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Level 3 Physics 2022

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.

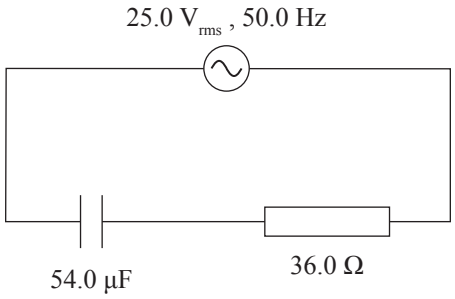
Check that this booklet has pages 2 – 8 in the correct order and that none of these pages is blank.

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: AC CIRCUITS

George is investigating AC circuits. He connects a 54.0 μF (54.0×10^{-6} F) capacitor in series with a 36.0 Ω resistor and a 25.0 V_{rms}, 50.0 Hz AC supply, as shown in the diagram below.

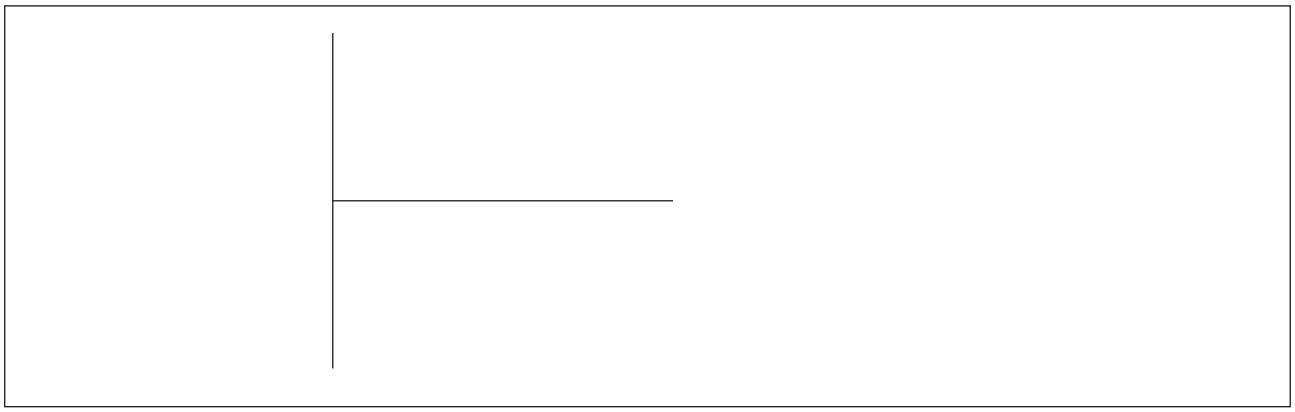


(a) Show that the reactance of the capacitor is 58.9 Ω.

(b) Calculate the circuit current.

(c) Calculate the phase difference between the supply voltage and the circuit current for the circuit shown on page 2. State which one leads.

You may draw a phasor diagram in the space below.



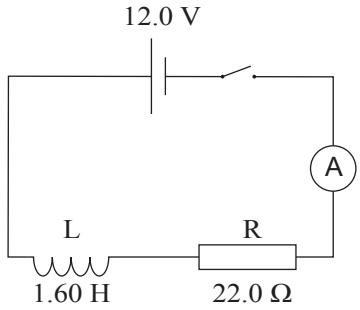
(d) Explain how the addition of a suitable inductor to the resistor-capacitor circuit with the AC supply, can make the circuit resonate.

Begin your answer by explaining the meaning of resonance in a circuit.

QUESTION TWO: ELECTROMAGNETISM

David is investigating inductors and magnets.

He uses a 1.60 H, 22.0 Ω inductor, and connects it to a 12.0 V power supply. The inductor can be considered as a pure inductor in series with a resistor, as shown in the diagram below.



(a) Calculate the circuit current **after two time constants**, once the switch is closed and current begins to flow.

(b) State the voltage across the pure inductor and the voltage across the resistor once the current is steady.

Voltage across the pure inductor = _____

Voltage across the resistor = _____

(c) Once the current has reached a steady value, the switch is opened, and current falls to zero in 2.50×10^{-2} s.

Calculate the size of the average induced voltage.

State the direction of the induced voltage across the inductor.

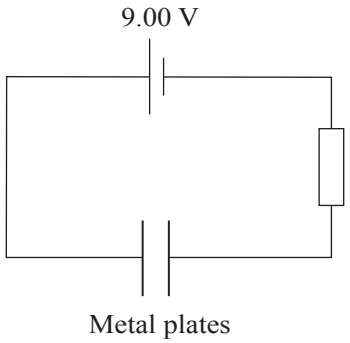
(d) The 22.0 Ω resistor is replaced with a 44.0 Ω resistor, and the switch is then closed.

Explain, by comparing quantitatively (how much), the changes that will take place for:

- the size of the maximum current drawn from the circuit
- the time constant
- the energy stored in the inductor once the current is steady.

QUESTION THREE: CAPACITORS IN DC CIRCUITS

Anne is carrying out some experiments using parallel metal plates to investigate capacitors. She takes a pair of metal plates with an area of 0.160 m^2 and connects them to a 9.00 V DC supply.



The plates of the air-filled capacitor ($\varepsilon_{air} = 1.00$), are separated by a distance of 1.00×10^{-3} m.

(a) Show that the capacitance of the capacitor is 1.42×10^{-9} F.

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

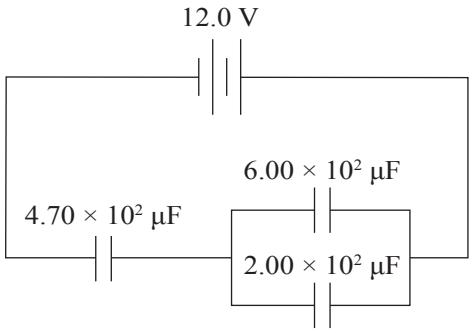
(ii) Describe the effect on the energy stored in the capacitor when a sheet of mica with relative permittivity of 7.00 is introduced between the capacitor plates.

(c) Anne then disconnects the plates from the 9.00 V DC supply, so that the plates are electrically isolated. She then pulls the plates apart.

Explain what would happen to:

- the charge on the plates
- the voltage across the plates.

(d) Anne then experiments with connecting some different capacitors, in series and in parallel, across a 12.0 V supply, as shown in the diagram below.



Calculate the voltage across the 4.70×10^2 μF capacitor.

Begin your answer by calculating the total capacitance.

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

QUESTION NUMBER