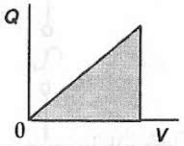
Capacitors

Exercise 7.1 Capacitance

1. The graph shows how the charge Q on a capacitor is related to the p.d. V applied across its plates.

   a) What does the shaded area under the graph represent?
   b) What does the gradient of the graph represent?



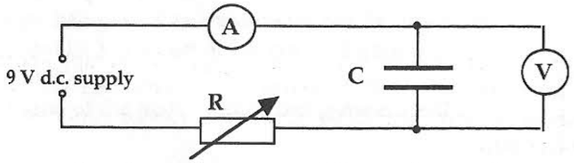
2. A capacitor takes 320 μC to fully charge when connected to an 8 V supply.
   Calculate the capacitance of the capacitor.

3. "A capacitor has a capacitance of 4 microfarads."
   Explain what is meant by this statement.

4. Which of the following units is equivalent to a farad?

   A. V   B. C   C. CV   D. CV^{-1} E. VC^{-1}

5. In the circuit shown the capacitor C is charged with a steady current of 1 mA by carefully adjusting the variable resistor R.



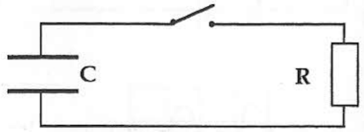
The voltmeter reading is taken every 10 s. The results are shown in the table.

Time/s	0	10	20	30	40
Voltage/V	0	1.9	4.0	6.2	8.1

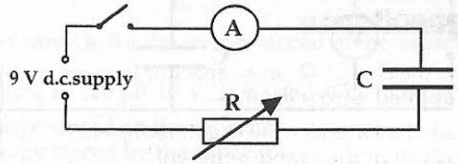
Plot a graph of charge against voltage for the capacitor and hence find its capacitance.

6. In the circuit shown C is a 1.0 μF capacitor holding a charge of 10^{-5} C and R is a 10 Ω resistor.

   a) Calculate the voltage across the capacitor.
   b) Calculate the initial current flowing in the circuit when the switch is closed.

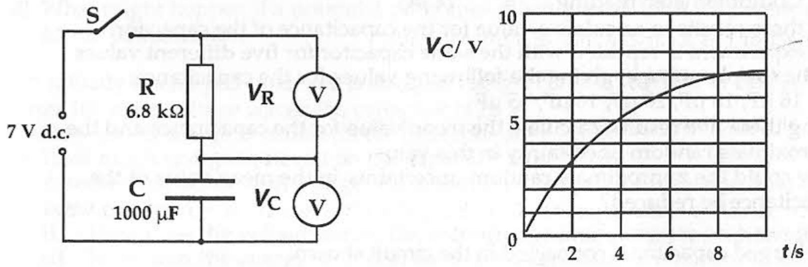


7. After the switch is closed in the circuit shown, the variable resistor R is adjusted to give a constant charging current of 2.0×10^{-5} A for a time of 30 s. During this time the p.d. across the capacitor rises from 0 V to 9 V.



   a) What change must be made to the variable resistor R?
   b) Calculate the capacitance of the capacitor.

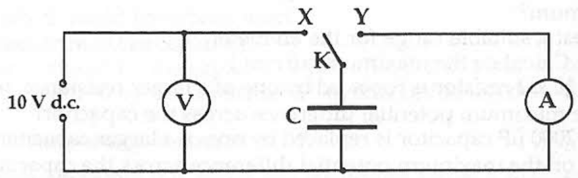
8. The circuit shown is set up to investigate the charging of a capacitor.



At the start of the experiment the capacitor is uncharged. The graph shows how the p.d. V_C across the capacitor varies with time from the instant the switch S is closed.

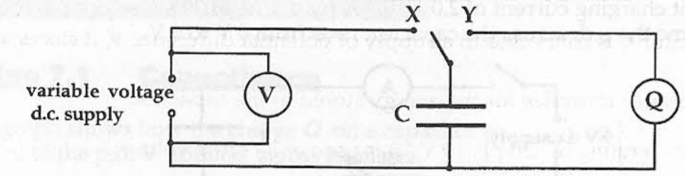
   a) Draw a graph showing how the p.d. V_R across the resistor varies with time during the first 10 s of charging.
   (Numerical values are required on both axes.)
   b) Calculate the current in the circuit at the instant the p.d. across the capacitor is 6.0 V.

9. The switch K is made to vibrate between contacts X and Y at a rate of 50 complete vibrations (to and fro) per second. The voltmeter reads 10.0 V and the milliammeter A reads 8.00 mA.



   a) How much charge passes through the milliammeter in 1 s?
   b) How much charge passes through the milliammeter each time the switch makes contact with Y?
   c) Calculate the capacitance of the capacitor C?

10. The circuit shown is used to find the capacitance of a capacitor.



With the switch in position X, the capacitor charges up to the supply voltage. The reading on the voltmeter is noted and the switch is moved to position Y. The coulombmeter Q then indicates the charge stored by the capacitor.

a) One set of results is:

Voltmeter reading	=	1.5 V
Coulombmeter reading	=	24 μC

Use these results to calculate a value for the capacitance of the capacitor.

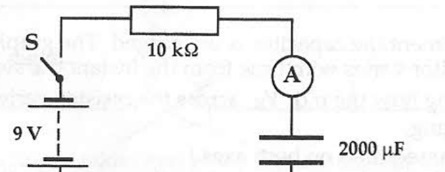
b) The experiment is repeated with the **same** capacitor for five different values of the supply voltage, giving the following values for the capacitance:

16 μF, 18 μF, 20 μF, 16 μF, 15 μF

Using these five results, calculate the mean value for the capacitance **and** the approximate random uncertainty in this value.

c) How could the approximate random uncertainty in the mean value of the capacitance be reduced?

11. An uncharged capacitor is connected in the circuit shown.



a) Describe the response of the ammeter after the switch S is closed.

b) How would you know when the potential difference across the capacitor is at its maximum?

c) Suggest a suitable range for the ammeter.
(Hint: Calculate the maximum current.)

d) If the 10 kΩ resistor is replaced by one of a larger resistance, what will be the effect on the maximum potential difference across the capacitor?

e) If the 2000 μF capacitor is replaced by one of a larger capacitance, what will be the effect on the maximum potential difference across the capacitor?

Exercise 7.2 Energy in Capacitors

1. When a capacitor ***C*** is connected to a supply of potential difference ***V***, it stores a charge ***Q***.

Give **three** possible formulae for the energy stored in the capacitor.

2. A capacitor has a rating of 220 pF, 10 V. It is used at its rated voltage.

a) Calculate the charge stored on the capacitor.
b) Calculate the energy stored by the capacitor.

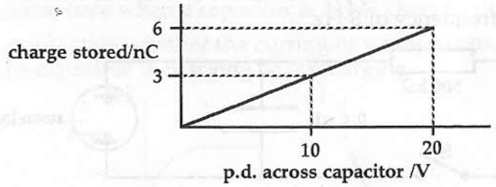
3. A capacitor is marked "Electrolytic 2000 μF, 16 V".

a) How much charge does it store when fully charged?
b) How much energy does it store when fully charged?
c) What does the word "Electrolytic" tells you about this capacitor.
d) What might happen if a potential difference much greater than 16 V were applied across its terminals?

4. An initially uncharged capacitor is charged using a constant current of 90 μA. After 100 s the voltage across the capacitor is 12 V.

a) How much charge is stored on the capacitor after 100 s?
b) How much energy is stored on the capacitor after 100 s?
c) A second capacitor with a larger capacitance is charged for the same time using the same current.
 i) How does the voltage across the second capacitor compare with the first?
 ii) How does the energy stored in the second capacitor compare with the first?

5. A capacitor is connected to a circuit and the graph shown is obtained.



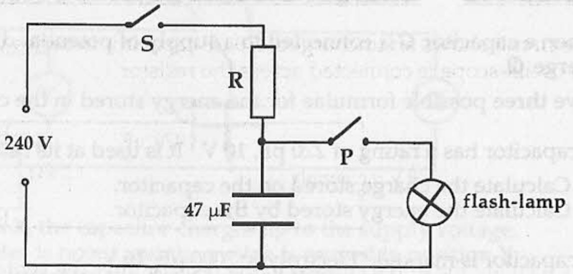
a) Draw the circuit which could have been used.
b) Calculate the capacitance of the capacitor.
c) Calculate the energy stored by the capacitor when charged to a p.d. of 10 V.
d) Calculate the energy stored by the capacitor when charged to a p.d. of 20 V.

6. An 800 μF capacitor is fully charged at a p.d. of 12 V.

a) The capacitor is removed from the circuit and connected across a 10 Ω resistor. What is the total energy dissipated in the resistor?

b) In another experiment, the fully charged capacitor is connected across a 20 Ω resistor instead of the 10 Ω resistor.
How does the energy dissipated in this resistor compare with that calculated in part a)?
You must justify your answer.

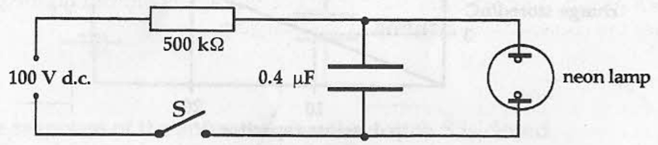
7. The diagram shows the flash-lamp circuit for a camera.



a) Initially the capacitor is uncharged and switches S and P are open. Switch S is now closed.
   i) Calculate the energy stored in the capacitor when it is fully charged.
   ii) When the camera shutter is operated, switch S is opened and switch P is closed. The capacitor now fully discharges through the flash-lamp in a time of 1.6 ms. What is the average power developed in the flash-lamp?

b) The following information is marked on the capacitor: 47 μF; 300 V. This means that the maximum voltage that should be applied across the capacitor is 300 V.
   i) Why does the capacitor have a maximum voltage?
   ii) Could this capacitor be safely connected to a 230 V a.c. supply? Justify your answer.

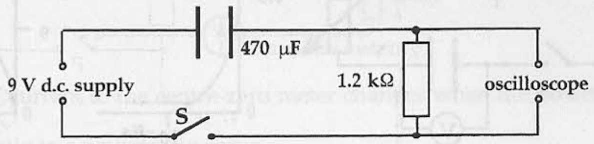
8. A neon lamp lights when the voltage across it rises to 80 V and goes out when the voltage falls to 60 V. In the circuit shown, the 0.4 μF capacitor is connected in series with a 500 KΩ resistor to a 100 V d.c. supply. When the switch S is closed the neon lamp flashes at a frequency of 8 Hz.



a) Calculate the charge stored in the capacitor when the voltage across it is
   i) 80 V,
   ii) 60 V.
b) Determine the energy dissipated in each flash of the neon lamp.
c) Sketch the waveform which would be seen on a suitably adjusted oscilloscope connected across the neon lamp.
d) If the value of the resistor is increased, the frequency of the flashing neon lamp changes. How would the value of the capacitor require to be changed to restore the frequency to its original value?
e) The flash frequency could also have been restored to its original value by increasing the supply voltage. Explain this.
f) If the supply voltage is in increased further, the neon lamp stays on all the time. Explain why this happens.

Exercise 7.3 Charge, Discharge Characteristics

1. The circuit shows an uncharged 470 μF capacitor in series with a 1.2 kΩ resistor. An oscilloscope is connected across the resistor.

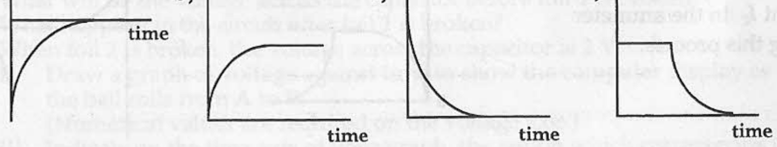


a) Calculate the initial current in the resistor after the switch S is closed.
b) Calculate the final charge on the capacitor.
c) Calculate the energy stored on the capacitor.
d) Draw the graph of the voltage across the capacitor against time for the charging period. (Numerical values are only required on the voltage axis.)
e) Draw the graph of the current against time for the charging period. (Numerical values are only required on the current axis.)

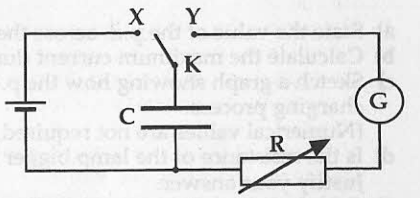
2. You are given a capacitor, a battery, two resistors, a two way switch, an ammeter, an oscilloscope and connecting wires. You are asked to set up a circuit which would allow you to look at the variation of current and voltage across the capacitor on charging and discharging the capacitor.
a) Draw a diagram of the circuit you would use.
b) Explain how the circuit operates to show both charge and discharge characteristics.
c) Draw the graphs that would be obtained, explaining carefully which graphs show charging and which show discharging.

3. Each of the following graphs shows either voltage across a capacitor against time or current against time when a capacitor is either charged or discharged.

For each graph state whether the current or voltage is plotted on the y-axis and whether the capacitor is charging or discharging.

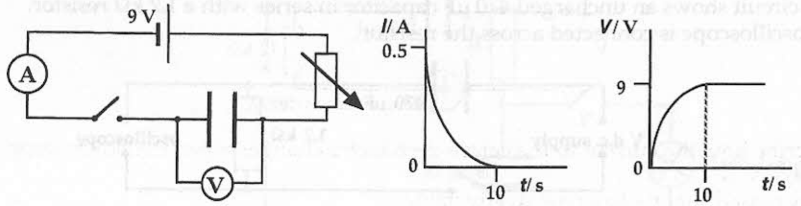


4. By moving the switch K in the circuit shown from X to Y the capacitor C may be discharged through a variable resistor R and a sensitive meter G. In one such discharge the meter shows a maximum deflection of 5 units and it took 8 s for the reading to become 1 unit.



a) If R is set at a decreased value, suggest values for the maximum deflection and the time to reduce to 1 unit.
b) If R is set at an increased value, suggest values for the maximum deflection and the time to reduce to 1 unit.

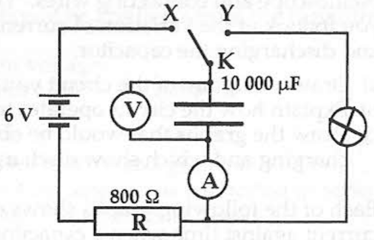
5. The circuit shown is used to charge a capacitor and the graphs show the variation of current I with time t, and voltage V with time t.



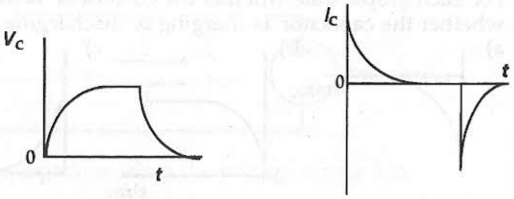
a) The capacitor is discharged and the value of the variable resistor is **increased**. The experiment is then repeated.
Copy the two graphs shown and sketch the **new** current-time graph and voltage-time graph on the same axes.

b) The capacitor is discharged and the value of the variable resistor is **decreased below the original value**. The experiment is then repeated.
Copy the two graphs shown and sketch the **new** current-time graph and voltage-time graph on the same axes.

6. The circuit shown was set up to investigate the charge-discharge characteristics of the capacitor. The 6 V supply has negligible internal resistance.
Initially the capacitor is uncharged and the switch is in position Y. The switch is moved to position X until the capacitor is fully charged and then finally back to Y.

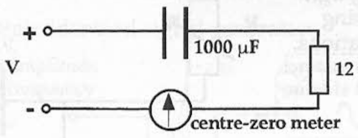


The graphs show the p.d. V_c across the capacitor and the current I_c in the ammeter during this process.



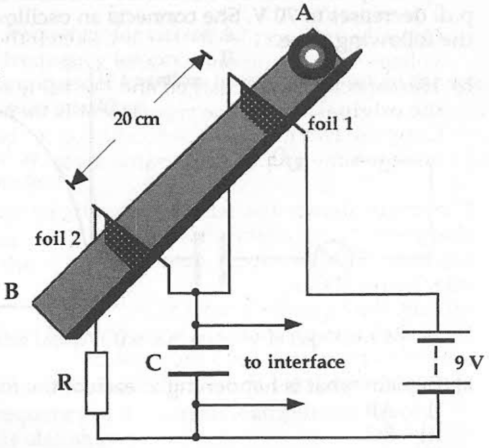
a) State the value of the p.d. across the capacitor when fully charged.
b) Calculate the maximum current during the charging process.
c) Sketch a graph showing how the p.d. across resistor **R** varies with time during the charging process.
(Numerical values are not required.)
d) Is the resistance of the lamp bigger or smaller than 800 Ω?
Justify your answer.
e) Calculate the energy stored in the capacitor when it is fully charged.

7. The capacitor in the circuit shown is fully charged at a certain voltage, V.



Describe how the current to the centre-zero meter changes when the power supply voltage V is
a) increased slightly to a new steady value,
b) decreased slightly to a new steady value.

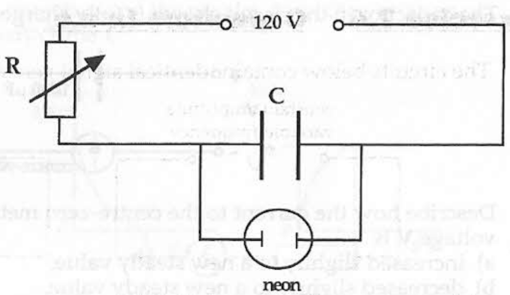
8. A pupil sets up the apparatus shown to measure how long it takes a ball to travel between two thin strips of metal foil on a track. The ball breaks each foil in turn as it rolls past.



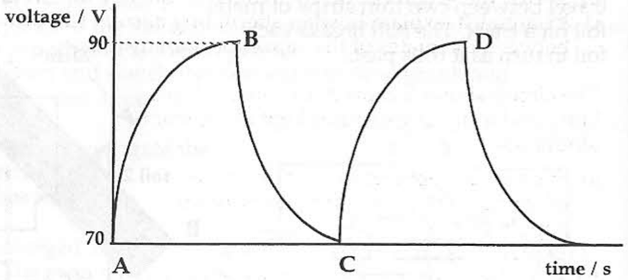
A computer with an appropriate interface is used to monitor and display the voltage across the capacitor **C**.

a) What will be the voltage across the capacitor before foil **1** is broken?
b) What happens in the circuit after foil **1** is broken?
c) When foil 2 is broken, the voltage across the capacitor is 2 V.
   i) Draw a graph of voltage against time to show the computer display as the ball rolls from **A** to **B**.
   (Numerical values are required on the voltage axis.)
   ii) Indicate on the time axis of your graph, the region which corresponds to the ball travelling between the foils.

9. A roads engineer uses the circuit shown to produce a flashing light which acts as a hazard warning indicator during work operations.



When the p.d. across the neon bulb increases to 90 V it lights up and stays lit until the p.d. decreases to 70 V. She connects an oscilloscope across the neon bulb and obtains the following trace.

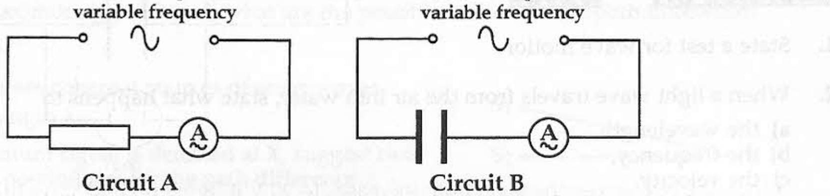


a) Explain what is happening at each of the following sections of the trace.
   i) AB
   ii) BC
   iii) CD

b) State **one** method of **decreasing** the frequency of flashes of the neon bulb.

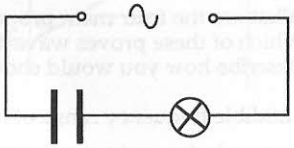
Exercise 7.4 Capacitors in a.c.

1. The circuits below contain identical signal generators.



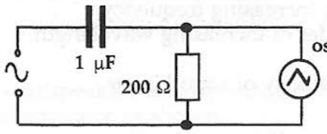
a) Sketch the graph of current against frequency for circuit **A**.
b) Sketch the graph of current against frequency for circuit **B**.
c) In circuit **B**, explain how an alternating current can flow in the circuit when the space between the plates of the capacitor is an insulator.

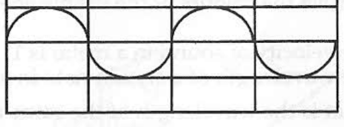
2. The circuit shows a capacitor connected to a lamp and a signal generator kept at constant amplitude.



a) State what happens to the brightness of the lamp when the frequency of the supply is increased. Explain this observation.
b) What happens to the brightness of the lamp if the a.c. supply is replaced by an equivalent d.c. supply?

3. When the circuit below is set up, the frequency of the constant amplitude supply is 1 kHz. The trace on the oscilloscope is also shown.

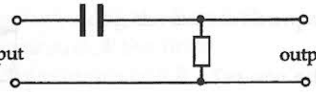




The frequency is now increased to 2 kHz while the oscilloscope controls are left untouched.

Make a sketch, with grid lines as shown, of the trace you would now expect to see on the oscilloscope.

4. A pupil notices the following filter network in the circuit diagram for her new stereo amplifier.



Explain whether this filter is intended to remove low frequency "rumble" or high frequency "hiss."