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Level 3 Physics, 2017

91526 Demonstrate understanding of electrical systems

2.00 p.m. Monday 20 November 2017
Credits: Six

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of electrical systems.	Demonstrate in-depth understanding of electrical systems.	Demonstrate comprehensive understanding of electrical systems.

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 attempt ALL the questions in this booklet.

Make sure that you have Resource Booklet L3–PHYSR.

In your answers use clear numerical working, words, and/or diagrams as required.

Numerical answers should be given with an SI unit, to an appropriate number of significant figures.

If you need more room for any answer, use the extra space provided at the back of this booklet.

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.

TOTAL

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QUESTION ONE

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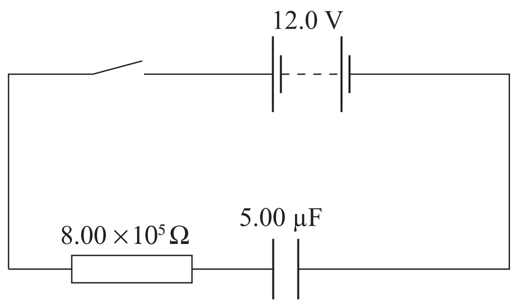
Thomas's car has an interior light that turns on when a door is opened. When the door closes, there is a time delay before the light turns off. The time delay is determined by the time constant of a resistor-capacitor (RC) circuit.

(a) Describe what is meant by the term time constant.

The diagram below shows an RC circuit. The capacitor is initially uncharged.

After the switch is closed, the battery supplies 7.20×10^{-4} J of energy.



(b) (i) Calculate the energy stored in the capacitor when it is fully charged.

(ii) Explain why this energy stored in the capacitor is less than the energy supplied by the battery.

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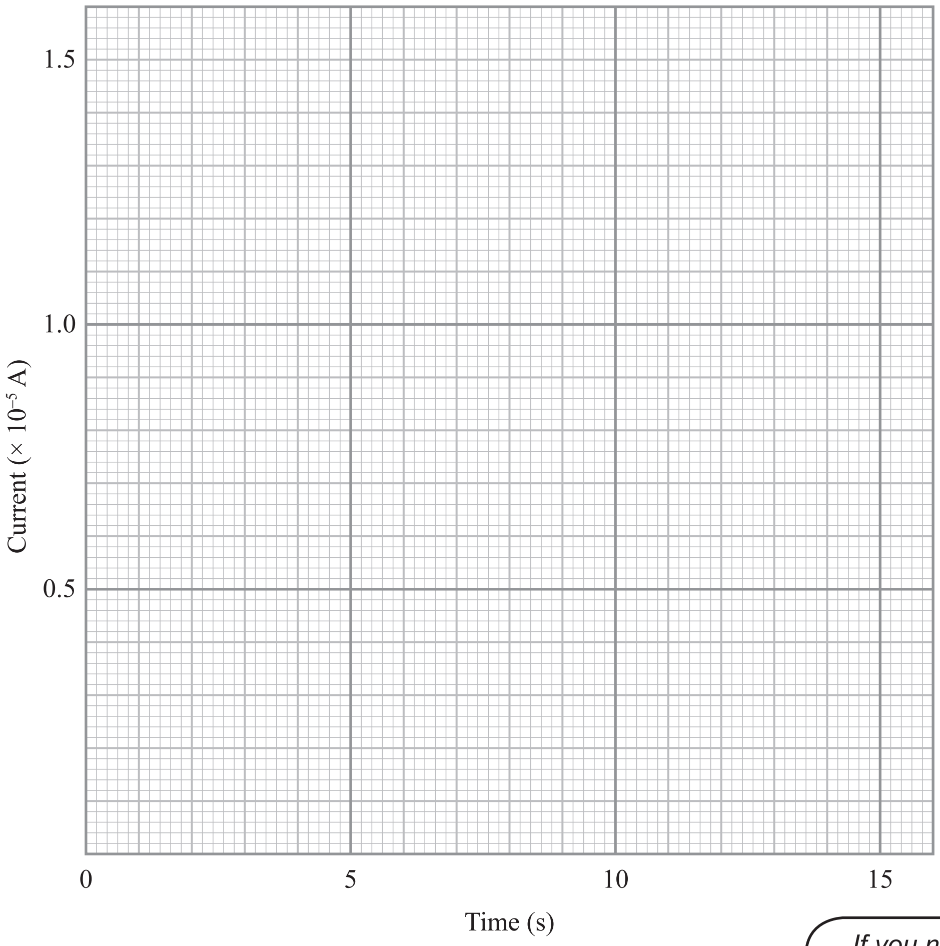
(c) (i) Draw a graph of circuit current against time for 15 seconds after the switch is closed. Data points should include the initial current and the current after one time constant.

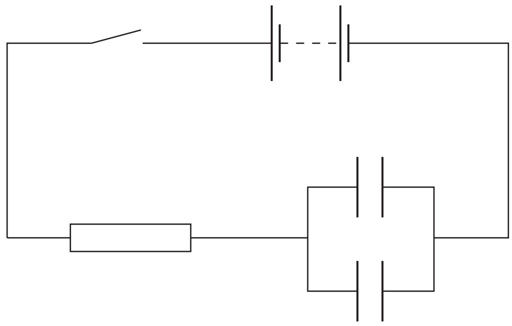


If you need to redraw your graph, use the grid on page 11.

Space for working

(ii) Explain why the graph has the shape you have drawn.

(d) The time constant of the RC circuit can be changed by adding a second capacitor, as shown below.



Explain how this affects the time taken for the capacitor to charge up.

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The examination continues on the following page.

QUESTION TWO

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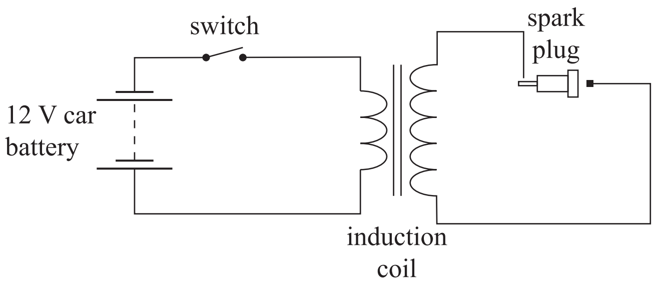
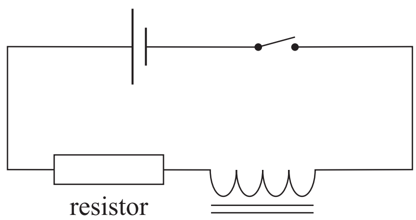
In a car engine, an induction coil is used to produce a very high voltage spark. An induction coil acts in a similar way to a transformer.

The diagram below shows the circuit arrangement that will enable a spark to be produced in the spark plug when the switch is opened.

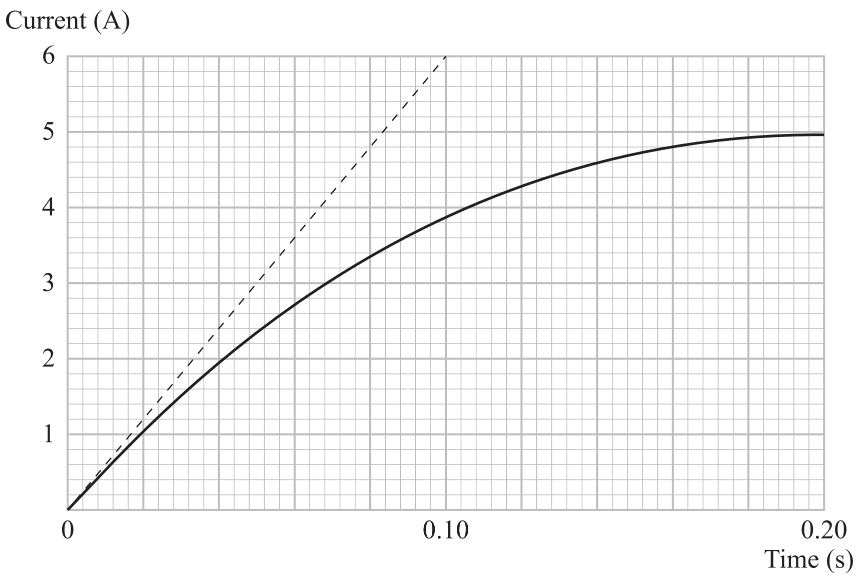
The induction coil has 50 turns in the primary coil and 8000 turns in the secondary coil. Both coils are wrapped around an iron core.



The primary coil of the induction coil can be modelled by a resistor in series with an ideal inductor as shown in the diagram below.



The following graph shows the current changing with time after the switch is closed (solid line).



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(a) State the value of the voltage across the ideal inductor once current has reached a maximum value of 5.0 A.

(b) Explain why the current does not immediately reach maximum value as soon as the switch is closed.

(c) Immediately after the switch is closed, the back EMF across the ideal inductor is 12.0 V.

Using the dotted line on the graph on page 6, calculate the self-inductance of the ideal inductor.

(d) Sparks require a very high voltage to be produced.

Explain how it is possible for a spark to be produced across the gap in the spark plug when the switch is opened.

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QUESTION THREE

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It is important that the wood used in buildings does not have much water in it.

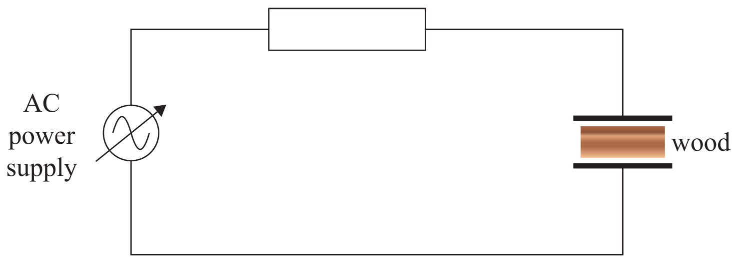
Thomas uses a parallel-plate capacitor, with the wood as the dielectric, to measure the water content of the wood.

Water has a higher dielectric constant than wood.

One way of measuring the water content in the wood is by using the circuit shown below.

Thomas connects the circuit, and makes the following measurements:

Supply voltage	= 12.0 V_{rms}
Frequency	= 151 Hz
Resistance of the resistor	= 50.0 Ω
Reactance of capacitor	= 23.5 Ω



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

(b) Calculate the rms current in the circuit.

Question Three continues on the following page.

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(c) Explain what would happen to the circuit current when the wood in the capacitor is replaced by a similar piece of wood that contains more water.

(d) An inductor is added in series with the capacitor and resistor in the circuit. The reactance of the inductor is 35.7 Ω at 151 Hz. The reactance of the capacitor is 23.5 Ω at 151 Hz.

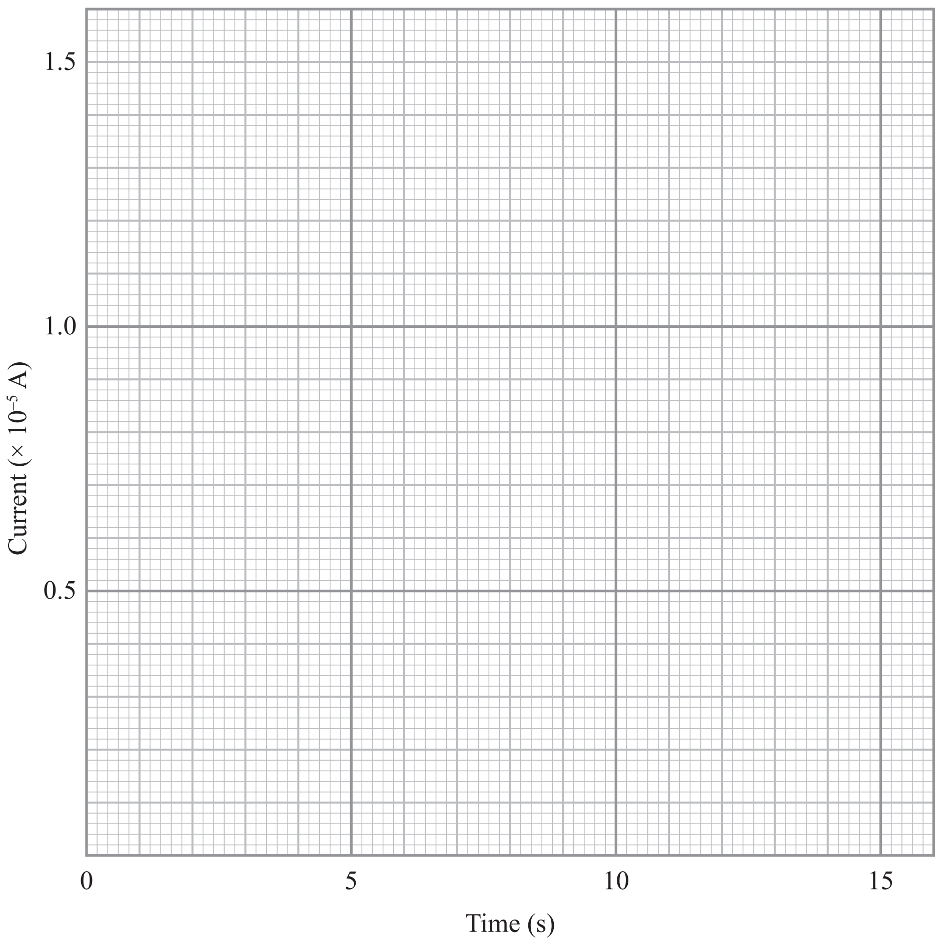
Thomas adjusts the frequency until the current is maximum.

(i) Calculate the resonant frequency.

(ii) Explain why the current is maximum at the resonant frequency.

SPARE DIAGRAMS

If you need to redraw your graph for Question One (c)(i), draw it on the grid below. Make sure it is clear which answer you want marked.



Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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