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90523

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Level 3 Physics, 2005

90523 Demonstrate understanding of electrical systems

Credits: Five
9.30 pm Tuesday 29 November 2005

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 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 2–12 in the correct order and that none of these pages is blank.

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

For Assessor's use only	**Achievement Criteria**	
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Identify or describe aspects of phenomena, concepts or principles.	Give descriptions or explanations in terms of phenomena, concepts, principles and / or relationships.	Give concise explanations that show clear understanding in terms of phenomena, concepts, principles and / or relationships.
Solve straightforward problems.	Solve problems.	Solve complex problems.
Overall Level of Performance		

You may find the following formulae useful.

$V = Ed$ $\Delta E = Vq$ $E_{cap} = \frac{1}{2}QV$ $Q = CV$ $P = VI$

$C = \dfrac{\varepsilon_o \varepsilon_r A}{d}$ $C_T = C_1 + C_2 + C_3 + \ldots$ $\tau = RC$ $V = IR$

$\dfrac{1}{C_T} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3} + \ldots$ $R_T = R_1 + R_2 + \ldots$ $\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

$\phi = BA$ $\varepsilon = -L\dfrac{\Delta I}{\Delta t}$ $\varepsilon = -\dfrac{\Delta \phi}{\Delta t}$ $\varepsilon = -M\dfrac{\Delta I}{\Delta t}$

$\dfrac{N_p}{N_s} = \dfrac{V_p}{V_s}$ $E = \frac{1}{2}LI^2$ $\tau = \dfrac{L}{R}$ $I = I_{\mathrm{MAX}} \sin \omega t$

$V = V_{\mathrm{MAX}} \sin \omega t$ $I_{\mathrm{MAX}} = \sqrt{2}\, I_{\mathrm{rms}}$ $V_{\mathrm{MAX}} = \sqrt{2}\, V_{\mathrm{rms}}$ $X_c = \dfrac{1}{\omega C}$

$X_L = \omega L$ $V = IZ$ $\omega = 2\pi f$ $f = \dfrac{1}{T}$

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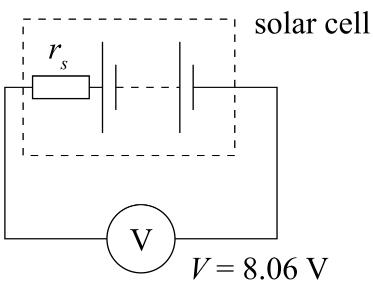
You are advised to spend 50 minutes answering the questions in this booklet.

QUESTION ONE: SOLAR RACING

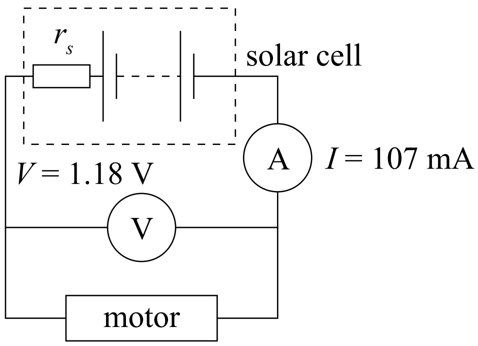
As part of a technology challenge Tui and Richard are building a solar powered model car. They plan to use a solar cell connected to a small motor to drive the car.

They have been told that the internal resistance, r_s, of a solar cell is relatively large and so, before they start, they decide to investigate the electrical properties of the solar cell.

First they connect the solar cell to a voltmeter with no other components and find the voltage is 8.06 V.



Then they connect the solar cell to the motor. They measure the voltage across the terminals of the cell to be 1.18 V, and the current to be 107 mA.



(a) Show that, in this circuit, the internal resistance of the solar cell is 64.3 Ω.

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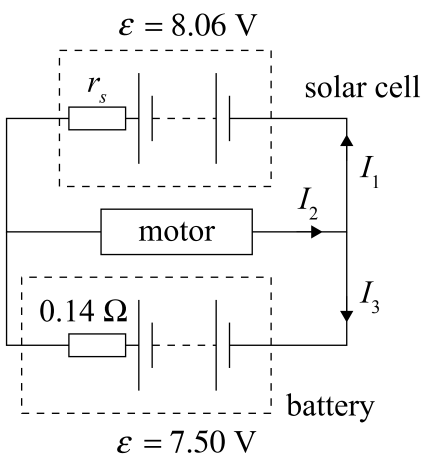
The arrangement on page 3 does not make the motor go. Richard suggests they use a battery to drive the motor and then, when the motor isn't going, use the solar cell to charge the battery. A diagram of this arrangement is shown below.



(b) Explain why this arrangement is more likely to make the motor go.

(c) State, in words, Kirchhoff's Voltage Law.

In the circuit above, $I_1 = 0.029$ A, $I_2 = 0.674$ A and $I_3 = 0.645$ A.

(d) Calculate the internal resistance, r_s, of the solar cell when connected in this circuit.

internal resistance = ______________

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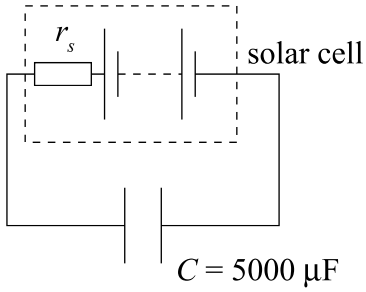
Their investigation shows the students that the internal resistance of the solar cell is not constant. It decreases as the current decreases.

They wonder what would happen if the cell was used to charge a capacitor.



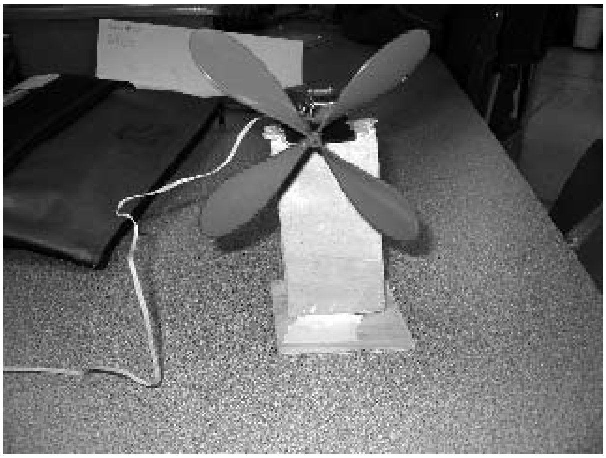
(e) What would be the time constant of the circuit to charge a 5000 μF (5.00×10^{-3} F) capacitor if the circuit resistance was 64.3 Ω?

time constant =

(f) Explain how the time taken to charge a capacitor with a solar cell would compare with the time taken to charge the same capacitor using a charging circuit that has constant resistance.

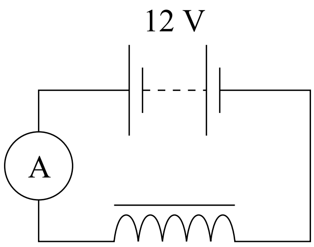
Assume both circuits have the same resistance at the start of the charging process.

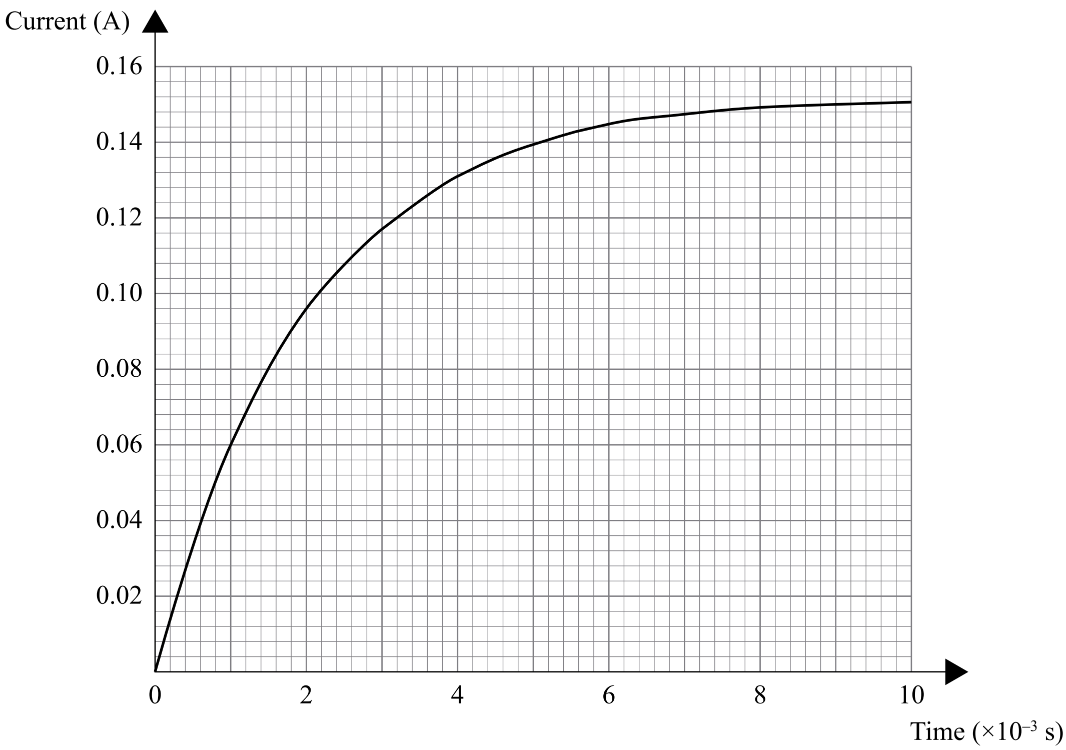
QUESTION TWO: WIND POWER



Jill is making a model wind turbine. It includes a generator constructed from a strong horseshoe magnet and a coil of wire, with 500 turns.

Jill decides to investigate the electrical properties of the coil of wire by connecting it in the circuit shown. She finds that the current takes some time to reach a steady value. A graph of the increase in current against time is also shown.





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When the current is steady the ammeter gives a reading of 0.152 A.

(a) Calculate the resistance of the coil. Give your answer to the correct number of significant figures.

resistance = ____________________

(b) Explain why the ammeter took some time to reach a steady reading.

(c) Calculate the self-inductance of the coil.

self-inductance = ____________________

The poles of the horseshoe magnet produce a uniform magnetic field with a magnetic flux density of 0.21 T. The coil has an area of 5.20×10^{-3} m^2, and, on a windy day, completes 2.0 rotations per second.

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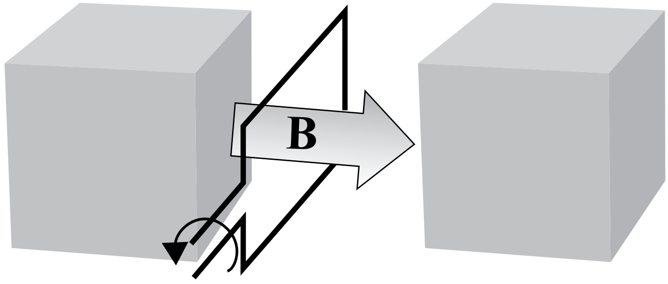


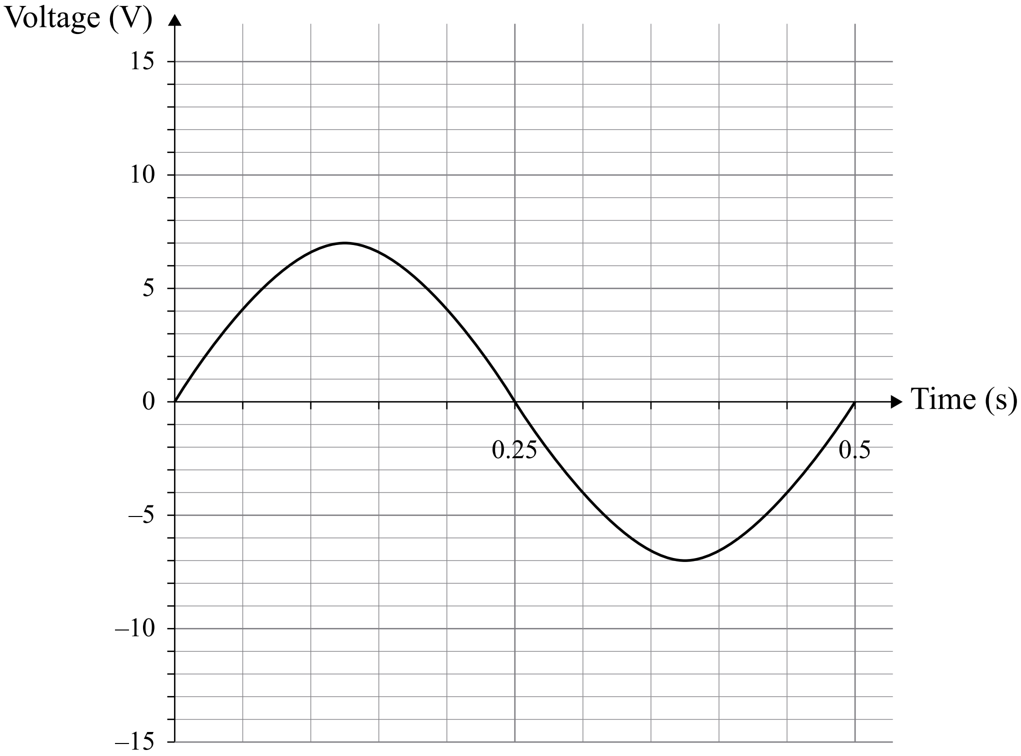
(d) Calculate the maximum magnetic flux through the coil.

magnetic flux =

(e) Calculate the average voltage induced in the coil when the coil rotates from a position of maximum flux to the first position of zero flux.

voltage =

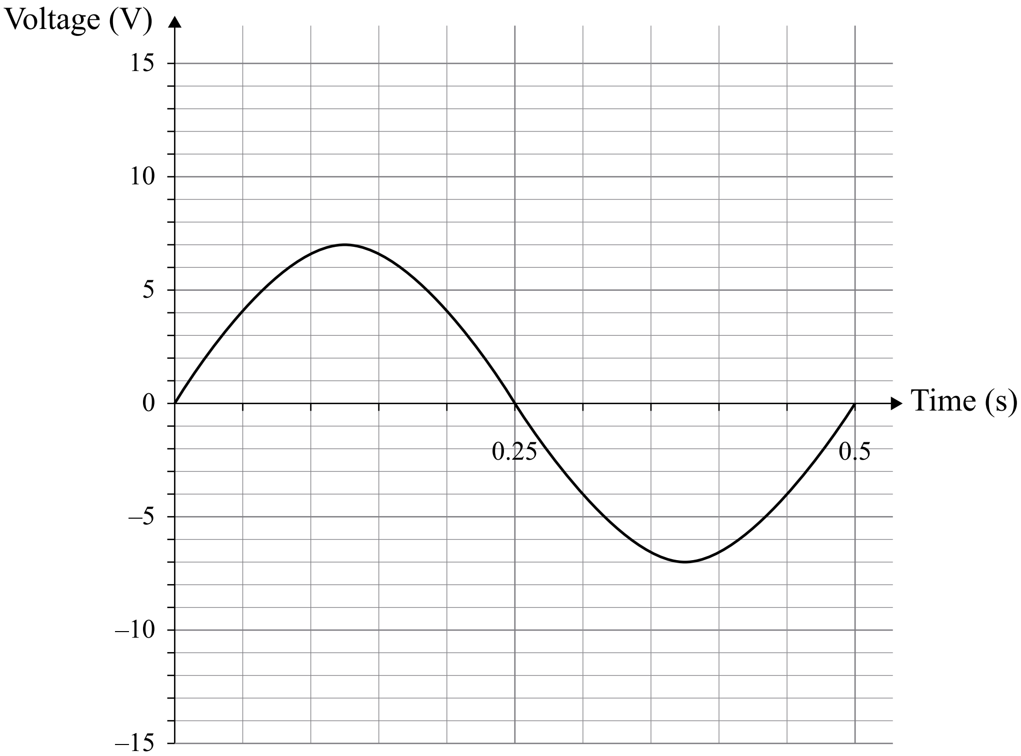
The graph below shows how the voltage induced in the coil changes with time when the coil completes 2.0 rotations per second.



On a particularly windy day, one gust of wind **doubles** the rate of rotation of the coil.

(f) **On the same axes, above**, sketch the shape of the voltage against time graph when the rate of rotation of the coil has doubled.

Use the graph below if you need to redraw your answer.
Make sure it is clear which graph you want marked.



QUESTION THREE: SECURITY SYSTEM

As part of the security measures at a political meeting, a portable metal detector has been installed.

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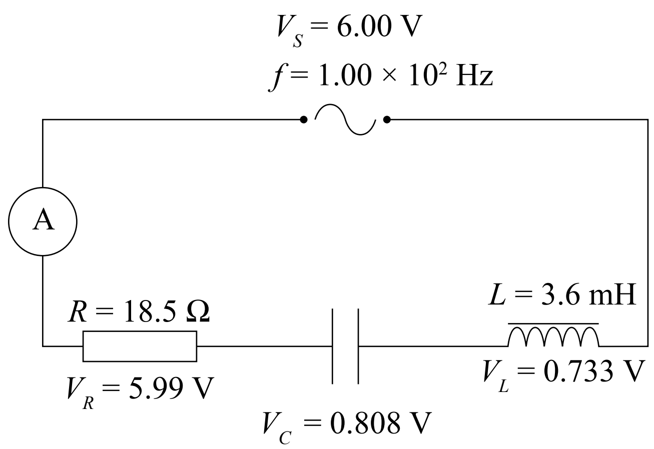
www.highcomsecurity.com

The detector includes an AC supply, producing an rms voltage of 6.00 V at a frequency of 100 Hz.

(a) Calculate the peak voltage of the AC supply.

voltage = ____________________

The AC supply is connected in series with an ammeter, resistor, capacitor and inductor, as shown in the diagram (all voltages are rms values).



(b) Explain why the numerical values of V_R, V_C and V_L in the diagram do not add up to the numerical value of the supply voltage.

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(c) Show that the ammeter reading in the circuit is 324 mA.

(d) Show that the capacitance of the capacitor is 638×10^{-6} F.

(e) State the mathematical condition for resonance, and use it to show that the resonant frequency of this circuit is 105 Hz.

The main frame of the detector is the inductor in the circuit. When someone walks through the detector they are, temporarily, the core of the inductor.

(f) Knowing that the resonant frequency is slightly higher than the supply frequency, explain how the reading on the ammeter would show that there was metal in the person's pocket.

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

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Question number