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OUTSTANDING SCHOLARSHIP



Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2025 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 2–28 in the correct order and that none of these pages is blank.

Do not write in the margins (✂). This area will 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.**

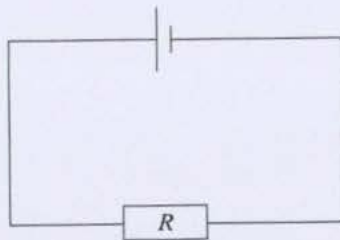
The formulae below may be of use to you.

$v_f = v_i + at$ $d = v_i t + \frac{1}{2} at^2$ $d = \frac{v_i + v_f}{2} t$ $v_f^2 = v_i^2 + 2ad$ $F_g = \frac{GMm}{r^2}$ $F_c = \frac{mv^2}{r}$ $\Delta p = F \Delta t$ $\omega = 2\pi f$ $d = r\theta$ $v = r\omega$ $a = r\alpha$ $W = Fd$ $F_{\text{net}} = ma$ $p = mv$ $x_{\text{COM}} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$ $\omega = \frac{\Delta\theta}{\Delta t}$ $\alpha = \frac{\Delta\omega}{\Delta t}$ $L = I\omega$ $L = mvr$ $\tau = I\alpha$ $\tau = Fr$ $E_{K(\text{ROT})} = \frac{1}{2} I\omega^2$ $E_{K(\text{LIN})} = \frac{1}{2} mv^2$ $\Delta E_p = mg\Delta h$ $\omega_f = \omega_i + \alpha t$ $\omega_f^2 = \omega_i^2 + 2\alpha\theta$ $\theta = \frac{(\omega_i + \omega_f)}{2} t$ $\theta = \omega_i t + \frac{1}{2} \alpha t^2$	$T = 2\pi\sqrt{\frac{l}{g}}$ $T = 2\pi\sqrt{\frac{m}{k}}$ $E_p = \frac{1}{2} ky^2$ $F = -ky$ $a = -\omega^2 y$ $y = A \sin \omega t$ $y = A \cos \omega t$ $v = A\omega \cos \omega t$ $v = -A\omega \sin \omega t$ $a = -A\omega^2 \sin \omega t$ $a = -A\omega^2 \cos \omega t$ $\Delta E = Vq$ $P = VI$ $Q = CV$ $C_T = C_1 + C_2$ $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$ $E = \frac{1}{2} QV$ $C = \frac{\epsilon_0 \epsilon_r A}{d}$ $\tau = RC$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ $R_T = R_1 + R_2$ $V = IR$ $F = BIL$ $V = BvL$ $F = Bqv$ $F = Eq$ $E = \frac{V}{d}$	$\phi = BA$ $\epsilon = -\frac{\Delta\phi}{\Delta t}$ $\epsilon = -L \frac{\Delta I}{\Delta t}$ $\frac{N_p}{N_s} = \frac{V_p}{V_s}$ $E = \frac{1}{2} LI^2$ $\tau = \frac{L}{R}$ $I = I_{\text{MAX}} \sin \omega t$ $V = V_{\text{MAX}} \sin \omega t$ $I_{\text{MAX}} = \sqrt{2} I_{\text{rms}}$ $V_{\text{MAX}} = \sqrt{2} V_{\text{rms}}$ $X_C = \frac{1}{\omega C}$ $X_L = \omega L$ $V = IZ$ $f_0 = \frac{1}{2\pi\sqrt{LC}}$ $v = f\lambda$ $f = \frac{1}{T}$ $n\lambda = \frac{dx}{L}$ $n\lambda = d \sin \theta$ $f' = f \frac{V_w}{V_w \pm V_s}$ $E = hf$ $hf = \phi + E_K$ $E = \Delta mc^2$ $\frac{1}{\lambda} = R \left(\frac{1}{S^2} - \frac{1}{L^2} \right)$ $E_n = -\frac{hcR}{n^2}$
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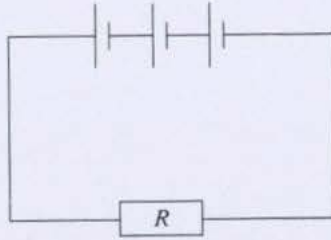
QUESTION ONE: INTERNAL RESISTANCE

A battery can be made by connecting a number of individual cells together. The cells can be connected either in series or in parallel.

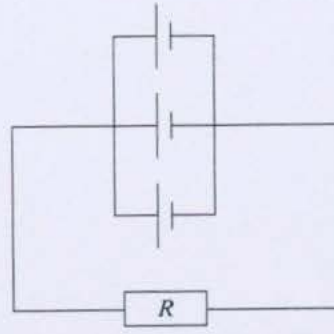
Circuit 1



Circuit 2



Circuit 3



- (a) Compare the total power dissipated in the resistor R in the three circuits above: with a single cell, with three cells connected in series, and with three cells connected in parallel.

Assume the cells are all identical and ideal for this part of the question.

Circuit 1 will have the full voltage across the resistor, and current of $\frac{V}{R}$, meaning power of $\frac{V^2}{R}$. Circuit 2 has series arrangement of cells, meaning voltage of $3V$ and current of $\frac{3V}{R}$, so power of $9V^2/R$. Circuit 3 will have voltage of V , and current of $\frac{V}{R}$ through the resistor. power in this resistor is V^2/R

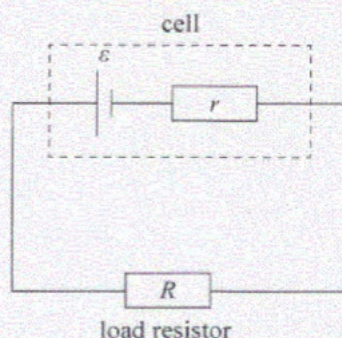
$$P_1 = \frac{V^2}{R}$$

$$P_2 = \frac{9V^2}{R}$$

$$P_3 = \frac{V^2}{R}$$

P_2 has 9 times more power

- (b) A real cell produces an emf $\mathcal{E}$ and has internal resistance r . The cell is connected to a load resistor with resistance R .



- (i) Show that the power dissipated by the load resistor is given by the expression:

$$P_R = \frac{\mathcal{E}^2 R}{(r+R)^2}$$

$$P = IV \quad \frac{V}{R}$$

~~the average I in load resistor is~~

$$R_T = R + r \quad V = \mathcal{E}$$

$$\text{total current} = \frac{\mathcal{E}}{R + r}$$

$$\text{Voltage across } R = IR = \frac{\mathcal{E}}{R + r} \cdot R$$

$$P = IV = \frac{\mathcal{E}}{R + r} \cdot \frac{\mathcal{E}}{R + r} \cdot R = \frac{\mathcal{E}^2 R}{(r + R)^2}$$

- (ii) For a cell with constant $\mathcal{E}$ and constant r , the power dissipated by the load resistor is maximum when $R = r$.

Use appropriate physics concepts to explain why the power dissipated by the load resistor is small at extremely large and at extremely low values of R .

At extremely large R , R is way bigger than r , total resistance of circuit ~~is~~ is very large, current is very small, ~~but the voltage~~
 $P = I^2 R$, so small I will outweigh large R , leading to low power.

At extremely low R , R is smaller than r , so total current is reasonably high, yet voltage across R ($V = IR$) is very very small due to the small resistance, leading to a small amount of power, since the small size of the voltage outweighs the slightly large current. $P = IV$, so ~~the~~ low power.

All voltages and currents referred to in parts (c) and (d) of this question are rms values.

- (c) A real inductor has both inductance L and internal resistance r .

A real inductor with internal resistance $r = 72.0 \, \Omega$ is connected in series with a capacitor to an AC power supply with voltage V_S and frequency f .

Assume that both the capacitor and the power supply are ideal.

The current in the circuit is $I = 2.20 \times 10^{-2} \, \text{A}$. An AC voltmeter, connected as shown, measures the combined voltage of both the inductance and internal resistance of the real inductor as $V = 4.20 \, \text{V}$. The voltage V across the real inductor leads the voltage of the AC power supply V_S by 120° .

Sketch a phasor diagram for the voltages, and use it to calculate the value of the power supply voltage V_S .

$$I = 0.022 \, \text{A} \quad r = 72 \, \Omega$$

$$V_r = Ir = 1.584 \, \text{V}$$

$$4.2 \, \text{V} = L + R$$

$$V_C = \sqrt{V^2 - V_r^2}$$

$$V_C = \sqrt{4.2^2 - 1.584^2} = 3.88985 \, \text{V}$$

~~120~~

$$\theta = \cos^{-1}\left(\frac{A}{H}\right) = \cos^{-1}\left(\frac{1.584}{4.2}\right)$$

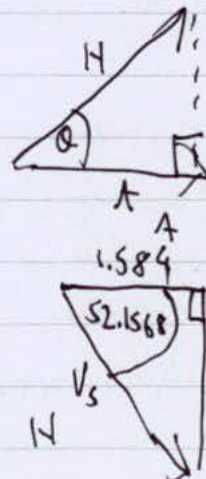
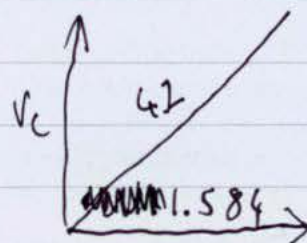
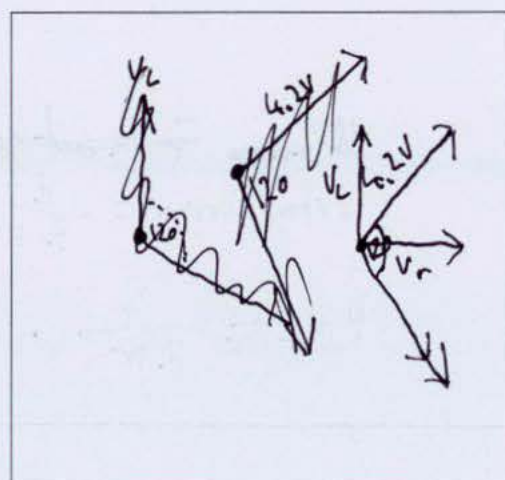
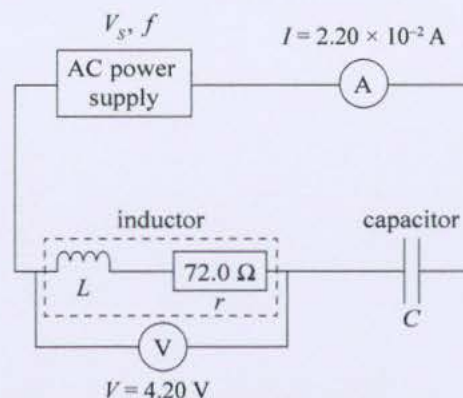
$$\theta = 67.843^\circ$$

$$120 - 67.843 = 52.1568$$

$$\cos \theta = \frac{A}{H}$$

$$H = \frac{A}{\cos \theta} = \frac{1.584}{\cos 52} = V_S$$

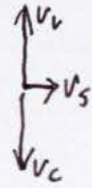
$$V_S = 2.58 \, \text{V}_{\text{rms}}$$



- (d) An ideal inductor, resistor, and capacitor are connected in series to an AC power supply. In certain conditions, the voltage across the inductor and the voltage across the capacitor can both exceed the voltage of the power supply.

Describe the conditions required for both V_L and V_C to exceed V_S .

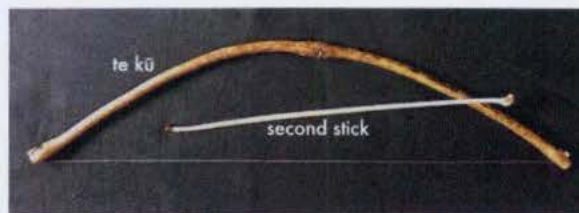
Explain the energy transfers occurring in the circuit under these conditions.



for both V_L and V_C to exceed V_S , the circuit must be at or near resonance. This means that it will be at its resonant frequency, where f and therefore ω is such that $X_C = X_L$ (or roughly equals) and $\frac{1}{\omega C} = \omega L$. at resonance, since V_L and V_C are 180° out of phase, they cancel each other out, leaving the total impedance Z to be equal to R , since $Z = \sqrt{R^2 + (V_L - V_C)^2}$ if $V_L - V_C \approx 0$ then $Z \approx R$, allowing the V_S to exceed V_L and V_C . Under these conditions, Energy is transferred most efficiently with little losses due to the R . Energy oscillates between the capacitor's electric field and the inductor's magnetic field, going back and forth over time.

QUESTION TWO: TAONGA PŪORO

- (a) Te kū is a traditional Māori musical instrument that consists of a single string connected between the ends of a bent stick. The string is struck with a second stick to produce a sound.



<https://www.haumanucollective.com/ku/>

A traditional Māori musician wants to make a second te kū that produces a sound with a higher frequency.

Describe TWO separate changes that could be made to the design to increase the frequency of the sound produced.

Explain how each of these changes alters fundamental parameters that result in a higher frequency sound.

~~higher frequency requires a higher harmonic.~~

- 1: if he uses a stiffer bent stick, there will be more tension in the string. more Tension means more wave velocity if it is the same length stick, the wave λ is constant, resulting in a higher frequency.
$$\frac{v}{\lambda} = \frac{f\lambda}{\lambda} = f$$
- 2: if he uses a shorter ~~bent stick~~ bent stick which exerts the same tension, the wave on the stick will have the same velocity, but a smaller λ , leading to higher frequency
$$v = \frac{f\lambda}{\lambda} = f$$

- (b) A pōrutu is a traditional Māori musical wind instrument that is carved from wood or bone. A pōrutu is a hollow pipe that is open at both ends. It is played in a similar way to a flute, by blowing across one of the open ends and covering small holes with the fingers.



<https://collection.nelsonmuseum.co.nz/objects/G30429/porutu-long-flute>

Harmonic frequencies in a pipe occur when sound waves travelling along the pipe reflect from the end and interfere, forming a standing wave.

A simple model of this situation assumes that an antinode always occurs at an open end of a pipe.

Explain how a sound wave reflects from an open end of a pipe, and how this results in an antinode being formed.

open at both ends, antinode at each

for a node to form, there is no air movement and no displacement, so no sound. However to form an antinode, the opposite happens, where the air particles are capable of maximum movement/oscillations, since they are most free to move at the open ends of the pipe, as they move out of the pipe they affect the large volume of air outside which can have a 'rebound' effect and cause the wave to essentially reflect back, but still in ~~the same~~ the same phase, relative to the original wave, allowing it to constructively interfere instead of destructively, resulting in an antinode.

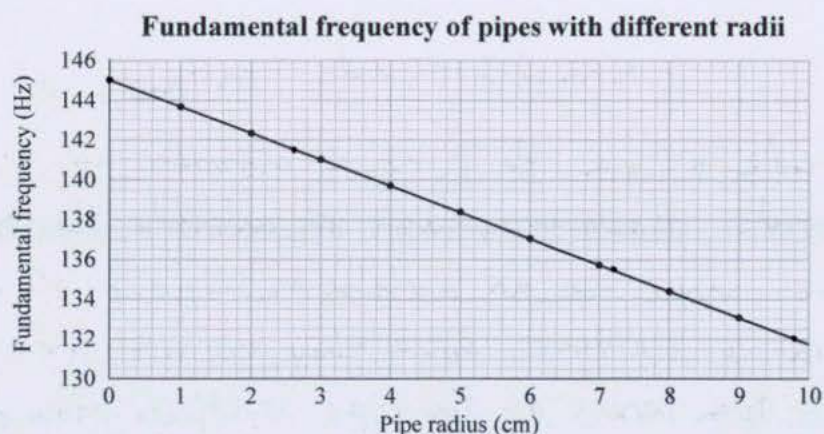
- (c) For an open end, the oscillation of air particles extends beyond the end of the pipe, making the pipe behave as if it is slightly longer than it really is. The larger the radius of the pipe, the more significant this effect becomes.

The apparent extra length at an open end of a pipe is called the end correction, e . For a cylindrical pipe, the end correction can be expressed as:

$$e = kr$$

where r is the radius of the pipe and k is a constant.

The fundamental frequency is measured for a range of uniform cylindrical pipes that are open at both ends. The pipes have the same length L , but different radii. The results and trend line are plotted on the graph below.



Use information from the graph above to determine the length of the pipes, L , and the value of the constant k .

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

$$e = kr$$

$$v = f\lambda \quad \text{at radius of } 3 \text{ cm, } f = 141 \text{ Hz} \quad v = 343$$

$$\lambda = \frac{v}{f} \text{ so } \lambda = 2.4326 \text{ m}$$

$$L + 2r = 2.4326$$

$$\text{at radius } 6 \text{ cm, } f = 137 \text{ Hz}$$

$$\lambda = \frac{v}{f} = 2.5036 \text{ m}$$

$$L + 2r = 2.5036 \text{ m}$$

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$$L + 3r = 2.4326 \quad \text{and} \quad L + 6r = 2.5036$$

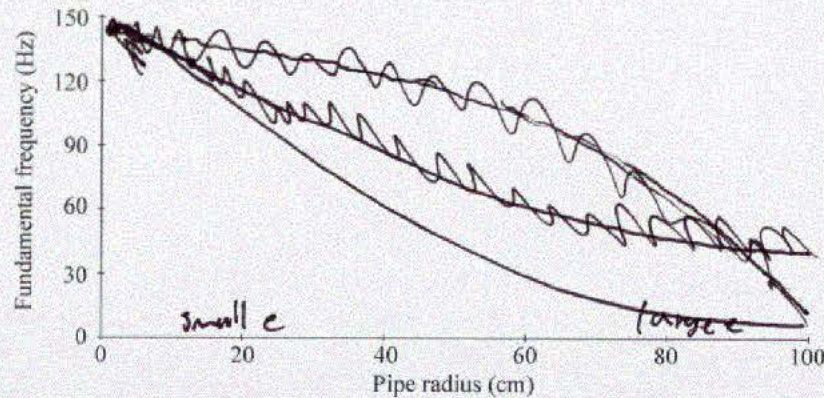
$$L = 2.4326 - 3r \quad \text{so:} \quad 2.4326 - 3r + 6r = 2.5036$$

$$2.4326 + 3r = 2.5036 \quad 3r = 0.071$$

$$r = 0.0236667$$

$$L = 2.361$$

- Use relevant physics concepts to explain why you expect the trend to behave in this way.



for very large radius, the more significant the effect,
so a large radius will behave like a much larger
pipe, ~~larger pipe has~~ $v = \frac{f\lambda}{v}$ proportionally
~~lower frequency, so the gradient will decrease~~
~~for large values of radius.~~

$\text{gradient} = \frac{1}{\lambda}$
 higher λ means
 smaller gradient
 gradient depends only on frequency
 inversely on wavelength

for larger and larger radiuses, the more significant the effect, so ~~larger~~ water pipes behave larger and larger, which means they have longer wavelengths (they are all at f_0). Frequency is inversely proportional to wavelength, so larger wavelengths mean smaller frequencies, which means the change in the frequency is smaller. So the gradient flattens out and approaches 0.

QUESTION THREE: X-RAY PHOTOELECTRON SPECTROSCOPY

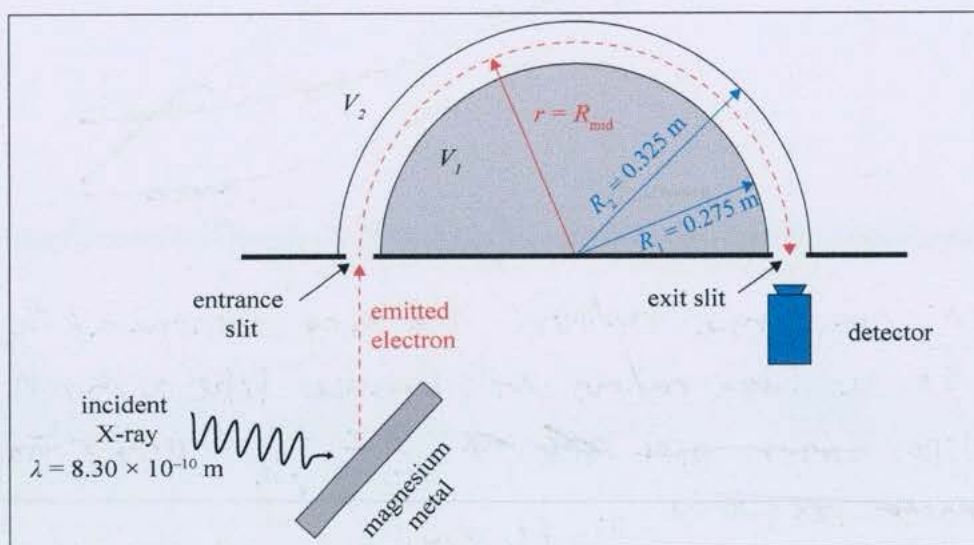
Charge of an electron = $-1.60 \times 10^{-19} \text{ C}$

Planck's constant = $6.63 \times 10^{-34} \text{ J s}$

Speed of light = $3.00 \times 10^8 \text{ m s}^{-1}$

X-ray photoelectron spectroscopy (XPS) is a technique used to determine the energy of electrons emitted by a material when it is illuminated with X-rays.

Electrons emitted by the illuminated material enter a hemispherical electron energy analyser, which consists of two concentric metal hemispheres with a narrow gap between them. The hemispheres have a potential difference of $V_2 - V_1$ between them, as shown in the diagram below.



In an experiment to measure the energy of electrons in magnesium, a sample of magnesium metal is illuminated by X-rays with a wavelength of $8.30 \times 10^{-10} \text{ m}$.

A narrow opening at the entrance ensures that the electrons enter the gap between the hemispheres midway between their surfaces, and that they enter at a tangent to the hemispheres. At the exit, on the other side of the analyser, a detector records any electrons that successfully travel around the semicircular path from the entrance to the exit.

The radii of the inner and outer hemispheres are $R_1 = 0.275 \text{ m}$ and $R_2 = 0.325 \text{ m}$ respectively. The potential difference between the hemispheres is varied, and the rate of electrons received by the detector is observed. Electrons are observed at the detector when the potential difference between the analyser plates is set to 60.0 V .

- (a) Explain whether the potential difference $V_2 - V_1$ should be negative or positive.

electrons moving, have negative charge, and to go in circle F_c must be towards centre, so towards V_1 . if V_1 is more positive than V_2 , then this will work so $V_2 - V_1$ should be negative in order to create the centripetal force for the electrons.

- (b) (i) Show that the kinetic energy of electrons that reach the detector is 180 eV.

Assume the magnitude of the electric field between the hemispheres is uniform, and any relativistic effects can be ignored.

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

$$F = Eq \quad E = \frac{V}{d} \text{ so } F = \frac{Vq}{d}$$

$$\frac{Vq}{d} = \frac{mv^2}{r}$$

$$mv^2 d = Vqr$$

$$v^2 = \frac{Vqr}{md}$$

$$v = \sqrt{\frac{Vqr}{md}}$$

~~$$V = 60 \cdot 1.6 \cdot 10^{-19} \cdot 0.3$$~~

$$r = 0.3 \text{ m} \quad d = 0.05$$

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

$$v = \sqrt{\frac{2E}{m}}$$

$$\frac{2E}{m} = \frac{Vqr}{md}$$

$$2E = \frac{Vqr}{d}$$

$$E = \frac{Vqr}{2d} = \frac{60 \cdot 1.6 \times 10^{-19} \cdot 0.3}{2 \cdot 0.05}$$

$$E = 2.88 \times 10^{-17} \text{ J} \quad \text{divide by } e$$

$$\text{so } 2.88 \times 10^{-17} / 1.6 \times 10^{-19} = E = 180 \text{ eV}$$

- (ii) Calculate the minimum amount of energy that would be required to remove one of these electrons from the magnesium metal.

~~$$hf = \phi + E_k$$~~
$$\phi = hf - E_k$$

~~$$f = \frac{c}{\lambda}$$~~
$$f = 3.6166 \times 10^{17} \text{ Hz}$$

$$\phi = 6.63 \times 10^{-34} \cdot 3.6166 \times 10^{17} - 2.88 \times 10^{-17}$$

$$\phi = 2.108 \times 10^{-16} \text{ J}$$

or

$$\phi = 1317.74 \text{ eV}$$

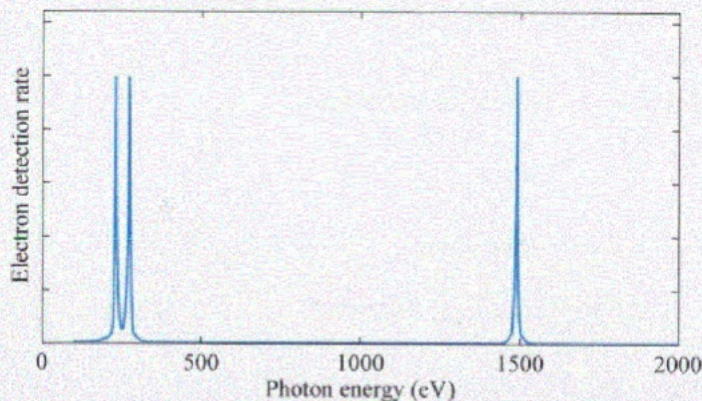
- (c) In this experiment, the magnesium must be electrically connected to ground.

Explain why this is necessary, and discuss how the kinetic energy of a photoemitted electron would be affected if the magnesium was not electrically connected to ground.

It is necessary to ground the magnesium, since it is losing electrons due to the photoelectric effect, so it is gaining a overall positive charge. if not electrically grounded, as an electron leaves the metal, it would experience an electrostatic force pulling it towards the metal, therefore decreasing it's kinetic energy. grounding the metal will allow the charge to be neutralised by allowing electrons to flow back into the metal, giving it no charge and therefore no effect on the kinetic energy of a photoemitted electron.

- (d) In this experiment, the photon wavelength can be varied to change the photon energy. The graph below shows the rate at which electrons are observed at the detector as photon energy is varied. The count rate displays three clear peaks.

Explain what this implies about the energy of the electrons inside the magnesium metal.



for an electron to be detected, ~~the energy of~~ the energy of the photon must exceed the work function of the metal, to release the electron from the nucleus. the fact that there are clear distinct peaks implies that only specific photon energies can release electrons with enough kinetic energy, so there must be distinct energy levels of the electrons within the atom, as for the large gap between two peaks, this means there must be two levels, ~~the one of which~~ one of which requires far more energy to be released (there at 1500 eV) this is a lower shell than the other peaks, where for higher shells, the difference in energy levels is smaller, and does not require much energy to release compared to lower shells.

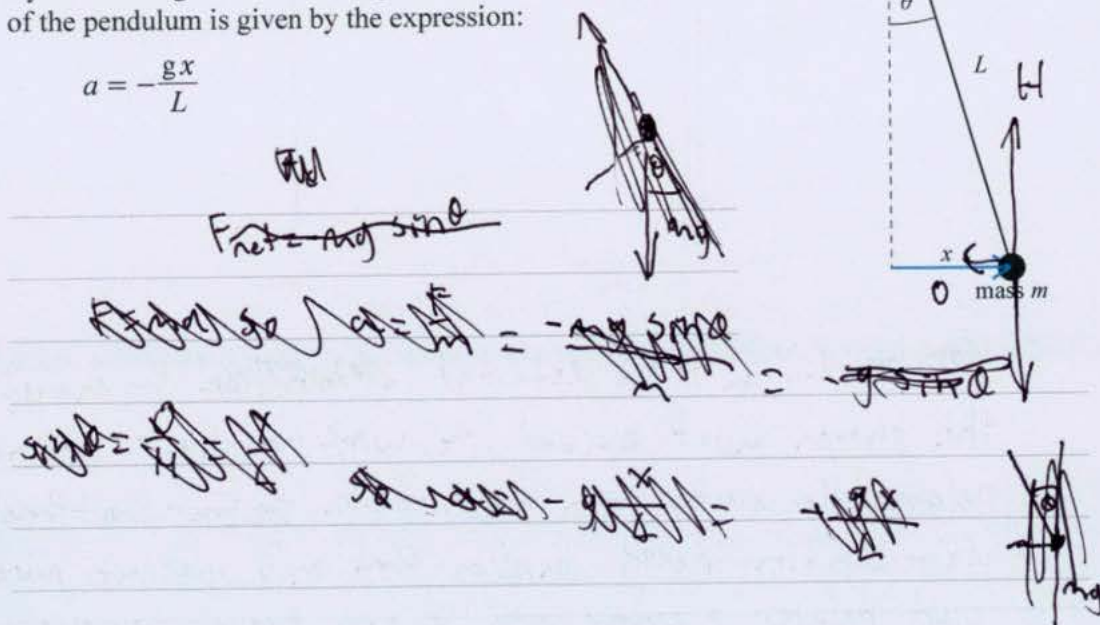
QUESTION FOUR: PENDULUMS AND SPRINGS

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

A simple pendulum, with a string of negligible mass, that is oscillating with a small angle θ , can be approximated as moving with simple harmonic motion.

- (a) (i) By considering the forces acting, show that the acceleration of the pendulum is given by the expression:

$$a = -\frac{gx}{L}$$



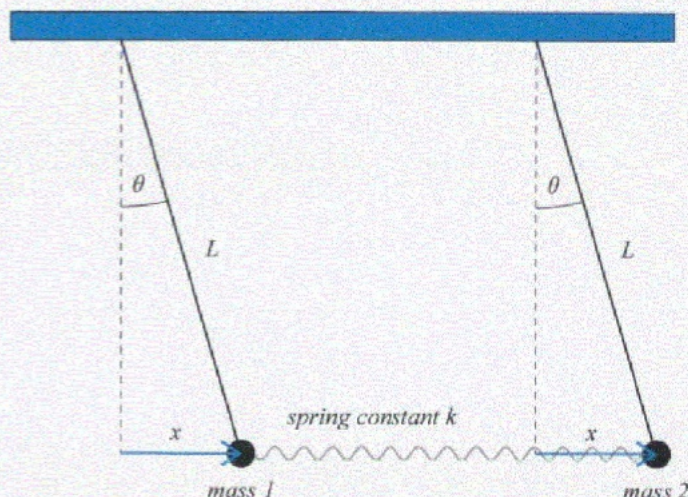
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- (ii) Explain how this expression shows that when the angle θ is small, the motion of a simple pendulum can be approximated as simple harmonic motion.

~~When the pendulum is not quite SHM, but for very small values of θ , usually less than 10° , the expression proves that $\sin \theta$ has approximately the same value as θ , however for large values this approximation becomes unreasonable.~~
 to get the expression it is assumed that $\sin \theta \approx \tan \theta$, or is very close. this arises due to how the net force vector is calculated, whether to be directly horizontal like true SHM, or to be perpendicular to the string like real pendulum. for small theta these are pretty much the same and $\sin \theta \approx \tan \theta$, so it can be approximated as SHM

- (b) Two identical pendulums are independently suspended from a fixed beam and connected by a spring with negligible mass. The spring has spring constant k , and the natural unstretched length of the spring is the same as the distance between the two points from which the pendulums are suspended.

The two pendulums can be independently moved either to the left or to the right before being released to investigate the motion of the pendulums with different initial conditions.



For the first investigation, the two pendulums are both moved to the right with the same initial displacement x , as shown in the diagram above. The pendulums are released at the same time so that they oscillate in phase.

The pendulums are set up with the following values:

- pendulum length = 0.560 m
- pendulum mass = 50.0 g
- initial displacement = 2.50 cm
- spring constant = 13.0 N m⁻¹

Calculate the period of the pendulums in this system.

Use appropriate reasoning to justify your answer.

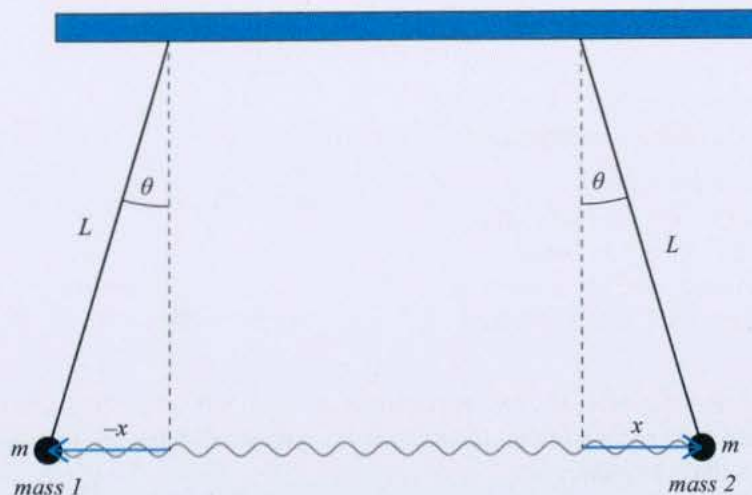
The spring will not be stretched, so each pendulum will function like usual. The spring might as well not exist.

$$L = 0.56 \quad g = 9.81$$

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{0.56}{9.81}} = 1.5012$$

$$T = 1.50 \text{ s}$$

- (c) For the second investigation, the two pendulums are moved the same initial distance x , but in opposite directions, as shown below. They are then released at the same time, so that they oscillate in opposite phase.



By considering the forces acting on one of the masses, show that the period of the opposite phase oscillations is given by:

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

mass 2: ~~g~~ $F = -mg \sin \theta$

~~g~~ $F = -2kx$

$F_{\text{total}} = -mg \sin \theta - 2kx$

$\sin \theta = \frac{x}{L}$ $F = -mg \frac{x}{L} = -\frac{mgx}{L}$

$F_{\text{total}} = -\frac{mgx}{L} - 2kx$

$a = -\omega^2 y$

$F = ma$

$a = -\frac{mgx}{mL} - \frac{2kx}{m} = -\frac{gx}{L} - \frac{2kx}{m}$

$-\frac{gx}{L} - \frac{2kx}{m} = -\omega^2 x$ $+\frac{g}{L} + \frac{2k}{m} = +\omega^2$

$\omega = \sqrt{\frac{g}{L} + \frac{2k}{m}}$

$\omega = 2\pi f$ $f = \frac{\omega}{2\pi}$ $\frac{1}{T} = \frac{\omega}{2\pi}$

$\omega = \frac{2\pi}{T}$

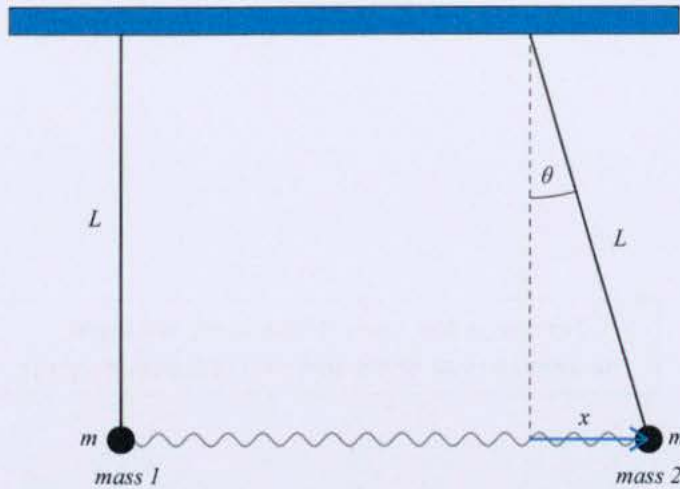
$T = \frac{2\pi}{\omega}$

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

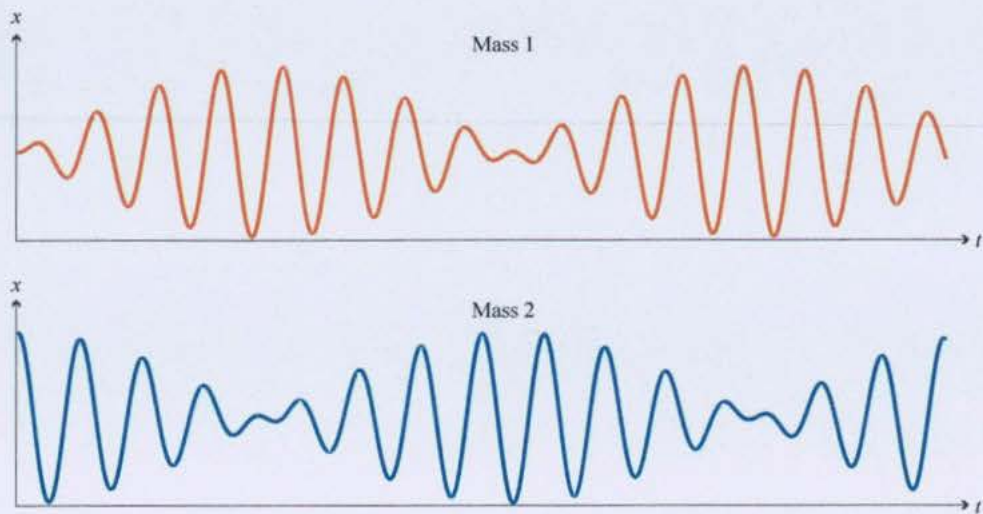
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The assessment continues on the following page.**

*Question Four continues
on the following page.*

- (d) For the third investigation, mass 1 is held at its equilibrium position, while mass 2 is displaced to the right, as shown below.



Both masses are released at the same time. The two pendulums oscillate with varying amplitude, and are neither purely in phase nor in opposite phase with each other. The displacement of the two masses over time is shown below.



By considering the forces acting on the two masses, explain why the oscillations vary in this way, and how energy in the system is transferred between the two masses.

The oscillations vary in this way because the masses were released 90° out of phase, with the spring stretched, meaning that their range of amplitudes will become out of phase with each other as they each 'take turns' at maximum amplitude before the ~~the~~ spring transfers energy to the other pendulum. By looking at the forces on mass 2, there is its pendulum restoring force pulling to the left, and also the spring restoring force pulling to the left. mass 1 has this same force of spring restoration on it but instead to the right, so it will move to the right and mass 2 will move to the left until the spring is at ~~equilibrium's~~ natural length, it will be at its natural length while not in the centre, meaning that the pendulums can not be in phase with each other, yet they can not be fully out of phase, since this will only happen if they are released symmetrically from the centre, in which case they will stay out of phase. The total energy in the system is the same at any time since it is conserved, but it moves between the potential energy of the spring and the kinetic/potential energy of the ~~the~~ masses. The masses move such that when one is stationary the spring is at its maximum extension. sometimes the spring will reach its natural length, which means all the energy will be in the ball's kinetic or gravitational potential energy.

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

QUESTION
NUMBERTwo
(c)

$$L + kr = 2.4326 \quad \text{at } r = 0.03$$

$$L + kr = 2.5036 \quad \text{at } r = 0.06$$

$$L + 0.03k = 2.4326 \quad L + 0.06k = 2.5036$$

$$L = 2.4326 - 0.03k$$

$$2.4326 - 0.03k + 0.06k = 2.5036$$

$$0.03k = 0.071$$

$$k = 2.366667$$

$$L = 2.3616 \text{ m}$$

Four
(a)(i)

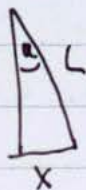
$$\tan \theta = \frac{F_{\text{net}}}{mg}$$

$$F_{\text{net}} = -mg \tan \theta$$

$$F = ma \quad a = \frac{F}{m}$$

$$a = -\frac{mg \tan \theta}{m} = -g \tan \theta$$

Small



$$\sin \theta = \frac{0}{h} \approx \frac{x}{L}$$

for small θ
 $\sin \theta \approx \tan \theta$

so

$$a \approx -g \sin \theta$$

$$a = -g \frac{x}{L} = -\frac{gx}{L}$$

Outstanding Scholarship

Subject: Physics

Standard: 93103

Total score: 29

Q	Score	Marker commentary
1	8	Outstanding Scholarship level understanding of a range of DC and AC electrical concepts.
2	6	High level understanding across a range of situations involving waves concepts mainly relating to open ended pipes.
3	8	Outstanding Scholarship level understanding of modern physics in a unique and challenging context.
4	7	Outstanding Scholarship level understanding of a range of DC and AC electrical concepts.