1. Fig.1 shows two capacitors, **A** of capacitance 2μF, and **B** of capacitance 4μF, connected in parallel. Fig. 2 shows them connected in series. A two-way switch **S** can connect the capacitors either to a d.c. supply, of e.m.f. 6 V, or to a voltmeter.

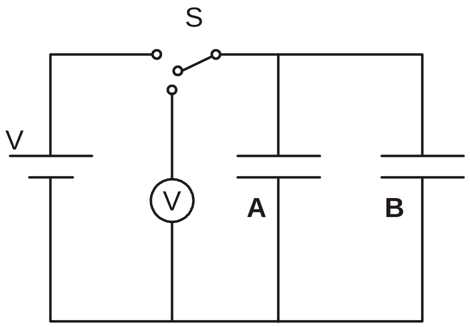


Fig. 1

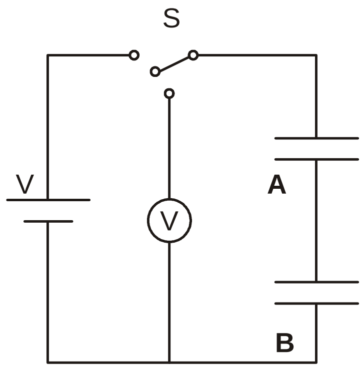


Fig. 2

(a) Calculate the total capacitance of the capacitors

(i) when connected as in Fig. 1

capacitance = ... μF

[1]

(ii) when connected as in Fig. 2

capacitance = ... μF

[2]

(b) The switch in the circuit shown in Fig. 1 is then connected to the battery. Calculate

(i) the potential difference across capacitor **A**

potential difference = ... V

[1]

(ii) the total charge stored on the capacitors.

charge = ...μC

[2]

(c) The switch in the circuit shown in Fig.2 is then connected to the battery. Calculate the total energy stored in the two capacitors.

energy = ... J

[2]

(d) The switch S in the circuit of Fig. 1 is moved to connect the charged capacitors to the voltmeter. The voltmeter has an internal resistance of 12 MΩ.

(i) Explain why the capacitors will discharge, although very slowly.

....

....

....

[1]

(ii) Calculate the time t taken for the voltmeter reading to fall to a quarter of its initial reading.

t = ... s

[3]

[Total 12 marks]

2. Fig. 1 shows a football balanced above a metal bench on a length of plastic drain pipe. The surface of the ball is coated with a smooth layer of an electrically conducting paint. The pipe insulates the ball from the bench.

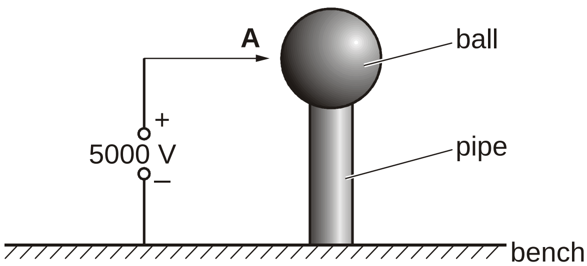


Fig. 1

(a) The ball is charged by touching it momentarily with a wire **A** connected to the positive terminal of a 5000 V power supply. The capacitance C of the ball is 1.2×10^{-11} F. Calculate the charge Q_o on the ball. Give a suitable unit for your answer.

Q_o = ... unit ....

[3]

(b) The charge on the ball leaks slowly to the bench through the plastic pipe, which has a resistance R of $1.2 \times 10^{15}\ \Omega$.

(i) Show that the time constant for the ball to discharge through the pipe is about 1.5×10^{4} s.

[1]

(ii) Show that the initial value of the leakage current is about 4×10^{-12} A.

[1]

(iii) Suppose that the ball continues to discharge at the constant rate calculated in (ii). Show that the charge Q_o would leak away in a time equal to the time constant.

[2]

(iv) Using the equation for the charge Q at time t

$$Q = Q_0 e^{-t/RC}$$

show that, in practice, the ball only loses about 2/3 of its charge in a time equal to one time constant.

[2]

(c) The ball is recharged to 5000 V by touching it momentarily with wire **A**. The ball is now connected in parallel via wire **B** to an uncharged capacitor of capacitance 1.2×10^{-8} F and a voltmeter as shown in Fig. 2.

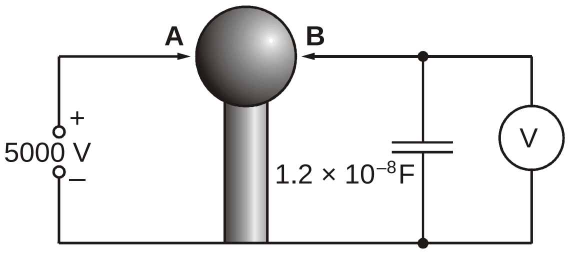


Fig. 2

(i) The ball and the uncharged capacitor act as two capacitors in parallel. The total charge Q_0 is shared instantly between the two capacitors. Explain why the charge left on the ball is $Q_0/1000$.

....

....

....

....

....

....

[3]

(ii) Hence or otherwise calculate the initial reading V on the voltmeter.

V = ... V

[2]

[Total 14 marks]

3. This question is about the energy stored in a capacitor.

(a) (i) One expression for the energy W stored on a capacitor is

$$W = \frac{1}{2}QV$$

where Q is the charge stored and V is the potential difference across the capacitor.
Show that another suitable expression for the energy stored is

$$W = \frac{1}{2}CV^2$$

where C is the capacitance of the capacitor.

[2]

(ii) Draw a graph on the axes of Fig. 1 to show how the energy W stored on a 2.2 F capacitor varies with the potential difference V across the capacitor.

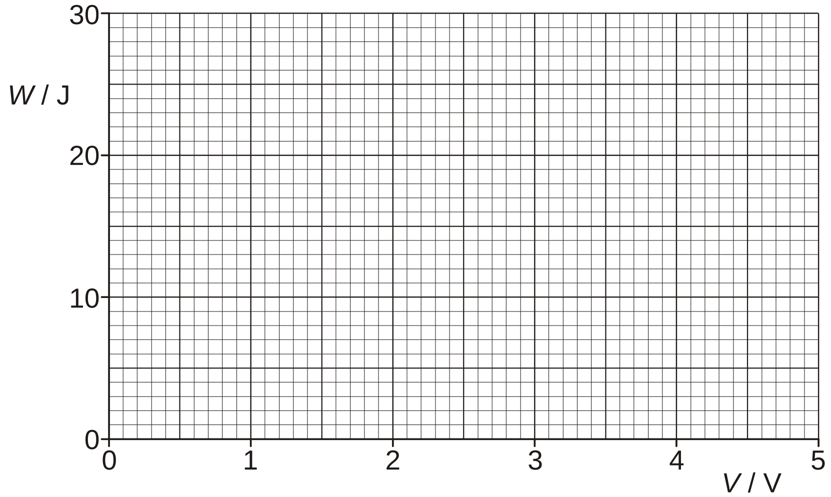


Fig. 1

[2]

(b) The 2.2 F capacitor is connected in parallel with the power supply to a digital display for a video/DVD recorder. The purpose of the capacitor is to keep the display working during any disruptions to the electrical power supply. Fig. 2 shows the 5.0 V power supply, the capacitor and the display. The input to the display behaves as a 6.8 kΩ resistor. The display will light up as long as the voltage across it is at or above 4.0 V.

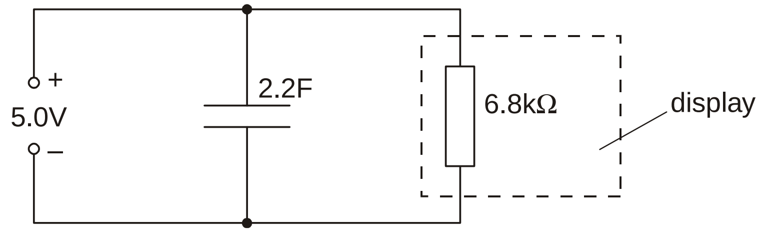


Fig. 2

Suppose the power supply is disrupted.

(i) Show that the time constant of the circuit of Fig. 2 is more than 4 hours.

[2]

(ii) Find the energy lost by the capacitor as it discharges from 5.0 V to 4.0 V.

energy lost = ...J

[2]

(iii) The voltage V across the capacitor varies with time t according to the equation

$$V = V_o e^{-t/RC}.$$

Calculate the time that it takes for the voltage to fall to 4.0 V.

time = ... s

[2]

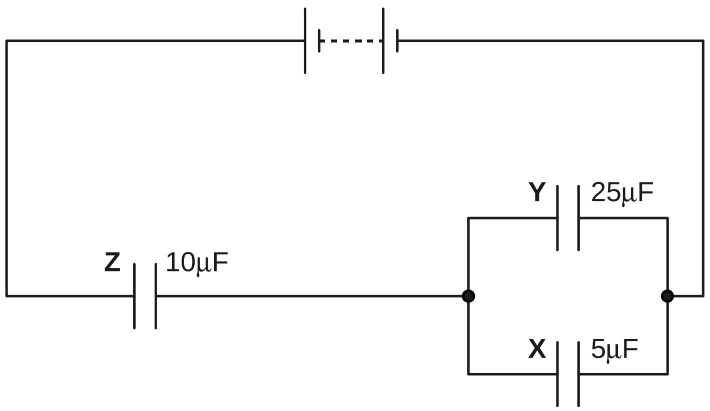
(iv) Calculate the mean power consumption of the display during this time.

mean power = ... W

[1]

[Total 11 marks]

4. The charge stored in the capacitor **X** of capacitance 5 µF in the circuit given in the figure below is 30 µC.



(a) (i) Complete the table for this circuit.

capacitor	capacitance / µF	charge / µC	p.d. / V	energy / µJ
X	5	30		
Y	25			
Z	10			

[9]

(ii) Using data from the table find

1 the e.m.f. of the battery

e.m.f. = ... V

[1]

2 the total charge supplied from the battery

charge = ... μC

[1]

3 the total circuit capacitance

capacitance = ... μF

[1]

4 the total energy stored in all the capacitors.

energy = ... μJ

[1]

(b) (i) What law or principle of physics was used to determine **(a)(ii)1**?

....

[1]

(ii) What law or principle of physics was used to determine **(a)(ii)2**?

....

[1]

(c) The battery is removed and replaced by a resistor of resistance 200 kΩ. The capacitors now discharge through this resistor. Calculate

(i) the time constant of the circuit

time constant = ... s

[2]

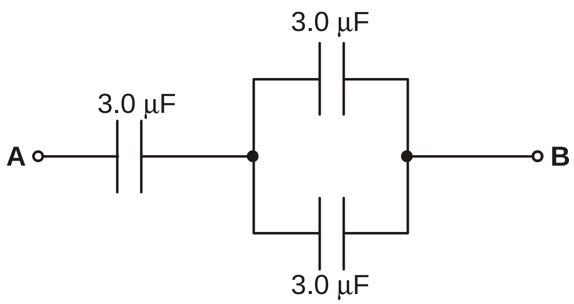
(ii) the fraction of the total charge remaining on the capacitors after a time equal to **four** time constants.

fraction remaining = ...

[2]

[Total 19 marks]

5. You are provided with a number of identical capacitors, each of capacitance 3.0 μF. Three are connected in a series and parallel combination as shown in the diagram below.



(i) Show that the total capacitance between the terminals **A** and **B** is 2.0 μF.

[3]

(ii) Draw a diagram in the space below to show how you can produce a total capacitance of 2.0 μF using **six** 3.0 μF capacitors.

[2]

[Total 5 marks]