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For Supervisor's use only

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Scholarship 2010
Physics

2.00 pm Wednesday 17 November 2010
Time allowed: Three hours
Total marks: 48

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 space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–22 in the correct order and that none of these pages is blank.

You are advised to spend approximately 30 minutes on each question.

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

The formulae below may be of use to you.

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

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You have three hours to complete this examination.

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QUESTION ONE: NUCLEAR EXCHANGES (8 marks)

Surface area of a sphere = $4\pi r^2$
Distance from the Sun to the Earth = 1.50×10^{11} m
The speed of light = 3.00×10^{8} m s^{-1}

(a) Nuclear fission and nuclear fusion are opposite processes, yet each releases energy.

Explain why this is not a contradiction.

(b) Explain why controlled nuclear fusion is difficult to achieve.

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(c) Give physical reasons why each of the two statements below is incorrect.

(i) The nucleus of an atom cannot consist of neutrons and protons, because negatively charged particles, much lighter than either neutrons or protons, are often emitted from the nucleus.

(ii) The nucleus of an atom cannot consist of neutrons and protons because protons repel each other, so any nucleus with more than one proton would be unstable.

(d) The Sun loses mass at the rate of 4×10^9 kg s^{-1}.

Calculate the site area required for a 1000 MW solar power station on the Earth.

State all assumptions.

(8)

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QUESTION TWO: ELECTRICITY (8 marks)

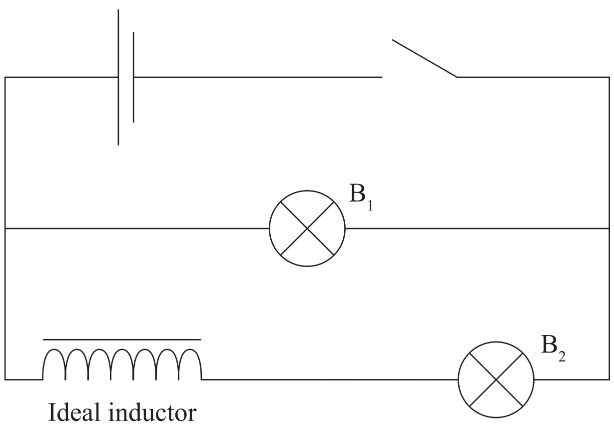
A 75 W non-inductive filament light bulb is designed to run from an AC supply of 120 V_{RMS} and 50 Hz. The only supply available is 240 V_{RMS} and 50 Hz.

(a) Calculate the resistance, *R*, that would have to be placed in series with the bulb so that the bulb could run at the correct power, and calculate the resultant power drawn from the supply.

(b) The resistance is replaced with an ideal inductor.

Calculate the inductance, *L*, that must be used so that the bulb can operate at the correct power, and calculate the resultant power drawn from the supply.

(c) In the circuit shown below, the bulbs B_1 and B_2 are identical.



(i) Describe what will happen to the brightness of B_1 and B_2 when the switch is closed.

(ii) Describe what will happen to the brightness of B_1 and B_2 when the switch is then opened.

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(d) Explain the effect on the previous answers if the inductor is "non-ideal":

(i) when the switch is closed

(ii) when the switch is then opened.

(8)

QUESTION THREE: CAPACITOR ENERGY (8 marks)

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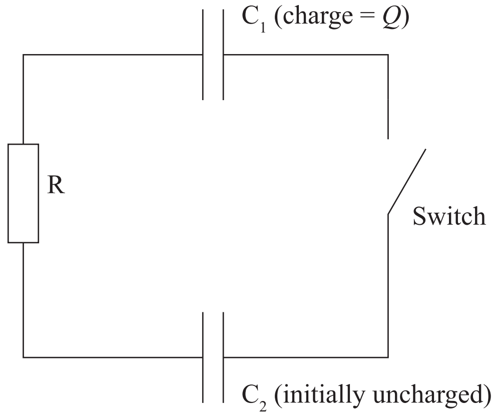
In the circuit shown, a capacitor C_1, which is holding a charge Q, has an initial potential difference of V_o. Capacitor C_2 is initially uncharged.

At time $t = 0$, the switch is closed.



(a) Explain what changes will take place to the charge on each capacitor and to the potential difference across each capacitor.

(b) The value of $C_2 = \frac{C_1}{p}$ (where $p \geq 0$).

Show that the final charge on C_1 is $Q_{1f} = Q\frac{p}{p+1}$

and that the final charge on C_2 is $Q_{2f} = Q\frac{1}{p+1}$.

(c) Explain, using physical principles, the meaning of these results by considering the limiting cases when p approaches zero and when p tends to infinity.

(d) Show that when the switch is closed, the stored energy will change by a factor of $\frac{p}{p+1}$.
Comment on the role of the resistor R when the switch is closed.

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QUESTION FOUR: SPECTROSCOPE (8 marks)

The speed of light = 3.00×10^8 m s^{-1}

A spectroscope fitted with a diffraction grating is used to observe the spectrum of excited helium gas in a laboratory discharge tube. One first order bright line of wavelength 587.563 nm is observed at a deviation of 20.6426°.

(a) Calculate the number of lines per cm on the diffraction grating.

The spectroscope and grating are used to obtain the spectrum of a distant star, which shows a bright line blurred between 587.60 nm and 587.67 nm. This line is thought to be due to the same electron transition that produced the 587.563 nm line in the laboratory.

(b) Explain the difference between the laboratory and the stellar wavelengths.

(c) Using the equations for the Doppler effect, show that

$$\frac{v_{source}}{c} = \frac{\Delta\lambda}{\lambda}$$

where c is the speed of light, $\Delta\lambda$ is the difference between the wavelength from the star and λ, the wavelength as measured in the laboratory, and v_{source} is the speed of the star relative to the Earth.

(d) Estimate the speed of the star relative to the Earth.

State any assumptions.

(e) Explain two possible mechanisms that cause the emission line from the star to be blurred.

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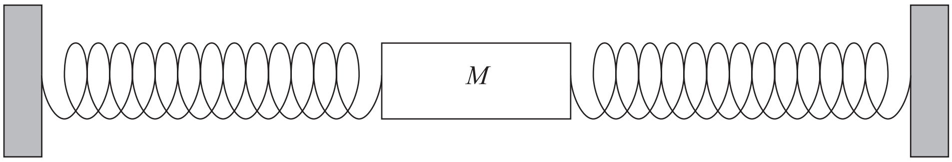
QUESTION FIVE: SIMPLE HARMONIC MOTION (8 marks)

An object of mass *M* is connected to a pair of identical springs as shown.



(a) Show that *M* will oscillate with SHM when given a small horizontal displacement, *x*.

(b) This oscillating mass system starts with zero momentum when released from its initial displacement. At the mid point of the motion the system seems to have gained quite a lot of momentum. This appears to contradict the law of conservation of momentum.

Explain why there is no contradiction.

(c) A second object of mass m, initially at rest, is placed gently onto mass M and sticks to it.

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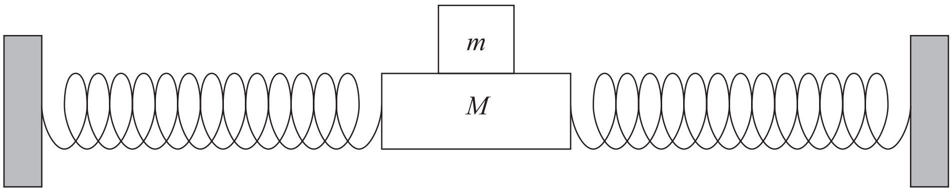

(i) By what factor does the energy of the oscillation change if mass m is added when the mass M is moving through its position of maximum velocity?

(ii) By what factor does the energy of the oscillation change if mass m is added when mass M is at its position of maximum acceleration?

(d) The maximum frictional force between masses m and M is μN, where μ is the coefficient of static friction between the pair of masses and N is the normal reaction force on mass m.

Show that the maximum amplitude of oscillation, A, for which the mass m will not slip is given by

$$\frac{\mu g\left(M+m\right)}{2k},$$ where k is the spring constant of each spring, and g is the acceleration due to gravity.

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QUESTION SIX: ELEMENTS OF MECHANICS (8 marks)

(a) If a light object (small mass) and a heavy object (large mass) have the same kinetic energy, explain which of the two has the larger momentum.

(b) (i) A television safety advertisement features a car taking corners at dangerously high speeds. The danger is symbolised by land-mines appearing scattered around the corners. As the vehicle approaches a corner, the voice-over says "There is more force taking you off the road and less force keeping you on it." The car skids across the road and rolls over an embankment.

Discuss the accuracy of the voice-over statement, with reference to centripetal force and friction.

(ii) In another safety advertisement, a car is shown going into a skid. We are told that if the driver had started the skid while doing 50 km h^{-1}, he would have stopped at point A. However he started the skid while doing 60 km h^{-1}.

Calculate his speed when he reached point A.

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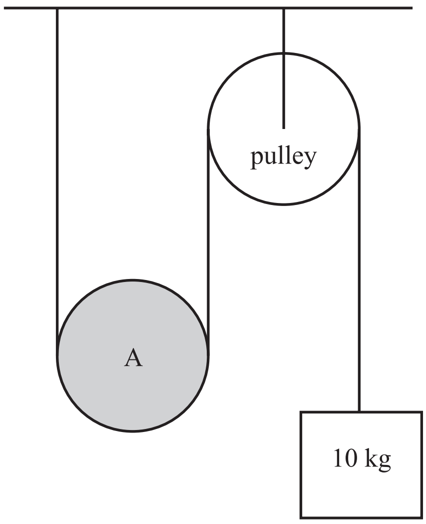
(c) A light, frictionless belt carries a smooth cylinder (A), as shown in the diagram. The 10 kg mass is falling at constant velocity.

Assume the pulley is frictionless.



Calculate the mass of cylinder A.

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Extra paper for continuation of answers if required.
Clearly number the question.

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Question	Mark
ONE	(8)
TWO	(8)
THREE	(8)
FOUR	(8)
FIVE	(8)
SIX	(8)
TOTAL	(48)