LAXMI INTERNATIONAL SCHOOL - SRI BHARADWAJ Edu-Genea

Department of PHYSICS

UNIT - 1 (ELECTROSTATICS)

Electric Charge and Field

1. State and Explain Coulomb's law in electrostatics. Express the same in SI units
2. State and Explain superposition principle for electric forces.
3. Obtain expression for electric field intensity due to a point charge
4. Find the expression for the electric field intensity at any point on the axis of a uniformly charged ring or hoop. What happens if the ring is far away from the point.
5. Explain the term electric dipole and dipole moment. Derive an expression for electric field intensity at any point on the axial line of the dipole.
6. What is an electric dipole? Derive an expression for the electric field intensity at any point on the equatorial line of the dipole?
7. Derive an expression for the torque acting on an electric dipole placed in a uniform electric field.
8. Derive an expression for potential energy of an electric dipole placed in a uniform electric field.
9. Derive an expression for work done in rotating an electric dipole through angle θ in a uniform electric field.

Electric potential and Flux

10. Derive an expression for potential at a point due to a point charge.
11. Derive an expression for potential at a point due to an electric dipole.
12. Derive an expression for potential energy of a system of two charges.
13. State and prove Gauss's theorem in electrostatics.
14. Derive Coulomb's law from Gauss's theorem.
15. Using Gauss's law, derive an expression for electric field intensity at a point due to (i) a line of charge (ii) a uniformly charged spherical shell
16. Using Gauss's law, derive an expression for electric field intensity at a point due to (i) uniformly charged solid sphere (ii) an infinite plane sheet of charge
17. Derive an expression for work done in moving a charge in an electric field.

Capacitance

18. Derive an expression for the capacitance of a parallel plate air capacitor.
19. Derive an expression for the capacitance of a spherical capacitor.

20. What is the effect of introducing (i) a conducting slab (ii) a dielectric slab between the plates of a parallel plate capacitor on the capacitance of the capacitor.

21. Three capacitors C_1, C_2 and C_3 are connected in series and then in parallel. Derive an expression for the equivalent capacitance respectively.

22. Derive an expression for the capacitance of a cylindrical capacitor.

23. Derive an expression for the energy stored in a parallel plate capacitor.

24. Derive an expression for the energy density of electric field.

25. Derive an expression for the capacitance of a parallel plate capacitor having a conducting slab between the plates.

26. Derive an expression for the capacitance of a parallel plate capacitor having a dielectric slab between the plates.

27. Explain the behaviour of non-polar and polar dielectrics in an electric field

Q.No		Marks
	Electric Field and Charges	
01	What is the work done in moving a test charge 'q' through a distance of 1 cm along the equatorial line of an electric dipole? [Hint : on equatorial line V=0]	01
02	Why in Millikan's Oil Drop experiment, the charge measured was always found to be of some discrete value and not any arbitrary value? Ans: Because charge is always quantized ie., $Q = n \times e$	01
03	What is meant by electrostatic shielding? Ans: Electric filed inside a cavity is zero. To protect any device from electric field , it is to be placed inside the cavity. It is called electrostatic shielding.	01
04	Why an electric dipole placed in a uniform electric field does not undergoes acceleration? Ans: Because the net force on the dipole is zero. $F_{net} = 0$ as $F=\pm qE$	01
05	Why electric field lines (i) Can never intersect one another? (ii) Cannot form closed loop? (iii) Cannot have break in between? Ans : Because (i) Electric field has an unique direction at any given point (ii) Monopoles or single isolated charges exist unlike magnetism (iii) Start from +ve charges and terminate at –ve charges	01
06	Show that at a point where the electric field intensity is zero, electric potential need not be zero. Ans: If E = 0⇒ $V = constant$ according to the equation E=-dV/dr	02

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07 Write the expression for the electric field, charge density for a uniformly charged thin spherical shell. 02

Ans: $E = \frac{kQ}{r^2}$; $\sigma = \frac{Q}{4\pi r^2}$

08

02

Write the expression for the electric field in the regions I, II, III shown in the above figure.

Ans: $E_I = E_{III} = 0$ $E_{II} = \sigma/\varepsilon_0$

09 Two free protons are separated by a distance of 1 A°. if they are released, what is the kinetic energy of each proton when at infinite separation.[Hint : at inifinte distance $K.E = \frac{e^2}{4\pi\epsilon_o r}$] 02

10 How does the electric flux, electric field enclosing a given charge vary when the area enclosed by the charge is doubled? Ans: (a) Ø= constant (b) E is halved 02

11 The electric field in a certain region of space is $\vec{E} = 10^4 \hat{\imath} NC^{-1}$. How much is the flux passing through an area 'A' if it is a part of XY plane, XZ plane, YZ plane, making an angle 30^0 with the axis? 02

Ans: Φ_{XY} =10A Vm E ΔS COSϕ [ϕ=0] $\phi_{XZ} = \phi_{YZ}$ = 0 Vm (ϕ =90°) $=10^4$ A cos30° Vm

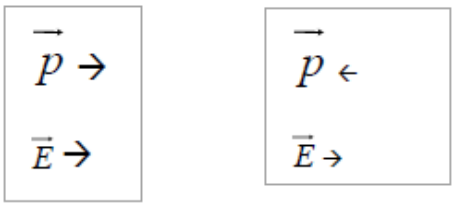
12 An electric dipole ±4μC is kept at co-ordinate points (1, 0, 4) are kept at (2,-1, 5), the electric field is given by $\vec{E} = 20\,\hat{\imath}$ NC^{-1}. Calculate the torque on the dipole.

Ans: Calculate first dipole moment using $\vec{p}$ =q.2$\vec{a}$ 02

Then calculate torque using $\vec{\tau} = \vec{p} \times \vec{E}$ and hence find $|\vec{\tau}|$ =13.4 N m

13 Show diagrammatically the configuration of stable and unstable equilibrium of an electric dipole ($\vec{p}$) placed in a uniform electric field ($\vec{E}$).

Ans:

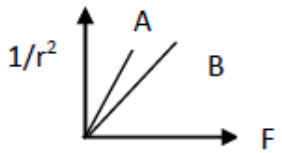


Stable Unstable

02

14 Plot a graph showing the variation of coulomb force F versus $\frac{1}{r^2}$ where r is the distance between the two charges of each pair of charges: (1μC, 2μC) and (2μC, -3μC) Interpret the graphs obtained. 02

[Hint : graph can be drawn choosing –ve axis for force only]



Ans: $|\overrightarrow{F_B}| > |\overrightarrow{F_A}|$

15 A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire. Find the expression for electric flux through the surface of the cylinder. 02

Ans: Using Gauss's Law obtain: $\Phi = \frac{\lambda l}{\varepsilon_0}$

16 Calculate the force between two alpha particles kept at a distance of 0.02mm in air.

Ans: $F = 9 \times 10^9 \frac{4\times(1.6\times10^{-19})^2}{(2\times10^{-5})^2}$ 02

17 Explain the role of earthing in house hold wiring.

Ans: During short circuit, it provides an easy path or emergency way out for the charges flowing to the ground, preventing the accidents. 02

18 What is the difference between charging by induction and charging by friction?

* In frictional method, transfer of charges takes place from one object to the other.
* During induction, redistribution of charges takes place within the conductor. 02

19 A charge +Q fixed on the Y axis at a distance of 1m from the origin and another charge +2Q is fixed on the X axis at a distance of √2 m from the origin. A third charge – Q is placed at the origin. What is the angle at which it moves? 03

Ans: Force due to both the changes are equal = KQ^2 & $\perp^r$ to each other so the resultant force will make 45° with X-axis.

20 Two charges 5μC, -3μC are separated by a distance of 40 cm in air. Find the location of a point on the line joining the two charges where the electric field is zero.

Ans: Solve for x from the equation: $k\frac{5X10^{-6}}{x^2} = k\frac{3X10^{-6}}{(40-x)^2}$ 03

21 Deduce Coulomb's law from Gauss' law.

Ans: $\emptyset = \vec{E}.\vec{S} = Q/\varepsilon_0$ $\quad E\times4\pi r^2 = Q/\varepsilon_0$

$F = Eq_0 \therefore F = [\![Qq_o/(4\pi\varepsilon_0 r^2)$ 03

22 State Gauss's law and use this law to derive the electric filed at a point from an infinitely long straight uniformly charged wire. 03

23 Three charges –q, Q and –q are placed at equal distances on a straight line. If the potential energy of system of these charges is zero, then what is the ratio of Q:q [Ans : 1:4] 03

Electric Potential

01 Is it possible that the potential at a point is zero, while there is finite electric field intensity at that point? Give an example. 01

Ans: Yes , Centre of a dipole

02 Is it possible that the electric field $\vec{E}$ at a point is zero, while there is a finite electric potential at that point. Give an example. 01

Ans: Yes, Inside charged shell

03 Can two equipotential surfaces intersect? Justify your answer.
Ans: No. Otherwise it would mean two directions for force at a point. 01

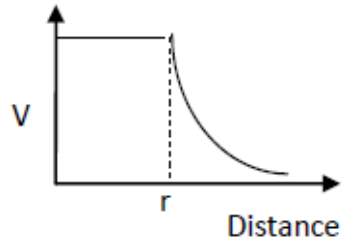
04 Is potential gradient a vector or a scalar quantity?
Ans: Scalar quantity 01

05 Write the dimensional formula of 'ϵ_0' the permittivity of free space.
Ans: $[M^{-1}L^{-3}T^4A^2]$ 01

06 An electric dipole is placed in an electric field due to a point charge. Will there be a force and torque on the dipole? 01

Ans: Yes, Both force and torque will act as the Electric Field is non uniform.

07 Draw the graph showing the variation of electric potential with distance from the centre of a uniformly charged shell.

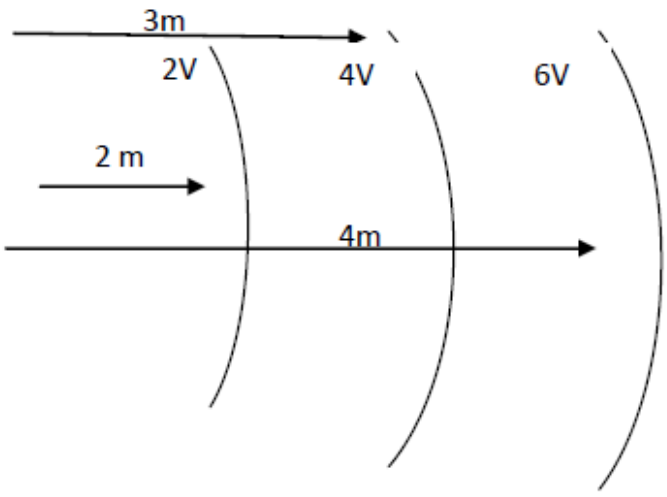


01

08 Find the ratio of the electric field lines starting from a proton kept first in vacuum and then in a medium of dielectric constant 6. 01

Ans: 6 : 1

09 Calculate the electric field from the equipotential surface shown below.



01

Ans: 2 V $\left[E = \frac{-dv}{dr}, dv = 2V, dr = 1m\right]$

10 Two charges are kept as shown. Find dipole moment.
Ans: (0,0,2)-q ..... +q(0,0,-2)
-15 µc +15 µc 01

11 Compare the electric flux in a cubical surface of side 10 cm and a spherical surface of radius 10 cm, when a change of 5μC is enclosed by them. 01

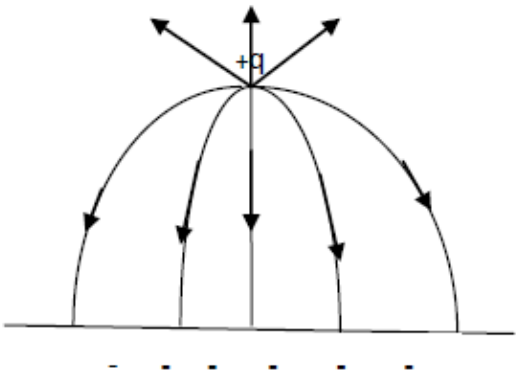
Ans: Electric flux will be same in both the cases.

12 Explain why the electric field inside a conductor placed in an external electric field is always zero. 01

Ans: Charge lies on the surface of a conductor only

13 Sketch the electric field lines, when a positive charge is kept in the vicinity of an uncharged conducting plate.

Ans



02

14 Two identical metal plates are given positive charges Q_1 and Q_2,where $Q_1 > Q_2$. Find the potential difference between them, if they are now brought together to form a parallel plate capacitor with capacitance C. 02

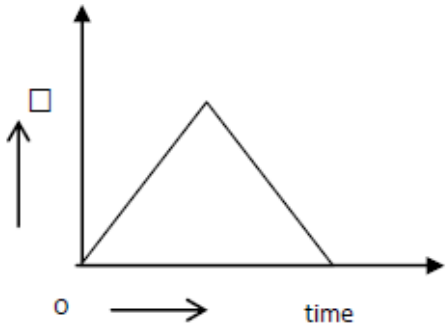
Ans: $(Q_1 - Q_2)/2C$

15 27 small drops of mercury having the same radius collage to form one big drop. Find the ratio of the capacitance of the big drop to small drop. 02

Ans: [3:1]

16 A uniformly charged rod with linear charge density λ of length L is inserted into a hollow cubical structure of side 'L' with constant velocity and moves out from the opposite face. Draw the graph between flux and time.

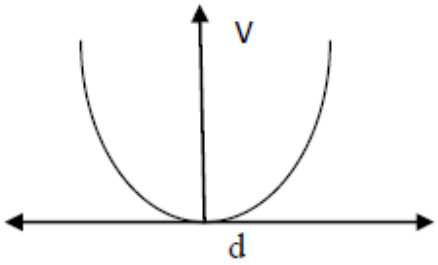
Ans



02

17 Draw a graph showing the variation of potential with distance from the positive charge to negative charge of a dipole, by choosing the mid-point of the dipole as the origin. 02

Ans



18 If $\vec{E} = 3\hat{\imath} + 4\hat{\jmath} - 5\hat{k}$, calculate the electric flux through a surface of area 50 units in z-x plane 02

Ans: 200 unit

19 Name the physical quantities whose SI units are Vm, Vm^{-1}. Which of these are vectors? 02

Ans: Vm → electric flux, scalar ; Vm^{-1}→electric field, vector

20 How will you connect seven capacitors of 2μf each to obtain an effective capacitance of 10/11 μf. 02

Ans: 5 in parallel and 2 in series

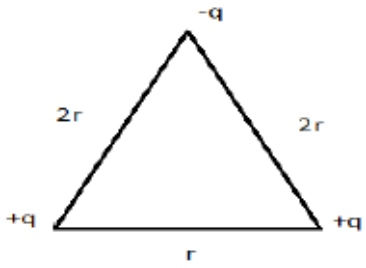
21 A proton moves with a speed of 7.45×10^5m/s directly towards a free proton initially at rest. Find the distance of the closest approach for the two protons. 02

Ans: 5.56×10^{-23}m

22 Three point charges of 1C, 2C & 3C are placed at the corners of an equilateral triangle of side 1m. Calculate the work done to move these charges to the corners of a smaller equilateral triangle of sides 0.5m. 02

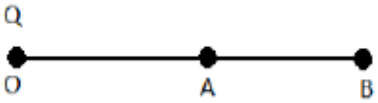
Ans: 9.9×10^{10} J

23 Suggest an arrangement of three point charges, +q,+q, -q separated by finite distance that has zero electric potential energy 02



24 A point charge Q is placed at point O as shown. Is the potential difference (V_A-V_B) positive, negative or zero if Q is (i) positive (ii) negative 02

Ans:

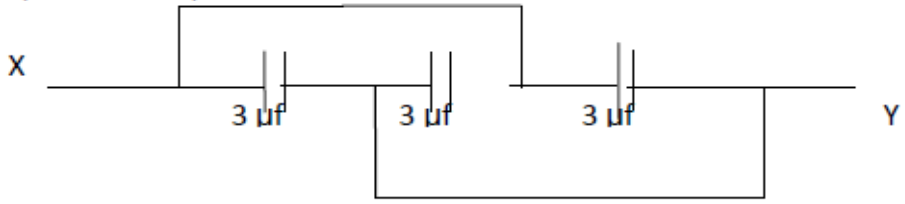


Capacitance

01 What happens to the capacitance of a capacitor when a copper plate of thickness one third of the separation between the plates is introduced in the capacitor? 02
Ans: 1.5 times C_o

02 A parallel plate capacitor is charged and the charging battery is then disconnected. What happens to the potential difference and the energy of the capacitor, if the plates are moved further apart using an insulating handle? 02
Ans: Both Increases

03 Find the equivalence capacitance between X and Y.

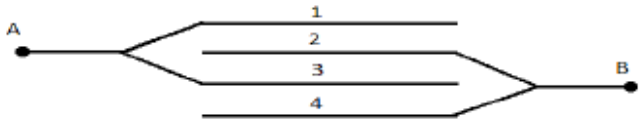


02

Ans: 9 µf

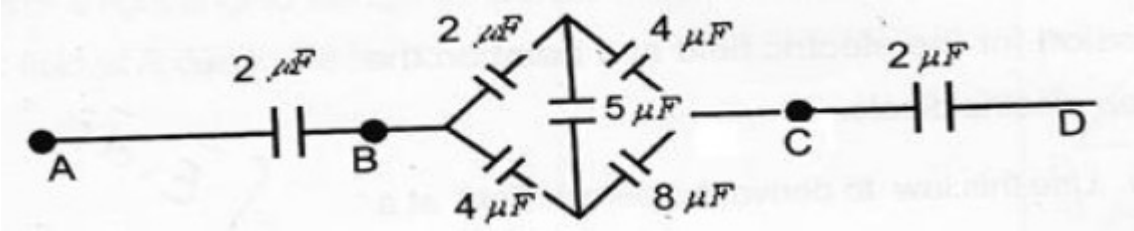
04 A pith ball of mass 0.2 g is hung by insulated thread between the plates of a capacitor of separation 8cm. Find the potential difference between the plates to cause the thread to incline at an angle 15^0 with the vertical, if the charge in the pith ball is equal to 10^{-7}C. 02
Ans: 429 V

05 Find the capacitance of arrangement of 4 plates of Area A at distance d in air as shown.



02

06 What is an equivalent capacitance of the arrangement the shown below



03

If 6V cell is connected across AD. Calculate the potential difference between B&C.

07 A parallel plate capacitor is charged to a potential difference V by d.c. source and then disconnected. The distance between the plates is then halved. Explain with reason for the change in electric field, capacitance and energy of the capacitor. 03
Ans: Use the formulae - Electric field remains same, Capacitance doubled, Energy halved

08 Derive an expression for capacitance of parallel plate capacitor, when a dielectric slab of dielectric constant k is partially introduced between the plates of the capacitor. 03

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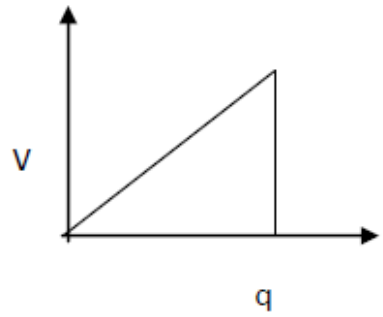
09 A potential difference of 1200 V is established between two parallel plates of a capacitor. The plates of the capacitor are at a distance of 2 cm apart. An electron is released from the negative plate, at the same instant, a proton is released from the +ve plate.
(a)How do their (i) velocity (ii) Energy compare, when they strike the opposite plates. 03
(b) How far from the positive plate will they pass each other?
Ans a. (i)42.84 (ii)equal b. 2.7cm

10 Draw a graph to show the variation of potential applied and charge stored in a capacitor. Derive the expression for energy stored in a parallel plate capacitor from the capacitor. 03



11 Find the capacitance of a system of three parallel plates each of area A m^2 separated by d_1 and d_2 m respectively. The space between them is filled with dielectrics of relative dielectric constant ϵ_1 and ϵ_2. 02

12 Two parallel plate capacitors A and B having capacitance 1μF and 5 μF are charged separately to the same potential 100V. They are then connected such that +ve plate of A is connected to –ve plate of B. Find the charge on each capacitor and total loss of energy in the capacitors. 03
Ans: 400μC, 500μC and 5/3 x 10J

13 Calculate the capacitance of a system having five equally spaced plates, if the area of each plate is 0.02 m^2 and the separation between the neighboring are 3 mm. in case (a) and (b) 03

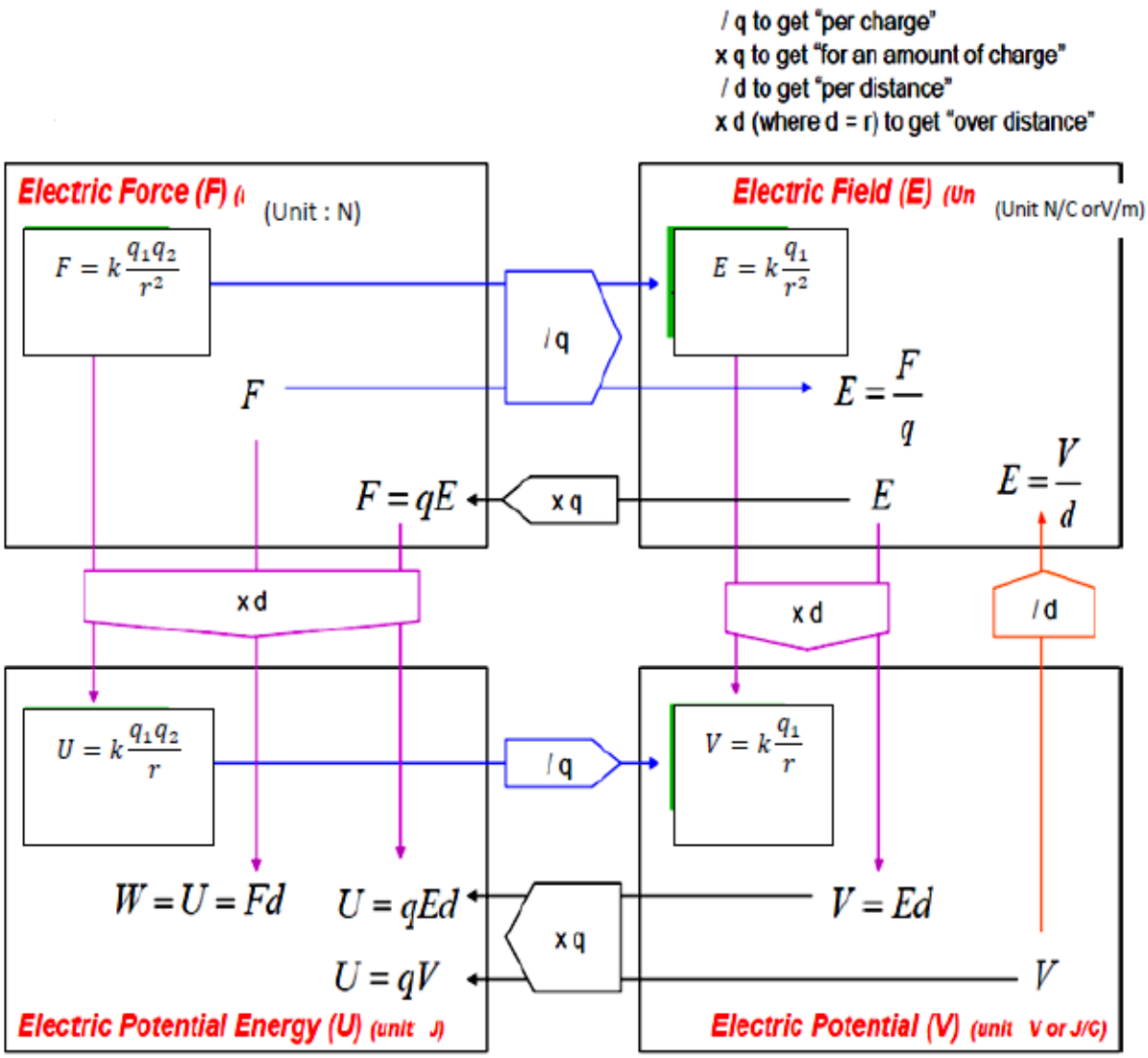
(a) (b)

Ans: (Hint: Capacitance of a parallel plate capacitor $\varepsilon_o A/d$)
1.18×10^{-4} μ F and 2.36 x 10 μ F

14 Net capacitance of three identical capacitors in series is 1μf. What will be their net capacitance if connected in parallel?
Find the ratio of energy stored in the two configurations, if they are both connected to the same source. 02
Ans: 9μf 1 : 9

CONCEPT MAP

Electric Force/Field/Potential/P.E.



CONCEPT MAP

Charge and it's impact

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