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Level 3 Physics 2020

91526 Demonstrate understanding of electrical systems

2.00 p.m. Wednesday 2 December 2020
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 2–8 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: AC CIRCUITS

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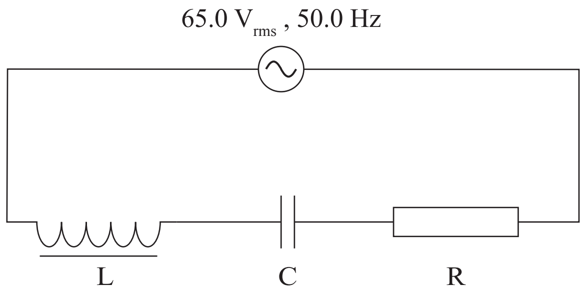
Tui is investigating LCR circuits. She sets up the circuit shown below using a signal generator, and sets the supply voltage to 65.0 V_{rms}, 50.0 Hz.



(a) Calculate the peak voltage of the supply.

(b) The supply voltage in the circuit above leads the circuit current by 35.0°. The resistor has a resistance of $1.50 \times 10^2\ \Omega$.

Calculate the total impedance of the circuit.

A phasor diagram may be useful.

(c) The inductor has an inductance of 0.380 H.

By calculating the total reactance of the circuit, determine the capacitance of the capacitor.

(d) Explain what change needs to be made to the frequency of the signal generator to bring the circuit to resonance.

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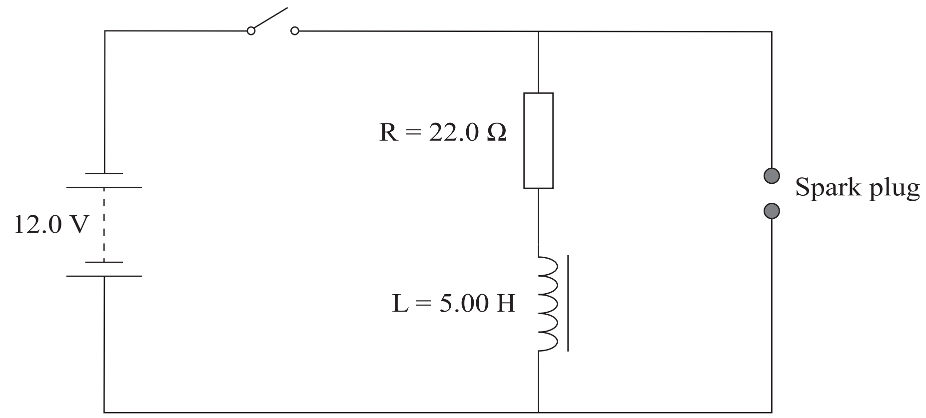
QUESTION TWO: CAR IGNITION SYSTEM

The circuit below shows a simplified version of a car ignition system. The ignition coil is comprised of an inductor of 5.00 H, 22.0 Ω. The inductor can be modelled by a 5.00 H ideal conductor and a separate 22.0 Ω resistor, as shown in the diagram. The 12.0 V battery is connected to a switch and the inductor and resistor in series. The spark plug is placed in parallel with the inductor and resistor.



(a) State the voltages across the inductor and resistor the instant after the switch is closed.

(b) Explain why the current takes time to reach a maximum once the switch is closed.

(c) Calculate the circuit current one time constant after the switch is closed.

(d) Spark plugs need a very high voltage of nearly 20 000 V to produce a spark.

Explain why a spark is produced when the switch is opened, but not when it is closed.

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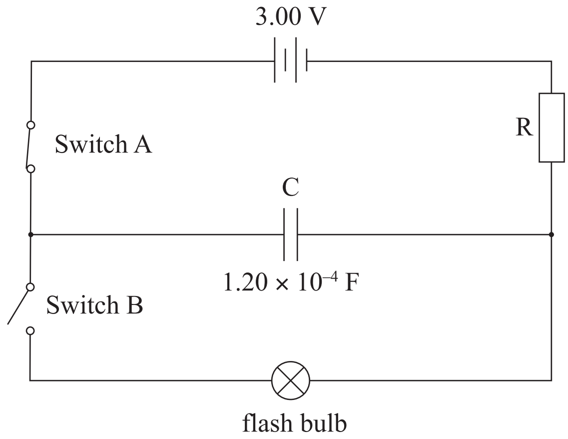
QUESTION THREE: DISPOSABLE CAMERA FLASH

Capacitors are commonly used in electrical circuits to store and dissipate energy. In a disposable camera a capacitor is charged by a battery. This energy is used to flash the bulb while the photo is being taken.

One such disposable camera uses a 1.20×10^{-4} F capacitor.

The camera is supplied with a battery of emf 3.00 V with no internal resistance.

A simplified diagram of the circuit is provided on the right.



Switch A is closed and switch B remains open.

(a) Sketch a graph in the space below to show what happens to the size of the current over time as the capacitor charges.

State what determines the size of the maximum current.

(b) Calculate the energy stored in the capacitor once it is fully charged. Compare this with the energy supplied by the battery and account for any difference in the energy.

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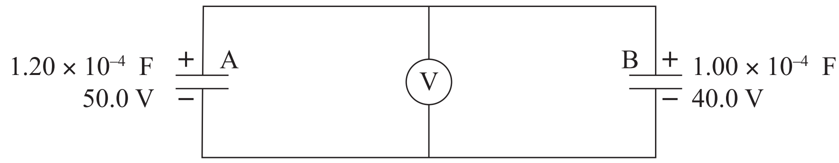
(c) Emily decides to investigate capacitors further. She uses a sheet of plastic insulator with a thickness of 2.00×10^{-3} m and a relative permittivity (dielectric constant) of 10, by placing metal foil on either side of the plastic sheet to make a capacitor.

Calculate the area of the metal foil on either side of the plastic sheet Emily would have to use in order to get the same capacitance as the camera flash (1.20×10^{-4} F).

(d) Emily experiments with two capacitors by pre-charging them and then connecting them in parallel.

She takes the 1.20×10^{-4} F capacitor and charges it to 50.0 V, and she takes a 1.00×10^{-4} F capacitor and charges it to 40.0 V. She then connects them in parallel such that the positive plates are connected together, as shown in the diagram below.



- Describe the direction of motion of charge once the capacitors are connected together.
- By calculating the total charge, show that the common voltage that each capacitor has once equilibrium is reached is 45.5 V.
- Hence calculate the new charge on capacitor A once equilibrium has been reached.

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

QUESTION NUMBER

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