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91526

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QUALIFY FOR THE FUTURE WORLD
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Level 3 Physics, 2018

91526 Demonstrate understanding of electrical systems

2.00 p.m. Tuesday 20 November 2018
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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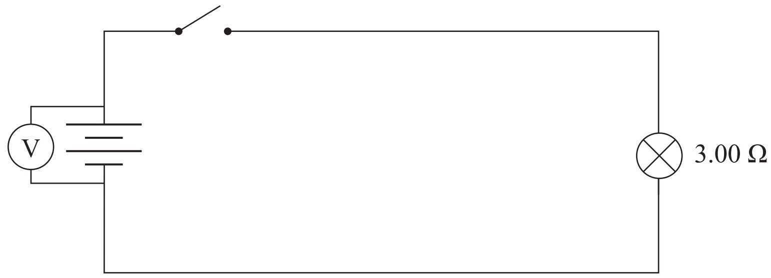
Casey sets up a battery, a switch, and a 3.00 Ω light bulb in series.



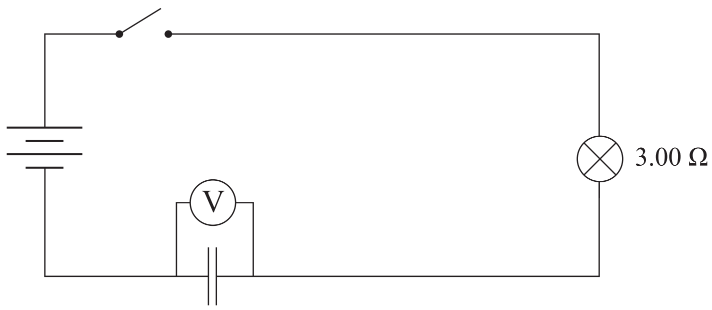
The battery voltage is measured to be 6.02 V when the switch is open. However, when the switch is closed, Casey notices that the battery voltage drops to 5.85 V.

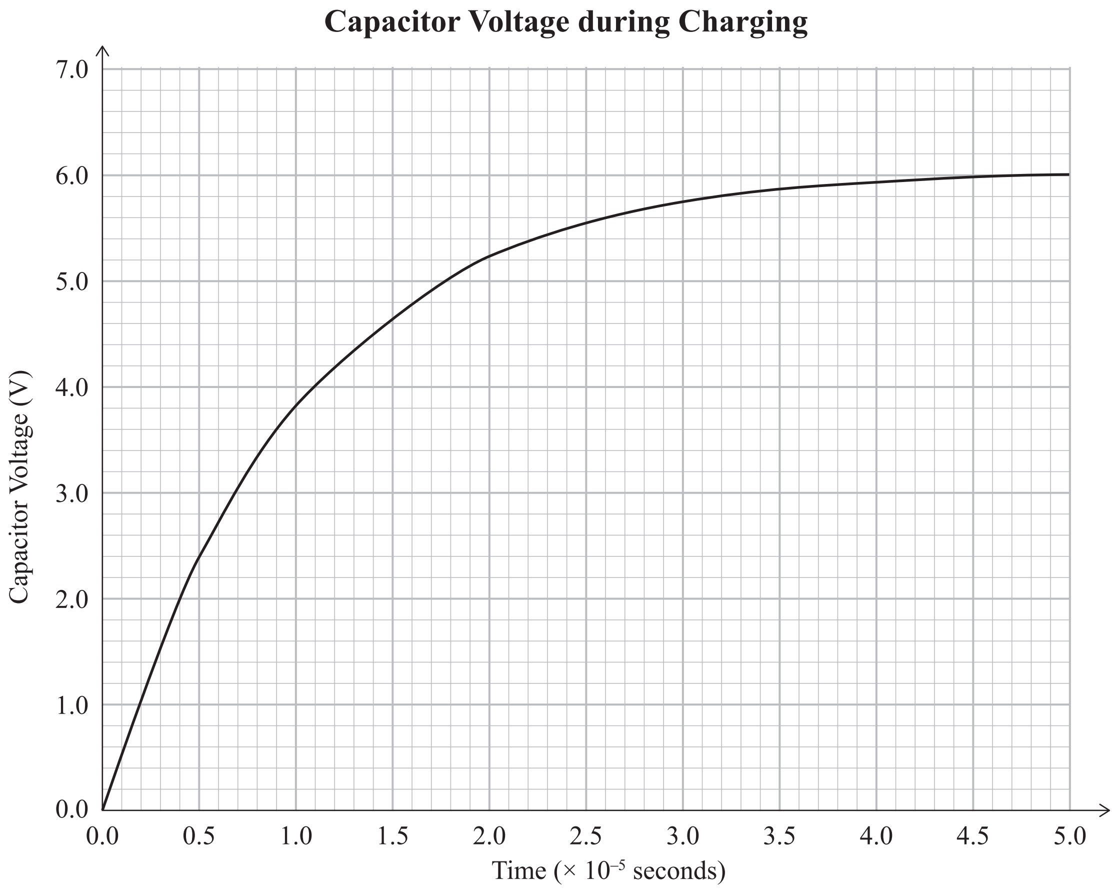
(a) Explain why the battery voltage is less when the switch is closed.

(b) Casey measures the current through the circuit to be 1.89 A.

State the EMF, and show that the internal resistance of the battery is approximately 0.09 Ω.

Casey now adds a capacitor in series with the battery and closes the switch. Casey measures the voltage across the capacitor as it charges.





(c) Using information from the graph, determine the capacitance of the capacitor.

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(d) Casey discharges the capacitor, removes the light bulb, and begins to charge the capacitor again. Casey predicts that, by removing the light bulb, less energy will be converted to light and heat, and so the capacitor will charge more quickly, and have more stored energy once fully charged.

Use physical reasoning to discuss each aspect of Casey's prediction.

You should discuss, with explanations:

- whether the capacitor will charge more quickly than before
- whether less energy will be converted to light and heat during the charging process without the light bulb
- whether more energy will be stored in the fully charged capacitor.

QUESTION TWO

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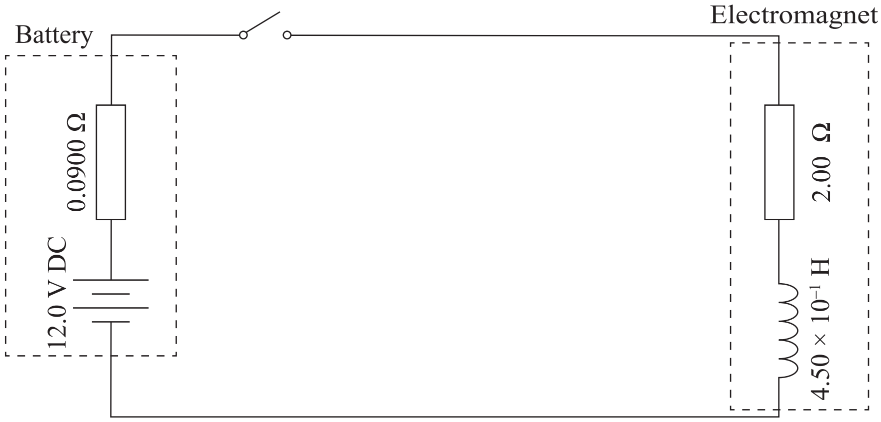
Casey is using an electromagnet that has an inductance of 4.50×10^{-1} H and a resistance of 2.00 Ω. Casey connects it to a 12.0 V DC battery with an internal resistance of 0.0900 Ω.



(a) Determine the current through the electromagnet a few minutes after the switch is closed.

(b) Casey opens the switch and a large spark jumps across the terminals of the open switch.

Explain how the coil can produce such a high voltage when the switch is opened.

(c) To prevent damaging sparks, Casey places a 20.0 Ω resistor in parallel with the electromagnet.

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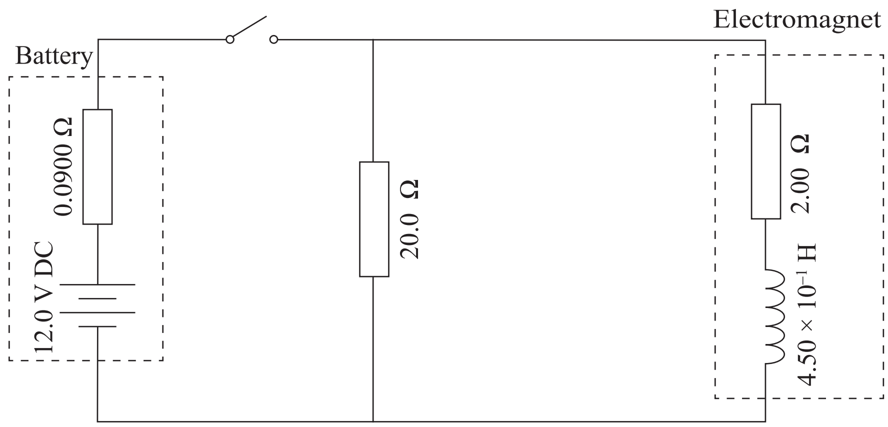

At one point, shortly after the switch is closed, the rising current drawn from the battery has reached 2.00 A and a back EMF of 9.00 V has been induced across the inductor.

Show that the current through the electromagnet at this time is 1.41 A.

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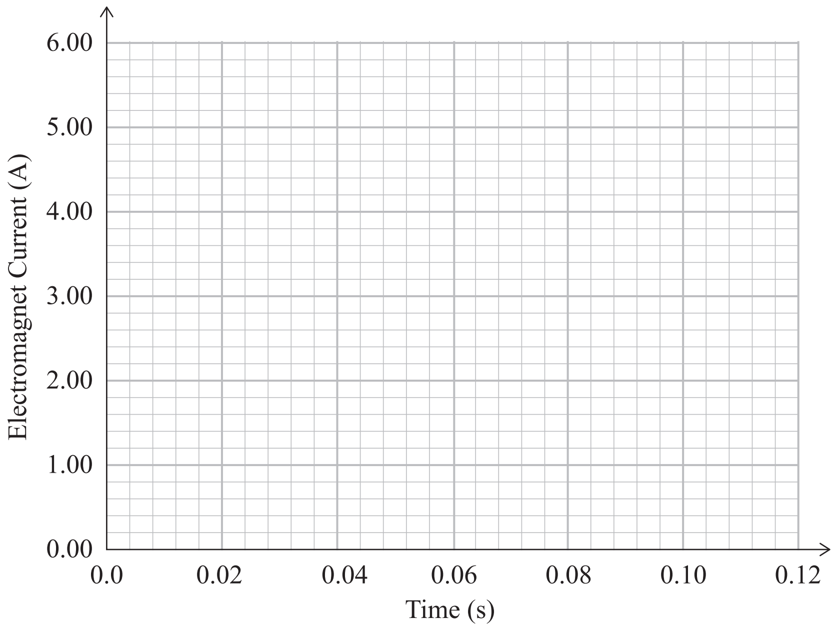
(d) After many more minutes, the current through the coil is a steady 5.72 A.

The switch is now opened.

(i) Plot the graph of current versus time for the electromagnet as the current falls to zero.



(ii) Explain how the presence of the 20 Ω resistor protects against the high voltage sparks that Casey witnessed earlier.

QUESTION THREE

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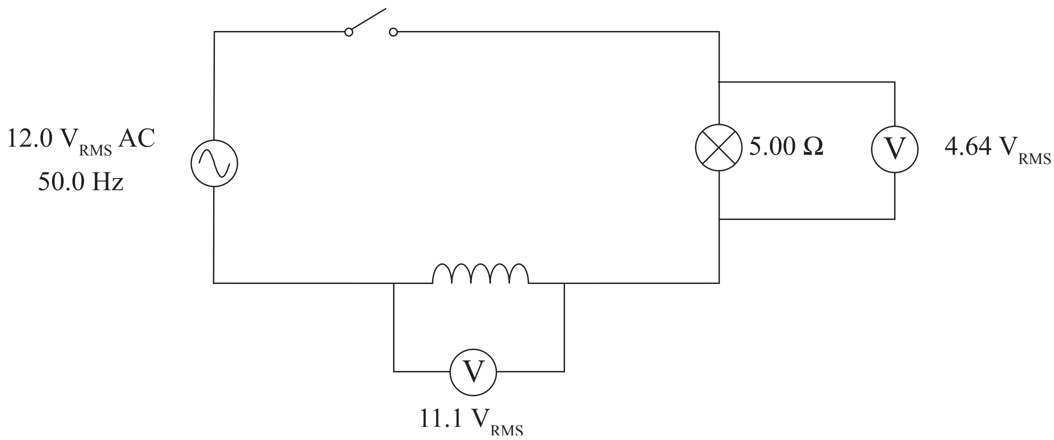
Casey is experimenting with building inductors and capacitors.

To make a capacitor, Casey places a thin layer of rubber between two 1.20 m^2 aluminium plates, and then squeezes the sheets together. The rubber has a dielectric constant of 8.90 and is compressed to a thickness of 1.00×10^{-4} m.

(a) Show that the capacitance of Casey's capacitor is 9.45×10^{-7} F.

To make an inductor, Casey winds several hundred turns of insulated copper wire around an iron rod. Casey wants to test its inductance.

Casey connects the circuit shown below. The voltage across the lamp is measured to be 4.64 V_{RMS}, and across the inductor to be 11.1 V_{RMS}.



(b) Show that the inductance of Casey's inductor is 3.81×10^{-2} H.

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Casey adds in the 9.45×10^{-7} F capacitor to create an LCR series circuit. The light bulb barely glows. Casey switches the AC power supply to its maximum frequency setting of 4.00×10^{2} Hz.

(c) Determine the new impedance of the circuit.

(d) (i) Calculate the resonant frequency for the circuit and compare this with the maximum frequency setting of the power supply.

(ii) Describe how Casey could physically alter the inductor and capacitor to increase the current through the light bulb using this power supply.

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

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