1. Details of unit revision and its structure

Subject Name	Physics
Course Name	Physics 03 (Physics Part – 1, Class XII)
Title	Revision Unit-01_Problems
Pre-requisites	Study of all Electric charges and fields and Electrostatic potential and Capacitance
Objectives	After going through these problems the students will gain conceptual understanding of each topic.
Keywords	Electric Charges and Fields, Electrostatic Potential and Capacitance

2. Development Team

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Conceptual Problems with explanations

- There are two problems per module

Module 1

1. **Although quarks (+up 2/3e and down -1/3e) are discovered, the quantization of charge is still valid. Justify**

Quantization of charge is based on electron as atomic particle. The electrons stay outside the nucleus and revolve around it.
In electrostatics the electron transfer from one result in
a) Addition of electrons creating negative charge
b) Removal of electrons or deficiency of electrons results in creating positive charge

A quark is a type of elementary particle and a fundamental constituent of matter. Quarks combine to form composite particles called hadrons, the most stable of which are protons and neutrons, the components of atomic nuclei. Due to a phenomenon known as color confinement, quarks are never directly observed or found in isolation (Wikipedia). You may also read

hyperphysics.phy-astr.gsu.edu/hbase/Particles/quark.html

2. **A polythene piece rubbed with wool is found to have a negative charge of $3 \times 10^{-7} C$.**
   (1) Estimate the number of electrons transferred from which to which?
   (2) Is there transfer of mass?

- Polythene sheet gets $6.25 \times 10^{18} \times 3 \times 10^{-7} = 18.75 \times 10^{11}$ electrons
- Yes equal to the net mass of electrons transferred

Module 2

1. **If the total charge enclosed by a surface is zero, does it imply that the electric field everywhere on the surface is zero? Conversely, if the electric field everywhere on a surface is zero, does it imply that net charge inside is zero.**

- No, the field may be normal. However the converse is true

2. **An oil drop of charge q and mass m is held stationary under a constant field E. If the density of oil drop is X. Find an expression for the radius of oil drop.**

- Electrostatic force on the drop qE=weight of the drop mg

$$qE = \frac{4}{3}\pi r^3 X\, g$$

(density X=mass/volume)

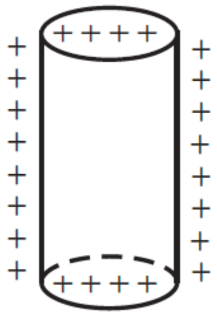
$$r = \sqrt[3]{\frac{3qE}{4\pi Xg}}$$

Module 3

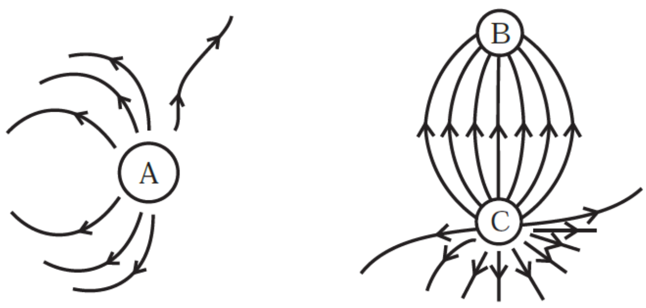
1. **An electrstatic field line is a continuous curve. That is field line cannot have sudden breakes. Why? Justify your answer.**

- ❖ An electrostatic field line is the path of a positive test charge , however small .since the force is continuous the field line is also continuos

2. **Sketch electrostatic field lines**
   a) **uniformly charged hollow cylinder**



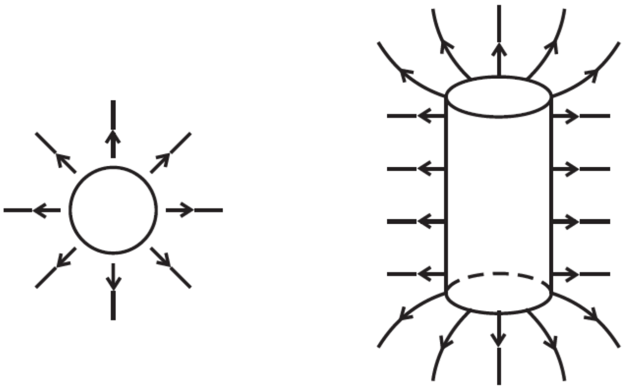
   b) **Answer the following**
      I. **based on field lines predict the nature of charge on A B and C**



      II. **which charge has the largest magnitude ? why?**
      III. **In which region or regions could the electric field be zero ?**

Answers:

a)



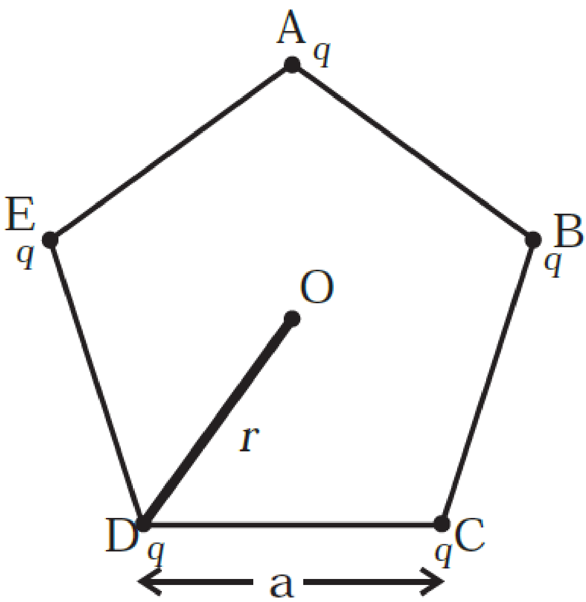
Top view   Side view

b)

I. Charges A and C are positive since lines of force emanate from them.
II. Charge C has the largest magnitude since maximum numbers of field lines are associated with it.
III. near A

There is no neutral point between a positive and a negative charge. A neutral point may exist between two like charges. From the figure we see that a neutral point exists between charges A and C.
Also between two like charges the neutral point is closer to the charge with smaller magnitude. Thus, electric field is zero near charge A

3. Five charges, *q* each are placed at the corners of a regular pentagon of side '*a*'.



I. **What will be the electric field at O, the centre of the pentagon?**
II. **What will be the electric field at O if the charge from one of the corners (say A) is removed?**
III. **What will be the electric field at O if the charge *q* at A is replaced by -q**

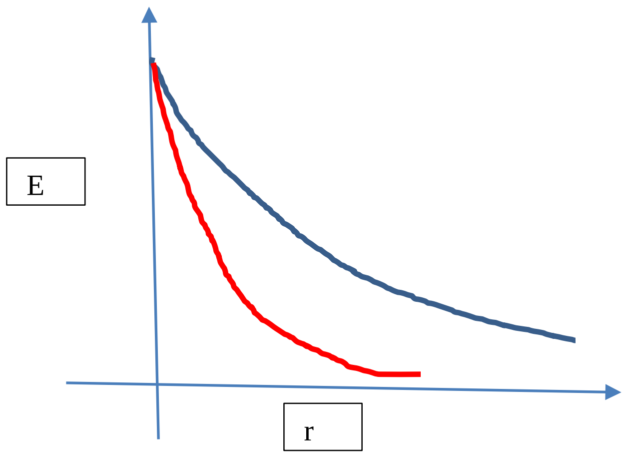
Answers:

I. Zero due to symmetry
II. $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ $along\ OA$
III. $\frac{1}{4\pi\varepsilon_0}\frac{2q}{r^2}$ $along\ OA$

Module 4

1. **Sketch the variation of electric field variation of electric dipole axial field and that of point charge with position vector.**

❖ The $1/r^3$ dependence of dipole electric fields should be noted in contrast to the $1/r^2$ dependence of electric point charges.



Red curve is for electric field variation with distance

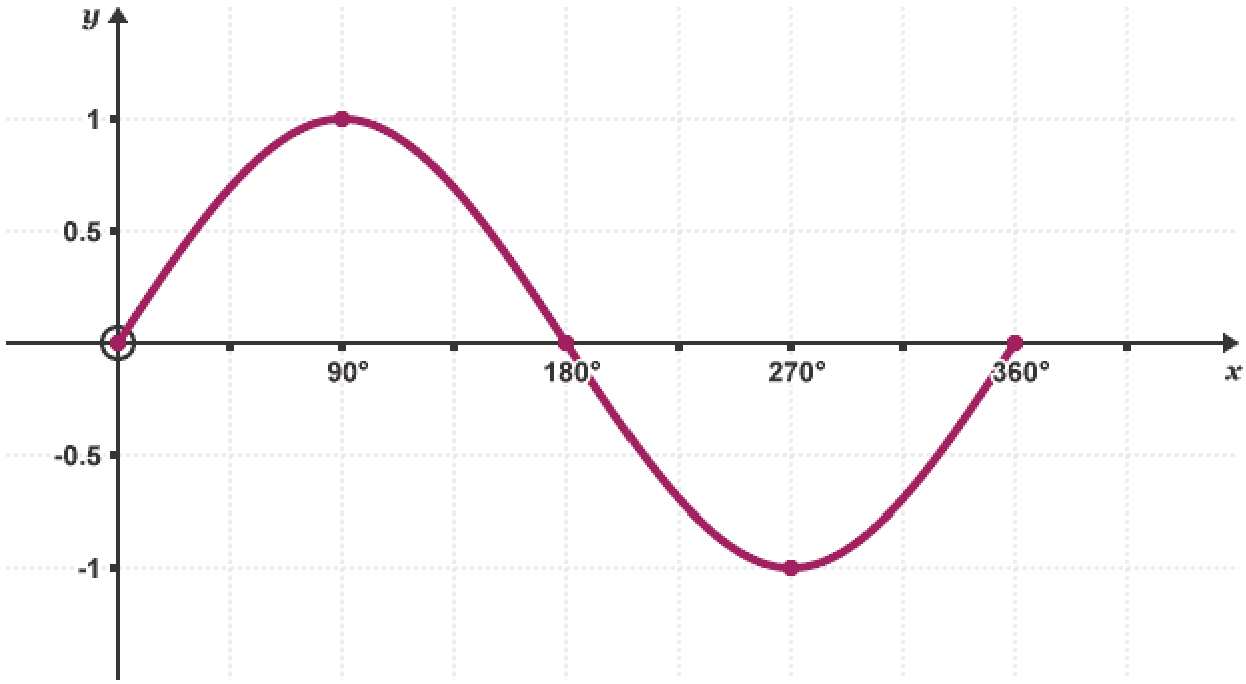
2. **Draw the orientation of electric dipole in a uniform electric field where it experiences a half of maximum torque.**

❖ Torque on the dipole = $qE \times 2asin\theta$

Torque is maximum when $sin\theta$=1

Which is when $\theta = 90^0$

Torque value varies as shown by the sin curve plotted for different angles from 0 to 360



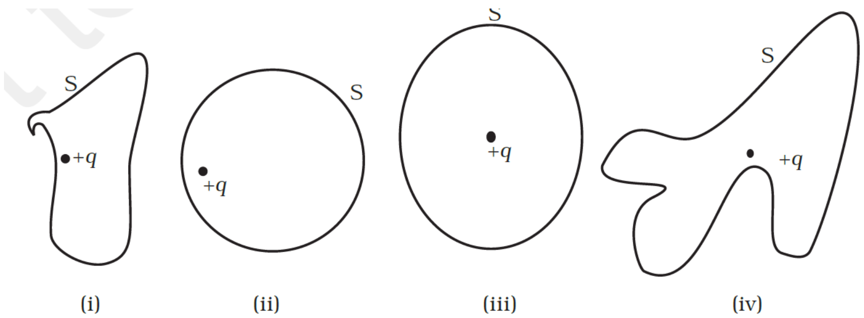
The angle for which $sin\theta = ½$

$$sin^{-1}\left(\frac{1}{2}\right) = \frac{\pi}{6} or \frac{5\pi}{6}$$

$=30^{0}$ and 150^{0}

Module 5

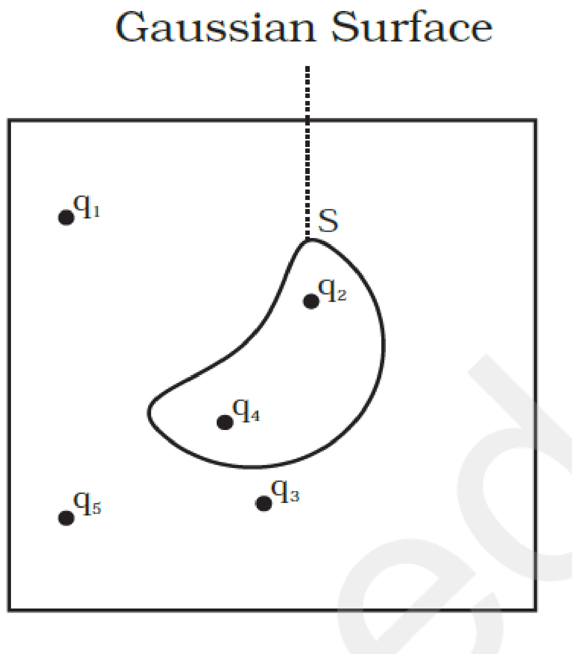
1. The electric flux through the surface



a) Largest in (iv)
b) Least in (iii)
c) Same in (ii) and in(iii)
d) Same in all

❖ Same in all as the charge enclosed is the same

2. **Five charges *q1*, *q2*, *q3*, *q4*, and *q5* are fixed at their positions as shown in Fig *S* is a Gaussian surface.**



The Gauss's law is given by

$$\int E.ds = \frac{q}{\varepsilon_0}$$

Which of the following statements is correct?

(a) E on the LHS of the above equation will have a contribution from *q1*, *q5* and *q3* while *q* on the RHS will have a contribution from *q2* and *q4* only.

(b) E on the LHS of the above equation will have a contribution from all charges while *q* on the RHS will have a contribution from *q2* and *q4* only.

(c) E on the LHS of the above equation will have a contribution from all charges while *q* on the RHS will have a contribution from *q1*, *q3* and *q5* only.

(d) Both E on the LHS and *q* on the RHS will have contributions from *q2* and *q4* only

❖ (d)

Module 6

1. **A metallic spherical shell has an inner radius *R*1 and outer radius *R*2. A charge +*Q* is placed at the centre of the spherical cavity.**
   What will be surface charge density on
   I. **the inner surface, and**
   II. **the outer surface**

❖ As the electrostatic field inside a conductor is zero, using Gauss's law, charge on the inner surface of the shell = -Q

Charge on the outer surface of the shell = +Q

I. $\frac{-Q}{4\pi R_1^2}$

II. $\frac{Q}{4\pi R_2^2}$

2. **Total charge –Q is uniformly spread along length of a ring of radius *R*. A small test charge +*q* of mass *m* are kept at the centre of the ring and is given a gentle push along the axis of the ring.**

I. **Show that the particle executes a simple harmonic oscillation.**

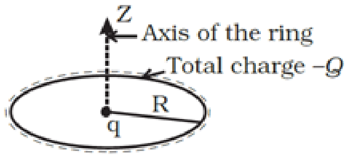
II. **Obtain its time period.**

❖ Slight push on q along the axis of the ring gives rise to the situation shown in Fig b. A and B are two points on the ring at the end of a diameter.

Force on q due to line elements $\frac{-Q}{2\pi R}$ at A and B is

$$F_{A+B} = 2.\frac{-Q}{2\pi R}.q.\frac{1}{4\pi\varepsilon_\circ}.\frac{1}{r^2}.\cos\theta$$

$$= \frac{-Qq}{\pi R.4\pi\varepsilon_\circ}.\frac{1}{(z^2+R^2)}.\frac{z}{(z^2+R^2)^{1/2}}$$



(a)

Total force due to ring on $q = (F_{A+B})(\pi R)$

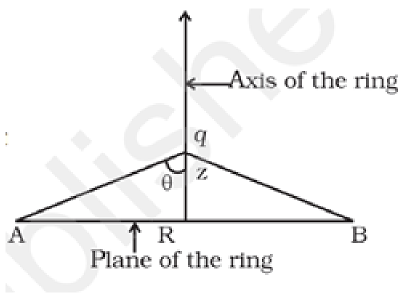
$$= \frac{-Qq}{4\pi\varepsilon_\circ}\frac{z}{(z^2+R^2)^{3/2}}$$

$$\frac{-Qq}{4\pi\varepsilon_\circ}\ for\ z \ll R$$

Thus the force is proportional to the negative of displacement

❖ Frequency under such force is harmonic

$$m\frac{d^2z}{dt^2} = -\frac{Qqz}{4\pi\varepsilon_\circ R^3} \text{ or } \frac{d^2z}{dt^2} = -\frac{Qq}{4\pi\varepsilon_\circ mR^3}z$$



That is, $\omega^2 = \frac{Qq}{4\pi\varepsilon_\circ mR^3}$

Hence, Time Period

$$T = 2\pi\sqrt{\frac{4\pi\varepsilon_\circ mR^3}{Qq}}$$

Module 7

1.

a) Electrostatic potential due to a point charge q at a distance r in 3 dimensional space is

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

I. Find change the expression to give the value of potential at a point if q is negative

II. What changes can you predict if the medium around the charge is not homogeneous

Answers:

I. $V = -\frac{1}{4\pi\epsilon_0}\frac{q}{r}$

II. If the medium is not homogeneous the permittivity will change and so will the potential

b) Electrostatics potential due to a short electric dipole at a distance r from its center

I. at its axis

II. at its equatorial position

III. due to a system of charges

IV. How much energy is stored to bring the charges closer?

Answer:

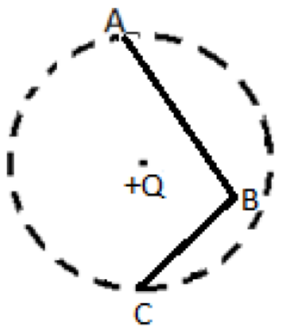
I. $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$

II. Zero

III. $V = V_1 + V_2 + V_3 \dots \dots . + V_n = \frac{1}{4\pi\epsilon_0}$

IV. The total energy stored or the energy which would be released is the sum of potential due to each charge forming the collection of charges

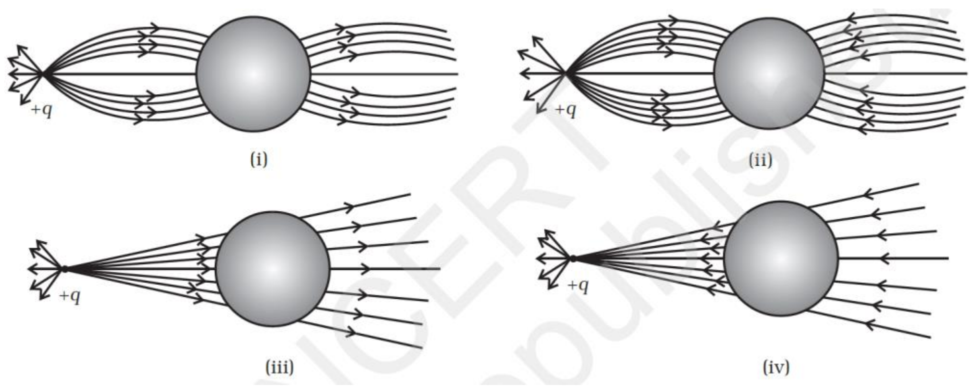
2. In the given figure, charge +Q is placed at the centre of a dotted circle. Work done in taking another charge +q from A to B is W1 and from B to C is W2. Which one of the following is correct: W1 > W2, W1=W2 and W1 < W2?



❖ As $V_A - V_B = V_B - V_C$ the magnitude of work done is the same so **W1=W2**

Module 8

1. **A point positive charge is brought near an isolated conducting sphere (Fig). The electric field is best given by**



❖ (i), Because the isolated conducting sphere will acquire negative charge on the side closer to the point positive charge and positive at the far end, due to electrostatic induction the field lines can only be as in (i)

.

2. **In a region of constant potential**
   I. **the electric field is uniform**
   II. **the electric field is zero**
   III. **There can be no charge inside the region.**
   IV. **the electric field shall necessarily change if a charge is placed outside the region**

❖ II. If potential is constant no work is being done in moving charges in the field hence the field should be zero or non-existent

And

IV. If the region is of constant potential and a charge is placed outside the region, the charge will change the electric field

Module 9

1.

I. **How many electrons must be added to one plate and removed from the other so as to store 25.0 J of energy in a 5.0 pF parallel plate capacitor?**
II. **How would you modify this capacitor so that it can store 50.0 J of energy without changing the charge on its plates?**

❖

I

$$c = 5 \times 10^{-9}F, \; U = 25J$$
$$u = \frac{Q^2}{2C}$$
$$Q^2 = 2UC = 2 \times 25 \times 5 \times 10^{-9}$$
$$Q = 5 \times 10^{-4}C$$
$$Q = ne$$
$$n = \frac{Q}{e} = 3.125 \times 10^{15}$$

❖

II Without changing charge on the plates, we can make C half. $C = \frac{\epsilon_0 A}{d}$, i.e. double the plate separation or inserting dielectric of dielectric of a value such that C becomes ½ .

2. **A capacitor has some dielectric between its plates, and the capacitor is connected to a DC source. The battery is now disconnected and then the dielectric is removed. State whether the capacitance, the energy stored in it, electric field, charge stored and the voltage will increase, decrease or remain constant**

❖ C will decrease
Energy stored = $\frac{1}{2}CV^2$ and hence will increase.
Electric field will increase.
Charge stored will remain the same.
V will increase

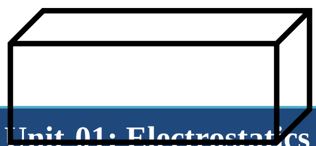
Module 10

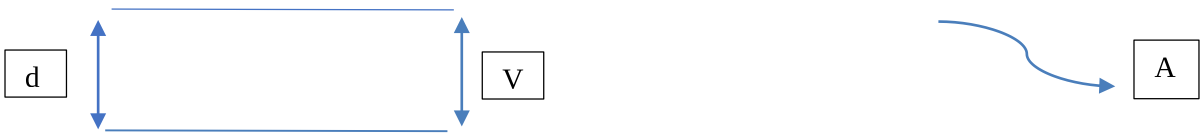
1. **Capacitors P, Q and R have a capacitance of C respectively. A battery can charge capacitor P to a potential difference of V.**
If after charging P, the battery is disconnected from it and the charged capacitor P is connected to Q and R in the following way
   I. **Q in parallel**
   II. **r in series**
   What will be the potential difference between the plates of P in the two cases?

❖

I. V/2
II. V

2. **While obtaining the formulae for parallel plate capacitor consider the following**





A line diagram and a 3 D diagram are shown, V is the potential difference between plates of area A, separated by a distance of d, in vacuum

Suppose two parallel plates of a capacitor each have a charge = Q

If the surface charge density = charge on surface/area of surface σ = $\frac{Q}{A}$
The electric field strength between the plates is E

a) **E =** $\frac{\sigma}{\varepsilon_0} = \frac{Q}{\epsilon_0 A}$ **what is the assumption in this expression**

b) **E=**$\frac{V}{d}$ **or electric field = potential gradient Why?**

c) $\frac{V}{d} = \frac{Q}{\epsilon_0 A}$ **justify this equation**

d) **C=**$\frac{Q}{V} = \frac{\epsilon_0 A}{d}$ **how will you modify the expression for a parallel plate capacitor with mica between the plates?**

e) **Can we place a conductor between the parallel plate capacitor? Why?**

❖ $E = \sigma/\varepsilon_\circ$ is the electric field at a point between two closely spaced parallel plates of equal and opposite charge in vacuum where σ is the surface charge density on each plate

❖ We know that $E = F/q$
And also F = W/d
By substituting the value of F in E = F/q
We get E = W/qd
Here W/q = V
So, we have E = V/d
Electric field is the gradient of potential i.e. potential changes as the distance between plate changes.

❖ Here the space between plates is filled with mica. Let us assume that the dielectric constant of mica is K.
We get

$$C = K\frac{\varepsilon_\circ A}{d}$$

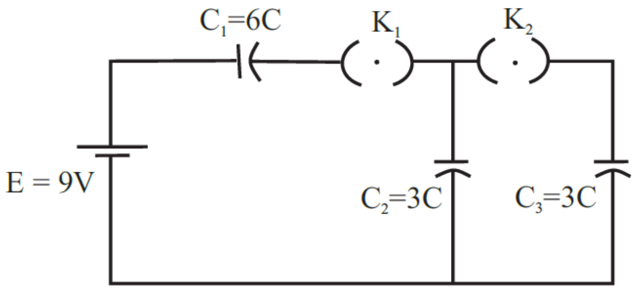
❖ There are two conditions on placing a conductor between a capacitor-
When the conductor is connected with the plates of the capacitor then it will simple flow the charge form one end to other end and the capacitor will behave like a simple wire.

When there is dielectric between the plates of capacitor and conductor then the capacitance of the capacitor will decrease since the whole system will work as two capacitor placed in series.

So it is useless to put a conductor between the plates of a capacitor unless you want to reduce the capacitance of capacitor.

Module 11

1. In the circuit shown in Fig.



I. Initially K1 is closed and K2 is open.
What are the charges on each capacitor?

II. Then K1 was opened and K2 was closed (order is important),
What will be the charge on each capacitor now? [C = 1 μF]

❖ Initially

$$V \propto \frac{1}{C} \, and \; V_1 + V_2 = E$$
$$V_1 = 3\,V \;\; and \; V_2 = 6V$$

Hence, $$Q_1 = C_1V_1 = 6C \times 3 = 18\mu C$$

$$Q_2 = 9\mu C \;\; and \; Q_3 = 0$$

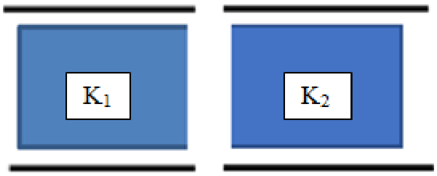
❖ Later: $$Q_2 = Q_2' + Q_3$$

With $C_2V + C_3V = Q_2$
$$V = \frac{Q_2}{C_2 + C_3} = \frac{3}{2}V$$

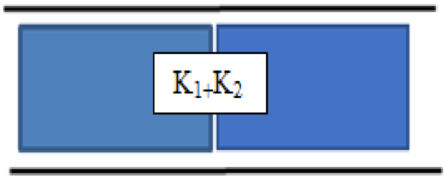
$$Q_2' = \frac{9}{2}\mu C \quad and \quad Q_3' = \frac{9}{2}\mu C$$

2. Two dielectric slabs of dielectric constant K_1 and K_2 are filled in between the two plates, each of area A, of the parallel plate capacitor. Find the net capacitance of the capacitor

- The schematic diagram should look as shown



After combining



We can consider them as two capacitors

As the two capacitors are connected in parallel the net capacitance is given by

$$C_{net} = C_1 + C_2$$

$$C_1 = K_1 \frac{\epsilon_0 A}{d}$$

$$C_2 = K_2 \frac{\epsilon_0 A}{d}$$

$$C_{net} = K_1 \frac{\epsilon_0 A}{d} + K_2 \frac{\epsilon_0 A}{d}$$