasing at a constant rate.

If the emf induced in the top circle is 1 Volt, then:

(a) determine the magnitude of the total emf induced in the entire loop.

$\mathcal{E} = (4 - 1)$ 1 $(A = \pi r^2)$

$= 3$ Volts 1

If $4+1=5$ V
$= 1$ mark

2

(b) determine the direction of the force on the current induced in the wire at point A due to the external magnetic field.

Up the page.

1

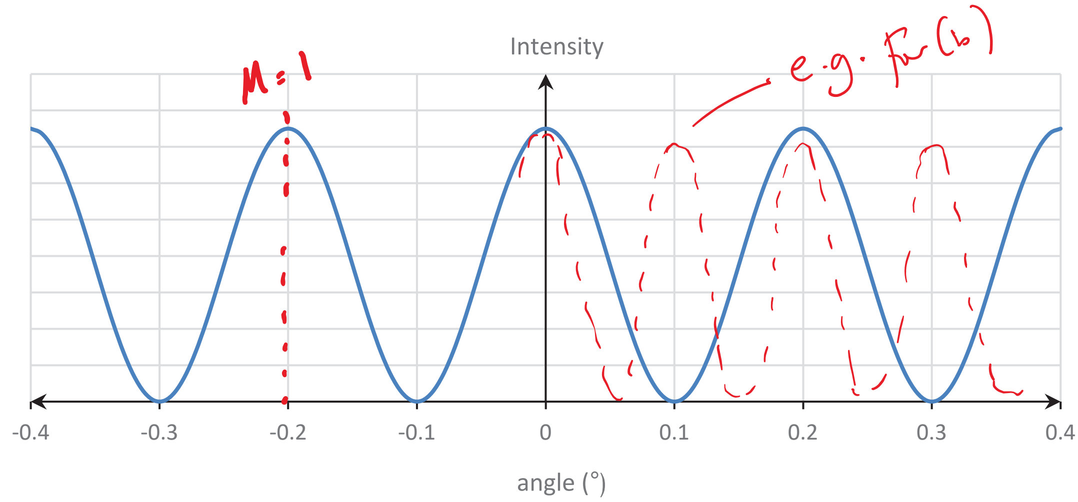
SECTION II: Part C (20 Marks)

CANDIDATE NUMBER

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

Question 31 (4 marks) **Marks**

In the diagram below, an interference pattern is created on a screen by the use of a laser passing through a pair of narrow slits, 2.0 x 10^{-4} m apart.



(a) Using the information given, determine the wavelength of the light used in this experiment.

$m\lambda = d \sin\theta$ $(m = 1,\ \theta = 0.2°)$ (1)

$\therefore\ \lambda = 2.0 \times 10^{-4} \times \sin 0.2°$

$\lambda = 6.98 \times 10^{-7}$ m — (2)

NB! For incorrect answers
(e.g. if $m = 2$, or $\theta = 0.1°$) → Max (1) **2**

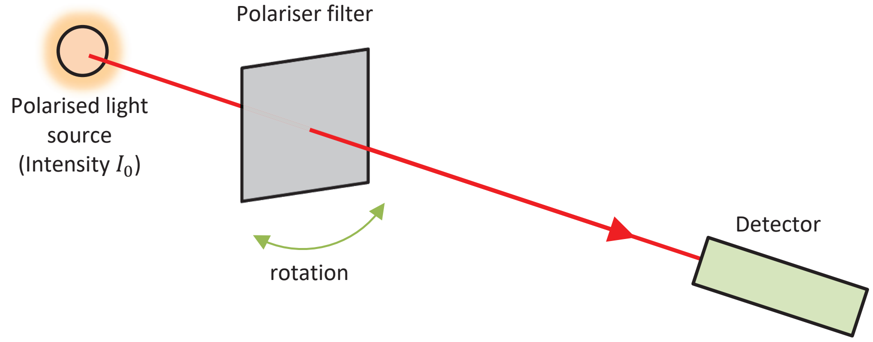
(b) Draw on the above diagram the effect of repeating this experiment if the slits are further apart. **2**

Peaks should be closer together, (1) but the pattern is otherwise essentially the same (1)

- Peaks are further apart → Max (1) for similar pattern
- Diffraction pattern only → (0)

Question 32 (5 marks) **Marks**

A student performs an experiment into polarisation of light using the equipment shown below.



The student begins with a polarised light source of intensity I_0. They adjust the polarising filter until the maximum amount of light passes though it, and set this angle equal to zero. Then, they adjust the angle of the filter relative to this, and record the amount of light that passes through. Their data is recorded in the table below.

Angle (°)	**Intensity** (kW m^{-2})		
15	11.19		
30	8.99		
45	5.97		
60	2.97		
75	0.78		

The student hypothesises that their results will support Malus's Law.

(a) By plotting a suitable graph, assess whether or not the student's data supports their hypothesis.

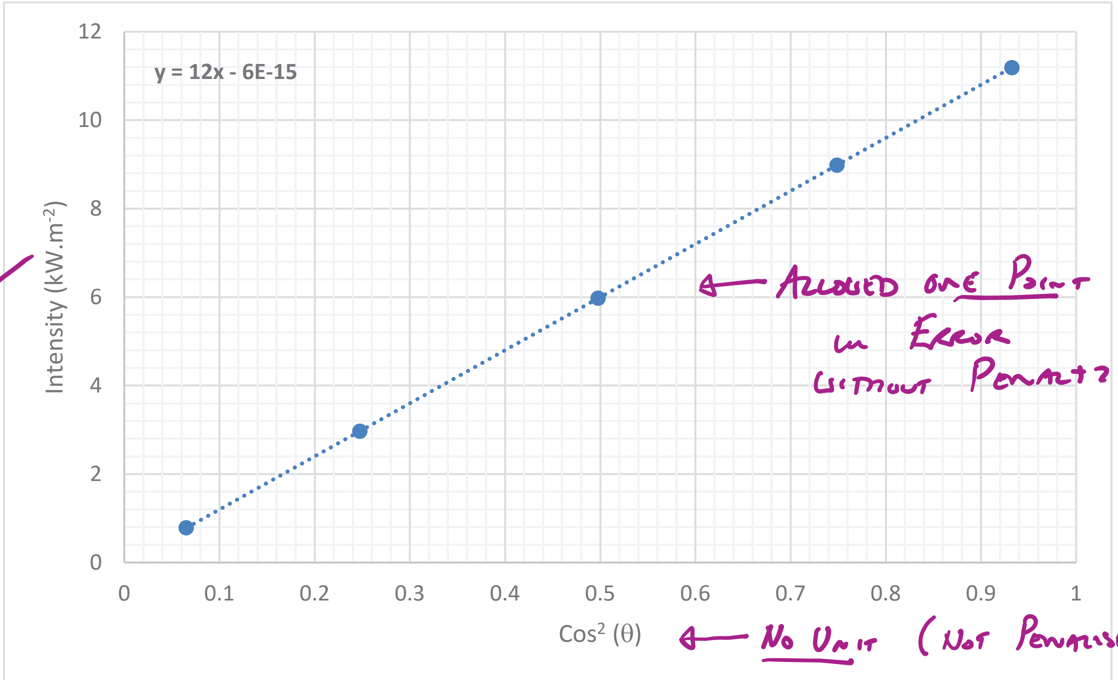
Two extra blank columns have been added to the data table in case you wish to perform any calculations.

Question 32 continued on next page.

Question 32 continued

Marks

Unit Required



← Allowed one point in error without penalty

← No Unit (Not penalised!)

For (4): • Plots a graph of I v $\cos^2\theta$

• Recognises that the linear graph suggests $I \propto \cos^2\theta$ as predicted by the hypothesis

Plots I v θ — Max (3) **4**

(b) Estimate the original intensity of the light source, I_0.

• From the gradient or otherwise, $I_0 = 12\ \mathrm{kW\,m^{-2}}$ (1)

(allowed $11.5 < I_0 < 12.5$) **1**

(NB – If I v θ plotted, did not accept y-intercept of a straight line of best fit)

Question 33 (4 marks) **Marks**

In 1865 Maxwell James Clerk Maxwell published "*A Dynamical Theory of the Electromagnetic Field*"

Outline the contribution of James Clerk Maxwell to our understanding of light.

This question primarily addresses the following *two points of the syllabus*:

- *investigate Maxwell's contribution to the classical theory of electromagnetism, including:*
  - *unification of electricity and magnetism*
  - *prediction of electromagnetic waves*
  - *prediction of velocity*
- *describe the production and propagation of electromagnetic waves and relate these processes qualitatively to the predictions made by Maxwell's electromagnetic theory.*

The question refers to our understanding of *light*, not of *electromagnetism*, so it is *not necessary* to discuss Maxwell's four equations which unified electricity and magnetism in any detail.

Outline is a low-order verb, so great depth is not required; a *broad* overview is sufficient.

For 4 Marks, an answer should clearly address the following points:

- The *prediction of the existence of e/m waves*.
- The *production of e/m waves* via oscillating charges.
- The *nature of e/m waves*: self-propagating, perpendicular, oscillating E and B-fields, transverse to the wave velocity. (*Some detail is required here: diagrams usually helped.*)
- The *wave velocity*, $c = 1/(\varepsilon_o\mu_o)^{1/2} = 3.0\text{x}10^8\ \text{ms}^{-1}$ – the accepted value for the speed of light.

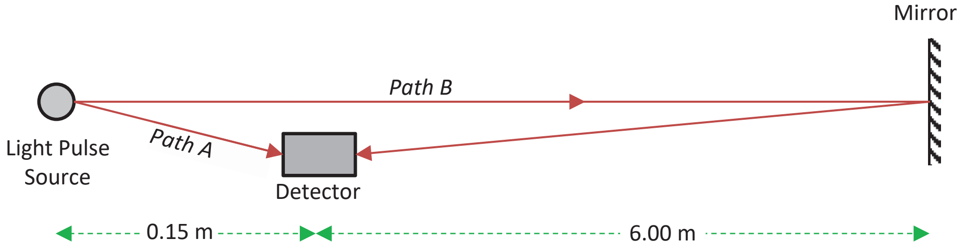
Where these points are missing or incomplete, some further comment is necessary; for example, the existence of an e/m spectrum of varying frequency / wavelength, of which visible light is small part.

Less complete answers scored correspondingly fewer marks.

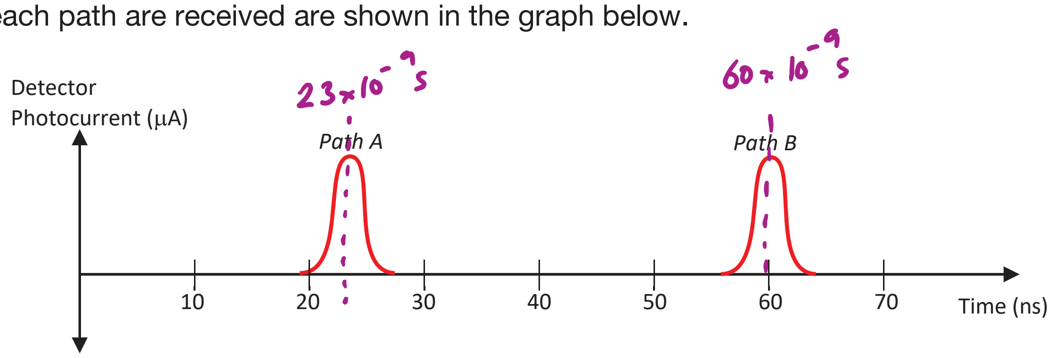
Answers that discussed the effects of JCM's work on e.g. relativity or quantum physics did not score highly unless they also addressed the specifics of the work itself.

Question 34 (2 marks) **Marks**

The experiment below is set up to measure the speed of light. As shown in the diagram, a light source creates a pulse of light which travels in two paths to a detector, one directly, and the other to a mirror that reflects the light back to the detector. The diagram is not to scale, and the paths of the light can be considered approximately parallel.



The detector is a photocell that converts the light into a photocurrent. The photocell can only record received signals, so there is no way to know on the graph when the pulse was sent. After the detector was set to record, the times at which the light from each path are received are shown in the graph below.



Estimate the speed of light obtained by this method.

$C = \frac{S}{t} = \frac{2^* \times 6}{(60-23)\times 10^{-9}} = 3.24 \times 10^{8}\ ms^{-1}$ 2

(ACCEPTED $3.2 \pm 0.1 \times 10^{8}\ ms^{-1}$)

* FORGOT the 2 : MAX 1

* CORRECT METHOD BUT MISREAD the TIME : MAX 1

2

Question 35 (5 marks) **Marks**

"The Physics that explains the operation of the induction motor is the same Physics that explains back emf in DC Motors."

With reference to the operation of both DC motors and induction motors, justify this statement.

Marks	Criteria
4-5	A logically presented answer that uses correct terminology to address the following points: • An explicit (or very heavily implied) justification that recognises that both phenomena involve Faraday's and Lenz's Laws / the concept of electromagnetic induction. • An outline of the operation of the DC motor, and an explanation for back emf in terms of electromagnetic induction. • An outline of the operation of the induction motor, that explains its rotation in terms of electromagnetic induction. *(The best answers in this category received 5 Marks)*
2-3	An answer that addresses most, but not all, of the points above:
1	An answer that: ***recognises the significance of electromagnetic induction*** in these two phenomena; **OR** provides an explanation for ***either back emf in an dc motor*** or ***rotation in an induction motor*** in terms of electromagnetic induction.

(In general, this question was well answered.)

Sample Answer:

"As explained below, both work on the following principles of Physics:

- Faraday's Law – a conductor experiencing a changing magnetic flux has a voltage induced across it, equal to the rate of change of flux.
- Lenz's Law – the current that flows as a result of an induced voltage creates a magnetic field, which interacts with the external magnetic field to oppose the change in flux creating it.

And so the statement is justified.

In a DC Motor, a current-carrying coil experiences a torque in an external magnetic field, via the motor effect. (A split ring commutator keeps the torque acting in a constant direction, so the coil rotates continuously.)

The rotating coil is a conductor experiencing a changing magnetic flux. Thus, by Faraday's Law, a voltage is induced across it. By Lenz's Law, the voltage acts in the opposite direction to the supply voltage: this is the back emf.

An induction coil consists of two main components: a conducting *rotor* within a *stator*, around which are wrapped several electromagnets. By turning the electromagnets on and off in sequence, the rotor experiences a rotating magnetic flux.

By Faraday's Law, this generates a voltage and thus eddy currents within the rotor.

By Lenz's Law, these eddy currents produce a magnetic field that opposes the changing flux. As a result, the rotor experiences a force, and begins to rotate, in the same direction as the magnetic field."

5

SECTION II: Part D (20 Marks)

CANDIDATE NUMBER							

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

Question 36 (2 marks) **Marks**

A spacecraft is travelling at 0.87c between Earth and Teegarden's Star, a distance of 12.51 lightyears from Earth's frame of reference.

Calculate the distance of the journey in the spacecraft's frame of reference.

$$L_v = L_0\sqrt{1-\frac{v^2}{c^2}}$$

$L_v = 12.51\sqrt{1-0.87^2}$ =6.168077035 or **6.2 light-years**

(some unnecessarily converted 1 light-year = 9.4607×10[15] m so answer is 5.8×10[16] m)

Criteria	Mark
Correct answers	2
Single mistake: Answer must still be a distance • Length contraction equation is wrong equation, but right data used. • Right equation but error in calculation like missing square/square root	1

2

Question 37 (3 marks)

A muon is an elementary particle which decays into an electron. When at rest the decay time of a muon is 2.2 μs, but when observed moving at a relativistic velocity its decay time is measured as 8.8 μs.

Explain how these muons provide evidence for Einstein's theory of special relativity and hence calculate the speed of the muons.

Explain: Relate cause and effect; make the relationships between things evident; provide why and/or how
Note: There is no mention of muons created in the atmosphere reaching the surface. You are just comparing two different decay times. Many answers are assuming information with no context that they should be explaining or excluding.

The question is asking you to show how the observation
- that muons decaying slower when moving

supports Einstein's special theory of relativity
- where he predicts that time dilation will occur as a consequence of his postulate that light will travel the same velocity in all inertial reference frames
- The moving muons are experiencing slower time (to external observer)
- Einstein's equation relates the time dilation to the speed, and it can be calculated using

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

$\left(\frac{t_0}{t_v}\right)^2 = 1-\frac{v^2}{c^2}$ and $\left(\frac{v}{c}\right)^2 = 1-\left(\frac{t_0}{t_v}\right)^2$ and $\frac{v}{c} = \sqrt{1-\left(\frac{t_0}{t_v}\right)^2} = \sqrt{1-\left(\frac{2.2}{8.8}\right)^2} = \sqrt{0.9375}$

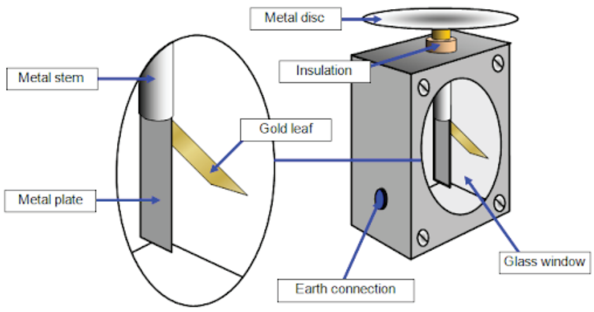
So $v = 0.9682458 37c$ or $v = 0.968c$ or $v = 290473751\ \mathrm{ms^{-1}}$ or $2.9\times10^8\mathrm{ms^{-1}}$

Criteria	Mark
Identify that the decay time difference is a prediction of Einstein and is therefore evidence for it (i.e. identifying it is because of time dilation). Must be more than what is given in question. AND A more detailed explanation directly stating what Einstein's prediction is (moving clocks run slower) and linking to how the moving muons will be observed (by external observer) to be experiencing less time (increasing decay time). Must be clear about which frame of reference or observer is being referred to. Better answer link this to consequences of postulates. AND Being able to correctly calculate the velocity using Einstein's time dilation equation	3
TWO of the above (i.e. not specifying slowing time of moving observer)	2
ONE of the above	1

3

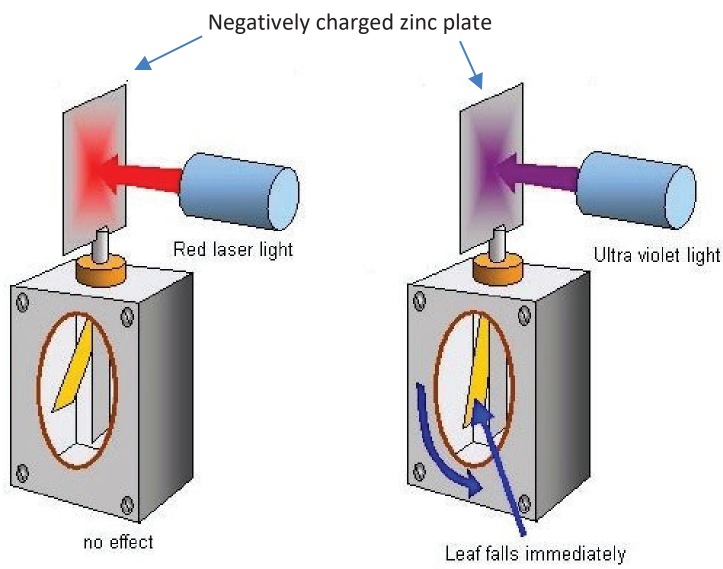
Question 38 (4 marks) **Marks**

A leaf electroscope is a device for measuring electrostatic charge. When an electroscope has a net charge on it the movable gold leaf swings outwards as it is repelled electrostatically from the stationary metal plate which contains the same charge.



A zinc plate is attached to the top of the electroscope and the electroscope is given a net negative charge; this puts the gold leaf is in an outward position. Two different coloured lights are shone on it separately.

As illustrated below, when red light is shone onto the zinc plate the gold leaf remains stationary and does not fall. When ultraviolet light is shone on the zinc plate, then the gold leaf falls immediately.



Question 38 continued on next page.

Question 38 continued

Marks

Explain the behaviour of the different coloured lights on the negatively charged electroscope.

4

Explain: Relate cause and effect; make the relationships between things evident; provide why and/or how
Answers must explain why the golf leaf drops when only UV light is shone on it.
Cause: Different coloured lights shone of negatively charged electroscope
Effect: The gold leaf falls for UV light. The gold leaf stays outwards for red light.

Explanation using relevant physics

According to Einstein's explanation of the photoelectric effect, light is comprised of individual photons with energy (hf) and when they hit an electron it receives all this energy. If the energy is greater that the workfunction of zinc (ϕ_{Zn}), which is the work energy required to move an electron away from zinc, then the electron can leave the metal with a kinetic energy given by: $K_{max} = hf - \phi_{Zn}$

The UV light has a shorter wavelength and hence is a higher energy photon ($\mathrm{E} = hf = \frac{hc}{\lambda}$) than the red light. For UV light to discharge the electroscope then the energy of the individual UV photons must be greater than the workfunction of zinc ($hf > \phi_{Zn}$) and the red photon energy is not

The gold leaf will fall if the negative charge on the electroscope is being neutralised and there is no longer an electrostatic repulsive force pushing it outwards. Negatively charged means an excess of electrons, so to become neutral (zero net charge) negative electrons are being removed.

Electrons are being removed from the electroscope by the photoelectric effect is where electrons are ejected from a metal when light is shone on it. This is occurring only for the UV light and not the Red light.

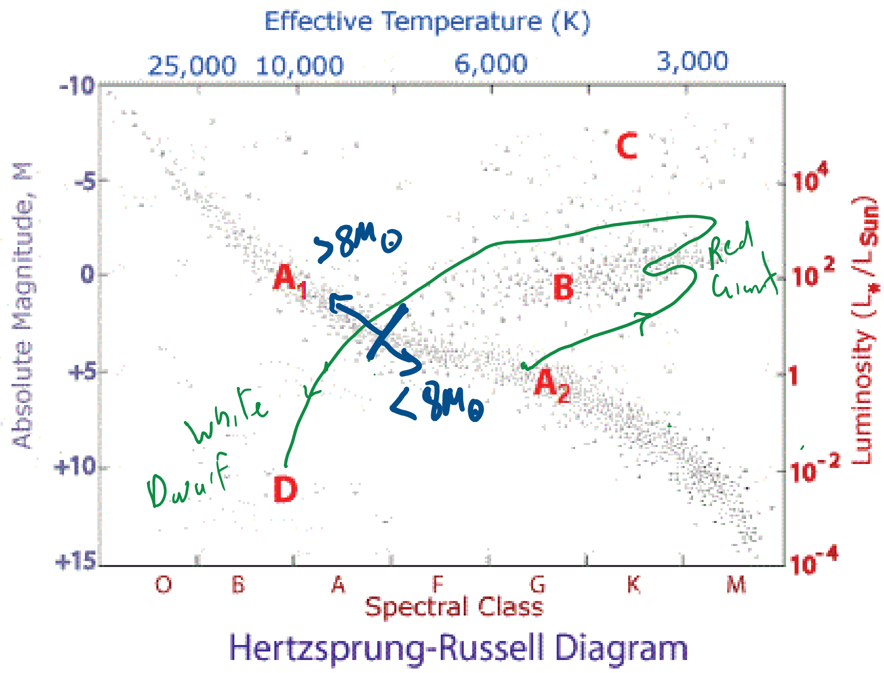
Criteria	Mark
Key elements required in an answer: A. Identifies and describes the photoelectric effect B. Identifies UV has higher photon energy than red light (E=hf). Einstein's photon model is necessary to explain why threshold frequency exists. Many answers indicate that it is just the light frequency that matters, but this fails to distinguish the classical theory and photon model. C. Linking Zn workfunction to why UV light emits electrons and not red light. This mark can also be given to explanations that simply state without explanation that there is a threshold frequency and UV is above and red is below this threshold frequency. D. Links electrons removed by UV reducing negative charge to why gold leaf falls (D1) (otherwise answer is not accounting for observation) AND links red to no change (D2)	4
THREE of the above	3
TWO of the above	2
ONE of the above or a relevant fact about the photoelectric effect	1

Commentary:
Overall, this question was answered quite well. If marked harder, like in the HSC, answers may have to make a better distinction of why the intensity of the red made no difference. I decided not to insist that workfunction be defined in answers. This generosity might not be given by HSC markers. Many addressed why the leaf fell 'immediately' as the photon giving all its energy up to the electron and there is no classical build-up of energy. No additional marks were given to this, but it would still be good to leave in an HSC answer.

Notes on bad terminology: The photoelectric effect is simply when electrons are emitted from a metal when light shines on it. The threshold frequency was an observation that was made about it. It is not part of the definition. Phrases like "The UV frequency overcomes the workfunction" is mixing and comparing apples and oranges physical properties. As is "the workfunction is the force required to overcome electrostatic attraction" – Workfunction is an energy, not a force.

Question 39 (5 marks) **Marks**

The following is a HR diagram with several groups of stars labelled.



(a) In the following table contains possible fusion reactions that can occur in stars.

p-p hydrogen fusion	CNO hydrogen fusion
$^1H + \ ^1H \rightarrow \ ^2H + e^+ + \nu_e$ $^2H + \ ^1H \rightarrow \ ^3He + \gamma$ $^3He + \ ^3He \rightarrow \ ^4He + 2\ ^1H$	$^{12}C + \ ^1H \rightarrow \ ^{13}N + \gamma$ $^{13}N \rightarrow \ ^{13}C + e^+ + \nu_e$ $^{13}C + \ ^1H \rightarrow \ ^{14}N + \gamma$ $^{14}N + \ ^1H \rightarrow \ ^{15}O + \gamma$ $^{15}O \rightarrow \ ^{15}N + e^+ + \nu_e$ $^{15}N + \ ^1H \rightarrow \ ^{12}C + \ ^4He$

Identify the region(s) where the following predominately occur in the core:

Key Terms

i. p-p hydrogen fusion

Region A_2 (less than 1.3 solar masses in main sequence)

Criteria	Mark
Identifies A2 (ignore B, C additions, wrong if A1 or D included)	1

1

ii. CNO hydrogen fusion

Region A_1 (greater than 1.3 solar masses in main sequence)

Criteria	Mark
Identifies A1 (ignore B, C additions wrong if D or A2 included)	1

1

Question 39 continued on next page.

(b) For a star starting in region A2, describe its movement in the HR diagram as it ages, linking this to the changes that are occurring inside it.

Most of stars in region A_2 are lower mass main sequence stars.

We are therefore looking at the evolutionary stages of stars with masses less than 8 solar masses.

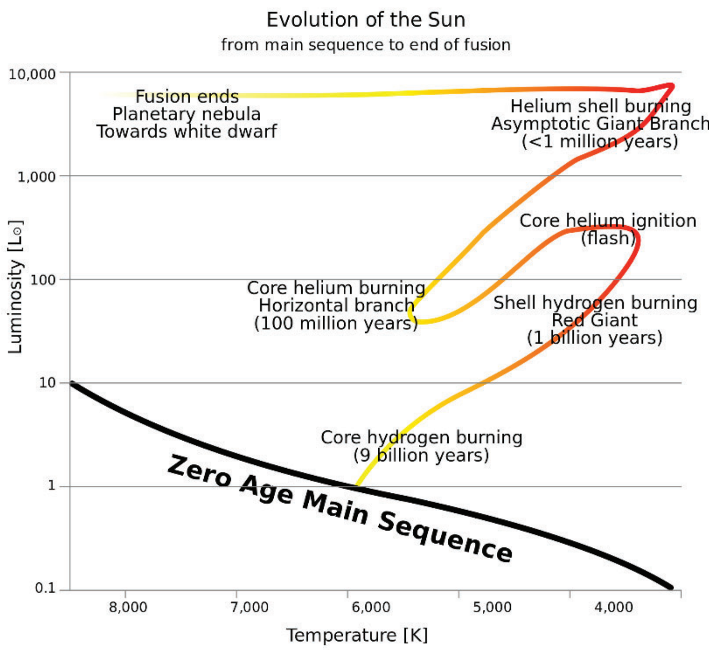
As a main sequence star in region A2 it eventually runs low of fuel (H→ He in core) and helium has built up in the core inhibiting the reaction. It expands, becoming more luminous, and the surface temperature falls (Red Giant in region B). H→ He burning continues in a shell and He in the core ignites producing other light elements (He→C). When this fuel is exhausted, fusion stops and it shrinks, becomes much less luminous, but with a higher surface temperature (White dwarf in Region D).

	Evolutionary Stage		
Region	A_2	B	D
Identify	**Main Sequence**	**Red Giant**	**White Dwarf**
Fusion	H→He (in core)	H→He (in shell) He→C (in core)	No Fusion
Reason for change		He builds up in core until it can no longer continue there, only occurring in shell around the core (outward pressure increases expanding the star)	Fuel can no longer continue burning Gravity collapses star to small size (after blowing off outer layer as a planetary nebula)
Change in HR position	There is some movement during main sequence (but stays in the region) Luminosity increases, Temperature decreases And the star moves up and to the right in the main sequence. https://cseligman.com/text/stars/sunms.htm	Larger radius More luminosity Lower surface temperature	Much smaller radius Small luminosity High surface temperature
Time in stage	Long time	Short time	Cooling over very long time

Some answers only talk about movement in main sequence. Which is a very limited interpretation of the star aging.
Too many think CNO progresses after p-p. CNO and p-p are both converting hydrogen to helium (CNO does not produce CNO). In main sequence both these processes occur in the core. At around 1.3-1.5 solar masses CNO is more predominant.
Many didn't identify the labelled regions in their answer. Many thought that the mass lost through fusion ($E=mc^2$) was significant to alter HR movement.

3

Criteria	Mark
Identifies correct sequence A2→B→D (naming labelled regions) AND Demonstrating a good understanding of all the fusion changes inside the star and how this changes luminosity/surface temp changes/size to explain its movement on HR diagram	3
Demonstrating some understanding of the changes in the HR diagram	2
Identifies correct sequence only OR can identifies some details	1



Do all main sequence stars become supergiant?
Supergiants can be defined as a specific phase in the evolutionary history of certain stars. Stars with initial masses above 8-10 M⊙ quickly and smoothly initiate helium core fusion after they have exhausted their hydrogen, and continue fusing heavier elements after helium exhaustion until they develop an iron core, at which point the core collapses to produce a Type 2 supernova.

What elements do Red Giants make?
Red giants start from 0.3–8 solar masses (M⊙) stars. Helium can fuse up to Carbon and Nitrogen

Do all supergiants form an iron core?
Once these massive stars leave the main sequence, their atmospheres inflate, and they are described as supergiants. Stars initially under 10 M⊙ will never form an iron core and in evolutionary terms do not become supergiants, although they can reach luminosities thousands of times the sun's. They cannot fuse carbon and heavier elements after the helium is exhausted, so they eventually just lose their outer layers, leaving the core of a white dwarf.

Does p-p and CNO determine evolutionary path?
The transition in a main sequence star from Predominately p-p to CNO is 1.3-1.5 M⊙. This does not directly relate to evolutionary path.

Question 40 (6 marks) **Marks**

Explain how the properties of stars can be determined from their spectra.

Explain requires underlying physics to be used to link an observation/measurement to star property. An explanation requires more than identifying or describing how the property is determined. Some physics must be included to explain the method to determine the stars property.

Star Property	Underlying Physics (Explain how it is determined)
Composition (C0-4)	Absorption spectrum. When white light is passed through a gas, specific **discrete** wavelengths of light are absorbed depending on the composition of the gas. Each element has a specific pattern of spectra lines (wavelengths of light that are absorbed) and if this pattern is found in the spectrum of the star, then the surface of the star contains that element. ▪ *Describes what absorption lines are in an absorption spectrum* ▪ *Explains that different elements have distinct absorption line patterns* ▪ *Describes how finding these patterns in stellar spectra determines composition*
Surface Temperature (T0-4)	Blackbody radiation Objects emit a **continuous** spectrum of light that depends on the temperature of the object. The wavelength where the peak intensity occurs can be used to calculate the surface temperature of the object (Wiens law $T = \frac{b}{\lambda_{max}}$). Stars are close to ideal blackbody radiators and by matching their spectra to a blackbody their surface temperature can be determined. *(Surface temperature can also be determined by spectral class – the Relative intensity of spectral lines can also be used based on the ionisation the elements at the stars surface)* ▪ *Describe what a blackbody spectrum is, and how it is a result of the objects temperature.* ▪ *Explain how it is used to determine the surface temperature of a star*
Surface density (D0-2) (also evolutionary stage in HR)	Spectral line broadening Stars with a higher density exhibit spectral broadening where the width (range of wavelengths) of absorption spectral lines is increased (from textbook The pressure of the gas from which the light originated has a subtle effect on the width of spectral lines as they are sensitive to the number of collisions the atoms are experiencing. The collisions tend to slightly increase or decrease the energy and hence wavelength of the emitted light) ▪ *Describe spectral broadening* ▪ *Descibe/Explains the link between broad lines to more surface density.* By combining information about luminosity and temperature, then evolutionary stage can also be determined
Radial velocity (V0-4)	Doppler Effect When light is emitted from a moving object then the frequency of the light is shifted. (the velocity is always constant according to Einstein's 2nd postulate). An approaching object emitting light is catching up to the light that it is emitting so the distance between waves is shorter (shorter wavelength, higher frequency means the light is shifted towards the blue). Conversely a receding object's light will be red-shifted. The amount of shift can be used to find the objects velocity. Spectral lines occur at fixed wavelengths, so if a characteristic pattern is found to be shifted from where it should be then the objects radial velocity can be determined (side-ways motion relative to the observer cannot be measured this way) ▪ *Explains the link between the Doppler effect of wavelengths of a spectrum from moving object becoming longer (red-shifted) if moving away and longer (blue-shifted) if approaching* ▪ *Describe how amount of shift (and velocity) can be measured from characteristic absorption lines*
Rotational Velocity (R0-2)	Spectral line broadening A rotating star will blue-shift the light from the side from side that is approaching and red-shift the light from the side receding. This has the effect of broadening the range of wavelengths that a spectral line will be measured. If light can be sampled from either side independently, then this is an easier measurement. ▪ *Explains how rotation leads to slightly blue or red-doppler shifts of the spectrum from approaching-receding sides* ▪ *Explains rotational velocity can be determined from spectral broadening (whole star spectrum) or 2 spectra from each side*
Others	
Distance/size (D/R)	Direct observation If a star is close enough then its distance can be determined by parallax. (this is from changing position, not from the spectra) Its size can be measured by direct measurement or how it eclipsed by another binary star or planets.
Luminosity (L0-2)	Radius and Temperature if radius is known, and temperature from blackbody then Stefan-Boltzmann law can be used $L \approx 4 \pi R^2 \sigma T^4$ Brightness and distance If distance can be known by other means (parallax) we can use brightness. Spectral Class and spectral line broadening Luminosity class can be determined from these factors (see diagram)
Miscellaneous (M0-1)	Most of these are inferences from other data Mass, radius, Fusion process (pp, CNO), star type HR diagram Some of these properties can be inferred from position on HR diagram and modelling.

6

Here is one outline of how some stellar properties are determined from Pearson Physics 12 textbook.

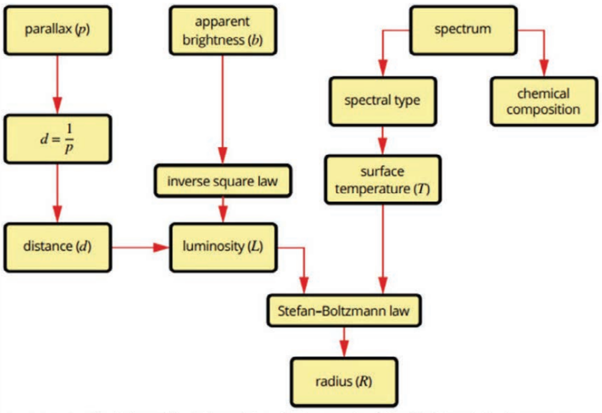
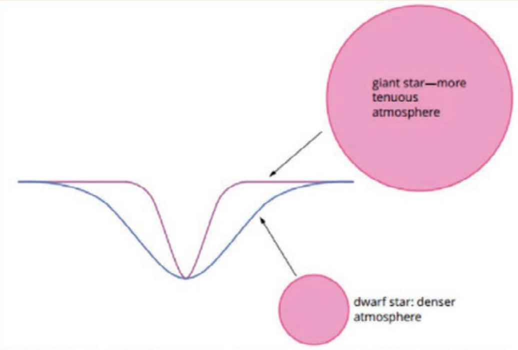


FIGURE 13.2.2 A mind map illustrating what particular aspects of stars' light can tell astronomers about a star.

Information about spectral broadening leading to estimation of luminosity.



13.2.6 The pressure in the atmosphere of a star is proportional to the broadening of the absorption lines seen in their spectra. The higher the pressure in the atmosphere, the more broadened the absorption lines are.

Known relationships between the amount of line broadening due to pressure and the luminosity of stars have led to a classification system using luminosity classes as shown in Figure 13.2.7. This system uses Roman numerals I to V. A numerical way of classifying a star from its spectral features then consists of its spectral class and luminosity class, e.g. our Sun has a spectral class G2 and a luminosity class V. This allows the position of the Sun to be located on the H–R diagram on both axes.

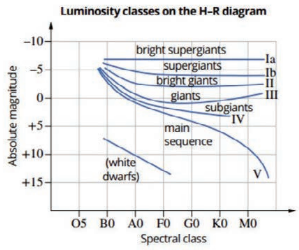


FIGURE 13.2.7 Luminosity class provides an estimation of the vertical position of a star on the H–R diagram when a direct measurement of luminosity is not available.

Criteria	Mark
Comprehensive explanation of at least 4 properties. Answers must be concise and contain no errors	6
Good explanation of at least 3 properties.	5
Sound explanation of at least 3 properties	4
Some explanation of at least 3 properties OR Sound explanation of at least 2 properties	3
Several properties identified but poorly explained OR One good explanation of 1 property	2
At least one method identified for determining a star's properties.	1

Commentary:

- Answers are identifying and describing the method, but not explaining the method of determining a star's properties.
- Marked close to HSC standards. However, we were probably more generous with 5-6 marks.
- Many are missing surface temperature for some reason. Also, assuming it is a blackbody with describing what that is or why a star can be modelled as one.
- Many answers try to address red/blue shift in stellar rotation before linear motion.
- Doppler shifting is the general term for both red and blue shifting. It can only measure radial or approaching and receding velocities. Not translational.
- Some answers describe red-shift only and link it to Hubble's Law, which is only used on galactic spectra.
- Many answers should have used the extra writing space and not tried to limit their answer to the space provided.
- Many answers misuse or cannot identify relevant terminology. Correct examples include: 'absorption spectral lines' or 'spectral line broadening', 'wavelength where maximum intensity is emitted'
- Stars have absorption spectral lines, not emission lines. Also, 'spectra' is not the same as a 'spectral line pattern'
- Many answers do not introduce/describe relevant terms and just assume the examiner 'knows' what they are talking about. The point is to demonstrate that you know what you are talking about and have not just remembering a keyword like spectral line, doppler shift, red-shift, black body radiation.