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Level 3 Physics, 2016

91526 Demonstrate understanding of electrical systems

2.00 p.m. Tuesday 15 November 2016
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.

Achievement

TOTAL 11

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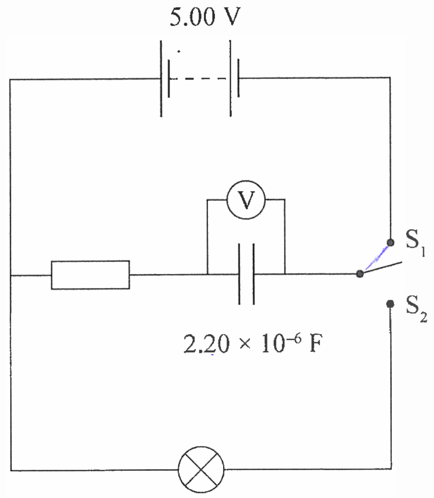
QUESTION ONE: CHARGING A CAPACITOR

Eleanor sets up a circuit to investigate how capacitors operate. The circuit is shown below. The circuit includes a 2.20×10^{-6} F capacitor and a double pole switch.



(a) Calculate the maximum charge stored by the capacitor in this circuit.

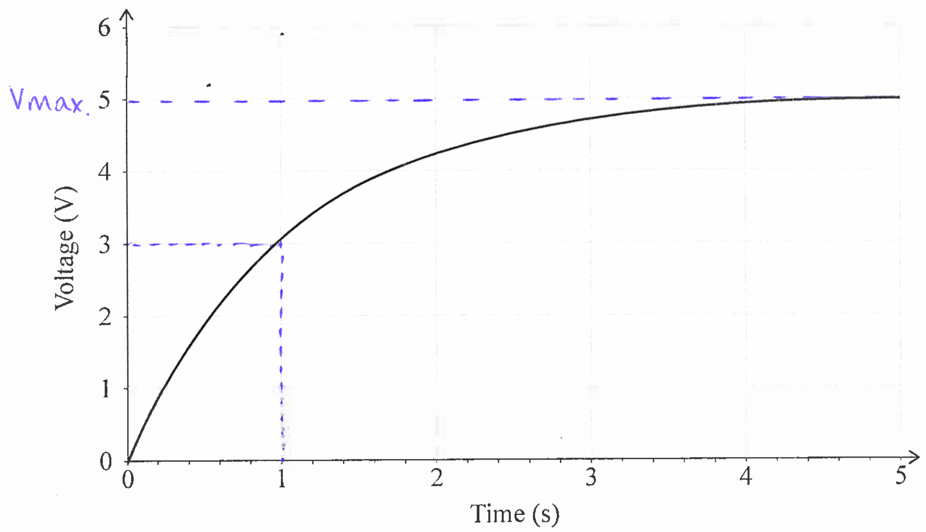
Q

$Q = CV$.

$= 2.20 \times 10^{-6} \times 5 = 1.1 \times 10^{-5}$ c

A

The capacitor is initially uncharged, and the switch is in the position shown. Eleanor moves the switch to S_1 and the capacitor charges up. A graph of the capacitor voltage against time is shown below.



(b) Use the graph to calculate the resistance of the resistor.

Draw lines on the graph to help explain your working.

~~[illegible]~~ $5 \times 0.63 = 3.15$ v at 3.15v, t = 1

$R = \frac{t}{C} = \frac{1}{2.20 \times 10^{-6}} = 4.5 \times 10^{5}\ \Omega$

M

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(c) Give a comprehensive explanation for the shape of the capacitor voltage graph.

Include the reasons for the starting voltage and the final voltage.

When the switch is open the circuit is incomplete and the voltage does not supply a current to the capacitor. and therefore when $t=0$, $V=0$. When the switch moves to S_1, a current flows in the circuit supplied from the source voltage. (initial voltage) Charge builds up in the capacitor as more voltage is supplied into the circuit ($Q=CV$). When the capacitor becomes charged current falls to zero and the voltage is at its maximum value (final voltage)

a

(d) Eleanor connects another 2.20×10^{-6} F capacitor in series with the original capacitor, and repeats the experiment.

Describe and explain how this affects:

- the final voltage across the original capacitor
- the time constant of the circuit.

The voltage now is now halved due to double the capacitance $V=\frac{Q}{C}$, $V \propto \frac{1}{C}$. This means that the time constant is doubled ($t=RC$) as it now takes more time to charge 63% of the capacitor

n

A4

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QUESTION TWO: THE TRANSFORMER

Transformers can be used to increase or decrease the size of an AC voltage. Wei has a transformer that is designed to convert 240 V into 12.0 V. $V_p = 240$

The secondary coil has 40 turns. $N_s = 40$ $V_s = 12$

(a) Calculate the number of turns on the primary coil.

$N_p = \frac{V_p}{V_s} \times N_s = \frac{240}{12} \times 40 = 800$ turns

a

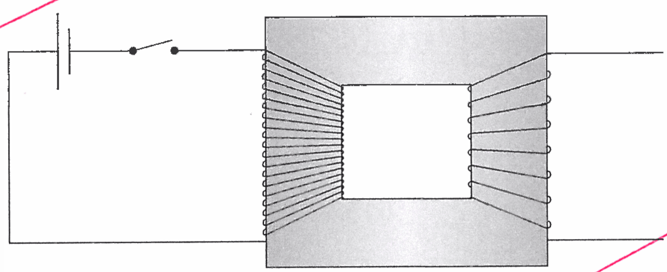
(b) Explain how an alternating voltage across the primary coil creates an alternating current in a light bulb connected to the secondary coil.

An alternating voltage will create an alternating current in the light bulb from the secondary coil due to Lenz law. Lenz law is when the current induced opposes the magnetic feild which changed it. The magnetic feild changed due to the alternating voltage (faradays law) will create a current in the opposite direction to which the alternating voltage created it and thus creating alternating current

na

Each coil of a transformer acts as an inductor.

A primary coil is attached to a battery and switch as shown in the diagram below. The switch is closed and then some time later the switch is opened.



(c) Sketch a graph showing how the current in the coil changes when the switch is closed and then some time later is opened.

Give a comprehensive explanation for the shape of your graph.

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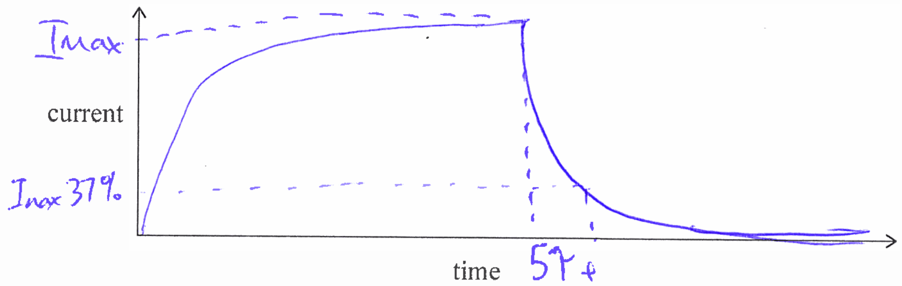

If you need to redraw your response, use the graph on page 8.

As the current increases in the coil, the inductor stores charge in its magnetic feild and creates an backwards emf due to the rate of current increasing $\varepsilon = -L\frac{\Delta I}{\Delta t}$. The current then reaches a stable state after 5 time constants before it is later discharging after 5 time constants or more. The 6th time constant will be 37% of Imax and so on until the current is zero in the inductor.

a

(d) Calculate the energy stored in the primary coil's magnetic field when the switch has been closed for several seconds.

E

battery voltage = 6.0 V V

resistance of primary coil = 35 Ω R

inductance of primary coil = 0.10 H L

$I = \frac{V}{R} = \frac{6}{35} = 0.17\,A$

$E = \frac{1}{2}LI^2 = \frac{1}{2} \times 0.10 \times 0.17^2$

$= 1.45 \times 10^{-3}\,J$

M

A4

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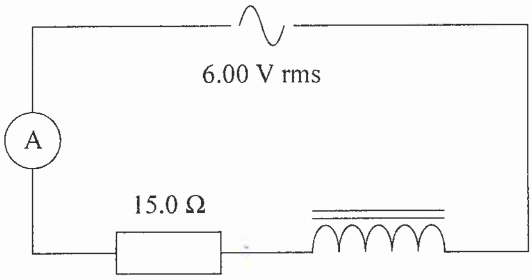
QUESTION THREE: MEASURING IRON IN SAND

Vivienne wants to measure the amount of iron in iron-sand mixtures collected from different beaches. The diagram below shows the circuit that she uses. The circuit includes a 500-turn coil with a resistance of 15.0 Ω, and an AC supply. N

R

The coil behaves like a resistor and an inductor in series.



The coil has a hollow core that is initially empty. Vivienne adjusts the power supply voltage to 6.00 V rms.

(a) Calculate the instantaneous maximum (peak) voltage across the power supply.

$V_{max} = \sqrt{2}\, V_{rms}$

$= \sqrt{2} \times 6 = 8.49\text{v}$

a

During testing, Vivienne puts a mixture of iron and sand inside the core of the coil.

(b) State what effect this has on the size of the coil's reactance.

With reference to impedance, explain what happens to the size of the current in the circuit as she adds the mixture of iron and sand.

Z

Iron has a high magnetic permiability which allows it to increase flux. An increase in flux would increase the current due to Faraday's Law and thus would decrease the size of the impedance $V = I Z$.

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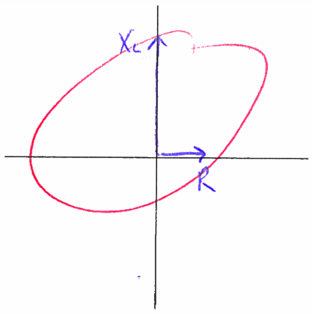
(c) When Vivienne sets the frequency of the current to 1.00×10^3 Hz, the inductance of the coil is 3.18×10^{-3} H.

f

L

Using a phasor diagram or otherwise, calculate the size of the rms current in the circuit.



$\omega = 2\pi f = 2\pi \times 1 \times 10^3 = 6283.19 \text{ rads}^{-1}$

$X_L = \omega L = 19.98$

a

(d) Vivenne adds a capacitor in series with the coil, and finds that the current increases.

Explain why the current increases.

Putting a capacitor in series with an inductor would decrease impedance, Z, due to the circuit being in resonance. This would therefore increase the current as $V = IZ$ and $Z = \sqrt{R^2 + (X_L - X_C)^2}$

a

A3