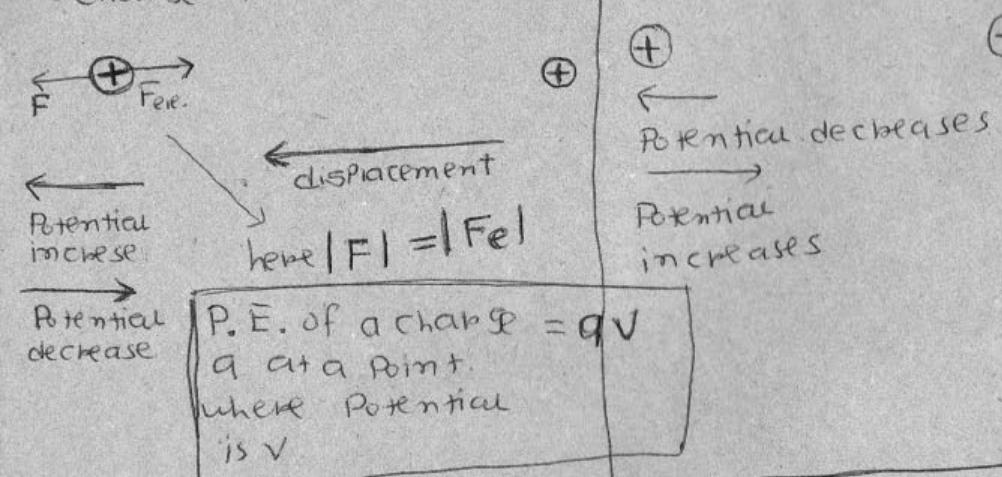


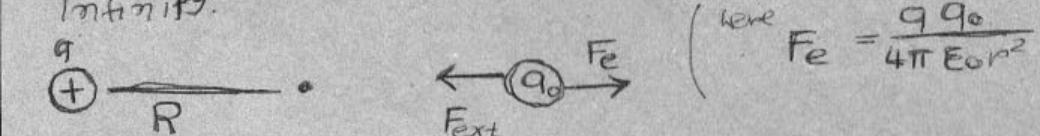
Electric Potential

⇒ electric potential at a point is equal to work done by external agency to bring a unit charge from infinity.



### Electric Potential by Point Charge

⇒ electric potential at a point is equal to work done by external agency to bring a unit charge from infinity.



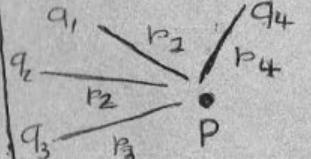
$$dW = F \cdot dP$$

$$W = \int_{\infty}^R dW = \int_{\infty}^R -\left(\frac{q q_0}{4\pi\epsilon_0 r^2}\right) dr$$

$$W = \frac{q q_0}{4\pi\epsilon_0} \left[ \frac{1}{r} \right]_{\infty}^R = \frac{q q_0}{4\pi\epsilon_0 R} \Rightarrow V = \frac{q}{4\pi\epsilon_0 R}$$

Electric Potential due to a System of Charges

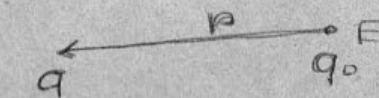
Potential is a scalar quantity



$$V_p = \frac{q_1}{4\pi\epsilon_0 r_1} + \frac{q_2}{4\pi\epsilon_0 r_2} + \frac{q_3}{4\pi\epsilon_0 r_3} + \frac{q_4}{4\pi\epsilon_0 r_4}$$

Relation between Electric field and Potential

$$F_{in} = -\frac{dU}{dr} = -\frac{d(q_0 V)}{dr} \quad (\because U = P.E. = q_0 V)$$



$$F_{in} = F_{ext} = \frac{q_0 E_0}{4\pi\epsilon_0 r^2}$$

$$F_{in} = -q_0 \frac{dV}{dr} = q_0 E$$

$$E = -\frac{dV}{dr} \quad \bar{E} = -\text{Gradient } V$$

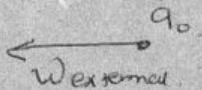
$$\Rightarrow \bar{E} = E_x i + E_y j + E_z k$$

$$E_x = -\frac{\partial V}{\partial x} \quad \begin{array}{l} \text{Similarly} \\ E_y = -\frac{\partial V}{\partial y} \end{array} \quad E_z = -\frac{\partial V}{\partial z}$$

Potential difference  
of  $\sqrt{W}$  f.t.

Electric field constant  $E$

## Electric Potential Energy



$$P.E. = U$$

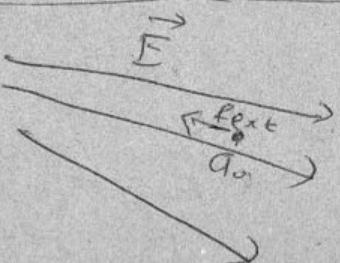
$$W_{ext.} = \Delta U_{sys}$$

$$P.E. \text{ of charge} = qV.$$

$$\boxed{\Delta V = q \Delta V}$$

$$\text{Def. } \boxed{\Delta V = V_f - V_i}$$

Work Done on a Charge by External Agency

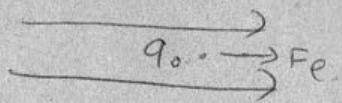


$$W_{ext.} = q_0 \Delta V$$

$$= -W_{field}$$

$$\Delta V = V_f - V_i$$

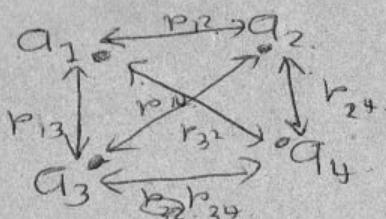
Work done on a charge by field



$$-\Delta V = \Delta K.E.$$

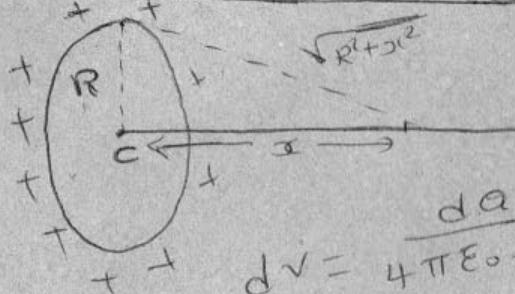
$$W_{field} = -q_0 \Delta V = \Delta K.E.$$

## Electric Potential Energy of System of charges



$$\begin{aligned} P.E. \text{ of system} = & \frac{q_1 q_2}{4\pi\epsilon_0 r_{12}} + \frac{q_2 q_3}{4\pi\epsilon_0 r_{23}} + \frac{q_3 q_4}{4\pi\epsilon_0 r_{34}} \\ & + \frac{q_4 q_1}{4\pi\epsilon_0 r_{41}} + \frac{q_2 q_4}{4\pi\epsilon_0 r_{24}} + \frac{q_1 q_3}{4\pi\epsilon_0 r_{13}} \end{aligned}$$

Variation of Electric Potential on the axis of a Charged Ring



$$dV = \frac{dq}{4\pi\epsilon_0 \sqrt{R^2 + x^2}}$$

$$V = \frac{q}{4\pi\epsilon_0 \sqrt{R^2 + x^2}}$$

$$\boxed{E = -\frac{dv}{dr} = -\frac{dv}{dx}}$$

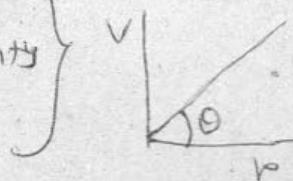
Relation  
Between  
Electric field  
and Potential

$$V = -E \cdot l, E = -\frac{V}{l}$$

$$E = E_x + E_y + E_z \quad (\text{net electric field})$$

$$E_x = -\frac{dV}{dx}, E_y = -\frac{dV}{dy}, E_z = -\frac{dV}{dz}$$

Negative of slope of  
V-l graph denote intensity  
of electric field



$$\tan \theta = \frac{V}{l} = -E$$

~~Q~~  
Work Done on  
Displacing a charge

$$W = q \cdot (DV)$$

$$= q \cdot (E \cdot \Delta r) \quad (V = E \cdot r)$$

( $\Delta r$  is Work done  
to take  $P_2$  Point to  
 $P_2$  ( $P_2 - P_1 = \Delta r$ )

$$\text{By component } W = q \cdot (E \cdot \Delta r)$$

$$W = q \cdot (E_1 P_1 + E_2 P_2 + E_3 P_3)$$

→ Electric field is depend on work done by  $W = qER$ .

So, Electric field is conservative.

it does not depend on Path.

depend only on final and initial position of charge.

### Equilibrium of charge

When net force on charge is zero

Stable equilibrium

→ If particle displace from  
its Position and returns  
Back

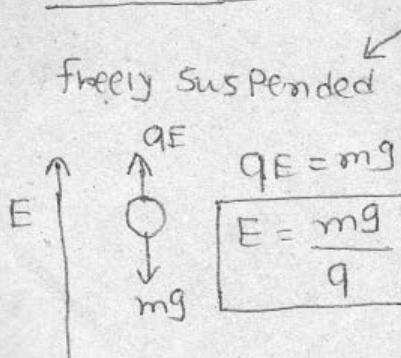
Unstable equilibrium

→ Particle displace from  
its Position and never  
Returns Back

neutral  
equilibrium

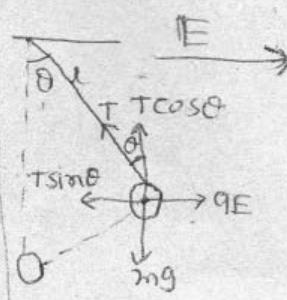
If particle  
displaced and  
it neither  
comes back  
nor move away  
then it is  
neutral equilib.

### Equilibrium of suspended charge in electric field



$$qE = mg$$

Suspended by  
massless  
insulated string



$$T \sin \theta = qE \quad \dots (i)$$

$$T \cos \theta = mg \quad \dots (ii)$$

By squaring and adding

$$T = \sqrt{(qE)^2 + (mg)^2}$$

Divide (i) by (ii)

$$\tan \theta = \frac{qE}{mg} \Rightarrow \theta = \tan^{-1} \frac{qE}{mg}$$