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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 2017
Physics

9.30 a.m. Wednesday 22 November 2017
Time allowed: Three hours
Total marks: 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	Mark
ONE	
TWO	
THREE	
FOUR	
FIVE	
TOTAL	/40

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The formulae below may be of use to you.

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

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QUESTION ONE: DOPPLER DROP

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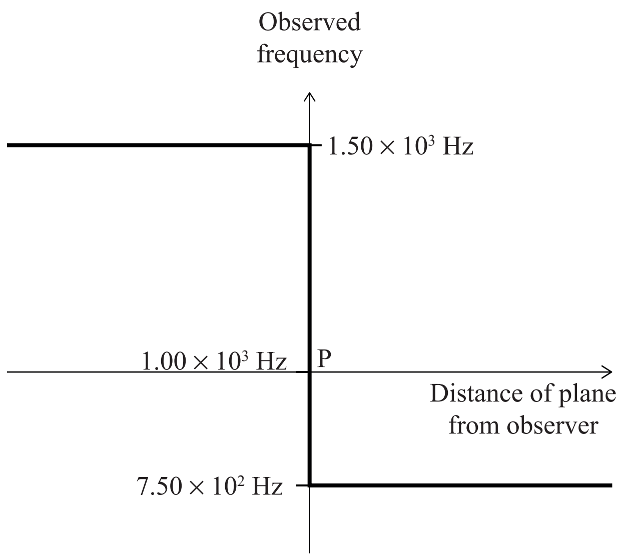
Speed of sound in air = 3.40×10^2 m s^{-1}

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

(a) The graph shows the theoretical sound frequency of a plane flying by an observation point, P, against the distance of the plane from that observation point. The plane is emitting a sound frequency of 1.00×10^3 Hz and has a constant speed relative to the ground.



(i) Explain the physical process that causes the changes in frequency.

State any assumptions that are implied by the shape of the graph.

(ii) Show that the plane's speed is 113 m s^{-1}.

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(b) The plane flies with constant speed of 113 m s^{-1} at a height of 5.00×10^2 m above an observer on the ground.

Calculate the frequency of the sound reaching the observer when the plane is seen to be directly overhead.

(c) The plane flies with a constant vertical lift-force so that it maintains a uniform height. It has an unloaded mass of 3.00×10^3 kg and is carrying a cargo pod of 1.00×10^3 kg.

When it is overhead it drops its cargo pod, but maintains the same constant vertical lift-force.

Calculate the vertical separation between the pod and the plane when the pod has been falling for 1.50 seconds.

(8)

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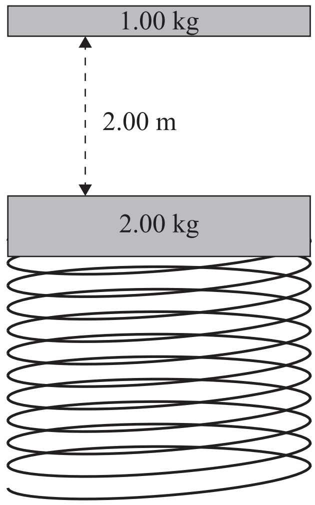
QUESTION TWO: THE SPRING

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

If $ax^2 + bx + c = 0$ then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

A mass of 1.00 kg is dropped 2.00 m onto a sticky platform of mass 2.00 kg. The platform sits on a spring of spring constant = 1.00×10^2 N m^{-1}.



(a) By using appropriate conservation laws, show that, during the collision between the mass and the platform, ⅔ of the gravitational potential energy lost by the mass is converted into heat.

State any assumptions made.

(b) Show that the maximum amount of additional compression that occurs in the spring is 0.473 m.

(c) Calculate the amplitude of the resulting vibrations.

(d) Show that the total energy at the bottom of the motion is equal to the total energy at the top of the motion.

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(8)

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QUESTION THREE: PHOTONS AND ELECTRONS

The distance between the surfaces of the Earth and Moon	$= 3.80 \times 10^{8}$ m
The charge on the electron	$= -1.60 \times 10^{-19}$ C
Speed of light	$= 3.00 \times 10^{8}$ m s^{-1}
Planck's constant	$= 6.63 \times 10^{-34}$ J s
Mass of the electron	$= 9.11 \times 10^{-31}$ kg

(a) Monochromatic light of wavelength 375 nm is incident on a metal surface. A potential difference of 1.31 V is required to cut off the flow of photoelectrons.

Calculate the work function of the metal.

(b) A 0.450 mW laser, of wavelength 581 nm, is pointing at the Moon. The laser beam spreads out at an angle of 1.65×10^{-3} radians.

Calculate the maximum number of photons arriving per second per square metre on the Moon.

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(c) A photon of frequency f_1 and wavelength λ_1, is scattered by a stationary electron. The photon has a momentum, given by the de Broglie relationship, of $\frac{h}{\lambda_1}$.

Due to the interaction, a photon of frequency f_2 and wavelength λ_2 results. It travels in the opposite direction to the initial photon, and the electron gains energy of 4.00 keV, with velocity v in the same direction as the incident photon.

Calculate the value of λ_1.

The effects of special relativity can be assumed to be negligible.

(d) The number of electrons in a 1 gram sample of hydrogen is approximately twice the number of electrons in a 1 gram sample of any other light element (of atomic number less than 8).

Explain.

(8)

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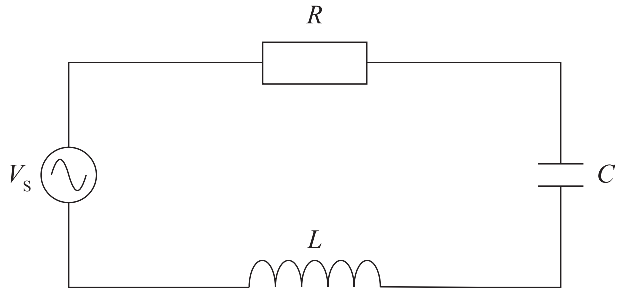
QUESTION FOUR: LCR CIRCUITS

The LCR circuit below is driven by an AC source at an angular frequency, ω.

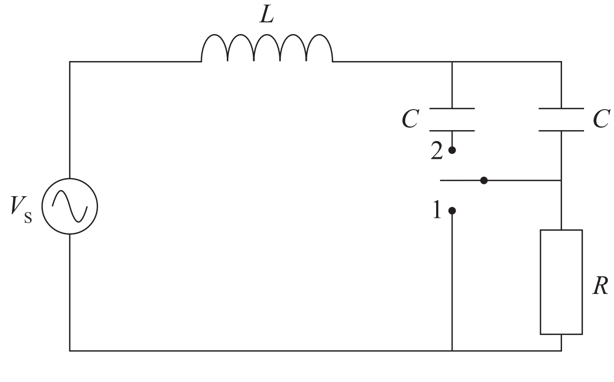


(a) (i) Show, for the case where $\omega L > \dfrac{1}{\omega C}$, that $\tan\phi = \dfrac{\left(\omega L - \dfrac{1}{\omega C}\right)}{R}$

where ϕ is the phase angle between the source voltage V_s and the current I.

(ii) Explain, using physical principles, what happens to the angle ϕ when the capacitance increases.

(b) Another circuit is constructed as shown in the diagram. The source voltage, $V_s = 185\ V_{RMS}$.



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(i) When the switch is in position 1, the rms current is 1.50 A. The switch is now moved to the position shown in the diagram so that the resistance is included in the circuit. The source voltage lags the current by 30.0°.

Show that the resistance is 214 Ω.

(ii) The switch is now moved to position 2. The source voltage now leads the current by 15.0°.

Show that the reactance of the circuit is given by the following expression:

$$\left(\omega L - \frac{1}{2\omega C}\right) = 57.2$$

(iii) Determine the values of the inductance, L, and capacitance, C. The angular frequency of the source voltage is 3.50×10^{2} rad s^{-1}.

(8)

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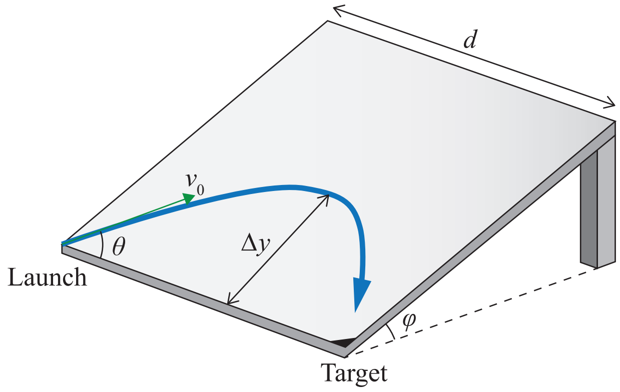
QUESTION FIVE: THE RAMP PROJECTILE

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

$\sin^2\theta + \cos^2\theta = 1$

$\sin 2\theta = 2\sin\theta\cos\theta$



A spring-loaded plunger launches a ball at a speed v_0 from one corner of a smooth flat board that is tilted at an angle φ in order to make the ball hit a small target at the adjacent corner, a distance d away, as shown in the diagram. The ball can be considered to be sliding without friction.

(a) (i) Assuming the angle θ required to hit the target is known,

show that the maximum distance up the board is given by $\Delta y = \frac{1}{2}\frac{(v_0 \sin\theta)^2}{g\sin\varphi}$.

(ii) By considering the horizontal motion, show that the time to reach the target, Δt, is given by $\Delta t = \frac{d}{v_0\cos\theta}$.

(iii) Derive a relationship for the time to reach the maximum height Δy.

Express your answer in terms of v_0, θ and φ.

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(b) Show that the angle θ at which the ball should be launched so that the target is reached is

$$\theta = \frac{1}{2}\sin^{-1}\left(\frac{gd\sin\varphi}{{v_0}^2}\right).$$

(c) We now consider the case where the ball rolls without slipping.

If the ball, with mass m and radius r, has a rotational inertia of $\frac{2}{5}mr^2$, and assuming again that θ is known, show, by considering conservation of energy, that $\Delta y = \frac{7}{10}\frac{(v_0\sin\theta)^2}{g\sin\varphi}$.

Explain all reasoning.

(d) (i) Consider the situation when the angle $\varphi = 0°$.

Explain the result produced.

(ii) Comparing the answers for (a)(i) and (c), explain why the answer for (c) is larger.

(8)

Extra space if required.
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