SUPERVISOR'S USE ONLY

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Draw a cross through the box (☒) if you have NOT written in this booklet

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NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Physics 2025

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 appropriate SI unit.

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.

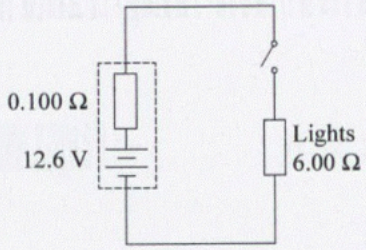
Do not write in the margins (⁄⁄⁄). This area will be cut off when the booklet is marked.

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

Achievement TOTAL 10

QUESTION ONE: DC CIRCUITS

Mereana has a caravan, which has a simple battery-powered circuit for the lighting with a total resistance of 6.00 Ω. The battery has an EMF of 12.6 V, and an internal resistance of 0.100 Ω.



(a) When the switch is closed, the current from the battery is 2.07 A.

Show that the terminal voltage of the battery is 12.4 V.

$V = IR$

$V = 2.07 \times 6$

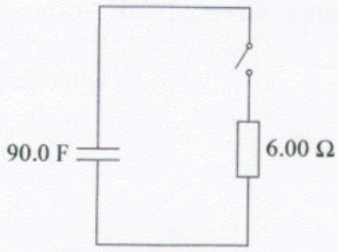
$V = 12.4\,V$

(b) As the battery is used over time, its internal resistance will increase.

Explain the effect that this will have on the terminal voltage of the battery.

the terminal voltage of the batery is not effected by the internal resistance of the battery only of the circuit.

(c) Mereana is investigating using a capacitor to power her caravan. The capacitor has a capacitance of 90.0 F, and is fully charged by connecting it to a 4.20 V battery. Mereana discharges the capacitor for 2500 s through a 6.00 Ω resistor to model the caravan circuit.

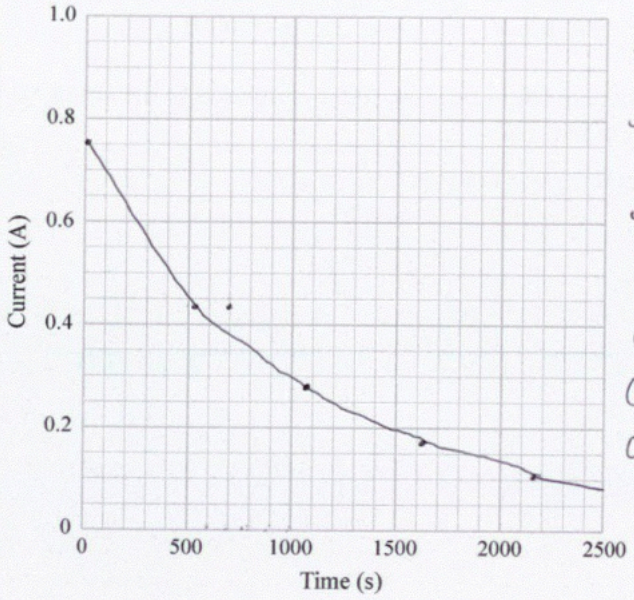


(i) Sketch a graph of current against time for 2500 s after the switch is closed.

Your graph should include the initial current and the final current after one time constant.

Show all calculations clearly.

If you need to redraw your response, use the diagram on page 10.



Space for calculations

$V = IR \quad I = V/R \quad I = 4.2/6 = 0.7\,A$

$\tau = RC \quad \tau_4 = 42160$

$= 6 \times 90 \quad \tau_3 = 1620$

$\tau_1 = 540 \quad \tau_2 = 1080$

$0.7 \times 0.63 = 0.441$

$0.441 \times 0.63 = 0.278$

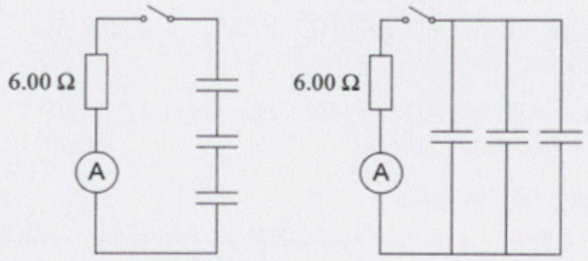
$0.278 \times 0.63 = 0.175$

$0.175 \times 0.63 = 0.110$

(ii) Explain, using physics principles, why the graph has the shape you have drawn.

The graph has the shape drawn because every time constant (τ) the current decreases by 37% to 63% of its previous current.

(d) Mereana fully charges six 90.0 F capacitors individually with the 4.20 V battery. She connects three of them in series with an ammeter and a 6.00 Ω resistor (Circuit A), and three of them in parallel to an ammeter and a 6.00 Ω resistor (Circuit B), as shown below. Each circuit has its switch closed and the capacitors are discharged.



Circuit A Circuit B

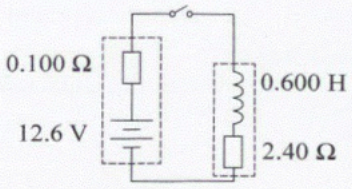
For each circuit, explain how the current varies over time compared to the single capacitor in series with a 6.00 Ω resistor, as in part (c).

You may use calculations to support your answer.

with circuit A because the capacitors are in series the total capacitince will be much lower than the capacitors in parallel. This means that series A will have a much smaller time constant as $\tau = RC$ and smaller τ means smaller τ with the same R like we have. This means that circuit A will also hold less charge and discharge it much faster than circuit B.

QUESTION TWO: INDUCTORS

Mereana finds an old coil and connects it to her caravan battery.
The corresponding circuit diagram is shown. The coil can be modelled as an inductor with an inductance of 0.600 H, and a resistor with a resistance of 2.40 Ω.



(a) State the size of the induced EMF across the inductor when the switch is first closed.

when the switch is first closed there is no induced emf as time = 0

(b) Calculate the size of the induced EMF across the inductor 0.240 s after the switch is closed.

$t = 0.24$ s $L = 0.6$ H $r = 2.4\ \Omega$ $V = 12.6$ V

$\varepsilon = -L\frac{\Delta I}{\Delta t}$ $V = IR$

$\varepsilon = -0.6 \times \frac{5.25}{0.24}$ $I = V/R = 12.6/2.4$

$\varepsilon = -13.125$ V $I = 5.25$ A

or 13.125 V in the opposite direction to normal flow of current

(c) When the switch is opened, a small spark is observed where the switch breaks the circuit.

Explain why the small spark is produced.

The small spark is produced because when the switch is opened there is a very large back emf which produces flux this ~~large~~ flux ignights in the air creating a small spark.

(d) Mereana knows that the maximum amount of energy is stored in an inductor when a steady current is flowing through it. She knows that if she replaces the inductor with the right capacitor, she can store an equal amount of energy.

Calculate the capacitance required to store this energy when the capacitor is fully charged by the 12.6 V battery.

$E = \frac{1}{2} L I^2$ $E = \frac{1}{2} Q V$ $Q = CV$

$E = \frac{1}{2} C V^2$

$\frac{1}{2} L I^2 = \frac{1}{2} C V^2$

$L I^2 = C V^2$

$(0.6)(5.45)^2 = C (12.6)^2$

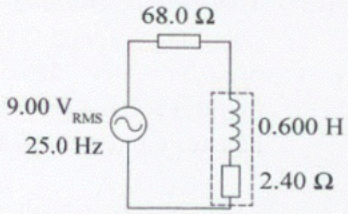
$17.8215 = C (158.76)$

$17.8215 / 158.76 = C$

$C = 0.112 F$

QUESTION THREE: AC INDUCTORS AND CAPACITORS

Mereana takes the coil back to school, and connects it to a variable frequency AC supply. The 0.600 H coil (modelled as an ideal inductor and a resistor) is now connected in series with a 68.0 Ω resistor to the supply, set to 25.0 Hz and 9.00 V_{RMS} as shown.



(a) Show that the reactance of the inductor is 94.2 Ω.

$X_L = \omega L \quad \omega = 2\pi f$

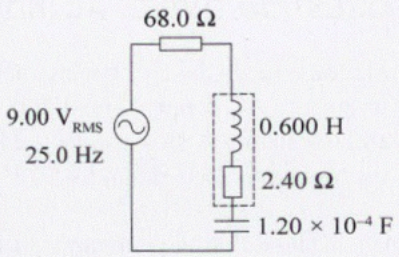
$X_L = 2\pi f L = (2\pi)(25)(0.6) = 94.2\,\Omega$

(b) Mereana notices that she can insert an iron nail inside the coil.

Explain what effect this would have on the RMS voltage across the 68.0 Ω resistor.

This would cause the RMS voltage to flow the opposite direction around the coil.

(c) The nail is then removed from the coil and a 1.20×10^{-4} F capacitor is added to the circuit in series with the coil and the 68.0 Ω resistor. Mereana reduces the frequency and notices that the voltage across the 68.0 Ω resistor increases and reaches a maximum value at a particular frequency.



Explain why the voltage across the 68.0 Ω resistor reaches a maximum value at one particular frequency.

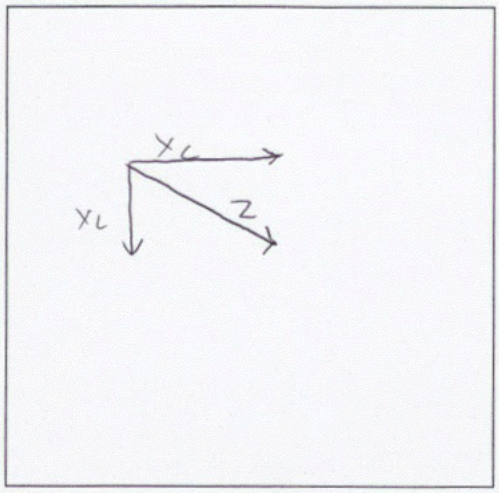
No calculations are required.

The voltage across the 68.0 Ω resistor reaches a maximum value at reasonant frequency this means that $X_L = X_C$ and this can only be achieved at on particular frequency (reasonance) this causes the voltage accross the resistor to reach maximum.

(d) The supply frequency of the circuit in part (c) is then further reduced.

Calculate the RMS current in the circuit when the frequency of the supply is 16.0 Hz.

A phasor diagram may assist your answer.



If you need to redraw your response, use the box on page 10.

$X_L = 2\pi f L$

$X_L = 2\pi(16)(0.6)$

$= 60.32$

$X_C = \frac{1}{\omega C}$

$X_C = \frac{1}{2\pi f C}$

$X_C = \frac{1}{2\pi(16)(1.2\times10^{-4})}$

$X_C = 82.89$

$Z = \sqrt{X_L^2 + X_C^2}$

$Z = \sqrt{60.32^2 + 82.89^2}$

$Z = 102.49$

$V_{RMS} = I_{RMS} Z$

$I_{RMS} = V_{RMS}/Z$

$= 9/102.49$

$I_{RMS} = 0.0878\ A$

Achievement

Subject: L3 Physics

Standard: 91526

Total score: 10

Q	Grade score	Marker commentary
One	4	(a) Correct use of current and external resistance to calculate terminal voltage. (c) A graph had been drawn using the correct initial current and time constant, but the current has been calculated incorrectly after one time constant. (d) The candidate has correctly compared the total capacitance, time constants and how current varies for the two circuits, but has omitted to compare the size of the original current in each circuit.
Two	3	(c) The candidate has stated that a large back emf will be produced, but has not explained why. (d) Correct method using energy equations to calculate the capacitance, but the candidate has used an incorrect current.
Three	3	(a) Correct formula and substitution for 'Show that' question. (c) The candidate has identified that the circuit is at resonance and that $X_L = X_C$, but has not stated that they are 180° out of phase and cancel out. (d) X_C and X_L have been correctly calculated, but the candidate has used an incorrect formula to calculate the impedance.