For Supervisor's use only

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93103

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Scholarship 2005
Physics

9.30 am Thursday 8 December 2005
Time allowed: Three hours
Total Marks: 54

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

Answer ALL questions.

Write all your answers 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 an 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 2–26 in the correct order.

You are advised to spend approximately 60 minutes on Section A and 120 minutes on Section B.

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

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PERFORMANCE CATEGORY

The formulae below may be of use to you.

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

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

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

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

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

SECTION A

Assessor's use only

QUESTION ONE (6 marks)

Universal Gravitational Constant = 6.67×10^{-11} N m^2 kg^{-2}

(a) The fastest rate of rotation of a planet is that for which the gravitational force on matter at the equator just provides the centripetal force necessary for that matter to move with circular motion.

Show that the period of rotation in this case is given by

$$T = \sqrt{\frac{3\pi}{G\rho}}$$

where the planet is assumed to be a uniform sphere of density ρ (which has units of kg m^{-3}).

The volume of a sphere is $\frac{4}{3}\pi r^3$.

(b) The mean density of the Earth is 5500 kg m^{-3}. Is Earth close to disintegration?

(c) The reading on a bathroom scale is less at the equator than at the poles. Suggest TWO reasons for this.

Assessor's use only

(6)

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QUESTION TWO (6 marks)

In 1905 Albert Einstein made a number of significant scientific breakthroughs. Write a short essay on ONE of the two topics below, focussing on the physical principles involved. Your essay, which may include diagrams and / or graphs, should be **no longer** than one page.

EITHER

(a) The implications of $E = \Delta mc^2$ with regard to the generation of energy by fission and fusion.

OR

(b) Einstein's theory explaining the photoelectric effect.

PLAN YOUR ESSAY HERE.

WRITE YOUR ESSAY HERE.

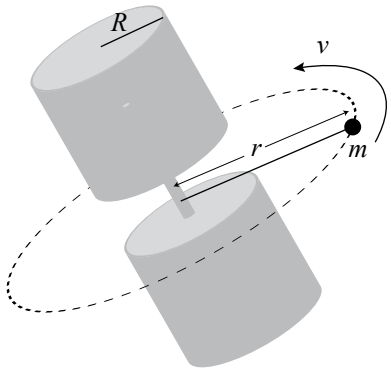
Assessor's use only

(6)

QUESTION THREE (6 marks)

Assessor's use only

A large satellite in orbit has a mechanism that allows a camera to revolve around it. The camera has mass m and is travelling at speed v on the end of a cord of length r which extends to the centre of the satellite. The satellite is cylindrical in shape with radius R.



The initial speed of the camera is v_0 and the initial radius of its circular path is r_0. A mechanism within the satellite allows the cord to be drawn in so that the radius of revolution for the camera decreases.

(a) Suppose that the cord begins to be drawn in towards the satellite at a constant rate. Express the speed v of the camera in terms of r, r_0 and v_0. Ignore friction.

(b) In order to bring the camera within the radius of the satellite (ie $r \leq R$), the camera must be drawn inwards by the cord. Derive an expression for the tension as the radius of the camera's orbit is reduced, in terms of m, r, r_0 and v_0. Explain what will happen to the tension as the camera is brought towards the centre of the satellite.

(c) Derive an expression for the amount of work required to bring the camera from radius r_0 to radius R.

Assessor's use only

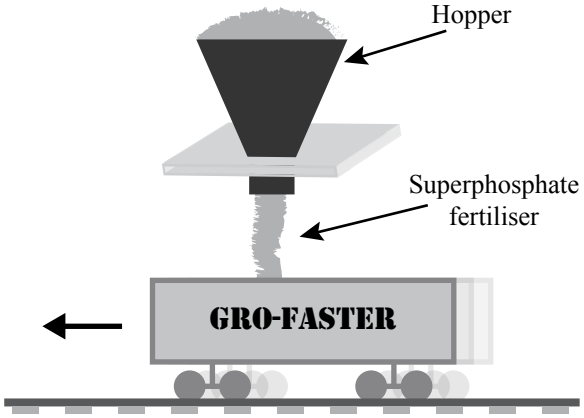
(6)

SECTION B

Assessor's use only

QUESTION ONE: "GRO-FASTER" FERTILISER FACTORY (8 marks)

At the "Gro-Faster" fertiliser factory, superphosphate fertiliser is transferred from a hopper into railway wagons, which are directly under the hopper as the superphosphate is released (see diagram below). An empty railway wagon has a mass of 2.20×10^4 kg and each wagon has a speed of 1.25 m s^{-1} as it approaches the hopper. Wagons are not connected with each other.



1.5×10^4 kg of superphosphate fertiliser are transferred from the hopper to each wagon.

(a) Calculate the momentum and velocity of a wagon after the superphosphate has been transferred, ignoring friction.

(b) One wagon has a hole in its floor, which allows some of the superphosphate to fall below the wagon as it rolls along the track. Discuss the effect, if any, this will have on the motion of the wagon, ignoring friction.

(c) The density of superphosphate fertiliser is 1.1×10^3 kg m^{-3} and the wagons are 1.5 m wide and 1.5 m high. Estimate the maximum mass of superphosphate that can be transferred in one hour.

Assessor's use only

(d) In fact, there is some friction, so to keep the wagons rolling at a constant speed, the track slopes downward at an angle θ. The frictional force is given by $F = \mu N$, where μ is the coefficient of friction between the rotating wheel and the track and N is the normal force of the track on the wheel. If the coefficient of friction is 0.005, calculate the angle of the track so that the wagons maintain a constant speed.

(8)

QUESTION TWO: PHUGOID OSCILLATIONS (8 marks)

Assessor's use only

Acceleration due to gravity = 9.80 m s^{-2}
Speed of sound in air = 340 m s^{-1}

Phugoid oscillations are a form of simple harmonic motion that arise when an aeroplane flying at a constant speed, v, experiences a vertical impulse (a sudden downdraft, for example) causing the aircraft to increase or decrease its altitude by a small amount. The period of such oscillations is given by the formula

$$T = \frac{\pi\sqrt{2}}{g}v$$

Tom is flying his radio-controlled model Spitfire aeroplane (mass = 3.67 kg) at a speed of 36.0 m s^{-1} in a straight and level flight at an altitude of 50.0 m. The plane suddenly experiences a region of turbulence, causing it to lift several metres above its original altitude.

(a) The amplitude of the vertical oscillations is 4.56 m. Calculate the maximum upward force acting on the plane during the time that the plane is oscillating.

(b) From long experience Tom knows that to stop the phugoid oscillations he must send a control signal to the plane that will act on the plane's airspeed, but the signal must come into effect at the midpoint of the oscillations, ie when the altitude is 50.0 m. Given that it takes 1.5 seconds for the aircraft's controls to react to the signal sent by Tom, at what altitudes should Tom activate the control signal?

Assessor's use only

(c) To obtain a measurement of the plane's speed, Tom adds a siren to his aircraft and sets up a microphone equipped with special filtering circuits that select a narrow band of frequencies from 800 – 1200 Hz (model aircraft produce a noise that has a wide frequency spectrum!). Tom flies the plane at its maximum speed along a line that passes directly over the microphone. When the plane is at a long horizontal distance from the microphone, and travelling towards it, the observed frequency is 1133 Hz. As the plane flies directly over the microphone the observed frequency is 1000 Hz, and when travelling away from the microphone the observed frequency falls to 895 Hz. Calculate the plane's speed, stating all assumptions made.

(d) Explain whether it would be possible for Tom to detect phugoid oscillations using the siren and microphone technique described above.

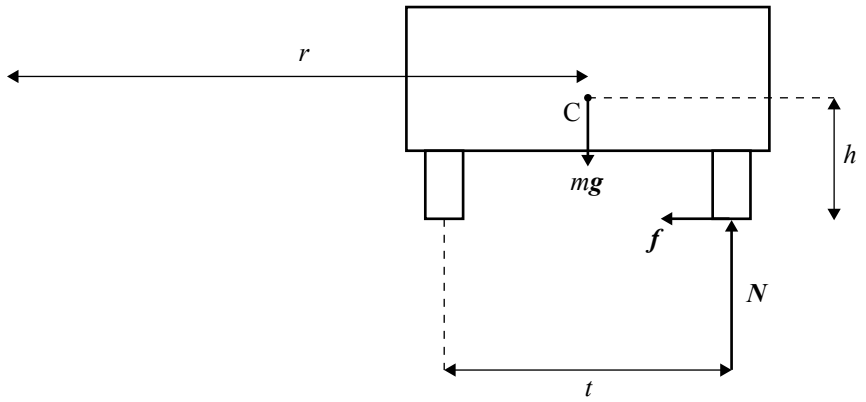
(8)

QUESTION THREE: SPORT UTILITY VEHICLES (8 marks)

Assessor's use only

Acceleration due to gravity = 9.80 m s^{-2}

In recent years a large number of sport utility vehicles (SUVs) have appeared on New Zealand roads. SUVs can be susceptible to rolling under certain conditions. The diagram below is a representation of an SUV rounding a left-handed curve.



In the diagram, m = mass of the SUV, $\boldsymbol{g}$ = acceleration due to gravity, $\boldsymbol{f}$ = total frictional force on the two outside wheels, $\boldsymbol{N}$ = total normal force on the two outside wheels, C = centre of gravity of the SUV, t = track width, h = height of the centre of gravity, and the radius of the curve is r.

(a) Explain why the frictional force on the left-hand wheels is not considered here and why the frictional force on the right-hand wheels is in the direction shown.

Assessor's use only

(b) By taking moments about C, derive the condition for the vehicle to roll over.

$$\frac{t}{2h} = \frac{v^2}{rg}$$

The term $\frac{t}{2h}$ is referred to as the Static Stability Factor (SSF).

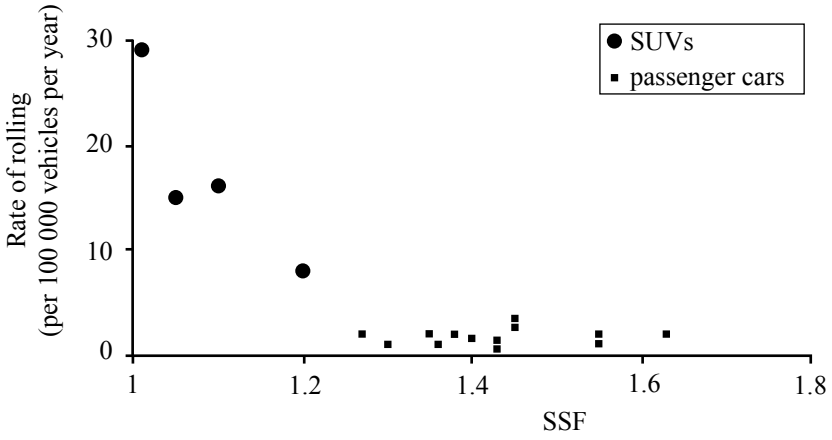
One particular unloaded vehicle has $t = 1.7$ m and $h = 0.8$ m. Its capacity is five passengers and it has storage at the back of the vehicle and on a roof-rack. The vehicle has to take three passengers and their camping equipment.

(c) Explain the effect of this load on the stability of the SUV and on the way the vehicle should be driven.

(d) Data has been collected for the rates at which various cars and SUVs roll. This data is shown below. Comment on the relationship between the rate of rolling, the SSF and the type of vehicle, and make a recommendation on the minimum SSF that should be allowed.

Assessor's use only

Rates of rolling for passenger cars and SUVs



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QUESTION FOUR: DC CIRCUITS (6 marks)

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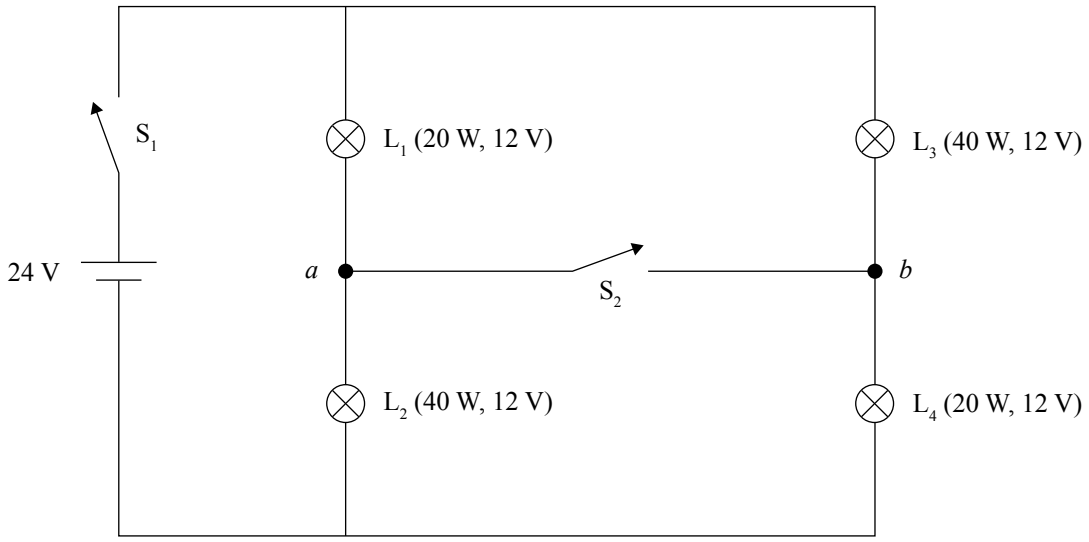
David and Helen buy four electric lightbulbs from the hardware store. Two of them are labelled 20 W, 12 V and the other two are labelled 40 W, 12 V. They set up the following circuit.



(a) When switches S_1 and S_2 are closed, what is the current through the branch *ab* and in what direction is it?

(b) Switch S_2 is now opened. Explain how the intensities of bulbs L_1 and L_2 change.

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(c) David and Helen wish to calculate the potential difference between points *a* and *b*, V_{ab}, when switch S_2 is open.

What additional information would they require in order to make this calculation?

(6)

QUESTION FIVE: CAPACITORS (6 marks)

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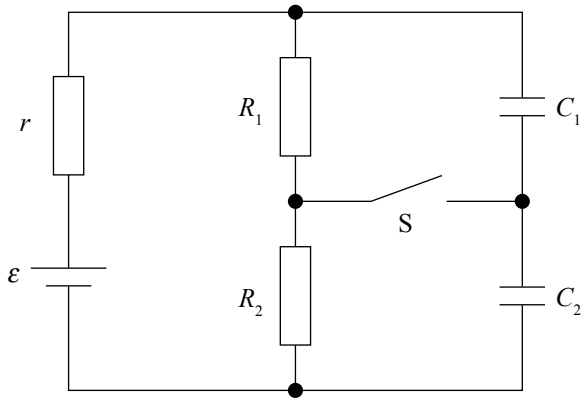
(a) In the circuit shown below, an emf source $\varepsilon = 12$ V, with an internal resistance of $r = 0.3\ \Omega$, is connected to two resistors $R_1 = 1.5\ \Omega$ and $R_2 = 1.2\ \Omega$. Two capacitors $C_1 = 0.05\ \mu$F and $C_2 = 0.02\ \mu$F are connected in parallel to the resistors, and the switch S is open. Calculate the current in the circuit and the charges Q_1, Q_2 on the capacitors once a steady state is reached. (A steady state is reached when no further charging of the capacitors takes place.)



(b) What values do the current in the circuit and charges Q_1 and Q_2 take if the switch is closed and a new steady state is reached?

(c) Calculate the capacitance between terminals A and B for the circuit shown below. Each capacitor has a capacitance of 1 μF. Explain all reasoning.

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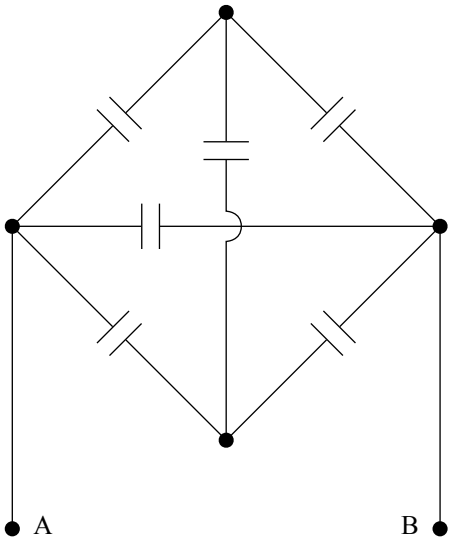

(6)

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

Assessor's use only

Question number	

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		Marks
SECTION A	Q1	(6)
	Q2	(6)
	Q3	(6)
SECTION B	Q1	(8)
	Q2	(8)
	Q3	(8)
	Q4	(6)
	Q5	(6)
	TOTAL	(54)

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Keep Flap Folded In.