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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!

Scholarship 2019
Physics

9.30 a.m. Monday 25 November 2019
Time allowed: Three hours
Total score: 40

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 35 minutes on each question.

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

Question	Score
ONE	
TWO	
THREE	
FOUR	
FIVE	
TOTAL	/40

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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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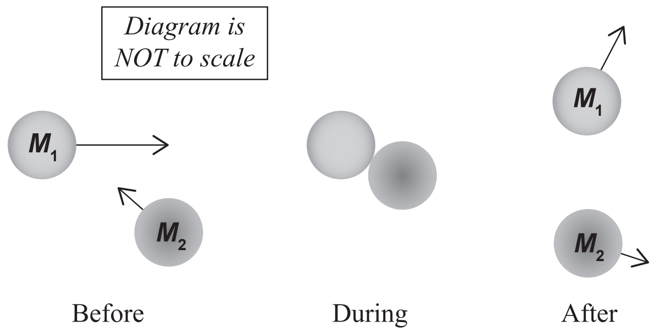
QUESTION ONE: COLLISIONS



The diagram above represents the motion of a pair of discs sliding (with only linear motion prior to the collision) on a frictionless surface, shown before they collide, at the point of collision and shortly after the collision. The discs have the same radii but are made of materials of different densities.

M_1 has a mass of 3.0 kg and an original velocity vector [using coordinates (x,y)] of (2.0,0.0) m s^{-1}. After the collision, M_1 has a velocity vector of (0.50,1.0) m s^{-1}. M_2 has a mass of 5.0 kg and an original velocity vector of (–0.50,0.50) m s^{-1}.

(a) Show that the velocity vector of M_2 immediately after the collision is (0.40,–0.10) m s^{-1}.

(b) Show that the collision is inelastic and explain how the collision does not violate the principle of conservation of energy.

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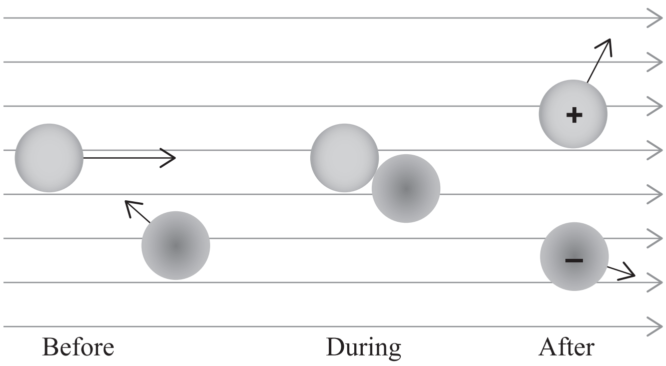
(c) Describe and explain the motion (both linear and rotational) of each disc after the collision, assuming that there is friction between the edges of the discs.

(d) When the discs collide, there is a separation of charge, as shown below.



If the collision takes place inside a region of uniform electric field (as shown above), describe how the motion of the discs might be affected both before and after the collision.

You may use diagrams to assist your answer.

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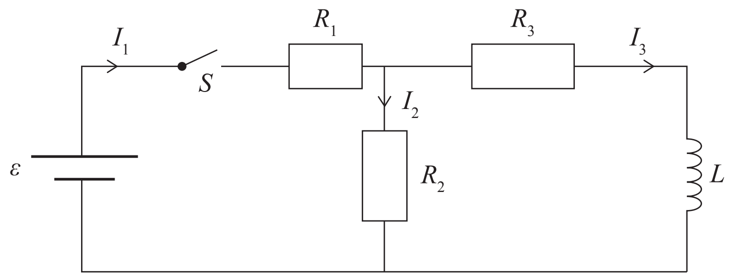
QUESTION TWO: DC CIRCUITS

The circuit below is constructed with the following values for the respective components: $R_1 = 10.0\ \Omega$, $R_2 = 20.0\ \Omega$, $R_3 = 30.0\ \Omega$, $L = 2.00$ H and the emf of the cell, $\varepsilon = 1.00 \times 10^2$ V. The currents in the respective branches are also indicated in the diagram.



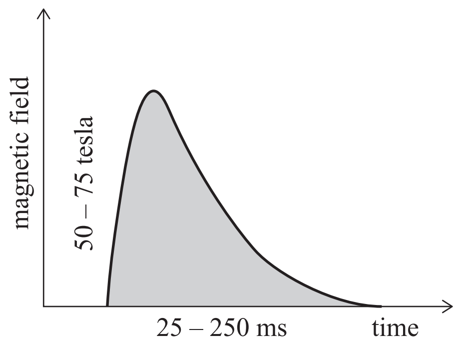
(a) Calculate the values of I_1 and I_2 immediately after switch S is closed.

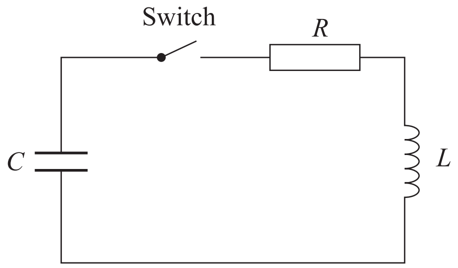
(b) Calculate the values of I_1 and I_2 a long time after switch S is closed.

(c) (i) Calculate the values of all three currents immediately after reopening the switch.

(ii) Explain why all currents will be zero a long time after the switch is reopened.

(d) A pulsed magnet utilises charge stored in a large capacitor to drive a very large current through a coil of wire. The pulsed magnet can be modelled as a series RLC circuit, where the coil of wire is represented as an inductor of inductance *L*, and resistance *R*. After closing the switch, the magnetic field rises to a peak value that can be much larger than is possible in a conventional DC electromagnet, before decaying away. An example of the magnetic field versus time for a pulsed magnet is shown below.





(i) Explain why the field takes some time to build to its maximum value, and why it eventually decays away.

(ii) Suggest a practical reason why this circuit is preferred to using a DC circuit with the same current.

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QUESTION THREE: THE SWINGING MASS

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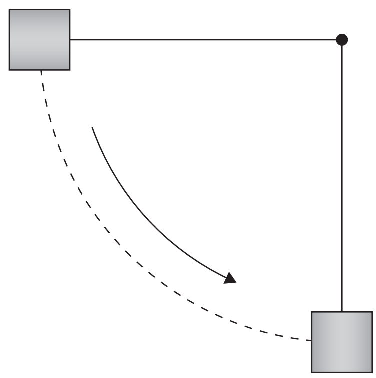
A mass m, connected to an inextensible light rope of length L, is allowed to swing down from a horizontal position to the vertical as shown in the diagram.



(a) (i) Show that the maximum tension in the rope is $3mg$.

(ii) Explain why the length of the rope does not affect the maximum tension.

(b) (i) The rope is replaced by a piece of extensible rubber (spring constant k) of the same length, L.

Show that the maximum tension reached in the rubber when the mass is allowed to swing down is given by:

$$T_{\text{max}} = \frac{3mg(L+x)}{L+2x}$$

where L is the unstretched length of the rubber, and x is the maximum extension of the rubber.

(ii) Explain why, despite the mass falling a greater distance, the maximum tension in the rubber is less than the maximum tension in the rope.

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QUESTION FOUR: ALL THINGS WAVES

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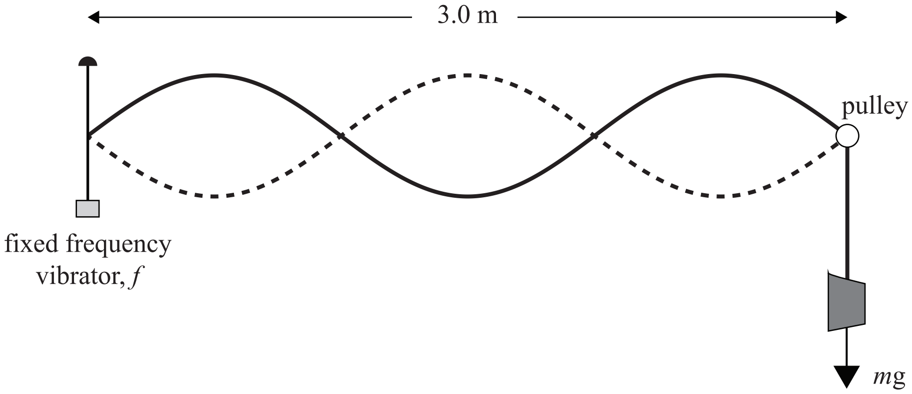

A string, given a constant small amplitude by the vibrator of fixed frequency f, has the third harmonic standing wave established when under a tension of $T = mg$, as shown above.

(a) Explain how a standing wave forms with this experimental arrangement.

(b) (i) The speed of a wave on a string is given by the relationship

$$v = \sqrt{\frac{T}{\mu}}$$ where μ = mass per unit length and T is the tension.

Show that the tension is given by the following expression: $T = \mu f^2 \lambda^2$

(ii) Show that this expression for the tension is dimensionally correct.

(c) A fan now blows a breeze against the hanging mass, pushing it out at some angle to the horizontal. The standing wave changes under these conditions to the second harmonic.

Determine an expression for the new tension in the string.

(d) Explain, using examples of physical phenomena, how light demonstrates both wave-like and particle-like behaviours.

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QUESTION FIVE: CRUMPLE ZONES

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Crumple zones are parts of a vehicle that are designed to deform during a collision, converting kinetic energy into heat of deformation.

As a test, a 2.20 kg model truck moving at 8.33 m s^{-1} collides with the back of a stationary 1.50 kg model car that is fitted with a crumple zone.

Immediately after the collision, the model car is moving at 5.55 m s^{-1}.

(a) If the model truck is not damaged and a constant force of 5.00×10^2 N was exerted during the collision, calculate the maximum change in length of the model car as a result of the collision.

Explain all working.

(b) State the major assumption you had to make in order to complete (a) above, and give reasons why the assumption is unlikely to be correct.

(c) Calculate the time the two vehicles are in contact.

(d) Using physical principles, explain why it is a cause for concern if vehicles do not have crumple zones.

(e) Using physical principles, explain how a seat belt can reduce the risk of injury in a collision.

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