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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Tick this box if there is no writing in this booklet

Scholarship 2020
Physics

2.00 p.m. Wednesday 25 November 2020
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 2.

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 2–19 in the correct order and that none of these pages is blank.

You are advised to spend approximately 45 minutes on each question.

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

Question	Score
ONE	
TWO	
THREE	
FOUR	
TOTAL	/32

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The formulae below may be of use to you.

$v_f = v_i + at$	$T = 2\pi\sqrt{\frac{l}{g}}$	$\phi = BA$
$d = v_i t + \frac{1}{2}at^2$	$T = 2\pi\sqrt{\frac{m}{k}}$	$\varepsilon = -\frac{\Delta\phi}{\Delta t}$
$d = \frac{v_i + v_f}{2}t$	$E_p = \frac{1}{2}ky^2$	$\varepsilon = -L\frac{\Delta I}{\Delta t}$
${v_f}^2 = {v_i}^2 + 2ad$	$F = -ky$	$\frac{N_p}{N_s} = \frac{V_p}{V_s}$
$F_g = \frac{GMm}{r^2}$	$a = -\omega^2 y$	$E = \frac{1}{2}LI^2$
$F_c = \frac{mv^2}{r}$	$y = A\sin\omega t$ $y = A\cos\omega t$	$\tau = \frac{L}{R}$
$\Delta p = F\Delta t$	$v = A\omega\cos\omega t$ $v = -A\omega\sin\omega t$	$I = I_{MAX}\sin\omega t$
$\omega = 2\pi f$	$a = -A\omega^2\sin\omega t$ $a = -A\omega^2\cos\omega t$	$V = V_{MAX}\sin\omega t$
$d = r\theta$	$\Delta E = Vq$	$I_{MAX} = \sqrt{2}\,I_{rms}$
$v = r\omega$	$P = VI$	$V_{MAX} = \sqrt{2}\,V_{rms}$
$a = r\alpha$	$V = Ed$	$X_C = \frac{1}{\omega C}$
$W = Fd$	$Q = CV$	$X_L = \omega L$
$F_{net} = ma$	$C_T = C_1 + C_2$	$V = IZ$
$p = mv$	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$	$f_0 = \frac{1}{2\pi\sqrt{LC}}$
$x_{COM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$	$E = \frac{1}{2}QV$	$n\lambda = \frac{dx}{L}$
$\omega = \frac{\Delta\theta}{\Delta t}$	$C = \frac{\varepsilon_o\varepsilon_r A}{d}$	$n\lambda = d\sin\theta$
$\alpha = \frac{\Delta\omega}{\Delta t}$	$\tau = RC$	$f' = f\frac{V_W}{V_W \pm V_S}$
$L = I\omega$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$	$E = hf$
$L = mvr$	$R_T = R_1 + R_2$	$hf = \phi + E_K$
$\tau = I\alpha$	$V = IR$	$E = \Delta mc^2$
$\tau = Fr$	$F = BIL$	$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$
$E_{K(ROT)} = \frac{1}{2}I\omega^2$		$E_n = -\frac{hcR}{n^2}$
$E_{K(LIN)} = \frac{1}{2}mv^2$		$v = f\lambda$
$\Delta E_p = mgh$		$f = \frac{1}{T}$
$\omega_f = \omega_i + \alpha t$		
$\omega_f^2 = \omega_i^2 + 2\alpha\theta$		
$\theta = \frac{(\omega_i + \omega_f)t}{2}$		
$\theta = \omega_i t + \frac{1}{2}\alpha t^2$		

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QUESTION ONE: RESONANCE CIRCUIT

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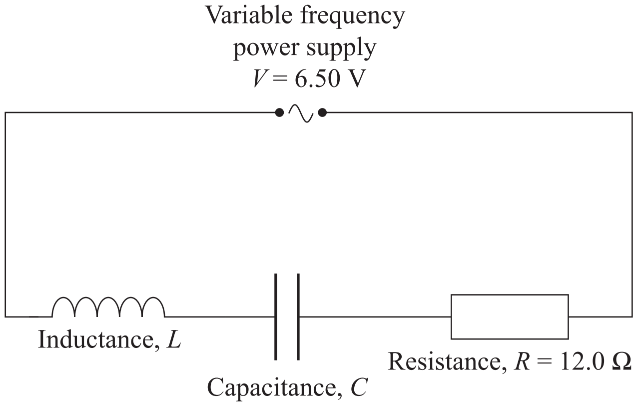
A capacitor, ideal inductor, and 12.0 Ω resistor are connected in series to a 6.50 V_{rms} variable frequency power supply.



(a) State the conditions for resonance in a circuit of this type, and describe what you could measure to determine when resonance has been reached.

(b) If a circuit like this is at or near resonance, it is possible for both the inductor rms voltage and the capacitor rms voltage to exceed the rms voltage of the power supply.

Explain how this can occur.

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The frequency of the power supply is adjusted, while the supply voltage remains constant at 6.50 V_{rms}. When the frequency of the supply is f = 134 Hz, the current in the circuit is 0.400 A_{rms}. The supply frequency is then increased, and the current changes. But at f = 199 Hz, the current in the circuit is again 0.400 A_{rms}. None of the components are changed while this occurs.

(c) Explain how it is possible to have the same current in the circuit at two different frequencies.

(d) Calculate the values of the capacitance, C, and inductance, L, in the circuit.

(8)

QUESTION TWO: THE DOPPLER EFFECT

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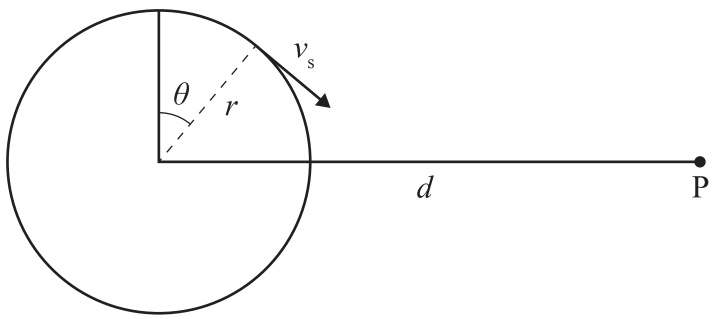
For a moving source of sound, the frequency heard by a stationary observer can be calculated using the following equation:

$$f' = \frac{f v_\mathrm{w}}{v_\mathrm{w} \pm v_\mathrm{s}}$$

(a) (i) Explain the use of the $\pm$ symbol in this equation.

(ii) State the assumptions made about the velocity of the moving source of sound.

(b) An object is moving in a circle with radius, r, at a constant speed, v_s, while emitting sound with a constant frequency.



At the instant the observer, at point P, hears the sound at maximum frequency, the source has reached the position indicated in the diagram.

Show that $\theta = \dfrac{v_\mathrm{s}\sqrt{d^2 - r^2}}{v_\mathrm{w} r} + \sin^{-1}\dfrac{r}{d}$.

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(c) The Doppler effect can also be observed when a moving observer approaches a stationary wave source at a speed v_o. The relationship for the apparent frequency f', when an observer moving at speed v_o approaches a stationary source, is given by: $f' = \frac{f(v_w + v_o)}{v_w}$.

Explain when the observer would experience the greater Doppler shift: when the source approaches the stationary observer at a speed v; or when the observer approaches the stationary source at the same speed v.

(8)

QUESTION THREE: COLLISIONS

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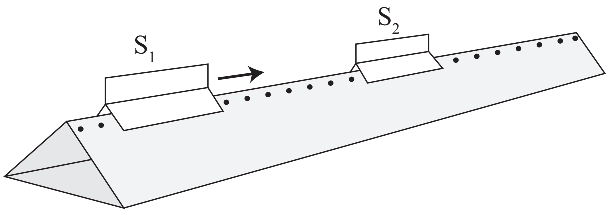
Mass of neutron = 1.675×10^{-27} kg

1 eV = 1.602×10^{-19} J

(a) (i) A slider S_1 is moving along an air track at constant velocity v, and collides elastically with a stationary, identical slider S_2, as shown in the diagram.



Explain why S_1 stops and S_2 moves off with velocity v.

(ii) In a second experiment, slider S_1 is given a velocity of 1 m s^{-1} along the air track and collides elastically with another slider S_3 that has mass n times that of S_1, and is stationary.

Show that, after the collision, the velocity of S_1 is given by $v_1 = \dfrac{1-n}{1+n}$ m s^{-1}, and the velocity of S_3 is given by $v_3 = \dfrac{2}{1+n}$ m s^{-1}.

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(iii) In a third experiment, the two sliders change roles, so that S_3 is moving at a velocity of 1 m s^{-1} along the air track, and collides elastically with S_1, which is initially stationary.

Use the answer from (a)(ii), and noting that S_1 has mass $\frac{1}{n}$ times that of S_3, show that after the collision,

$$v_3 = \frac{n-1}{n+1} \text{ m s}^{-1} \text{ and } v_1 = \frac{2n}{n+1} \text{ m s}^{-1}.$$

(b) Use the result of (a)(iii) to show that, if a massive bat is swung with a top speed of V m s^{-1} to hit a stationary light ball in an elastic collision, the top speed of the ball is approximately $2V$.

(c) (i) In the reactor of nuclear power stations, fast neutrons with energies of about 2 MeV typically, are produced by fission of ^{235}U. For a chain reaction to occur, these neutrons must be slowed down to energies of 1 eV or less, by colliding with materials, such as heavy water (water that contains hydrogen nuclei with an additional neutron).

Calculate the velocity lost when these fast neutrons are slowed down.

(ii) Using the results from parts (a) and (b), explain why heavy water is used to slow down the fast neutrons, and suggest a reason why heavy water is used rather than common water.

(8)

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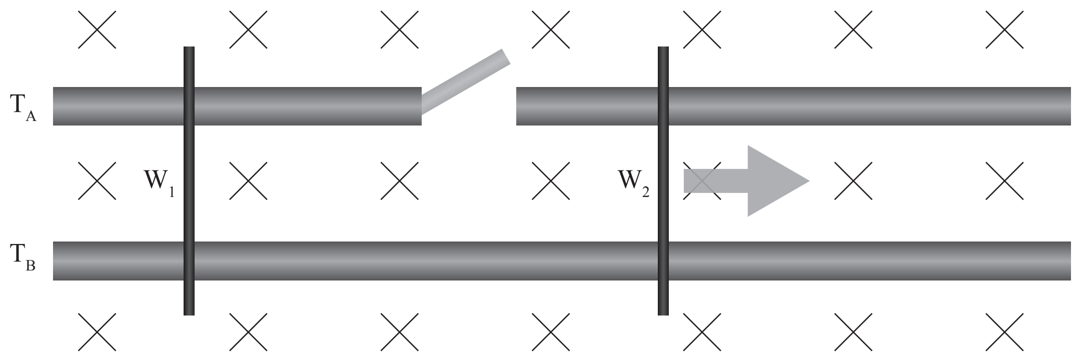
QUESTION FOUR: SLIDING WIRES



A parallel pair of fixed, horizontal conducting tracks T_A and T_B lie in a uniform magnetic field B, as shown.

Track T_A is divided by a switch, on either side of which rest two identical metal wires (each of resistance R) that can slide without friction along the track.

Initially, both wires, W_1 and W_2, are stationary.

With the switch open, wire W_2 is given a short push to the right, and then moves at a constant velocity, v.

(a) Explain what occurs to the electrons in W_2 as they move through the magnetic field.

(b) Explain why W_2 slides along at a constant velocity.

While W_2 is moving to the right, the switch is snapped shut.

(c) Describe and explain the subsequent motions of both W_1 and W_2.

(d) Determine the final velocities of W_1 and W_2.
Explain your reasoning.

(e) Explain the energy changes that follow as a result of the switch being closed.

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(8)

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