VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2020

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

ANS.

STUDENT NUMBER | | | | | | | | | Letter | |

PHYSICS
Written examination

Tuesday 24 November 2020

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (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 38 pages
- Formula sheet
- Answer sheet for multiple-choice questions

Instructions
- Write your student number in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- 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 for multiple-choice questions inside the front cover of this book.
- You may keep the formula sheet.

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

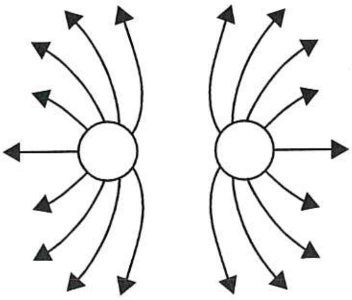
SECTION A – Multiple-choice questions

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 diagram below shows the electric field lines between two charges of equal magnitude.



Field lines coming out of charge $\Rightarrow$ +ve.

The best description of the two charges is that the

A. charges are both positive.
B. charges are both negative.
C. charges can be either both positive or both negative.
D. left-hand charge is positive and the right-hand charge is negative.

Question 2

Jupiter's moon Ganymede is its largest satellite.
Ganymede has a mass of 1.5×10^{23} kg and a radius of 2.6×10^{6} m.
Which one of the following is closest to the magnitude of Ganymede's surface gravity?

A. 0.8 m s^{-2}
B. 1.5 m s^{-2}
C. 3.8 m s^{-2}
D. 9.8 m s^{-2}

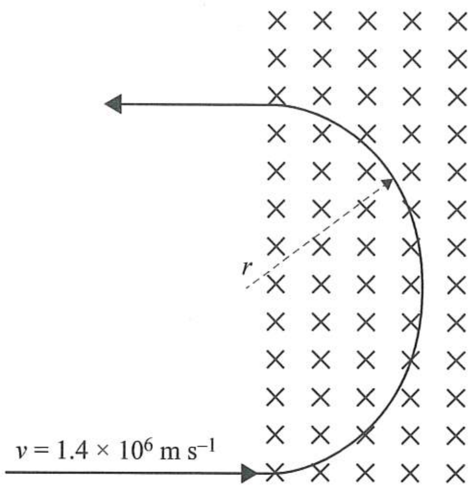
$g = \frac{GM}{r^2}$ ← Formula Sheet

$= \frac{6.67 \times 10^{-3} \times 1.5 \times 10^{23}}{(2.6 \times 10^{6})^2}$

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 3 and 4.

A positron with a velocity of 1.4×10^6 m s^{-1} is injected into a uniform magnetic field of 4.0×10^{-2} T, directed into the page, as shown in the diagram below. It moves in a vacuum in a semicircle of radius r. The mass of the positron is 9.1×10^{-31} kg and the charge on the positron is 1.6×10^{-19} C. Ignore relativistic effects.



Question 3

Which one of the following best gives the speed of the positron as it exits the magnetic field?

A. 0 m s^{-1}

B. much less than 1.4×10^6 m s^{-1}

C. 1.4×10^6 m s^{-1}

D. greater than 1.4×10^6 m s^{-1}

Force acts 90° to direction of travel => no change in 'speed' component.

Question 4

The speed of the positron is changed to 7.0×10^5 m s^{-1}.

Which one of the following best gives the value of the radius r for this speed?

A. $\frac{r}{4}$

B. $\frac{r}{2}$

C. r

D. $2r$

Speed $1.4 \times 10^6 \rightarrow 7.0 \times 10^5$.

$\div 2$

Equating $F_M = Bqv$

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

$F_M = F_C$

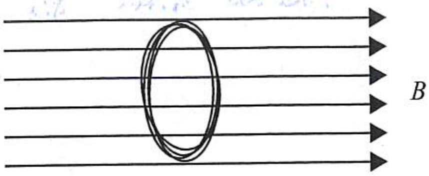
$Bqv = \frac{mv^2}{r} \Rightarrow r = \frac{mv^2}{Bqv} = \frac{mv}{Bq}$

$\Rightarrow r \propto v$

$v \div 2 \rightarrow r \div 2$.

Question 5 Not Needed. $= 10 \div 10^4\ m^2 = 10\times10^{-4}\ m$

A coil consisting of 20 loops with an area of 10 cm^2 is placed in a uniform magnetic field B of strength 0.03 T so that the plane of the coil is perpendicular to the field direction, as shown in the diagram below.



$\Phi = BA$
$= 0.03 \times (10\times10^{-4})$
$= 3\times10^{-5}$

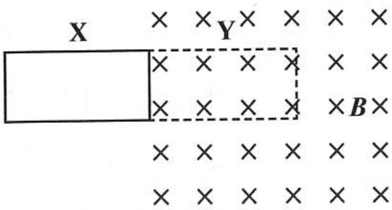
The magnetic flux through the coil is closest to

A. 0 Wb
B. 3.0×10^{-5} Wb
C. 6.0×10^{-4} Wb
D. 3.0×10^{-1} Wb

Question 6

A single loop of wire moves into a uniform magnetic field B of strength 3.5×10^{-4} T over time $t = 0.20$ s from point X to point Y, as shown in the diagram below. The area A of the loop is 0.05 m^2.

loop moves in $\Rightarrow \Phi \uparrow$.



$\mathcal{E} = -N \dfrac{\Delta\Phi}{\Delta t}$

$\mathcal{E} = -1 \times \dfrac{+(3.5\times10^{-4} \times 0.05)}{0.20}$

$= -8.8\times10^{-5}$

The magnitude of the average induced EMF in the loop is closest to

A. 0 V
B. 3.5×10^{-6} V
C. 8.8×10^{-5} V
D. 8.8×10^{3} V

Question 7

An ideal transformer has an input DC voltage of 240 V, 2000 turns in the primary coil and 80 turns in the secondary coil.

The output voltage is closest to

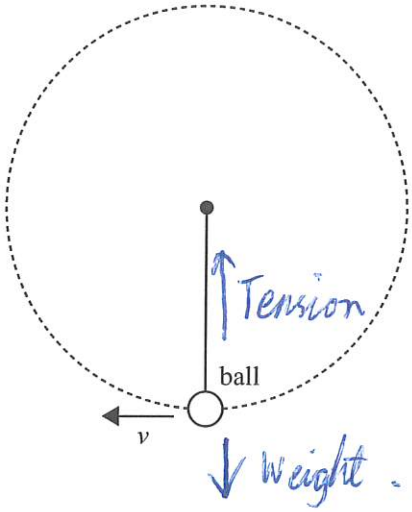
DC voltage $\rightarrow \Phi_B = 0$
$\Rightarrow$ Induced Voltage $= 0$

A. 0 V
B. 9.6 V
C. 6.0×10^{3} V
D. 3.8×10^{7} V

Note: Transformers only work for AC.

Question 8

A ball is attached to the end of a string and rotated in a circle at a constant speed in a vertical plane, as shown in the diagram below.

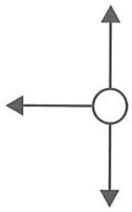


Only forces are Weight of ball and Tension in string.
As the ball moves 'up' after this instant Tension > Weight.

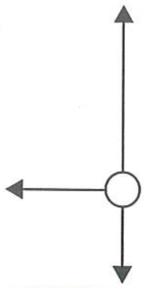
The arrows in options A. to D. below indicate the direction and the size of the forces acting on the ball.

Ignoring air resistance, which one of the following best represents the forces acting on the ball when it is at the bottom of the circular path and moving to the left?

A.

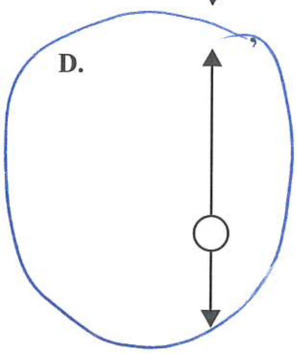


B.



C.

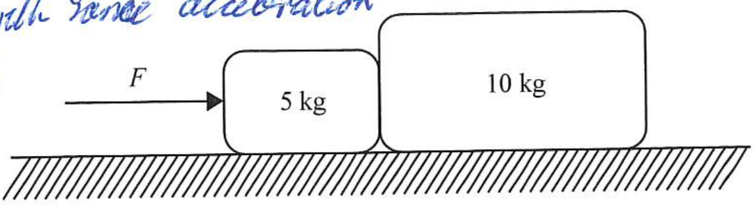
D.



Use the following information to answer Questions 9 and 10.

Two blocks of mass 5 kg and 10 kg are placed in contact on a frictionless horizontal surface, as shown in the diagram below. A constant horizontal force, *F*, is applied to the 5 kg block.

Move together with same acceleration
10 kg needs Twice the force as the 5kg to have the Same acceleration



Question 9

Which one of the following statements is correct?

A. The net force on each block is the same.

B. The acceleration experienced by the 5 kg block is twice the acceleration experienced by the 10 kg block.

C. The magnitude of the net force on the 5 kg block is half the magnitude of the net force on the 10 kg block.

D. The magnitude of the net force on the 5 kg block is twice the magnitude of the net force on the 10 kg block.

Question 10

If the force *F* has a magnitude of 250 N, what is the work done by the force in moving the blocks in a straight line for a distance of 20 m?

A. 5 kJ

B. 25 kJ

C. 50 kJ

D. 500 kJ

$W = Fd$

$= 250 \times 20$

$= 5000$

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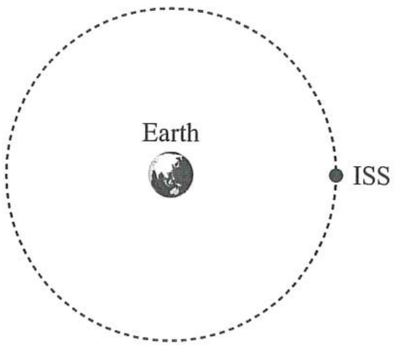
Question 11

The International Space Station (ISS) is travelling around Earth in a stable circular orbit, as shown in the diagram below.



'Speed' constant
Direction changes
K.E. is a Scalar → Constant.

Momentum is a Vector
The direction of travel keeps changing → Momentum changes

Which one of the following statements concerning the momentum and the kinetic energy of the ISS is correct?

A. Both the momentum and the kinetic energy vary along the orbital path.

B. Both the momentum and the kinetic energy are constant along the orbital path.

C. The momentum is constant, but the kinetic energy changes throughout the orbital path.

D. The momentum changes, but the kinetic energy remains constant throughout the orbital path.

Question 12

A high-energy proton is travelling through space at a constant velocity of 2.50×10^8 m s^{-1}.

The Lorentz factor, γ, for this proton would be closest to

A. 1.81

B. 2.44

C. 3.27

D. 3.39

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\frac{(2.50\times10^8)^2}{(3.0\times10^8)^2}}}$$

Question 13

Matter is converted to energy by nuclear fusion in stars.

If the star Alpha Centauri converts mass to energy at the rate of 6.6×10^9 kg s^{-1}, then the power generated is closest to

A. 2.0×10^{18} W

B. 2.0×10^{18} J

C. 6.0×10^{26} W

D. 6.0×10^{26} J

$E = mc^2$.

$= 6.6\times10^9 \times (3.0\times10^8)^2$

$= 6.0\times10^{26}$ J each Second.

as Power $= \frac{E}{t}$.

Power $= 6.0\times10^{26}$ W.

Question 14

Students are investigating the diffraction of waves using a ripple tank. Water waves are directed towards barriers with gaps of different sizes, as shown below.

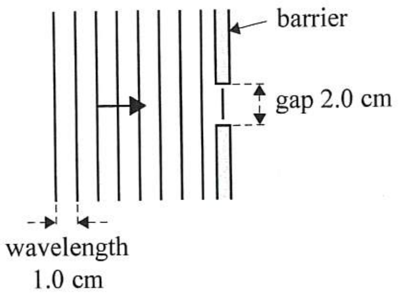
In which one of the following would the greatest diffraction effects be observed?

$\frac{\lambda}{w}$ ratio ~ 1 for diffraction

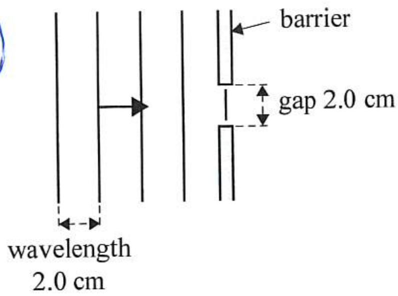
$\frac{1}{2}$, 1

$\frac{1}{3}$, $\frac{2}{3}$

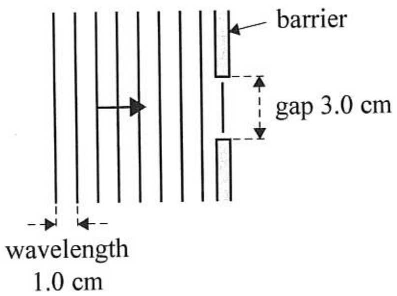
A.



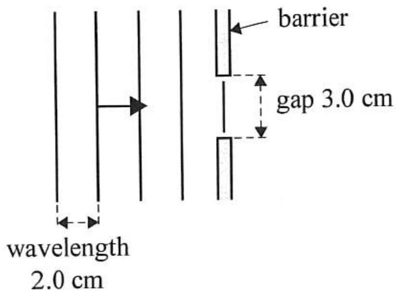
B.



C.



D.



Question 15

I The energy of a light wave increases with increasing amplitude.

II The energy of a light wave increases with increasing frequency.

III The energy of a light wave increases with decreasing wavelength.

Which of the statements above about the energy of light waves is correct?

A. III only

B. I and II only

C. I and III only

D. all of the statements are correct

Particle (Photon) Model

$E_{photon} = hf$. or $h\frac{c}{\lambda}$

$E_p\uparrow \Rightarrow f\uparrow$ $E_p\uparrow \Rightarrow \lambda\downarrow$

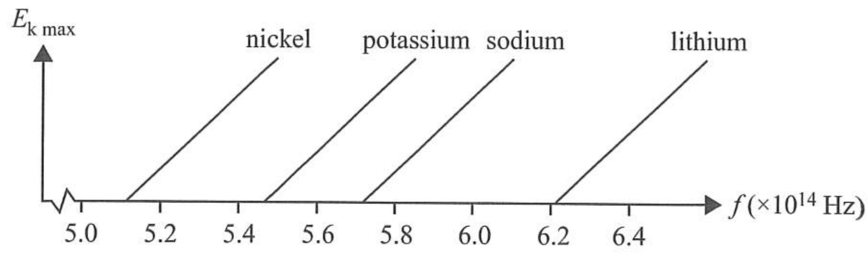
Wave Model.

Energy $\propto$ Amplitude

All statements Correct.

Question 16

The diagram below shows a plot of maximum kinetic energy, $E_{k\,max}$, versus frequency, f, for various metals capable of emitting photoelectrons.



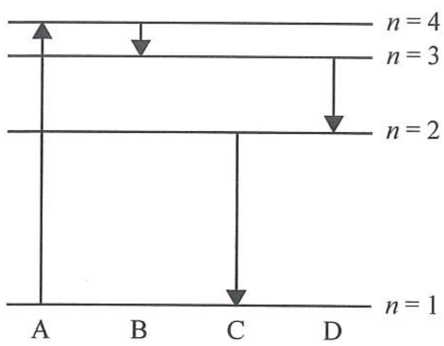
Which one of the following correctly ranks these metals in terms of their work function, from highest to lowest in numerical value?

A. sodium, potassium, lithium, nickel
B. nickel, potassium, sodium, lithium
C. potassium, nickel, lithium, sodium
D. lithium, sodium, potassium, nickel

highest Work function has highest Threshold frequency
$\phi = h f_0$
⇒ Lithium first

Question 17

The diagram below shows some of the energy levels for the electrons within an atom. The arrows labelled A, B, C and D indicate transitions between the energy levels and their lengths indicate the relative size of the energy change.



Which transition results in the emission of a photon with the most energy?

A. A
B. B
C. C
D. D

Longest Arrow.
Must be dropping Down.

Question 18

Quantised energy levels within atoms can best be explained by

A. electrons behaving as individual particles with different energies.

B. electrons behaving as waves, with each energy level representing a diffraction pattern.

C. protons behaving as waves, with only standing waves at particular wavelengths allowed.

D. electrons behaving as waves, with only standing waves at particular wavelengths allowed.

Question 19

Which one of the following best describes a hypothesis? ← The thing to be tested.

A. a testable scientific explanation

B. a well-tested scientific explanation

C. a scientific explanation by a famous scientist

D. a widely believed and highly plausible explanation

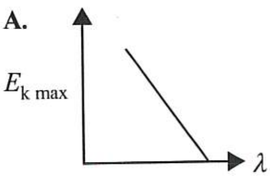
Question 20

When photons with energy E strike a metal surface, electrons may be emitted.

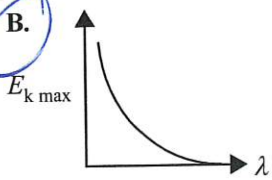
The maximum kinetic energy, $E_{k\,max}$, of the emitted electrons is given by $E_{k\,max} = E - W$, where W is the work function of the metal.

Which one of the following graphs best shows the relationship between the maximum kinetic energy of these electrons, $E_{k\,max}$, and the wavelength of the photons, λ?

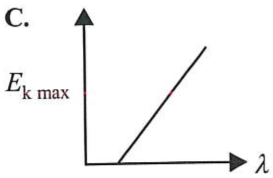
A.



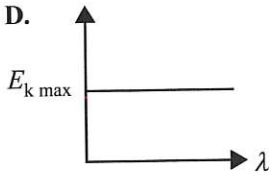
B.



C.



D.



$E_{kMax} = E - W.$

$E_{kMax} = hf - W$

$E_{kMax} = \frac{hc}{\lambda} - W$

$E_{kMax} \propto \frac{1}{\lambda}$ → Hyperbolic in Shape.

END OF SECTION A

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TURN OVER

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.
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 (2 marks)

Two bar magnets are placed close to each other, as shown in Figure 1.

Sketch the shape and the direction of **at least four** magnetic field lines between the two poles within the dashed border shown in Figure 1.

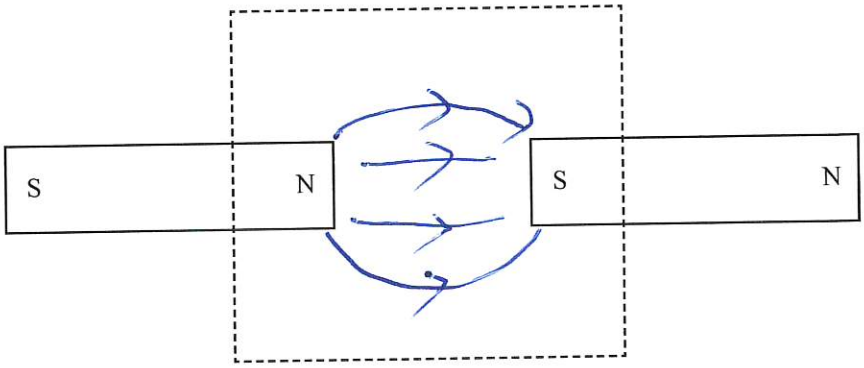


Figure 1

Magnetic field lines go North → South

Note: Question asks for within the dashed border.
Lines must be in there to get full marks.
Also asks for Between the two Poles.
Lines must go North to South within the box.

DO NOT WRITE IN THIS AREA

Question 2 (3 marks)

Gravitation, magnetism and electricity can be explained using a field model. According to our understanding of physics and current experimental evidence, these three field types can be associated with only monopoles, only dipoles or both monopoles and dipoles.

In the table below, indicate whether each field type can be associated with only monopoles, only dipoles or both monopoles and dipoles by ticking (✓) the appropriate box.

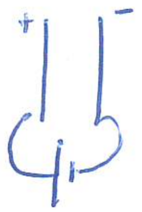
Field type	Only monopoles	Only dipoles	Both monopoles and dipoles
gravitation	✓		
magnetism		✓	
electricity			✓

Gravitation – Attracted to ONE thing O

Magnetism – A North and a South $\boxed{N \quad S}$

Electricity – A point charge. +

→ Parallel Plates



Question 3 (6 marks)

Electron microscopes use a high-precision electron velocity selector consisting of an electric field, E, perpendicular to a magnetic field, B.

Electrons travelling at the required velocity, v_0, exit the aperture at point Y, while electrons travelling slower or faster than the required velocity, v_0, hit the aperture plate, as shown in Figure 2.

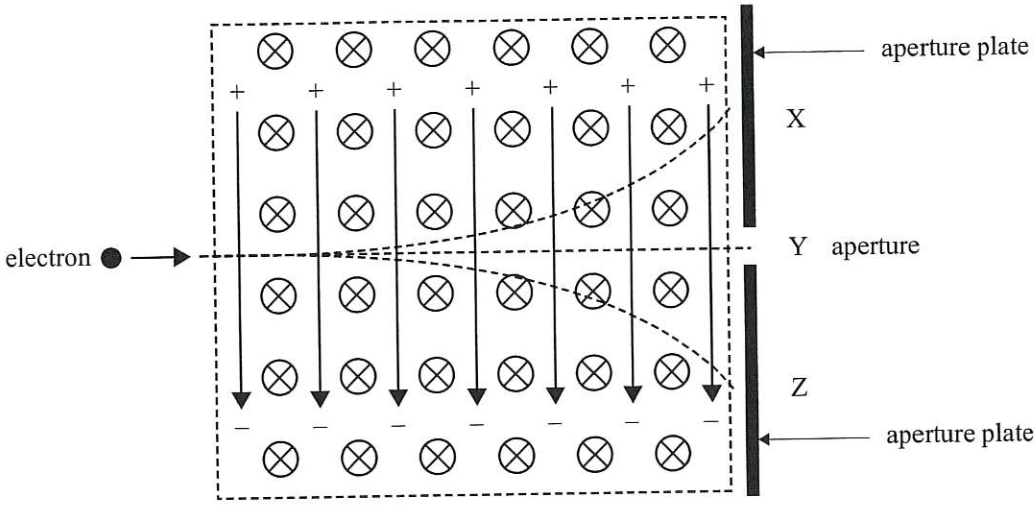


Figure 2

a. Show that the velocity of an electron that travels straight through the aperture to point Y is given by $v_0 = \dfrac{E}{B}$. 1 mark

$F_E = F_m$

$qE = qv_0 B$

$v_0 = \dfrac{E}{B}$.

b. Calculate the magnitude of the velocity, v_0, of an electron that travels straight through the aperture to point Y if $E = 500$ kV m^{-1} and $B = 0.25$ T. Show your working. 2 marks

$v_0 = \dfrac{500 \times 10^3}{0.25}$

$= 2.0 \times 10^6$

$\boxed{2.0 \times 10^6}$ m s^{-1}

DO NOT WRITE IN THIS AREA

c. **i.** At which of the points – X, Y or Z – in Figure 2 could electrons travelling faster than v_0 arrive? 1 mark

Z

$F_m = qvB$. $F_E = qE$

$F_m \uparrow$ when $v_0 \uparrow$ F_E stays same.

ii. Explain your answer to **part c.i.** 2 marks

Force due to electric field remains the same.

Force due to magnetic field depends on the velocity. $v \uparrow$ then $F_m \uparrow$.

The Forces are no longer in Balance.

$F_M > F_E$

Net force Down the page.

Question 4 (10 marks)

The Ionospheric Connection Explorer (ICON) space weather satellite, constructed to study Earth's ionosphere, was launched in October 2019. ICON will study the link between space weather and Earth's weather at its orbital altitude of 600 km above Earth's surface. Assume that ICON's orbit is a circular orbit. Use $R_E = 6.37 \times 10^6$ m.

a. Calculate the orbital radius of the ICON satellite. 1 mark

$R_0 = R_E + \text{Altitude} = 6.37 \times 10^6 + 600 \times 10^3$

$= 6.97 \times 10^6$

$\boxed{6.97 \times 10^6 \text{ m}}$

b. Calculate the orbital period of the ICON satellite correct to three significant figures. Show your working. 4 marks

Circular Motion

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

Acceleration due to gravity $g = \frac{GM}{r^2}$

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

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

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

$T = \sqrt{\frac{4\pi^2 (6.97 \times 10^6)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$

$= 5789.195$

$= 5.79 \times 10^3$

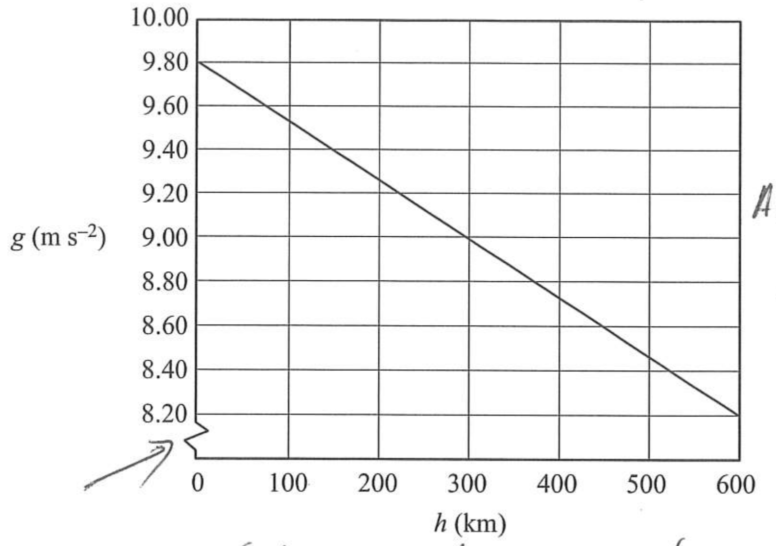
Note: $T = \sqrt{\frac{4\pi^2 r^3}{GM}}$ Handy for your Sheet of Notes.

$\boxed{5.79 \times 10^3 \text{ s}}$

c. Explain how the ICON satellite maintains a stable circular orbit without the use of propulsion engines. 2 marks

The only force acting on ICON is gravity, acting towards Earth.
This force is constant in Magnitude and 90° to the direction of travel.
Thus the satellite maintains a circular orbit.

d. Figure 3 shows the strength of Earth's gravitational field, g, as a function of orbital altitude, h, above the surface of Earth.



Area of Δ part
$A = \frac{1}{2} \times (600 \times 10^3) \times (1.6)$

Careful!
Broken axis - area of lower part $= 8.2 \times (600 \times 10^3)$.

Figure 3

Determine the change in gravitational potential energy of the ICON satellite as it travels from Earth's surface to its orbital altitude of 600 km above Earth's surface. The mass of the ICON satellite is 288 kg.

3 marks

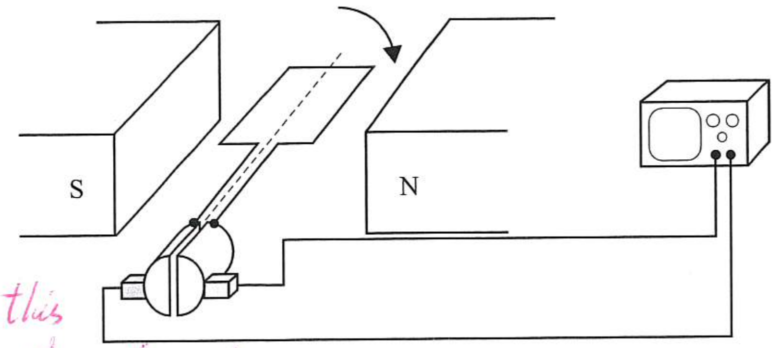
$\text{Area} = 8.2 \times (600 \times 10^3) + \frac{1}{2} \times (600 \times 10^3) \times (1.6)$
$= 5{,}400{,}000$
$\Delta U_g = \text{mass} \times \text{Area}$
$= 288 \times 5\,400\,000$
$= 1{,}555{,}200{,}000 = 1.56 \times 10^9$

1.56×10^9 J

Note: * Area under Gravitational field strength Vs Height graph is Energy per kilogram ($J\ kg^{-1}$).
Thus $\Delta U_g = \text{mass} \times \text{Area}$.
* Can't use $\Delta U_g = m g \Delta h$, since g is not constant.

Question 5 (9 marks)

A rectangular wire loop with dimensions 0.050 m × 0.035 m is placed between two magnets that create a uniform magnetic field of strength 0.2 mT. The loop is rotated with a frequency of 50 Hz in the direction shown in Figure 4. The ends of the loop are connected to a split-ring commutator to create a DC generator. The loop is initially in the position shown in Figure 4.



Careful with this one. Easy to get confused.

Figure 4

a. In which direction – clockwise or anticlockwise – will the induced current travel through the loop for the first quarter turn as seen from above? 1 mark

Flux changes from 0 to Max-to left
Induced opposes that change - to right.
Right Hand Grip gives Anticlockwise

$\boxed{\text{Anticlockwise}}$

b. Calculate the average EMF measured in the loop for the first quarter turn. 3 marks

$\mathcal{E} = -N \frac{\Delta\Phi}{\Delta t} = -N \frac{\text{Area} \times B}{\Delta t}$

$= -1 \times \frac{0.050 \times 0.035 \times 0.2 \times 10^{-3}}{0.005}$

$= -7 \times 10^{-5}$

$\boxed{7 \times 10^{-5}}$ V

Note: B in milli Tesla.
The negative is not needed.

$f = 50 \rightarrow T = \frac{1}{f}$

$T = \frac{1}{50}$

$T = 0.02$

for a full Turn.

We have $\frac{1}{4}$ turn $t = 0.02 \div 4 = 0.005$

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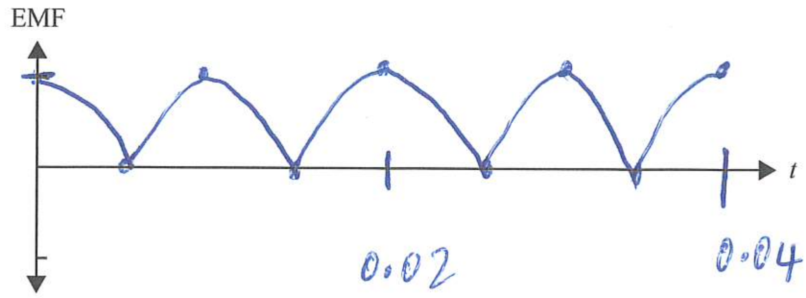
c. On the axes provided below, sketch the output EMF versus time, *t*, for the first two rotations. Include a scale on the horizontal axis. 3 marks



d. Suggest **two** modifications that could be made to the apparatus shown in Figure 4 that would increase the output EMF of the DC generator. 2 marks

Any TWO from
- Increase field strength
- Increase the number of Coils
- Increase the Area of the coil
- Increase the frequency of rotation.

Note: For PART C.

Split Ring Commutator thus not

Two Rotations = 2 × 0.02 = 0.04 sec.

Carefull when drawing to make it look uniform

PART D

Increase

Using → $\mathcal{E} = -N \dfrac{\text{Area} \times \text{Field Strength}}{\text{time}}$

To Increase. decrease.

Question 6 (6 marks)

Two Physics students hold a coil of wire in a constant uniform magnetic field, as shown in Figure 5a. The ends of the wire are connected to a sensitive ammeter. The students then change the shape of the coil by pulling each side of the coil in the horizontal direction, as shown in Figure 5b. They notice a current register on the ammeter.

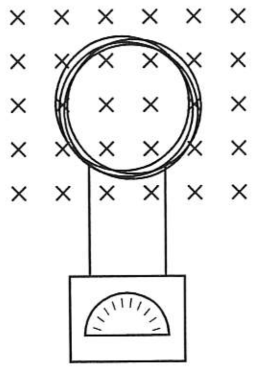


Figure 5a

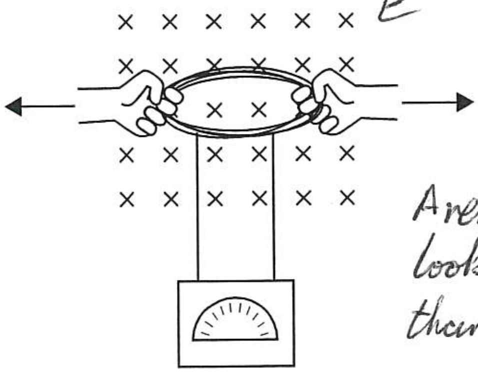


Figure 5b

Field IN

Area of coil looks Smaller than in 5a.

a. Will the magnetic flux through the coil increase, decrease or stay the same as the students change the shape of the coil? 1 mark

Decrease.

Current on Ammeter
=> Induced Current
=> Flux change -> Decrease.

b. Explain, using physics principles, why the ammeter registered a current in the coil and determine the direction of the induced current. 3 marks

Flux into page decreases.
Lenz's law states an Induced current will produce a flux to oppose the change.
ie. Into page
Right Hand Grip rule gives the direction of the induced current as clockwise.

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c. The students then push each side of the coil together, as shown in Figure 6a, so that the coil returns to its original circular shape, as shown in Figure 6b, and then changes to the shape shown in Figure 6c.

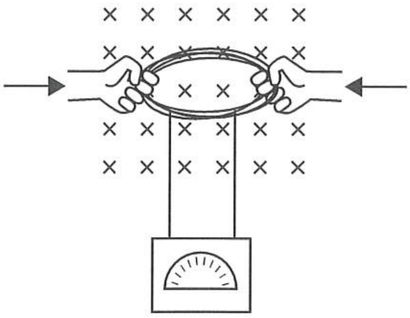

Figure 6a

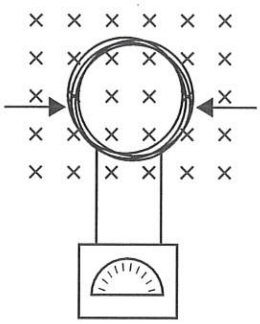

Figure 6b

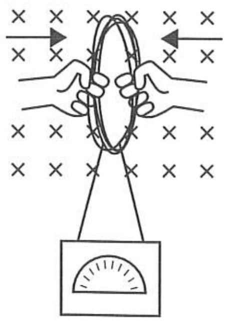

Figure 6c

Describe the direction of any induced currents in the coil during these changes. Give your reasoning. 2 marks

6a → 6b : Flux increasing into page.
⇒ Induced out of page.
⇒ RH Grip induced current Anticlockwise

6b → 6c : Flux decreasing into Page
⇒ Induced Flux into Page
⇒ RH Grip induced current Clockwise

Note: Current Induced only when Flux changes.
ie. 6a → 6b, then 6b → 6c.

Question 7 (5 marks)

A rechargeable electric toothbrush uses a transformer circuit, as shown in Figure 7. A secondary coil inside the toothbrush is connected, via an iron core, to a primary coil that is connected to the mains power supply. The mains power is 240 V_{RMS} and the toothbrush recharges at 12 V_{RMS}. The average power delivered by the transformer to the toothbrush is 0.90 W. Assume that the transformer is ideal.

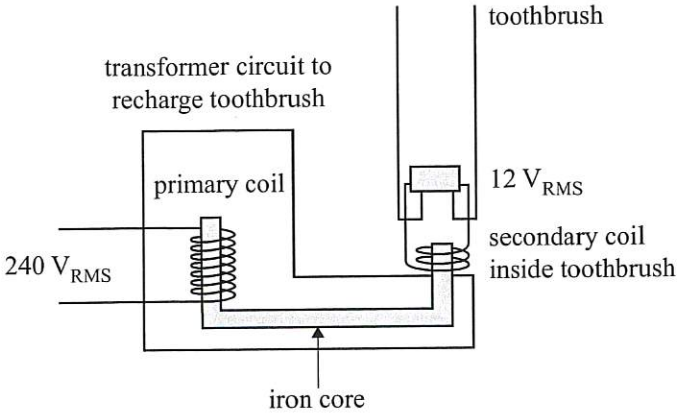

Figure 7

a. Calculate the peak voltage in the secondary coil. Show your working. 2 marks

$V_{rms} = \frac{1}{\sqrt{2}} V_{peak}$

$12 = \frac{1}{\sqrt{2}} V_{peak}$

$V_{peak} = \sqrt{2} \times 12 = 16.971 = 17\ V$

| 17 V |

b. Determine the ratio of the number of turns $\frac{N_p}{N_s}$. 1 mark

$\frac{V_p}{V_s} = \frac{N_p}{N_s}$

$\frac{240}{12} = \frac{N_p}{N_s}$

$\frac{N_p}{N_s} = 20$

| 20 |

OR 20 : 1

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DO NOT WRITE IN THIS AREA

c. Calculate the RMS current in the primary coil while the toothbrush is charging. Show your working. 2 marks

Idea Transformer ⟹ Power Primary = Power Secondary

$P = VI$

$0.90 = 240 \times I$

$I = 3.75 \times 10^{-3}$ A.

$= 3.75$ mA

$= 3.8$ mA

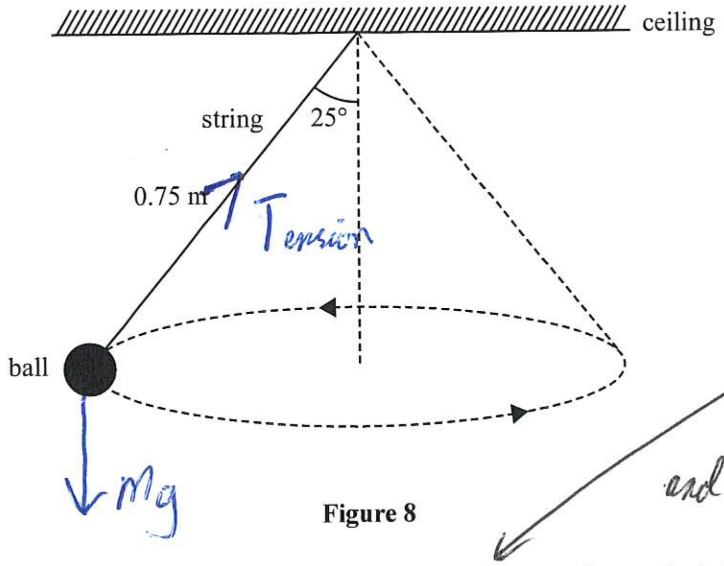
3.8 mA

Note: "Power Delivered by Transformer" = 0.90 W
ie. Power Secondary = 0.90 W

* Voltage in Primary ≅ 240 V.

Question 8 (6 marks)

Figure 8 shows a small ball of mass 1.8 kg travelling in a horizontal circular path at a constant speed while suspended from the ceiling by a 0.75 m long string.



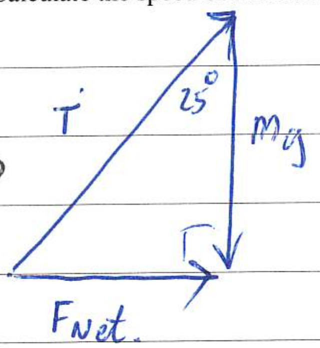
only Gravity and Tension acting

Figure 8

a. Use labelled arrows to indicate on Figure 8 the two physical forces acting on the ball. 2 marks

b. Calculate the speed of the ball. Show your working. 4 marks

Force Diagram



$F_{Net} = mg \tan 25°$

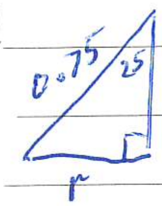
$= 1.8 \times 9.8 \times \tan 25°$

$= 8.22566709.$

Circular Motion $F_c = \frac{mv^2}{r}$

$8.22566709 = \frac{1.8 \times v^2}{0.75 \sin 25}$

Physical Dimensions



$v^2 = 1.44846545$

$v = 1.20352211$

$\boxed{1.2 \quad \text{m s}^{-1}}$

Note: * The centripetal force is the RESULT of adding the forces acting. ie. T + Mg.

* Use Trigonometry.

Question 9 (5 marks)

An ideal spring is compressed by 0.15 m. A ball of mass 0.20 kg is placed in contact with the compressed spring. The spring is then released, causing the ball to move horizontally, with a velocity of *v*, across a smooth surface, as shown in Figure 9.

Spring Potential E → Kinetic E.

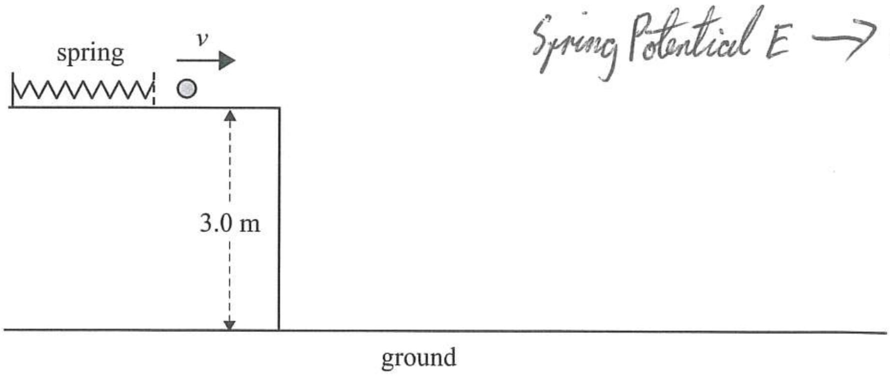


Figure 9

Must have this

a. If the spring constant is 1250 N m^{-1}, show that the magnitude of the initial velocity, *v*, of the ball is 12 m s^{-1}, correct to two significant figures. Show your working. 2 marks

$U_s = E_K$

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

$\frac{1}{2} \times 1250 \times 0.15^2 = \frac{1}{2} \times 0.20 \times v^2$

$v^2 = 140.625$

$v = 11.85585$

$= 12\ ms^{-1}$

b. Calculate the speed of the ball after it has fallen a vertical distance of 2.5 m. Show your working. 3 marks

Horizontally

$u = v = 12.$

Vertically

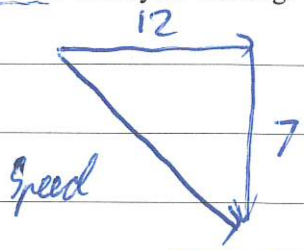
$u = 0 \quad a = 9.8 \quad x = 2.5$

$v^2 = u^2 + 2ax$

$v^2 = 0^2 + 2 \times 9.8 \times 2.5$

$v^2 = 49$

$v = 7.$



$\text{Speed} = \sqrt{12^2 + 7^2}$

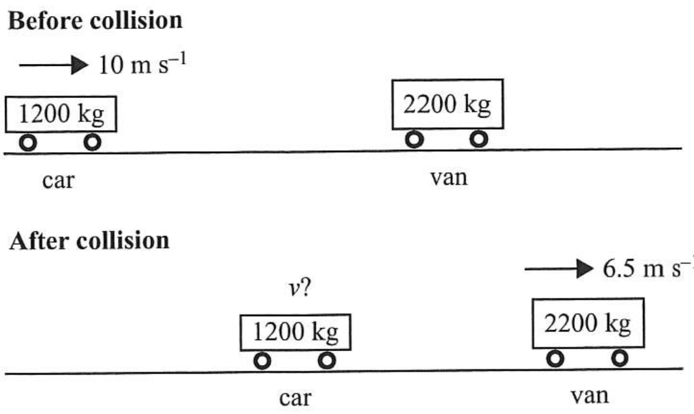
$= 13.89244$

$= 14$

14 m s^{-1}

Question 10 (12 marks)

Jacinda designs a computer simulation program as part of her practical investigation into the physics of vehicle collisions. She simulates colliding a car of mass 1200 kg, moving at 10 m s^{-1}, into a stationary van of mass 2200 kg. After the collision, the van moves to the right at 6.5 m s^{-1}. This situation is shown in Figure 10.



+ve

Figure 10

a. Calculate the speed of the car after the collision and indicate the direction it would be travelling in. Show your working. 4 marks

$P_{before} = P_{after}$

$(1200 \times 10) + (2200 \times 0) = (1200 \times v) + (2200 \times 6.5)$

$12000 = 1200v + 14300$

$-2300 = 1200v$

$-1.916667 = v$

1.9 m s^{-1}	Left.

Note: If you choose to use compass bearings. ie East-West You MUST draw West–East (North, South) to make it clear what you mean by East and West.

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DO NOT WRITE IN THIS AREA

b. Explain, using appropriate physics, why this collision represents an example of either an elastic or an inelastic collision. 3 marks

K.E. Before

$E_K = \frac{1}{2} m v^2$

$= \frac{1}{2} \times 1200 \times 10^2$

$= 60\,000$

$= 6 \times 10^4$ J

K.E After

$E_K = (\frac{1}{2} \times 1200 \times 1.9^2) + (\frac{1}{2} \times 2200 \times 6.5^2)$

$= 48641$

$= 4.8 \times 10^4$ J

K.E After < K.E. Before

The collision is INELASTIC.

c. The collision between the car and the van takes 40 ms. 40×10^{-3}

i. Calculate the magnitude and indicate the direction of the average force on the van by the car. 3 marks

$I = F_{ave} \times \Delta t$

$I = \Delta p$. of Van

$\Rightarrow F_{ave} = \frac{\Delta p}{\Delta t}$

$= \frac{p_{after} - p_{before}}{\Delta t}$

$F_{ave} = \frac{(2200 \times 6.5) - (2200 \times 0)}{40 \times 10^{-3}}$

$= 357{,}500$

$= 358$ kN

+ve ⇒ Right

358 kN	to the Right.

ii. Calculate the magnitude and indicate the direction of the average force on the car by the van. 2 marks

Using Newton's THIRD Law

- Same Size
- Opposite direction

Note: Could do a similar calculation to Ci.

358 kN	to the Left

Note: Explain – Can use calculations. In this case you need them.

Question 11 (4 marks)

An astronaut has left Earth and is travelling on a spaceship at $0.800c$ ($\gamma = 1.67$) directly towards the star known as Sirius, which is located 8.61 light-years away from Earth, as measured by observers on Earth.

a. How long will the trip take according to a clock that the astronaut is carrying on his spaceship? Show your working. 2 marks

Earth

$t = \frac{d}{v}$

$= \frac{8.61}{0.8} = 10.76$ years.

Astronaught.

$t = t_0 \gamma$

$10.76 = t_0 \times 1.67$

$t_0 = 6.4446.$

$\boxed{6.44 \text{ years}}$

b. Is the trip time measured by the astronaut in **part a.** a proper time? Explain your reasoning. 2 marks

It is proper time.
As the clock is STATIONARY in the Astronaughts frame of reference.

Question 12 (5 marks)

In a Young's double-slit interference experiment, laser light is incident on two slits, S_1 and S_2, that are 4.0×10^{-4} m apart, as shown in Figure 11a.

Rays from the slits meet on a screen 2.00 m from the slits to produce an interference pattern. Point C is at the centre of the pattern. Figure 11b shows the pattern obtained on the screen.

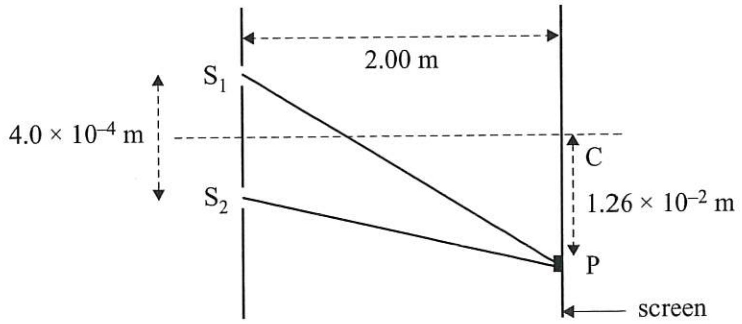

Figure 11a

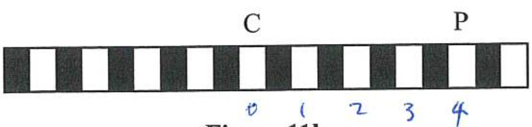

Figure 11b

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a. There is a bright fringe at point P on the screen.

Explain how this bright fringe is formed. 2 marks

P is the Fourth Bright Fringe.
→ Path difference of four wavelengths
→ Constructive interference
Need both for full marks.

b. The distance from the central bright fringe at point C to the bright fringe at point P is 1.26×10^{-2} m.

Calculate the wavelength of the laser light. Show your working. 3 marks

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

$\Delta x = \frac{1.26 \times 10^{-2}}{4}$

$= 3.15 \times 10^{-3}$

$3.15 \times 10^{-3} = \frac{\lambda \times 2.00}{4.0 \times 10^{-4}}$

$\lambda = 6.3 \times 10^{-7}$ m

$= 630$ nM

$\boxed{630 \text{ nm}}$

Note: P is the 4th fringe.
Δx is distance between each fringe.
$\therefore 4 \times \Delta x = 1.26 \times 10^{-2}$

Question 13 (4 marks)

A 0.8 m long guitar string is set vibrating at a frequency of 250 Hz. The standing wave envelope created in the guitar string is shown in Figure 12.

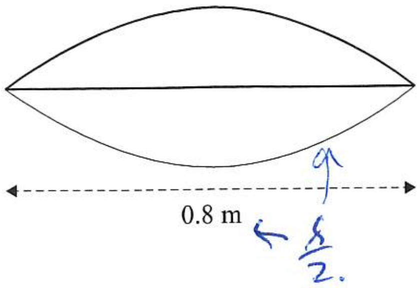


Figure 12

a. Calculate the speed of the wave in the guitar string. 2 marks

$v = \lambda f$

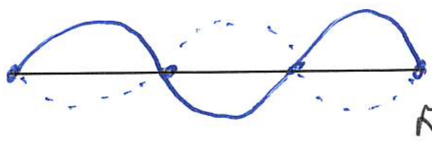
$= 1.6 \times 250$

$= 400$

$\boxed{400 \text{ m s}^{-1}}$

b. The frequency of the vibration in the guitar string is tripled to 750 Hz.

On the guitar string below, draw the shape of the standing wave envelope now created. 2 marks



Need one SOLID one DASHED.

Note: Fig 12 shows $\frac{\lambda}{2}$.

$f \times 3$.

$\Rightarrow$ New will show $3 \times \frac{\lambda}{2}$

or $1\frac{1}{2}\lambda$

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Question 14 (3 marks)

Figure 13 shows a representation of an electromagnetic wave.

Correctly label Figure 13 using the following symbols.

E – electric field B – magnetic field c – speed of light λ – wavelength

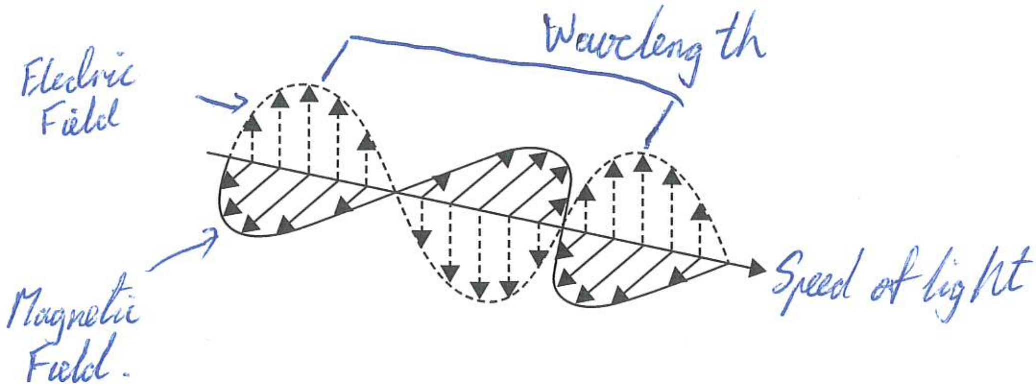

Figure 13

Question 15 (4 marks)

The metal surface in a photoelectric cell is exposed to light of a single frequency and intensity in the apparatus shown in Figure 14.

The voltage of the battery can be varied in value and reversed in direction.

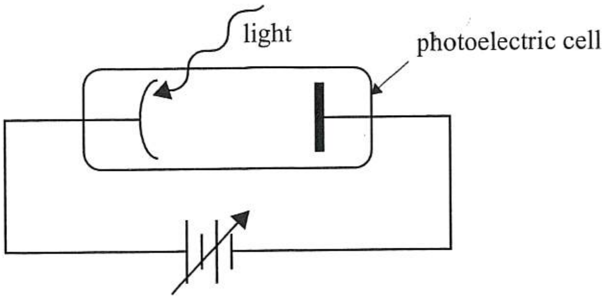

Figure 14

a. A graph of photocurrent versus voltage for one particular experiment is shown in Figure 15.

On Figure 15, draw the trace that would result for another experiment using light of the same frequency but with triple the intensity. 2 marks

triple Photocurrent

same Stopping Voltage

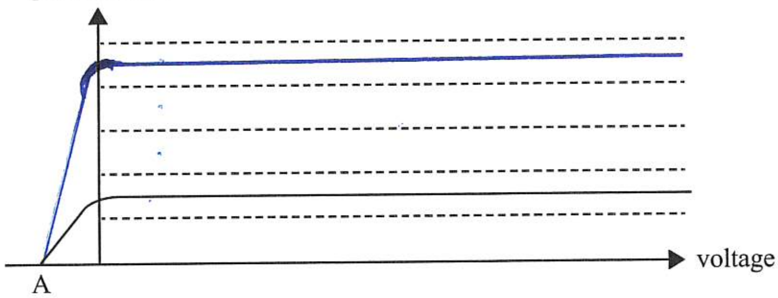

Figure 15

b. What is a name given to the point labelled A on Figure 15? 1 mark

Stopping Voltage

c. Why does the photocurrent fall to zero at the point labelled A on Figure 15? 1 mark

Stopping voltage is enough to prevent the most energetic electrons reaching the other side

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Question 16 (5 marks)

A beam of electrons travelling at 1.72×10^5 m s^{-1} illuminates a crystal, producing a diffraction pattern as shown in Figure 16. Take the mass of an electron to be 9.1×10^{-31} kg. Ignore relativistic effects.

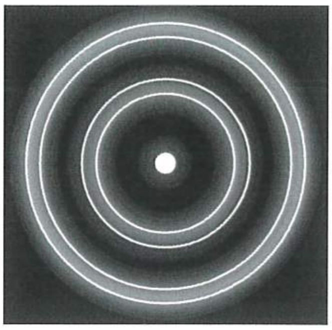

Figure 16

a. Calculate the kinetic energy of one of the electrons. Show your working. 2 marks

$E_K = \frac{1}{2} m v^2$

$= \frac{1}{2} \times 9.1 \times 10^{-31} \times (1.72 \times 10^5)^2$

$= 1.346 \times 10^{-20}$ J

$= (1.346 \times 10^{-20}) \div (1.6 \times 10^{-19}) = 0.0841$ eV

$\boxed{0.08 \text{ eV}}$ ← Check units

b. The electron beam is now replaced by an X-ray beam. The resulting diffraction pattern has the same spacing as that produced by the electron beam.

Calculate the energy of one X-ray photon. Show your working. 3 marks

$\lambda_e = \lambda_{x\text{-ray}}$

$\lambda_e = \frac{h}{p}$

$= \frac{6.63 \times 10^{-34}}{1.72 \times 10^5 \times 9.1 \times 10^{-31}}$

$= 4.2358 \times 10^{-9}$

Note: Joule version of h here.

$E_{x\text{-ray}} = \frac{hc}{\lambda}$

$= \frac{4.14 \times 10^{-15} \times 3.0 \times 10^8}{4.24 \times 10^{-9}}$

$= 293$ eV

Note: Required units eV. Use eV version of h in this part of the calculation

$\boxed{293 \text{ eV}}$

Question 17 (5 marks)

Figure 17 shows the emission spectrum for helium gas.

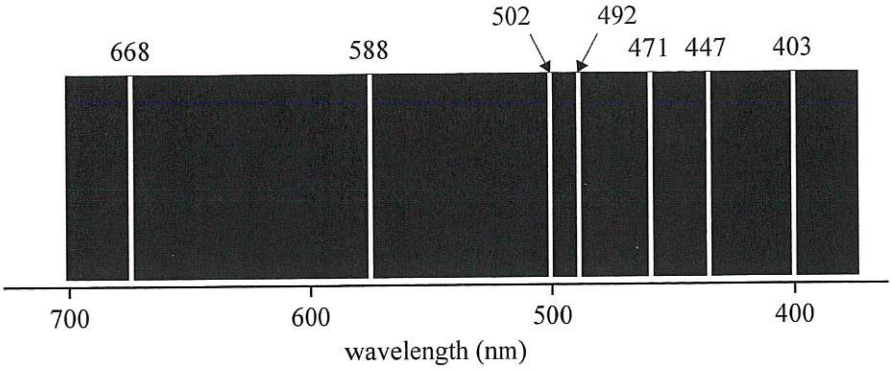

Figure 17

a. Which spectral line indicates the photon with the lowest energy? 1 mark

Lowest frequency → long wavelength

668 nm

b. Calculate the frequency of the photon emitted at the 588 nm line. Show your working. 2 marks

$v = \lambda f$

$3.0 \times 10^{8} = 588 \times 10^{-9} f$

$f = 5.10204 \times 10^{14}$

5.1×10^{14} Hz

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DO NOT WRITE IN THIS AREA

c. Explain why only certain wavelengths and, therefore, certain energies are present in the helium spectrum. 2 marks

* Electrons exist in certain energy levels
* Electrons transitioning between these levels can only emit discrete amounts of energy
* Only certain wavelengths are present.

Question 18 (16 marks)

Students are modelling the effect of the resistance of electrical cables, r, on the transmission of electrical power. They model the cables using the circuit shown in Figure 18.

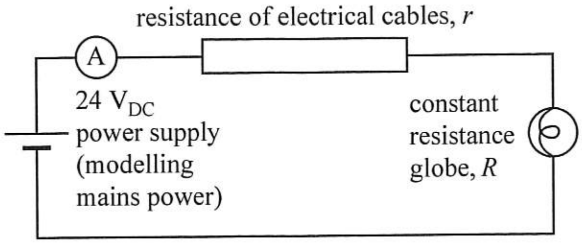

Figure 18

a. The 24 V_{DC} power supply models the mains power.

Describe the effect of increasing the resistance of the electrical cables, r, on the brightness of the constant resistance globe, R. 2 marks

The brightness of the globe would reduce. Since increasing resistance, r, will reduce the current in the circuit

Note: 2 marks Need – What happens to the globe
– and a reason.
either • reduced current
• increased voltage drop in cables.
• increased power loss in cables.

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The students investigate the effect of changing r by measuring the current in the electrical cables for a range of values. Their results are shown in Table 1 below.

Table 1

Resistance of cables, r (Ω)	Current in cables, i (A)	$\frac{1}{i}$ (A^{-1})
2.4	2.4	$\frac{1}{2.4} = 0.4166 = 0.42$
3.6	2.0	0.50
6.4	1.7	0.59
7.6	1.5	0.67
10.4	1.3	0.77

b. Identify the dependent and the independent variables in this experiment. Give your reasoning. 2 marks

Independent - Resistance of Cables, This is what the students change
Dependent - Current in cables. This is what the students measure

c. To analyse the data, the students use the following equation to calculate the resistance of the cables for the circuit.

$$r = \frac{24}{i} - R$$

use $V = i R_T$ where $R_T = r + R$.

Show that this equation is true for the circuit shown in Figure 18. Show your working. 2 marks

$24 = i\,(r + R)$

$\frac{24}{i} = r + R$

$r = \frac{24}{i} - R$

d. Calculate the values of $\frac{1}{i}$ and write them in the spaces provided in the last column of Table 1. 2 marks

Note: 9 of the 10 given data values have 2 significant figures
Give $\frac{1}{i}$ to 2 significant figures.

19 divisions

Use 2 divisions = 0.1

USE a RULER!

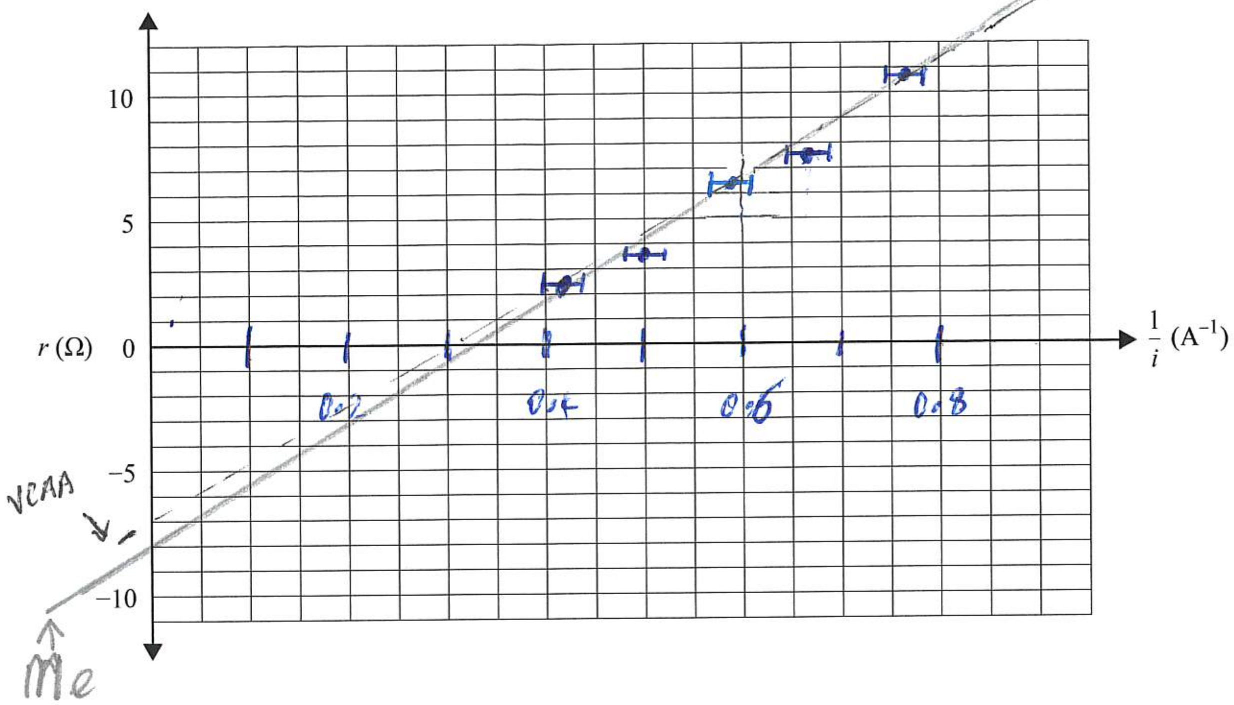
e. Plot a graph of r on the y-axis against $\frac{1}{i}$ on the x-axis on the grid provided below. On your graph:

- choose an appropriate scale and numbers for the x-axis
- draw a straight line of best fit through the plotted points
- include uncertainty bars ($\pm$ x-direction only) of $\pm 0.02\ \text{A}^{-1}$. (Uncertainty bars in the y-direction are not required.)

on graph. $0.1 \approx 13$ mm

$\Rightarrow 0.02 \approx 2.5$ mm

6 marks



f. Use the straight line of best fit to find the value of the constant resistance globe, R. Give your reasoning.

2 marks

The resistance of the globe is the intercept on the y-axis.

$R = 8\ \Omega$.

Eqn of line has the form

$r = \text{gradient} \times \frac{1}{i} - R$

| 8 Ω |

Note: Official answer was 7 Ω. However there is some allowance is given for the plotting and fitting of the line of best fit.

END OF QUESTION AND ANSWER BOOK