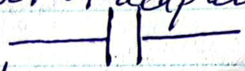
CAPACITORS.

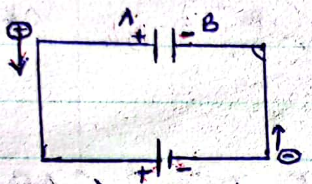
A capacitor is a device used for storing charge.
Basically a capacitor consists of a pair of parallel metal plates separated by an insulator known as a dielectric between the plates.
Each plate of a capacitor will store separate type of electric charge.
Dielectric materials may include air, glass or paper.

Symbol of a capacitor.



Mechanism of storing charge or charging a capacitor.

When a battery is connected to a capacitor, there is a momentary flow of current after which current stops flowing.



Direction of flow of electrons.

Electrons are drawn from point A by the positive terminal of the battery and are deposited at the action of the negative terminal.
After a short time, the potential of A will be equal to that of the positive terminal of the battery and potential at B equals to that of the negative terminal of the battery.
At this stage, the p.d across the capacitor becomes equal to that of the battery and no current flows.
1 The capacitor is now fully charged.

NB. Energy changes in charging a capacitor include chemical, heat and electrical energy which is stored in the plates of a capacitor.

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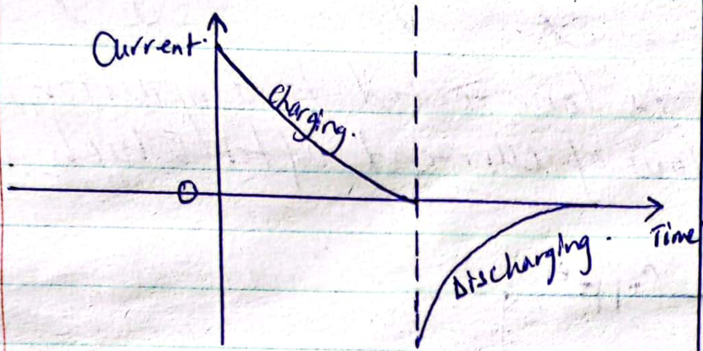
Discharging a capacitor.

When the battery is disconnected and the plates are joined together by a wire, electrons flow back from the -ve plate to the +ve plate until the +ve charge on it is completely neutralized.

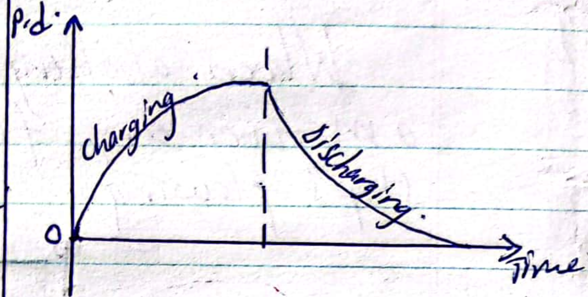
A current thus flows for a short time in the wire in the opposite direction and then stops.

At this stage charges on the capacitor plates is Zero. The capacitor is fully discharged.

CURRENT AGAINST TIME.

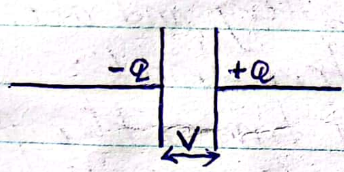


P.d AGAINST TIME.



CAPACITANCE OF A CAPACITOR (C)

Is defined as the charge stored per unit p.d across its plates.



This is the ratio of the magnitude of charge on either ~~of the~~ plates of a capacitor to the p.d betn the plates of the capacitor.

By definition.
$$C = \frac{\text{Charge on one plate of capacitor}}{\text{P.d across the capacitor}}$$

$$C = \frac{Q}{V}$$

Where Q is the charge stored in the capacitor plates when connected to p.d V.

The SI unit of capacitance is the Farad (F).

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FARAD.

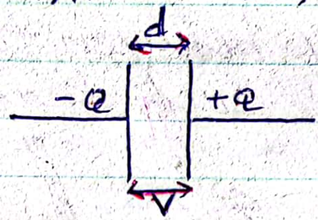
The farad is the capacitance of a capacitor which stores one coulomb of charge when a p.d across the capacitor is one volt.

Derived Units of Capacitance

Microfarad $1\mu F = 1\times10^{-6}F$.
Nano Farad $1nF = 1\times10^{-9}F$
Picofarad $1pF = 1\times10^{-12}F$.

Use of capacitor
- Energy storage
- power conditioning
- Remote sensing
- Engine starters
- Signal processing devices

THE CAPACITANCE OF A PARALLEL PLATE CAPACITOR



Suppose that when a parallel plate capacitor is charged to a p.d V the charge on each plate is Q

From $C = \dfrac{Q}{V}$ - - - - - (i)

The uniform electric field intensity E between the plates is given by

$$E = \frac{V}{d} \quad \text{- - - - (ii)}$$

From Gauss's law, Electric field intensity E is also given by

$$E = \frac{\sigma}{\varepsilon}$$

Where σ is the charge density, given by

$\sigma = \dfrac{Q}{A}$.

Therefore $E = \dfrac{Q}{\varepsilon A}$. - - - (iii)

$$\frac{V}{d} = \frac{Q}{\varepsilon A}$$

$$\frac{\varepsilon A}{d} = \frac{Q}{V} \quad \text{- - - - (IV)}$$

Combine 1 and 4

ε_0 – The.

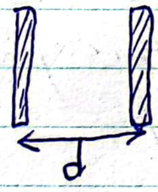
$$\boxed{C = \frac{\varepsilon A}{d}}$$

Where ε is the permittivity of the dielectric material.

If the space between the plates is vacuum or air $\varepsilon = \varepsilon_0$ such that

$$C_0 = \frac{\varepsilon_0 A}{d}$$

Qn. Calculate the capacitance of a pair of parallel circular discs each diameter 16cm with an air gap of 5mm. assume $\varepsilon_0 = 8.85 \times 10^{-12} Fm^{-1}$.



$d = 16cm$.
$r = 8cm = 0.08m$.

$A = \pi r^2$

$= \frac{22}{7} \times 0.08 \times 0.08$

$A = 0.02011 m^2$.

From $C_0 = \frac{\varepsilon_0 A}{d}$

$$C_0 = \frac{8.85 \times 10^{-12} \times 0.02011}{\cancel{0.16}\ 5 \times 10^{-3}}$$

$= \cancel{1.112 \times 10^{-12}} F$ $3.55947 \times 10^{-11} F$

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2. Given that capacitance of the capacitor of $4\mu F$ and charge on the plate is $5\mu C$, Find the p.d across the plate.

$$C = \frac{Q}{V}$$

$$4\times10^{-6} = \frac{5\times10^{-6}}{V}$$

$$V = \frac{5\times10^{-6}}{4\times10^{-6}}$$

$$= 1.25V$$

Qn ~~What~~ capacitance of a capacitor of $14\mu F$ and the p.d across the plates is 12V.

3. Calculate the capacitance of a parallel plate capacitor whose plates are 10cm by 10cm separated by an air gap of 5mm. $C = 1.77\times10^{-11}F$

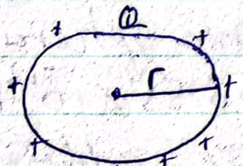
4. A parallel plate capacitor consists of two separate plates each of size 25cm and 3.0mm apart. If a p.d of 200V is applied to the capacitor. Calculate the charge in the plates. $Q = 3.708\times10^{-8}C$ ($3.6875\times10^{-8}C$)

5. The plates of a parallel plate capacitor each of area 2.0 cm^2 are 5mm apart. The plates are in vacuum and a potential difference of 10,000V is applied across the capacitor. Find the magnitude of the charge on the capacitor.

CAPACITANCE OF AN ISOLATED SPHERE:

$\frac{Q}{V} = C$

Consider an isolated sphere of radius r. If the conductor is given charge Q, then its p.d V is:



$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

Where ε_0 is the permittivity of free space.

$$4\pi\varepsilon_0 r = \frac{Q}{V} \quad \text{But } C = \frac{Q}{V}$$

$$\therefore \boxed{C = 4\pi\varepsilon_0 r}$$

$V = \frac{Q}{C}$

Qn: Calculate the capacitance of the earth given that the radius of the earth is 6.4×10^{6} m

Ans From $C = 4\pi\varepsilon_0 r$.

$= 4 \times \frac{22}{7} \times 8.85 \times 10^{-12} \times 6.4 \times 10^{6}$.

K H D M d c m

1 0 0 0

4.45×10^{-9}

1m = 1000mm

x = 80,000

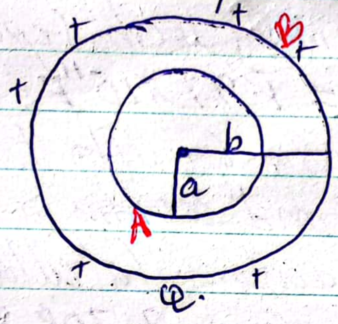
1000x = 80,000 / 1000

$C = 7.1205 \times 10^{-4}$ F

$80/2 = 40$

CAPACITANCE OF A CONCENTRIC SPHERE.

Consider two concentric spheres A and B each of radius a and b respectively.



$$V = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{a} - \frac{1}{b}\right)$$

$$\frac{V}{Q} = \frac{1}{4\pi\varepsilon_0}\left(\frac{b-a}{ab}\right)$$

$$\frac{Q}{V} = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right).$$

$$\boxed{C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)}$$

$$\frac{V}{1} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{b-a}{ab}\right)$$

$$\frac{V}{Q} = \frac{1}{4\pi\varepsilon_0}\left(\frac{b-a}{ab}\right)$$

$$\frac{Q}{V} = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$$

$$C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$$

Qn1 Find the capacitance of concentric sphere of radius 9cm and 10cm. Given that $\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} [1.0×10^{-10} F]

Qn2. Given two concentric sphere of radius 5cm and 2cm separated by material of permittivity 8.0×10^{-11} Fm^{-1}. Calculate the capacitance [$C = 3.352 \times 10^{-11}$ F]

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RELATIVE PERMITTIVITY / DIELECTRIC CONSTANT.

It is defined as the ratio of capacitance of a capacitor when the insulating material (dielectric) between its plates to the capacitance of the same capacitor with a vacuum between its plates.

$$\varepsilon_r = \frac{C}{C_o} \quad \text{---(1)}$$

$C \leftrightarrow C_o$

But $C = \frac{\varepsilon A}{d}$ and $C = \frac{\varepsilon_o A}{d}$ put into (1)

$$\varepsilon_r = \frac{\frac{\varepsilon A}{d}}{\frac{\varepsilon_o A}{d}}$$

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_o} \quad \text{-----------2}$$

$$\boxed{\varepsilon = \varepsilon_r \varepsilon_o}$$

Relative permittivity can also be defined as the ratio of the permittivity of a material to permittivity of free space.

Qn1 A parallel plate capacitor was charged to 100V and then isolated. When a sheet of a dielectric is inserted betn its plates, the P.d decreases to 30V. Calculate the dielectric constant of the dielectric.

Soln.

By law of conservation of charge

$Q_o = Q$.

$C_o V_o = CV$

$\frac{V_o}{V} = \frac{C}{C_o}$

$\varepsilon_r = \frac{100}{30} = 3.33$

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2. A 2MF capacitor that can just withstand a p.d of 5000V uses a dielectric with a dielectric constant 6 which breaks down if the electric field strength in it exceeds $4\times10^{7}Vm^{-1}$ Find the
(i) Thickness of the dielectric.
(ii) Effective area of each plate.
(iii) Energy stored per unit volume of dielectric

soln

(i) Thickness.

$$E = \frac{V}{d}$$

$$4\times10^{7} = \frac{5000}{d}$$

$$= \frac{5000}{4\times10^{7}}$$

$$= 1.25\times10^{-4}m$$

(ii)

$$C = \frac{\varepsilon A}{d}$$

but

$$\varepsilon = \varepsilon_r \varepsilon_0$$

$$2\times10^{-6} = \frac{8.85\times10^{-12}\times A\times6}{1.25\times10^{-4}}$$

$$A = \frac{2\times10^{-6}\times1.25\times10^{-4}}{6\times8.85\times10^{-12}}$$

$$A = 4.71m^2$$

(iii)

$$\frac{Energy}{volume} = \frac{\frac{1}{2}CV^2}{Ad} = \frac{\frac{1}{2}\times2\times10^{-6}\times5000^2}{4.71\times1.25\times10^{-4}}$$

$$= 4.2463\times10^{4}Jm^{-3}$$

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3. A parallel plate capacitor has an area of $100cm^2$, plate separation of 1 cm and charged initially with the p.d of 100V supply, It's disconnected and a slab of dielectric 0.5cm thick and relative permittivity 7 is then placed betn plates.

a Before the slab was inserted calculate;

(i) Capacitance

(ii) Charge on the plates

(iii) Electric field strength in the gap between plates.

Soln:

(i) $C = \frac{\varepsilon_0 A}{d}$

$= \frac{8.85 \times 10^{-12} \times 100 \times 10^{-4}}{1 \times 10^{-2}}$

$C = 8.85 \times 10^{-12} F$

(ii) $Q = CV$

$Q = 8.85 \times 10^{-12} \times 100$

$= 8.85 \times 10^{-10} C$

(iii) $E = \frac{V}{d} = \frac{100}{1 \times 10^{-2}}$

$= 10,000 \, Vm^{-1}$

b After the dielectric was inserted, find.

(i) Electric field strength.

(ii) p-d betn the plates

(iii) Capacitance.

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soln.

b(i) $E = \frac{Q}{\varepsilon A} = \frac{8.85 \times 10^{-10}}{7 \times 8.85 \times 10^{-12} \times 100 \times 10^{-4}}$

But $\varepsilon = \varepsilon_r \varepsilon_0$

$= 1.428 \times 10^{3}\ Vm^{-1}$

(ii) $E = \frac{V}{d}$

$V = Ed$

$= 1.428 \times 10^{3} \times 0.5 \times 10^{-2}$

$= 7.14 V$

(iii) Capacitance $C = \frac{\varepsilon_0 A}{d}$

$= \frac{7 \times 8.85 \times 10^{-12} \times 100 \times 10^{-4}}{0.5 \times 10^{-2}}$

$= 1.239 \times 10^{-10} F$

DIELECTRIC STRENGTH.

It is the Maximum electric field Intensity an insulate can withstand without Conducting.

OR

Is the Maximum potential gradient an Insulator can withstand without Conducting.

USES OF DIELECTRIC.

* It should Increase the capacitance of a capacitor.
* It is used to separate the plates of a capacitor.
* It reduces the change of dielectric breakdown.

QUALITIES OF A GOOD DIELECTRIC.

It should have a large dielectric constant.

It should have a high dielectric strength.

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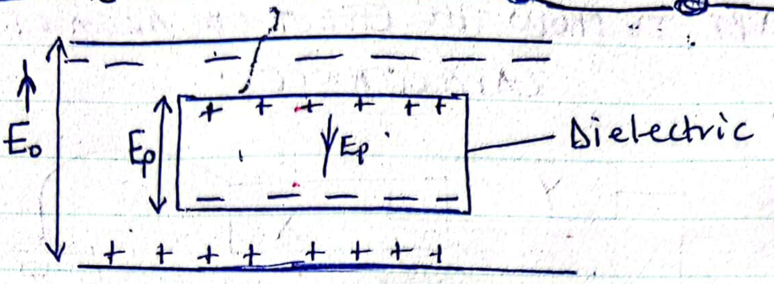
ACTION OF A DIELECTRIC.



The molecules of the insulator get polarized. charge inside the material cancel each other's influence but the surface develop charge opposite to that on the near plate.

Since charges are bound, electric field Intensity E_p develops betn the opposite faces of the Insulator in opposition to the applied field E_0.

The resultant electric field Intensity between the plates is thus reduced. But electric field Intensity $E = V/d$ thus p.d betn the plates reduces, since $C = Q/V$ hence the capacitance increases.

NOTE: If a Conductor Instead of a dielectric is placed between the plates of a charged capacitor, charge reduces to zero on the plates.

This is because electrons move from the negative plate to the positive plate to neutralize the positive charge.

FACTORS THAT AFFECT CAPACITANCE OF A CAPACITOR

Capacitance of a capacitor is affected by;

(i) Area of overlap of the plates.
(ii) Distance of separation of the plates.
(iii) Presence of a dielectric.

$$C = \frac{\varepsilon A}{d}$$

Here

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1 EXPT TO SHOW THE EFFECT OF AREA OF OVERLAP ON CAPACITANCE.

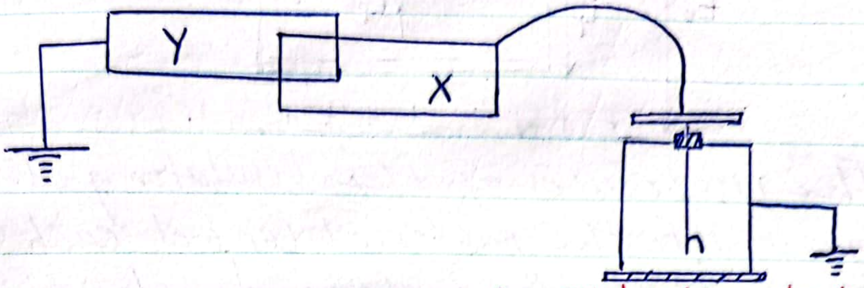


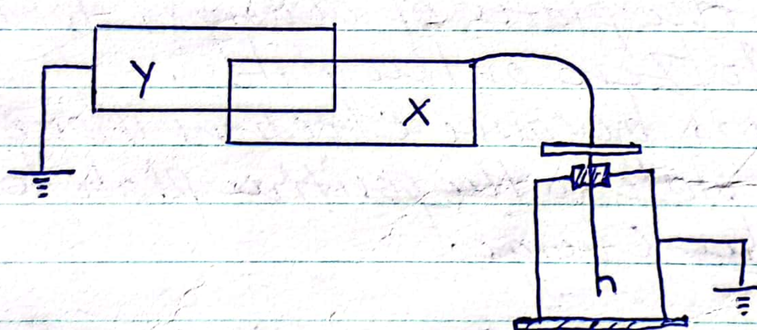
Plate X is charged and connected to the electroscope and divergence of the leaf of the electroscope noted.

Plate Y is then displaced upwards relative to X and the divergence of the leaf is seen to increase and it corresponds to the p.d V.

The p.d between the plates has increased.

Since $C = \frac{Q}{V}$, capacitance has decreased with decrease in area of overlap and $C \propto A$

2. EXPT TO SHOW THE EFFECT OF PLATE SEPARATION ON CAPACITANCE.



XY are metal plates near each other but not touching.

Plate X is charged and divergence of the leaf is noted.

Plate Y is then moved closer to X and the divergence of the leaf is seen to decrease.

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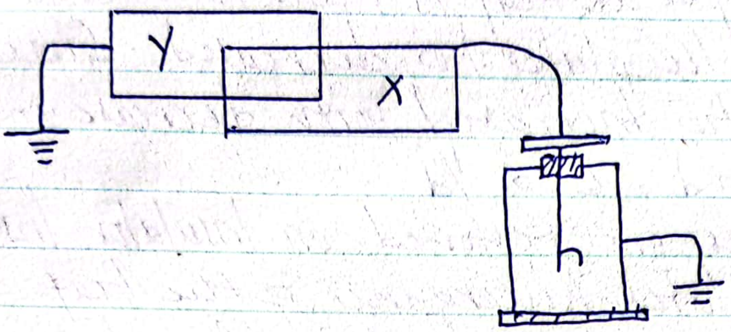
The p.d V between the plates has decreased.
Since $C = \frac{Q}{V}$, capacitance has increased with decrease in plate separation and $C \propto 1/d$

3 EXPT TO SHOW THE EFFECT OF DIELECTRIC ON CAPACITANCE



X Y are metal plates near each other but not touching.
plate X is charged and divergence of the leaf is noted.
Insert a dielectric material between the plates and the divergence of the leaf is seen to decrease.
The p.d between the plates has decreased.
Since $C = \frac{Q}{V}$, capacitance has increased and $C \propto \varepsilon$

INVESTIGATION OF ALL FACTORS THAT AFFECT CAPACITANCE OF A PARALLEL PLATE CAPACITOR.

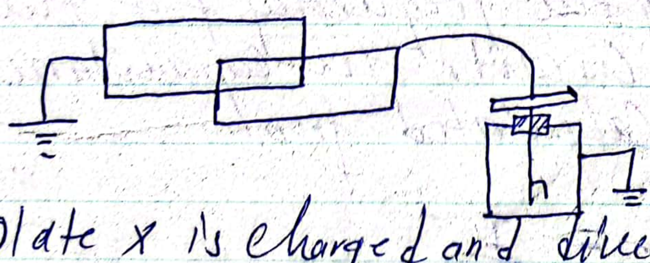


plate X is charged and divergence of the leaf is noted.
plate Y is then displaced upwards relative to X and the divergence of the leaf is seen to increase.

The p.d betn the plates has Increased. Since $C = \frac{Q}{V}$, capacitance has decreased with decrease in area of over lap. and $C \propto A$.

plate y is now restored to its Initial position.

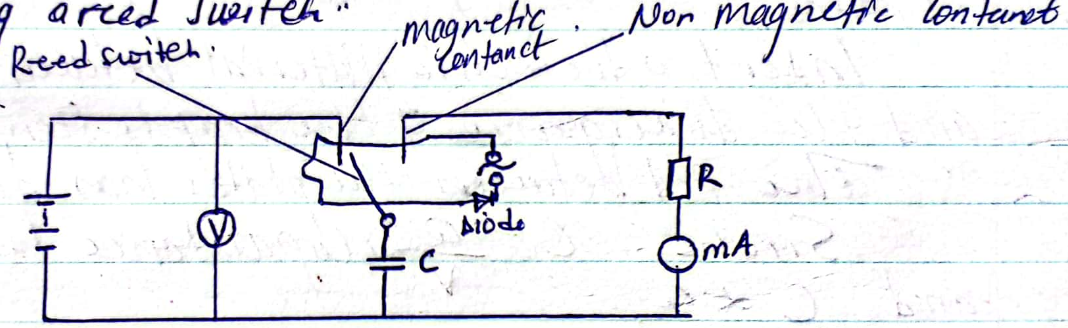
plate y is then Moved Closer to x and the divergence of the leaf is seen to decrease. The p.d betn. the plates has decreased. Since $C = \frac{Q}{V}$. Capacitance has Increased with decrease in plate separation and $C \propto 1/d$

The plates are restored, an Insulator Inserted between the plates, Divergence of the leaf decreases.

Since $C = Q/V$, Capacitance has Increased. and $C \propto \varepsilon$.

• MEASUREMENT OF CAPACITANCE.

(a) Using a reed Switch.



The circuit is Connected as above.

The switch is Closed, the Micrometer reading I is taken together with the Voltmeter reading.

Knowing the frequency f of the AC in the reed switch circuit, the capacitance of the capacitor is Calculated from

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

Q. A capacitor filled with a dielectric is charged and then discharged through a milliammeter. The dielectric is then withdrawn half way and the capacitor charged to the same voltage, and discharged through the milliammeter again, Show that relative permittivity ε_r of the dielectric is given by $\varepsilon_r = \frac{I}{2I'-I}$.

Where I, and I' are the readings of the milliammeter respectively.

Solution:

From $C = \frac{I}{fV}$ But $C = \frac{\varepsilon A}{d}$.

$$I = CfV$$

$$I = \frac{\varepsilon A}{d} fV \quad \text{---(i)}$$

When the dielectric is withdrawn half way the area is halved on both portions, one with a dielectric and the other without a dielectric contributes to current:

$$I' = \frac{\varepsilon A f V}{2d} + \frac{\varepsilon_0 A f V}{2d}$$

$$2I' = \frac{\varepsilon A f V}{d} + \frac{\varepsilon_0 A f V}{d}$$

$$2I' = I + \frac{\varepsilon_0 A f V}{d} \quad \text{---(ii)}$$

eq (i) ÷ (ii)

$$\frac{I = \frac{\varepsilon A f V}{d}}{2I' = I + \frac{\varepsilon_0 A f V}{d}}$$

$$\frac{I}{2I'-I} = \frac{\frac{\varepsilon A \cancel{fV}}{\cancel{d}}}{\frac{\varepsilon_0 \cancel{fV}}{\cancel{d}}}$$

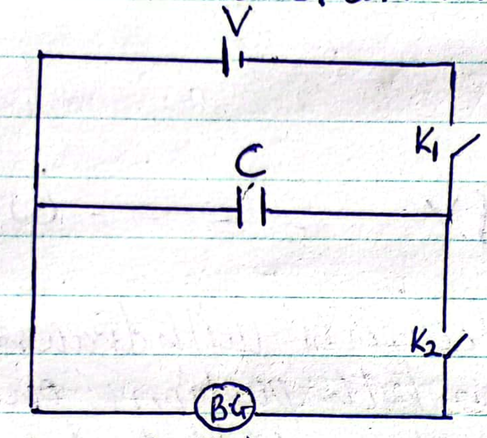
$$\frac{I}{2I'-I} = \frac{\varepsilon}{\varepsilon_0}.$$ But $\varepsilon_r = \varepsilon / \varepsilon_0$.

$$\varepsilon_r = \frac{I}{2I'-I}.$$ as required.

b. Using a Ballistic Galvanometer:

$\frac{C_s}{C} = \frac{\theta_s}{\theta}$

$C\theta_s = \frac{C_s \theta}{\theta_s}$



B·G – Ballistic galvanometer.

The circuit is connected as shown above

First with a standard capacitor of capacitance, C_s switch K_1 is closed and after a short time it is opened.

Switch K_2 is now closed and the deflection of the B-G θ_s is noted.

The capacitor is replaced with the test capacitor of capacitance C and the procedure repeated.

The deflection θ of B-G is noted.

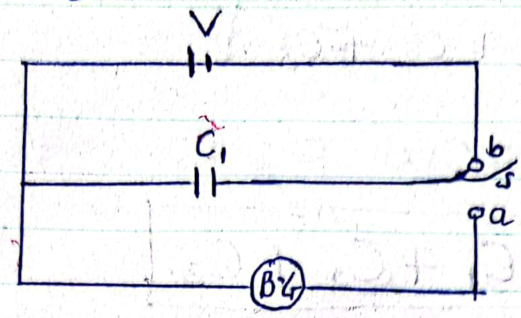
Capacitance, C is calculated from

$$\frac{C_s}{C} = \frac{\theta_s}{\theta} \qquad C = \frac{\theta\, C_s}{\theta_s}.$$

$$\frac{C_s}{\theta_s} = \frac{C}{\theta}$$

$$C = \frac{C_s \theta}{\theta_s}.$$

COMPARING CAPACITANCE USING A B.G



The capacitor of capacitance C_1 is charged by connecting S to b. After sufficiently charging, S is now connected to a.

The deflection θ_1 of the B.G is noted.

The capacitor of capacitance C_1 is then replaced by one of capacitance C_2.

The capacitor is charged by connecting S to b.

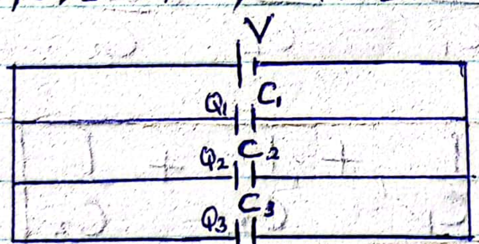
It is then discharged through a B.G by connecting S to a. The deflection θ_2 of the B.G is noted.

Then $\dfrac{C_1}{C_2} = \dfrac{\theta_1}{\theta_2}$

END

CAPACITOR NETWORKS.

a. Capacitors in Parallel.



For capacitors connected in parallel p.d across the plate of capacitors is the same.

$$Q = Q_1 + Q_2 + Q_3.$$

But $Q_1 = C_1V$, $Q_2 = C_2V$ and $Q_3 = C_3V$.

$$Q = C_1V + C_2V + C_3V.$$ Divide by V.

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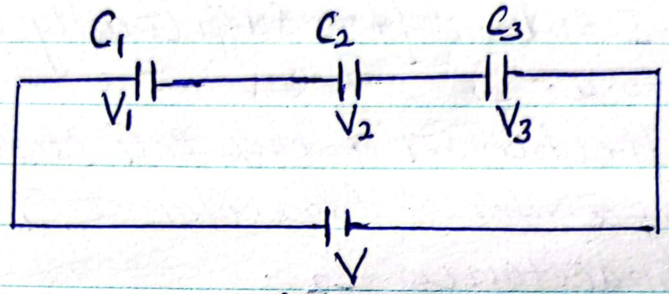
$$\frac{Q}{V} = C_1 + C_2 + C_3 .$$

But $Q/V = C$.

$$\boxed{C = C_1 + C_2 + C_3.}$$

b) Capacitors in Series..



For Capacitors Connected in series Charge stored on the plates of Capacitors is the same.

$$V = V_1 + V_2 + V_3 .$$

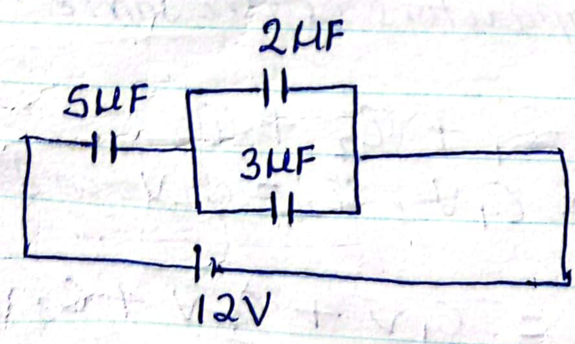
But $V_1 = \frac{Q}{C_1}$ $\quad V_2 = \frac{Q}{C_2}$ $\quad V_3 = \frac{Q}{C_3}$.

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} .$$

$$= \boxed{\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

Examples.

1



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A battery of emf 12V is connected across a system of capacitor. Calculate the total energy stored in capacitor network.

Soln

Capacitance in parallel:

$$C_p = 2\mu F + 3\mu F$$
$$= 5\mu F$$

Now total capacitance: $\frac{1}{5\times10^{-6}} + \frac{1}{5\times10^{-6}} = \frac{1}{C}$

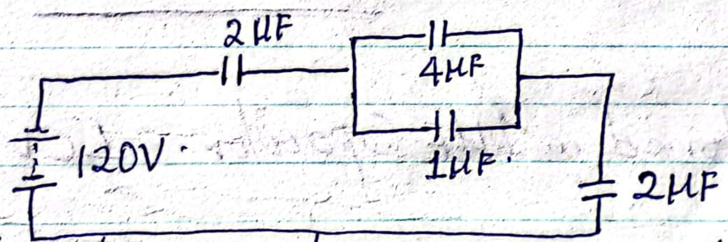
$$C = \frac{5\times10^{-6} \times 5\times10^{-6}}{10\times10^{-6}}$$

$$C = 2.5\times10^{-6} F$$

Total Energy $= \frac{1}{2} CV^2$

$$= \frac{1}{2} \times 2.5\times10^{-6} \times 12^2$$

$$= 1.8\times10^{-4} J$$

2. 

The diagram above shows a network of capacitors connected to a 120V supply. Calculate the

(i) Charge on the 4μF capacitor.

(ii) Energy stored in 1μF capacitor.

Soln:

Capacitance in parallel
$= 4\mu F + 1\mu F$
$= 5\mu F$. 4

Total capacitance in series

$$\frac{1}{C} = \frac{1}{5} + \frac{1}{2} + \frac{1}{2}$$ 4

$$\frac{1}{C} = \frac{2+5+5}{10} = \frac{12}{10}$$

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$$C = \frac{10}{12} \times 10^{-6} F$$

$$= 8.33 \times 10^{-7} F$$

(i) charge on the $4\mu F$

$$C = \frac{Q}{V}$$

Total charge

$$Q = CV$$
$$= 8.33 \times 10^{-7} \times 120$$
$$= 1.0 \times 10^{-4} C$$

01

P.d V across the prallel $V_p = \frac{Q}{C}$

$$= \frac{1.0 \times 10^{-4}}{5 \times 10^{-6}}$$
$$= 20V$$

01

Charge on $4\mu F$

$$Q = CV$$
$$= 4 \times 10^{-6} \times 20$$
$$= 8.0 \times 10^{-5} C$$

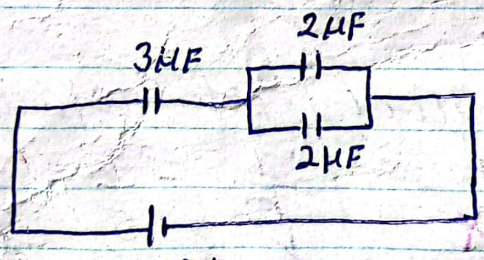
01

(ii) Energy stored in $1\mu F$ Capacitor $= \frac{1}{2} CV^2$

$$= \frac{1}{2} \times 1 \times 10^{-6} \times 20^2$$
$$= 2 \times 10^{-4} J$$

01

3



$$\varepsilon_3 = \varepsilon_r C_0$$
$$= 3 \times 3 \mu F$$
$$= 9 \mu F$$

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Calculate energy stored in a system of capacitors, if the space betn the 3μF is filled with an insulator of dielectric constant 3 and capacitors are fully charged.
$13.8 \times 10^{-3} J$

4. A 47μF capacitor is used to power the flash gun of a camera. The average power output of the gun is 4.0KW for a duration of the flash which is 2.0ms. Calculate the,
(i) p.d betn the terminals of the capacitor immediately before a flash.
(ii) Maximum charge stored by the capacitor.
(iii) Average current provided by the capacitor during a flash.

Solution:

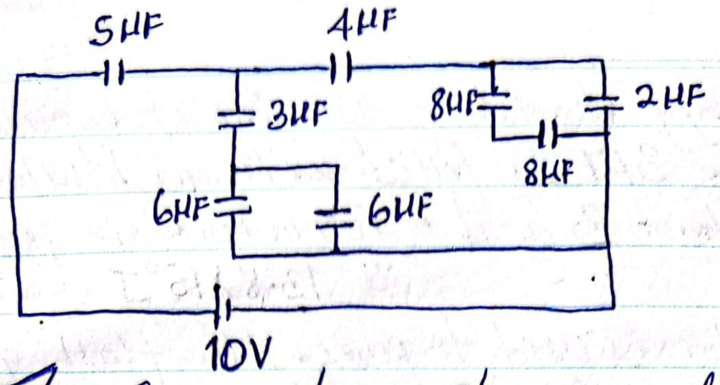
$$Energy = Pt$$
$$\frac{1}{2}CV^2 = 4000$$
$$\frac{1}{2} \times 47 \times 10^{-6} \times V^2 = 4000 \times 2 \times 10^{-3}$$
$$2.35 \times 10^{-5} V^2 = 4000 \times 2 \times 10^{-3}$$
$$V^2 = \frac{4000 \times 2 \times 10^{-3}}{2.35 \times 10^{-5}}$$
$$V^2 = 170212766$$
$$V = \sqrt{170212766}$$
$$= 583.5V$$

(ii) $$Q = CV$$
$$= 47 \times 10^{-6} \times 583.5$$
$$= 2.74 \times 10^{-2} C$$

(iii) $$I = Q/t = \frac{2.74 \times 10^{-2}}{2 \times 10^{-3}}$$
$$= 13.7A$$

Classic

5.



The figure above shows a network of capacitors connected to a 10V battery. Calculate the total energy stored in the network. $C = \frac{120}{49}\mu F$ OR $2.45 \times 10^{-6} F$.

Energy stored $= 1.224 \times 10^{-4} J$

ENERGY STORED IN A CAPACITOR..

Suppose the p-d between the plates at some instant was V. When a small charge of +dq is transferred from the negative plate to the positive plate, the p-d increases by δv

Work done to transfer charge

$$dw = (v + dv)dq$$

$$dw = v\,dq$$

But $V = \frac{Q}{C}$

$$dw = \frac{q}{c}\,dq$$

Total work done to charge the capacitors to Q is

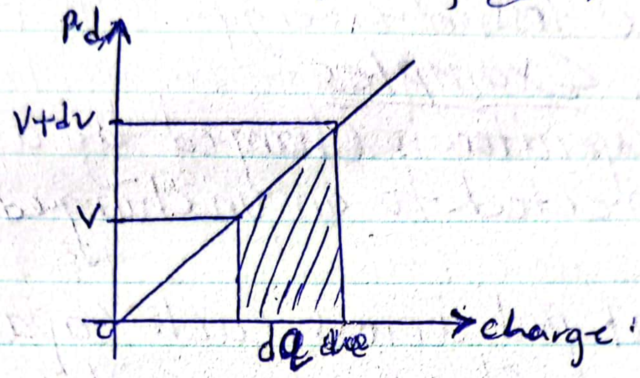
$$W = \int_0^Q \frac{q}{c}\,dq = \frac{1}{2}\frac{Q^2}{C}$$

But $Q = CV$

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

Alternatively.

from $q = CV$.
V is proportional to q, giving a graph of V against Q.



$\frac{1}{2}h(a+b)$
$\frac{1}{2}dq(V+V+dV)$
$\frac{1}{2}(2V+dV)dq.$
$\frac{1}{2}(2V+dV)dq$
$\frac{(2V+dV)}{2}dq$
$=\frac{2Vdq+dVdq}{2}$
$=\frac{2Vdq}{2}$

Area of the Shaded part $= \frac{1}{2}(V+V+dV)dq$.

Work done to Increase Charge on the Capacitor from $q=0$ to $q=Q$.

Work done W = Average Voltage × Charge.

$$= \frac{1}{2}(0+V)Q.$$

$$= \frac{1}{2}QV \qquad \text{But } Q = CV.$$

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

$\frac{1}{2}QV$
$\frac{1}{2}CV^2$
$Q=CV$
$V=\frac{Q}{C}$
$\frac{1}{2}C\cdot\frac{Q^2}{C^2}$
$=\frac{1Q^2}{2C}$

JOINING TWO CAPACITORS.

When two capacitors are joined together,
→ Charge flows until p.d across the Capacitors is the same.
→ Total charge on the Circuit is Conserved.
→ Capacitors are in parallel i.e. $C = C_1 + C_2$.

NOTE:

There is loss of energy when capacitors are joined together. This is because charge flows until the p.d across the capacitor is the same.
The flow of charge results in heating of the wire and hence loss in energy.

Examples

1 A $5\mu F$ capacitor is charged by a 40V supply and then connected to an uncharged $20\mu F$ capacitor. Calculate

(i) Final p.d across each capacitor.
(ii) Final charge on each.
(iii) Energy lost. **0.0032J**

Solution.

(i) $C = C_1 + C_2$

$= 5\times10^{-6} + 20\times10^{-6}$

$= \underline{2.5\times10^{-5}\,F}$

Charge before = Charge after connection

$Q_1 + Q_2 = Q$

$C_1V_1 + C_2V_2 = CV$

$5\times10^{-6}\times40 + 20\times10^{-6}\times0 = 2.5\times10^{-5}\times V$

$V = \underline{8V}$

(ii) $Q = Q_1 + Q_2$

$= C_1V_1 + C_2V_2$

$= 5\times10^{-6}\times40 + 20\times10^{-6}\times0$

$= \underline{2\times10^{-4}\,C}$

But $Q = CV$

$Q = 2.5\times10^{-4}\times8$

$= \underline{2\times10^{-4}\,C}$

Kyanaisoree
Fq 25
$C_4 = 3$