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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, 2004

90523 Demonstrate understanding of electrical systems

Credits: Five
9.30 am Thursday 18 November 2004

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 pages provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–15 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.

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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 (all criteria within a column are met)		

You may find the following formulae useful.

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

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

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

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

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

$$V = V_{\text{MAX}} \sin \omega t \qquad I_{\text{MAX}} = \sqrt{2}\, I_{\text{rms}} \qquad V_{MAX} = \sqrt{2}\, V_{\text{rms}} \qquad X_c = \frac{1}{\omega C}$$

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

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

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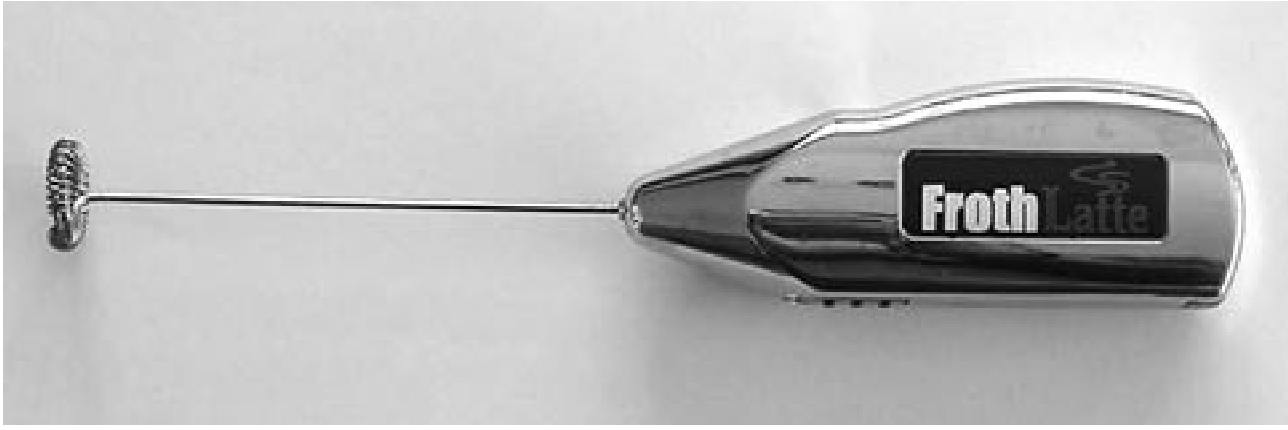
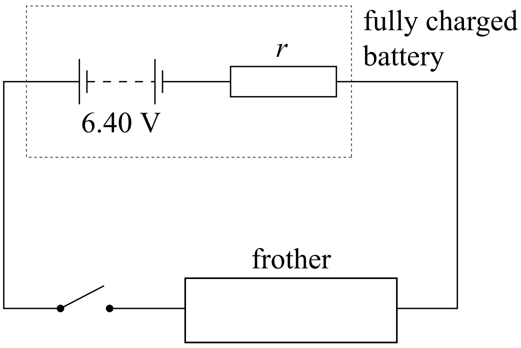
QUESTION ONE: CAPPUCCINO ESSENTIALS

Jodi has a battery-operated rotary whisk that makes frothy milk for her coffee.



The electrical circuit of the frother is shown below; the motor that drives the frother is shown as a resistor. The battery has an emf of 6.40 V, and when fully charged it has internal resistance r.



At maximum speed the power output of the frother is 4.5 W and this is achieved when the voltage across it is 6.25 V.

(a) Calculate the current through the frother when it is operating at maximum speed.

current = ______________________

The frother operates at maximum speed when the battery is fully charged.

(b) Calculate the internal resistance, r, of the fully charged battery.

internal resistance = ______________________

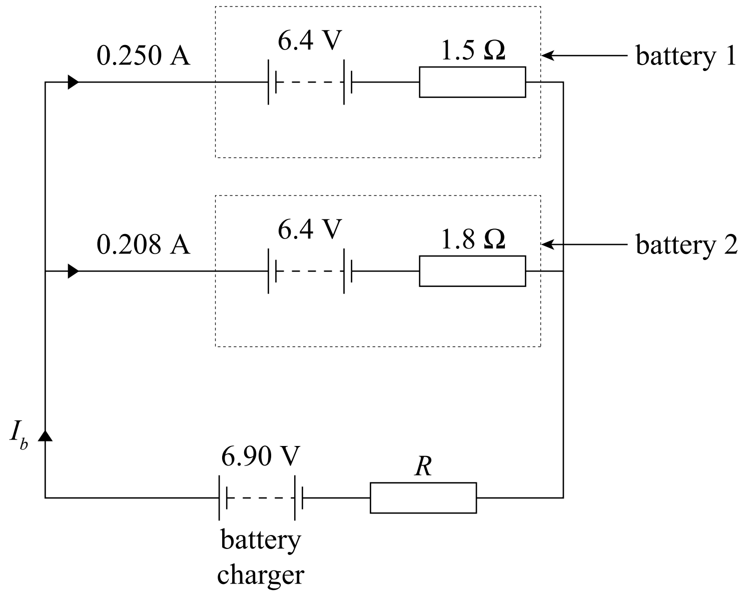
After some time, the frother slows down because the battery is becoming flat. Jodi removes the battery and starts to recharge it, together with another battery that is also flat.

The internal resistance of the battery Jodi removed is now 1.5 Ω and the internal resistance of the second flat battery is 1.8 Ω.

The battery charger has a voltage of 6.90 V.

The initial current through battery 1 is 0.250 A and through battery 2 is 0.208 A.

The diagram shows the recharging circuit.



(c) Calculate the current, I_b, through the battery charger.

current = ______________________

(d) Calculate the resistance, R, of the resistor.

resistance = ______________________

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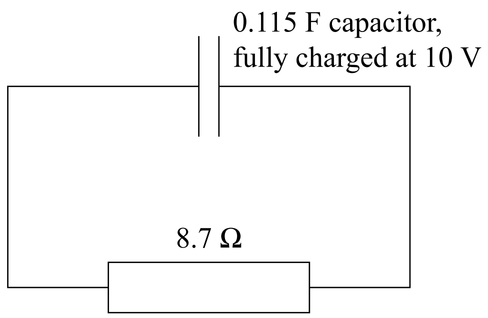
Jodi wondered what would happen if the battery in the frother were replaced with a charged capacitor.

She found a 0.115 F capacitor and used a 10 V supply to charge it. She then discharged the capacitor through the frother. The resistance of the frother is 8.7 Ω.



(e) Calculate the time constant for this circuit.

time constant = ______

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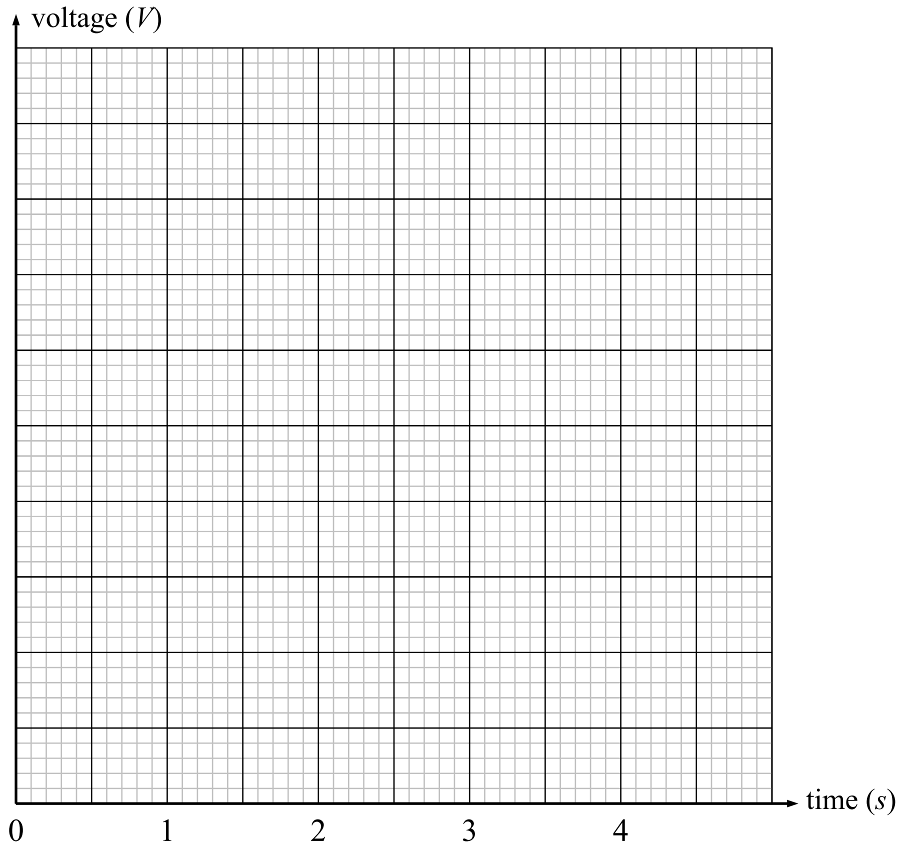
(f) On the axes below carefully plot a graph to show how the voltage across the capacitor would vary with time during the discharging of the capacitor over the first 4 s.

(If you need to redraw this graph, use the spare grid provided on page 15.)



(g) The minimum power that must be delivered to the frother to make it work is 1.3 W.

Calculate the length of time for which Jodi might expect the frother to work when it is powered by the capacitor.

time = ______________________

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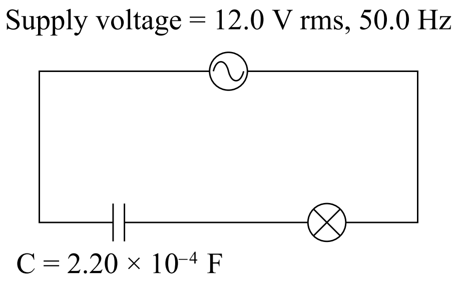
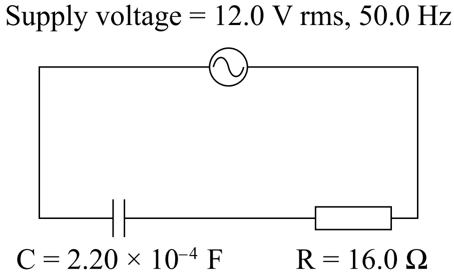
QUESTION TWO: AC CIRCUITS

Ana and Craig were investigating AC circuits. They constructed an AC circuit with a lamp and capacitor in series as shown below.



(a) Explain why the capacitor in this AC circuit allows the lamp to glow continuously, but would not do so if connected into a DC circuit.

The students replaced the lamp with a resistor of resistance 16.0 Ω as shown.



(b) The diagram below shows the phasors for:

- the voltage, V_C, across the capacitor,
- the voltage, V_R, across the resistor,
- the voltage, V_S, across the supply.

Label the phasors correctly.

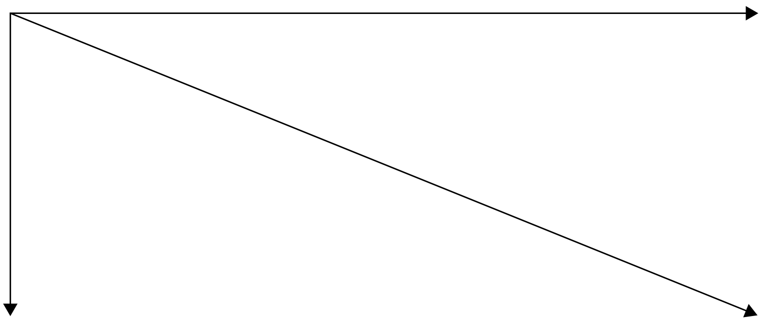


Diagram is not to scale.

(c) Show that the angular frequency of the supply voltage of this circuit is 314 rad s^{-1}.

(d) Calculate the impedance of this circuit.

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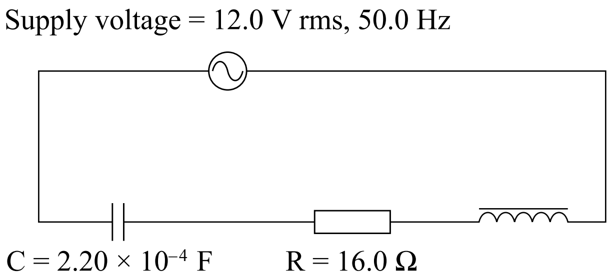
In a further investigation of AC circuits, Ana and Craig added an ideal inductor to the series circuit.

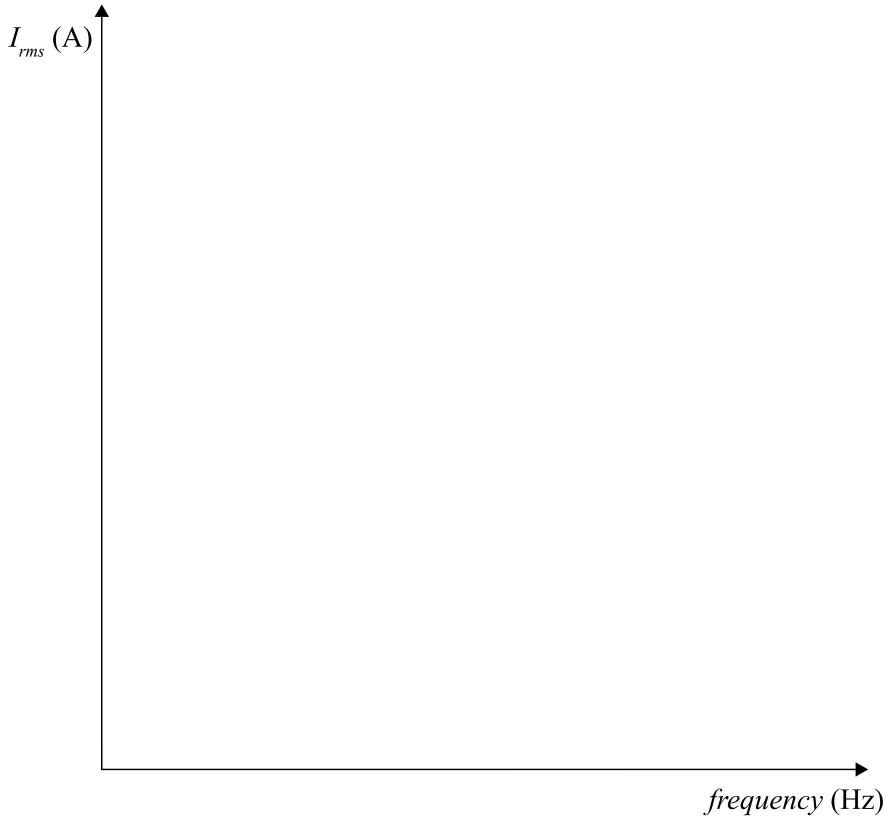


(e) Calculate the inductance of the inductor that will make this a resonant circuit.

(f) Explain fully what is meant by a resonant circuit.

(g) Calculate the value of the rms current in the circuit when it is at resonance.

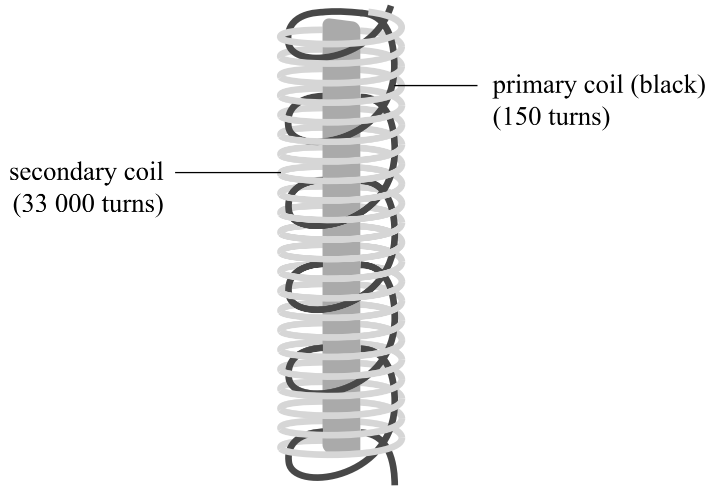
(h) On the axes below, sketch a graph of rms current against frequency for the circuit. Indicate appropriate current and frequency values.



QUESTION THREE: THE 'COIL'

In the engine of a car the 'coil' is the device that generates the **high voltage** required to create the spark that ignites the petrol vapour.

The 'coil' is essentially made up of **two** coils of wire. One coil is called the **primary coil**. Wrapped around it is the **secondary coil**. The secondary coil normally has hundreds of times more turns of wire than the primary coil. The diagram below shows a simplified view of this arrangement of coils.



Current from the battery flows through the primary coil. When the circuit is suddenly broken, the magnetic field in the primary coil, and hence also in the secondary coil, collapses (falls rapidly). The mutual induction that takes place between the two coils produces the high voltage needed to create a spark.

(a) Describe what is meant by mutual induction.

In questions (b) to (g), assume that the secondary coil is not connected so the primary coil experiences self-induction only.

In Jessie's car, the primary coil has 150 turns, cross-sectional area of 2.00×10^{-3} m^2, and resistance 0.750 Ω. The magnetic field in the primary coil, when it is connected to the 12 V battery, is 4.20×10^{-2} T.

(b) Calculate the flux in the primary coil when it is connected to the battery.

flux = ____________________

When the circuit is broken, there is an average voltage of 85.0 V across the primary coil.

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(c) Explain why there is a voltage across the primary coil when the circuit is broken.

(d) Show that the time it takes for the flux in the primary coil to collapse is 1.48×10^{-4} s.

(e) Show that the self-inductance of the primary coil is 7.9×10^{-4} H.

(f) (i) Calculate the time constant for the primary circuit when it is completed.

time constant =

(ii) Justify the number of significant figures to which you have rounded your answer.

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(g) Explain why the time taken for the current to build in the primary coil, when the circuit is completed, is **longer** than the time taken to fall when the circuit is broken.

When the secondary coil is connected, mutual induction takes place, and there is a maximum voltage of 410 V across the primary coil.

(h) Calculate the maximum voltage induced across the secondary coil.

maximum induced voltage = ____________________

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

Question number

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If you wish to redraw the graph from Question 1 (f), use the grid below.