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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.

Merit

TOTAL 16

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QUESTION ONE: CHARGING A CAPACITOR

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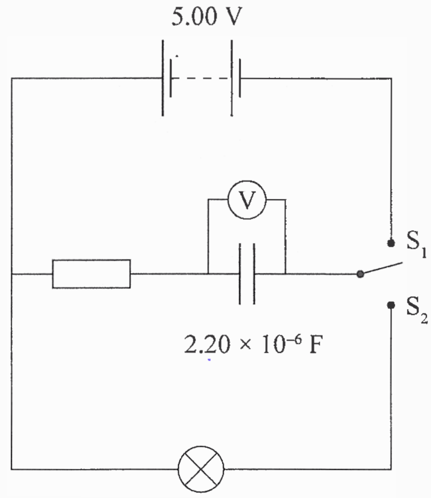
Eleanor sets up a circuit to investigate how capacitors operate. The circuit is shown below. The circuit includes a 2.20×10^{-6} F capacitor and a double pole switch.



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

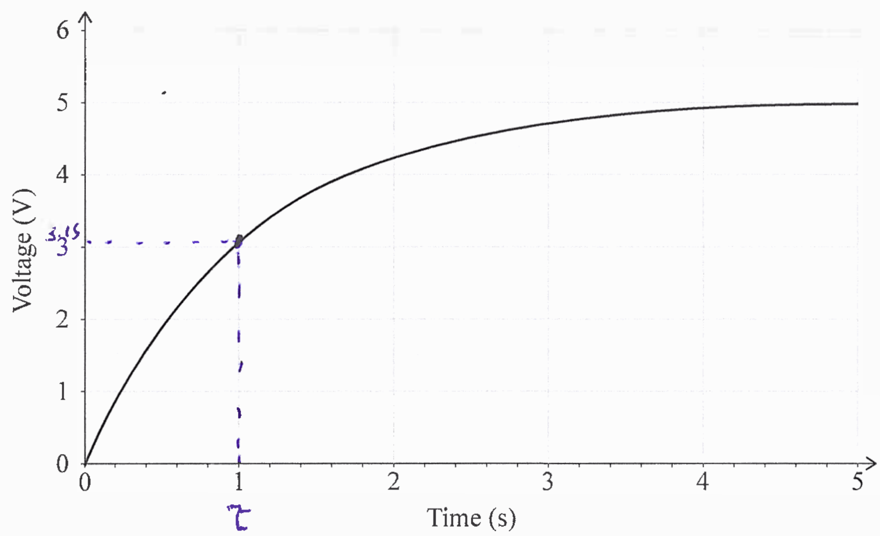
$Q = CV$

$= 2.2 \times 10^{-6} \times 5$

$= 1.1 \times 10^{-5}$ 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.

$\tau = 1$

$\tau = RC$

$R = \tau / C$

$= 1 / 2.2 \times 10^{-6}$

$R = 455000\ \Omega$ (3sf)

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 t = 0 there is no charge stored in the capacitor ~~be~~ meaning there is a voltage of 0. As time passes after the switch is turned on more electrons travel from one plate to the other but since the -ve charged plate ~~at~~ starts to gain electrons the electrons in the circuit slow down, slowing the increase in volts.
The capacitor cant gain the original 5 V meaning the graph ~~is at a tangent to always~~ gets close to 5 V but never touches it. We consider 5 τ to be effectivally fully charged.

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.

This acts as empty space

since $C \propto 1/d$ by adding a second capacitor in series it increases ~~the~~ d, thus decreasing C. since $\tau = RC$ if C were to decrease the time constant would decrease as well.
Also $V = Q/C$ so if C would decrease then V would increase if Q remained the same.

a

M5

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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.

The secondary coil has 40 turns.

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

$\frac{N_p}{N_s} = \frac{V_p}{V_s}$ $N_p = \frac{N_s V_p}{V_s}$

$= \frac{40 \times 240}{12}$

$= 800$ turns

a

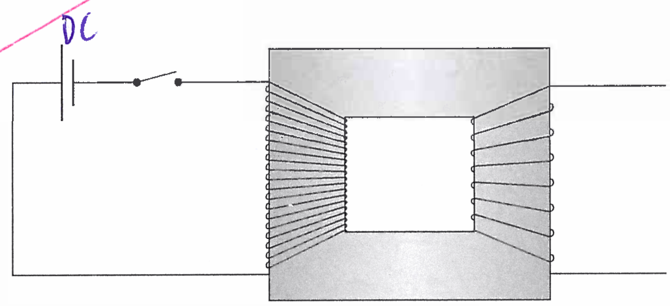
(b) Explain how an alternating voltage across the primary coil creates an alternating current in a light bulb connected to the secondary coil.

An alternating voltage across the primary coil means there is an alternating current as well. The alternating current ~~induced~~ induces a ~~change~~ current to the transformer by changing the magnetic field. The ~~cu~~ alternating current in the transformer then induces an AC in the secondary wire through the light bulb.

A

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.



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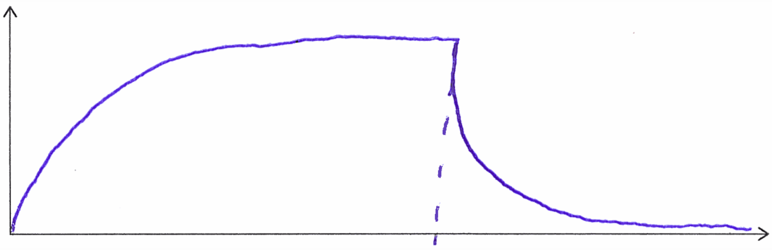
(c) Sketch a graph showing how the current in the coil changes when the switch is closed and then some time later is opened.

Give a comprehensive explanation for the shape of your graph.

current



time

Opening the switch.

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

When the switch is closed ~~the transtor~~ a current flows through the coils. The inductor resists the change in current as a back emf, $\varepsilon = -L\frac{\Delta I}{\Delta t}$. As ΔI is +ve then a $-\varepsilon$ is produced. When the switch is opened the inductor resists the decrease in ΔI by creating an ε to keep the circuit running.

R

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

battery voltage = 6.0 V

resistance of primary coil = 35 Ω

inductance of primary coil = 0.10 H

$I = V/R$
$= 6/35$
$= 0.171\text{ A (3sf)}$

$E = \frac{1}{2} L I^2$
$= \frac{1}{2} \times 0.1 \times (0.171)^2$
$= 1.47\text{ J (3sf)}$

M

M5

QUESTION THREE: MEASURING IRON IN SAND

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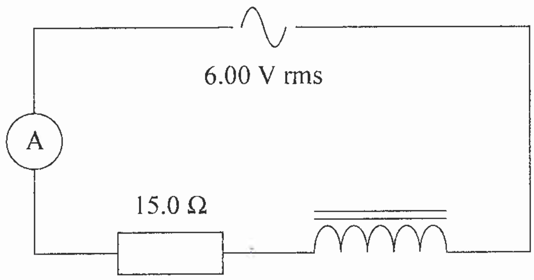
Vivienne wants to measure the amount of iron in iron-sand mixtures collected from different beaches. The diagram below shows the circuit that she uses. The circuit includes a 500-turn coil with a resistance of 15.0 Ω, and an AC supply.

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.

$V_{max} = \sqrt{2}\, V_{rms}$
$= \sqrt{2} \times 6$
$= 8.49$ V. (3sf)

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.

The iron sand acts like a core meaning L would increase. since $X_L = \omega L$ the increase in L also increases X_L. Impedance, $Z = \sqrt{X_L^2 + R^2}$ so an increase in X_L increases impedance, Z. As $I = V/Z$ if Z increases, current must decrease

m

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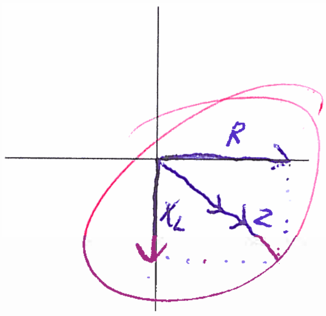
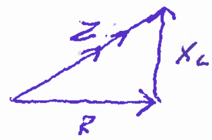
(c) When Vivienne sets the frequency of the current to 1.00×10^3 Hz, the inductance of the coil is 3.18×10^{-3} H.

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





$Z = \cancel{\sqrt{X_L^2 + R^2}}$
$= \sqrt{}$

$\omega = 2\pi f$
$= 2\pi \times 1000$
$= 6283 \text{ rad s}^{-1}$ (4sf)

$X_L = \omega L$
$= 6283 \times 3.18 \times 10^{-3}$
$= 20.0\ \Omega$ (3sf)

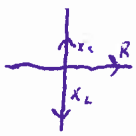
$Z = \sqrt{X_L^2 + R^2}$
$= \sqrt{20^2 + 15^2}$
$= 25.0\ \Omega$ (3sf)

$I_{rms} = V_{rms}/Z$
$= 6/25$
$= 0.240$ A (3sf)

M

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

Explain why the current increases.



The capacitor would cancel out some of the inductors impedance meaning Z would decrease. As $I = V/Z$ if Z decreases then I increases.

M

M6