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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 2015
Physics

9.30 a.m. Monday 16 November 2015
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.

$$F_g = \frac{GMm}{r^2}$$
$$F_c = \frac{mv^2}{r}$$
$$\Delta p = F\Delta t$$
$$\omega = 2\pi f$$
$$d = r\theta$$
$$v = r\omega$$
$$a = r\alpha$$
$$W = Fd$$
$$F_{net} = ma$$
$$p = mv$$
$$x_{COM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$
$$\omega = \frac{\Delta\theta}{\Delta t}$$
$$\alpha = \frac{\Delta\omega}{\Delta t}$$
$$L = I\omega$$
$$L = mvr$$
$$\tau = I\alpha$$
$$\tau = Fr$$
$$E_{K(ROT)} = \tfrac{1}{2}I\omega^2$$
$$E_{K(LIN)} = \tfrac{1}{2}mv^2$$
$$\Delta E_p = mgh$$
$$\omega_f = \omega_i + \alpha t$$
$$\omega_f^2 = \omega_i^2 + 2\alpha\theta$$
$$\theta = \frac{(\omega_i + \omega_f)t}{2}$$
$$\theta = \omega_i t + \tfrac{1}{2}\alpha t^2$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$
$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$E_p = \tfrac{1}{2}ky^2$$
$$F = -ky$$
$$a = -\omega^2 y$$

$$y = A\sin\omega t \qquad y = A\cos\omega t$$
$$v = A\omega\cos\omega t \qquad v = -A\omega\sin\omega t$$
$$a = -A\omega^2\sin\omega t \qquad a = -A\omega^2\cos\omega t$$

$$\Delta E = Vq$$
$$P = VI$$
$$V = Ed$$
$$Q = CV$$
$$C_T = C_1 + C_2$$
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$
$$E = \tfrac{1}{2}QV$$
$$C = \frac{\varepsilon_o\varepsilon_r A}{d}$$
$$\tau = RC$$
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$R_T = R_1 + R_2$$
$$V = IR$$
$$F = BIL$$

$$\phi = BA$$
$$\varepsilon = -\frac{\Delta\phi}{\Delta t}$$
$$\varepsilon = -L\frac{\Delta I}{\Delta t}$$
$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$
$$E = \tfrac{1}{2}LI^2$$
$$\tau = \frac{L}{R}$$
$$I = I_{MAX}\sin\omega t$$
$$V = V_{MAX}\sin\omega t$$
$$I_{MAX} = \sqrt{2}\,I_{rms}$$
$$V_{MAX} = \sqrt{2}\,V_{rms}$$
$$X_C = \frac{1}{\omega C}$$
$$X_L = \omega L$$
$$V = IZ$$
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$
$$n\lambda = \frac{dx}{L}$$
$$n\lambda = d\sin\theta$$
$$f' = f\frac{V_W}{V_W \pm V_S}$$
$$E = hf$$
$$hf = \phi + E_K$$
$$E = \Delta mc^2$$
$$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$$
$$E_n = -\frac{hcR}{n^2}$$
$$v = f\lambda$$
$$f = \frac{1}{T}$$

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QUESTION ONE: PARTICLES AND WAVES

(a) (i) Describe the photoelectric effect.

In your answer you should include a derivation of the relationship between the incident photon's frequency and the electron's kinetic energy, and how these relate to the work function of the metal.

(ii) The photoelectric effect was unable to be fully explained using classical physics.

Comment on this statement.

(b) Describe the similarities and the differences between the orbit of the Moon around the Earth and the orbit of an electron around a proton in a hydrogen atom.

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(c) Sound from a small loudspeaker L reaches a point P by two paths, which differ in length by 1.2 m. When the frequency of the sound is gradually increased, the resultant intensity at P goes through a series of maxima and minima. A maximum occurs when the frequency is 1000 Hz, and the next maximum occurs at 1200 Hz.

(i) Explain what causes the maxima and minima to occur.

(ii) Calculate the speed of sound in the medium between L and P.

(8)

QUESTION TWO: THE VERTICAL CIRCLE

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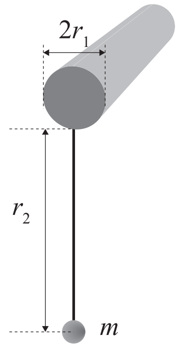
A small ball of mass m, hangs from a light, inextensible string attached to a fixed horizontal post of radius r_1, as shown.



The ball is hit horizontally with a large bat so that the ball wraps the string around the post.

(a) Show that the ball's speed at the top of its first swing must be at least

$$v_{\text{top}} = \sqrt{g\left(r_2 - \frac{\pi r_1}{2}\right)}$$ so that the string remains taut.

(b) For the speed of the ball in (a), show that the initial speed must be at least

$$v_{\text{initial}} = \sqrt{g\left(5r_2 - \left(\frac{3\pi}{2} - 2\right)r_1\right)}.$$

(c) Assuming an elastic collision, show that the speed of the bat is approximately half that of the ball's initial speed.

State any other assumptions made, and the reasons for them.

(d) As the ball completes its first orbit around the post, explain why the ball appears to be travelling at a speed greater than its initial value.

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(8)

QUESTION THREE: CRICKET – THROW IN FROM THE BOUNDARY

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

(a) Show that the range, R, of a projectile thrown from ground level at angle, ϕ, to the horizontal with starting velocity, v, is $\dfrac{v^2 \sin 2\phi}{g}$.

(Note that $2\sin\phi\cos\phi = \sin 2\phi$.)

(b) A cricket ball is thrown from ground level with a velocity 28.0 m s^{-1}, and hits a target on the ground 80.0 m away.

Show that the time of flight of the ball is 4.04 s.

The effects of air resistance can be ignored.

(c) The ball is now thrown at the same target, with the same initial speed, but at a lower angle. This time, it is aimed to bounce in front of the target, so that it hits the target on the second bounce. When the ball bounces the first time, it rebounds with the same angle as it came in, but it loses half its speed.

(i) Calculate the time taken for the ball to reach the target.

(ii) Discuss, with physical reasons, the difference in times between parts (b) and (c)(i).

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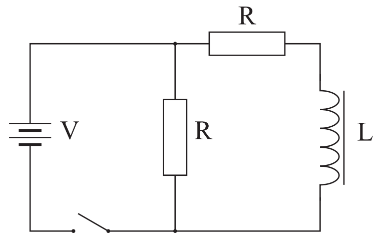
(d) Any real throw of a ball would be from approximately head height, rather than from ground level.

Show that the range achieved by a throw from a height of 2 m above the ground would be

$$v\cos\phi\left(\frac{v\sin\phi+\sqrt{v^2\sin^2\phi+4\text{g}}}{\text{g}}\right)$$

(8)

QUESTION FOUR: CIRCUITS



(a) In the electric circuit shown, the switch is closed at time $t = 0$.

(i) Write an expression for the current immediately after the switch is closed.

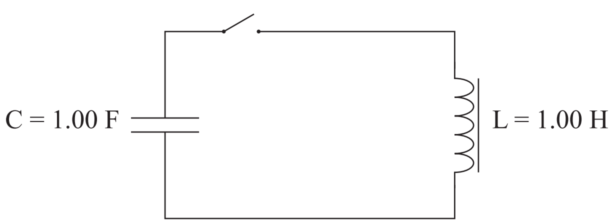
Explain your reasoning.

(ii) Write an expression for the limiting value of the current a long time after the switch is closed.

Explain your reasoning.

(b) (i) A charged capacitor (1.00 F) is connected to an inductor (1.00 H), as shown in the diagram below. When the switch is closed (at $t = 0$), the current in the circuit will oscillate sinusoidally with a period of 6.28 s.

Describe the energy changes that take place in the course of one complete cycle.



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(ii) The capacitor plates can be moved closer together so that the capacitance is increased to 4.00 F.

Explain at what point in the cycle, could the plates of the capacitor be moved closer to each other so that no energy is transferred to the circuit.

(c) A slab of copper falls freely under the influence of gravity before entering the region between the poles of a strong magnet. As it enters the magnetic field, the copper slab slows considerably.

Explain why this occurs, and state what has happened to the kinetic energy of the copper slab.

(8)

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QUESTION FIVE: WAVES ON STRINGS

The speed v of a wave on a string is given by, $v=\sqrt{\frac{T}{\mu}}$, where T is the tension in the string, and μ is the mass per unit length, measured in kg m^{-1}.

(a) Show that the above equation is dimensionally correct.

(b) One end of a string of mass per unit length μ is attached to a solid wall, while the other end passes over a pulley, and is attached to a hanging mass, m, as shown in Figure 1.

A second string of the same length and made of the same material, but with twice the diameter, is mounted in a similar fashion with an identical mass, m, as shown in Figure 2.

The first string oscillates in its first harmonic when it is driven at a frequency of 200 Hz.

Calculate the frequency that will cause the second string to oscillate in its third harmonic.

Figure 1

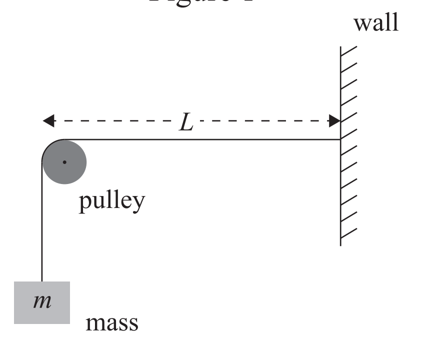
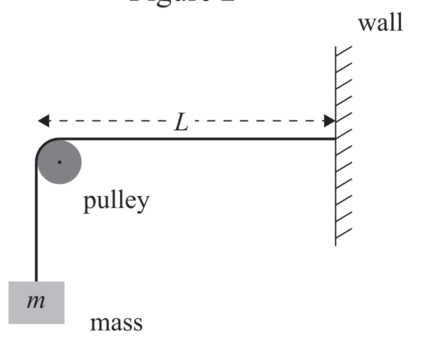


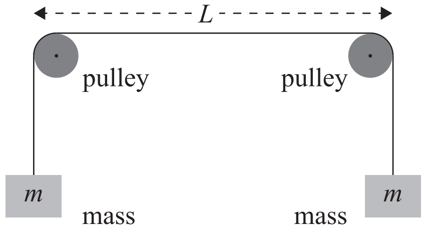
Figure 2



(c) Now the first string is hung so that both ends go over pulleys, with the masses suspended at each end, as shown in Figure 3.

Calculate the frequency of the fifth harmonic.

Figure 3



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(d) Two strings made from the same material are both fixed at each end, and both are under the same tension. The first string has a length L_1 (= 1.00 m), and is being driven so that it oscillates in a transverse standing wave mode with a frequency of 400 Hz. The second string, with length L_2 (= 1.18 m), is also oscillating in a standing wave mode, but with a slightly lower frequency. An observer notices that the standing wave on the second string has one more node than that on the first string. The observer hears a 4.5 Hz beat, as a result of the combined sound coming from the two standing waves.

Calculate the number of nodes present in the first standing wave.

(8)

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

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