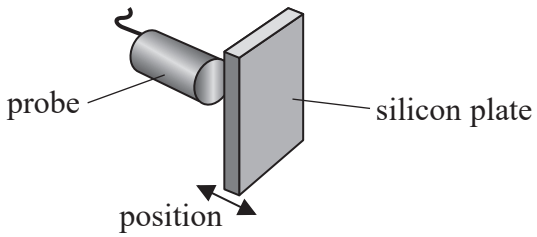
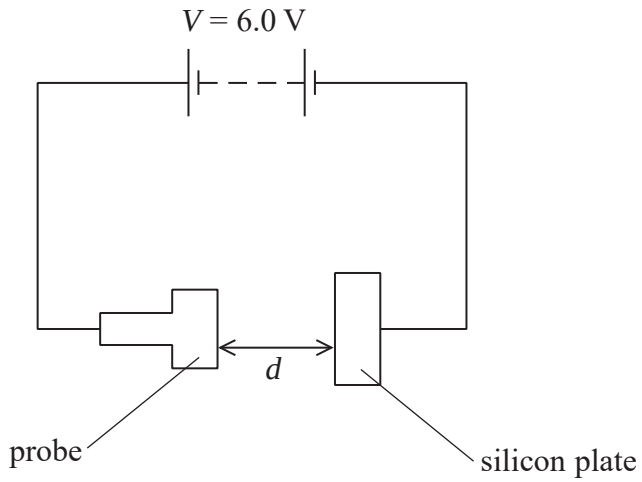
1 During the manufacture of some computer components it is necessary to monitor the position of pieces of silicon.

Capacitors can be used to detect a change in the position of a piece of silicon. The piece of silicon forms one plate of a capacitor whilst a probe acts as the other plate as shown in the diagram.



The capacitor is charged by connecting it to a 6.0 V battery as shown in the diagram below.



The relationship between the capacitance C and the distance d between the silicon plate and the probe is

$$C = k/d$$

where k is a constant.

(a) Explain qualitatively how the charge on the capacitor will vary if the silicon plate moves away from the probe.

(2)

(b) When the silicon is in a certain position, the probe is 3.5 mm from it. The silicon must remain within 0.70 mm of this position.

Determine the maximum allowable percentage decrease in the charge on the capacitor.

$k = 2.8 \times 10^{-15}$ F m

(4)

Maximum allowable percentage decrease =

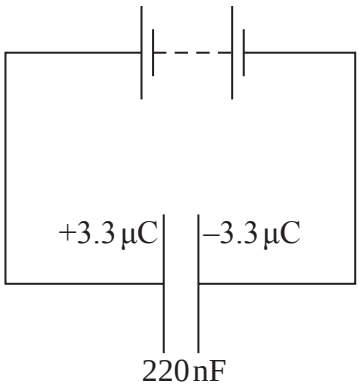
(c) In order to detect rapid changes in the position of the silicon, it is necessary to use a capacitor with a small capacitance.

Explain why.

(2)

(Total for Question = 8 marks)

2 A capacitor is charged by a battery as shown in the circuit diagram2



(a) Calculate the e.m.f. of the battery and the energy stored in the charged capacitor.

(4)

E.m.f. =

Energy =

(b) The capacitor is disconnected from the battery and discharged through a 20 MΩ resistor.

Calculate the time taken for 80% of the charge on the capacitor to discharge through the resistor.

(3)

Time taken =

(c) Use an equation to explain whether the time taken for the capacitor to lose half its energy is greater or less than the time taken to lose half its charge.

(3)

(d) A student carries out an experiment to record data so that she can plot a graph of potential difference against time as the capacitor discharges.

State **two** advantages of using a datalogger rather than a voltmeter and stopwatch to record this data.

(2)

(Total for Question = 12 marks)

3 In recent years there has been a development of ultracapacitors which have much higher capacitance than traditional capacitors. Capacitors store energy due to charge in an electric field whereas batteries store energy due to a chemical reaction. There are several applications where ultracapacitors have an advantage over batteries; for example storing energy from rapidly fluctuating supplies or delivering charge very quickly.

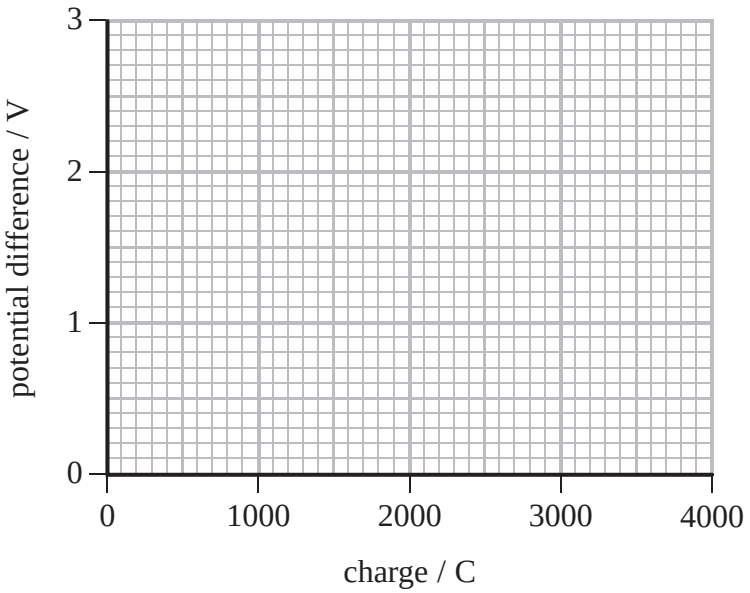
(a) A typical ultracapacitor has a capacitance of 1500 F and a maximum operating potential difference of 2.6 V.

(i) Show that the charge on this capacitor when fully charged is about 4000 C.

(2)

(ii) Complete the graph on the axes below to show how the potential difference varies with charge for this capacitor.

(2)

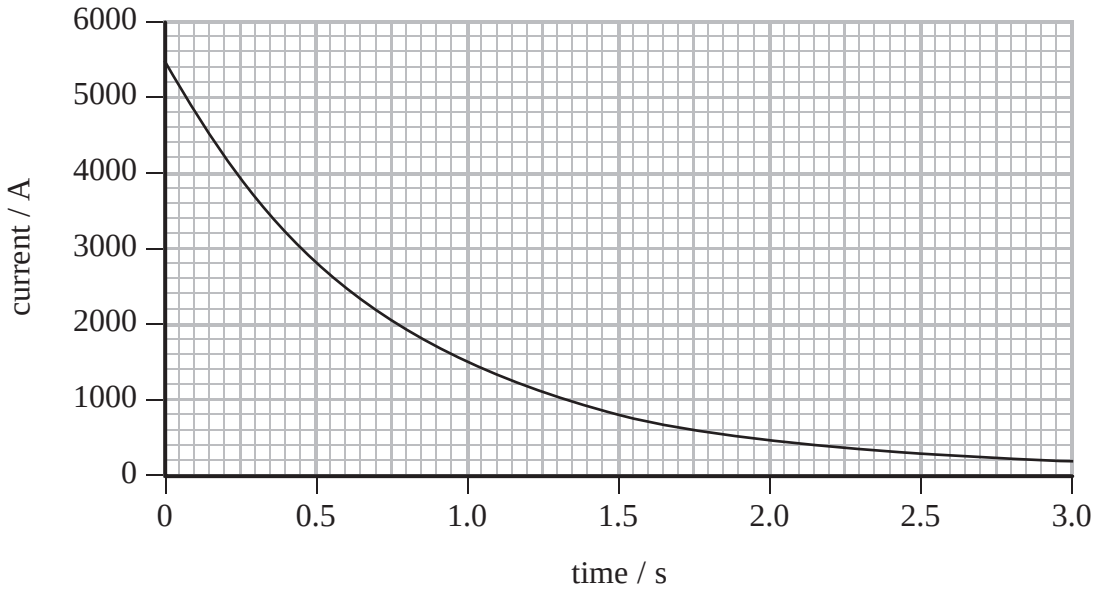


(iii) Calculate the energy stored in this capacitor when fully charged.

(2)

Energy =

(b) The graph below shows how the current varies with time as the capacitor is discharged through a circuit.



(i) Describe and explain the shape of the graph.

(2)

(ii) Calculate the resistance of the circuit.

(4)

Resistance =

(c) There is a limit to the amount of charge an ultracapacitor can hold but it can deliver the charge very quickly. A battery can deliver much more charge but only at a slower rate. For electric powered vehicles it is suggested that using a combination of batteries and ultracapacitors would give the best performance.

Suggest, with reasons, which stages of a journey would be more suited to ultracapacitors and which would be more suited to batteries.

(3)

(Total for Question = 15 marks)

4 A student is investigating how the potential difference across a capacitor varies with time as the capacitor is charging.

He uses a 100 μF capacitor, a 5.0 V d.c. supply, a resistor, a voltmeter and a switch.

(a) (i) Draw a diagram of the circuit he should use.

(2)

(ii) Suggest why a voltage sensor connected to a data logger might be a suitable instrument for measuring the potential difference across the capacitor in this investigation.

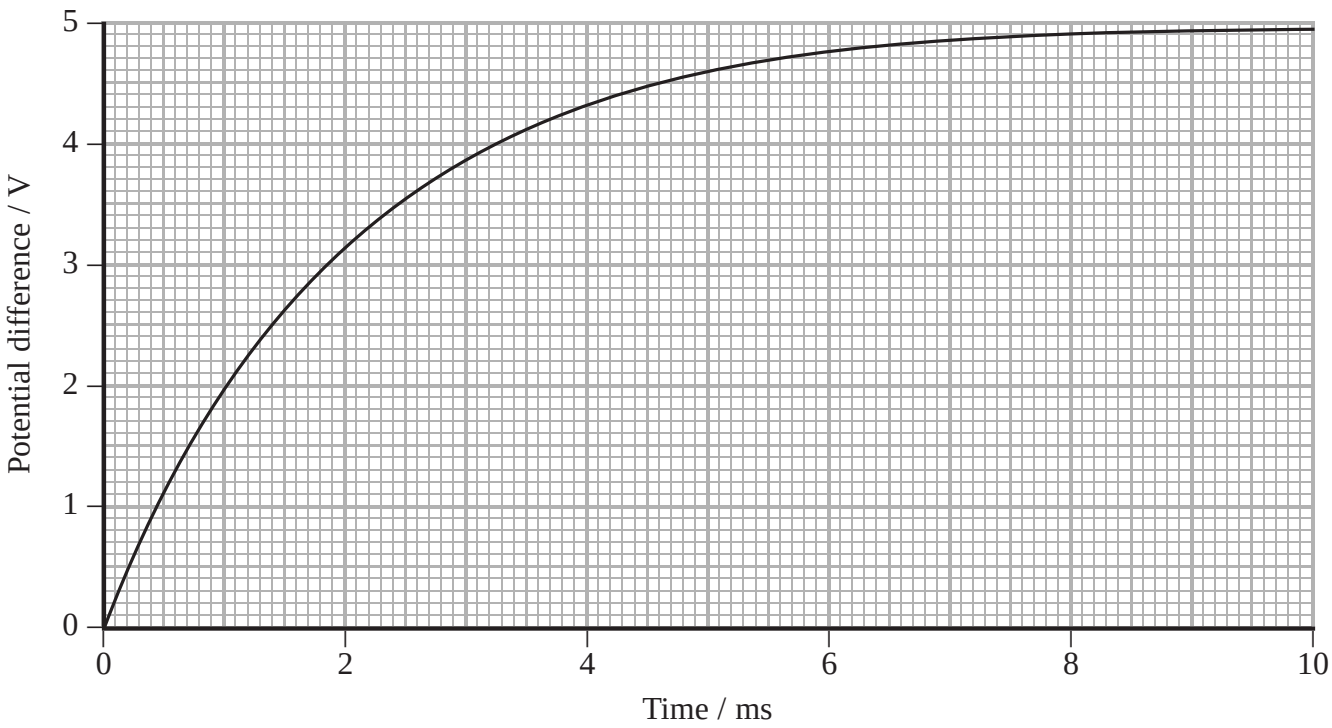
(1)

(b) Calculate the maximum charge stored on the capacitor.

(2)

Charge =

(c) The graph shows how the potential difference across the capacitor varies with time as the capacitor is charging.



(i) Estimate the average charging current over the first 10 ms.

(2)

Average charging current =

(ii) Use the graph to estimate the initial rate of increase of potential difference across the capacitor and hence find the initial charging current.

(3)

Initial charging current =

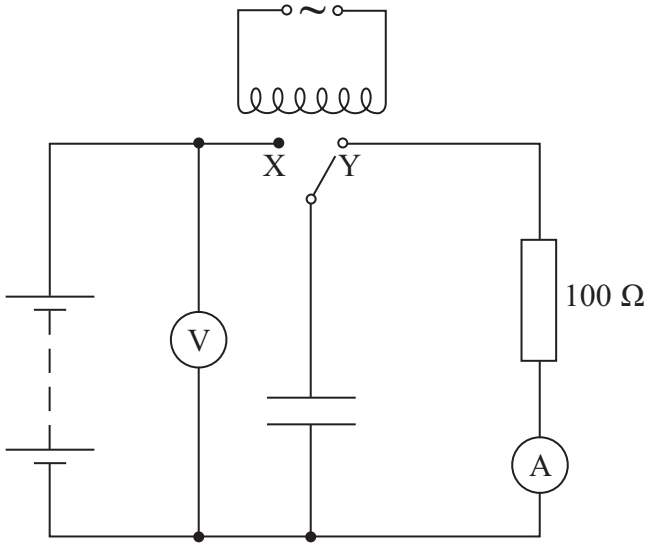
(iii) Use the value of the initial charging current to find the resistance of the resistor.

(2)

Resistance =

(Total for Question = 12 marks)

5 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges *f* times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for *f*.

(3)

(ii) Show that the capacitance C can be given by

$$C = \frac{I}{fV}$$

where I is the reading on the ammeter and V is the reading on the voltmeter.

(3)

(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

C .....

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

.....

.....

.....

Energy .....

(Total for Question 12 marks)

6 A student needs to order a capacitor for a project. He sees this picture on a web site accompanied by this information: capacitance tolerance ±20%.

Taking the tolerance into account, calculate

(a) the maximum charge a capacitor of this type can hold.

(3)

Maximum charge =

(b) the maximum energy it can store.

(2)

Maximum energy =

(Total for Question = 5 marks)