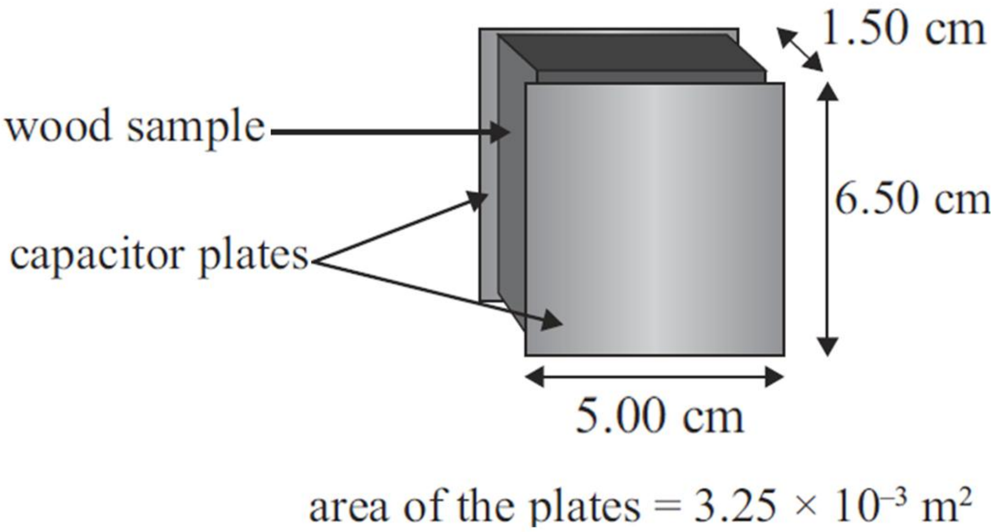
ELECTRICITY: DC CAPACITORS QUESTIONS

CAPACITANCE MOISTURE METER (2010;2)

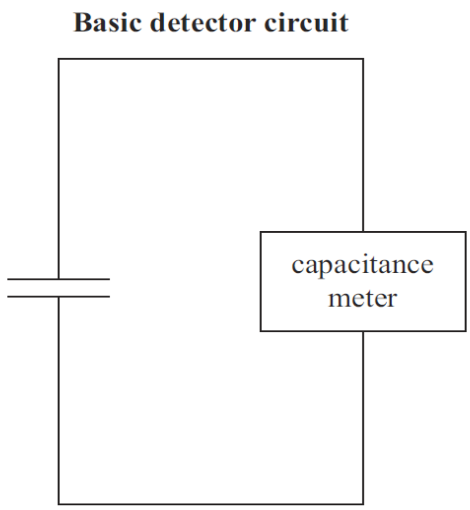
The moisture content of wood can be tested by measuring capacitance.
A simple moisture meter is based on two parallel metal plates. The test sample fits between the plates.



The relative permittivity of wood decreases when wood is dried. By measuring the capacitance of this capacitor the moisture content of the wood can be determined.

(a) Explain how the capacitance will change as the wood dries.

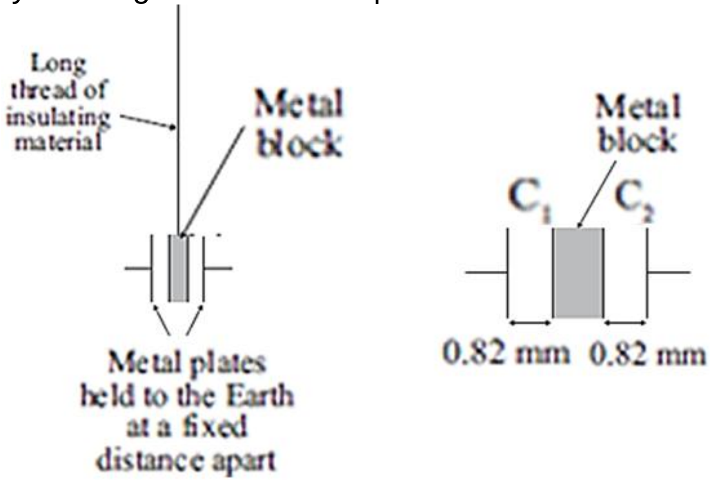
(b) The plates are connected to a capacitance meter. This measures 4.99×10^{-11} F. Calculate the relative permittivity, ε_r, of the wood.



TILTMETER (2009;3)

Permittivity of free space = 8.85×10^{-12} Fm^{-1}
Relative permittivity of air is 1.00

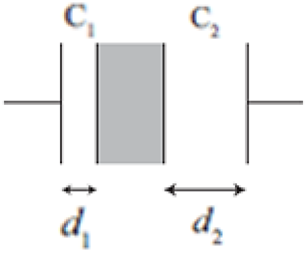
The diagram shows a simple tiltmeter, a device that detects minute movements in the Earth's crust. The metal block, suspended by a thread, forms a capacitor with each of the fixed plates either side of it, effectively creating two air-filled capacitors in series with each other.



The distance between the plates of each capacitor is 0.82 mm. The area of overlap of the capacitor plates is 0.50 m^2.

(a) Calculate the capacitance of each capacitor.

(b) The Earth's crust moves and the metal block moves closer to the left hand outer plate.

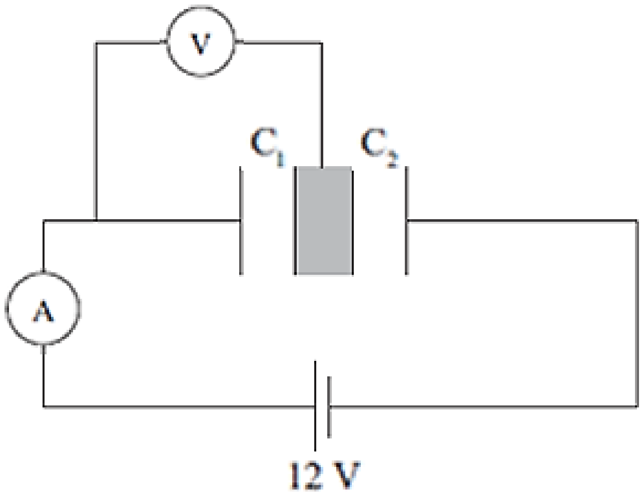


Show that the total capacitance of the two capacitors is given by:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d_1 + d_2}$$

(c) Describe why the total capacitance of the two capacitors does not change, no matter how far the metal block moves.

In order to measure the distance the metal block moves, the capacitors are connected into the following circuit.



(d) By considering the total capacitance of the two capacitors and the total voltage across them, show that no current flows when the Earth causes the metal block to move.

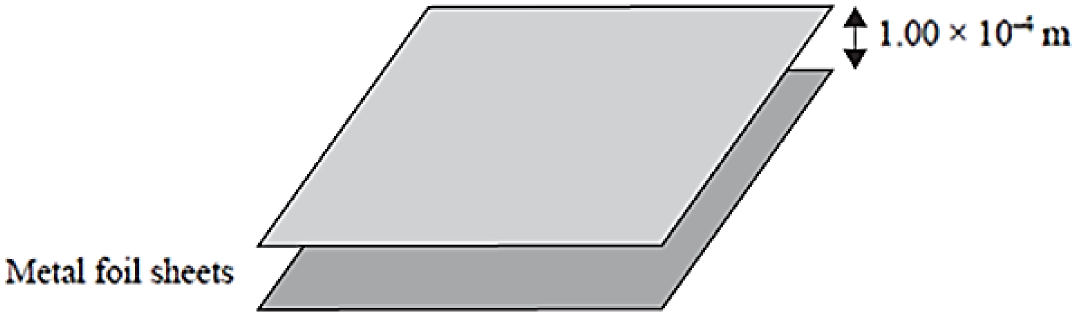
(e) Explain how the voltage reading changes when the metal block moves to the left.

(f) At one instant, the metal block has moved and the voltmeter reading is 5.1 V. Calculate the distance moved by the metal block.

THE CAPACITOR (2008;3)

The permittivity of free space = 8.84×10^{-12} Fm^{-1}

The capacitor in the induction cooker has a capacitance 1.65×10^{-8} F. Sam wanted to make a capacitor of this capacitance using two metal foil sheets.



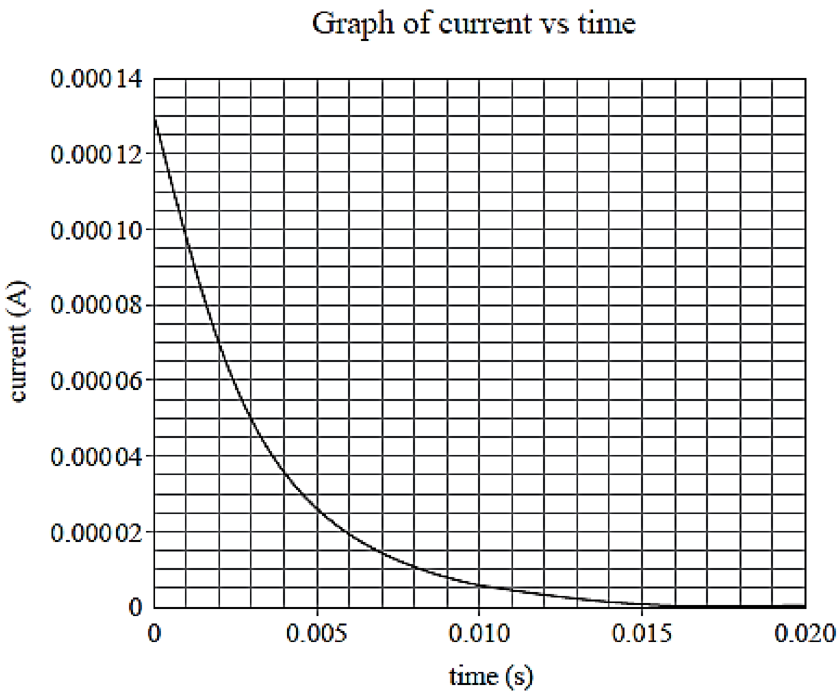
The two sheets of foil are separated by a layer of air 1.00×10^{-4} m thick.

(a) Calculate the area of the foil sheets that Sam should use.

(b) State two ways that Sam could increase the capacitance using the same pieces of foil.

After making the capacitor, Sam checked the value of its capacitance by charging it in a circuit in series with a resistor and a 19.5 V DC supply.

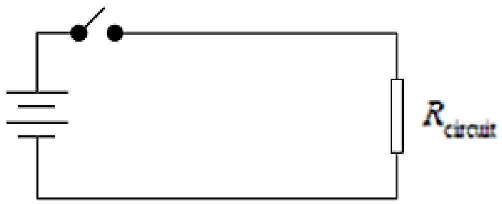
A graph of current versus time for the charging circuit is shown below.



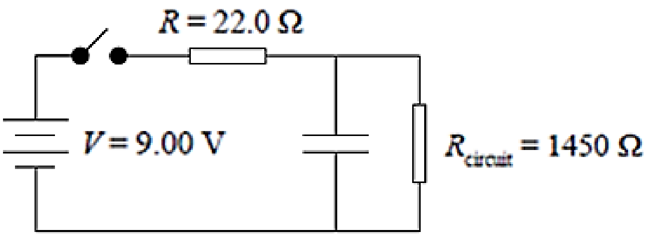
(c) Show that the resistance of the resistor is 150 kΩ.
(d) Determine the actual capacitance of the capacitor.

SWITCH BOUNCE (2006;1)

When an ideal switch is closed, the contacts touch one another and the circuit is completed instantaneously. In many real switches the contacts will 'bounce' a few times before making permanent contact. This means that the circuit is switched on and off rapidly as the contacts bounce.



The effects of switch 'bounce' can be minimised using the circuit modification shown. Assume this modification is in place when answering the following questions.



(a) Describe the charge flow in the circuit when the switch first closes and completes the circuit.
(b) State why there will still be a current through $R_{circuit}$ when a bounce opens the switch and breaks the circuit.

When the switch is opened, the time constant for the circuit is 0.11 s.
(c) (i) Show that the capacitance of the capacitor has an unrounded value of 7.5862×10^{-5} F.
(ii) Round this value to the appropriate number of significant figures.

(d) Calculate the charge on the capacitor plates when the voltage across them is 5.5 V.

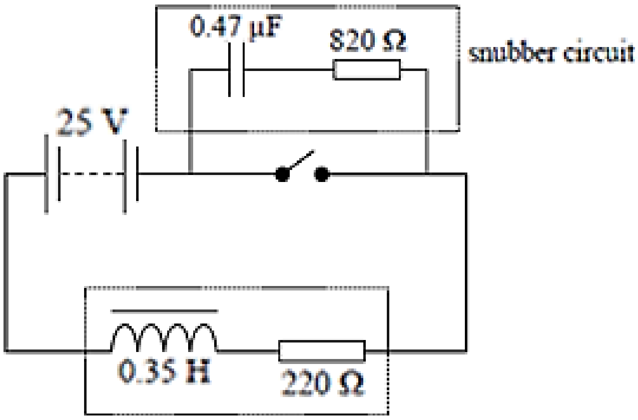
(e) The time between the first contact completing the circuit and the first bounce breaking it is very short. Explain why the time constant for the charging circuit must be even shorter.

(f) Calculate the voltage across the capacitor when the circuit has been closed for some time (i.e. when the current in the circuit has become constant).

SNUBBER SWITCH (2006;2)

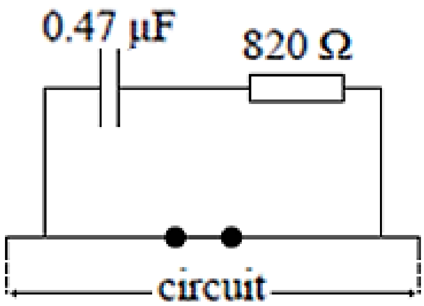
In a DC inductor circuit there is an important difference between switching on and switching off.

The diagram shows a simple snubber circuit connected across the switch. The capacitor has capacitance 4.7×10^{-7} F.



(a) After the switch has been opened and the voltage across the capacitor has reached a steady value, explain how this capacitor voltage will relate to the voltage of the source.

(b) By first calculating the charge on the capacitor (or otherwise), calculate the energy stored in the capacitor when the voltage across it is 25 V.



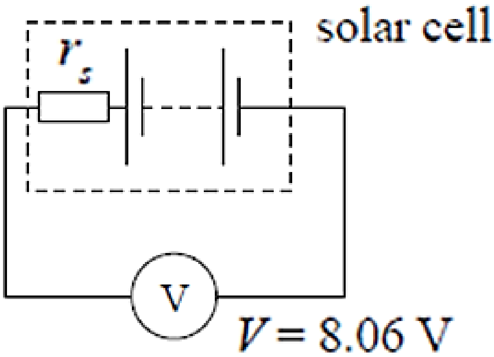
(c) When the switch is closed again (as shown in the diagram), explain what will happen to this stored energy.

(d) Explain why the presence of the resistor in the snubber circuit protects the switch.

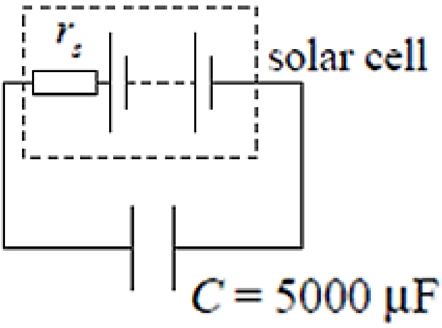
SOLAR RACING (2005;1)

As part of a technology challenge Tui and Richard are building a solar powered model car. They plan to use a solar cell connected to a small motor to drive the car.

They have been told that the internal resistance, r_s,of a solar cell is relatively large and so, before they start, they decide to investigate the electrical properties of the solar cell.
First they connect the solar cell to a voltmeter with no other components and find the voltage is 8.06 V.



Their investigation shows the students that the internal resistance of the solar cell is not constant. It decreases as the current decreases.
They wonder what would happen if the cell was used to charge a capacitor.

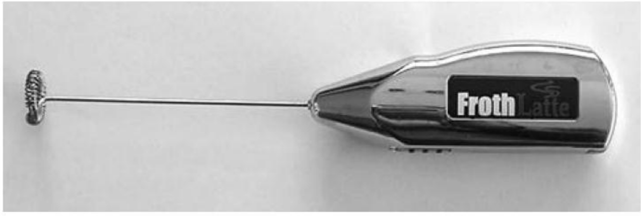


(a) What would be the time constant of the circuit to charge a 5000 μF (5.00×10^{3} F) capacitor if the circuit resistance was 64.3 Ω?

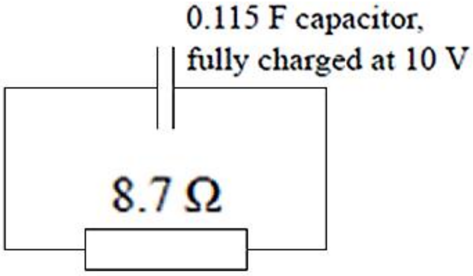
(b) Explain how the time taken to charge a capacitor with a solar cell would compare with the time taken to charge the same capacitor using a charging circuit that has constant resistance. Assume both circuits have the same resistance at the start of the charging process.

CAPPUCCINO ESSENTIALS (2004;1)

Jodi has a battery-operated rotary whisk that makes frothy milk for her coffee.

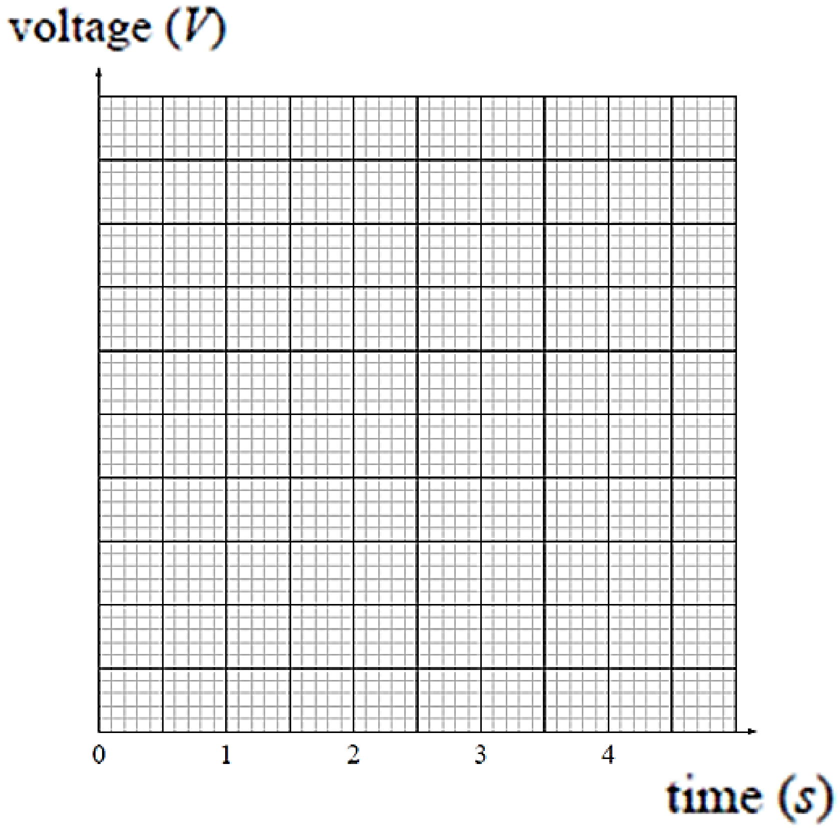


Jodi wondered what would happen if the battery in the frother were replaced with a charged capacitor. She found a 0.115 F capacitor and used a 10 V supply to charge it. She then discharged the capacitor through the frother. The resistance of the frother is 8.7 Ω.



(a) Calculate the time constant for this circuit.

(b) On the axes below carefully plot a graph to show how the voltage across the capacitor would vary with time during the discharging of the capacitor over the first 4 s.



(c) The minimum power that must be delivered to the frother in order to make it work is 1.3 W. Calculate the length of time for which Jodi might expect the frother to work when it is powered by the capacitor.