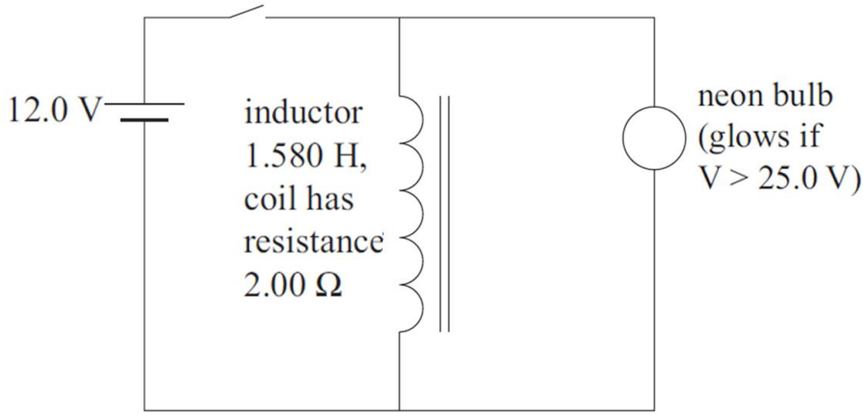
ELECTRICITY: DC INDUCTORS QUESTIONS

PORTABLE POWER (2010;1)

(c) Another group of students wants to understand how a 12.0 V battery can be used in a circuit to produce a high enough voltage to light a 25.0 V neon bulb. They are shown the circuit below.



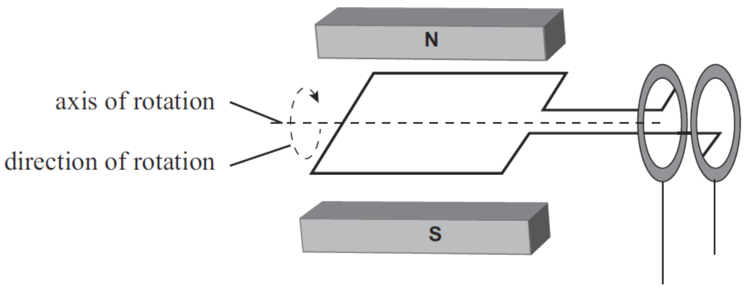
The instructions tell them to close the switch, slowly count to ten and then open the switch. The students see that the neon bulb flashes when they switch **off** the circuit.

(i) Explain why the bulb only lights when the circuit is switched off.

(ii) Explain why the students have to count to ten before turning off.

GENERATORS (2010;1)

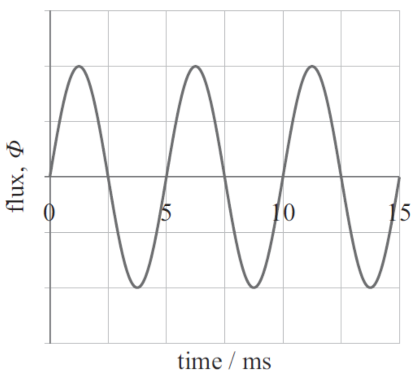
The diagram below shows a coil turning in a uniform magnetic field, working as an AC generator.



coil area = 0.015 m^2

B = 0.35 T

number of turns = 500

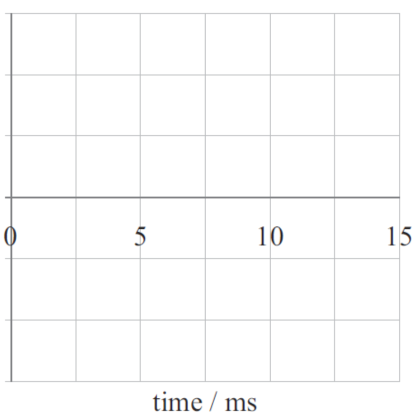


(a) Calculate the maximum flux cutting a single loop of the coil as it rotates.

(b) Given that $V_{max} = \Phi_{max} N \omega$ (where N is the number of turns), calculate the rms voltage produced when the coil is rotated at 220 radians per second.

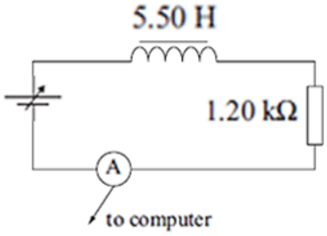
(c) When the coil turns at a steady speed, the flux cutting the coil varies as shown in the graph. (1 ms = 1 × 10^{-3} s). Describe and explain how the induced voltage will vary with time. You may use words, equations and / or sketches on the adjacent graph to explain your answer.

(d) The coil is made to rotate faster. Explain how this will affect the output voltage. You may use words, equations and / or sketches on the adjacent grid to explain your answer.

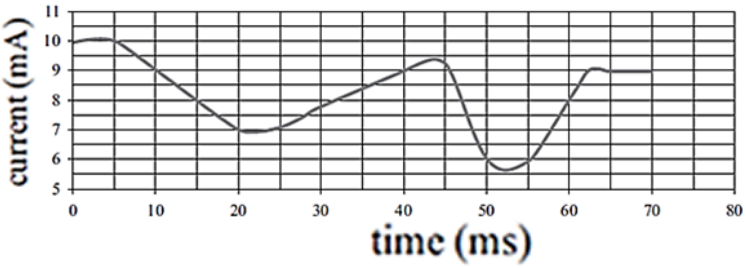


INDUCTOR PROPERTIES (2009;2)

Lafi builds a simple inductor circuit, as illustrated. She uses a computer data logger to continuously monitor the current in the circuit. The resistance of the inductor wiring is negligible.



Lafi changes the voltage of the supply and this makes the current vary as shown.



(a) For most of the time, even though the resistance of the inductor is effectively zero, there is a voltage across it. Explain why.

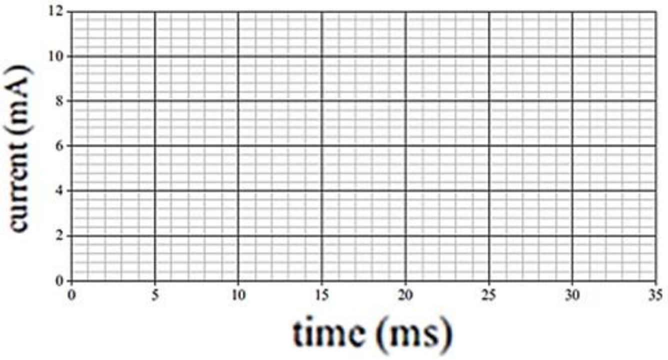
(b) Between t = 10.0 ms and t=15.0 ms, the current can be considered to be dropping at a steady rate from 9.00 mA to 8.00 mA.

  (i) Show that the size of the voltage induced across the inductor during this time period is 1.10 V.

  (ii) Describe and explain the direction of the induced voltage.

(c) At one moment, while Lafi is changing the current, the supply voltage is 11.5 V and the current is 7.75 mA. Calculate the rate of change of current that could cause these readings.

(d) Lafi then swaps her power supply for a 12 V D.C. battery. By calculating appropriate values, sketch a graph to accurately describe the change in current when she switches on the circuit.



TORCH INVESTIGATION (2008;1)

Jess is investigating a torch to find out the characteristics of the battery and the lamp. The torch uses a filament lamp. The filament is a long coil of fine wire that heats up and glows when it carries sufficient current. For the purposes of calculation, assume that the resistance of the filament remains constant. Jess measures the battery voltage when the lamp is switched off and finds the voltage to be 6.12 V. When Jess switches on the lamp, the voltage drops to 5.87 V. The current through the lamp is then 0.743 A.

Jess suggests that it could take a few milliseconds for the lamp to reach full brightness when it is switched on, and that the lamp's filament coil could be acting as an inductor.

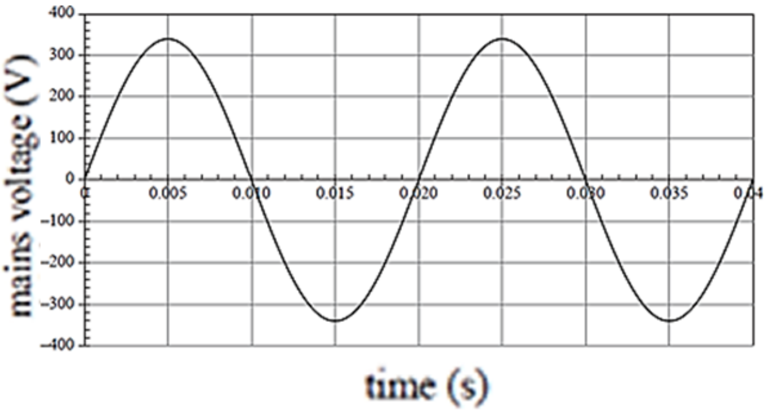
(a) Assuming the time constant for the filament is 1.2 ms calculate the inductance of the filament coil. Give your answer to the correct number of significant figures.

(b) Inductance can be defined from the equation

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

Use this definition to explain why an inductor would delay a bulb reaching full brightness after it is switched on.

The lamp is connected to an AC supply from a transformer. The supply for the transformer is a 50 Hz mains supply, with a peak voltage of 340 V. The graph below shows the variation of the mains supply with time.

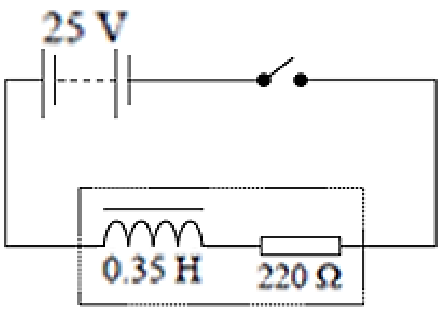


Use the graph to show that the maximum rate of change of voltage in the primary coil of the transformer is approximately 100×10^{3} Vs^{-1}.

(c) The output of the transformer from the secondary coil is labelled "6 V AC". The lamp connected to this output appears to light with the same brightness as it did when it was connected to the battery. Explain whether the 6 V from the secondary coil of the transformer output is a peak value or an r.m.s value.

(d) The current in the primary coil changes at a maximum rate of 8.7 A s^{-1}. Calculate the mutual inductance of the transformer.

SNUBBER SWITCH (2006;2)



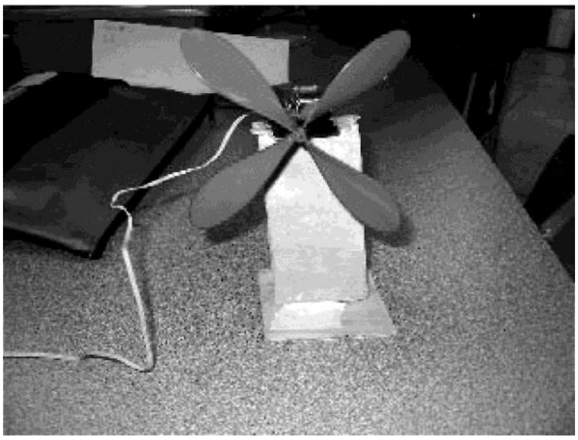
In the circuit shown above, a power supply of 25V is connected to an inductor with inductance 0.35 H and resistance of 220 Ω. The switch is closed, and after a time of 8.0×10^{-3} s, the circuit current has reached a value that is sufficiently close to the steady current value for any difference to be ignored.

(a) Show that the average voltage induced in the inductor during this time period is 5.0 V.

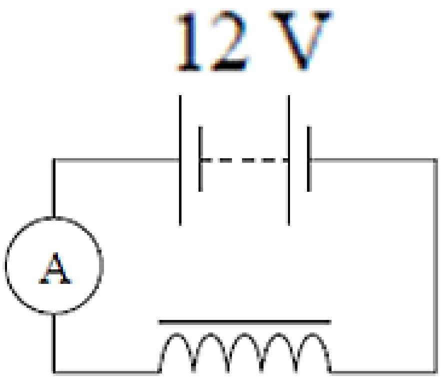
(b) Calculate the flux in the coil after this time period.

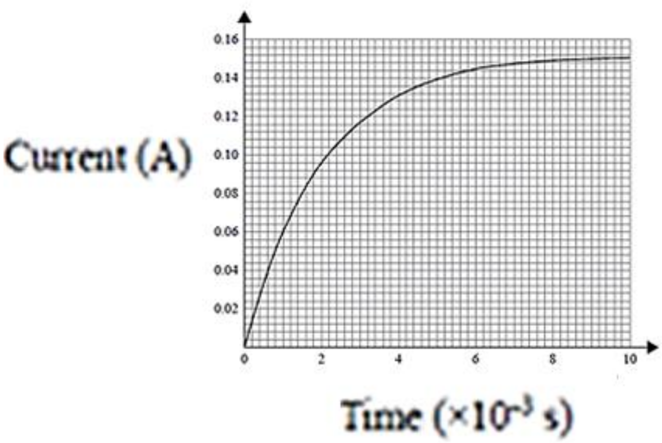
(c) Explain why, when the switch is opened, the maximum induced voltage will be much larger than when the switch is closed.

WIND POWER (2005;2)



Jill is making a model wind turbine. It includes a generator constructed from a strong horseshoe magnet and a coil of wire, with 500 turns.
Jill decides to investigate the electrical properties of the coil of wire by connecting it in the circuit shown. She finds that the current takes some time to reach a steady value. A graph of the increase in current against time is also shown.





When the current is steady the ammeter gives a reading of 0.152 A.

(a) Calculate the resistance of the coil. Give your answer to the correct number of significant figures.

(b) Explain why the ammeter took some time to reach a steady reading.

(c) Calculate the self-inductance of the coil.

THE 'COIL' (2004;3)

In the engine of a car the 'coil' is the device that generates the high voltage required to create the spark that ignites the petrol vapour.
The 'coil' is essentially made up of two coils of wire. One coil is called the primary coil. Wrapped around it is the secondary coil. The secondary coil normally has hundreds of times more turns of wire than the primary coil.

The diagram below shows a simplified view of this arrangement of coils.

Current from the battery flows through the primary coil. When the circuit is suddenly broken, the magnetic field in the primary coil, and hence also in the secondary coil, collapses (falls rapidly). The mutual induction that takes place between the two coils produces the high voltage needed to create a spark.
Describe what is meant by mutual induction.

In questions (b) to (g), assume that the secondary coil is not connected so the primary coil experiences self-induction only.

In Jessie's car, the primary coil has 150 turns, cross-sectional area of 2.00×10^{-3} m^2, and resistance 0.750 Ω. The magnetic field in the primary coil, when it is connected to the 12 V battery, is 4.20×10^2 T.

(a) Calculate the flux in the primary coil when it is connected to the battery.

When the circuit is broken, there is an average voltage of 85.0 V across the primary coil.

(b) Explain why there is a voltage across the primary coil when the circuit is broken.

(c) Show that the time it takes the flux in the primary coil to collapse is 1.48×10^{-4} s.

(d) Show that the self-inductance of the primary coil is 7.9×10^{-4} H.

(e) (i) Calculate the time constant for the primary circuit when it is completed.
(ii) Justify the number of significant figures to which you have rounded your answer.

(g) Explain why the time taken for the current to build in the primary coil, when the circuit is completed, is longer than the time taken to fall when the circuit is broken.

When the secondary coil is connected, mutual induction takes place, and there is a maximum voltage of 410 V across the primary coil.

(h) Calculate the maximum voltage induced across the secondary coil.