

1. Fig.1 shows two capacitors, **A** of capacitance $2\mu\text{F}$, and **B** of capacitance $4\mu\text{F}$, 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.

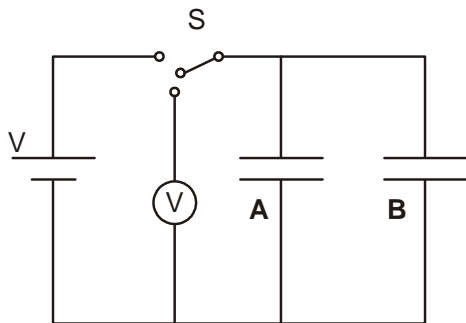


Fig. 1

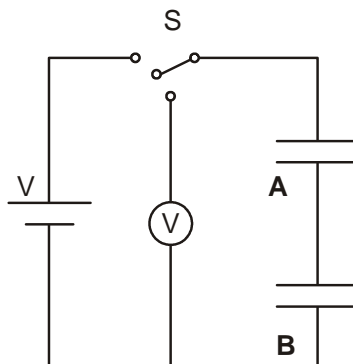


Fig. 2

- (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 M Ω .

(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.

$t = \dots\dots\dots$ 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.

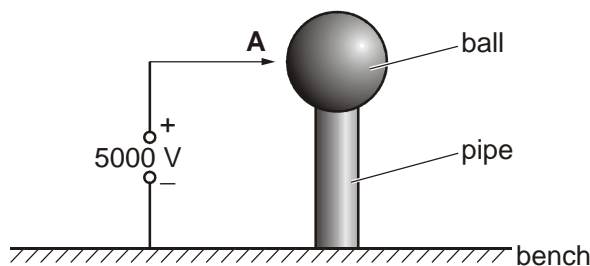


Fig. 1

- (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_0 on the ball. Give a suitable unit for your answer.

$Q_0 = \dots\dots\dots$ unit $\dots\dots$

[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_0 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 $1.2 \times 10^{-8} \text{ F}$ and a voltmeter as shown in Fig. 2.

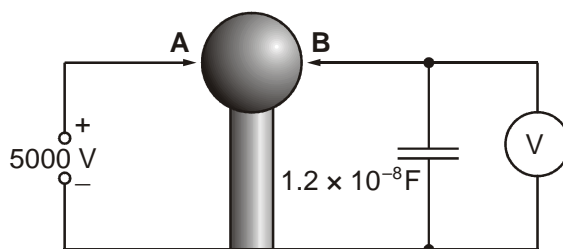


Fig. 2

- (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 $Q_0/1000$.

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.....

.....

.....

.....

.....

.....

[3]

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

$$V = \dots\dots\dots V$$

[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.

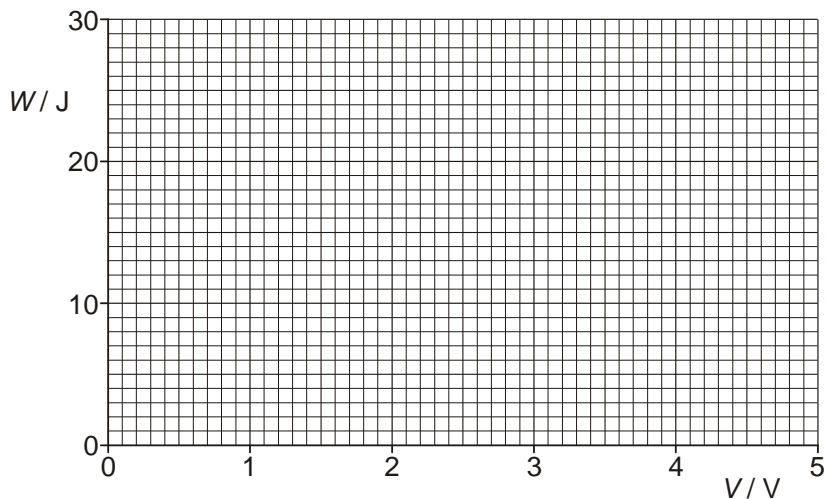


Fig. 1

[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.

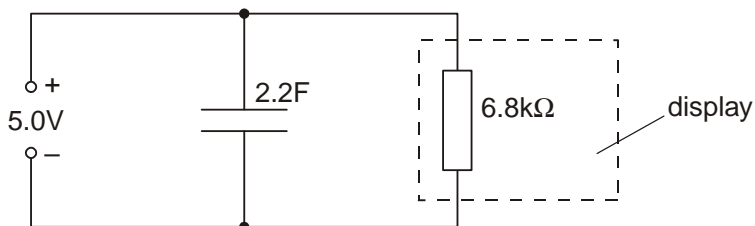


Fig. 2

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

$$V = V_0 e^{-t/RC}.$$

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

time = s

[2]

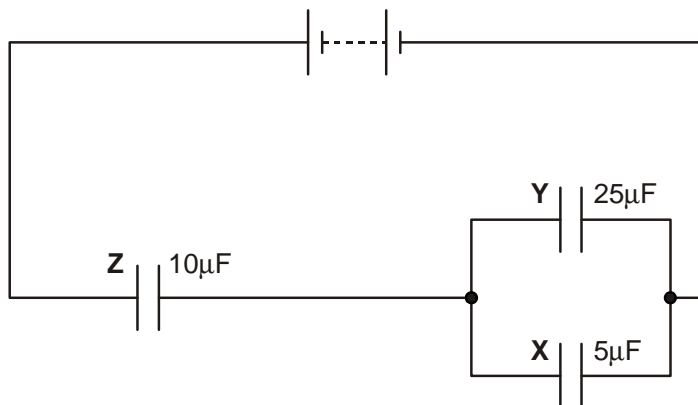
- (iv) Calculate the mean power consumption of the display during this time.

mean power = W

[1]

[Total 11 marks]

4. The charge stored in the capacitor **X** of capacitance $5\ \mu\text{F}$ in the circuit given in the figure below is $30\ \mu\text{C}$.



- (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			

(ii) Using data from the table find

1 the e.m.f. of the battery

$$\text{e.m.f.} = \dots\dots\dots \text{ V}$$

[1]

2 the total charge supplied from the battery

$$\text{charge} = \dots\dots\dots \mu\text{C}$$

[1]

3 the total circuit capacitance

$$\text{capacitance} = \dots\dots\dots \mu\text{F}$$

[1]

4 the total energy stored in all the capacitors.

$$\text{energy} = \dots\dots\dots \mu\text{J}$$

[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 $200\text{ k}\Omega$. The capacitors now discharge through this resistor. Calculate

(i) the time constant of the circuit

time constant = s

[2]

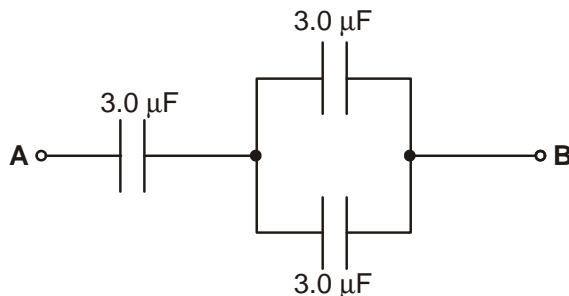
(ii) the fraction of the total charge remaining on the capacitors after a time equal to **four** time constants.

fraction remaining =

[2]

[Total 19 marks]

5. You are provided with a number of identical capacitors, each of capacitance $3.0\text{ }\mu\text{F}$. 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 $2.0 \mu\text{F}$.

[3]

- (ii) Draw a diagram in the space below to show how you can produce a total capacitance of $2.0 \mu\text{F}$ using **six** $3.0 \mu\text{F}$ capacitors.

[2]

[Total 5 marks]