INTRODUCTION

Have you ever wondered what electricity is and where it comes from?

About 3000 years ago people began to notice that certain materials had 'magical' properties: if a piece of amber was rubbed with a woolen cloth it would attract small objects. Much later, the rubbed objects were described as 'charged with electricity' – thought to be an invisible fluid of which there were two kinds, ***negative*** for the amber, ***positive*** for the glass. **Lightning** is another phenomenon of sudden electrostatic discharge during an electrical storm between electrically charged regions of a cloud. **Electrostatics** is a branch of physics that deals with the phenomena and properties of stationary or slow-moving electric charges with no acceleration. In this chapter we are going to deal with charges at rest and related laws and effects.

UNIT FRAME

Periods: 14

Concept/Process skills	Learning Activity/Assessment	Learning Objectives
Electric charges, Conductors and Insulators # Experimenting # Observing # Classifying # Interpreting # Analyzing	**General Discussion** on charges **Simple Experiment –** Frictional Electricity **ICT** – Types of Charges and electroscope	**Explains** the types and properties of charges and electroscope. **Distinguishes** conductors and insulators by citing examples.
Conductors and Insulators **-Charging by conduction and induction** **-Basic properties of electric charges** # Observing # Experimenting # Analysing # Interpreting	**Simple experiment** - Charging by conduction and induction. **General discussion** on basic properties of charges.	**Explains** the charging by conduction and induction with examples. **Explains** the basic properties of charges -Additivity, conservation and quantization
	Assessment: # Active participation in General discussion (Process) # Activity Log Book (Portfolio)	
Coulomb's law **-Forces among multiple charges.** # Observing # Problem solving. # Analysing # Interpreting	**General Discussion** on Coulomb's law **ICT** on Coulomb's law	**States and formulates** the Coulomb's law and solves numerical problems related to it. **Explains** the forces among multiple charges.
Electric field -Electric field due to a system of charges. -Physical significance of electric field.	**ICT** about electric field **General Discussion** on electric field due to a system of charges.	**Explains** electric field and its physical significance. **Formulates** the electric field due to a system of charges and

# Observing # Problem Solving # Analysing # Interpreting		solves numerical problems related to it.
	Assessment: # Active participation in General discussion (Process) # Activity Log Book (Portfolio)	
Electric field lines -Electric flux # Observing # Identifying # Analysing	**ICT** – PhET simulation on electric field lines and flux. **General discussion** on Electric Flux	**Explains** the properties of field lines. **Defines** electric flux and **formulates** the relation connecting electric flux and area.
Electric dipole -Field at a point on its axial and equatorial lines # Problem Solving # Observing # Analysing	**General Discussion** on electric dipole and intensity at a point on its axial and equatorial lines. **ICT** about electric dipole.	**Defines** electric dipole and dipole moment **Formulates** the electric intensity due to an electric dipole on its axial and equatorial lines and **solves** numerical problems related to it.
Dipole in a uniform external field. # Observing # Problem Solving # Analysing	**General Discussion** on dipole in a uniform external field **ICT** about the above cases.	**Formulates** the expression for torque of a dipole in uniform electric field and explains dipole in a non uniform electric field
Continuous charge distribution # Observing # Problem Solving # Analysing	**General Discussion** on continuous charge distribution. **Group Discussion** on continuous charge distribution.	**Explains** different types of continuous charge distribution.
Gauss' law **Applications of Gauss' law** # Observing # Problem Solving # Analysing # Interpreting.	**General Discussion** on Gauss' law and its applications. **ICT** about Gauss' law.	**Explains** and proves Gauss' law in electrostatics. **Formulates** the expression of electric intensity due to an infinitely long straight uniformly charged wire, uniformly charged thin spherical shell and uniformly charged infinite thin sheet and **solves** problems related to the above cases.
	Assessment: # Active participation in General discussion (Process) # Activity Log Book (Portfolio)	

TOWARDS THE UNIT

Content: **Electric Field Lines**
Suggested Activity: **PhET Simulation – *Charges and Fields***

To transact the idea of Electric field lines, teacher uses the simulation named ***Charges and Fields*** available in www.phet.colorado.edu.

Discussion Points:
Teacher places a single charge from the positive charge basket (Available on the right side of the window). By clicking the *show hi-res view* (or *show lo-res view*), the variation of Electric Field intensity is seen (in red colour).
How do you find the Intensity of Electric field at a point around this source charge?
[Hint: By placing a unit positive charge at the given point]
Teacher asks a student to come and do the simulated experiment by using the options available in the above PhET Simulation. A test charge is taken from the E – Field sensor basket and placed it at various locations. What do you observe?
[Hint: The arrow showing the magnitude and direction of Electric field changes in length and direction at different locations]
Teacher asks another student to do the same experiment using negative source charge.

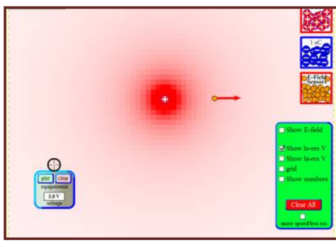


Figure 1

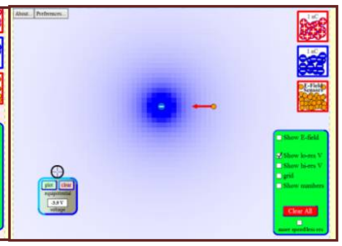


Figure 2

Teacher introduces the concept Electric field lines. To make the idea concrete, teacher asks the students to do the following experiment.
Place a test charge near the positive source charge. A long Electric field line directing outward is obtained. Place another test on the head of arrow. Another Electric field line with decreased length is obtained. Repeat this experiment, and a screen is obtained as in the figure 3.
Students are asked to repeat the experiment with a negative charge, a system of positive and negative charges, a system of two positive charges and a system of two negative charges.

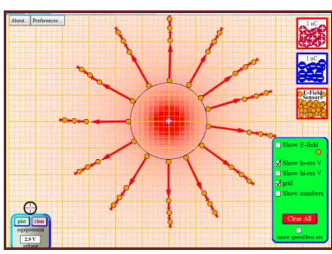


Figure 3

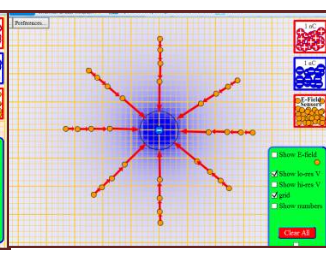


Figure 4

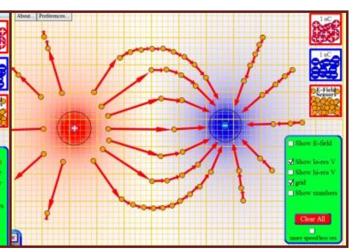


Figure 5

Teacher explains various properties of Electric field lines and asks the students to draw Field lines due to Point charge, system of two like and unlike charges in their activity logbook.

Consolidation:
Teacher consolidates the concept Electric Field lines and their properties.

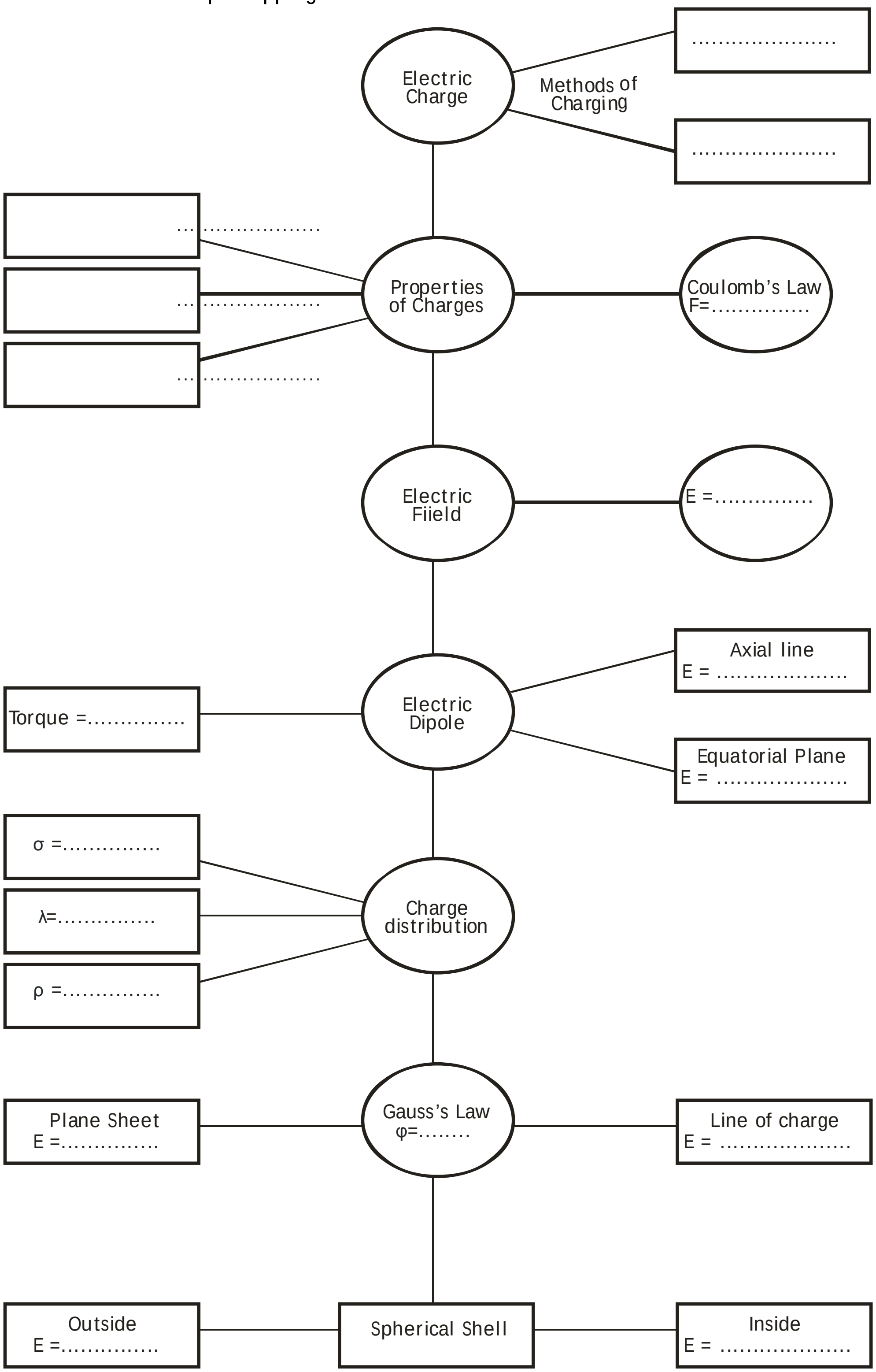
REPOSITORY OF CE ITEMS

1. **Process Assessment**
    - General Discussion
    - Group Discussion

2. **Portfolio Assessment**
    - Activity Log book
    - Worksheets
    -
3. **Unit Based Assessment**
    - Unit Test
    -
4. **ICT Possibilities**
    - PhET Simulations

WORKSHEEETS

Worksheet-1: Concept Mapping



Worksheet-2: Electric Force and Field

Complete the table

Sl. No.	Charge creating the electric field (Q)	Charge used to test the electric field (q)	Force experienced by test charge (F)	Electric field intensity (E)	Distance
1	4×10^{-4} C	1×10^{-6}C	0.20 N	-------------	d
2	4×10^{-4} C	2×10^{-6}C	-------------	$2 \times 10^{+5}$ N/C	d
3	8×10^{-4} C	1×10^{-6}C	0.40 N	-------------	d
4	8×10^{-4} C	2×10^{-6}C	-------------	$2 \times 10^{+5}$ N/C	d
5	8×10^{-4} C	-------------	0.60 N	-------------	d
6	8×10^{-4} C	1×10^{-6}C	-------------	$2 \times 10^{+5}$ N/C	2d
7	8×10^{-4} C	2×10^{-6}C	-------------	-------------	2d
8	8×10^{-4} C	-------------	0.10 N	-------------	2d
9	4×10^{-4} C	-------------	-------------	$2 \times 10^{+5}$ N/C	0.5d
10	4×10^{-6} C	-------------	-------------	-------------	0.5d

Work sheet-3: Electric dipole

Complete the table

Charge (q)	Dipole length (2a) mm	Dipole moment(P)	Distance from the centre of dipole (r)	Electric field along axial line	Electric field along equatorial line
10×10^{-6} C	0.5×10^{-6}m		1 m		
10×10^{-6} C	0.5×10^{-6}m		2 m		
10×10^{-6} C	0.5×10^{-6}m		3 m		
20×10^{-6} C	0.5×10^{-6}m		1 m		
20×10^{-6} C	0.5×10^{-6}m		1 m		
20×10^{-6} C	0.5×10^{-6}m		1 m		
10×10^{-6} C	1×10^{-6}m		1 m		
10×10^{-6} C	1×10^{-6}m		1 m		
10×10^{-6} C	1×10^{-6}m		1 m		

Work sheet 4: Draw Electric field lines

Charge distribution	Field lines due to charge distribution
Point charge	
Dipole	
Infinite long charged wire	
Infinite plane sheet	
Spherical shell	

Worksheet-5: Graphical Representation of variation of Fields with distance
Complete the table and draw all the variations of electric field with r
(E_0 (=100 units) is the Intensity of Electric field for unit distance from the source charge)

r	r^2	r^3	Due to Infinite wire	Due to Point charge/Spherical Conductor	Due to Dipole	
			E_0/r	E_0/ r^2	E_0/ r^3	
1	1	1	100	100	100	
2	4	8	50	25		
3	9	27				
4	16	64				
5	25	125	20	4	0.8	

SAMPLE TE ITEMS

1. A] The SI unit of relative permittivity
   (a) Nm^2C^{-2} (b) $Nm^{-2}C^2$ (c) $C^2N^{-1}m^{-2}$ (d) None of these
   B] How does the Coulomb force between two point charges depend upon the dielectric constant of the intervening medium?
   C] Two point charges repel each other with a force F when placed in water of dielectric constant 81. What will be the force between them when placed the same charges at the same distance apart in air?
   [Score: 1+1+2 = 4]
2. A] Coulomb's law for the force between electric charges most closely resembles with
   (a) Hooke's law (b) Newton's law of Gravitation
   (c) Gauss' theorem (d) Law of Conservation of Energy
   B] What is the use of a Gold leaf electroscope?
   C] Mention any three properties of Electric field lines
   [Score: 1+1+2 = 4]
3. A] *A body is negatively charged by friction*. It means that
   a) The body gains some electrons b) The body loses some electrons
   c) The body loses some neutrons d) The body gains some neutrons
   B] Ordinary rubber is an insulator. But special rubber tyres of air crafts are made slightly conducting. Why?
   C] A polythene piece rubbed with wool is found to have a negative charge of 4×10^{-6}C. Calculate the number of electrons transferred from wool to polythene.
   [Score: 1+2+2]
4. Match the following

Sl No	A	B
1	Electric Field	$C^2N^{-1}m^{-2}$
2	Electric dipole moment	NC^{-1}
3	Electric flux	Cm
4	Absolute Permittivity	Vm

   [Score: 2]
5. An electric dipole is a pair of equal and opposite point charges *q* and –*q*, separated by a distance 2*a*.
   A] A particular dipole consists of a positive charge at x = 0 m, y = 0.1 m and a negative charge at x = 0 m, y = -0.1 m. The direction of the dipole moment is along
   (a) + x (b) –x (c) +y (d) –y
   B] Obtain the expression for electric field at a distance r on the perpendicular bisector of an electric dipole.
   C] An electric dipole with dipole moment 4×10^{-9} C m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^4 NC^{-1}. Calculate the magnitude of the torque acting on the dipole.
   D] By what power of distance does the strength of electric field due to a single point charge fall off? How does this compare with that of an electric dipole? Briefly explain the reason for the difference between these two cases
   [Score: 1+2+2+2]
6. A] The ratio of Electric fields on the axial line and at the equatorial line of an electric dipole will be
   (a) 1:1 (b) 2:1 (c) 4:1 (d) None of these
   B] An arbitrary surface encloses a dipole. What is the electric flux through this surface?
   C] An electric dipole, when held at 30^0 with respect to a uniform electric field of 10^4 NC^{-1} experiences a torque of 9×10^{26} Nm. Calculate the dipole moment.
   [Score: 1+1+2]
7. Electric Flux φ of electric field **E** through a small area element Δ**S** is given by φ = **E . ΔS**
   A] Electric field on a plane is described by V = 20 [(1 / r) + (1/r^2)]. The field is due to
   (a) a dipole (b) a monopole (c) a dipole and a monopole (d) None
   B] Find the total Electric flux originating from a point charge q = 8.854 µC.
   C] Deduce the expression for work done in rotating an electric dipole from its equilibrium position to an angle ϴ with the uniform electric field.
   [Score: 1+1+2]

REFERENCES

1. PHYSICS Text book for Class 11 - NCERT
2. Concepts of Physics - HC Verma
3. Concepts of Physics - Halliday, Resnick and Walker
4. www.phet.colorado.edu
5. Introduction to Electrodynamics – David J Griffiths

INTRODUCTION

Electric potential is a location-dependent quantity that expresses the amount of potential energy per unit charge at a point. In this unit we are going to discuss how to use the concept of Potential and Potential energy in the study of electrostatic phenomena. Equipotential surfaces, the properties of conductors and dielectrics, Capacitors and their combinations are also discussed

UNIT FRAME

Periods: 11

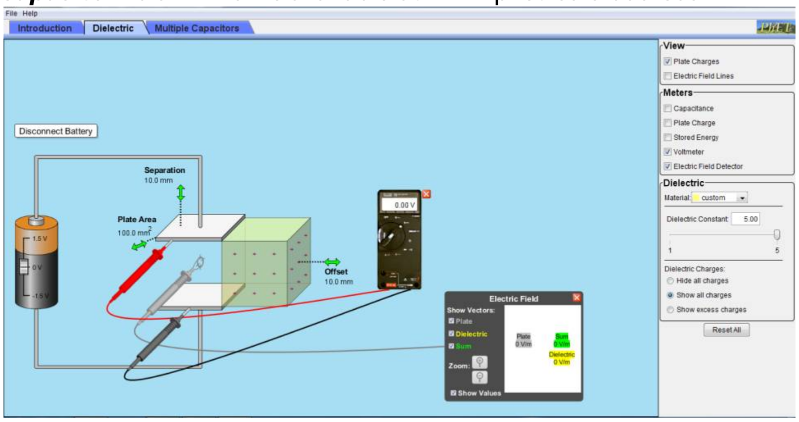
Concept/Process skills	Learning Activity/Assessment	Learning Objectives
Electrostatic potential and potential difference. # Observing # Problem solving # Analysing	**General Discussion** on electrostatic potential and potential difference.	**Explains** the difference between electrostatic potential and potential difference.
Potential due to a point charge and due to an electric dipole # Observing # Problem solving # Analysing # Interpreting	**General discussion** on Potential due to a point charge and electric dipole. **ICT** on electric dipole	**Formulates** the potential due to a point charge and an electric dipole. **Analyses** the graph and solves problems related to potential
Potential due to a system of charges **-**Equipotential surface, -Potential energy of a system of charges. # Observing # Problem solving. # Analysing # Interpreting	**ICT** on potential due to a system of charges and equipotential surface. **General Discussion** on P.E of a system of charges.	**Formulates** the potential due to a system of charges. **Explains** the equipotential surface by citing examples. **Formulates** the potential energy of a system of charges and solves numerical problems related to it.
	Assessment: # Active participation in General discussion (Process) # Activity Log Book (Portfolio) # Worksheet (Portfolio)	
Potential energy in an external field -Single charge -System of two charges and dipole. # Observing # Identifying # Analysing	**General Discussion** on potential energy a system of charges, single charge, system of two charges and dipole in an external field.	**Explains** the potential energy due to a single charge and defines electron volt **Formulates** the potential energy due to a system of two charges and dipole in an external electric field and **solves** numerical problems related to them.
Electrostatics of conductors, Dielectrics and polarization	**General discussion** on electrostatics of conductors. **ICT** on dielectrics and polarisation	**Explains** the concept of electrostatics of conductors.

# Observing # Analysing # Interpreting		**Differentiates** different dielectrics by citing examples and **explains** electric polarization.
Capacitors and Capacitance **-Parallel plate capacitor** **-Effect of dielectric** # Observing # Problem Solving # Interpreting # Analysing	**General discussion** and ICT on capacitors and parallel plate capacitor. **Generational discussion** and demonstration using PhET simulation about dielectric polarization.	**Defines** capacitance and its unit. **Formulates** the expression for capacitance of a parallel plate capacitor and **solves** problems related to it. **Explains** the effect of dielectric on capacitance.
	Assessment: # Active participation in General discussion (Process) # Activity Log Book (Portfolio) # Worksheet (Portfolio)	
Combinations of capacitors # Observing # Experimenting # **C**lassifying	**General Discussion** on combination of capacitors. **Simple experiment** on combination of capacitors.	**Formulates** the expression for effective capacitance when capacitors are connected in series and parallel and **solves** problems related to it.
Energy stored in a capacitor # Observing # Problem Solving # Interpreting # Analysing	**General discussion** on energy of a capacitor.	**Formulates** the energy of a capacitor.
Van de graff generator # Observing # Identifying # Interpreting # Analysing	**ICT-** video showing Van de graff generator	**Explains** the construction and working of a Van de graff generator
	Assessment: # Active participation in General discussion (Process) # Activity Log Book (Portfolio) # Worksheet (Portfolio)	

TOWARDS THE UNIT

Content: **Effects of Dielectrics on a Capacitor**
Suggested Activity: **PhET Simulation - *Capacitor Lab***

Teacher brushes up the idea of Capacitance of a Parallel plate capacitor and shows a simulation – ***Capacitor Lab*** – which is available at www.phet.colorado.edu.



Discussion Points:
Teacher connects Voltmeter to the upper and lower plates of the Capacitor and places Electric field detector in between the plates (the tools available in the Simulation).
Can you see the readings of Potential difference and Electric field between the plates? The capacitor is charged gradually by increasing the battery voltage.
What do you see now?
[Hint: Potential difference and Electric field between the plates increase. ie, V $\propto$ E]
After charging the Capacitor, Teacher disconnects the battery and increases the distance between the plates.
What do you observe now?
[Hint: E does not change, but V increases. ie, V $\propto$ d]
Then how do you relate E, V and d?
[Hint: V = Ed]

Teacher introduces a dielectric slab between the plates.
What do you observe inside the dielectric slab? What change does occur in the Electric field?
[Hint: Dielectric is Polarized, Net Electric field decreases]
Why does the net field decrease?
[Hint: The field produced by the dielectric Polarization is opposite to the applied field]

The students are asked to write a relation connecting the charge density of the Capacitor plate and the Electric field?
[Hint: E = $\frac{\sigma}{\varepsilon_0}$]
Then how do you express the net Electric field?
[Hint: E = $\frac{\sigma-\sigma_P}{\varepsilon_0}$]
What is the expression for Potential difference between the plates?
[Hint: V = Ed = $\frac{\sigma-\sigma_P}{\varepsilon_0}$ d]
What happens to σ_P when Electric field is increased?
[Hint: σ_P increases with E]
Teacher explains that $\sigma - \sigma_P$ also increases with E. Since E increases with σ, $\sigma - \sigma_P$ increases with σ.
ie, $\sigma - \sigma_P = \frac{\sigma}{K}$, where K is the Dielectric constant of the medium.

Now, How can you re write the expression V = $\frac{\sigma-\sigma_P}{\varepsilon_0}$d
[Hint: V = $\frac{\sigma d}{\varepsilon_0 K}$ = $\frac{Qd}{A\varepsilon_0 K}$]
Then, what will be the equation for Capacitance?

[Hint: C = $\frac{Q}{V}$ = $\frac{\varepsilon_0 KA}{d}$]
Teacher asks the students to do the worksheet No-2.

Consolidation:
Teacher consolidates the discussion by explaining that the effect of dielectric in a parallel plate capacitor.

REPOSITORY OF CE ITEMS

1. **Process Assessment**
   - General Discussion
   - Group Discussion

2. **Portfolio Assessment**
   - Activity Log book
   - Worksheets
   -
3. **Unit Based Assessment**
   - Unit Test
   -
4. **ICT Possibilities**
   - PhET Simulations

Worksheet 1

Charge distribution	Shape of Equipotential Surface
Point charge	
Dipole	
Linear charge	
Plane charge	
Spherical charge	

Worksheet 2: Using PhET simulation (Capacitor Lab)

Area of the plate (A)	Distance between the plates (d)	Dielectric constant of medium in between the plates	Electric field (E)	Potential difference (V)	Charge (Q)	Capacitance (C)
100 mm^2	5 mm 7 mm 10 mm	5 5 5				
100 mm^2 200 mm^2 300 mm^2	10 mm	5 5 5				
100 mm^2	10 mm	1 3 5				

Worksheet 3
Complete the table

	Capacitance C (μF)	Potential difference (V)	Total charge (Q)	Potential difference across C1 (V_1)	Potential difference across C_2 (V_2)	Charge stored in the capacitor C_1 (q_1)	Charge stored in the capacitor C_2 (q_2)
Capacitor-1 C_1	10	12					
Capacitor-2 C_2	20	12					
C_1 and C_2 are in series		12					
C1 and C2 are in Parallel		12					

Worksheet 4
Complete the Table

	Capacitance C (μF)	Potential difference (V)	Total charge (Q)	Total energy stored U	Energy stored in the capacitor 1 U1	Energy stored in the capacitor 2 U2	remarks
Capacitor 1 C1	10	12			---	----	
Capacitor 2 C2	20	12			-----	-----	
C1 and C2 are in series		12					
C1 and C2 are in Parallel		12					

SAMPLE TE ITEMS

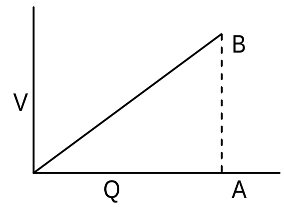
1. A] In a region of constant potential
   (a) the electric field is uniform
   (b) the electric field is zero
   (c) there can be no charge inside the region.
   (d) the electric field shall necessarily change if a charge is placed outside the region
   B] Arrive at an expression for Electric Potential a distance r from a point charge q placed in vacuum
   C] How does it differ from Electric field?
   D] In a television picture tube electrons are accelerated from rest through a potential difference of 10 kV using an electron gun. (a) What is the muzzle velocity of the electrons emerging from the gun? (b) If the gun is directed at a screen 35 cm away, how long does it take the electrons to reach the screen?
   [Score: 1 + 2 + 2 + 3]

2. A] The quantity electric potential is defined as the amount of _____.
   a. electric potential energy b. force acting upon a charge
   c. potential energy per charge d. force per charge
   B] Obtain an expression for the electric potential due to an electric dipole
   [Score: 1 + 3]

3. A proton is moved 10 cm on a path parallel to the field lines of a uniform electric field of 10^5 V/m.

A] What is the change in the proton's potential? Consider both cases of moving with and against the field?
B] What is the change in energy in electron volts?
C] How much work would be done if the proton were moved perpendicular to the electric field?
[Score: 1 + 1 + 1]

4.



A] How can you find energy stored in the capacitor using the above graph?
B] The plates of a parallel plate capacitor having area 90 cm^2 each are separated by 2.5mm. What would be its Capacitance? [ε_0 = 8. 85 x 10^{-12} $C^2N^{-1}m^{-2}$]
[Score: 1 + 2]

5. For a parallel plate capacitor with each plate of area 'A' separated by a distance 'd' in air, its Capacitance is given by, **$C = \epsilon_0 A/d$**
A] Represent the charge 'q' given to a capacitor of capacitance 'C' with potential difference 'V' in a graph. What is the shape of the curve?
B] If you connect the plates of a parallel plate capacitor by a copper wire, what happens to the Capacitance? Justify your answer.
C] Using the above expression, show that the energy density of a parallel plate capacitor is **$\frac{1}{2}\epsilon_0 E^2$** where 'E' is electric field between parallel plates**.**
[Score: 1 + 2 + 3]

6. A] Two metal spheres of radii R_1 and R_2 are charged to the same potential. The ratio of charges on the spheres
(a)$\sqrt{R_1} : \sqrt{R_2}$ (b) $R_1^2 : R_2^2$ (c) *$R_1 : R_2$* *(d)* $R_1^3 : R_2^3$
B] What do you mean by equipotential surfaces?
C] Draw the equipotential surface of an electric dipole
[Score: 1 + 1 + 1]

7. A] Electric potential at equatorial point of a small dipole with dipole moment **p** (At r, distance from the dipole) is.
(a) Zero (b) $p/4\pi\varepsilon_0 r^3$ (c) $p/4\pi\varepsilon_0 r^2$ (d) $2p/4\pi\varepsilon_0 r^3$
B] What is the electrical potential energy of an electron located 10.0 cm from a charge of +6.0 μC?
B] How much work is required to move the electron to an infinite distance from the charge?
[Score: 1 + 2 + 1]

8. A] What is the velocity of an alpha particle (containing two protons and two neutrons) if it is accelerated from rest through a potential difference of 100kV (in ms-1)
(a) 1.1 x 10^6 (b) 1.6 x 10^6 (c) 2.1x 10^6 (d) 3.1 x 10^6
B] Deduce an expression for the energy stored in a Capacitor.
C] A sphere of radius 1 cm has potential of 8000 V, Compute the energy density near its surface.
(Ans: 2.83 J/m^3)
[Score: 1 + 2 + 2]

9. A] The device used to build potential difference of the order of several million volts, which can be used for accelerating charged particles is …………………
B] What do you mean by Electrostatic shielding?
C] The potential energy of a dipole moment **p** in a uniform electric field **E** is –**p.E**.
[Score: 1 + 1 + 2]

REFERENCES

1. PHYSICS Text book for Class 11 - NCERT
2. Concepts of Physics - HC Verma
3. Concepts of Physics - Halliday, Resnick and Walker
4. www.phet.colorado.edu
5. Introduction to Electrodynamics – David J Griffiths