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Level 3 Physics 2021

91526 Demonstrate understanding of electrical systems

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.

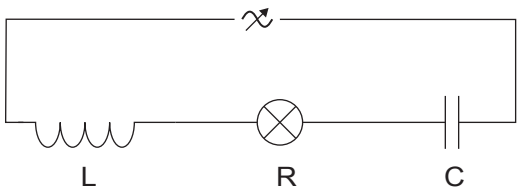
Check that this booklet has pages 2 – 11 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

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

QUESTION ONE: ALTERNATING CURRENT

Kate is experimenting with LCR circuits. She uses a signal generator and connects an inductor, a 1.00×10^{-4} F capacitor and a lamp to act as a resistor, all in series, as shown in the diagram and photograph below. Kate adjusts the frequency of the signal generator until the lamp glows brightly. (Assume the inductor is ideal.)



(a) The lamp is brightest at a particular frequency called the resonant frequency.

State one condition for resonance to occur.

(b) Kate observes that the resonant frequency is 2.10×10^2 Hz.

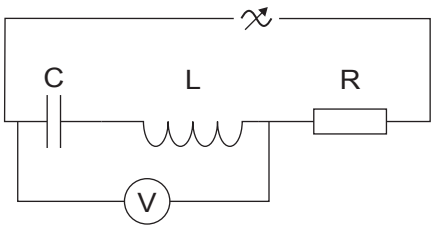
By first showing that the reactance of the capacitor is 7.58 Ω, calculate the inductance of the inductor.

(c) While the lamp is at maximum brightness, Kate inserts some iron rods into the core of the inductor.

(i) State how inserting the iron rods affects the inductance of the inductor.

(ii) Explain how the change in inductance will affect the brightness of the lamp.

(d) With the iron rods inserted in the solenoid, there is a 17.0° phase difference between the supply voltage of 12.0 V_{rms}, 210 Hz and the circuit current. Kate connects a voltmeter across the ideal inductor (with negligible resistance) and capacitor, as shown in the diagram below.



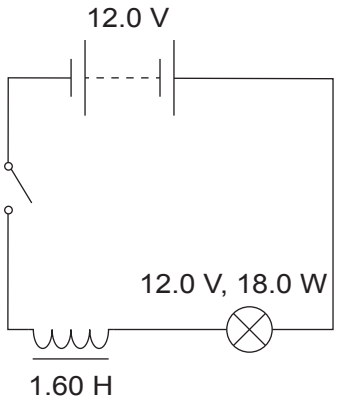
Phasor diagram if needed

Determine the rms voltage Kate's voltmeter would show.

State whether the supply voltage leads or lags the circuit current.

QUESTION TWO: INDUCTORS AND LAMPS IN DC CIRCUITS

Kate uses a 12.0 V DC battery with negligible internal resistance to connect a lamp in series with a 1.60 H ideal inductor (no resistance). Kate observes the brightness of the lamp in the circuit as she closes the switch.

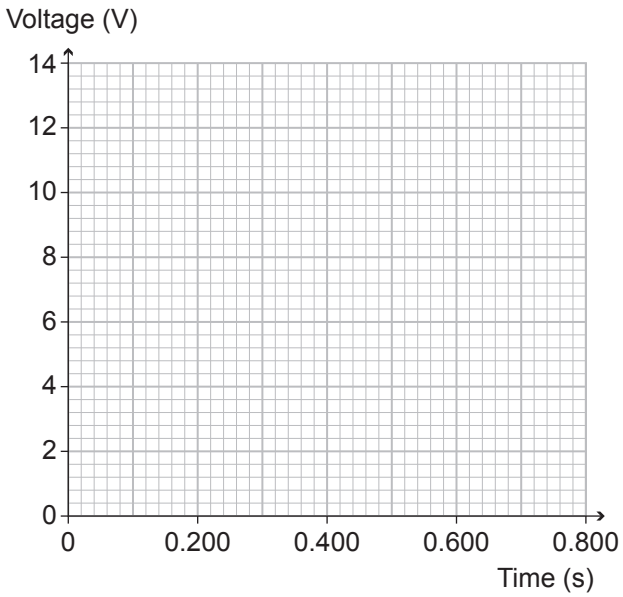


This question assumes the resistance of the lamp is the same for all voltages.

(a) Show that the time constant of this circuit with the inductor and lamp is 0.200 s.

(b) (i) On the space below, draw a graph of voltage against time for the lamp, starting at the instant the switch is closed.

Plot at least three non-zero points on the graph.



Space for calculations

If you need to redraw your response, use the graph on page 8.

(ii) Explain the reason for the shape of the graph that you have drawn for the lamp in part (i).
Discuss how the inductor affects the voltage across the lamp.
Comment on the gradient of your graph line.

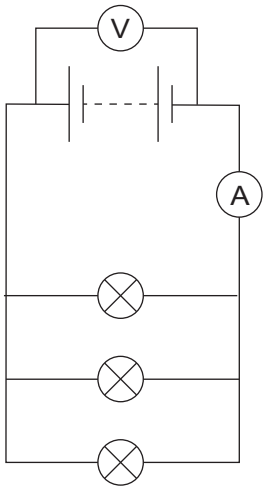
(c) Calculate the energy stored in the inductor once the current is steady.

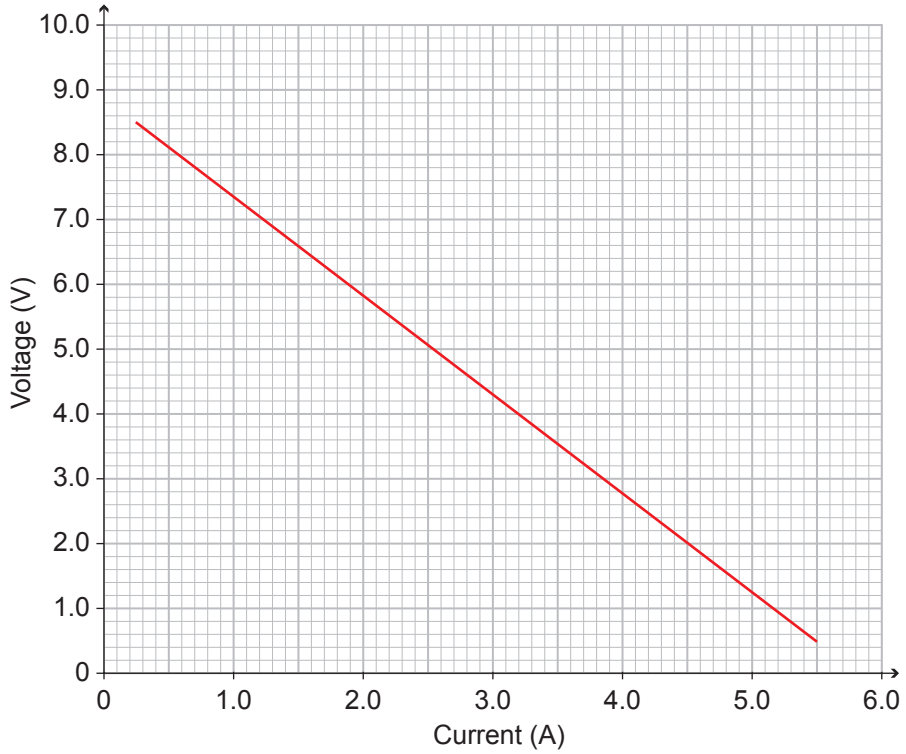
QUESTION THREE: BATTERIES AND INTERNAL RESISTANCE

Joel is experimenting measuring the terminal voltage across a battery and the current drawn from the battery while adding lamps in parallel.

He notices that the terminal voltage decreases as he adds more and more lamps in parallel.

He uses the data he gathers to plot a graph of terminal voltage across the battery against circuit current.



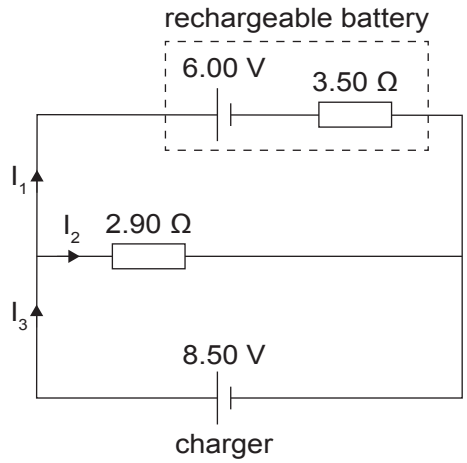


(a) State the physical meaning of the term emf.

(b) Using the graph, determine the emf of the battery and the internal resistance of the battery.

(c) Explain why the terminal voltage of the battery decreases as more lamps are added in parallel.

(d) Joel repeats his experiment using a different battery, but it becomes flat before he has finished. He recharges it using the circuit below.

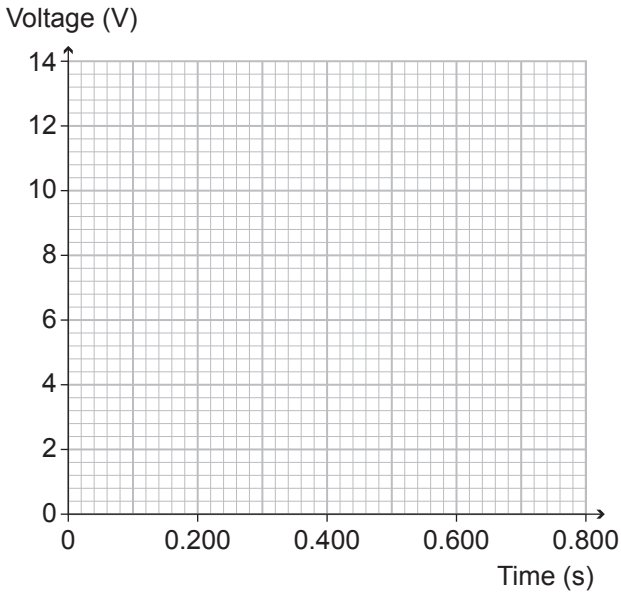


Using the information in the circuit above, calculate the current in each of the three branches using Kirchhoff's laws or any other method.

Begin your answer by writing a current equation for I_1, I_2, and I_3.

SPARE DIAGRAMS

If you need to redraw your response to Question Two (b)(i), use the diagram below. Make sure it is clear which answer you want marked.



Space for calculations

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

QUESTION NUMBER

Extra space if required.
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