CSE 250

Circuits & Electronics

Week-1,2

Electricity

- → Static Electricity
- → Current Electricity

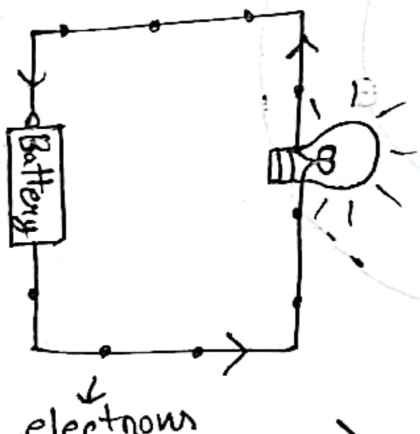
↓

Paths through which electron can move at a tremendous speed

↓

$\boxed{\text{Closed Loops}}$

⇓



↘

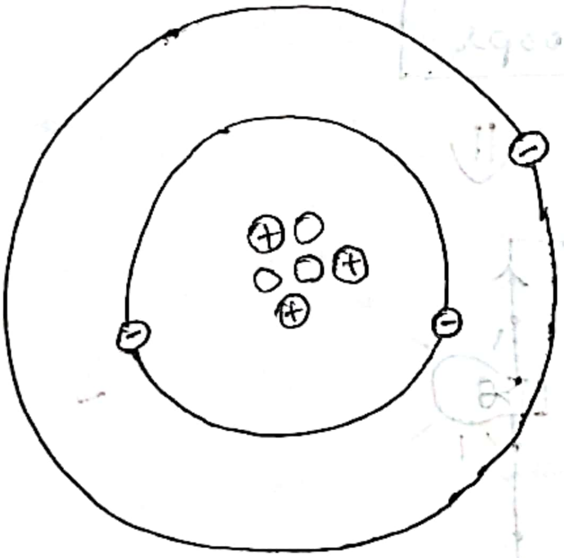
Electrical Circuit

We have to start with ⟶ Basic Electrical Quantities.

Charge

- A property of sub-atomic particles
  - electrons
  - protons
  - neutrons
- Positive ⊕
- Negative ⊖

An Atom



⊕ → Protons^{+}

o → neutrons

⊖ → Electrons^{-}

Unit of Charge ⟶ Coulomb (C).

Electron^{-} ⟶ -1.6×10^{-19} C

Proton^{+} ⟶ $+1.6 \times 10^{-19}$ C

} Smallest free charge

$\boxed{\cdot}$ $e = 1.6 \times 10^{-19}$ C

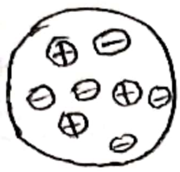
↓

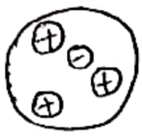
Another Unit

A Charged object

The atom from before $\longrightarrow$ Neutral.
(Usual Case)

2 ways (Only way basically)

 $\longrightarrow$ $-2 \cdot e$ | Adding Electrons |

 $\longrightarrow$ $+2 \cdot e$ | Taking away electrons |

$\boxed{\text{Always } N \cdot e}$

Effects

$\oplus \longrightarrow \longleftarrow \ominus$ | Opposite Charge Attracts |

$\longleftarrow \ominus \longleftarrow \qquad \longrightarrow \ominus \longrightarrow$

$\longleftarrow \oplus \qquad \oplus \longrightarrow$

| ~~Negative~~ Same Charge Repels |

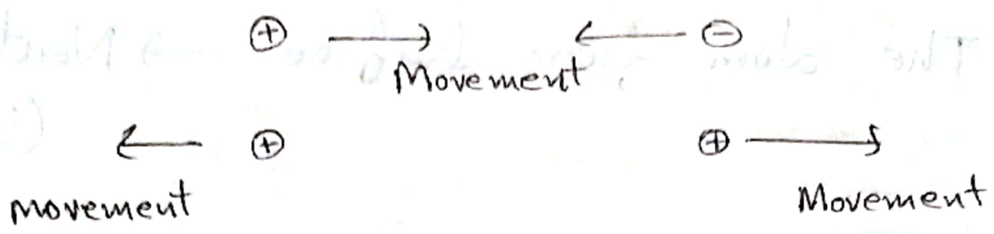
$\Downarrow$

Force

$\Downarrow$

Energy

Electrical Potential Energy



Initially

$$V = 0$$

$$K.E = \frac{1}{2}mv^2 = 0$$

Afterwards

$$V = 5$$

$$K.E = \frac{1}{2}m \cdot 5^2$$

But, K.E can't come out of nothing.

$\Uparrow$

$\boxed{\text{Conservation of Energy}}$

$\therefore$ K.E was transformed from another type of Energy.

$\Downarrow$

Electric Potential Energy (P.E)

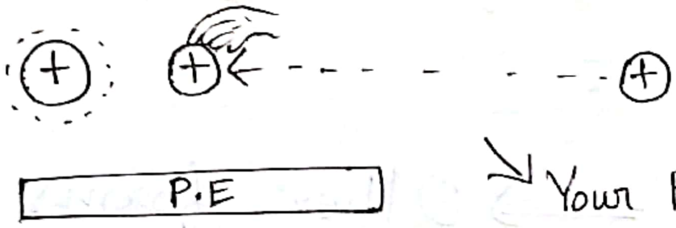
Without any outside effect.

$\triangle$ K.E + P.E = Total Energy [Constant]

3 types of Energies → Your Energy ↓ → Potential Energy ↓ → Kinetic Energy

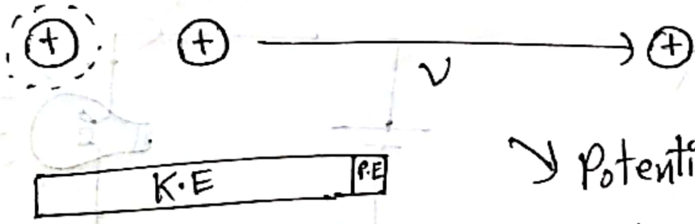
Same Charge

1.



↘ Your Energy transforming into Potential Energy stored inside $\oplus$.

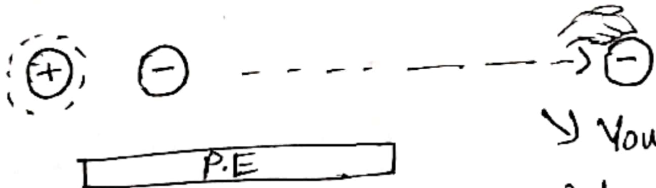
2.



↘ Potential Energy transforming into Kinetic Energy.

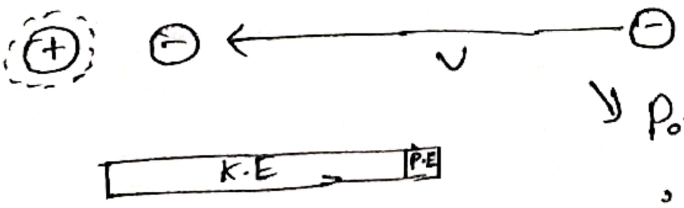
Opposite Charge

1.



↘ Your Energy transforming into Potential Energy stored inside $\ominus$

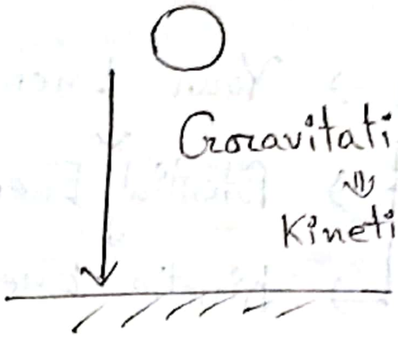
2.



↘ Potential Energy transforming into Kinetic Energy.

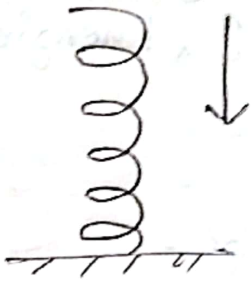
Other Kinds of P.E

→ The ball falls down



Gravitational P.E
⇓
Kinetic Energy

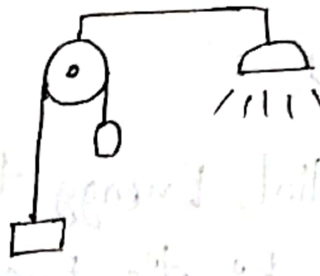
→ Spring goes back to original position



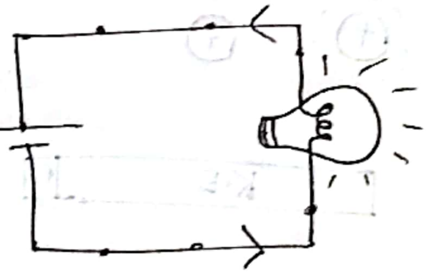
Elestic P.E
⇓
Kinetic Energy

Use

P.E ⟹ Other forms of Energy



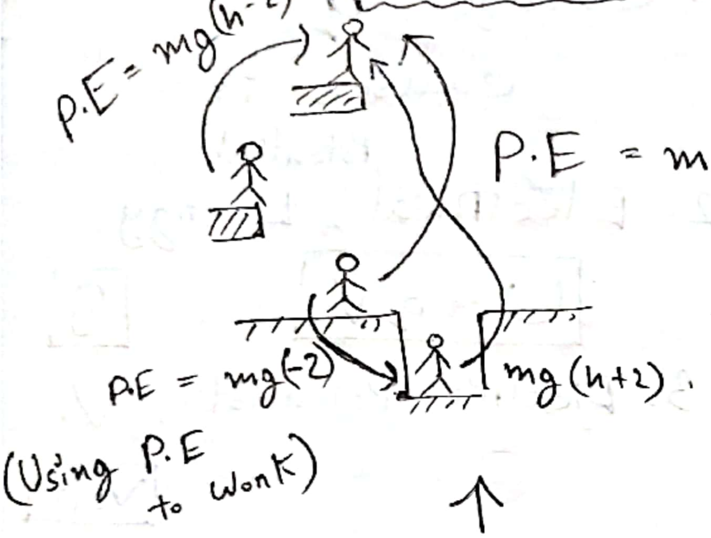
Gravitational P.E
↳ Light



Electrical P.E ⟹ Light

An Important Analogy

Gravitational P.E (U)



P.E = mgh |Working against gravity|

m = 5 kg

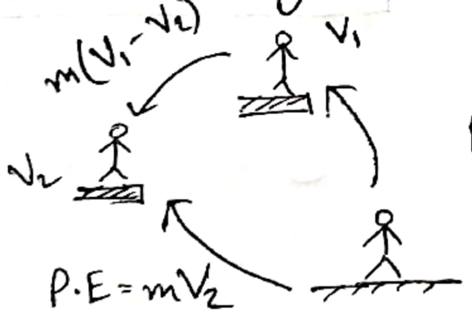
h = 4 m

g = 9.8 ms^{-2}

↑

For different reference points.

Let, $gh = V$ → Gravitational Potential.



$P.E = mV$

$\therefore$ Work done $= m\Delta V$

$= m(V_1 - V_2)$

Gravity	vs	Electricity
1. Mass, m causes it.		1. Charge, q causes it.
2. Gravitational Potential Energy. $\boxed{U = mgh}$ $\boxed{J}$		2. Electrical Potential Energy. $\boxed{U = qV}$ $\boxed{J}$
3. Gravitational Potential, V. $\boxed{J/Kg}$		3. Electric Potential, V. $\boxed{Volt}$
☆ 4. Work done, $W = m\Delta V$ $= \boxed{m(V_{\text{starting point}} - V_{\text{Ending Point}})}$		☆ 4. Work done, $W = q\Delta V$ $= \boxed{q(V_{\text{starting point}} - V_{\text{Ending Point}})}$

Important Concepts

1. Energy, m, q, v $\longrightarrow$ object's properties
2. Work, Potential, F $\longrightarrow$ Environmental effect
3. Higher P.E $\xrightarrow{\text{Spontaneously}}$ Lower P.E
4. Lower P.E $\xrightarrow[\text{not spontaneous}]{\text{Requires Energy}}$ Higher P.E
5. Calculating P.E from potentials (V)

$\Downarrow$

$$\boxed{\begin{aligned} U &= mV \\ W &= m\Delta V \end{aligned}} \qquad \boxed{\begin{aligned} U &= qV \\ W &= q\Delta V \end{aligned}}$$

Example

- $q = -2.5\ C$

$\ominus$ $V_1 = 2V$

$\Delta V = 2-(-1) = 3V$

$\ominus$ $V_2 = -1V$

$\therefore U_1 = qV_1 = -5\ J$ | Lower P.E |

$U_2 = qV_2 = 2.5\ J$ | Higher P.E |

$\therefore W = q(V_1 - V_2) = \boxed{-7.5\ J}$

(Work Done)

$\Downarrow$

Not spontaneous.

- $q = -2.5\ C$

$\ominus$ $V_1 = 2V$

$\Delta V = (-1-2)V = -3V$

$\ominus$ $V_2 = -1V$

$\therefore U_2 = qV_2 = 2.5\ J$ | Higher P.E |

$U_1 = qV_1 = -5\ J$ | Lower P.E |

$\therefore W = q(V_2 - V_1) = \boxed{7.5\ J}$

$\Downarrow$

Spontaneous

Conclusions

Positive Charge	Negative Charge
△ Higher P.E → Lower P.E	△ Higher P.E → Lower P.E
Spontaneous	Spontaneous
⊡ Higher Potential → Lower Potential	⊡ Higher Potential → Lower Potential
Spontaneous	Not Spontaneous
⊡ Lower Potential → Higher Potential	⊡ Lower Potential → Higher Potential
Not Spontaneous	Spontaneous

∴ Electron moves from Lower potential to Higher Potential Spontaneously

⇓

Electric Potential Energy is transformed to other forms of energy in the process.

$\boxed{\text{Electric Potential} \rightarrow \text{Voltage}}$

Voltage → Not a property of object.
→ Environmental Effect

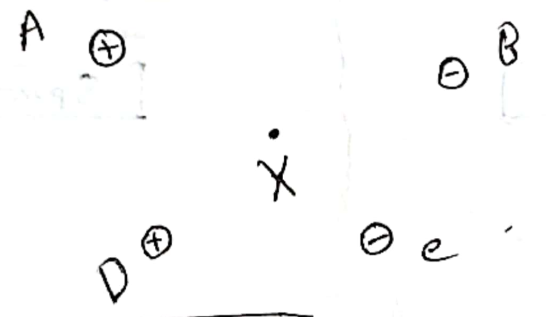
↓

In this case, Environment is the **presence of charges.**

Scalar

<u>Think:</u> What is Environment in case of gravitational potential?

Presence of Charges



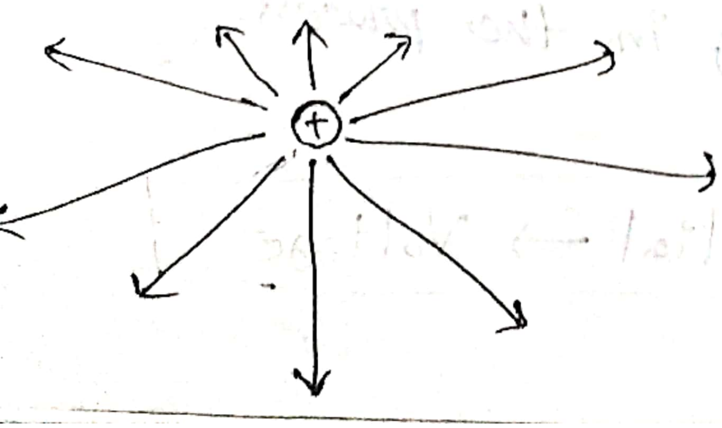
$\boxed{\text{V at point X}}$ = (V for charge A) + (V for charge B) + (V for charge C) + (V for charge D)

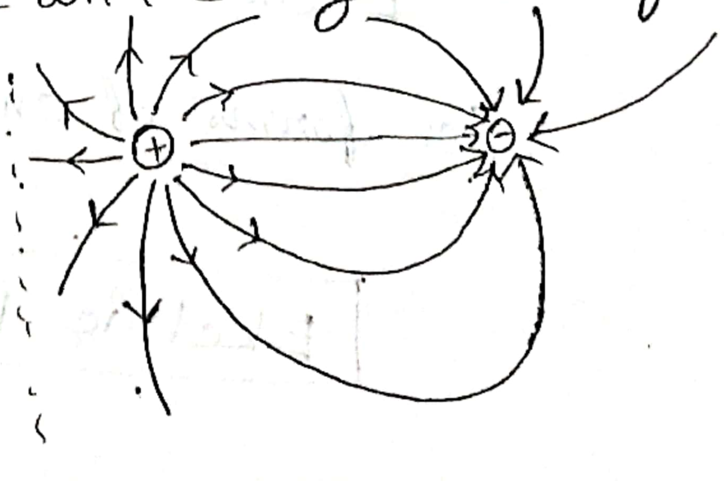
↓

That's all we need!

⇑ Voltage change

Electric fields change with every new charge.





Effect of Voltage

Property of object at point X.

Environmental Effect

Energy, $\boxed{U = qV}$

Current

Positive Charge

$V_1 = 2V$ ⊕

Feels a force from Higher to lower potential

$V_1 = -1V$ ⊕

Negative Charge

$V_1 = 2V$ ⊖

Feels a force from lower to higher potential

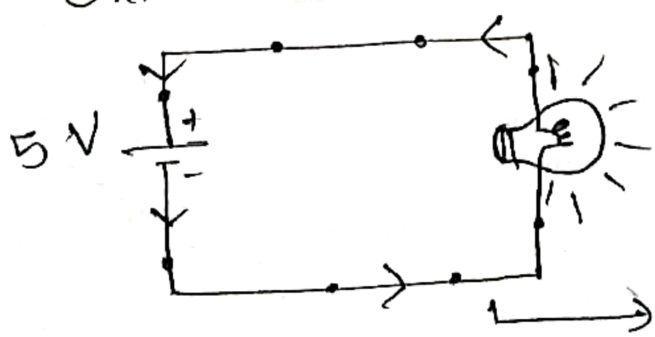
$V_2 = -1V$ ⊖

Charged particle (typically electron) moves when there is a difference of voltage.

⇓ Flow of Charge

Current

Unit → Ampere (A)



→ Flow of electron

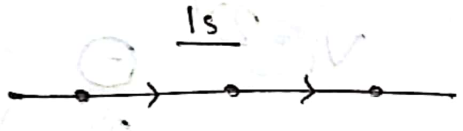
Definition

Current: Rate of flow of Charge.

$$\boxed{I = \frac{q}{t}}$$

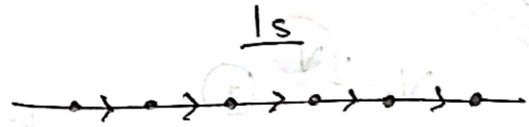
q → amount of charge

t → time taken



~~High~~ $I \downarrow$

Low Current flow



~~Low~~ $I \uparrow$

High Current flow

Conclusion

Cause	Effect
Voltage Difference $\Longrightarrow$	Current

Negative Current

Let,

$\oplus = 6\,C$ $\quad t = 2\,s$

$\oplus\ A \bullet \Longrightarrow \bullet B\ \oplus$

$\boxed{3A}$ from A to B. $\left| I = \frac{q}{t} \right|$

$\oplus = 6\,C$ $\quad t = 3\,s$

$\oplus\ A \bullet \Longrightarrow \bullet B\ \oplus$

$\boxed{2A}$ from A to B $\left| I = \frac{q}{t} \right|$

$\oplus \bullet A$ $\quad \bullet B$

$\boxed{0A}$

$\oplus = 6\,C$ $\quad t = 2\,s$

moving in opposite direction

$\oplus\ \bullet A \Longleftarrow \bullet B\ \oplus$ $\quad \left| I = \frac{q}{t} \right|$

$\boxed{-3A}$ from A to B

$\therefore$ Negative Current = Positive Current in opposite direction.

H.W: Try doing it for $q = -6\,C \Rightarrow \boxed{\ominus}$

Conclusion: → $\boxed{-3A \rightarrow} = \boxed{\leftarrow 3A}$

$\Downarrow$

~~for I = Is~~

⊕ $V_1 = 2V$

3A from V_1 to V_2 ↓

⊕ $V_2 = -1V$

$\equiv$

⊖ $V_1 = 2V$

↑ $-3A$ from V_2 to V_1

⊖ $V_2 = -1V$

Equivalent to $\Updownarrow$

⊕ $V_1 = 2V$

↓ 3A from V_1 to V_2

⊕ $V_2 = -1V$

⟹ Negative charges (say electron) flowing from point A to B $\xrightarrow{\text{Equivalent to}}$ Positive charges of same value flowing from point B to A.

What happens when current flows

5A  Current flowing upwards

⇕ is actually

 electrons flowing downwards.

We won't worry about electrons too much in this course. ;)

After all this gibberish about directions? :3

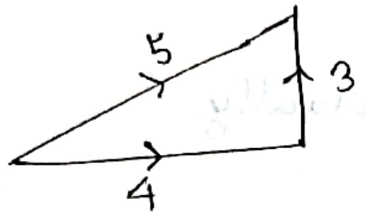
Current: A scalar (!) Quantity

Vector	Scalar
$\vec{4i} + \vec{3j} = \vec{5k}$	$4 + 3 = 7$ (always)

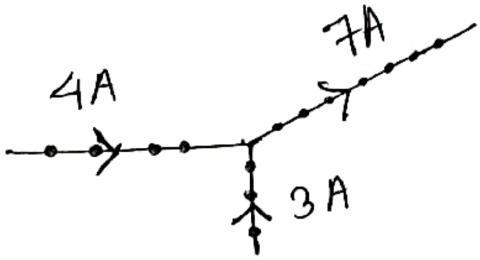
$\Downarrow$

$\boxed{4 + 3 = 5 \,(!)}$

$\Downarrow$



In case of current



N.B: This is Kirchoff's Current Law (KCL) {Coming soon}

$\Rightarrow$ Those electrons on charges have no other way to go $\rightarrow$ So they add up just like a scalar

$\therefore$ Even though we talked about positive and negative directions of current, current itself is a scalar quantity.