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Draw a cross through the box (☒) if you have NOT written in this booklet

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OUTSTANDING SCHOLARSHIP EXEMPLAR

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2023
Physics

Time allowed: Three hours
Total score: 32

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

For all numerical answers, full working must be shown and the answer must be rounded to the correct number of significant figures and given with the correct SI unit.

Formulae you may find useful are given on page 3.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–24 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (AREA DO NOT WRITE). This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

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The assessment starts on page 4.

The formulae below may be of use to you.

$v_f = v_i + at$

$d = v_i t + \frac{1}{2}at^2$

$d = \frac{v_i + v_f}{2}t$

$v_f^2 = v_i^2 + 2ad$

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

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

$\Delta p = F\Delta t$

$\omega = 2\pi f$

$d = r\theta$

$v = r\omega$

$a = r\alpha$

$W = Fd$

$F_{net} = ma$

$p = mv$

$x_{COM} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$

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

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

$L = I\omega$

$L = mvr$

$\tau = I\alpha$

$\tau = Fr$

$E_{K(ROT)} = \frac{1}{2}I\omega^2$

$E_{K(LIN)} = \frac{1}{2}mv^2$

$\Delta E_p = mg\Delta h$

$\omega_f = \omega_i + \alpha t$

$\omega_f^2 = \omega_i^2 + 2\alpha\theta$

$\theta = \frac{(\omega_i + \omega_f)}{2}t$

$\theta = \omega_i t + \frac{1}{2}\alpha t^2$

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

$T = 2\pi\sqrt{\frac{m}{k}}$

$E_p = \frac{1}{2}ky^2$

$F = -ky$

$a = -\omega^2 y$

$y = A\sin\omega t \quad y = A\cos\omega t$

$v = A\omega\cos\omega t \quad v = -A\omega\sin\omega t$

$a = -A\omega^2\sin\omega t \quad a = -A\omega^2\cos\omega t$

$\Delta E = Vq$

$P = VI$

$V = Ed$

$Q = CV$

$C_T = C_1 + C_2$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$

$E = \frac{1}{2}QV$

$C = \frac{\varepsilon_o \varepsilon_r A}{d}$

$\tau = RC$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

$R_T = R_1 + R_2$

$V = IR$

$F = BIL$

$V = BvL$

$F = Bqv$

$F = Eq$

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

$\phi = BA$

$\varepsilon = -\frac{\Delta\phi}{\Delta t}$

$\varepsilon = -L\frac{\Delta I}{\Delta t}$

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

$E = \frac{1}{2}LI^2$

$\tau = \frac{L}{R}$

$I = I_{MAX}\sin\omega t$

$V = V_{MAX}\sin\omega t$

$I_{MAX} = \sqrt{2}\,I_{rms}$

$V_{MAX} = \sqrt{2}\,V_{rms}$

$X_C = \frac{1}{\omega C}$

$X_L = \omega L$

$V = IZ$

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

$v = f\lambda$

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

$n\lambda = \frac{dx}{L}$

$n\lambda = d\sin\theta$

$f' = f\frac{V_W}{V_W \pm V_S}$

$E = hf$

$hf = \phi + E_K$

$E = \Delta mc^2$

$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$

$E_n = -\frac{hcR}{n^2}$

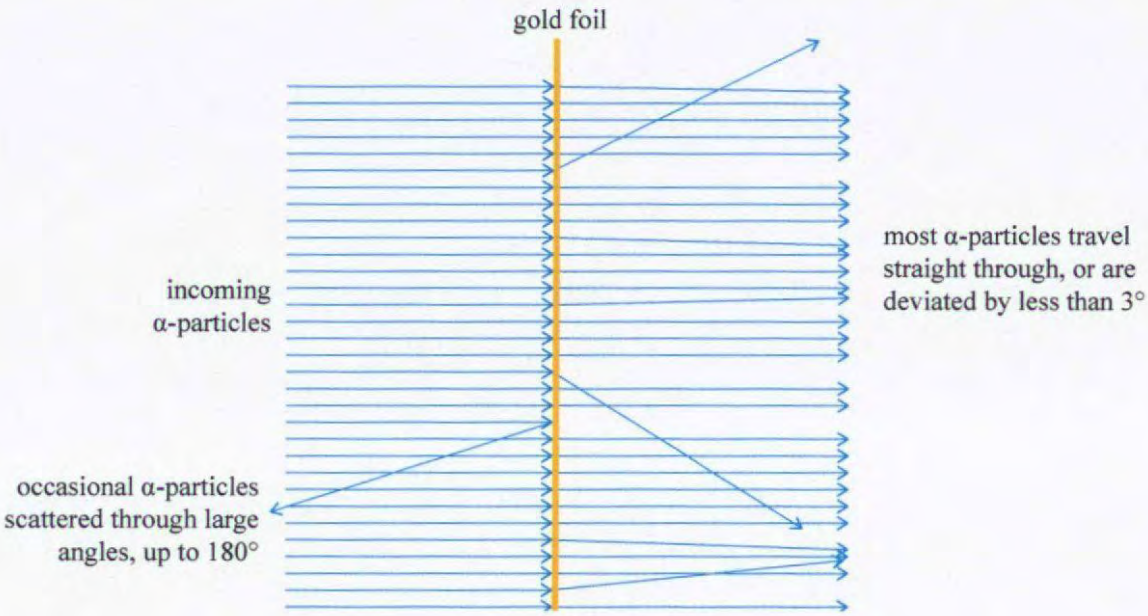
QUESTION ONE: THE DISCOVERIES OF ERNEST RUTHERFORD

Atomic number of gold $= 79$
Charge of an electron $= -1.60 \times 10^{-19}$ C

Ernest Rutherford won a Nobel Prize in 1908 for work on understanding radioactive decay and for discovering α-particles. Later, he and his fellow researchers used α-particles in two famous experiments.

Experiment 1: Scattering of alpha particles by gold foil

When Rutherford fired α-particles at a thin foil of gold, he observed that most went straight through or deviated by less than 3 degrees. However, the researchers were surprised to see occasional α-particles were scattered through large angles, some even returning in the direction from which they had come.



(a) Explain how these results were consistent with the model of the atom that Rutherford proposed.

With Rutherford's model most of the atom is empty space, but there is a dense (positively charged) nucleus at the centre composed of protons & neutrons. ~~Since~~ This is consistent with most α particles passing through with little deviation (due to the empty space), but some being deflected up to 180° when they collide directly with the like-charged nucleus ~~[illegible]~~ (which are much more massive).

While the electrons will also have some effect, it will be minimal since they are spread out over a large volume (compared to nucleus) around the nucleus in Rutherford's model, and this too is consistent with the small deviations in deflection angle.

(b) The electrostatic potential energy between two charges, of magnitudes q_1 and q_2, and separated by distance r, is given by $E_\text{p} = \dfrac{\text{k}q_1q_2}{r}$, where $\text{k} = 8.99 \times 10^9$ N m^2 C^{-2}.

An α-particle of mass m, velocity v, and charge $2e$, travels directly towards a nucleus that remains stationary at all times. The charge on the stationary nucleus is Ze, where Z is the atomic number of the stationary nucleus, and e is the charge of an electron.

(i) Show that the distance of closest approach, D, is given by:

$$D = \frac{4\text{k}Ze^2}{mv^2}$$

Explain your reasoning.

$$E_{p_i} = \frac{k(2e)(Ze)}{r}$$

$$= \frac{2kZe^2}{r}$$

assume $r = \infty$, i.e. starts w/ no E_p.

$$E_{pf} = \frac{2kZe^2}{D}$$

$\therefore$ E_p gained $= E_{pf}$.

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

E_k lost $=$ E_p gained

$$\frac{1}{2}mv^2 = \frac{2kZe^2}{D}$$

$$\frac{1}{D} = \frac{mv^2}{4kZe^2}$$

$$\boxed{D = \frac{4kZe^2}{mv^2}}$$

(ii) Calculate the distance of closest approach of a 4.78 MeV α-particle travelling directly towards a gold nucleus, which is fixed in position.

$D = \frac{4kZe^2}{mv^2}$

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

$mv^2 = 2E_k$

$mv^2 = 2 \times 4.78 \times 10^6 \times 1.6 \times 10^{-19}$

$= 1.5296 \times 10^{-12}$ J

$D = \frac{4 \times 8.99 \times 10^9 \times 79 \times (1.6 \times 10^{-19})^2}{1.5296 \times 10^{-12}}$

$D = 4.75454.. \times 10^{-14}$

$D = 0.0475$ pm (3s.f.)

(c) If a nucleus of charge *Ze* were free to move, as would occur if it were in the gaseous state for example, would the distance of closest approach be the same, greater, or less than given by the equation in part (b)(i)?

Same E_k @ start

Explain your answer using physical principles.

$\rightarrow E_p + E_{k\,Au}$

No calculation is required.

The distance of closest approach must be greater. In both situations the initial kinetic energy of the alpha particle is the same (assuming that the nucleus of charge Ze starts stationary). This kinetic energy is then converted into both electrostatic potential energy and kinetic energy (for the nucleus of ~~[illegible]~~ charge Ze), ∴ the electrostatic potential @ closest approach must be lower than before in b)i). Since at closest approach $E_p = \frac{2kze^2}{D}$, and E_p decreases (k, z, e constant) D must increase. The argument is ~~[illegible]~~ similar with the same conclusion if the nucleus of charge Ze starts with non-zero E_k.

(d) **Experiment 2: Bombardment of nitrogen gas by high-energy alpha particles**

Rutherford and his fellow researchers fired high-energy, 7.70 MeV, α-particles at a container of nitrogen gas and were surprised to see that protons, ${}^{1}_{1}\mathrm{H}$, were emitted. At the time, the researchers knew that a nuclear reaction had occurred, but they did not know what the reaction was. Two possible nuclear reactions are:

${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\alpha \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$ Reaction 1

${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\alpha \rightarrow {}^{13}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{H} + {}^{4}_{2}\alpha$ Reaction 2

(i) Using your knowledge of binding energy per nucleon, explain which reaction, Reaction 1 or Reaction 2, is more likely.

Graphing binding energy / nucleon for all nuclei, we find that nuclei w/ mass < 56 quickly rise in binding energy/nucleon w/ increasing mass, then binding energy / nucleon peaks @ ${}^{56}_{26}\mathrm{Fe}$. Since binding energy/nucleon is the energy required to separate a nucleus into ~~its~~ constituent nucleons (per # nucleons), nuclei w/ higher binding energy / nucleon are more stable. Since ${}^{17}_{8}\mathrm{O}$ has a higher mass (closer to ${}^{56}_{26}\mathrm{Fe}$) than ${}^{13}_{6}\mathrm{C}$ or ${}^{4}_{2}\alpha$, it has a higher binding energy / nucleon and ∴ its formation via Reaction 1 is more energetically favorable and likely.

(ii) Explain why it was necessary to use high-energy α-particles for this experiment.

It was necessary to use high energy α particles since the α particles must essentially collide w/ the ${}^{14}_{7}\mathrm{N}$ nuclei for the reaction to take place. ~~As seen earlier, with~~ α particles of lower initial KE will have a lower final E_p, which analogous to part c) will cause a greater distance of closest approach. ∴ to minimise the distance of closest approach & maximise the chances of a reaction occurring, high-energy (high KE) α particles were necessary.

8

QUESTION TWO: AXE THROWING

Acceleration due to gravity = 9.81 m s^{-2}

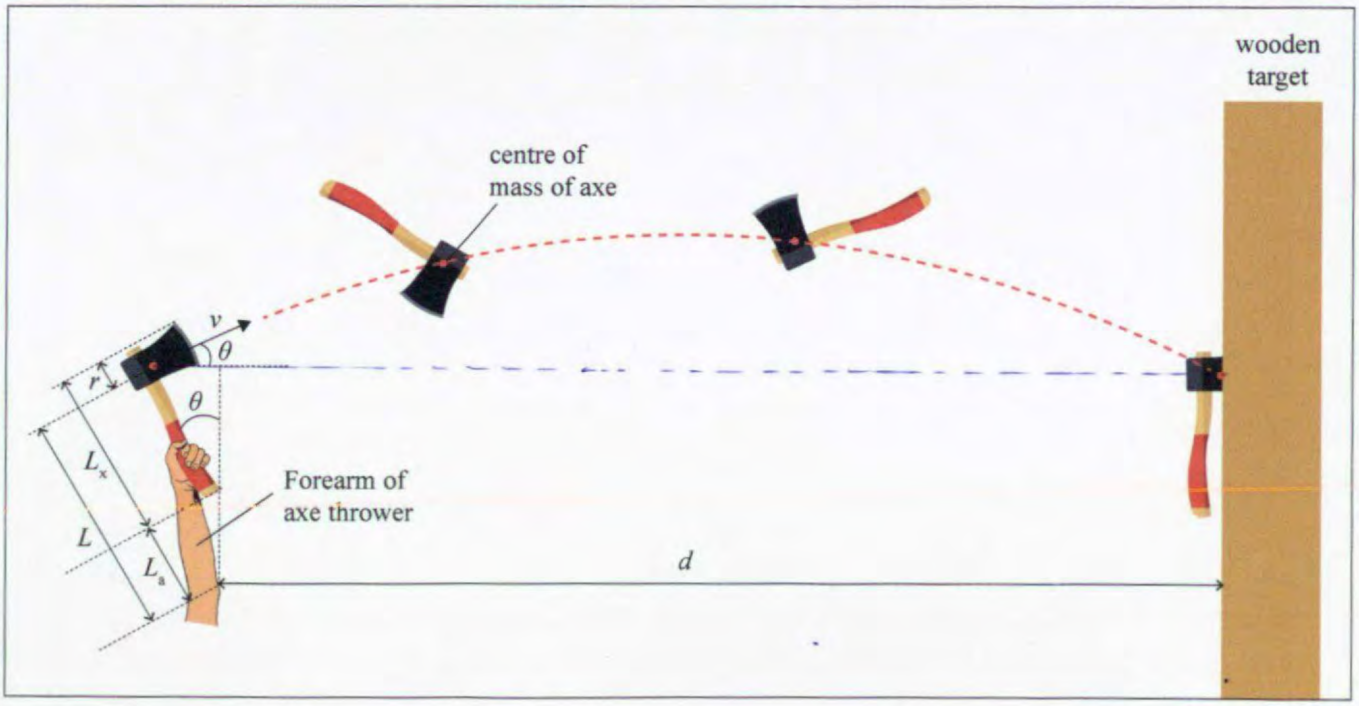
Source: www.sydney.com/destinations/sydney/sydney-west/penrith/attractions/throw-axe

Axe throwing is a traditional sport that has become more popular recently. It involves throwing an axe at a wooden target. The path of the axe can be described with the physics of projectile motion and of rotational motion. If the axe is thrown correctly, it rotates after it is thrown so that it is vertical as it reaches the target, allowing the blade to stick in the target.

Although everybody will throw the axe in a slightly different way, we can describe the throw as follows.

- The axe is held so that the forearm and the axe handle form a straight line, as shown in the diagram below.
- The throw is made by keeping the upper arm still and swinging the forearm from the elbow.

The axe is released at an angle θ, so that its centre of mass has a velocity, v. The axe is thrown from the same height as the target. The axe completes just over one full rotation as it travels from the release point to the target. The centre of mass of the axe finishes up level with the surface of the target, as shown in the diagram below. rotates $2\pi + \theta$



The velocity of the centre of mass at release is v.

r = distance from the end of the axe to centre of mass

L_x = total length of axe

L_a = length of axe thrower's forearm

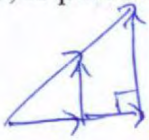
The length from the centre of mass to the elbow is, $L = L_a + L_x - r$

d = distance of axe thrower's elbow from the target

(a) An analysis of the projectile motion of the axe can be used to show that the time of flight of the axe, from the time it is released to when it strikes the target at exactly the same height, is $t = \dfrac{2v\sin\theta}{g}$.

Show that the initial velocity, v, required for the axe to strike the target successfully is given by:

$$v = \sqrt{\frac{g(d + L\sin\theta)}{2\sin\theta\cos\theta}}$$



Clearly show your working.

$t = \dfrac{2v\sin(\theta)}{g}$

$v\cos(\theta) = \dfrac{\Delta d}{\Delta t}$

$\Delta t\, v\cos(\theta) = \Delta d$

$\dfrac{2v^2\sin(\theta)\cos(\theta)}{g} = d + L\sin(\theta)$ ✓

$v^2 = \dfrac{g(d+L\sin(\theta))}{2\sin(\theta)\cos(\theta)}$ ✓

or $v = \sqrt{\dfrac{g(d+L\sin(\theta))}{\sin(2\theta)}}$

$\Rightarrow \boxed{v = \sqrt{\dfrac{g(d+L\sin(\theta))}{2\sin(\theta)\cos(\theta)}}}$

(b) The angular velocity of the axe is given by $\omega = \dfrac{v}{L}$. For a successful throw that ends up with the axe rotating and sticking in the target, as shown in the diagram opposite, show that the ratio of $\dfrac{d}{L}$ is given by:

$$\frac{d}{L} = (\theta + 2\pi)\cos\theta - \sin\theta$$

$\omega = \dfrac{\Delta\theta}{\Delta t}$ $\quad \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{L}$

$\Delta\theta = 2\pi + \theta$

$\Delta t = \sqrt{\dfrac{4v^2\sin^2(\theta)}{g^2}}$

$\omega = \dfrac{v}{L}$

$\Delta\theta = \dfrac{v\Delta t}{L}$

$\theta + 2\pi = \dfrac{1}{L}\sqrt{\dfrac{g(d+L\sin(\theta))}{\cancel{2\sin(\theta)}\cos(\theta)} \times \dfrac{\cancel{4}\,2v^2\sin^2(\theta)}{g^2}}$

$\theta + 2\pi = \dfrac{1}{L}\sqrt{\dfrac{2\sin(\theta)(d+L\sin(\theta))}{g\cos(\theta)} \times \dfrac{g(d+L\sin(\theta))}{2\sin(\theta)\cos(\theta)}}$

$\theta + 2\pi = \dfrac{1}{L}\sqrt{\dfrac{(d+L\sin(\theta))^2}{\cos^2(\theta)}}$

$\theta + 2\pi = \dfrac{d+L\sin(\theta)}{L\cos(\theta)}$

$\theta + 2\pi = \dfrac{d}{L\cos(\theta)} + \dfrac{\sin(\theta)}{\cos(\theta)}$

$\dfrac{d}{L\cos(\theta)} = \theta + 2\pi - \dfrac{\sin(\theta)}{\cos(\theta)}$

$\boxed{\dfrac{d}{L} = (\theta+2\pi)\cos(\theta) - \sin(\theta)}$ ✓ ✓

(c) In axe throwing, the angle θ is usually small.

Derive a simplified form of the equation in part (b), for a small angle θ.

Clearly show your working and state any assumptions made.

Assuming that θ is close to ϕ (i.e. $0° \leq \theta \leq 10°$), $\sin(\theta) \simeq \theta$ (first non-zero Maclaurin series term)

$$\boxed{\frac{d}{L} = \theta + 2\pi\left(1 - \frac{\theta^2}{2}\right) - \theta}$$

$\cos(\theta) \simeq 1 - \frac{\theta^2}{2}$ (first 2 non-zero Maclaurin series terms)

alternatively using only first non-zero term in $\cos(\theta)$ Maclaurin series gives $\frac{d}{L} = \theta + 2\pi - \theta$ or $\boxed{\frac{d}{L} = 2\pi}$ although this is less accurate.

(d) Axe throwers have limited scope to vary their angle of release, and can throw from any distance, provided they stay behind a line marked on the ground.

(i) Mika throws an axe with a larger total length, L_x.

What other adjustment can she make to ensure that her throw still hits the target successfully?

Since she throws an axe with larger total length L_x, the distance L will be larger too. For a successful throw, and assuming she wants to release the axe @ the same angle θ she usually does, $\frac{d}{L}$ must be constant. $\therefore$ d must increase by the same factor L has, i.e. Mika should step back a bit.

(ii) Giving reasons, explain which aspects of the axe's flight would change, and which would stay the same, if Mika were throwing an axe on the Moon, where the acceleration due to gravity is less than on Earth.

$v \downarrow$

$\frac{d}{L} =$

Assuming Mika wants to throw at the same angle and velocity she usually does, her axe would go further on the moon since the vertical component of the initial velocity would change more slowly (acceleration due to gravity is lesser) meaning a greater time in the air & thus greater range. However, the ratio $\frac{d}{L}$ will still be the same since it is independent of the gravitational acceleration, $\therefore$ to throw successfully on the moon she would only need to throw with less force.

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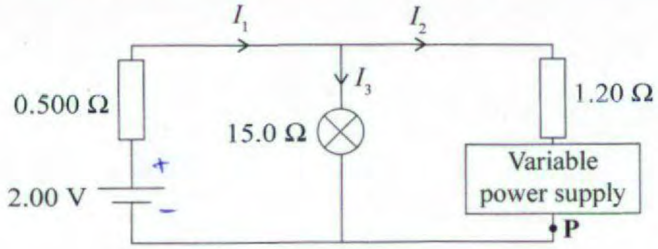
QUESTION THREE: DC AND DOPPLER

A circuit is set up with two power supplies. One supplies a constant EMF of 2.00 V, the other is a variable power supply that can provide a continuous range of EMFs.



(a) In addition to Ohm's Law, describe two other key circuit rules that could be applied to determine currents and potential differences in a circuit like this, and state the fundamental physics principles these rules are based on.

1) Kirchoff's current law: current entering a junction is equal to current exiting junction, direct implication of conservation of charge. 2) Kirchoff's voltage law: Voltages (sum of) around any loop in the circuit must be ∅, direct implication of conservation of energy.

✓ ✓

(b) The orientation and EMF of the variable power supply are adjusted until no current flows through the 15 Ω lamp, and it does not light up.

(i) Calculate the EMF of the variable power supply when the lamp does not light up, and clearly state whether point **P** shown on the diagram is the positive or negative end of the variable power supply.

0

(ii) With the variable power supply still set so the 15.0 Ω lamp does not light up, the lamp is replaced by another lamp with a lower resistance.

Explain whether the new lamp with lower resistance will light up or not.

0

v_f v_i d a

(c) A moving car, with a horn emitting sound with frequency, f, starts from rest and accelerates with constant acceleration, a, towards a stationary observer a distance, d, away.

Show that the observer will eventually hear a frequency of $2f$ only if $d > \frac{v_w^{\ 2}}{8a}$, where v_w is the speed of sound.

for doppler f of 2f:

d

$2f = f\left(\frac{v_w}{v_w - v_s}\right)$

$v_f^2 = v_i^2 + 2ad$

$\frac{v_w - v_s}{v_w} = \frac{1}{2}$

$\frac{v_w^2}{4} = 2ad$

$d = \frac{v_w^2}{8a}$

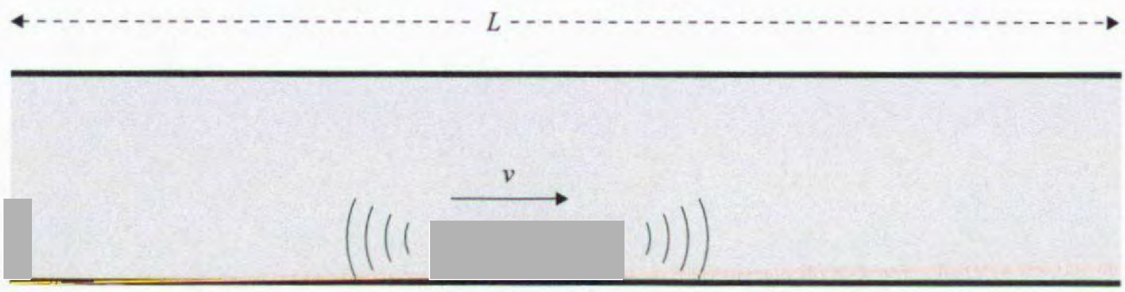
$v_w - v_s = \frac{v_w}{2}$

$v_s = \frac{v_w}{2}$

but if $d = \frac{v_w^2}{8a}$ sound of frequency 2f cannot be heard since car will collide w/ observer before this occurs, ∴ required $\boxed{d > \frac{v_w^2}{8a}}$

(d) A car travels through a tunnel at a constant speed. The car horn emits sound at a constant single frequency. When sound reaches one of the open ends of the tunnel it is reflected and travels back along the tunnel in the other direction.

The size of the car is small compared to the diameter of the tunnel, so that the presence of the car does not affect the sound travelling through the tunnel.



Observer

Sources: https://signalvnoise.com/posts/920-car-design-the-side-crease-is-in
https://www.istockphoto.com/photo/casual-man-side-view-gm183765770-15426060

$f = \frac{nv_w}{2L}$

NOTE: situation is simply reversed if car travels towards observer, argument here still stands.

An observer standing at one of the open ends of the tunnel will hear two distinct frequencies from the car horn.

(i) Explain why the observer hears two distinct frequencies from the car horn.

The observer hears a lower frequency sound ~~from~~ originating from behind the car since the car travels away from each wavefront creating a larger λ and thus lower frequency sound ($f \propto \frac{1}{\lambda}$). The observer also hears a higher frequency sound originating from the front of the car, since the car travels towards each wave front causing a smaller λ and thus higher frequency sound. This higher f sound reflects at the open end of the tunnel, travelling back towards the observer, $\therefore$ 2 f's heard

(ii) The car travels through the tunnel at a constant speed, v, while the horn emits sound at a constant frequency, f, so that both the 20th and 21st harmonics resonate in the tunnel. These harmonics cause a beat frequency of 4.76 Hz at the end of the tunnel.

Speed of sound = 343 m s^{-1}

Calculate the speed of the car, v, AND the frequency of the horn, f.

$f_{21} - f_{20} = 4.76$ Hz

$21f_1 - 20f_1 = 4.76$

$f_1 = 4.76$

$\frac{v_w}{2L} = 4.76$

$\frac{2L}{v_w} = \frac{1}{4.76}$

$L = \frac{343}{2(4.76)}$

$L = 36.029...$ m

$L = 36.0$ m (3s.f.)

$f' = f\frac{v_w}{v_w \pm v}$

$\cancel{4.76} = f\frac{343}{343 - v}$

$4.76 = f\frac{343}{343 + v}$

$343 - v = 343 + v$

~~horn frequency~~

~~f is 4.76 Hz~~

5

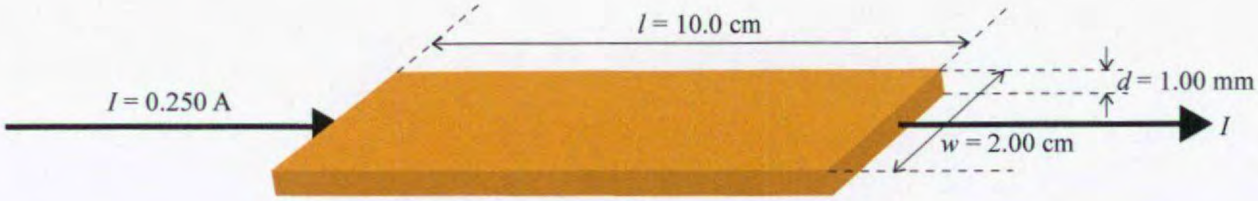
$V = IR$

QUESTION FOUR: HALL EFFECT

Charge of an electron = -1.60×10^{-19} C

When charge flows through a conductive material, e.g. a metal, only some of the electrons are free to move. A conductor has a fixed number of free electrons per unit volume, n.

For copper metal, $n = 8.49 \times 10^{28}$ electrons m^{-3}



(a) (i) A piece of copper metal 10.0 cm long, 2.00 cm wide, and 1.00 mm thick has a current of 0.250 A flowing through it.

$\frac{Q}{t}$

By first calculating the amount of free charge in the piece of copper, determine the average speed of a free electron as it flows through the piece of copper.

$V = 0.02 \times 0.1 \times 10^{-3}$
$= 2 \times 10^{-6}\ m^3$

$I = \frac{dQ}{dt}$

Free charge
$= 8.49 \times 10^{28} \times 2 \times 10^{-6}$
$= 1.698 \times 10^{23}$ electrons.
@ any point in time within slab.
or $1.698 \times 10^{23} \times 1.6 \times 10^{-19}$
$= 27168$ C

$v = \frac{0.25}{27168} \times 0.1$
$= 9.202... \times 10^{-7}\ ms^{-1}$
$= 0.92\ \mu m s^{-1}$

(ii) The current flowing through a conductor is given by the relationship:

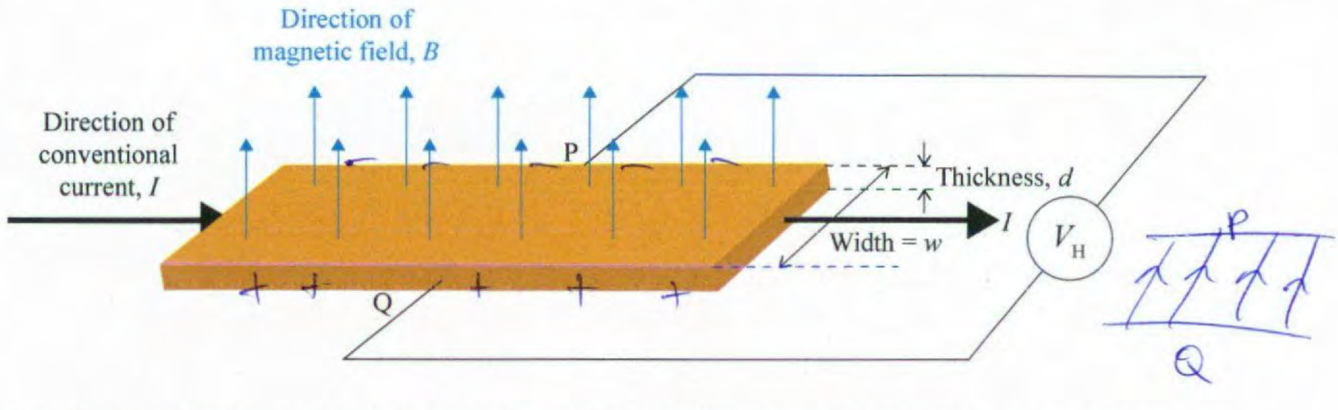
$I = neAv_d$

where e is the charge of an electron, A is the cross-sectional area of the conductor, and v_d is the average drift velocity of a free electron.

Show that the relationship above is dimensionally consistent.

$RHS = neAv_d$
$= m^{-3} \times C \times m^2 \times ms^{-1}$
$= Cs^{-1}$
$= I$
$= LHS.$

When charge flows through a conductor which is inside a uniform magnetic field, a sideways force is exerted on the moving electrons that pushes them to one side of the conductor. This makes one side of the conductor positively charged and the opposite side negatively charged. This separation of charge produces a potential difference, known as a Hall Voltage, V_H, across the two sides of the conductor.



(b) By considering the magnetic force acting on an electron moving through the conductor, state which side of the conductor, P or Q, is positively charged.

Your answer must include a description of how you made your selection.

The magnetic ~~field~~ force acting on an electron will be towards P, since this is opposite the force's ~~given~~ direction given by the right hand rule using the conventional current's direction(Q) ∴ there will be an electron deficit on side Q, meaning side Q is positively charged.

(c) (i) When a steady current is flowing, the sideways forces acting on an electron moving through the conductor are balanced.

$F = Ed$

Explain the origin of the force that balances the magnetic force on a moving electron.

The force that balances the magnetic force is due to the ~~build-up of~~ separation of charge across P and Q creating an electric field, which exerts an electrostatic force on the electrons towards Q i.e. opposing the magnetic force.

Question Four continues on the following page.

01202

$F = Eq$
$= \frac{V_H e}{w}$

$\frac{V_H e}{w} = \frac{BI}{ndw}$
$V_H = \frac{BI}{nde}$

(ii) By considering the sideways forces acting on a moving electron, show that the Hall Voltage, V_H, is given by the expression:

$$V_H = \frac{BI}{nde}$$

or Bwv_d

$\frac{I}{nde} = \frac{n\cancel{e}Av_d}{n d \cancel{e}} = \frac{w\cancel{d}v_d}{\cancel{d}}$

$F = Bvq$
$= \frac{BIe}{neA}$
$= \frac{BI}{nA}$
$= \frac{BI}{nwd}$

$F_e = Eq$
$= \frac{V_H e}{w}$

When forces equal:

$\frac{V_H e}{\cancel{w}} = \frac{BI}{n\cancel{w}d}$

$V_H = \frac{BI}{nde}$

(d) Measuring the Hall Voltage is a commonly used method for determining the strength of a magnetic field.

Describe the conditions necessary to achieve the most precise measurement of the strength of a magnetic field, and any practical limitations to achieving these conditions.

$V_H = \frac{BI}{nde}$ $B = \frac{V_H nde}{I}$

The current must be known, and the Hall voltage and height of the conductor, and the # of free electrons/volume. The charge on an electron has been measured to high accuracy, so is not a limitation. However, a material which has a known # of free electrons/volume must be used, which necessitates finding very standardised (and preferably pure) materials in reality — a limitation.

7

Extra space if required.
Write the question number(s) if applicable.

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QUESTION NUMBER

93103

Outstanding Scholarship

Subject: Physics

Standard: 93103

Total score: 28

Q	Score	Marker commentary
1	08	Outstanding scholarship level of understanding of atomic interactions demonstrated throughout.
2	08	Outstanding demonstration of understanding of projectile motion in a variety of circumstances.
3	05	Scholarship only level of understanding of the Doppler effect. Failure to complete calculations for both Kirchhoff and Doppler questions resulted in a lowering of the candidate's typical performance.
4	07	Outstanding understanding of a novel scenario. Exceptional skill shown in algebraic manipulation and appreciation of the significance of the relationships.