Equipotential surface is a charged body over which all the points are at the same electric potential and work done in moving a charge on the surface from one point to another is zero. The direction of force is always at right angles to equipotential surface. This implies that there is no component of electric field along the surface.

Examples:

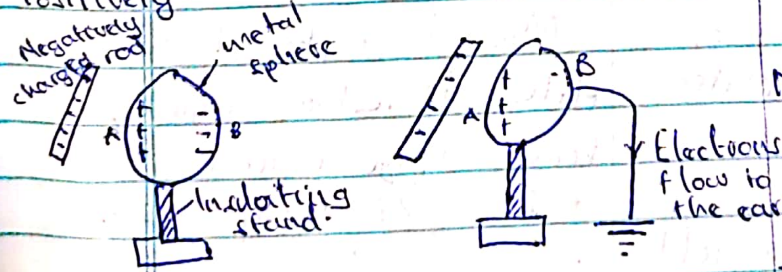
- The surface of a charged conductor
- The inside of a hollow charged conductor.

Coulomb's law

It states that the force between any two point charges is directly proportional to the product of the ~~exag~~ magnitude of the charges and inversely proportional to the square of distance of separation between the charges.

Charging a conductor by induction

Positively.



Metal sphere on an insulating stand is placed near a negatively charged rod. Free electrons are repelled to the far end of the sphere. The sphere is earthed while the charged rode still in position. Free electrons move from the sphere to the earth. The earthing wire is removed while the charged body still in position. The charge body is removed and charges distributes themselves all over the sphere. Hence the metal sphere is now positively charged.

CAPACITORS:

Capacitors is the device that stores charge.

Industrial applications of capacitors.

- Prevent sparking in gaps of large switches.
- Tuning radio and T.V circuit
- Smoothening and filtering process in the rectification process. Used in camera flash to source charge

Capacitance (C)

Is the ratio of magnitude of charge stored on either plates to the potential difference between the plates.

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

NB: Capacitance of a conductor is the ratio of magnitude of charge stored by a conductor to the potential difference across its ends

S.I units is farad (F)

Farad is the capacitance of a capacitor when the p.d across the plates is 1V and the magnitude of charge on either plates

Micro farad is capacitance of a capacitor when the p.d across the plates is 1V and the magnitude of charge on either plates is 1μC.

Dielectric is an insulator placed between plates of a capacitor

Desired properties of a dielectric

- Should have high dielectric constant ~~strength~~
- Should have high dielectric strength.

Examples of dielectric

rubber, paper, Ebonite, Oil

Dielectric constant.

Is the ratio of permitivity of a material to permitivity of free space.

$$\varepsilon_r = \varepsilon / \varepsilon_o$$

OR.

Is the ratio of capacitance of a capacitor when there is a dielectric between its plates to the capacitance of the same capacitor with a vaccum or free space between it plates

Dielectric strength

Is the maximum electric field intensity beyond which the insulating dielectric material breaks down.

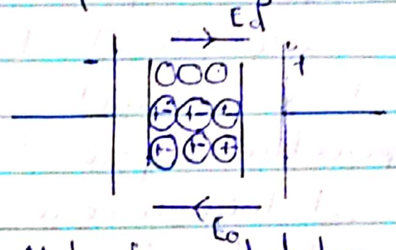
S.I unit is NC^{-1}

Uses of a dielectric

- Increases dielectric strength
- Separates plates of a capacitor
- Increases capacitance of a capacitor

Actions of the dielectric

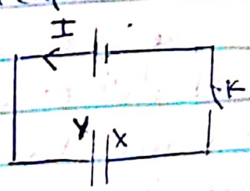
- Explain the action of dielectric
- Explain the effect of inserting a dielectric on $\vec{E}$, p.d, charge and capacitance



* Molecules of dielectric are polarised.
* Sides of a dielectric acquire charges opposite to adjacent plates.
* An electric field is created in a dielectric to oppose the applied field
* The resultant electric field intensity reduces to $E_o - E_d$.
* Therefore electric field intensity reduces.
* Therefore the potential difference reduces.

- More charge flows to the plates to restore original p.d hence charge increase.
- But $C = Q/V$, therefor $C \propto 1/V$ hence capacitance increase.

Explaining the charging process of a capacitor

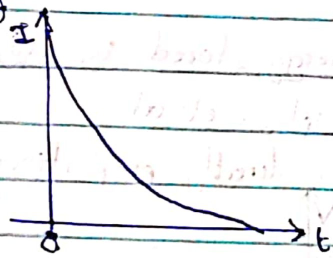


When K is closed, electrons flow from negative terminal of battery to plate X

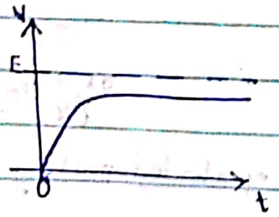
At same rate, electron flow from plate Y to positive terminal of battery. Hence ~~plate~~ plate X becomes negative while Y becomes positively charge.

- Charging current reduces to zero when capacitor is fully charged.
- At this point, the p.d across the capacitor is equal to the e.m.f of the battery.

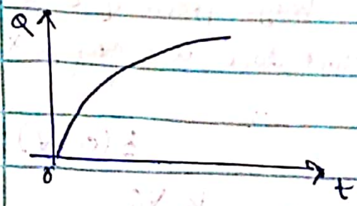
Variation of I with t during charging



Variation of V with t during charging



Variation of Q with t during charging



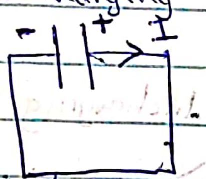
Qn. Explain the difference between energy supplied and energy stored by capacitor during charging.

Qn. Explain why a batter does work during charg process.

Energy changes during charging from a battery.

Chemical energy $\rightarrow$ electrical energy $\rightarrow$ electrostatic p.e, $\downarrow$ heat.

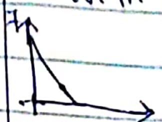
Discharging process.



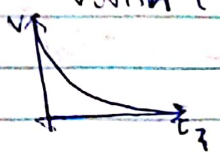
conducting wire

- Capacitor plates are connected using a conducting wire
- Electrons ~~that~~ flow from the negative plate towards the positive plate and neutralise the positive charges.
- Electrons flow until all the positive charges are neutralised. Hence capacitor is fully discharged

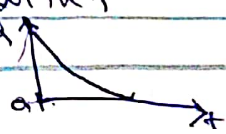
I with t

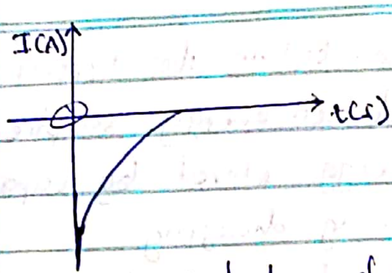


V with t

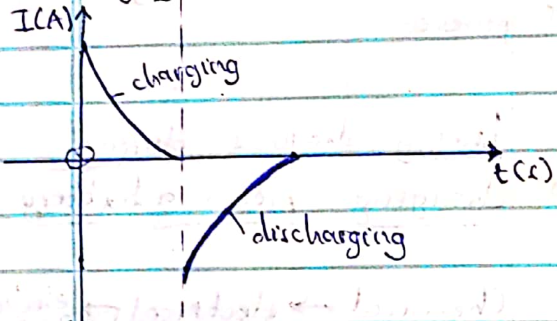


Q with t

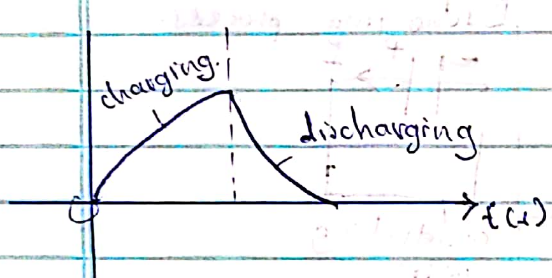




A graph of I against t for charging and discharging of a capacitor.



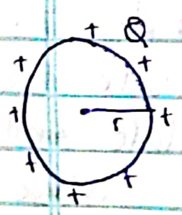
A graph of V against t



Explain the features of graphs above

TYPES OF CAPACITORS

Capacitance of an isolated sphere



Electric potential $V = \frac{Q}{4\pi\varepsilon_o r}$

$\frac{V}{Q} = \frac{1}{4\pi\varepsilon_o r}$

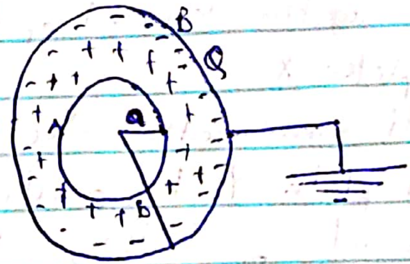
$Q = CV$

$\frac{1}{C} = \frac{V}{Q}$

$\frac{1}{C} = \frac{1}{4\pi\varepsilon_o r}$

$C = 4\pi\varepsilon_o r$

Capacitance of concentric spheres.



Electric potential on A

$V = V_A + V_B$

$V_A = \frac{Q}{4\pi\varepsilon_o a} + \frac{-Q}{4\pi\varepsilon_o b}$, $V_B = 0$

$\therefore V = \frac{Q}{4\pi\varepsilon_o}\left[\frac{1}{a} - \frac{1}{b}\right]$

$\frac{V}{q} = \frac{1}{4\pi\varepsilon_o}\left[\frac{1}{a} - \frac{1}{b}\right]$

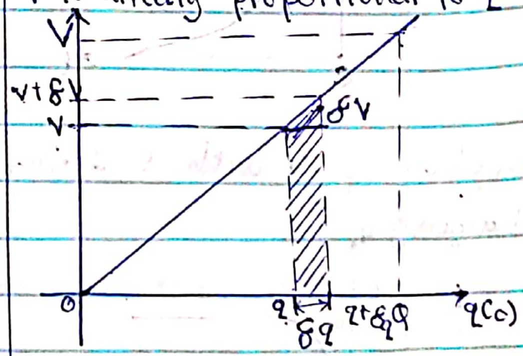
$\frac{1}{C} = \frac{1}{4\pi\varepsilon_o}\left[\frac{1}{a} - \frac{1}{b}\right]$

$C = 4\pi\varepsilon_o\left[\frac{ab}{b-a}\right]$

Energy stored by a capacitor

Graph method

V is directly proportional to q.



Area of shaded part $= \frac{1}{2}\delta q(V + V + \delta V)$

Work done when a capacitor is charge from $q = 0$ to $q = Q$

Work done w = Average p.d × charge

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

$w = \frac{1}{2}VQ$

Work done = Energy $= \frac{1}{2}QV$

But $Q = CV$

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

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

$$E = \frac{1}{2}\frac{Q^2}{C}$$

Method 2: calculus ~~method~~

~~Small charge~~ δq deposited on plates raises pd by δV

~~Pd → $V + \delta V$~~

Small work done

$$\delta w = (V + \delta V)\,\delta q$$

$$= V\delta q + \delta V \delta q$$

Since δV and δq is very small, $\delta V \delta q \approx 0$

$$\delta w = V\delta q$$

The total work done when a capacitor is charged from $q = 0$ to $q = Q$

$$\int dw = \int_0^Q V\,dq \quad \text{but } V = \frac{q}{C}$$

$$w = \int_0^Q \frac{q}{C}\,dq$$

$$w = \frac{1}{C}\int_0^Q q\,dq$$

$$W = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q$$

$$W = \frac{1}{2C}\left[Q^2 - 0^2\right]$$

$$W = \frac{1}{2}\frac{Q^2}{C}$$

Work done = Energy stored by the capacitor

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

Types of capacitors.

- Paper capacitor
- Electrolytic capacitor
- Variable air capacitor

Paper capacitor

It consists of two strips of metal and two piece of paper rolled over each other. The sandwich forms a small cylinder of large surface area

Electrolytic capacitor

It is made by passing a current through aluminium borate in which two strips of metal are soaked. This produces aluminium oxide film which acts as a dielectric

Variable air capacitor

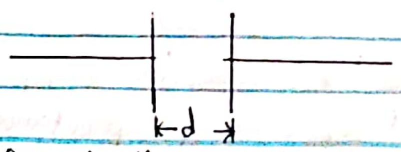
It is applied in tuning radios. It consists of two sets of plates interleaved in one another. ~~of two sets of plates~~ One set of plates is movable and another set is fixed

PARALLEL PLATE CAPACITOR

Factor that affect capacitance of a capacitor.

Distance of separation of the plates

- Area of overlap
- ~~Presences of a dielectric~~



- Permitivity of the dielectric

Capacitance of a parallel plate capacitor

Consider a capacitor of capacitance C, area of overlap A and distance of separation d

Electric flux, $\Phi = EA$

where E is electric field intensity

Q - Charge stored

ε - permittivity of the medium

Gauss's law

$$\Phi = \frac{Q}{\varepsilon}$$

$$E = \frac{Q}{A\varepsilon}$$

From $E = V/d$

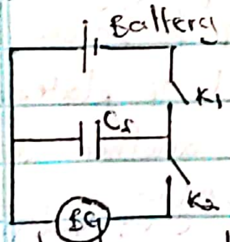
$$\frac{V}{d} = \frac{Q}{A\varepsilon} \quad \text{but } Q = CV$$

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

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

Measurement of capacitance.

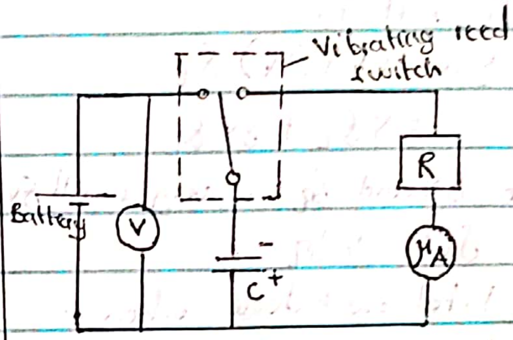
(i) Using a Ballistic galvanometer.



- A standard capacitor C_s is connected in circuit as shown above.
- With K_2 open, K_1 is closed for a short time for the capacitor to charge
- K_1 is opened and K_2 closed for the capacitor to discharge through the BG
- The first deflection θ_s of the BG is noted
- The standard capacitor is replaced with a test capacitor of capacitance, C
- The experiment is repeated and the first deflection θ of BG is noted
- Unknow capacitance, C is calculated from

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

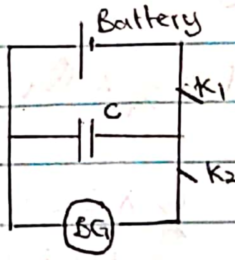
(ii) Vibrating reed switch.



- A test capacitor is connected in circuit as shown above
The reed switch is activated and its frequency set to value, f
- The capacitor then charges and discharges at frequency f
- The reading V of the voltmeter and I of the micro ammeter are noted
- Capacitance, $C = \frac{I}{Vf}$

Measurement of relative permittivity / dielectric constant.

(i) Using a ballistic galvanometer



An air filled capacitor C is connected in circuit as shown above.

With K2 open, K1 is closed for a short time for the capacitor to charge.

K1 is opened and K2 closed for the capacitor to discharge through the BG.

The first deflection θ_0 of the BG is noted.

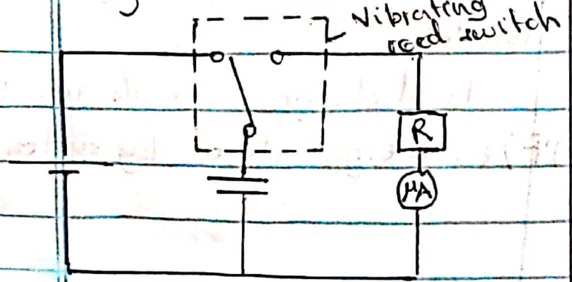
A material whose dielectric constant is required is inserted between the plates of the capacitor.

The experiment is repeated and the first deflection θ_1 of the ~~next~~ BG is noted.

- Dielectric constant ε_r, is calculated from

$$\varepsilon_r = \theta_1/\theta_0$$

(ii) Vibrating reed switch.

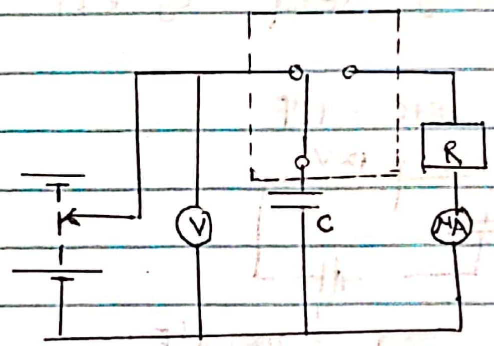


- An air filled capacitor is connected in circuit as shown above
- The reed switch is activated to charge and discharge the capacitor at frequency f
- The reading I of the micro ammeter are noted.
- The space between the capacitor plates is filled with a test material
- Experiment is repeated and reading I' of microammeter is noted.
- Relative permittivity,

$$\varepsilon_r = \frac{I'}{I}$$

Qn:

Experiment to investigate relationship between capacitor charge and p.d across it



A capacitor C is connected in circuit as shown above.

The reed switch is activated to charge and discharge.

The voltage is adjusted for suitable reading V of the voltmeter

- The reading I of the micro ammeter is noted.

The experiment is repeated with other values of V. Corresponding values of I are noted.

A graph of V against I is plotted and is straight line through origin.

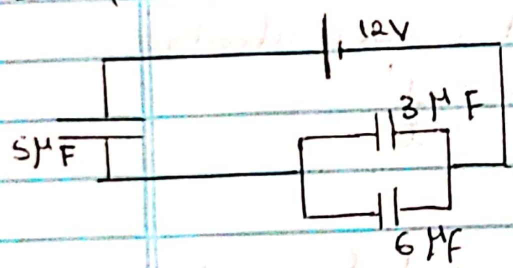
Therefore $V \propto I$

But $I \propto Q$, $\Rightarrow V \propto Q$

Numerical problems.

1. Capacitor networks

Example 1



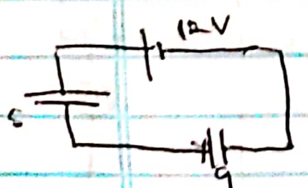
Find (i) total charge

(ii) energy stored by 5μF

(iii) energy ~~stoped~~ stopped by 6μF

Soln

$C_P = 3+6 = 9\mu F$



$C_t = \frac{5\times 9}{5+9} = 3.214\mu F$

$Q_t = CV = 3.214\times10^{-6} \times 12$

$= 3.84\times10^{-5}$

(ii) $E = \frac{1}{2}CV^2$ (NB: look for pd across 5μF)

$E = \frac{Q^2}{2C} = \frac{(3.85\times10^{-5})^2}{2\times5\times10^{-6}}$

$= 1.4823\times10^{-4}$

(iii) $E = \frac{Q^2}{2C}$

Q on $6\mu F = \frac{6}{9} \times Q_t$

$= \frac{6}{9} \times 3.85\times10^{-5}$

$= 2.567\times10^{-5} C$

$E = \frac{(2.567\times10^{-5})^2}{2\times6\times10^{-6}}$

$E = 5.49\times10^{-5} J$

Method 2

p.d across $6\mu F$ = p.d across $9\mu F$

$= \frac{Q}{C}$

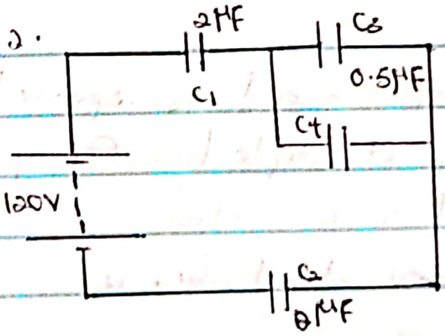
$= \frac{3.85\times10^{-5}}{9\times10^{-6}}$

$= 4.278V$

$E = \frac{1}{2}\times6\times10^{-6}\times4.278^2$

$\simeq 5.49\times10^{-5}$

2.



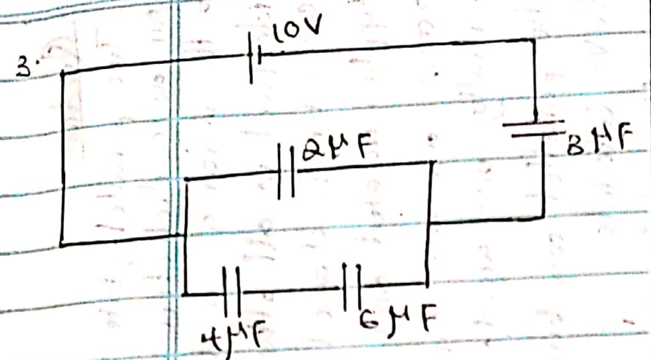
Dielectric of constants 3.5, 3, 4 and 2 are placed in plates of C_1, C_2, C_3 and C_4 respectively.

Calculate

(i) Final charge on each capacitor

(ii) energy stored by system.

3.



i) Total capacitance
ii) Charge stored by 8μF
iii) Energy stored by 2μF.

Soln

$$C_s = \frac{4\times6}{4+6}$$

$$= 2.4\,\mu F$$

$$C_p = 2.4 + 2$$

$$= 4.4\,\mu F$$

$$C_T = \frac{4.4\times3}{4.4+3}$$

$$C_T = 1.7838\,\mu F$$

ii)

$$Q = CV$$

$$Q = 1.7838\times10^{-6}\times10$$

$$Q = 1.7838\times10^{-5}\,C$$

Charge at 8μF = $1.7838\times10^{-5}\,C$

$$E_2 = \frac{Q^2}{2C}$$

$$Q_2 = \frac{2}{4.4}\times1.7838\times10^{-5}$$

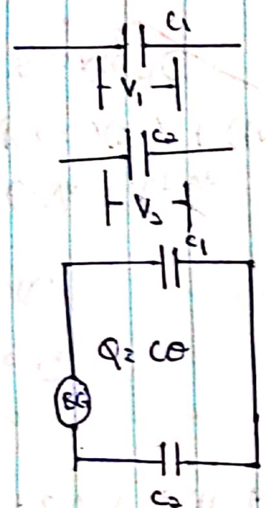
$$= 8.1082\times10^{-6}\,C$$

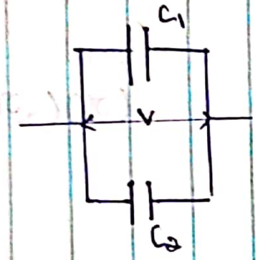
$$E_2 = \frac{(8.1082^2\times10^{-6})^2}{2\times2\times10^{-6}}$$

~~$E_2 = 1.644\times10^{-7}$ J~~

$E \ldots \times10^{-5}$ J

Joining of two capacitors





C_1 and C_2 are in parallel p.d across C_1 and C_2 is same

Total capacitance, $C = C_1 + C_2$

$Q_b = Q_f$

$C_1V_1 + C_2V_2 = (C_1 + C_2)V$

Charge stored by C_1 before joining

$Q_1 = C_1V_1$

Charge stored by C_1 after joining

$Q = C_1V$

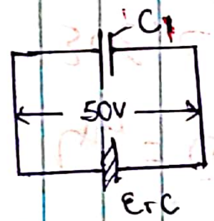
Charge flowing = difference btn Q_1 & Q

Total Charge before connection $= Q_1 + Q_2$

$= C_1V_1 + C_2V_2$

$= 400C_0 + \varepsilon_r C_0 \times 0$

$= 400C_0$



Total charge after connection $= (C_0 + \varepsilon_r C_0)V$

$= (C_0 + \varepsilon_r C_0) \times 50$

Total charge before connection = Total charge after connection

$400C_0 = 50(C_0 + \varepsilon_r C_0)$

$8 = 1 + \varepsilon_r$

$\varepsilon_r = 7$

(ii)

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

For C_1, $E_1 = \frac{1}{2}C_1 \times 50^2 = 1250C_1$ 1250 C

C_2, $E_2 = \frac{1}{2}C_2 \times 50^2 = 1250C_2$ $1250 \times 7C$

2. A capacitor C_1 of $2\mu F$ is charged to a p.d of 50V and a capacitor C_2 of $3\mu F$ is charged to a p.d of 100V. The capacitors C_1 and C_2 are connected with like plate together.

a) Calculate;

(i) Total energy before connection

(ii) the p.d after connection.

(iii) Difference in energy stored before and after connection. Account for the difference

(b) Calculate the charge flowing after connection.

Soln

(i)

$E = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2$

$E = \frac{1}{2}(2\times10^{-6})(50)^2 + \frac{1}{2}(3\times10^{-6})(100^2)$

$E = 0.0175\ J$

(ii) Charge bef

$Q_b' = C_1V_1 + C_2V_2$

Question

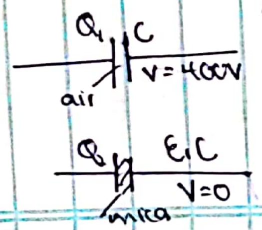
Two parallel-plate capacitors one with air as a dielectric and the other with mica as a dielectric, are identical in all other aspects. The air capacitor is charged from a 400V d.c supply, isolated and then connected across a mica capacitor which is initially uncharged. The p.d across the parallel combination becomes 50V. Calculate

(i) the relative permittivity of mica

(ii) Final energy stored by each capacitor after connection

(iii) the charge flowing when capacitor are connected

Soln



$\varepsilon_r = \frac{Cd}{C}$

(iii)

Charge stored by C_1 before joining $= Q_1$

$\boxed{\text{For } C_1}$

Charge before Connection

$Q_b = C_1 V_1$

$= 400C$

Charge after Connection

$Q_f = C_1 V$

$= 50C$

Charge flowing $= 400C - 50C$

$= (350\ C)\ C$

$= (2\times10^{-6})(50) + (3\times10^{-6})(100)$

$Q_b = 4\times10^{-4}$ C

(ii) Charge after

$Q_f = C_1V + C_2V$

$= (2\times10^{-6})V + (3\times10^{-6})V$

$Q_f = Q_b$

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

$V = 80V$

p.d $= 80V$

(iv)

$E_f = \frac{1}{2}C_1V^2 + \frac{1}{2}C_2V^2$

$= \frac{1}{2}V^2(C_1 + C_2)$

$= \frac{1}{2}(80)^2(3+2)\times10^{-6}$

$E_f = 0.016J$

$\Delta E = E_b - E_f$

$= 0.0175 - 0.016$

$\Delta E = 0.0015J$

→ Some energy is lost due to heat in connecting wires.

(b) Charge flowing = Charge before − Charge after

$= (2\times10^{-6}\times50) - (2\times10^{-6}\times80)$

$= |1\times10^{-4} - 1.6\times10^{-4}|$

$= 6\times10^{-5}$ C

3.

A 2μF capacitor and 3μF capacitors are connected in series with 100V battery. The capacitors are disconnected from battery and then connected with plates together. Calculate

(i) Find charge stored by each capacitor

(ii) Difference in total energy stored before and after connection

Soln

$Q = CV$

$C_{eff} = \frac{C_1C_2}{C_1+C_2}$

$= \frac{2\times3}{2+3}$

$= 6/5$

$= 1.2\mu F$

$Q = 1.2\times10^{-6}\times100$

$Q = 1.2\times10^{-4}$

$Q_f = C_AV + C_BV$

$= V(C_A + C_B)$

$Q_f = V(10+15)\times10^{-6}$

$Q_f = (2.5\times10^{-5}\,V)C$

$5.5\times10^{-4} = 2.5\times10^{-5}V$

$V = 22V$

Common p.d = 22V

$E_T = \frac{1}{2}C_AV^2 + \frac{1}{2}C_BV^2$

$= \frac{1}{2}(C_A + C_B)V^2$

$= \frac{1}{2}(2.5\times10^{-5})(22)^2$

$= 6.05\times10^{-3}$ J

$Q_{Af} = C_AV$

Difference

$Q = |Q_{Ab} - Q_{Af}|$

$Q = K\theta$

$\theta \propto Q$

$\theta = KQ$

$K = 2\,div\,\mu C^{-1}$

$= \frac{1}{2}\mu C\,div^{-1}$

$K \rightarrow C\,div^{-1}$

$\theta = \frac{1}{2}\times10^{-6}\times5.5\times10^{-4}$

$\theta = 2.75\times10^{-10}\,C\,div^{-1}$

$2d \rightarrow 1\mu C$

$1d \rightarrow \frac{1}{2}\mu C$

Question.

A rectangular piece of wood of dielectric constant 4 is placed between parallel plates of a capacitor of capacitance 16μF & a p.d of 6000V is connected across the plates.

(i) Find the capacitance of the capacitor when the piece of wood is withdrawn.

(ii) Calculate the difference in energy before and after withdrawing the piece of wood from the capacitor.

(iii) Account for the difference in the energy above.

Soln

(i)

$C = 16\mu F$

$K = \frac{1}{2}\mu C\,div^{-1}$!

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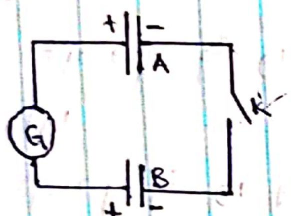
In the circuit shown below switch K is open, capacitors A and B have respective capacitances of 10μF and 15μF and are charged to p.ds of 25V and 20V respectively.



A ballistic galvanometer G, with sensitivity of 2 divisions per μC joins the positive plates of the capacitors. If K is now closed, what will be the throw on G?

Soln

Charge Q

$Q_b = Q_f$

$Q_b = C_A V_A + C_B V_B$

$= (10\times10^{-6})(25) + (15\times10^{-6})(20)$

$= 5.5\times10^{-4}C$

Charge before inserting the dielectric

$Q_b = CV$

$Q_b = 100C$ — — (i)

After.

$Q_f = CV$

$= \varepsilon_r C V$

$= 30\varepsilon_r C$ - - - (ii)

$Q_b = Q_f$.

$30\varepsilon_r C = 100C$

$\varepsilon_r = 100/30$

$= 3.3333$

ii)
Energy before $E_b = \frac{1}{2}CV^2$

$C = \varepsilon_r C_0$

$= 4\times16\mu F$

$= 64\mu F$

$E_b = \frac{1}{2}\times64\times10^{-6}\times6000^2$

$E_b = 1152J$

Energy after $E_f = \frac{1}{2}C_0V^2$

$= \frac{1}{2}\times16\times10^{-6}\times6000^2$

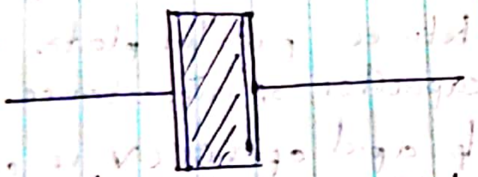
$E_f = 288J$

$\Delta E = E_b - E_f$

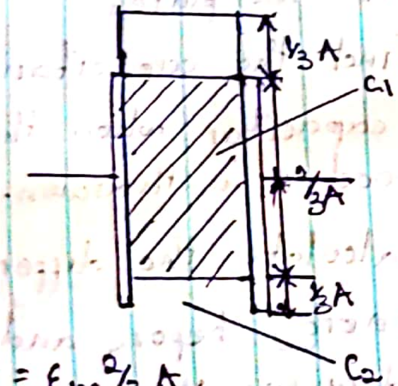
$= 1152 - 288$

$= 864J$

iii) Withdrawing the dielectric material decreases the capacitance of the capacitor which decreases the energy stored by capacitor since p.d is constant separation area of overlap.



$\frac{1}{3}$ of the dielectric withdrawn



C_1 and C_2 are in parallel

$$C_1 = \frac{\varepsilon_m \frac{2}{3} A}{d}$$

$\varepsilon_m = \varepsilon_r \varepsilon_0$

$$C_1 = \frac{2\varepsilon_r \varepsilon_0 A}{3d}$$

For C_2

$$C_2 = \frac{\varepsilon_0 \cdot \frac{1}{3} A}{d}$$

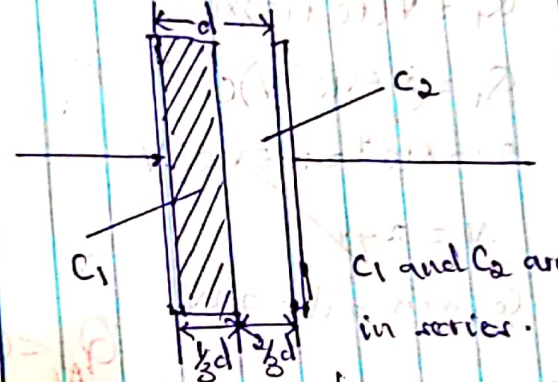
$$C_2 = \frac{\varepsilon_0 A}{3d}$$

Effective capacitan:

$$C = C_1 + C_2$$

$$C = \frac{\varepsilon_0 A}{3d} + \frac{2\varepsilon_r \varepsilon_0 A}{3d}$$

Dividing distance of separation of a capacitor by inserting a dielectric the ent.



C_1 and C_2 are in series.

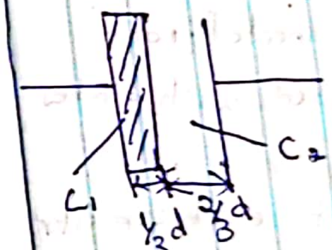
$$C_1 = \frac{\varepsilon_r \varepsilon_0 A}{\frac{1}{3}d}$$

$$C_1 = \frac{3\varepsilon_r \varepsilon_0 A}{d}$$

$$C_2 = \frac{\varepsilon_0 A}{\frac{2}{3}d}$$

$$C_2 = \frac{3\varepsilon_0 A}{2d}$$

A parallel plate charged air capacitor having places of effective area A and of distance d between the plates has a dielectric of relative permittivity ε_r and thickness $\frac{1}{3}d$ placed in contact with



$$\text{Capacitance } C_1 = \frac{\varepsilon_r \varepsilon_0 A}{\frac{1}{3}d}$$

$$= \frac{3\varepsilon_r \varepsilon_0 A}{d}$$

$$\text{Capacitance } C_2 = \frac{\varepsilon_0 A}{\frac{2}{3}}$$

$$= \frac{3\varepsilon_0 A}{2d}$$

Effective capacitance

$$\frac{1}{C} = \frac{1}{\frac{3\varepsilon_r \varepsilon_0 A}{d}} + \frac{1}{\frac{3\varepsilon_0 A}{2d}}$$

$$-\frac{1}{C} = \frac{d}{3\varepsilon_r \varepsilon_0 A} + \frac{2d}{3\varepsilon_0 A}$$

$$\frac{1}{C} = \frac{d + 2d\varepsilon_r}{3\varepsilon_r \varepsilon_0 A}$$

$$= \frac{3\varepsilon_r \varepsilon_0 A}{1 + 2d\varepsilon_r}$$

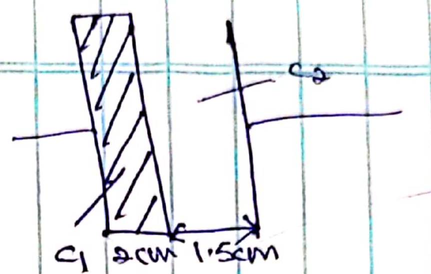
$$= \frac{3\varepsilon_r \varepsilon_0 A}{d(1 + 2\varepsilon_r)}$$

A parallel plate capacitor consists of two plates 3.5cm apart with a piece of glass 2cm thick filling part of the space between them. when the glass is removed the plates separation has to be reduced to 2cm in order to restore the capacitance to it's original value
(i) Explain why the observation above happens,
(ii) Calculate the relative permittivity of the glass.

soln

(i)
When the glass is removed the capacitance of the capacitor decreases since capacitance, $C \propto \frac{1}{d}$, the distance of separation of the plates has to be reduced which will increase the capacitance to the original value

soln.



$C_1 = \frac{\varepsilon_r \varepsilon_0 A}{0.02}$, $C_2 = \frac{\varepsilon_0 A}{0.015}$

Effective capacitance

$\frac{1}{C} = \frac{1}{\frac{\varepsilon_r \varepsilon_0 A}{0.02}} + \frac{1}{\frac{\varepsilon_0 A}{0.015}}$

$\frac{1}{C} = \frac{0.02}{\varepsilon_r \varepsilon_0 A} + \frac{0.015}{\varepsilon_0 A}$

$\frac{1}{C} = \frac{0.02 + 0.015\varepsilon_r}{\varepsilon_r \varepsilon_0 A}$

$C = \frac{\varepsilon_r \varepsilon_0 A}{0.02 + 0.015\varepsilon_r}$

When the glass is removed capacitance

$C = \frac{\varepsilon_r A}{0.02}$

$\frac{\varepsilon_0 A}{0.02} = \frac{\varepsilon_r \varepsilon_0 A}{0.02 + 0.015\varepsilon_r}$

$\frac{1}{0.02} = \frac{\varepsilon_r}{0.02 + 0.015\varepsilon_r}$

$\frac{0.02}{0.005} = \frac{0.005\varepsilon_r}{0.005}$

$\varepsilon_r = 4$

(d) A parallel plain air capacitor is charged to a p.d of 300V. It is then connected in parallel with another uncharged capacitor of equal dimensions with rubber as a dielectric between its plates. The p.d of the combination is found to be 75V. Calculate:

(i) the dielectric constant of the rubber. (04 marks)

(ii) the total energy stored in the two capacitors. (03 marks)

(iii) Account for the difference in the initial and final energy stored. (01 mark)

9. (a) What is meant by the following terms?

(i) Electrostatic induction? (01 mark)

(ii) Electric point discharge? (01 mark)

(b) (i) Describe, with the aid of a labeled diagram a Van de Graaf generator. (05 marks)

(ii) The high voltage terminal of such a generator consists of a spherical conducting shell of radius 50cm.

Calculate the maximum potential to which it can be raised in air for which electrical break down occurs when the electric intensity exceeds $3.0 \times 10^4 Vcm^{-1}$. (03 marks)

(c) A needle is mounted vertically, point upwards on the cap of a gold leaf electroscope, the blunt end being in contact with the cap. Explain what is observed.

(i) When a negatively charged body is brought close to the needle point without touching it, and is then quickly withdrawn. (03 marks)

(ii) When the negatively charged body is again brought near the needle point and left there for sometime and is withdrawn. (03 marks)

(d) Three charges $-1\mu C, 2\mu C,$ and $3\mu C$ are placed respectively at the corners A. B and C of an equilateral triangle of side 2m. Calculate the electric field intensity at a point X which is half way along BC. (04 marks)

10. (a) Define the terms;

(i) Resistivity (01 mark)

(ii) Temperature coefficient of resistance. (01 mark)

(b) A carbon lamp filament was found to have a resistance of 375Ω at the temperature of 20oc. The lamp was then connected in series with an ammeter and a d.c. supply, and a voltmeter of resistance 1050Ω was connected in

9. (a) Define the terms:

(i) Electric potential. (1 mark)

(ii) electric field intensity. (1 mark)

(b) Derive an expression relating the terms in (a) above. (3 marks)

(c) Figure 4 shows a vibrating reed circuit. Use it together with the information given on it where necessary to:

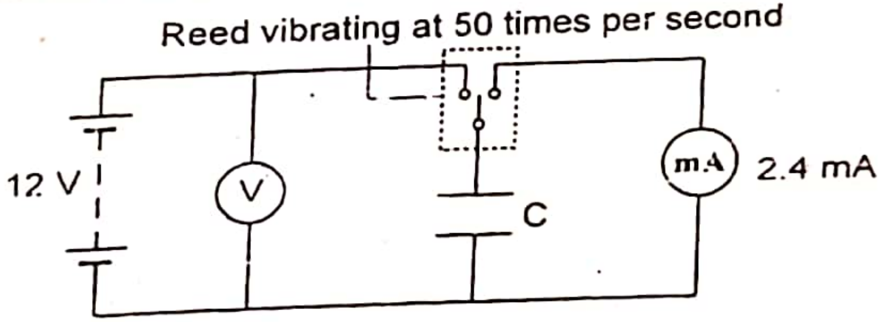


Fig.4

(i) Find the capacitance of the capacitor. (3 marks)

(ii) Investigate the effect of inserting a dielectric between the plates of the capacitor. (4 marks)

(d) A capacitor of capacitance 22μF is charged to a p.d of 200 V and then isolated from the supply.

(i) Determine the energy stored in the capacitor. (3 marks)

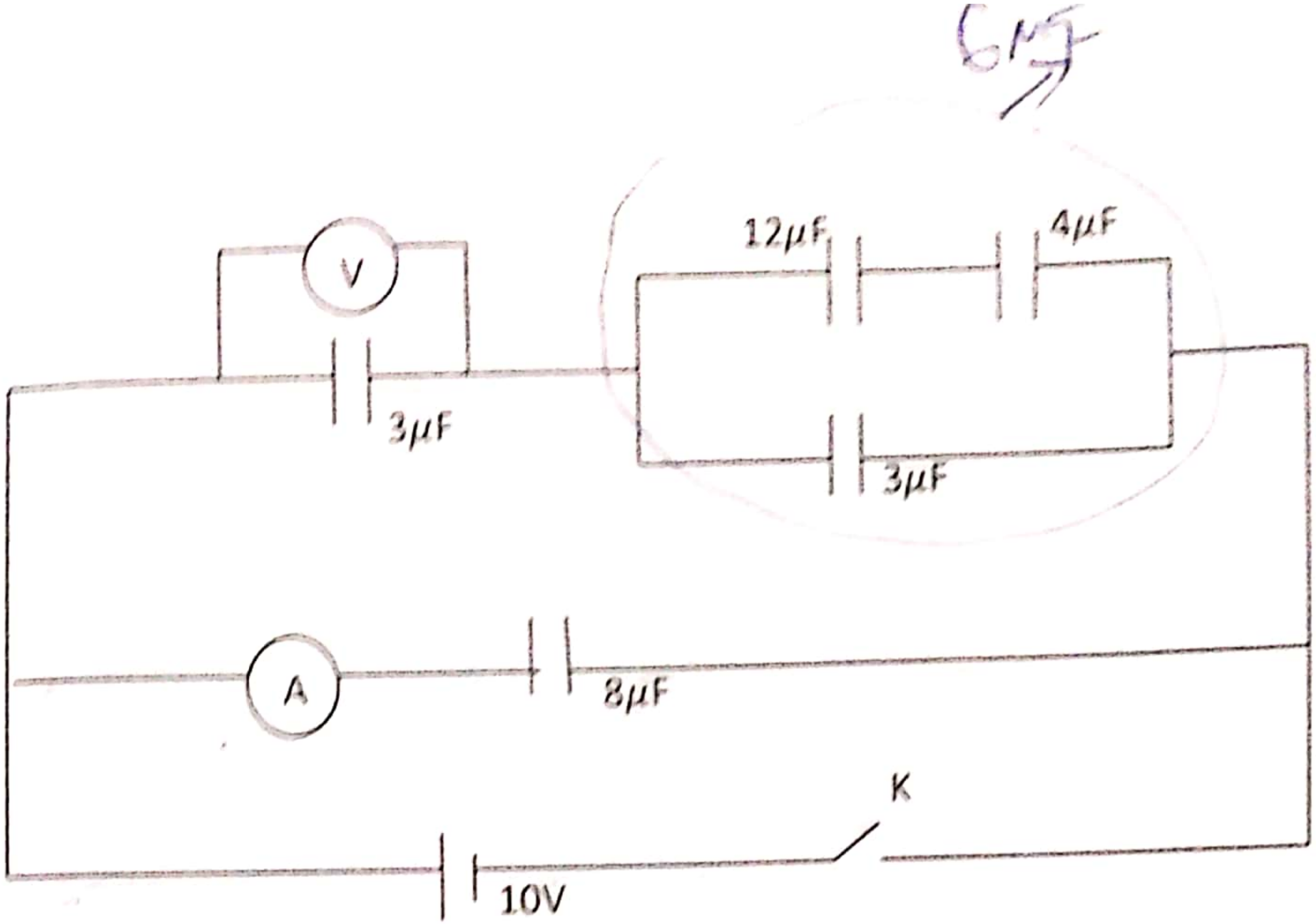
(c) (i) Define the capacitance of a conductor. *(01 mark)*

(ii) Explain how the capacitance of a conductor is affected by bringing an uncharged insulated conductor in the neighbourhood. *(03 marks)*

(d) (i) Two capacitors of capacitances $3\mu F$ and $2\mu F$ are connected in series with a battery of E.m.f 100Volts. The connection is broken and the like terminals of the capacitors are then joined.

Calculate the final charge on each capacitor *(05 marks)*

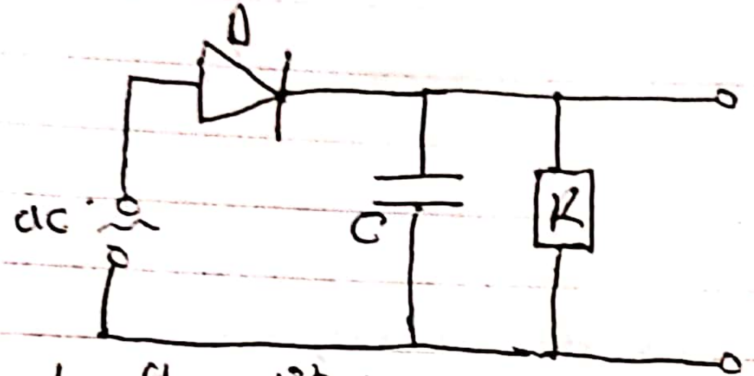
(ii) State the factors which determine the capacitance of an air-cored capacitor. *(01 mark)*



The figure above shows a circuit containing an ammeter of negligible resistance and a voltmeter.

(i)Explain what is observed on the ammeter when switch K is closed. (02marks)

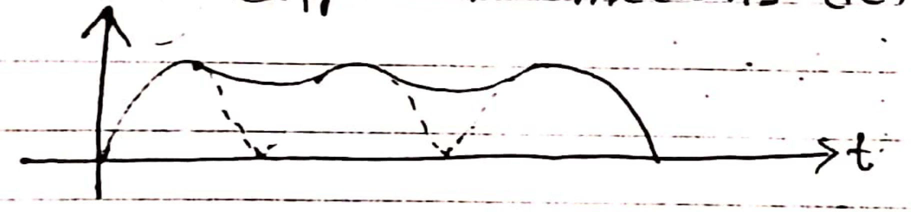
(ii)Find the voltmeter reading. (04marks)



In the 1st half cycle, diode conducts and current flows through the resistor. The capacitor also charges.

In the 2nd half cycle, the diode is reverse biased. No current flows through it but the capacitor discharged through the resistor. Hence p.d across the resistor remains fairly constant.

Hence capacitor smoothens output voltage



10. (a) (i) Define a **Farad**. *(01 mark)*

(ii) Describe briefly the energy transformations that take place when charging a capacitor using a dry cell. *(02 marks)*

(b) (i) What is meant by **dielectric constant**? *(01 mark)*

(ii) A parallel plate capacitor is charged to 100 V and then isolated. When a sheet of a dielectric is inserted between the plates, the p.d decreased to 30 V. Calculate the dielectric constant of the dielectric. *(03 marks)*

(c) A 60 μF capacitor is charged from a 120 V supply. It is then connected across the terminals of a 20 μF capacitor. Calculate the;

(i) final p.d across the combination. *(03 marks)*

(ii) difference in the initial and final energies stored in the capacitors and comment on the difference. *(05 marks)*

(d) Explain the principle of operation of a lightning conductor. *(05 marks)*