NAME: _____

VCE® PHYSICS

Units 3 & 4 Trial Written Examination

Reading time: 15 minutes
Writing time: 2 hours 30 minutes

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	18	18	110
			Total 130

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and Answer Book of 41 pages.
- Formula Sheet PROVIDED BY YOUR TEACHER.
- Answer Sheet for Multiple-Choice Questions.

Instructions
- Write your **student name** in the space provided above on this page and on the Multiple-Choice Answer Sheet.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the Answer Sheet around the outside of this book.
- You may keep the Formula Sheet.

Students are NOT permitted to bring into the examination room mobile phones and/or any other unauthorised electronic devices.

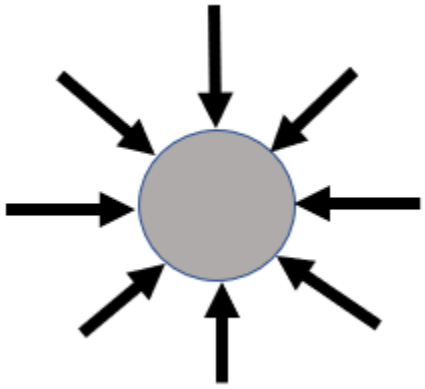
SECTION A – Multiple-Choice Questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for Multiple-Choice Questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1

The gravitational field surrounding a large planet is shown below.



The gravitational field would be described as:

A. dipolar, uniform and static.

B. dipolar, uniform and changing.

C. monopolar, non-uniform and changing.

D. monopolar, non-uniform and static.

Question 2

A charged particle of mass 6.6×10^{-27} kg enters a magnetic field of strength 0.02 T at a speed of 6.2×10^{6} m s^{-1} perpendicular to the field. The particle has a charge of 3.2×10^{-19} C.

The radius of the circular path that the charged particle will follow is closest to:

A. 5.4 cm

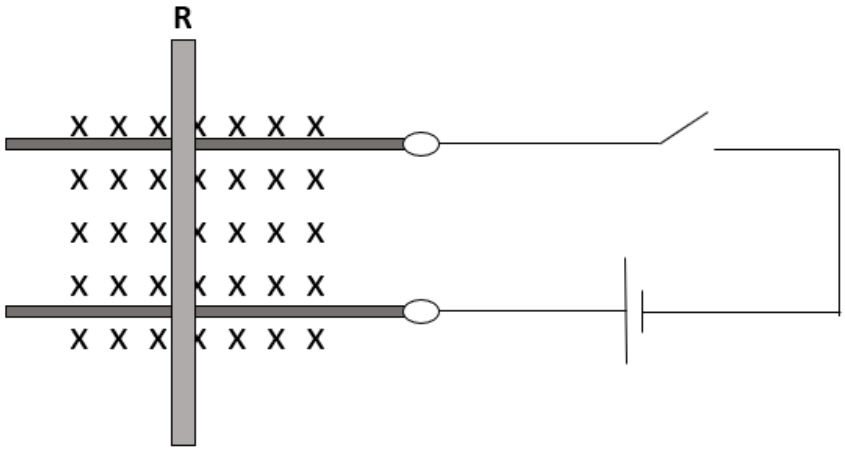
B. 3.2 m

C. 6.4 m

D. 8.5 m

Question 3

A copper rod (**R**) is placed on a pair of horizontal parallel copper rails as shown. It is free to roll along the horizontal rails. A magnet is placed under the copper rod to produce a magnetic field into the page. The diagram below shows the apparatus when viewed from above.



When the switch is closed, what will happen to the copper rod **R**?

A. It will roll to the left

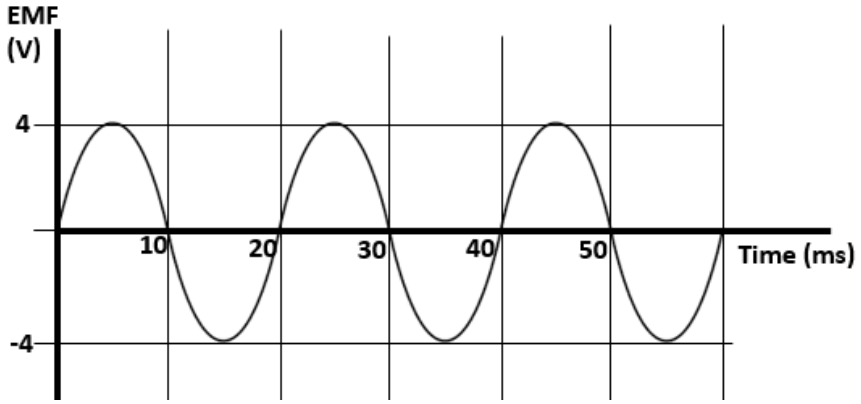
B. It will roll to the right

C. It will experience a force out of the page

D. It will experience a force into the page

Question 4

A generator produces the following EMF graph over time as the armature is rotated:



The rms voltage would be closest to

A. 2.2 V

B. 2.8 V

C. 4.0 V

D. 8.0 V

Question 5

An ideal transformer is operating with an input voltage of 24 V_{rms} and output of 72 V_{rms}. If there are 30 turns in the primary windings, how many turns are there in the secondary windings?

A. 8

B. 90

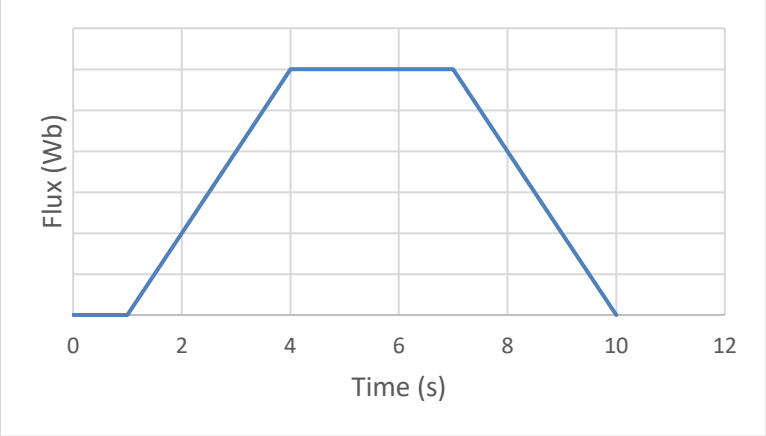
C. 72

D. 120

Question 6

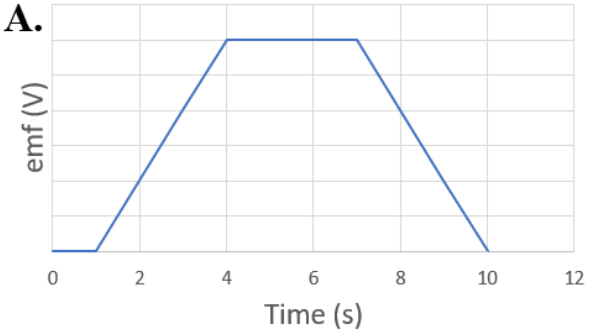
A square coil of wire enters a magnetic field at a constant speed with the plane of the coil perpendicular to the magnetic field.

The movement of the coil through the magnetic field produces the following flux over time graph:

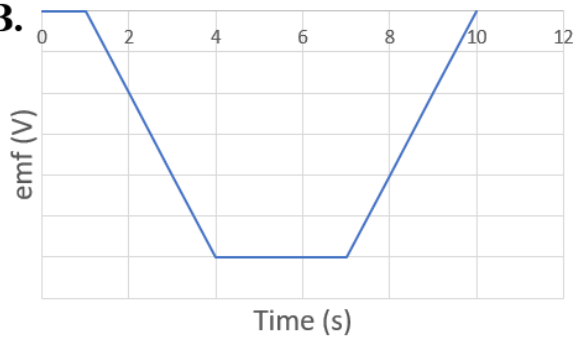


Which option below would be the corresponding emf over time graph?

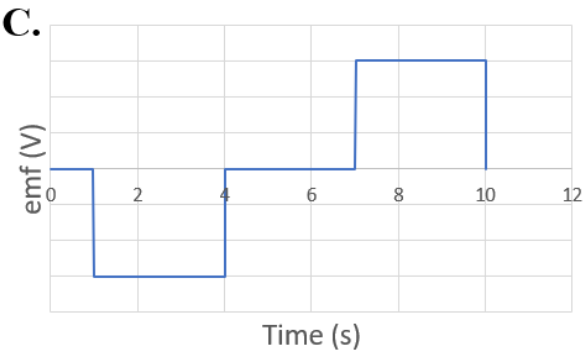
A.



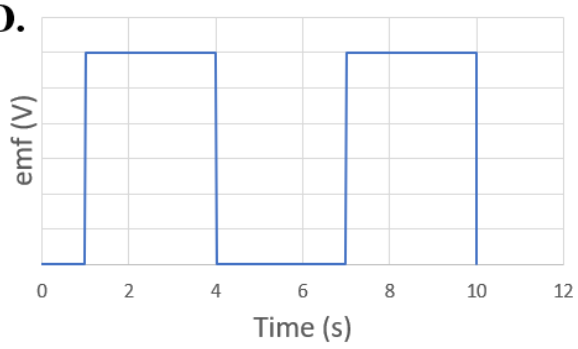
B.



C.

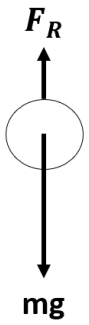


D.



Question 7

A ball of mass 'm' is falling vertically through the air. At a given point in time, the forces acting on the ball are as shown below.



Which expression is correct for the acceleration of the ball?

A. $a = o$

B. $a = mg$

C. $a = (mg - F_R)$

D. $a = \frac{(mg - F_R)}{m}$

Question 8

A game of totem tennis involves a tennis ball swinging on a rope from a central attachment at the top of a pole.

The 30 g tennis ball travels in a circular path of radius 0.8 m with a velocity of 1.3 m s^{-1}.

The net force acting on the tennis ball would be closest to

A. 6.3×10^{-2} N

B. 5.3×10^{-2} N

C. 6.2×10^{-4} N

D. 7.5×10^{-4} N

Question 9

A proton (mass =1.67×10^{-27} kg) is travelling at a speed of 0.7c which gives it a Lorentz factor of 1.4. The relativistic kinetic energy of the proton would be closest to

A. 4.0×10^{-28} J

B. 6.0×10^{-11} J

C. 8.0×10^{-8} J

D. 2.0×10^{-6} J

Question 10

A trolley is dragged 15 m along a horizontal surface by a constant horizontal force of 100 N. There is a 20 N frictional force between the trolley wheels and the surface. The total work done on the trolley is closest to

A. 1200 J

B. 1500 J

C. 1800 J

D. 2100 J

Question 11

Light emitted from a distant star has a wavelength of 500 nm. The star is moving away from Earth. As seen from Earth, the wavelength of the light would be:

A. Less than 500 nm

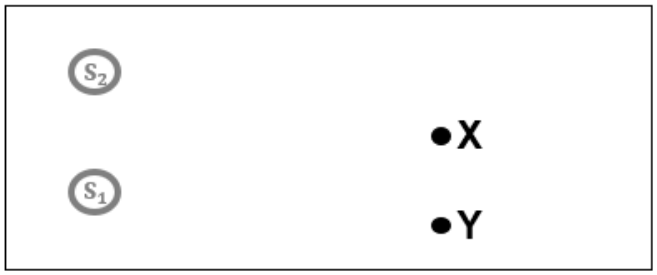
B. Exactly 500 nm

C. Greater than 500 nm

D. Depends on the colour of the light

Question 12

Two speakers (S_1 and S_2) are placed at one end of a room. They are both playing a constant sound at 200 Hz, producing sound waves with a wavelength of 1.7 m. Students stand at point X, equal distance from each speaker, and notice that the sound is quite loud. They move to point Y, and notice that the intensity of the sound decreases to a minimum. What is the difference in distance to speaker 1 compared to speaker 2 at point Y?



A. 25 cm

B. 40 cm

C. 85 cm

D. 170 cm

Question 13

A 20 cm string fixed at both ends is plucked, forming a standing wave at its fundamental frequency. The wavelength of the standing wave would be

A. 0.2 m

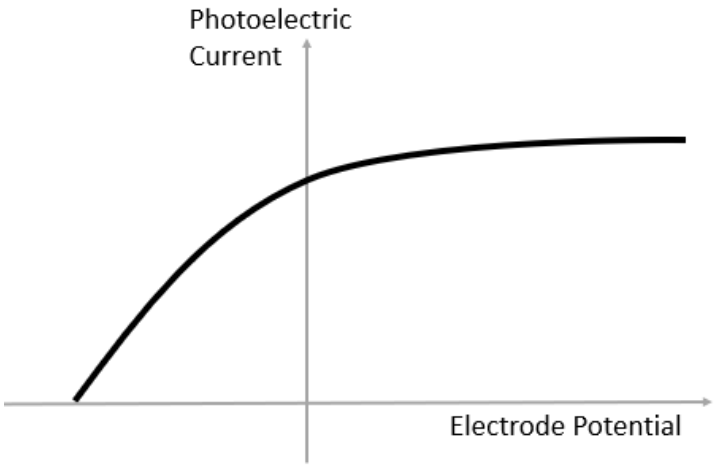
B. 0.4 m

C. 0.6 m

D. 0.8 m

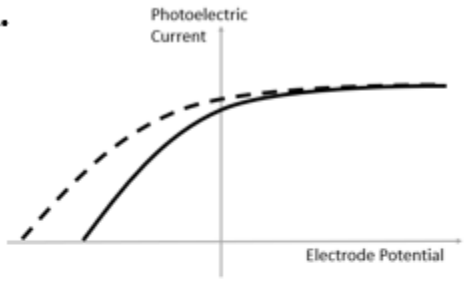
Question 14

The photoelectric current produced in the photoelectric effect was graphed at various electrode potentials. The graph is shown below:

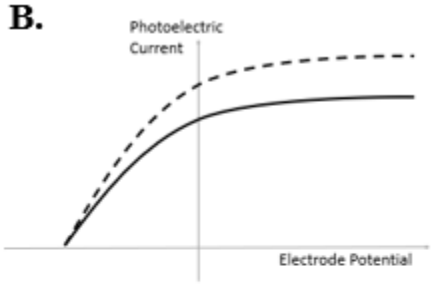


Which option below would show the new graph (dotted line) for incident light that had the same frequency, but increased intensity compared to the original (solid line)?

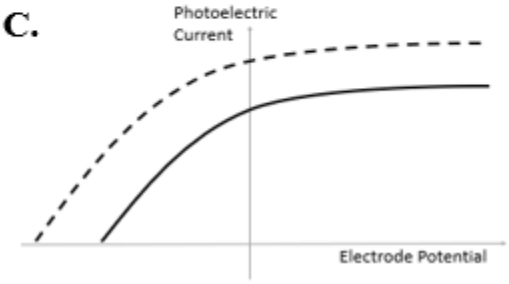
A.



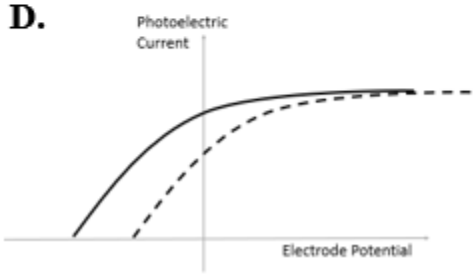
B.



C.



D.



Question 15

Electrons are travelling at a speed of 6.1×10^{7} m s^{-1}. The de Broglie wavelength of these electrons would be closest to

A. 3.4×10^{-19} m

B. 7.4×10^{-14} m

C. 2.5×10^{-11} m

D. 1.2×10^{-11} m

Question 16

Bohr's model of the atom states that electrons can exist only at specific energy levels and not in between. Which explanation below is most correct in explaining these specific energy levels?

A. Electrons have wave properties and can only exist when they form standing waves, which occurs when the circumference of the orbit is equal to a whole number of wavelengths.

B. Heisenberg's uncertainty principle states that electrons have a reduced uncertainty at specific locations, which makes them more stable.

C. Electrons can only absorb specific wavelengths of light and therefore can only exist at specific levels that correspond to each wavelength of light.

D. Polarisation of electrons proves that they have wave-like properties and move in a wave-like path in orbit around the nucleus.

Question 17

Light is produced from the acceleration of electrons from the force provided by magnetic fields. This produces light that has a high intensity and a wide range of possible wavelengths. The source of this light production is most likely

A. laser.

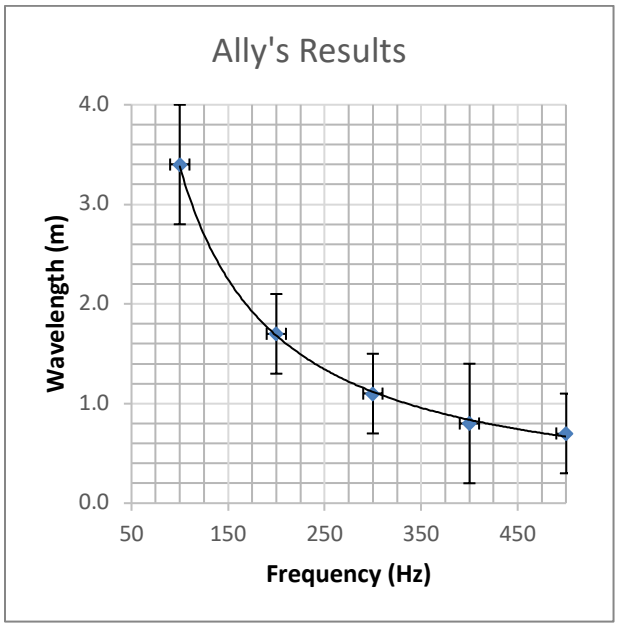
B. LED.

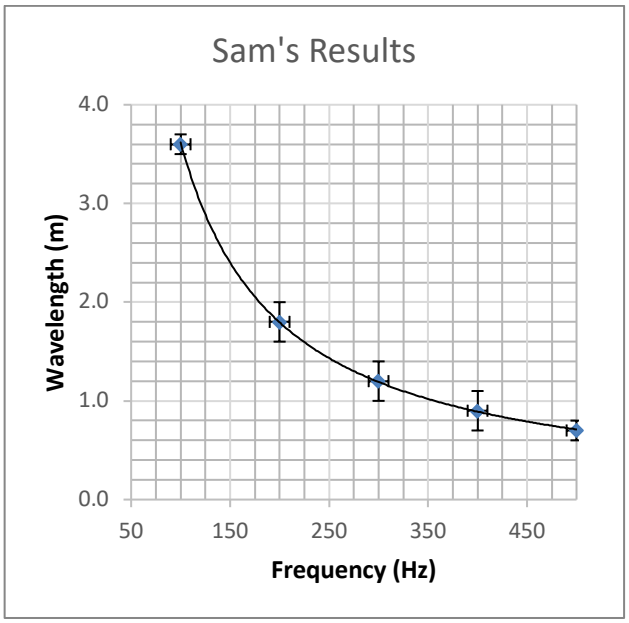
C. synchrotron.

D. incandescent light.

Questions 18 to 20 refer to the following information.

Students set up an experiment to measure the wavelength of sound waves through air at various frequencies. Using their data, the students were able to determine an experimental result for the speed of sound through air and compare it to the known value of 340 m s^{-1} under these conditions.





Ally's experimental speed of sound = 335 m s^{-1}

Sam's experimental speed of sound = 355 m s^{-1}

Question 18

Which row of the table below correctly identifies the variables in this experiment?

	Independent Variable	Dependent Variable	Controlled Variable
A.	Frequency	Velocity	Wavelength
B.	Wavelength	Velocity	Frequency
C.	Wavelength	Frequency	Velocity
D.	Frequency	Wavelength	Velocity

Question 19

The uncertainty value that Ally and Sam used for the frequency would be closest to

A. ± 1 Hz

B. ± 10 Hz

C. ± 25 Hz

D. ± 40 Hz

Question 20

Which description below most accurately describes the two sets of results?

A. Ally is more precise but less accurate

B. Sam is more precise but less accurate

C. Ally is more precise and accurate

D. Sam is more precise and accurate

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.
Write using blue or black pen.
Where an answer box is provided, write your final answer in the box. If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (6 marks)

Inside a nucleus, two protons are separated by a distance of 2.00×10^{-15} m. Each proton has a mass of 1.67×10^{-27} kg.

a. Calculate the gravitational force between the two protons. 2 marks

N

b. Calculate the electrostatic force between the two protons. 2 marks

N

c. On the diagram below, draw at least 4 field lines to show the electric field around the two protons. 2 marks

Question 2 (8 marks)

The image below shows two horizontal charged metal plates in a vacuum. Electrons travelling at a constant speed enter the space between the plates horizontally. They are deflected vertically.

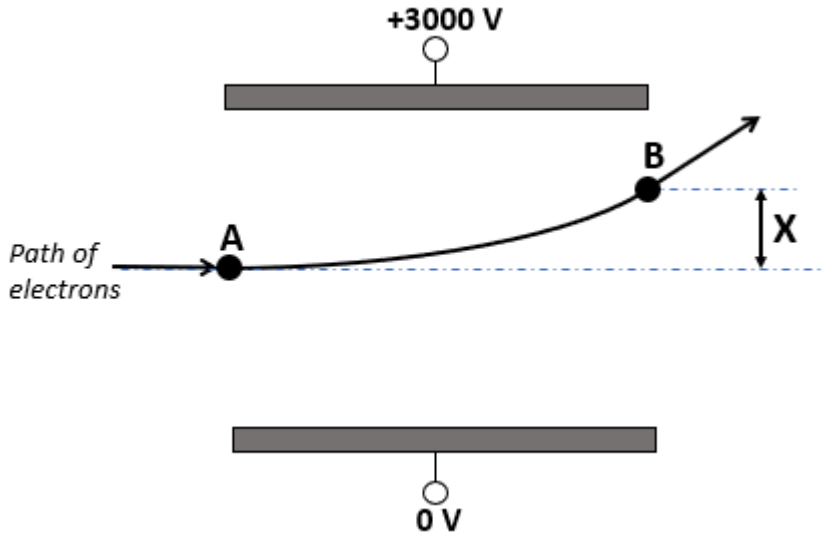


Diagram not to scale.

The potential difference between the plates is 3000 V. The distance between the plates is 10 cm. The initial speed of the electrons is 6.2×10^{7} m s^{-1}. The vertical deflection at the far end of the plates is labelled 'X'. Each plate has a length of 15 cm.

a. Show that the force acting on the electrons is 4.8×10^{-15} N vertically upwards. 1 mark

b. Calculate the acceleration of the electrons in the vertical direction. 2 marks

m s^{-2}

c. Calculate the value of 'X' (the vertical deflection of the electrons). Give your answer in cm.

3 marks

cm

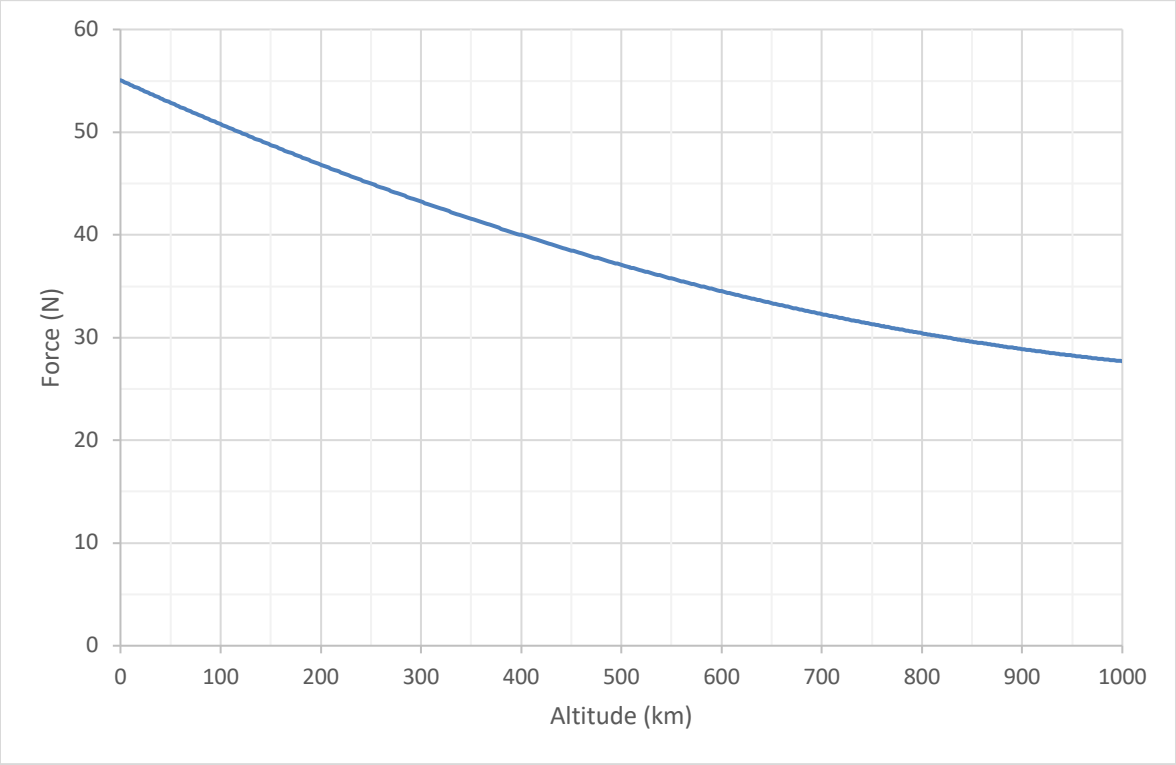
d. An electron exits the electric field and then enters a magnetic field of strength 3.3 mT with a velocity of 6.3×10^7 m s^{-1} perpendicular to the magnetic field.

Calculate the magnitude of the force acting on the electron. 2 marks

N

Question 3 (7 marks)

A 15 kg rock is travelling directly towards Mars. The following graph shows the gravitational force on the rock as a function of its altitude.



a. Calculate the value of 'g' at a distance of 400 km above the surface of Mars. Include an appropriate unit. 2 marks

	Unit:

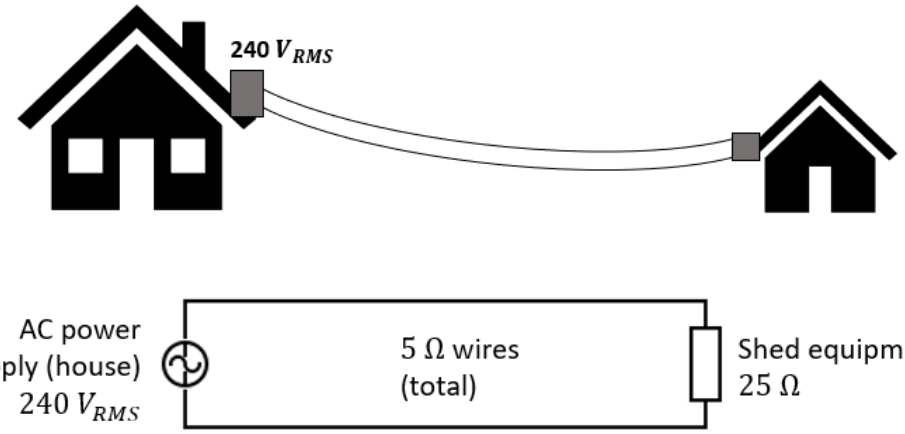
b. Calculate the change in potential energy as the rock moves from 800 km to 400 km above the surface of Mars. 2 marks

J

c. Identify if your answer to part (b) is an increase or decrease in gravitational potential energy. Explain how this does not violate the law of conservation of energy. 3 marks

Question 4 (8 marks)

A farmer is having troubles with the electricity supply to her shed at the back of her property. The shed contains equipment that is designed to operate at 240 V. The electrical circuit is set up as shown below:



The transmission wires have a total resistance of 5 Ω. The equipment in the shed has a total resistance of 25 Ω. The current flowing through the wires is 8A.

a. Calculate the total power loss that occurs over the transmission lines. 2 marks

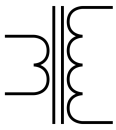
W

b. Calculate the power supplied to the shed. 2 marks

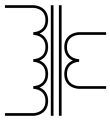
W

c. The farmer is aware that the equipment in the shed is not working as well as it should. She has access to two transformers: a 20:1 step-up transformer and a 1:20 step-down transformer. The farmer sets up the following circuit to increase the power supplied to the shed.

Symbols used:



1:20 Step-up transformer



20:1 Step-down transformer

Shed equipment

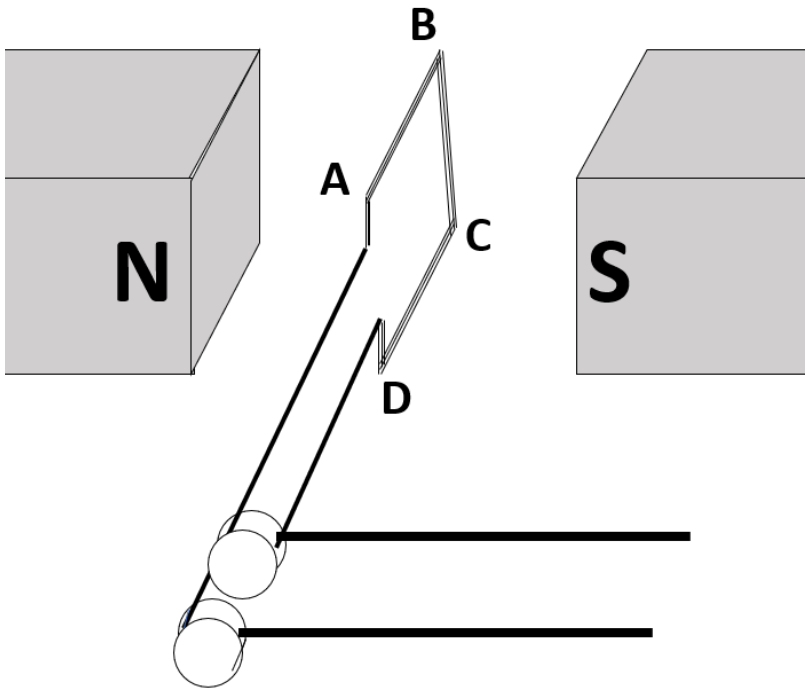
Explain why the new set up above improves the power supply to the shed. 3 marks

d. The farmer wants to connect the circuit to a large battery she has at the house, providing 240 V DC, while still utilising the transformers. Explain the problem with this arrangement.

1 mark

Question 5 (7 marks)

Students are investigating a simple alternator shown in the image below. The coil has 5 turns and is rotated at a frequency of 25 Hz. The magnets used provide a magnetic field of 0.04 T. The coil has dimensions of 10 cm x 15 cm.



a. Calculate the flux through the coils in the vertical position (where the plane of the coils are perpendicular to the magnetic field). 2 marks

Wb

b. Calculate the induced emf as the alternator coils are turned ¼ of a rotation clockwise as viewed from the position of the slip rings. 2 marks

V

c. In which direction is the induced current calculated in part (b): ABCD or DCBA? Justify your response. 3 marks

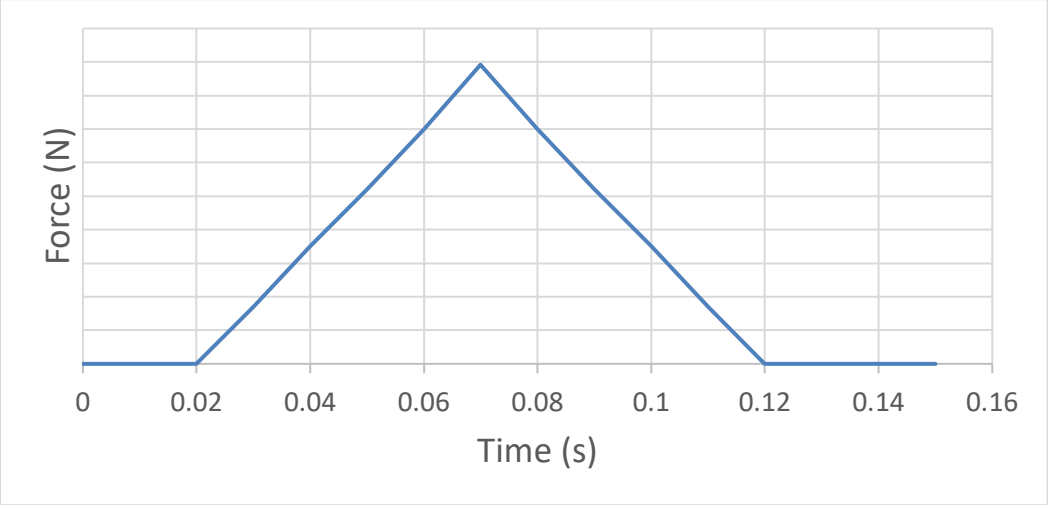
Question 6 (4 marks)

A ball of mass 0.15 kg is dropped 3 m vertically onto a hard surface. Just before it hits the ground the ball is travelling at 7.67 m s^{-1} and then it rebounds at 7.21 m s^{-1}.

a. Calculate the change in momentum of the ball during the impact with the ground. 2 marks

kg m s^{-1}

The contact between the ball and the ground is shown in the following force time graph.

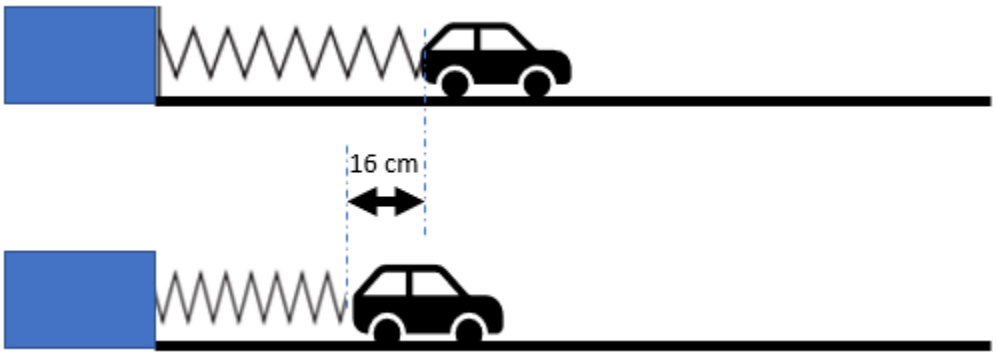


b. Calculate the maximum force applied to the ball during the collision. 2 marks

N

Question 7 (3 marks)

A 100 g toy car on a smooth horizontal track is pushed against the free end of a spring fixed to a wall. The spring is an ideal spring with a spring constant of 100 N m^{-1}. The spring compresses 16 cm and then the car is released. The car is pushed to the right until the spring reaches its original length, at which point the car continues forward on the friction free track.



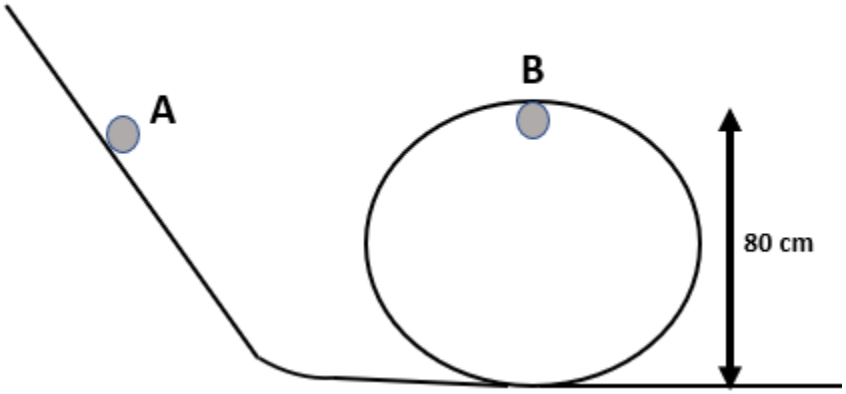
a. Show that the energy stored in the spring when it is compressed 16 cm is 1.28 J. 1 mark

b. Calculate the speed of the car as it leaves the spring. 2 marks

$m\ s^{-1}$

Question 8 (5 marks)

A 20 g marble travels on a marble track that has been set up as shown. The marble is released at the top of the ramp before travelling around a vertical loop. The marble is shown in two locations: point A and point B.



a. Draw and label the forces acting on the marble at point A. 2 marks

b. The marble reaches a speed of 1.6 m/s at the top of the loop. Will it be able to maintain contact with the loop and continue on the track? Justify your response. 3 marks

Question 9 (7 marks)

Amelia is travelling on a rocket towards Earth at a constant speed of 0.8c as shown. Amelia sends a signal via radio waves to her support team on Earth.

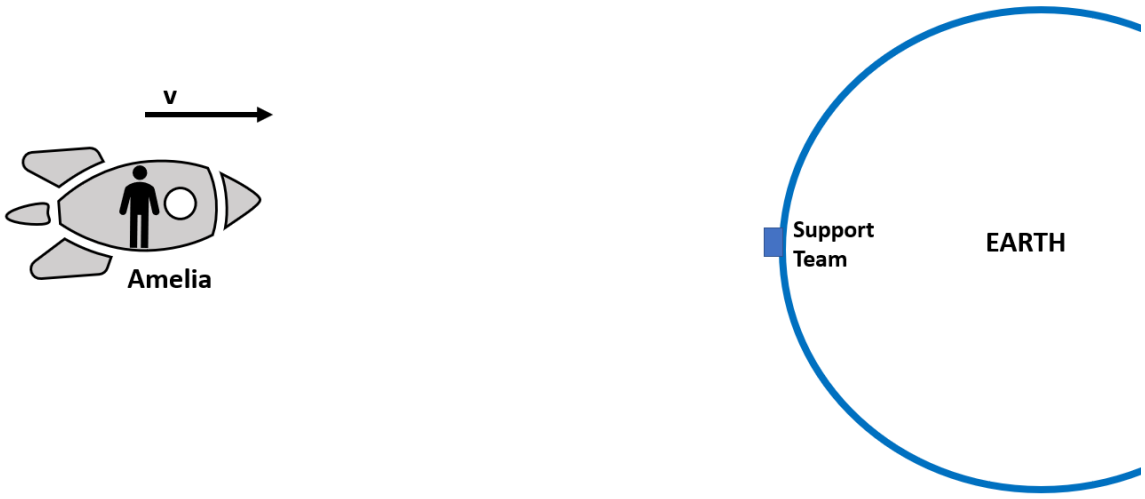


Diagram not to scale.

a. Will the support team on Earth measure the radio waves travelling at approximately 3×10^8 m s^{-1}, faster than 3×10^8 m s^{-1} or slower than 3×10^8 m s^{-1} towards them? Circle your answer below and provide a reason for your choice, referring to the appropriate postulate. 2 marks

3×10^8 m s^{-1} **Faster than 3×10^8 m s^{-1}** **Slower than 3×10^8 m s^{-1}**

b. Explain how classical physics would differ in its answer to **a.** 2 marks

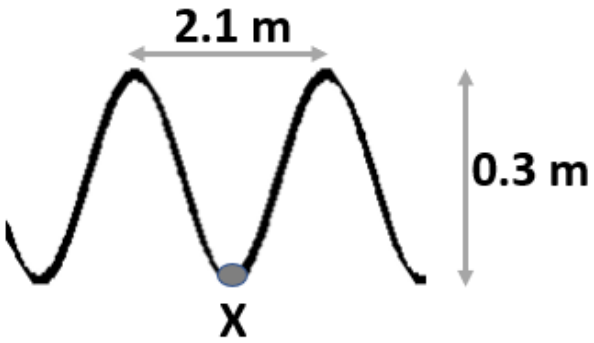
c. Amelia refuels on Earth and sets off on a journey to Pluto. She travels at the same speed of 0.8c to Pluto a distance of 5.2×10^9 km as measured by Earth. The journey will take 6.0 hours as measured by her support team on Earth.

Calculate the duration of the trip for Amelia. 3 marks

hrs

Question 10 (5 marks)

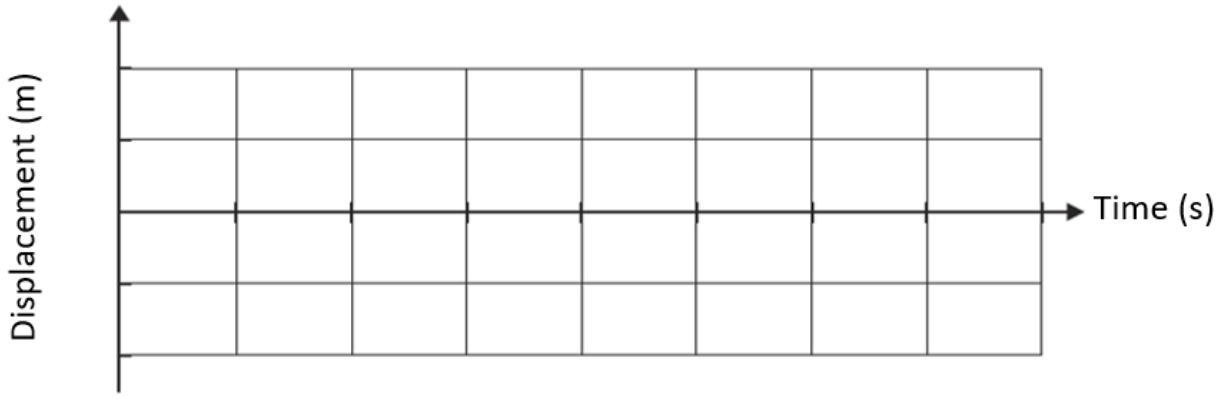
Water waves are produced by an oscillating source and travel out in all directions. The oscillating source moves up and down 2 times each second. The transverse wave travelling through the water is shown below.



a. Calculate the speed of the wave. 2 marks

$\mathrm{m\ s^{-1}}$

b. On the axis below, sketch the displacement-time graph for point X, starting from its position on the trough. Show at least 2 cycles and include a scale on each axis. 3 marks



Question 11 (6 marks)

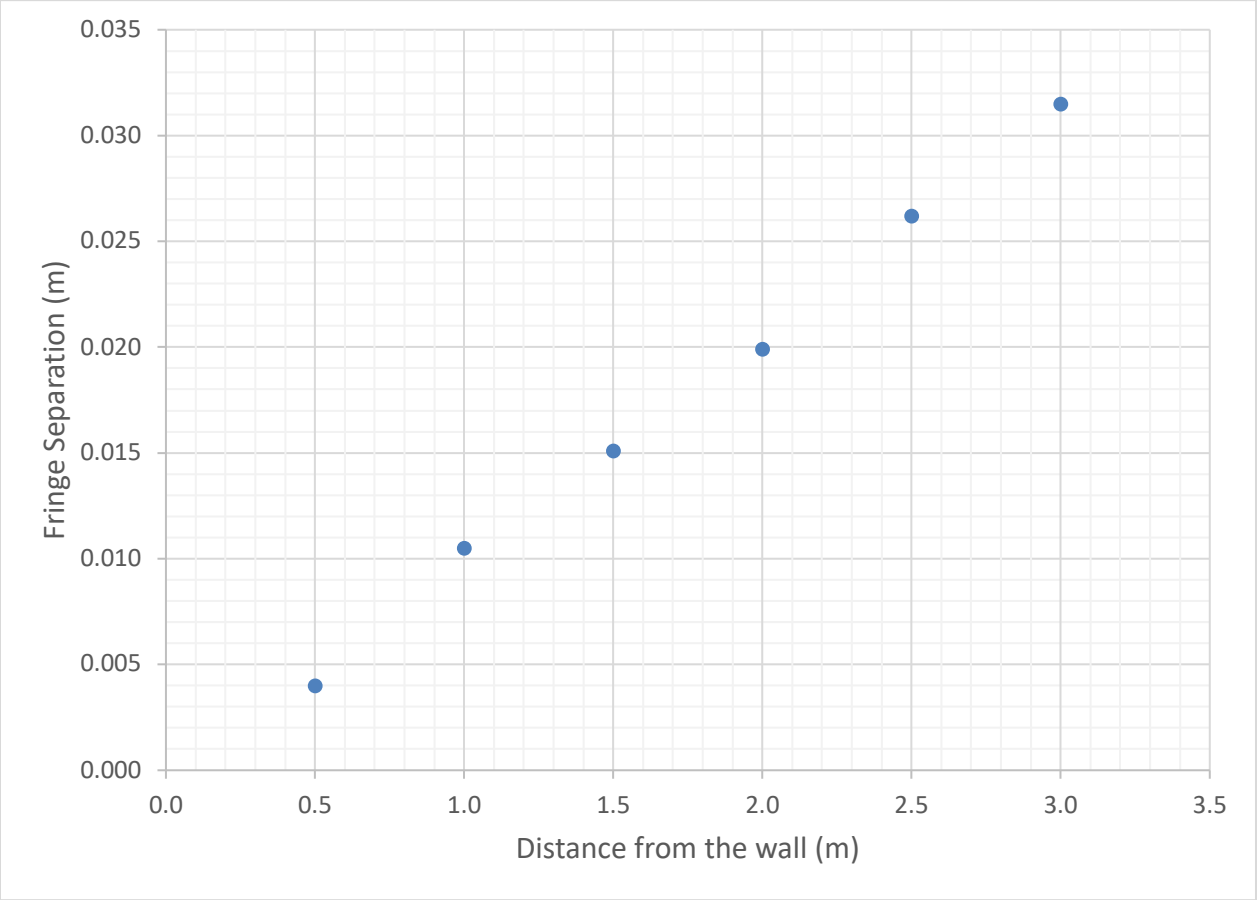
William and Mace are discussing the nature of light. William tells Mace that light behaves as a wave. Mace says he is wrong and tells William that light behaves as a stream of particles.

a. Explain why William is correct, including reference to an experiment that supports his idea.
3 marks

b. Explain why Mace is correct, including reference to an experiment that supports his idea.
3 marks

Question 12 (9 marks)

Students conducted a double slit experiment using a laser light and a double slit with the two slits 5×10^{-5} m apart. They moved the double slit different distances away from the wall and measured the distance between adjacent light bands. They obtained the following data:



a. The students estimated their uncertainty for the fringe separation measurements to be $\pm$ 1 mm. Add uncertainty bars to the 1st, 3rd, and last points. 1 mark

b. Add a straight line of best fit to the graph 1 mark

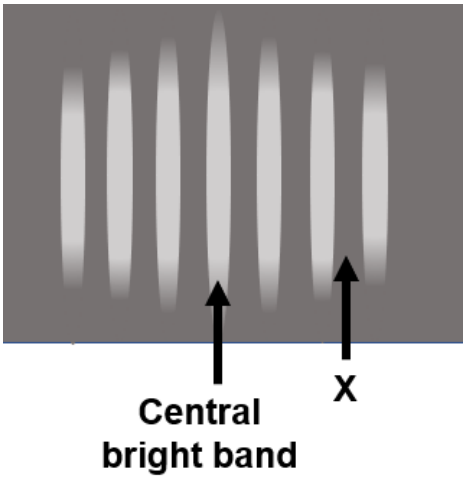
c. Calculate the gradient of the line of best fit. 2 marks

d. Show that the gradient is equal to $\frac{c}{fd}$. 1 mark

e. Use this information to determine the frequency of the light used in the experiment. 2 marks

Hz

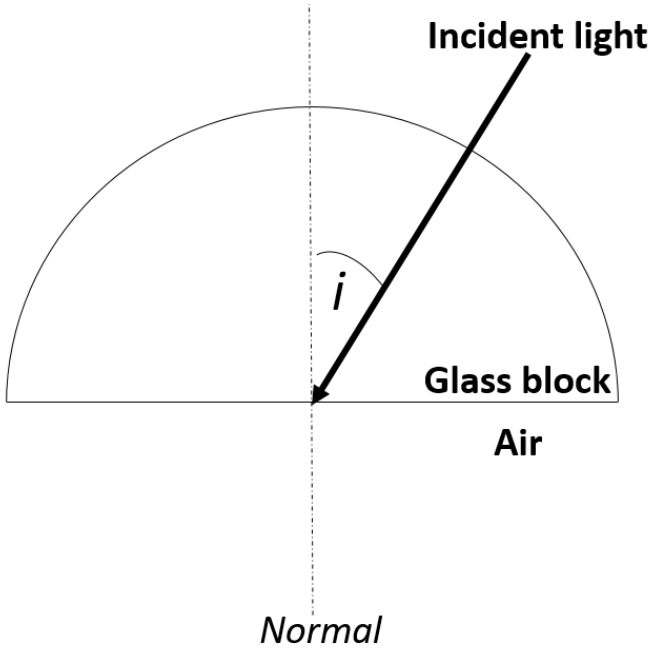
f. The central light band is equal distance from each slit. Calculate the path difference for the dark band marked 'X' in the diagram below. 2 marks



m

Question 13 (9 marks)

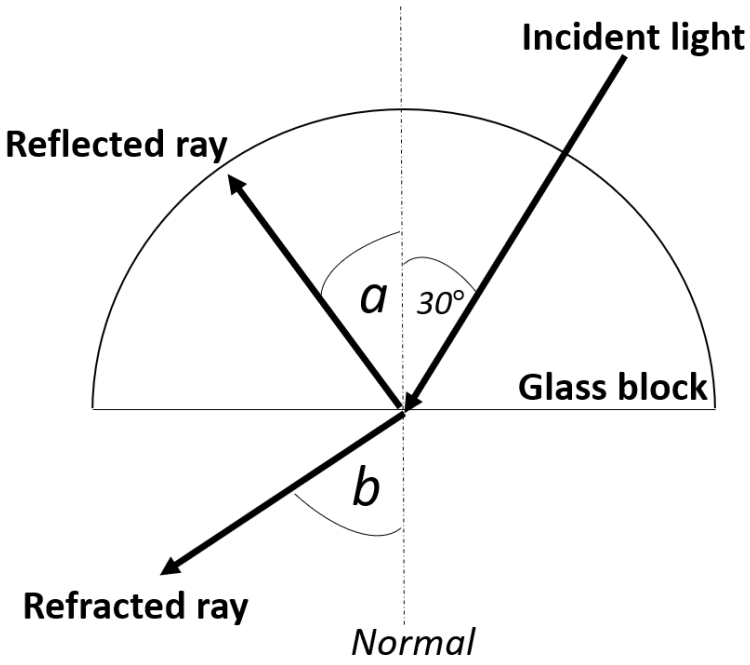
Students investigate light travelling from glass (n=1.53) into air (n=1.00) using a red laser light ($\lambda = 690$ nm) and a semicircular glass block.



a. Calculate the speed of the red light through the glass. 2 marks

m s^{-1}

b. The image below shows the path of the red light through the glass block and out into the air at an angle of incidence of 30°.



Calculate the angles 'a' and 'b'. Show your working for part ii. and give each answer to 2 significant figures.

i. a = _____ 1 mark

ii. _____

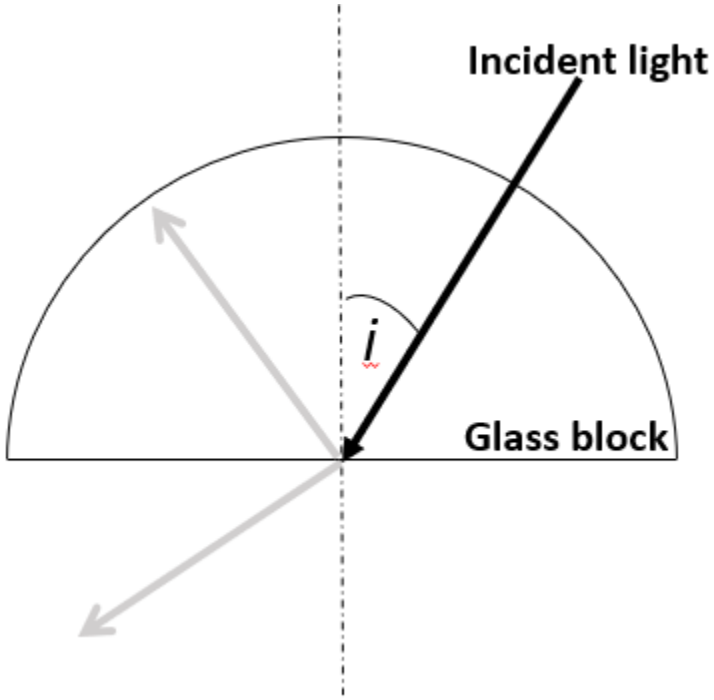
_____

_____

b = _____ 2 marks

c. The angle of incidence is increased from 30° to 60°. Will light still pass from the glass into the air? Justify your response. 2 marks

d. The process is repeated using blue light instead of red light. On the image below, sketch the refracted and reflected rays of the blue light. The original red light arrows are shown in light grey as a guide. 2 marks



Question 14 (2 marks)

While spending a day out on a boat, it is recommended to wear sunglasses that are polarised. These types of glasses reduce the intensity of the sunlight coming into the eye which in turn reduces the amount of damage to the retina at the back of the eye.

Explain how polarised sunglasses are able to reduce the intensity of the light coming into the eye. You may include a diagram in your answer.

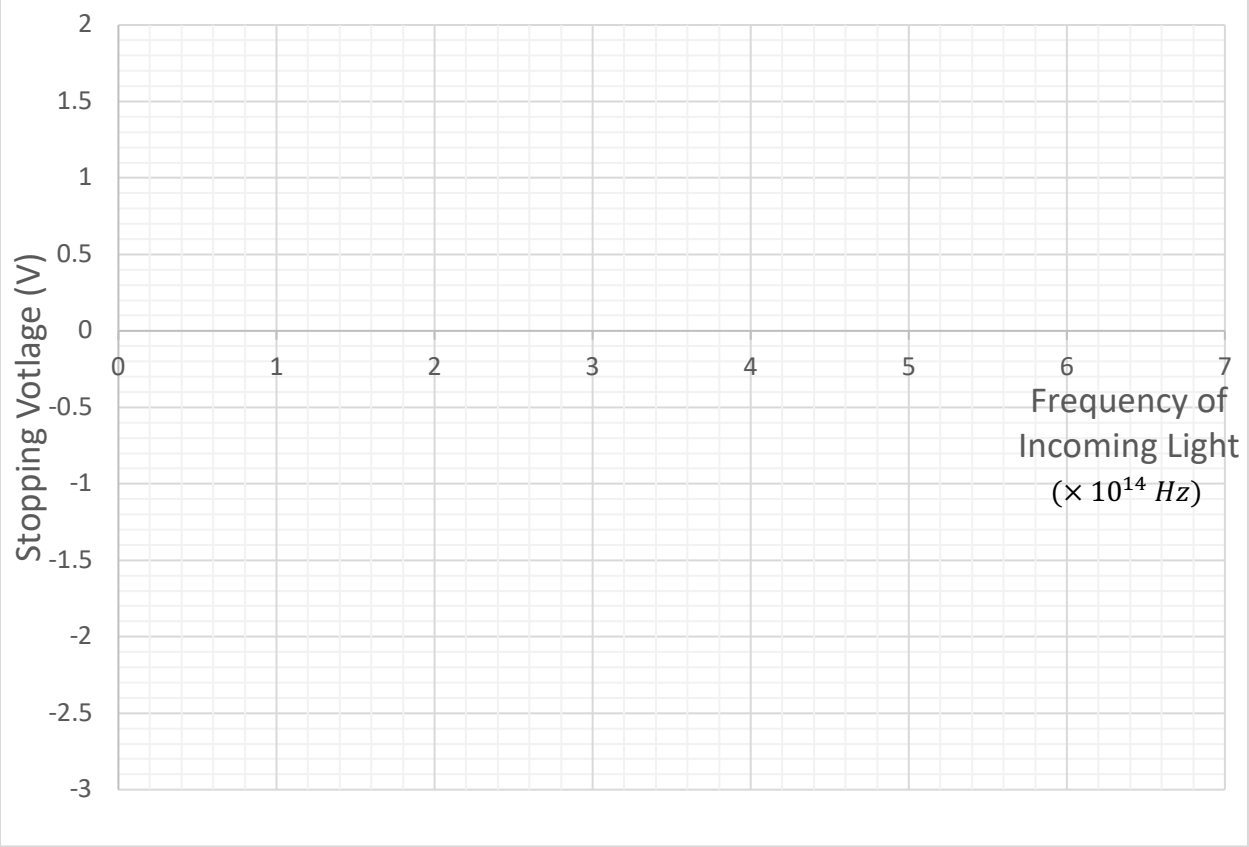
Question 15 (8 marks)

Students investigate the photoelectric effect using a photoelectric apparatus. They increased the frequency of the incoming incident light and measured the stopping voltage. Their results are shown in the table below:

Frequency of incoming light ($\times 10^{14}\ Hz$)	Stopping voltage (V)
6.25	1.05
5.74	0.75
5.15	0.43
4.89	0.26
4.55	0.13

a. Write a suitable hypothesis for this experiment. Give an explanation for your chosen hypothesis. 3 marks

b. Graph the students' data. 3 marks



c. Extrapolate the line of best fit to find the y intercept. Explain the significance of this point.
2 marks

Question 16 (3 marks)

A photoelectric effect experiment was completed with a metal that has a work function of 1.9 eV. Light from a laser of wavelength 410 nm is incident on the metal, causing photoemission of electrons.

Calculate the maximum kinetic energy of the electrons emitted in Joules.

J

Question 17 (8 marks)

A crystalline sample can be analysed using electron diffraction. The electrons are accelerated to a known speed using an accelerating voltage and then passed through a sample, forming a circular diffraction pattern on a fluorescent screen.

a. Explain how de Broglie would explain the light and dark rings produced on the fluorescent screen. 2 marks

b. Show that the speed of the electrons from an accelerating voltage of 1000 V is 1.9×10^7 m s^{-1}. 1 mark

c. If X-rays are used instead of the electrons and produce a diffraction pattern with the same spacing between light and dark bands, calculate the wavelength of the X-rays used.

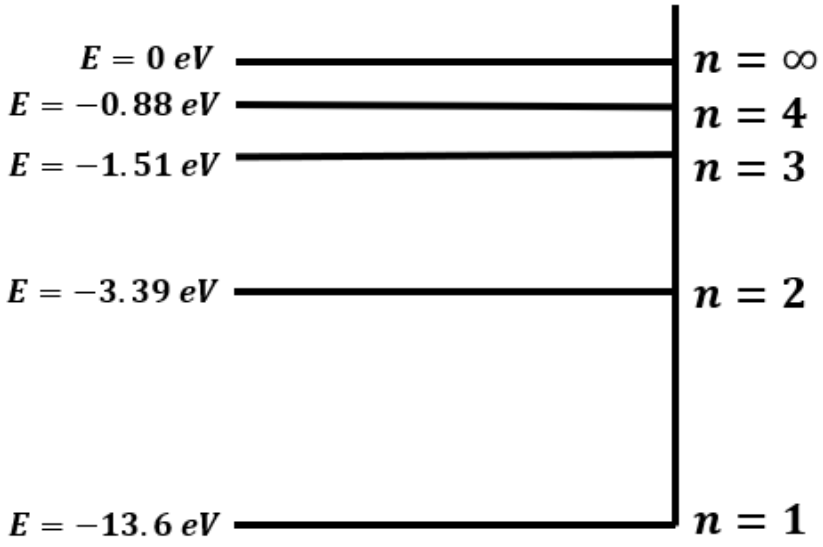
2 marks

m

d. Explain the effect that increasing the accelerating voltage would have on the diffraction pattern. Justify your response. 3 marks

Question 18 (5 marks)

The energy level diagram for the hydrogen atom is shown below.



a. A photon collides with a hydrogen atom in the ground state. An electron transitions from the ground state (n=1) to the n=3 energy level due to this collision. Calculate the wavelength of the photon involved in the collision. 2 marks

m

b. A photon of energy 0.63 eV is ejected from the nucleus. Draw an arrow to show the electron transition that would cause this photon emission. 1 mark

c. A photon of energy 9.6 eV collides with the hydrogen atom in the ground state. Describe the results of this collision. Justify your response. 2 marks

END OF EXAMINATION

VCE Physics **NAME:** _____

Section A: Multiple-Choice Answer Sheet

For each Multiple-Choice Question, shade letter of your choice.

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

VCE® Physics

Unit 3 and 4 Trial Written Examination

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Solution Pathway

FORMULA & DATA SHEET

This is available from the site below and must be provided to students.

http://www.vcaa.vic.edu.au/Documents/exams/physics/physics-formula-w.pdf

Below are sample answers. Please consider the merit of alternative responses.

SECTION A: Multiple Choice (20 marks)

Question	Answer	Explanation (if required)
Question 1	**D**	All gravitational fields are monopolar, non-uniform and static.
Question 2	**C**	$r = \frac{mv}{qB} = \frac{(6.6 \times 10^{-27})(6.2 \times 10^{6})}{(3.2 \times 10^{-19})(0.02)} = 6.4\ m$
Question 3	**A**	Using the right-hand slap rule, the current flows upwards, the magnetic field is into the page, the force is to the left.
Question 4	**B**	$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{4}{\sqrt{2}} = 2.8\ V$
Question 5	**B**	$\frac{N_1}{N_2} = \frac{V_1}{V_2}$ $\frac{30}{N_2} = \frac{24}{72}$ $N_2 = 90$
Question 6	**C**	The flux changes at a constant rate from 1-4 seconds, indicating there will be a constant induced EMF. From 7-10 seconds there will also be a constant induced EMF but in the opposite direction. Therefore, C is the only graph which would show the induced EMF.
Question 7	**D**	$a = \frac{F_{net}}{m} = \frac{mg - F_R}{m}$
Question 8	**A**	$F_{Net} = F_C = \frac{(mv^2)}{r} = \frac{(0.03)(1.3^2)}{0.8} = 6.3 \times 10^{-2}\ N$
Question 9	**B**	$E_k = (\gamma - 1)mc^2$ $= (1.4 - 1)(1.67 \times 10^{-27})((3 \times 10^8)^2)$ $= 6.01 \times 10^{-11}$ J
Question 10	**A**	$W = Fs = (100 - 20)(15) = 1200$ J
Question 11	**C**	Doppler effect. Light from a source moving away from the Earth would have an increased wavelength.
Question 12	**C**	Path difference = $\left(n - \frac{1}{2}\right)\lambda = \left(1 - \frac{1}{2}\right)(1.7)$ $= 0.85\ m = 85\ cm$
Question 13	**B**	At the fundamental frequency the length of the string is half the wavelength. Wavelength= $(2)(0.2) = 0.4\ m$

Question 14	**B**	The same frequency indicates the same stopping voltage (x intercept). The increased intensity would give an increased current. Therefore, B would be the corresponding graph.
Question 15	**D**	$\lambda = \frac{h}{mv}$ $\lambda = \frac{6.63 \times 10^{-34}}{(9.1 \times 10^{-31})(6.1 \times 10^{7})}$ $\lambda = 1.2 \times 10^{-11}$ m
Question 16	**A**	The energy levels in an atom are explained by the concept of standing waves, where electrons can only exist in locations where the circumference of the orbit is a whole number of wavelengths.
Question 17	**C**	Synchrotron light is the only source that meets all the requirements for production, intensity and wide range of wavelengths.
Question 18	**D**	The independent variable is changes in the experiment (frequency), the dependent variable is measured (wavelength) and the controlled variable is constant (velocity).
Question 19	**B**	This is observed from the graph. The uncertainty bars are less than 1 square (less than 25) but able to be seen and so larger than 1.
Question 20	**B**	Sam has smaller uncertainty bars so we would say they were more precise. Sam's final speed is further away from the true value, so we would say they were less accurate.

SECTION B (110 marks)

Question 1 (6 marks)

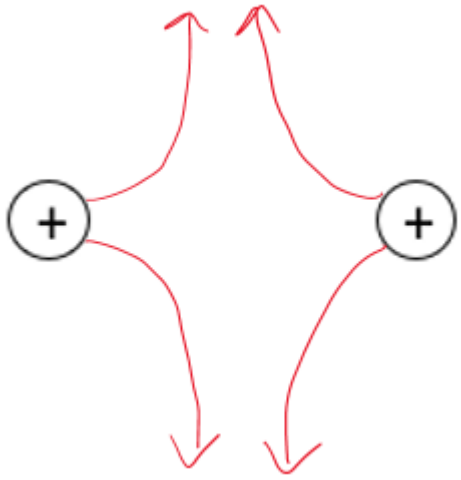
a. $F_G = \frac{GM_1M_2}{r^2} = \frac{(6.67\times10^{-11})(1.67\times10^{-27})^2}{(2\times10^{-15})^2} = 4.65 \times 10^{-35} N$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. $F_E = \frac{kQ_1Q_2}{r^2} = \frac{(8.99\times10^{9})(1.6\times10^{-19})^2}{(2\times10^{-15})^2} = 57.5\ N$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. *Diagram below*



- **1 mark** is awarded for arrows pointing towards both positive charges.
- **1 mark** is awarded for correct field interaction – lines never touching or crossing, no field lines directly in the middle in between the two charges.

Question 2 (8 marks)

a. $F = qE = \frac{qV}{d}$

$F = \frac{(1.6\times10^{-19})(3000)}{0.1} = 4.8 \times 10^{15}\ N$ upwards

- **1 mark** is awarded for correct working.

b. $a = \frac{F}{m} = \frac{4.8\times10^{-15}}{9.1\times10^{-31}} = 5.3 \times 10^{15}\ m\ s^{-2}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. Horizontally, $t = \frac{s}{u} = \frac{0.15}{6.2\times10^{7}} = 2.4 \times 10^{-9}\ s$

Vertically: $a = 5.3 \times 10^{15}\ m\ s^{-2}\ ,\ t = 2.4 \times 10^{-9}\ s,\ \ s = ?\ \ u = o$

$s = ut + \frac{1}{2}at^2 = (0) + \left(\frac{1}{2}\right)(5.3 \times 10^{15})\left(2.4 \times 10^{-9}\right)^2$

$= 1.53 \times 10^{-2}\ m$

$= 1.53\ cm$

- **1 mark** is awarded for correct time to cross from one side to the other.
- **1 mark** is awarded for correct working vertically.
- **1 mark** is awarded for correct final answer in cm.

d. $F = qvB = (1.6 \times 10^{-19})(6.3 \times 10^{7})(3.3 \times 10^{-3}) = 3.3 \times 10^{-14}\ N$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

Question 3 (7 marks)

a. $F = mg$
$F\ from\ graph = 40,\ \ m = 15kg$
$g = \frac{F}{m} = \frac{40}{15} = 2.7\ N\ kg^{-1}\ (or\ m\ s^{-2})$

- **1 mark** is awarded for correct answer.
- **1 mark** is awarded for correct unit.

b. Area = 55 squares = (55) (50000)(5)$= 1.4 \times 10^{7}\ J$

OR
$Area$ =rectangle + triangle
$=(400000 \times 30) + \left(\frac{1}{2} \times 400000 \times 10\right)$
$= 1.4 \times 10^{7}\ J$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. *Losing height so a decrease in gravitational potential energy. Converted into kinetic energy so total energy remains the same an no change in total energy, therefore obeying the law of conservation of energy.*

- **1 mark** is awarded for identifying that the gravitational potential energy decreases.
- **1 mark** is awarded for identifying that gravitational potential energy has been converted into kinetic energy.
- **1 mark** is awarded for identifying that total energy has remained the same.

Question 4 (8 marks)

a. $P_{loss} = I^2R = (8^2)(5) = 320\ W$

- **1 mark** is awarded for correct answer.
- **1 mark** is awarded for correct unit.

b. $P_{athouse} = VI = (240)(8) = 1920\ W$
$P_{atshed} = 1920 - 320 = 1600\ W$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. *The step-up transformer increases the voltage running through the wires which decreases the current for the same amount of power. This decreases the power loss in the transmission wires as $P_{loss} = I^2R$. The step-down transformer at the end allows the shed to access closer to 240 V.*

- **1 mark** is awarded for identifying that the transformer increases voltage and decreases current.
- **1 mark** is awarded for identifying that the reduced current decreases power loss as per $P_{loss} = I^2R$
- **1 mark** is awarded for reference to the role of the step-down transformer at the end.

d. *Transformers only work with AC power, not DC so this battery cannot be used.*

- **1 mark** is awarded for identifying that DC will not work with transformers.

Question 5 (7 marks)

a. $\phi = BA = (0.04)(0.1)(0.15) = 6 \times 10^{-4}\ Wb$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. $EMF = N\frac{\Delta\phi}{\Delta t}$

Time for ¼ rotation $= \frac{\frac{1}{25}}{4} = 0.01\ s$

$$EMF = \frac{(5)(6 \times 10^{-4})}{0.01} = 0.3\ V$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. *The current will flow DCBA. Lenz's law states that the induced current will act in a direction to oppose the change that caused it. As the coil turns, the flux decreases through the coil to the right. To oppose this, the current needs to induce a flux to the right.*

- **1 mark** is awarded for identifying Lenz's law.
- **1 mark** is awarded for identifying the change (decrease in flux into the coil to the right) and opposite (increase flux into the coil to the right).
- **1 mark** is awarded for correct direction of current.

Question 6 (4 marks)

a. $\Delta p = m(v - u) = (0.15)(7.21 - -7.67) = 2.23\ kg\ m\ s^{-1}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. Area under graph = change in momentum = 2.23$=\frac{1}{2}bh = \frac{1}{2}(0.1)(F_{max})$

$F_{Max} = 44.6\ N$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

Question 7 (3 marks)

a. $E = \frac{1}{2}kx^2 = \left(\frac{1}{2}\right)(100)(0.16^2) = 1.28\,J$

- **1 mark** is awarded for correct working.

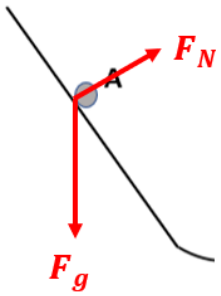
b. $E_k = 1.28 = \frac{1}{2}mv^2 \qquad 1.28 = \left(\frac{1}{2}\right)(0.1)(v^2)$

$v = 5.06\,m\,s^{-1}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

Question 8 (5 marks)

a. *Forces labelled as per diagram below:*



- **1 mark** is awarded for correct force due to gravity (or weight) acting straight downwards.
- **1 mark** is awarded for the normal force acting perpendicular to the surface.

b. $Minimum\ speed = \sqrt{gr} = \sqrt{(9.8)(0.4)} = 1.98\ m\ s^{-1}$

This is greater than the speed that the marble has at the top of the loop.

Therefore, no it will not maintain contact.

OR

Find normal force at top of loop

$F_c = \frac{(mv^2)}{r} = \frac{(0.02)(1.6^2)}{0.4} = 0.128$

$F_c = mg + N$

$0.128 = (0.02)(9.8) + N$

$N = -0.068\ N$

The normal force required is negative which is not possible.

Therefore, no it will not maintain contact.

- **1 mark** is awarded for correct working and calculation of minimum speed at the top of the loop OR normal force.
- **1 mark** is awarded for correct explanation as to what this means.
- **1 mark** is awarded for the conclusion that the marble will not maintain contact with the track.

Question 9 (7 marks)

a. $3 \times 10^8\ m\ s^{-1}$

Einstein's second postulate states that the speed of light is constant independent of the motion of the source or the observer.

- **1 mark** is awarded for circling the correct option for the speed.
- **1 mark** is awarded for a description of Einstein's second postulate.

b. *Classical physics would say that the speed observed by Earth would be greater than* 3×10^8 m s^{-1}. *The motion of the rocket would be added onto the speed of light, so the speed relative to Earth would be a combination of both.*

- **1 mark** is awarded for correctly identifying that classical physics would say there was an increase in the speed of light.
- **1 mark** is awarded for reference to motion relative to Earth.

c. *Lorentz factor* $= \frac{1}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}} = \frac{1}{\sqrt{1-0.8^2}} = 1.7$

From Earth: Proper length $(5.2 \times 10^9\ km)$ *Dilated time (6.0 hours)*

From Amelia: Proper time $t = t_0\gamma \quad 6 = t_0(1.7) \quad t_0 = 3.5\ hours$

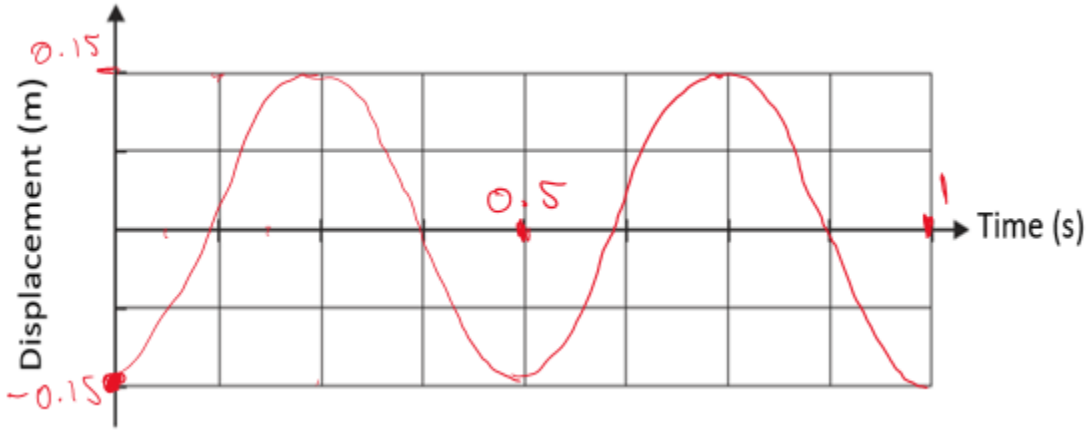
- **1 mark** is awarded for correct Lorentz factor calculation.
- **1 mark** is awarded for identifying that Amelia will observe proper time.
- **1 mark** is awarded for correct answer.

Question 10 (5 marks)

a. $v = f\lambda = (2)(2.1) = 4.2\ m\ s^{-1}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. *Graph as per below:*



- **1 mark** is awarded for correct shape of the graph.
- **1 mark** is awarded for the wave matching the correct scale on the x axis.
- **1 mark** is awarded for the wave matching the correct scale on the y axis.

Question 11 (6 marks)

a. *Light is a wave. Young's double slit experiment shows that light travelling through 2 slits produces an interference pattern after passing through the slits. If light was a stream of particles than it would produce two light spots directly behind the slits and not an interference pattern. Interference is only a property of waves and not of particles.*

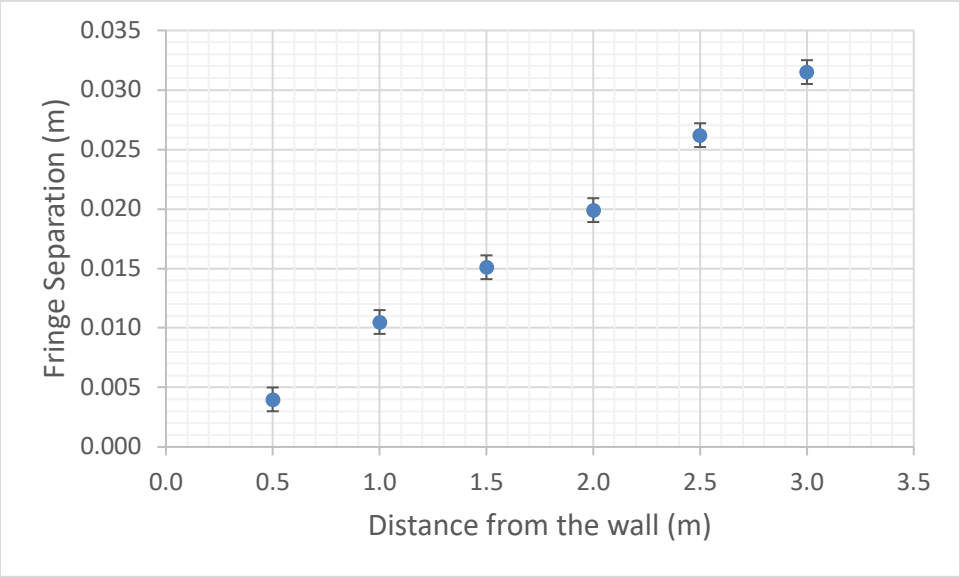
- **1 mark** is awarded for reference to Young's double slit experiment.
- **1 mark** is awarded for an explanation of the experimental results.
- **1 mark** is awarded for an explanation of wave properties and not particle properties shown in the experiment.

b. *Light is a stream of particles. In the photoelectric effect experiment, increasing the intensity of the light has no effect on the energy of the emitted electrons. If light was a wave, increasing the intensity would increase the energy of the wave which would be passed onto the electrons. As a particle, the light passes on its energy dependent on the frequency (wavelength) of the light only.*

- **1 mark** is awarded for reference to photoelectric effect experiment.
- **1 mark** is awarded for an explanation of the experimental results.
- **1 mark** is awarded for an explanation of particle properties and not wave properties shown in the experiment.

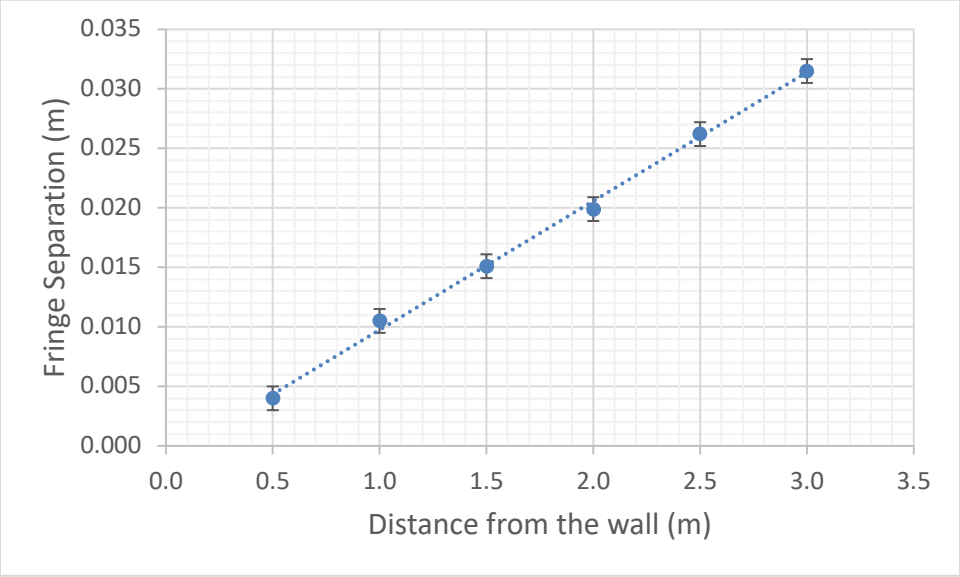
Question 12 (9 marks)

a. *Uncertainty bars as per graph below:*



- **1 mark** is awarded for correct uncertainty bars (on the 1st, 3rd, and last points). No marks lost for adding in extra uncertainty bars.

b. *Line of best fit as shown below:*



- **1 mark** is awarded for correct line of best fit.

c. *Gradient*$= \frac{Rise}{Run}$

$$= \frac{0.031 - 0.005}{3 - 0.5} = 0.01$$

- **1 mark** is awarded for correct working using points on the line of best fit
- **1 mark** is awarded for correct answer within acceptable range.

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

$$\lambda = \frac{c}{f}$$

$$\Delta x = \frac{cL}{df} = \left(\frac{c}{fd}\right) L$$

This is in the form of $y = mx$ with the gradient $=\left(\frac{c}{fd}\right)$

- **1 mark** is awarded for correct working.

e. *Gradient*$= 0.01 = \frac{c}{fd}$

$$0.01 = \frac{(3 \times 10^8)}{(f)(5 \times 10^{-5})}$$

$$f = 6.0 \times 10^{14}\ Hz$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer (accepting consequential errors from gradient calculation).

f. *Path difference* $= \left(n - \frac{1}{2}\right)\lambda$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{6.0 \times 10^{14}} = 5 \times 10^{-7}\ m$$

3rd dark band, so n=3

Path difference $= \left(3 - \frac{1}{2}\right) 5 \times 10^{-7} = 1.25 \times 10^{-6}\ m$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer (accepting consequential errors from frequency calculation).

Question 13 (9 marks)

a. $n_1 v_1 = n_2 v_2$

$(1)(3 \times 10^8) = (1.53)(v_2)$

$v_2 = 1.96 \times 10^8\ m\ s^{-1}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. *Angles:*

i. a=30°

- **1 mark** is awarded for correct angle for 'a'.

ii. b=50°

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

$(1.53)\sin(30) = (1)\sin(\theta_2)$

$\theta_2 = 50°$

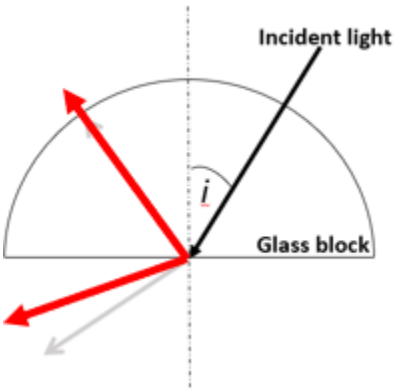
- **1 mark** is awarded for correct angle for 'b'.
- **1 mark** is awarded for correct working to calculate 'b'

c. $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.53}\right) = 40.8°$

Therefore, the angle of refraction will increase until the angle of incidence is 40.8° *at which point no more light will make it into the air. It will be totally internally reflected.*

- **1 mark** is awarded for correct calculation of critical angle.
- **1 mark** is awarded for total internal reflection that will occur above an angle of incidence of 40.8 °

d. *Lines as per image below:*



- **1 mark** is awarded for correct reflected ray (same as original for red light).
- **1 mark** is awarded for correct refracted ray (refracted more than the red light).

Question 14 (2 marks)

Polarised sunglasses have a filter that blocks all transverse waves that are not aligned with the filter. This reduces the amount of light that makes it through the glasses which reduces the intensity of light and therefore the damage to the retina.

- **1 mark** is awarded for appropriately reference to transverse waves.
- **1 mark** is awarded for correctly linking the axis of the filter to block a portion of the light.

Question 15 (8 marks)

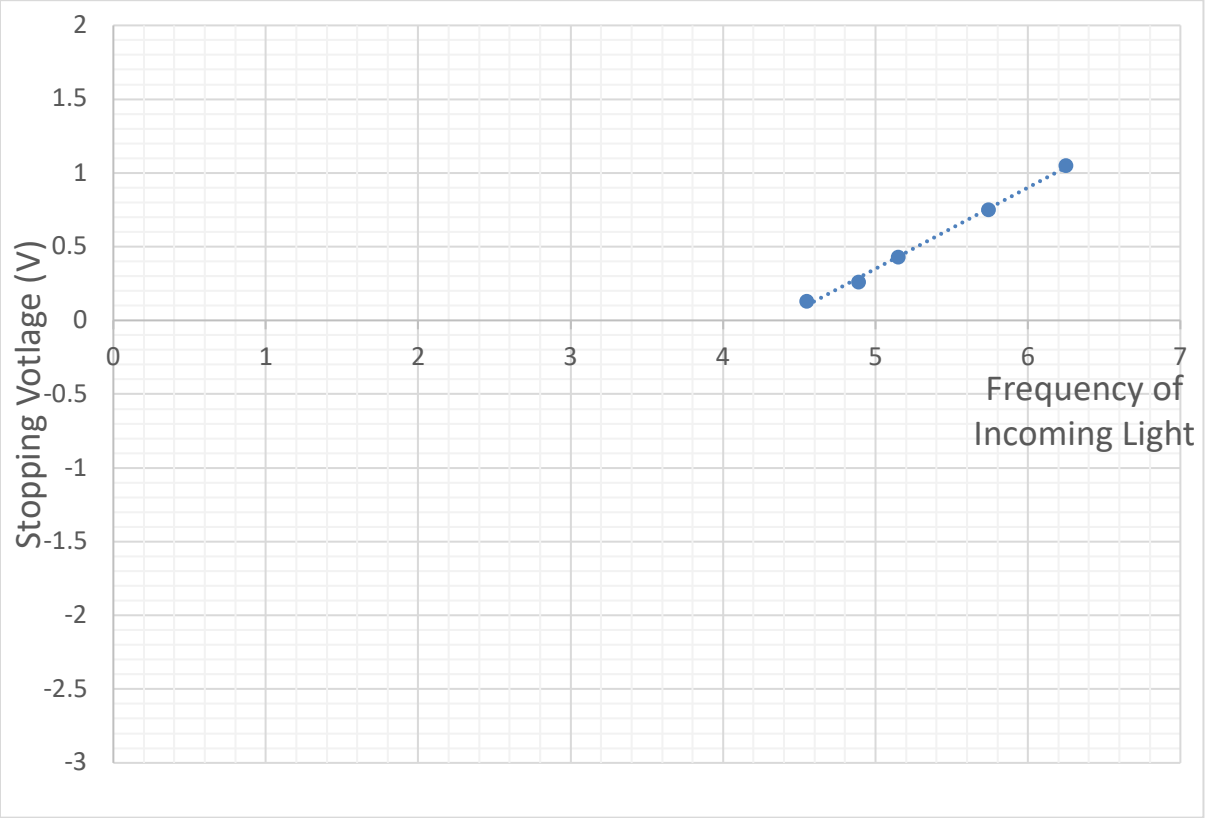
a. *As the frequency increases, the stopping voltage will increase.*

The frequency increases the energy of the incoming photons, so they are able to pass on more energy to the electrons.

Electrons with more energy will require a larger opposing voltage to stop them from reaching the collector plate.

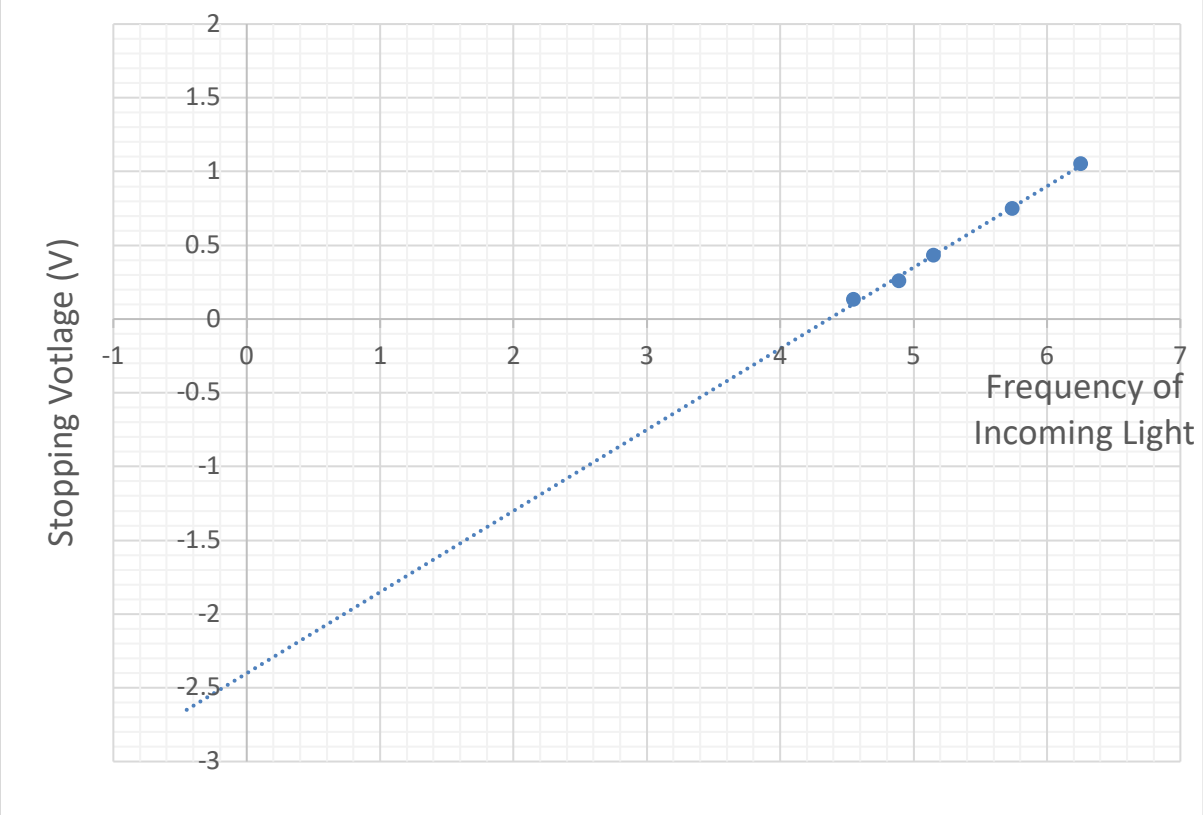
- **1 mark** is awarded for appropriately worded hypothesis, clearly identifying how the change in independent variable affects the dependent variable.
- **1 mark** is awarded for correctly linking frequency to energy passed onto electrons
- **1 mark** is awarded for correctly linking higher energy electrons to higher stopping voltage.

b. *Graph as per below:*



- **2 marks** are awarded for all correct points plotted.
- **1 mark** is awarded for correct straight line of best fit.

c. *Line extrapolated as per graph below:*



The y intercept is equal to approximately 2.4. This value represents the work function: the minimum energy required to emit electrons from the surface of a metal.

- **1 mark** is awarded for correct extrapolation of graph.
- **1 mark** is awarded for correct definition of work function.

Question 16 (3 marks)

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

$$E = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{410 \times 10^{-9}} - (1.9)(1.6 \times 10^{-19})$$

$$E = 1.81 \times 10^{-19}\ J$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded to conversion to Joules or using appropriate Planck's constant value.
- **1 mark** is awarded for correct answer.

Question 17 (8 marks)

a. *The electrons behave as waves, producing an interference pattern of constructive (light bands) and destructive (dark bands) interference.*

- **1 mark** is awarded for identification of electrons behaving as waves.
- **1 mark** is awarded for identification of interference pattern from constructive and destructive interference.

b. $\frac{1}{2}mv^2 = qV \quad \left(\frac{1}{2}\right)(9.1 \times 10^{-31})(v^2) = (1.6 \times 10^{-19})(1000) \;\; v = 1.9 \times 10^7 \; m\, s^{-1}$

- **1 mark** is awarded for correct working.

c. Same diffraction pattern, same wavelength.

$$\lambda_{photons} = \lambda_{electrons} = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{(9.1 \times 10^{-31})(1.9 \times 10^7)} = 3.8 \times 10^{-11}\; m$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

d. *Increasing the voltage would increase the velocity ($qV = \frac{1}{2}mv^2$) . This would decrease the wavelength ($\lambda = \frac{h}{mv}$) which would decrease the diffraction pattern ($diffraction \propto \frac{\lambda}{w}$).*

- **1 mark** is awarded for correct outcome for velocity (with equation)
- **1 mark** is awarded for correct outcome for wavelength (with equation)
- **1 mark** is awarded for correct outcome for diffraction pattern (with equation)

Question 18 (5 marks)

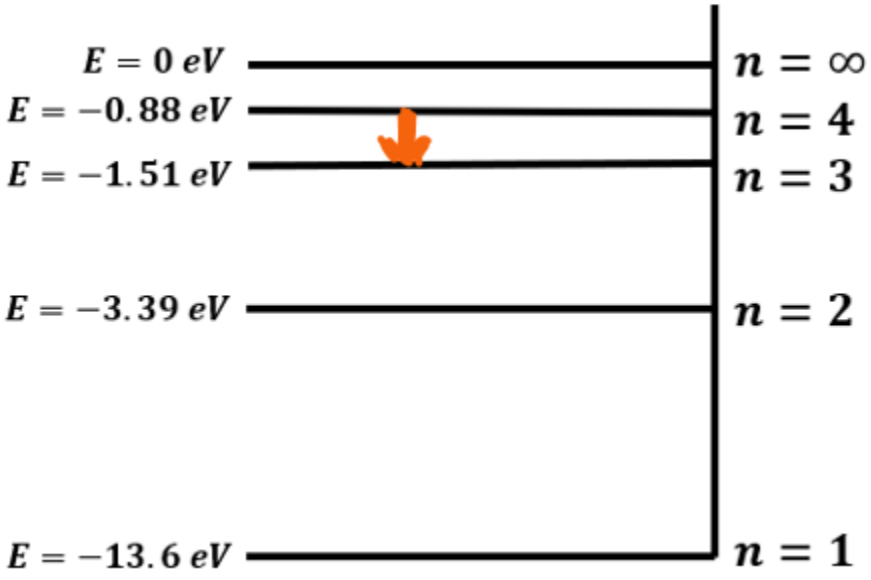
a. $E = hf = \frac{hc}{\lambda}$

$$(13.6 - 1.51) = \frac{(4.14 \times 10^{-15})(3 \times 10^8)}{\lambda}$$

$$\lambda = 1.03 \times 10^{-7}\; m$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. *Arrow as per image below:*



- **1 mark** is awarded for correct arrow pointing downwards from n=4 to n=3

c. *The energy of the photon is not equivalent to any possible electron transitions and so the photon would not be absorbed. It would continue as a photon.*

- **1 mark** is awarded for correctly identifying that there is no interaction between the photon and atom.
- **1 mark** is awarded for correctly linking this to the lack of energy transitions equal to the energy of the photon.