30th Nov 2021 VP

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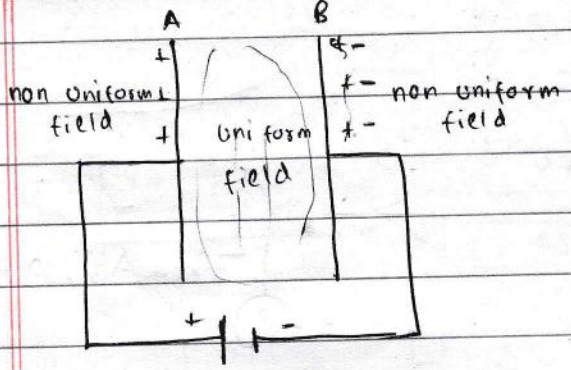
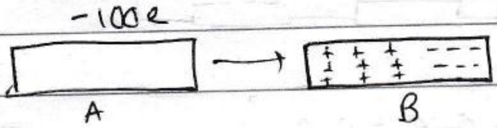
ELECTRIC FIELD

- A field is an area upto where objects experience various forces.
- Region around where a charged particle experiences force is called electric field.
- Uniform electric field is that where a charged particle experiences the same force throughout the field.

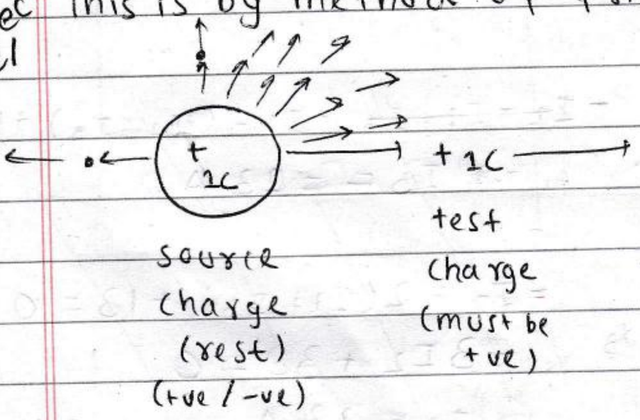


Electrostatic charging:



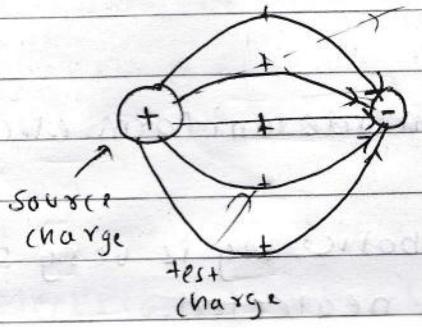
The -100e polarizes electrons in B and shifts them to one side.

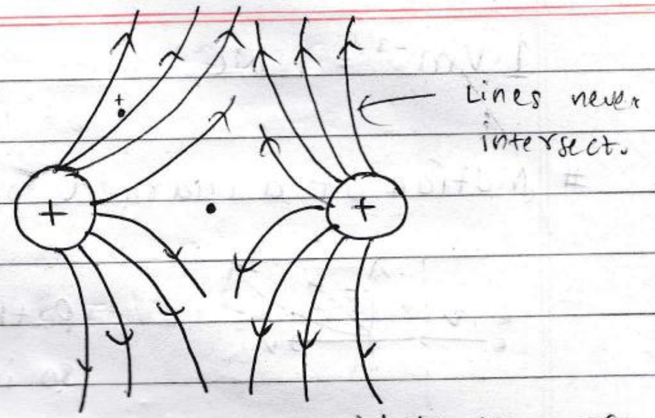
7th Dec 2021 This is by method of friction/induction



The path followed by test charge is electric line of force. When a unit +ve charge, free to move, is kept in an electric field, path followed by test charge is electric line of force.

The lines of force are radially away from the source charge if the source charge is +ve. This is only for isolated charge.



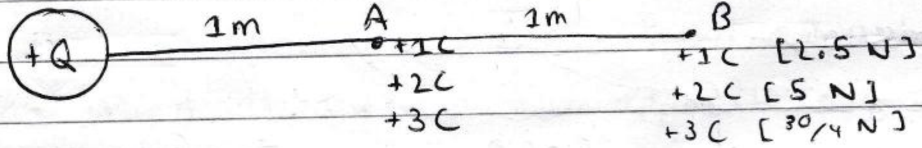


At the absolute middle, there are no lines of force, so charge remains stationary at this neutral point.

Electric field is stronger at points where more lines of force are concentrated.

Electric field strength / intensity

$F_1 = 10N$, $F_2 = 20N$, $F_3 = 30N$

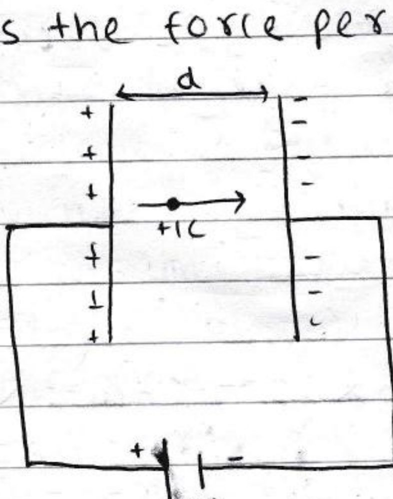


$F/q = 30/3 = 10\ NC^{-1}$ // [Electric field strength]

$E_A = 10\ NC^{-1}$ //

$E_B = 2.5\ NC^{-1}$ //

Electric field strength at a point inside electric field is the force per unit positive charge.



$E \propto V$, $E \propto 1/d$ $\Rightarrow$ $E \propto \frac{V}{d}$

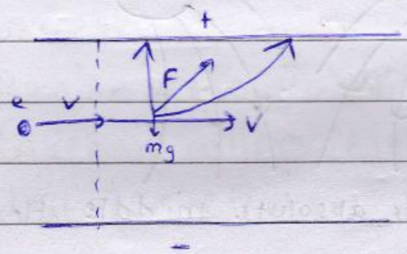
$E = k\frac{V}{d}$

[Experimentally proven $k = 1$]

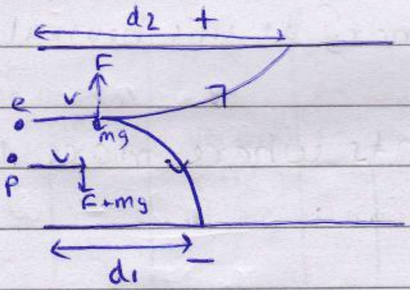
$\therefore E = \frac{V}{d}$ // Vm^{-1} //

$1\ Vm^{-1} = 1\ NC^{-1}$

Motion of a charged particle inside uniform electric field:



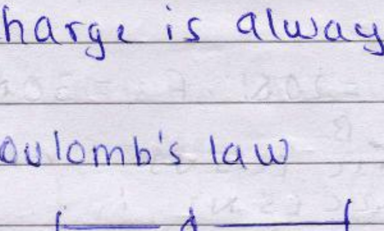
Path is parabolic. Mg is very small so it can be neglected.



Here $d_1 < d_2$ as mass of proton is 1800 times more than that of electrons. This shifts the trajectory.

Electric field strength $\vec{E}$ is from +ve to -ve as test charge is always positive.

Coulomb's law



$F \propto Q.q$ $F \propto Qq/d^2$

$F \propto 1/d^2$ $F = K\dfrac{Qq}{d^2}$

$\therefore F = K\dfrac{Q_1.Q_2}{d^2}$, where K is proportionality constant.

$K = \dfrac{1}{4\pi.\varepsilon_0}$ where ε_0 is permitivity of vacuum and changes with medium.

ε_0 of water $\neq$ ε_0 of vacuum.

ε_0 represents vacuum / air.

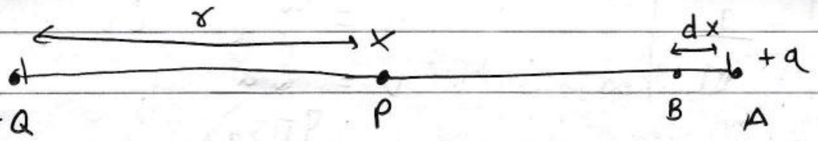
$\therefore F = \dfrac{1}{4\pi\varepsilon} \cdot \dfrac{Q_1.Q_2}{d^2}$,, $\therefore \varepsilon_0 = 8.85 \times 10^{-12}\ C^2m^{-2}N^{-1}$,,

$F_{vacuum} = 12\ N$

$F_{water} = 6\ N$

$\frac{F_V}{F_W} = 2$ ← relative permitivity

Electric potential (V)



- It is the work done/energy per unit charge.
- To move +ve charge +q to +Q, we need to apply some force against force of repulsion.

$$F_A = \frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{x^2}$$

To move q from A to B we need to apply some force that is equal to F_A, but opposite in direction.

$$dW = F_A\, dx$$

- Electric potential ~~at~~ of P is the amount of work done to move q ~~to~~ from infinity upto point P, under influence of charge Q.
- Electric potential at a point inside an electric field is the amount of work done per unit test charge to take this charge from infinity to that point. [This distance infinity is from source charge]
- Total work done,

$$W = \int_{\infty}^{r} dW$$

$$W = \int_{\infty}^{r} -\frac{1}{4\pi\varepsilon_0} \cdot \frac{qQ}{r^2}\, dx$$

$$= \frac{-Qq}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{1}{r^2}\, dx$$

$\boxed{W = \frac{1}{2} [illegible]}$

$$= \frac{-Qq}{4\pi\varepsilon_0} \left| -\frac{1}{r} \right|_{\infty}^{r}$$

$$= \frac{Qq}{4\pi\varepsilon_0 r}$$

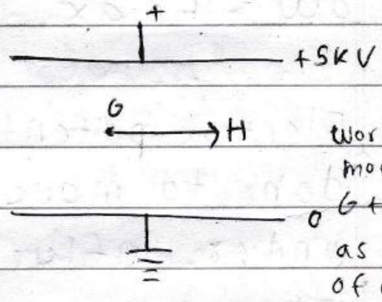
$V = W/q$ [V = potential]

$\therefore V = \dfrac{\frac{Qq}{4\pi\varepsilon_0 r}}{q}$

$\therefore V = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r}$ ... [Potential due to source charge]

$\therefore W = \frac{Qq}{4\pi\varepsilon_0 r}$ ... [Energy gained by q charge in field]

Electric potential is scalar quantity while Electric field intensity is a vector quantity.
This concept can be translated to potential difference.
If pd = 5V, it means we need to do 5 J work ~~per unit charge~~ to move 1C charge across the points.



Work done in moving from G to H is 0 as potential of G & H is same.

Coulumb's Law

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1 \cdot Q_2}{d^2}$ ... where ε_0 is permitivity of free space.

As value of ε increases, force ~~in~~ decreases. So ε of water is greater than ~~e~~ ε_0.

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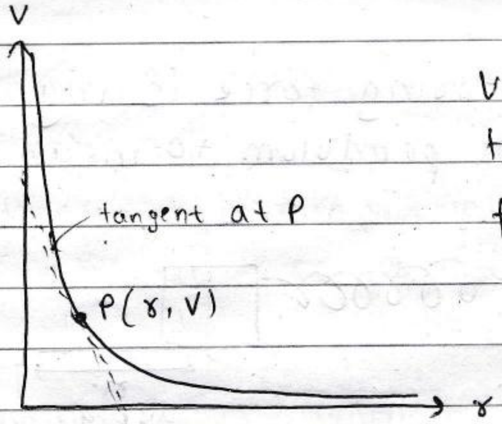
$E = -\frac{\Delta V}{\Delta d} \longrightarrow$ Potential gradient (as it gives gradient of graph)

$V = \frac{Qa}{4\pi\varepsilon_0} \times \frac{1}{r}$

$V = k \times 1/r$

$\therefore V \propto 1/r$



Value of E is the gradient of the tangent at P at a distance r from source charge.

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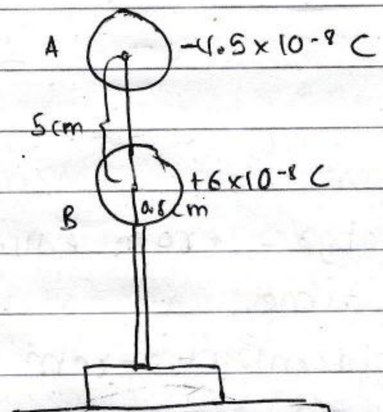


Electric potential at surface of B

$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qa}{r}$

$= \frac{1}{4\pi\varepsilon_0} \times \frac{6 \times 10^{-8}}{0.8/100}$

$= 6.74 \times 10^4$ V

Force between A and B = ?

$F = \frac{1}{4\pi\varepsilon_0} \times \frac{Qa}{r^2}$

$= \frac{1}{4\pi\varepsilon_0} \times \frac{(6\times10^{-8}) \times (4.5\times10^{-8})}{(5/100)^2}$

$= 9.71 \times 10^{-3}$ N

$= 9.71$ mN

New reading on balance

$= -9.71 + 0.0482$

$= \cancel{9.76 \text{ mN}}$ -9.66 mN

~~$W_1 = 9.7\times10^{-3}$ $W_2 = 0.012$~~

$W \cancel{=} \frac{Qa}{4\pi\varepsilon_0} \cancel{= 1.627\times10^{-3} \text{ J}}$ 6.03×10^{-9} J

W = Potential at 3.5 - Potential at 5

$= \frac{1}{4\pi\varepsilon_0}\left(\frac{Qa}{(5/100)^2} - \frac{Qa}{(3.5/100)^2}\right)$

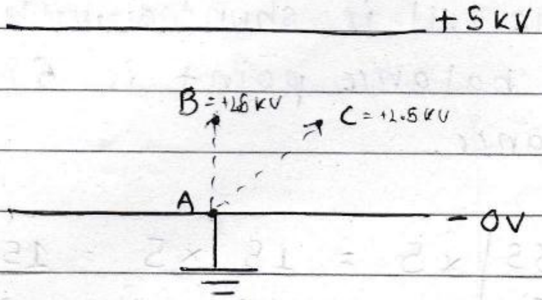
$= \cancel{0.01 \text{ J}}$ 2.08×10^{-4} J

~~Second sphere moves~~:

A moves down by 1.5 cm.

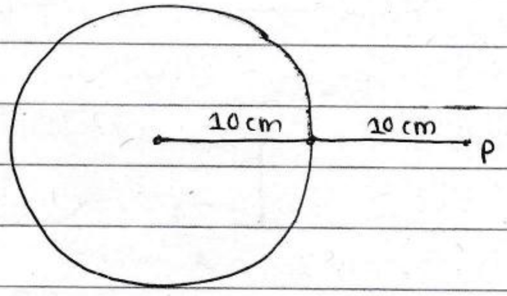
Calculate work done.

ELECTRIC FIELD



Work done to move +1 C of charge.
From A to B = +2.5 KJ.
From A to C = +2.5 KJ.

#



Van De graff genereator.
What charge should be deposited so potential at surface is 100 KV.

$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r}$$

or $(1 \times 10^5) \times (1.1 \times 10^{-10}) \times (10 \times 10^{-2}) = Q$

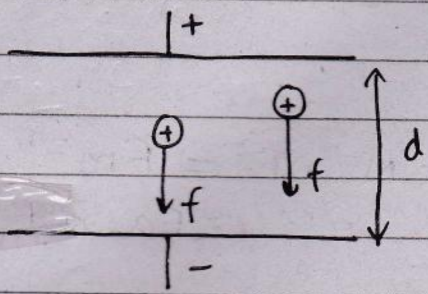
$\therefore Q = 1.1 \times 10^{-6}$ C.

$$V = \frac{1}{4\pi\varepsilon_0} \times \frac{(1.1 \times 10^{-6})}{(20/100)}$$

$\therefore V = 50$ KV.

Electric potential of a point is work done per unit test charge in bringing a test charge from infinity to that point.
The potential energy at that point of the test charge is simply the amount of work done in bringing that test charge from infinity to that point.
Work done in moving charge between two points is simply the difference in potential energies between the points.

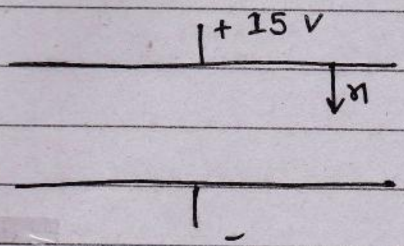
ELECTRIC FIELD

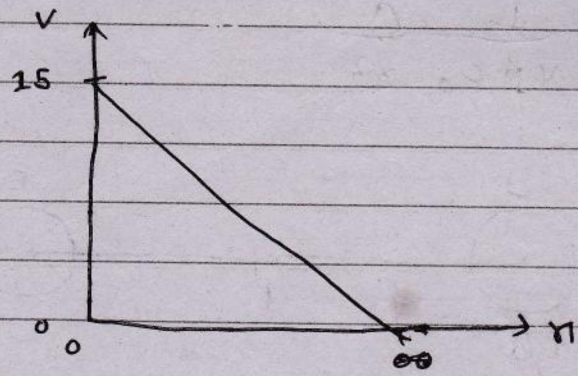


Uniform field is the field where a charged particle experiences the same force throughout the field.

$\mathcal{E} = V/d$, $\mathcal{E} = F/Q$

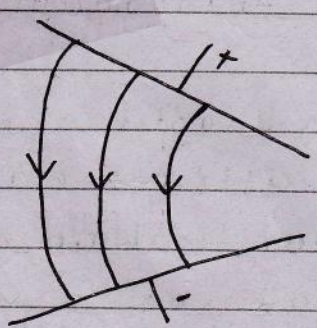
Direction of electric field is same as the direction of force experienced by +ve charge in the field.





Gradient of this graph gives us Electric field strength.

Every electric line of force is perpendicular to an equipotential surface.



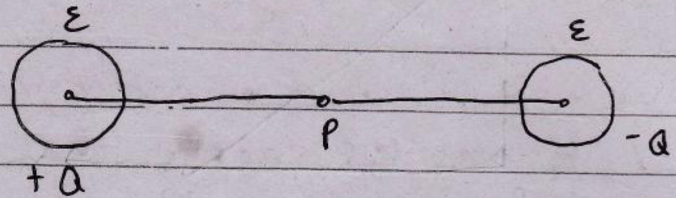
ε_0 = permitivity of free space (vacuum).
Property of a medium which decides force between charges.

$$\varepsilon_0 = \frac{1}{4\pi F}\frac{Q_1 Q_2}{r^2} = \frac{C\,C}{N m^2} = C^2 N^{-1} m^{-2} = F m^{-1}$$

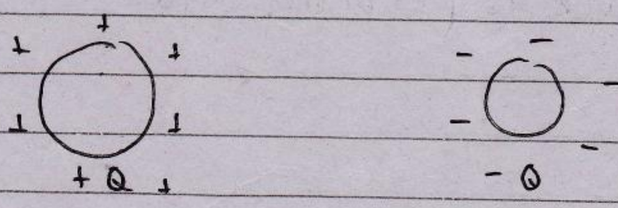
= Farad per met

Electric field strength of a point charge (ε)

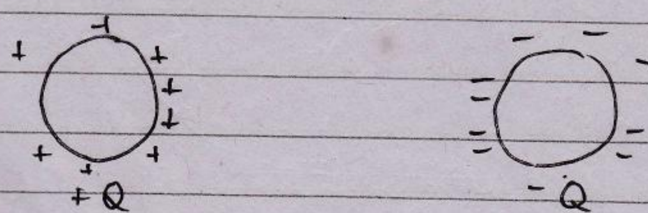
$$\varepsilon = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$



The field intensity at P seems to be 2ε but it is not 2ε in actuality.



This is how isolated charge behave, systematically spread throughout sphere



But when bought close, the charges attract each other thus making charges concentrate at a point.

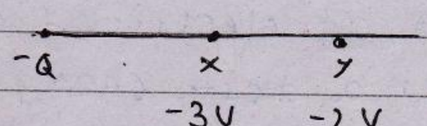
Thus field intensity $> 2\varepsilon$.

Electric Potential

The electric potential at a point is defined as the amount of work done in bringing a unit +ve charge from infinity to that point.

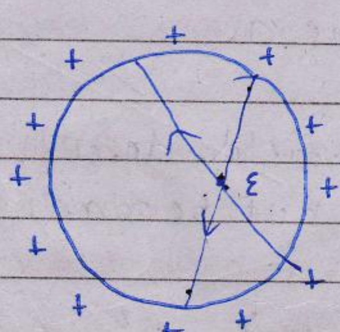
#Note: An α-particle is a He nucleus in motion, a He nucleus in rest is just a He nucleus.

In a field of charge Q, a charge q will have energy:
$$\left(\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}\right)q$$"

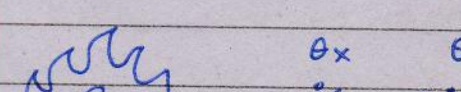


$V_x < V_y$ as when bringing +Q from ∞ to y it loses less energy but from ∞ to x it loses more energy.

Inside a ~~sphere, the~~ charged sphere, the volume is considered to be equipotential. Thus the potential difference inside is 0. $dV = 0$.



The Electric field strength inside at any point is 0 because the forces cancel out.
Thus the volume inside is safe as $\varepsilon = 0$.



Temp. gradient $= \frac{\theta y - \theta x}{r} = \frac{d\theta}{dr}$ "

Variation of temp. with distance.

Thus velocity gradient is not acceleration its dv/ds.

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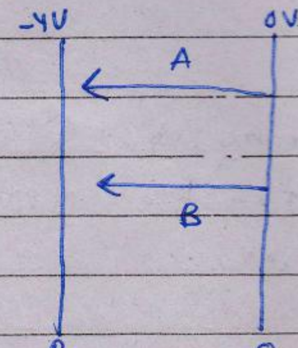
Thus potential gradient is variation of electric potential with distance.

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} \qquad \frac{dV}{dr} = \frac{Q}{4\pi\varepsilon_0} \times \frac{d}{dr}\left(\frac{1}{r}\right) = -\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

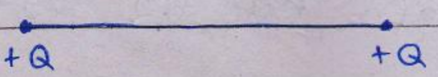
$$\therefore \frac{dV}{dr} = -\varepsilon$$

∴ Electric field strength is negative potential gradient

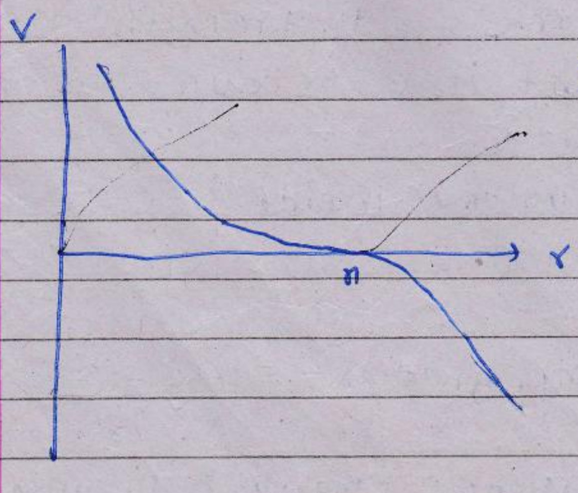
& -ve sign indicates that the direction of electric field strength is same as the direction of decreasing potential.



A is direction of decreasing potential so, B is direction of electric field strength. i.e when a test charge is kept in the field, it moves towards the negatively charged plate ~~Q~~ P.



Electric potential at no point is 0, but electric field strength at middle is 0.



The electric field doesn't change direction, but becomes 0 at n.

Gradient of U-r graph gives -F (Force)
U = Potential energy , r = distance.

$$U = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

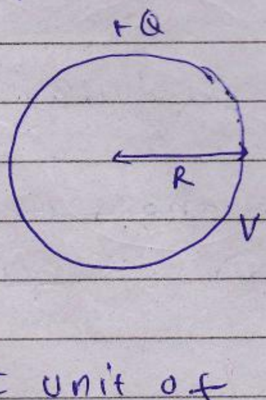
Gradient of PE - r graph gives -Force.
Force is in the direction of decrease of potential energy.

Q = Charge , V = Potential , C = Capacitance.

$Q \propto V$
$\therefore Q = CV$
where C is the constant of proportionality called capacitance of conductor.

$C = Q/V$, ~~Cha~~
Capacitance is the charge stored per unit potential difference.

Capacitance of an isolated sphere.



$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} \qquad C = \frac{Q}{V}$$

$$C = \frac{Q}{\frac{1}{4\pi\varepsilon_0}\frac{Q}{R}} \quad \therefore C = 4\pi\varepsilon_0 R \qquad C \propto R$$

SI unit of capacitance = CV^{-1} = Farad (F).
A metal sphere with capacitance 1F has radius 8.99×10^9 m
Larger than earth. So practical units are μF, pF, mF.