3

90523

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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2007

90523 Demonstrate understanding of electrical systems

Credits: Six
9.30 am Friday 30 November 2007

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 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.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

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 2–10 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 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)		

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You are advised to spend 55 minutes answering the questions in this booklet.

You may find the following formulae useful.

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

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

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

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

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

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

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

QUESTION ONE: CAPACITORS AND LOOPED CIRCUITS

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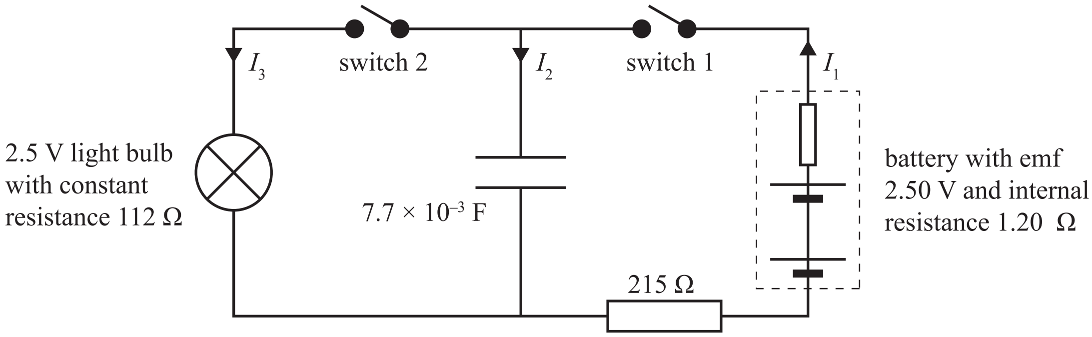
The following circuit was set up to model the operation of a camera flash unit.



With switch 2 open, switch 1 is closed and the capacitor starts to charge.

(a) Calculate the time constant for the charging circuit. Give your answer to the correct number of significant figures.

time constant = ______________

(b) Write a Kirchhoff's voltage equation for the closed loop to calculate the **initial** current in the circuit.

current = ______________

(c) What is the voltage of the capacitor when it is fully charged?

voltage = ______________

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(d) Explain why the current drops to zero.

(e) Switch 1 is opened and switch 2 is closed.

Explain why the bulb flashes (**glows** briefly then **goes out**).

With switch 2 still closed, switch 1 is now closed to re-charge the capacitor.

(f) Write a Kirchhoff's current equation for the circuit while the capacitor is charging.

(g) Show that the terminal voltage of the battery, when the capacitor has finished charging, is 2.49 V.

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(h) When the capacitor is charged, the voltage across the 215 Ω resistor is 1.64 V.

Calculate the voltage across the capacitor.

voltage =

(i) With switch 2 still closed, switch 1 is opened to make the bulb flash.

State why the bulb does **not** flash.

(j) To get the unit **ready** for a flash, switch 1 must be closed and switch 2 must be open.

Explain why each of these switch settings is necessary **before** a flash can be produced.

Switch 1 must be closed because:

Switch 2 must be open because:

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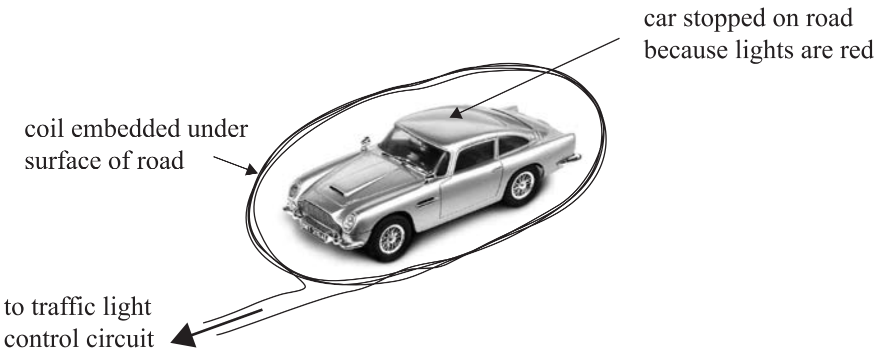
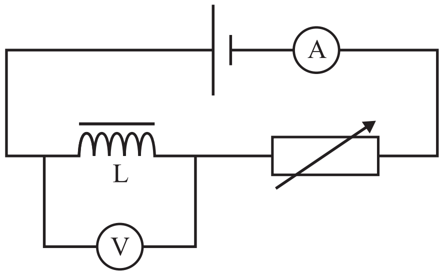
QUESTION TWO: INDUCTORS AND AC CIRCUITS

Traffic lights can be controlled by using an **inductive loop** to detect the presence of a car on the road. The loop is a large coil of wire embedded under the road surface. When a car stops over the loop, the inductance of the loop changes. This is sensed by an electrical circuit that causes the traffic lights to change from red to green.



The inductance of the coil of wire must be measured. A possible way of doing this is to use a circuit like the one below. The inductor, L, in the circuit models the coil of wire under the road.



The resistance of the rheostat is changed so that the current in the circuit drops steadily from its maximum value of 1.62 A to 0.13 A in 1.2 s. While the current is dropping, the voltmeter reads 4.0 mV.

(a) Explain why there is a voltage across the inductor.

(b) Calculate the inductance of the inductor.

inductance =

The inductor is now connected into the circuit below to model the traffic light control circuit.

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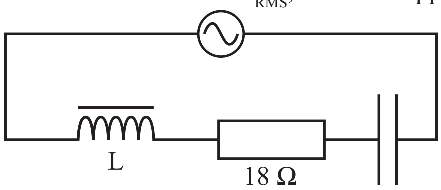
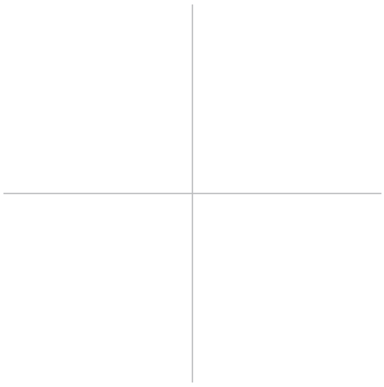


(c) In the space below draw and label phasors to show the voltages across the inductor, the capacitor and the resistor.



(d) If the reactance, X_L, of the inductor is smaller than the reactance, X_C, of the capacitor, would the supply voltage phasor lead or lag the current phasor? Explain your answer.

(e) The frequency of the supply is 81.6 Hz.

Calculate the angular frequency of the supply.

angular frequency = ______________

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(f) Show that the reactance of the capacitor is 9.75 Ω.

(g) If the reactance of the inductor is 1.65 Ω, calculate the current in the circuit.

current =

When a car stops on the road above the coil, the inductance of the coil increases causing the circuit to approach **resonance**.

(h) Why does the inductance increase when a car is standing above the coil?

(i) Explain how this increase in inductance will change the current in the circuit.

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(j) Calculate the value of the current in the circuit at resonance.

current =

(k) Calculate the inductance of the inductor that would bring the circuit to resonance.

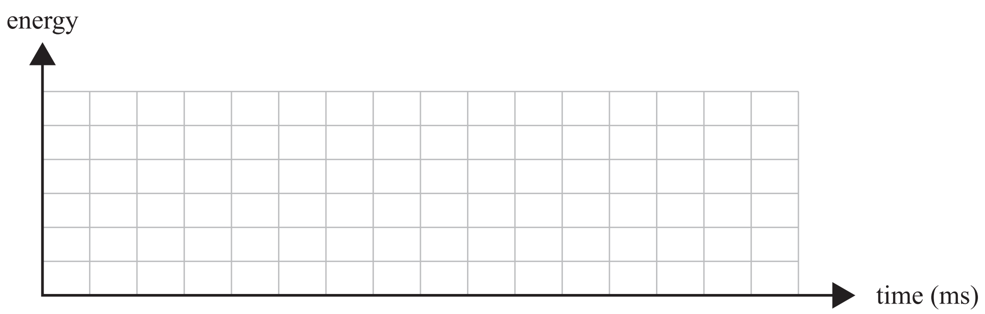
inductance =

Assuming the energy lost from the resistor is small enough to be ignored, the energy stored in the circuit oscillates between being totally stored in the capacitor and being totally stored in the inductor.

(l) Calculate the **maximum** energy stored in the capacitor at resonance.

energy =

(m) On the axes below, sketch graphs to show how the energy stored in the capacitor and the energy stored in the inductor change for **one complete period** of the alternating voltage. Label each graph line. Assume the capacitor is fully charged at $t = 0$. Show one non-zero value on the time axis. Ignore the energy loss from the resistor.



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

Question number

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