UNIT G485	Module 2	5.2.1	Capacitors

- **PRACTICE QUESTIONS (4)**

1 A **2200 μF** capacitor is charged to a p.d. of **9.0 V** and then discharged through a **100 kΩ** resistor.

(a) Calculate : (i) The **initial charge** stored by the capacitor.
(ii) The **time constant** of the circuit.

(b) Calculate the p.d. after :
(i) A time equal to the **time constant.**
(ii) **300 s.**

2 **A 1000 μF** capacitor initially stores **20 mC** of charge. It is discharged through a **500 kΩ** resistor. How much **charge** does it store after **100 s** ?

3 A **2.2 μF** capacitor is charged to a p.d. of **6.0 V** and then discharged through a **100 kΩ** resistor. Calculate :

(a) The **charge** and **energy stored** in the capacitor at 6.0 V,

(b) The **p.d** across the capacitor **0.5 s** after the discharge started,

(c) The **energy stored** at this time.

4 A **4.7 μF** capacitor is charged to a p.d. of **12.0 V** and then discharged through a **220 kΩ** resistor. Calculate :

(a) The **energy stored** in this capacitor at 12.0 V,

(b) The **time taken** for the p.d. to fall from **12.0 V to 3.0 V,**

(c) The **energy lost** by the capacitor in this time.

5 A capacitor is discharged through a resistor. The current through the resistor varies according to the following equation : *11*

$$I = 0.5\ mA \times e^{-(0.02t)s}$$

(a) What is the **initial current** flowing through the resistor (when t = 0) ?

(b) Calculate the **current** flowing **after 30 s.**

(c) What is the **time constant** for this circuit ?

6 A **100 μF** capacitor is charged to **6.0 V.** It is then discharged through a **500 kΩ** resistor.

(a) What is the **TIME CONSTANT** for this circuit ?

(b) Write down equations of the form $x = x_0\, e^{-t/CR}$ to show how :

(i) The **charge stored** by the capacitor,

(ii) The **current** through the resistor,

(iii) The **p.d.** across the capacitor, vary with time.

7 A washing machine timer uses a capacitor and a resistor in series to switch off the heater after a pre-set time. A **1000 μF** capacitor is charged to a p.d. of **25 V,** and allowed to discharge through a resistor of **470 kΩ.** If the switch is triggered when the p.d. falls to **5 V,** calculate :

(a) The **time** for which the heater is on.

(b) The new value of resistor required to operate the heater for **25 minutes.**

- **HOMEWORK QUESTIONS**

1 A **5 μF** capacitor and a **20 μF** capacitor are connected (a) **in series** and (b) **in parallel** to a **100 V** d.c. supply.

Calculate the values of **charge** on and **p.d.** across **each capacitor** in each of the circuits.

2 A variable capacitor is set to **200 pF** and connected across a **6.0 V** cell.

(a) Calculate or state the values of the **stored charge Q**, the **capacitance C**, the **p.d. V** across the capacitor and the **energy E** stored in the capacitor.

(b) The capacitance is reduced to **100 pF** with the capacitor still connected to the cell. Which of the four quantities in (a) is **unchanged?** Calculate or state the new values of **Q, C, V and E.**

(c) The capacitor is disconnected from the cell. The capacitance is increased back to **200 pF.** Which value of the four quantities will remain **unchanged?** Calculate or state the final values of **Q, C, V and E.**

3 (a) One expression for the **energy stored, W** on a charged capacitor is :

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

Where **Q** is the charge stored and **V** is the potential difference across the capacitor. Show that two other expressions for the energy stored are :

$$W = \tfrac{1}{2} CV^2 \qquad \text{and} \qquad W = \tfrac{1}{2} Q^2/C$$

Where **C** is the capacitance of the capacitor.

(b) Draw a graph to show how the **energy W in J** stored on a **2.2 F** capacitor varies with the **potential difference V** from **0 to 5.0 V** across the capacitor.

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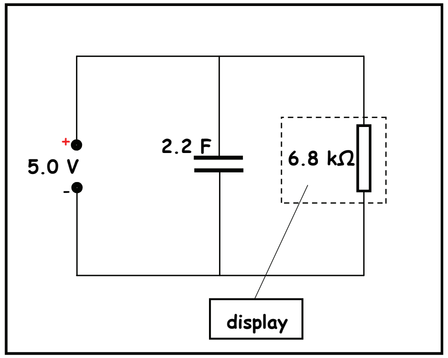
A **2.2 F** capacitor is connected in parallel with the power supply to a digital display for a video/DVD recorder. The purpose of the capacitor is to keep the display working during any disruptions to the electrical power supply.



The diagram opposite 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.**

Suppose the power supply is disrupted.

(a) Show that the **time constant** of the circuit is **more than 4 hours.**

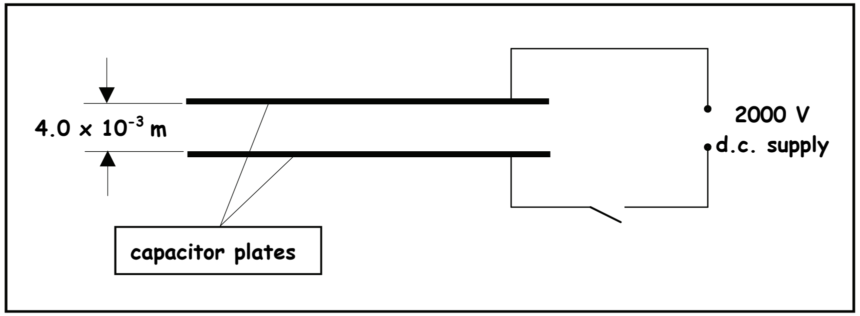
(b) Find the **energy lost in J** by the capacitor as it discharges from **5.0 V** to **4.0 V.**

(c) The **voltage** across the capacitor varies with **time t** according to the equation : $V = V_0 e^{-t/CR}$

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

(d) Calculate the **mean power consumption in W** of the display during this time.

5 The diagram below shows two large, insulated capacitor plates, separated by an air gap of **4.0×10^{-3} m**. The capacitance of the arrangement is **200 pF**. The plates are connected by a switch to a **2000 V** d.c. power supply. The switch is closed and then opened.



(a) Calculate :

(i) The magnitude of the **electric field strength** between the plates giving a suitable **unit** for your answer.

(ii) The magnitude in **μC** of the **charge** on each plate.

(iii) The **energy** in **μJ** stored in the capacitor.

(b) With the switch remaining **open**, the plates are pulled apart until their separation is **doubled**. The capacitor maintains the **same charge**. The electric field strength between the plates is **unchanged**. State the new :

(i) **Voltage** between the plates.

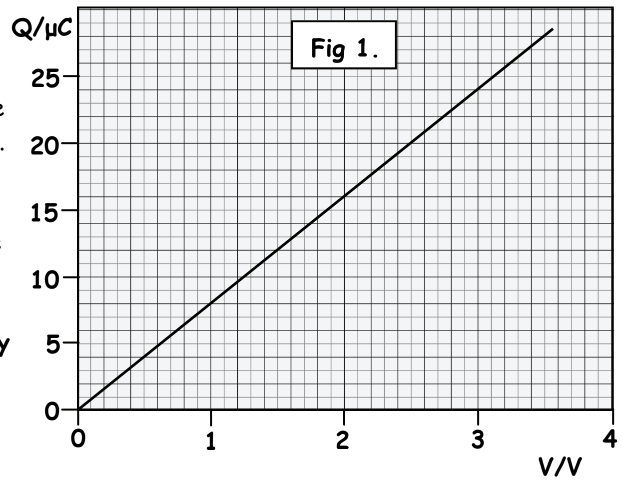
(ii) **Capacitance** of the plates.

(iii) **Energy stored** in the capacitor.

(c) The energy stored in the capacitor has increased. State the source of this energy.

(OCR A2 Physics - Module 2824 - January 2003)

(a) **Fig 1.** shows the graph of charge **Q** stored against potential difference **V** across a capacitor.



(i) Use the graph to find the **capacitance** of the capacitor.

(ii) Calculate the **energy** in the capacitor when it is charged to **3.0 V**.

(iii) The capacitor is discharged through a resistor. The charge falls to **0.37** of its initial value in a time of **0.040 s**. This is the **time constant** of the circuit. Calculate the **resistance** of the resistor.

(iv) Explain why the **discharge time** of the capacitor is **independent** of the **initial charge** on the capacitor.

(b) 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 **Fig 2.**

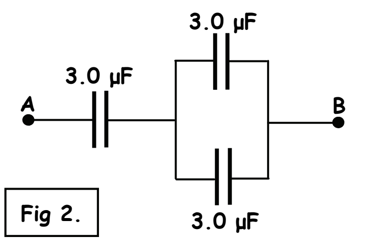


Fig 2.

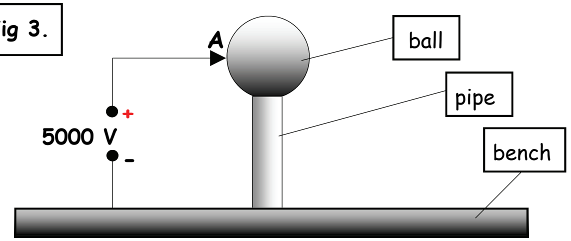
(i) Show that the total capacitance between the terminals **A** and **B** is **2.0 μF**.

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

(OCR A2 Physics - Module 2824 - January 2005)

7 **Fig 3.** 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 3.



(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 $\mathbf{1.2 \times 10^{-11}}$ **F.** Calculate the charge $\mathbf{Q_0}$ on the ball. Give a suitable **unit** for your answer.

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

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

(ii) Show that the **initial** value of the **leakage current** is about $\mathbf{4 \times 10^{-12}}$ **A.**

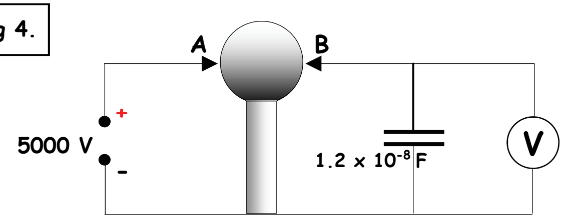
(iii) Suppose that the ball continues to discharge at the constant rate calculated in **(ii)**. Show that the charge $\mathbf{Q_0}$ would leak away in a time equal to the **time constant.**

(iv) Using the equation for the charge Q at time t, $Q = Q_0 e^{-t/CR}$

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

(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 $\mathbf{1.2 \times 10^{-8}}$ **F** and a voltmeter as shown in **Fig 4.**

Fig 4.



(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 is $\mathbf{Q_0/1000}$.

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