ENGINEERING PHYSICS

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Class #12

- Free particle solution
- Particles field interactions – a classical experiment
- Potential Step

Suggested Reading

1. *Concepts of Modern Physics, Arthur Beiser, Chapter 5*
2. *Learning Material prepared by the Department of Physics*

Reference Videos

1. *Video lectures : MIT 8.04 Quantum Physics I*
2. *Engineering Physics Class #11*

Problem statement - Free particle

- *A particle of mass* m *and energy* E *moving freely in space*
- *A particle is free if no force acts on the particle*
- $F = 0 \Rightarrow -\frac{dV}{dx} = 0$
- *This implies* $V = 0$ *or* $V = constant$
- *the simpler case of* $V = 0$
- *The general Schrodinger's wave equation*

$$\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{2m}{\hbar^2}(E - V)\psi(x) = 0$$

Free particle solution

With $V = 0$ the Schrodinger's wave equation reduces to

$$\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{2mE}{\hbar^2}\psi(x) = 0$$

$$\frac{\partial^2 \psi(x)}{\partial x^2} + k^2\psi(x) = 0$$

- *Where* $k^2 = \frac{2mE}{\hbar^2}$ *or* $k = \sqrt{\frac{2mE}{\hbar^2}}$
- *The general solution of this equation is of the form*

$$\psi(x) = Ae^{ikx} + Be^{-ikx}$$

Free particle solution

- *The two parts represent two possible state of motion*

  $Ae^{ikx} \Rightarrow$ *represents a particle moving in increasing* x *direction (+ve* x*)*

  $Be^{-ikx} \Rightarrow$ *represents a particle moving in decreasing* x *direction (-ve* x*)*

  where k is the propagation constant of the wave

  And the energy of the wave is $E = \frac{\hbar^2 k^2}{2m}$

- *No quantum effects since all k values are allowed and hence all energy states are allowed*
- *The free particle solution is the classical limit of quantum mechanics*

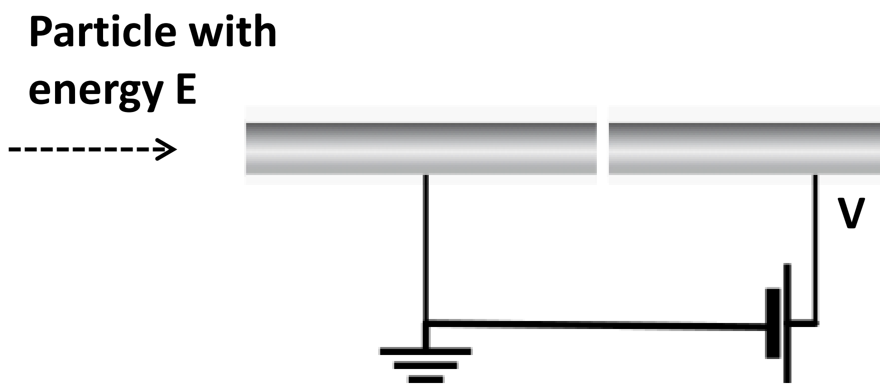
Particle interacting with fields

A system of a split tube of a highly conducting metal with a very narrow separation

The first part is at zero potential and the other held at a constant potential V

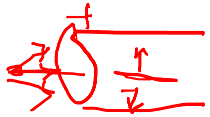
A charged particle with energy E moving along the axis of the tube

The particle continues to move in the first tube without any change in energy



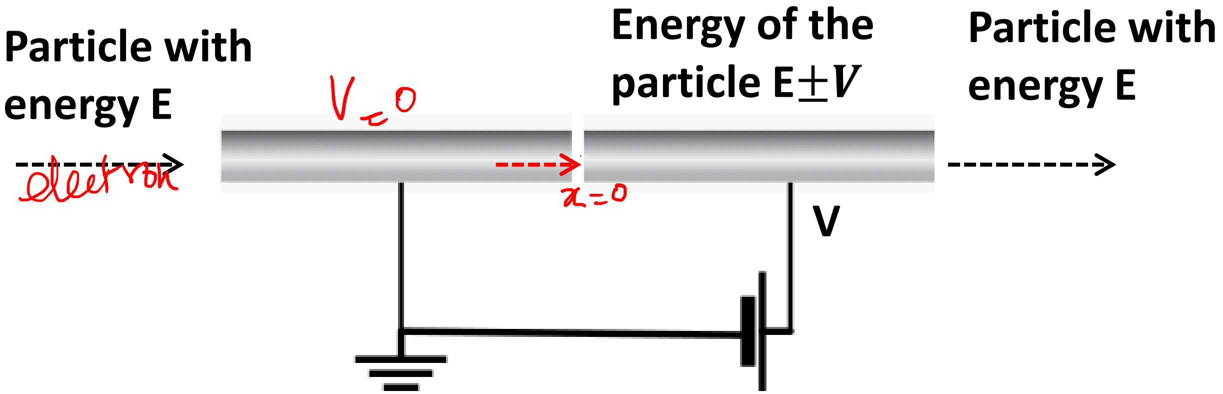
Particle interacting with fields

At the entrance of the second tube the particle feels an acceleration /deceleration



Once within the second tube the particle continues to move with energy $E \pm V$

The particle exiting the second tube feels a deceleration / acceleration and exits the tube with the initial energy



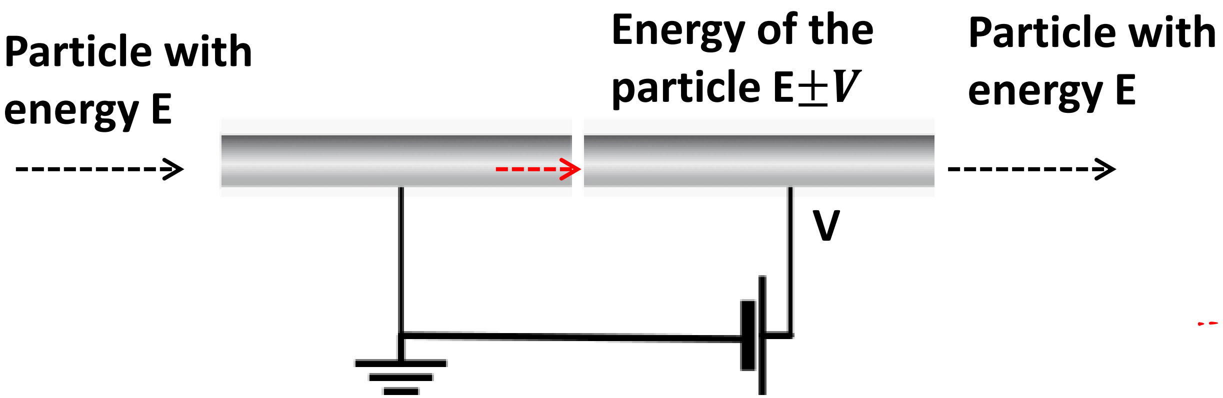
Particle interacting with fields

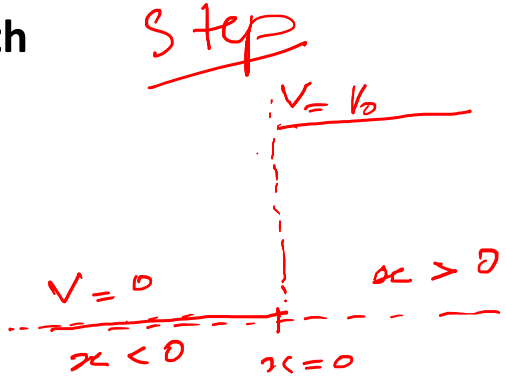
Classically if E < V the particle is repelled if the charge on the particle is of the same sign of the potential

Particle can interact with fields –

exchange energy with the field within the framework of the uncertainty principle

The plot of the potential as a function of distance with x=0 at the point of the separation of the tube is a step function





Class #12 …….. Quiz….

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The concepts which are true of topics discussed …

1. A free particle always move in a zero potential field
2. The two part wave function describe all possible paths of the particle
3. The energy of the particle is quantized
4. The propagation constant is not quantized for the free particle solution
5. The free particle solution is the classical Newton's law of motion.

THANK YOU

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