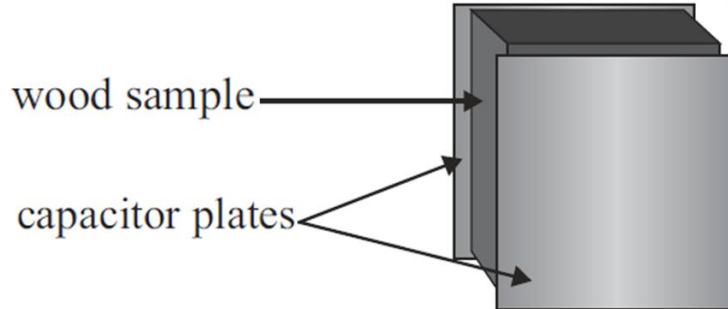


ELECTRICITY: AC QUESTIONS

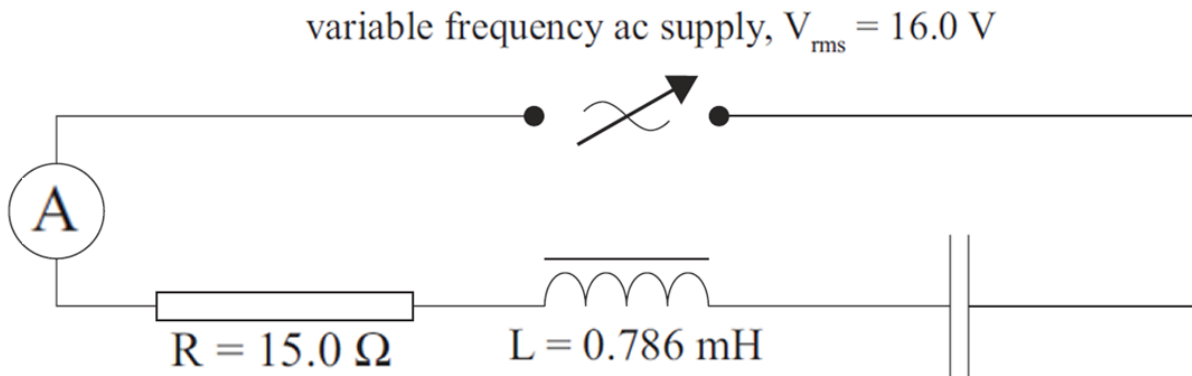
CAPACITANCE MOISTURE METER (2010;2)

The moisture content of wood can be tested by measuring capacitance. A simple moisture meter is based on two parallel metal plates. The test sample fits between the plates.



A museum wants to develop a circuit that will be much more sensitive to change in moisture content. To this end, the capacitor is included as part of an LCR circuit.

Sensitive detector unit



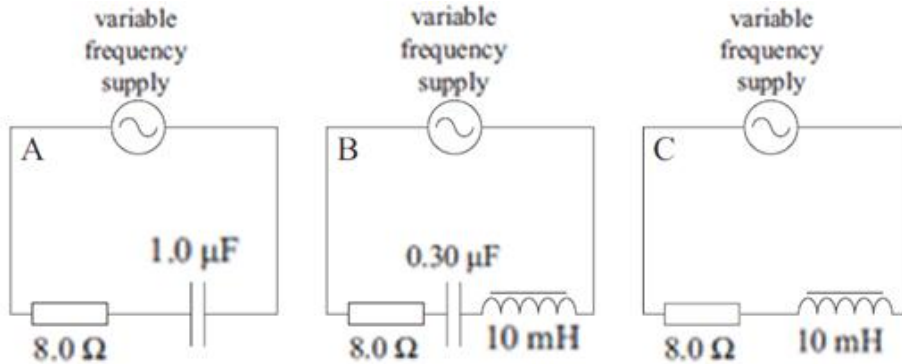
- (c) Show that the resonant frequency of the circuit depends on L and C according to the equation:

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

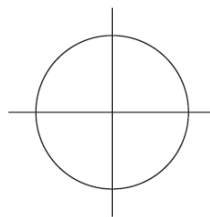
- (d) A wood sample is placed between the capacitor plates. Describe how you could find the resonant frequency of the circuit as you varied the frequency of the AC supply.
- (e) Wood with a moisture content of 15% has an ϵ_r of 16.8. Show that an AC supply set at $1.00 \times 10^6 \text{ Hz}$ will bring the circuit to resonance for a sample of wood with this moisture content.
- (f) The moisture content of the wood sample rises such that its relative permittivity increases to 16.9. The AC supply remains unchanged at $1.00 \times 10^6 \text{ Hz}$. Show that you would expect the ammeter to read approximately 0.5 A.
- (g) In the above example, the relative permittivity of the wood increases from 16.8 to 16.9. Compare the observed change this causes on the simple moisture meter with that on the sensitive detector, to show that the second circuit is more sensitive.

MODELLING SPEAKERS (2009;1)

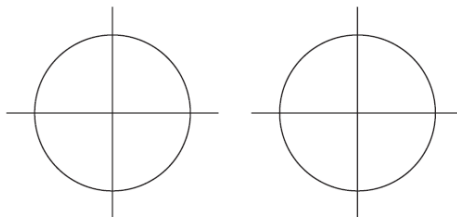
In a stereo sound system the sound is produced by speakers. Some stereo systems have three types of speaker. To model these speakers, Derek builds several circuits to study how the current varies with frequency. He uses an 8.0Ω resistor instead of a speaker. In all his experiments the voltage of the power supply remains constant.



- (a) Calculate the reactance of the capacitor in circuit A when the frequency is 2.00×10^2 Hz.
- (b) Describe and explain how increasing the frequency of the supply will affect the current in circuit A.
- (c) Which circuit will produce the largest current when connected to a very low frequency (0.10 Hz) signal? Explain your reasoning.
- (d) Calculate the frequency at which the current generated in circuit A is the same as the current in circuit C (The voltage of the supply is the same in both cases). Explain your reasoning clearly.
- (e) In circuit B there is one frequency, 2.9 kHz, at which the supply voltage is in phase with the current.
 - (i) Draw a phasor diagram to show the relationship between the voltages across the resistor, capacitor and inductor.

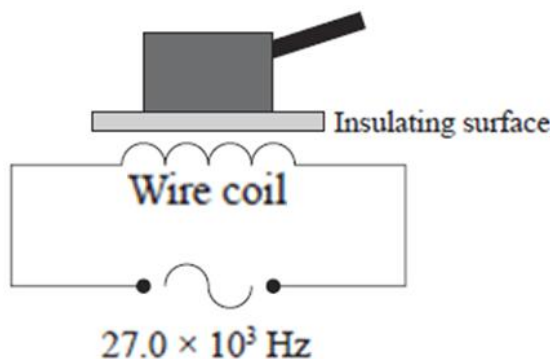


- (ii) Explain how the phase difference between the current and the supply voltage will change as the supply frequency is increased from 100 Hz to 10 kHz. Use phasor diagrams to illustrate your answer.



THE INDUCTION COOKER (2008;2)

Sam has an induction cooker and wants to find out how it works. After doing some research, Sam finds that it operates by having a coil of wire underneath an insulating surface. A high frequency alternating current is passed through the coil with a frequency of $27.0 \times 10^3 \text{ Hz}$.

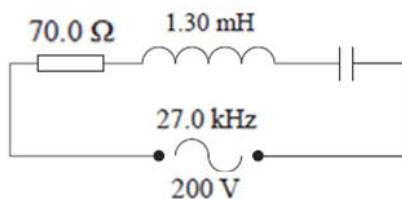


- (a) The arrangement can be used to generate heat within a metal pan placed above the coil. Explain how this occurs.

The coil used in a particular induction cooker is found to have an inductance of 1.30 mH .

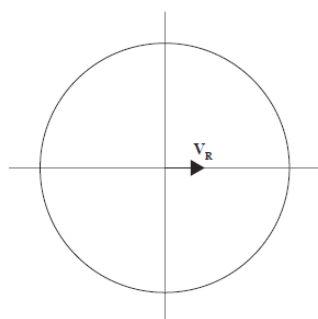
- (b) Show that when the frequency of the alternating current is $27.0 \times 10^3 \text{ Hz}$, the reactance of the coil is 221Ω .

In reality the inductor is part of an LCR circuit as shown below. The resistor has a resistance of 70.0Ω and the capacitor has a reactance of 358Ω at $27.0 \times 10^3 \text{ Hz}$.



- (c) Show that the capacitance of the capacitor is $1.65 \times 10^{-8} \text{ F}$.

The phasor diagram below shows the phasor representing the resistor voltage.

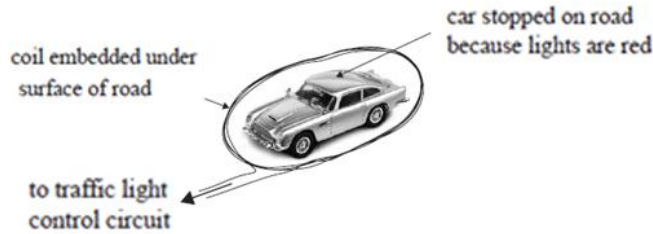


- (d) On the phasor diagram sketch the phasors representing:
- the capacitor voltage
 - the inductor voltage
 - the supply voltage.
- (Distances and angles should show the approximate relative size and direction of each phasor.)
- (e) Calculate the r.m.s current flowing in this LCR circuit if the r.m.s value of the supply voltage is 200 V .
- (f) Placing an iron saucepan on the hob increases the heating effect of the coil. Explain how an iron cooking pan close to the coil alters the inductance of the coil.
- (g) The iron saucepan has the effect of bringing the circuit to its resonance condition. Describe the condition for resonance in an AC circuit.

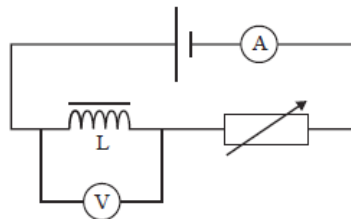
(h) Calculate the r.m.s current in the circuit at resonance.

INDUCTORS AND AC CIRCUITS (2007;2)

Traffic lights can be controlled by using an inductive loop to detect the presence of a car on the road. The loop is a large coil of wire embedded under the road surface. When a car stops over the loop, the inductance of the loop changes. This is sensed by an electrical circuit that causes the traffic lights to change from red to green.



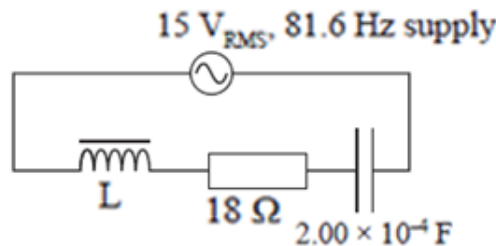
The inductance of the coil of wire must be measured. A possible way of doing this is to use a circuit like the one below. The inductor, L , in the circuit models the coil of wire under the road.



The resistance of the rheostat is changed so that the current in the circuit drops steadily from its maximum value of 1.62 A to 0.13 A in 1.2 s. While the current is dropping, the voltmeter reads 4.0 mV.

- (a) Explain why there is a voltage across the inductor.
- (b) Calculate the inductance of the inductor.

The inductor is now connected into the circuit below to model the traffic light control circuit.



- (c) In the space below draw and label phasors to show the voltages across the inductor, the capacitor and the resistor.



- (d) If the reactance, X_L , of the inductor is smaller than the reactance, X_C , of the capacitor, would the supply voltage phasor lead or lag the current phasor? Explain your answer.
- (e) The frequency of the supply is 81.6 Hz. Calculate the angular frequency of the supply.
- (f) Show that the reactance of the capacitor is 9.75 Ω .
- (g) If the reactance of the inductor is 1.65 Ω , calculate the current in the circuit.

When a car stops on the road above the coil, the inductance of the coil increases causing the circuit to approach resonance.

- (h) Why does the inductance increase when a car is standing above the coil?
- (i) Explain how this increase in inductance will change the current in the circuit.
- (j) Calculate the value of the current in the circuit at resonance.
- (k) Calculate the inductance of the inductor that would bring the circuit to resonance.

Assuming the energy lost from the resistor is small enough to be ignored, the energy stored in the circuit oscillates between being totally stored in the capacitor and being totally stored in the inductor.

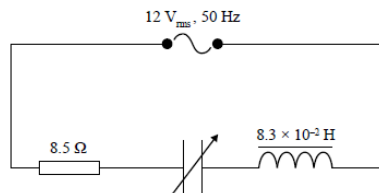
- (l) Calculate the maximum energy stored in the capacitor at resonance.
- (m) On the axes below, sketch graphs to show how the energy stored in the capacitor and the energy stored in the inductor change for one complete period of the alternating voltage. Label each graph line.

Assume the capacitor is fully charged at $t = 0$. Show one non-zero value on the time axis. Ignore the energy loss from the resistor.



REED SWITCH (2006;3)

A reed switch is operated by a changing magnetic field. One way to change the magnetic field is to change the current in an inductor. This could be done using the circuit below. In the circuit below, the 12 V supply has a frequency of 5.0×10^1 Hz.



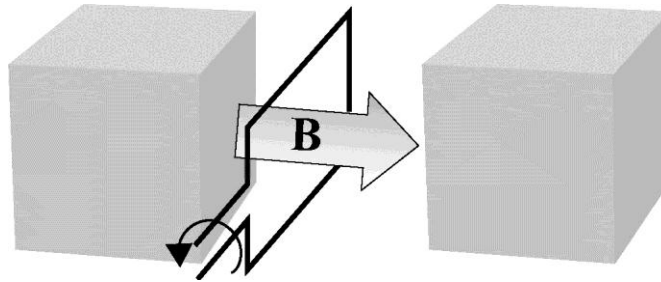
- (a) Calculate the angular frequency of the supply.
- (b) Show that the reactance of the inductor is 26Ω
- (c) The current in the circuit is 0.42 A. Calculate the reactance of the capacitor.
- (d) Explain how changing the capacitance of the capacitor affects the current in the circuit.
- (e) Calculate the current in the circuit at resonance.

WIND POWER (2005;2)



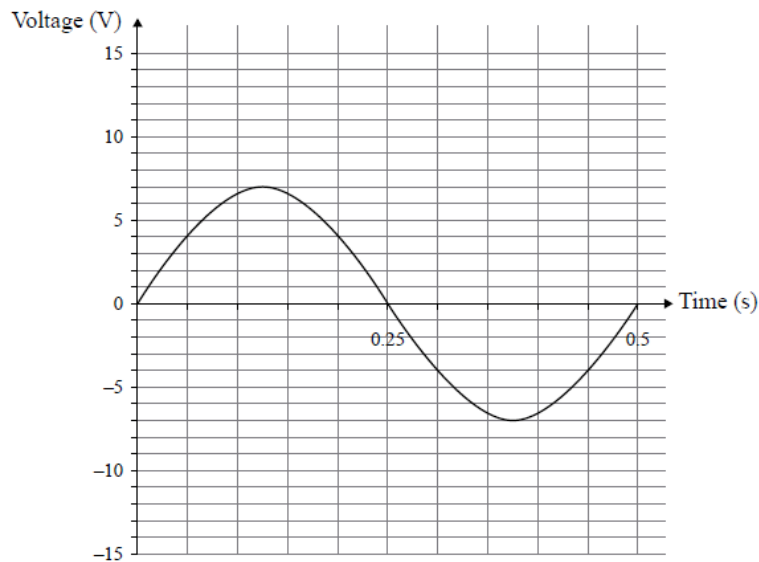
Jill is making a model wind turbine. It includes a generator constructed from a strong horseshoe magnet and a coil of wire, with 500 turns.

The poles of the horseshoe magnet produce a uniform magnetic field with a magnetic flux density of 0.21 T. The coil has an area of $5.20 \times 10^{-3} \text{ m}^2$, and, on a windy day, completes 2.0 rotations per second.



- Calculate the maximum magnetic flux through the coil.
- Calculate the average voltage induced in the coil when the coil rotates from a position of maximum flux to the first position of zero flux.

The graph below shows how the voltage induced in the coil changes with time when the coil completes 2.0 rotations per second.



On a particularly windy day, one gust of wind doubles the rate of rotation of the coil.

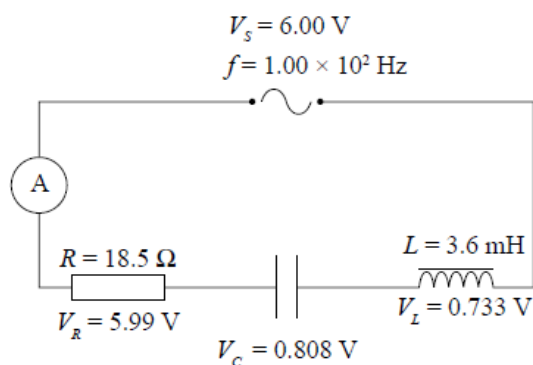
- On the same axes, above, sketch the shape of the voltage against time graph when the rate of rotation of the coil has doubled.

SECURITY SYSTEM (2005;3)

As part of the security measures at a political meeting, a portable metal detector has been installed. The detector includes an AC supply, producing an r.m.s voltage of 6.00 V at a frequency of 100 Hz.

- Calculate the peak voltage of the AC supply.

The AC supply is connected in series with an ammeter, resistor, capacitor and inductor, as shown in the diagram (all voltages are r.m.s values).



- (b) Explain why the numerical values of V_R , V_C and V_L in the diagram do not add up to the numerical value of the supply voltage.
- (c) Show that the ammeter reading in the circuit is 324 mA.
- (d) Show that the capacitance of the capacitor is $638 \times 10^{-6} \text{ F}$.
- (e) State the mathematical condition for resonance, and use it to show that the resonant frequency of this circuit is 105 Hz.

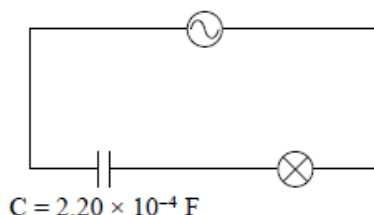
The main frame of the detector is the inductor in the circuit. When someone walks through the detector they are, temporarily, the core of the inductor.

- (f) Knowing that the resonant frequency is slightly higher than the supply frequency, explain how the reading on the ammeter would show that there was metal in the person's pocket.

AC CIRCUITS (2004;2)

Ana and Craig were investigating AC circuits. They constructed an AC circuit with a lamp and capacitor in series as shown below.

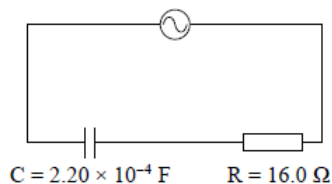
Supply voltage = 12.0 V rms, 50.0 Hz



- (a) Explain why the capacitor in this AC circuit allows the lamp to glow continuously, but would not do so if connected into a DC circuit.

The students replaced the lamp with a resistor of resistance 16.0 Ω as shown.

Supply voltage = 12.0 V rms, 50.0 Hz



- (b) The diagram below shows the phasors for:
- the voltage, V_C , across the capacitor,
 - the voltage, V_R , across the resistor,
 - the voltage, V_S , across the supply.

Label the phasors correctly.

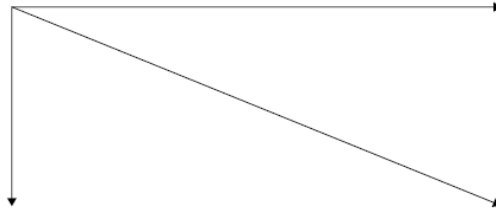
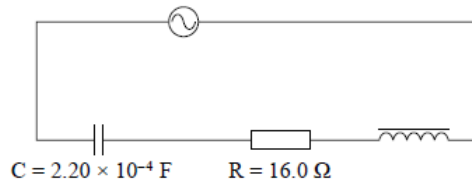


Diagram is not to scale.

- (c) Show that the angular frequency of the supply voltage of this circuit is 314 rads^{-1} .
- (d) Calculate the impedance of this circuit.

In a further investigation of AC circuits, Ana and Craig added an ideal inductor to the series circuit.

Supply voltage = 12.0 V rms, 50.0 Hz



- (e) Calculate the inductance of the inductor that will make this a resonant circuit.
- (f) Explain fully what is meant by a resonant circuit.
- (g) Calculate the value of the r.m.s. current in the circuit when it is at resonance.
- (h) On the axes below, sketch a graph of rms current against frequency for the circuit. Indicate appropriate current and frequency values.

