Newton's Law of Motion

1) A body at rest will remain at rest and a body in motion will remain in motion unless it is acted upon by an external force

2) The net force acting on an object is equal to the mass of that object times its acceleration

3) Newton's third law of motion : For every action, there is an equal and opposition reaction,

~~Weight → scales.~~

Quantum Mechanics : The branch of mechanics that deals with the mathematical description of the motion and interaction of Subatomic particle, incorporation the concepts of quantization of energy, wave - particle duality, the uncertainty principle, and the correspondance principle.

classical Mechanics : describes the motion of macroscopic objects, from projectiles to parts of machinery, and astronomical objects, such as spacecraft, planets, stars and galaxies.

If the present state, of an object is known it is possible to predict by the laws of classical Mechanics how it will move in the future and how it has

how it will move in the past.

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The elements most used in semi conducting devices are silicon and germanium.

Semiconductor

1. BMOS (Bipolar Metal oxide semiconductor.
2. PMOS (Posititve - channel. ")
3. NMOS
4. CMOS.

Semiconductor Devices

1. Diodes.
2. Transistors.

Course Outcomes

1) Understand the principle of semiconductor physics.

models of semiconductor junction.

Carrier transport in semiconductor

Models of MOS transistors.

Atom → (1) has a nucleus ~~both~~ having neutrons (no charge) protons (+ve charge) ~~right~~ and electrons revolve around it.
(2) Electrons are -ve charged particle
(3) charge of proton is 1.602×10^{-19}
(4) charge of electron is -1.602×10^{-19}
(5) Mass of electron is 9.109×10^{-31}

Rutherford theory does'nt explained that if the electron is revolving fast around the nucleus, ~~then it~~ then it will gain some acceleration and radiate energy, due to which it will collaps into the nucleus. but it does'nt happen;
then Bohr model gives the theory that electron does not take all energy level, it takes discrete energy and remains stationary i.e it does not radiate energy.

sev
re

Light also show dual Nature

Newton → is not able to define the interface

Hygenis ~~theory~~ → was suggest ~~theory~~ wave motion

Thomas

↳ ~~yongs~~ youngs.

Planks

Albert Einstein → suggested that light is composed of tiny particles called photons.

Last century physics discovered the sound and light waves. Sound waves need medium like air, water and matter, generally for its propagation, But the light waves on the other hand need no medium.

Thus in vaccume one can see and cannot hear.

The matter waves are proposed by de-Broglie.

De-Broglie suggested that these waves are generated due to the motion of anybody like a planet, a stone, a particle of dust or an electron.

human detectable range human eye (0.4 to 0.2 micron)

and ear (20-20 KHz)

But we can't see or detect de Broglie waves (matter waves)

Therefore, matter waves should be detectable by an appropriate detector.

However to understand why they remain obscure, we should consider the wavelength of the matter waves proposed by de-Broglie,

$$\lambda = \frac{h}{mv}$$

Let us consider three objects of different scale in mass and dimension

(a) Planet (b) human body (c) electron.

to understand why matter waves are imperceptible (not certain)

(a) Planet $m = 6 \times 10^{27}$ $v = 3 \times 10^{6}$ cm/sec

$$\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-27}}{6 \times 10^{27} \times 3 \times 10^{6}} = 36 \times 10^{-61} \text{ cm}$$

The value is extremely small ~~not~~

(b) human $m = 50 \times 10^{3}$ gm, speed $= 85$ cm/sec

$$\lambda = 1.38 \times 10^{-33} \text{ cm}$$

Even this is too small

(c) electron 10^{-27} gm acquire 6.1×10^{7} cm/sec.

$\lambda = 10^{-7}$ cm

This corresponds to wavelength of x-rays and is detectable with the principle of diffraction

Hence
nav

Hence the presence of matter waves at the nano scale dimensional particle is traceable and so the presence of ~~man~~ nano particle could be analyzed in terms of de Broglie wavelenth

- The detection of matter waves confirms the presence of moving particle say electron which ultimately decides the conductivity in nano devices.

Rutherford's Theory Of Atom

- The atom consists of a positively charged heavy nucleus surrounded by revolving negatively charged light particle called electrons.
  An ~~atom~~ Technically Atom is electrically neutral i.e charge of all electron is equal to charge of protons.

- charge of protons is 1.602×10^{-19} coulombs.
  charge of electron is -1.602×10^{-19} coulombs
  Mass of electron is 9.109×10^{-31} ~~coulombs~~ Kilogram

Bohr rejected the classical views on electron motion and introduced the concept of electron orbiting the nucleus the same way that the earth moves around the sun

Bohr Model of Atom

- In 1913, Niel Bohr proposed a model for the hydrogen atom which retained the earlier nucleur model of Rutherford but made stipulation as to the behaviour of the electrons.
  Following postulates are suggested

(1) Bohr postulated that in an atom, electron revolve in stable orbits without emitting radiant energy. Further, he stated that each atom can exist in certain stable states. Also each state has a definite total energy. These are stationary states of the atom.

[Planck's constant = 6.626×10^{-34} joule-second

2. ~~An~~ The permissible orbits of an electron revolving round a nucleus are those for one which the angular momentum of the electron is an integral multiple of $h/2\pi$, where h is the plank's constant.

$$m r_n v_n = n\left(\frac{h}{2\pi}\right)$$

m and v_n are the mass and the velocity of the electron, r_n the radius of the orbit of the electron, and n is +ve integer called the quantum number.

3. An atom radiates energy only when an ~~orbit~~ orbit electron jumps from stationary orbit of energy of energy E_i to a final orbit of energy E_f $(E_i > E_f)$. The frequency ν of the radiation is given by

$$E_i - E_f = h\nu$$

h is the plank's constant.

$$h = 6.626 \times 10^{-34}$$

Important Equations

Radii of Bohr's stationary orbit

$$r_n = n^2 \left(\frac{h^2 \epsilon_0}{\pi m Z e^2} \right)$$

Where $n \rightarrow$ integer

$r_n \rightarrow$ radius of the n^{th} orbit

$h \rightarrow$ Plank's constant

$\epsilon_0 \rightarrow$ Electric constant

$m \rightarrow$ Mass of electron.

hydrogen atom $Z=1$ $\rightarrow$ $Z \rightarrow$ The Atomic no. of the atom.

$e \rightarrow$ Elementary charge.

- The velocity of Electron in Bohr's stationary orbit.

$$v_n = \left(\frac{Z e^2}{2 h \epsilon_0} \right) \left(\frac{1}{n} \right)$$

- The Total Energy of Electron in Bohr's stationary orbit.

$$E_n = -\frac{m e^4}{8 \epsilon_0^2 h^2} \left(\frac{Z^2}{n^2} \right)$$

or $$E_n = -13.6 \left(\frac{Z^2}{n^2} \right) \text{ eV}.$$

–ve sign means the electron is bound to the nucleus.

Tut 1 Date 25/7/1?

Q1 Calculate the radii of the first, second and third permitted electron orbit in Bohr's hydrogen model.

$$r_n = \frac{\epsilon_0 h^2 n^2}{\pi m q^2} = \frac{(8.854\times10^{-12})(6.62\times10^{-34})n^2}{\pi(9.1\times10^{-31})(1.6\times10^{-19})^2}$$

$$= 0.527\times10^{-10} n^2 \text{ m}$$

$r_1 = 0.527\times10^{-10}$ m.

$r_2 = .2108\times10^{-10}$ m

$r_3 = .474\times10^{-10}$ m.

Q2 Let the charge (q) of an electron is -1.6×10^{-19} C and mass $= 9.1\times10^{-31}$ k.

$v = 1\times10^{5}$ m/s.

find momentum, K.E and wavelength

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

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

K.E

$\boxed{p = mv} \rightarrow$ momentum

K.E = $\frac{~~1~~}{2}$ = $\frac{1}{2}$ pv.

$$\boxed{K.E = \frac{1}{2m} m^2 v^2 = \frac{1}{2m}(p)^2}$$

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Dual Nature of Light and Matter

- It is well know that light exhibits the phenomenon of interferance, diffraction, polarization, photoelectric effect, compton effect, and discrete emissions and absorption.

- The phenomena of interference, diffraction and polarisation can only be explained on the basis of wave theory of light. These shows that light posses wave nature.

- The phenomena of photoelectric effect, Compton effect, discrete emission are explained on the basis of quantum theory of light, according to which light possesses corpuscular (or particle) nature.

- Thus we can say that light posseses dual nature. In some experiments it behaves as waves while in other experiments it behaves as particles.

- According to de-Broglie's a moving particle, whatever its nature, has wave properties associated with it. Broglie proposed that the wavelength λ associated with any moving particle of momentum p. (mass m and velocity v) is given be

$$\lambda = h/p = \frac{h}{mv}.$$

When h is plancks constant.

$h = 6.6 \times 10^{-34}$ Js

Wave particle Duality

- we know that as the size of the object is very small and mass is also very small ~~lea~~ ~~eg~~ like electron, photon or any other entity.
- When we do experiment to analyze the behaviour of these ~~seperate~~ entity or object, we see that, it behave like particle as well as wave.. [As seen in young's double slit method]
- So we need both i.e particle like nature and wave like nature ~~to~~ for the analysis of the particle
- Let us take the example of electron or photon for the this particle like nature we need ~~eae~~ K.E and momentum to define its nature, and ~~wavelength is used to define~~ we need wavelength for wave like nature ~~to~~
- So. This relation b/w wave like nature and particle like nature is defined by the

$\boxed{\text{de - Broglie Equation}}$ $\boxed{\lambda = \frac{h}{p}}$

h → plank's Constant

p → momentum.

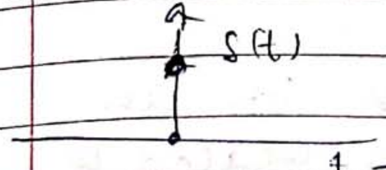
From Note Book:

→ more in book Page No 30

Heisenberg's Uncertainty Principle

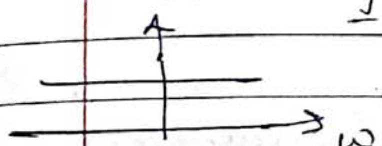
- principle of quantum mechanics described by Heisenberg
- The position and momentum of a particle cannot be accurately measured at the same time.

- Let us consider an example of time and freq.

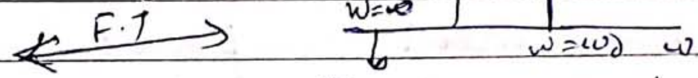


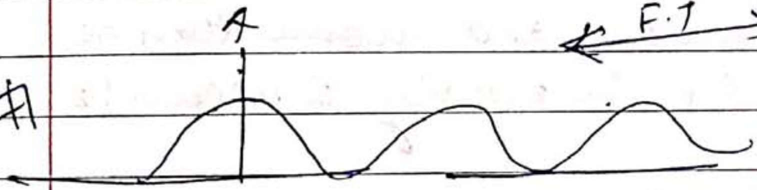
The given function is defined at t = 1. What is freq? then take F.T

$$\int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt = \int_{-\infty}^{\infty} \delta(t) e^{-j\omega t} = 1$$



→ frequency can not be measured.





The given function is sinusoidal

What is the position of this function in t, answer is available at all time, not exact position but it is defined in freq., one can identify its freq. or wavelength.

From the above observation, we can say that any given function position & freq. cannot be accurately measured at same time.

- So The magnitude of this inherent uncertainty is described by the Heisenberg uncertainty principle.

In general a signal in time/space ⟷ frequency will have this restriction

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- In any measurement of the positions and momentum of a particle, the uncertainties in the two measured quantities will be related by

$$(\Delta x)(\Delta p_x) \geq \hbar$$

- Similarly, the uncertainties in an energy measurement will be related to the uncertainty in the time at which the measurement was made by

$$(\Delta E)(\Delta t) \geq \hbar$$

- These limitation indicate that simultaneous measurement of position and momentum of energy and time are inherently inaccurate to some degree.

- One Implication of the uncertainty principle is that we can not properly define the position of an electron - i.e we must define per the "probability" of finding an electron at a certain position

- Thus one of the important result of quantum mechanics is that a probability density function can be obtained for a particle in a certain environment, and these function can be used to find the the expectation value of important quantities like position momentum, and energy.

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Questions :

$1\,kg = \cancel{1000}\,g$

$1\,kg = 10^3\,g$

$\cancel{10 \times 10^{-3}}$

$1\,g = 10^{-3}\,kg$

$10\,g = 10 \times 10^{-3}\,kg$

Q. A ball of mass 10g has velocity 1.0 m/s. Calculate the wavelength associated with it.
given $h = 6.62 \times 10^{-34}$ joul-sec

Solⁿ

$$\lambda = \frac{h}{mv} = \frac{6.62 \times 10^{-34}\ \text{Joul-Sec}}{(10 \times 10^{-3}\,kg)(1\,m/sec)}$$

$$= 6.62 \times 10^{-32}\,m$$

Q. Calculate the de-Broglie wavelength of neutron of energy 28.8 ev, Given
$h = 6.62 \times 10^{-34}$ joul-sec
$m = 1.67 \times 10^{-27}$ kg

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}} = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 28.8 \times 1.6 \times 10^{-19}\ \text{Joul}}}$$

$$\boxed{28.8\ ev = 28.8 \times 1.6 \times 10^{-19}\ \text{joule}}$$

$$= 4.2 \times 10^{-10}\,m = 4.2\,A^\circ$$

Q. An electron has a speed 1.05×10^4 m/s with in the accuracy of 0.01%. Calculate the uncertainty in the position of the electron.

$$\Delta p\, \Delta x = \hbar \qquad \boxed{p = mv}$$

$$\Delta v = 1.05 \times 10^4 \times \frac{0.01}{100}$$

$$= 1.05 \times 10^2 \times 0.01 = 1.05 \times 10^2 = \cancel{105} = 1.05$$

0.0105

$\cancel{.0105}$

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$\Delta p = m \Delta v = 9 \times 10^{-31} \times 1.05$

$9.45 \cancel{135} \times 10^{-31}$

$\Delta p \Delta x = \hbar \Rightarrow 13.5 \times 10^{-31} \Delta x = 1.05 \times 10^{-34}$

$\Delta x = \dfrac{1.05 \times 10^{-34}}{9.4\cancel{5135} \times 10^{-31}}$

$= \dfrac{1.05}{13.5} \times 10^{-3}$

$= \cancel{.077 \times 10^{-3}}$ mistake

0.111×10^{-3} same error

Answer

$\Delta x = \dfrac{1.05 \times 10^{-34} \times 100}{9 \times 10^{-31} \times \cancel{1.05 \times 10^{4} \times 0.01}}$ $\cancel{100}$

$= \dfrac{\cancel{1.05} \times 10^{-32}}{9 \times 10^{-31} \times \cancel{1.05} \times 10^{4} \times 0.01}$

$= \dfrac{10^{-32}}{.09 \times 10^{-27}} = 11.11 \times 10^{-5}$

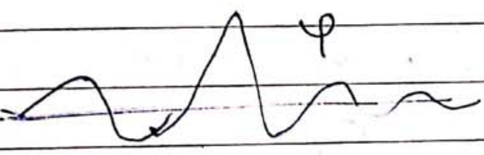
$= 1.11 \times 10^{-4}$ m/s

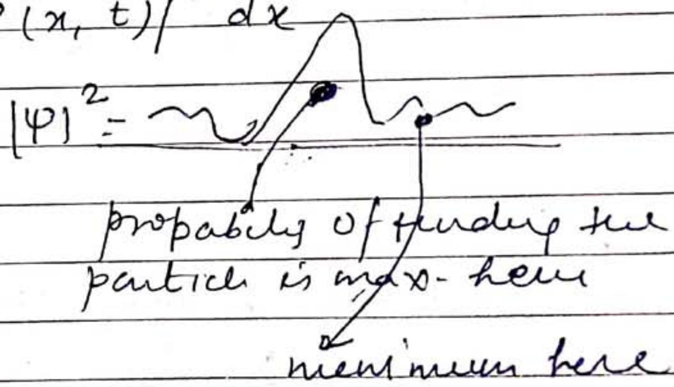
Wave function :- Mathematical function {space, → its a function of time

- contains information on all measurable parameters of the particle
- If we consider 1 Dimensional (say x direction), the wavefunction is $\psi(x, t)$
- $\psi\psi^* =$ for complex ψ

  $\psi\psi^* =$ ~~Propat~~ Probability density of finding the particle b/w x and $x + dx$

- If $\psi(x,t)$ is real probability of finding the particle b/w x and $x + dx$ $= |\psi(x,t)|^2 dx$





- Probability of finding the particle b/w $x = a$ and b is $\int_a^b |\psi|^2 dx$.

Operators → contains information on all measurable parameters of the particle

- Momentum Operator : $\hat{p}_x = \frac{\hbar}{i}\frac{\partial}{dx}$

  Thus $\frac{\hbar}{i}\frac{\partial\psi}{dx} = p_x\psi$

- Energy operator : $\hat{E} = -\frac{\hbar}{i}\frac{\partial}{dt}$, Thus $-\frac{\hbar}{i}\frac{\partial\psi}{dt} = E\psi$.

• Kinetic Energy : $\frac{p_x^2}{2m} = \frac{1}{2m}\frac{\hbar}{i}\frac{\partial}{\partial x}\left(\frac{\hbar}{i}\frac{\partial \psi}{\partial x}\right)$

$= -\frac{\hbar^2}{2m}\frac{\partial^2 \psi}{\partial x^2}$ K.E operator.

To understand

To find momentum in x direction then I use momentum operator $\hat{p}_x$

$\frac{\hbar}{i}\frac{d\psi}{dx}$ → means take the operator and applied on the ψ then I get the momentum in the x-direction next ψ

#

Let ψ is a plane wave

$$\psi = e^{i(kx - \omega t)}$$

$$k = \frac{2\pi}{\lambda}, \quad \omega = 2\pi\nu$$

$$i = \sqrt{-1}$$

(1) Let use momentum operator

$$\frac{\hbar}{i}\frac{d\psi}{dx} = \frac{\hbar}{i}\, ik\, e^{i(kx-\omega t)}$$

$\psi = e^{i(kx-\omega t)}$

$\frac{d\psi}{dx} = ik\underbrace{e^{i(kx-\omega t)}}_{\psi}$

$$= \hbar k\psi = \hbar\frac{2\pi}{\lambda}\psi = \frac{h}{\lambda}$$

$$\frac{h}{2\pi}\cdot\frac{2\pi}{\lambda}\psi = \frac{h}{\lambda}\psi$$

P → momentum

So therefore it is momentum operator.

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(2) use Energy operator

$$E = -\frac{\hbar}{i}\frac{d\psi}{dt}$$

$$\psi = e^{i(kx-\omega t)}$$

$$-\omega i \underbrace{e^{i(kx-\omega t)}}_{\psi}$$

$$= -\frac{\hbar}{i}\left[-\omega i\, e^{i(kx-\omega t)}\right]$$

$$= \hbar\omega e^{i(kx-\omega t)}$$

$$= \hbar\omega\psi$$

$$\frac{h}{\cancel{2\pi}} \cdot \cancel{2\pi}\nu\psi$$

$$\underbrace{h\nu}_{\text{Energy}}\psi$$

Energy $\rightarrow$ so $-\frac{h}{i}\frac{d}{dt}$ is Energy operator

(3) Similarly for K.E

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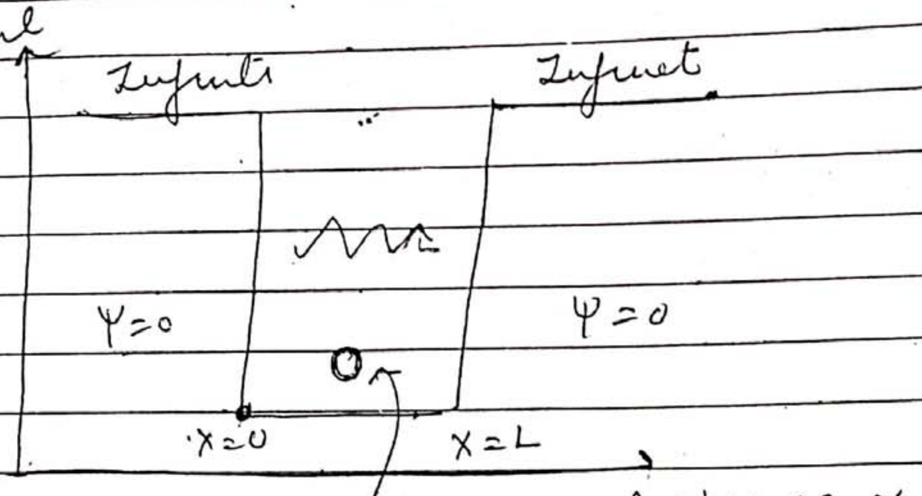
Application of Schrodinger's Equation

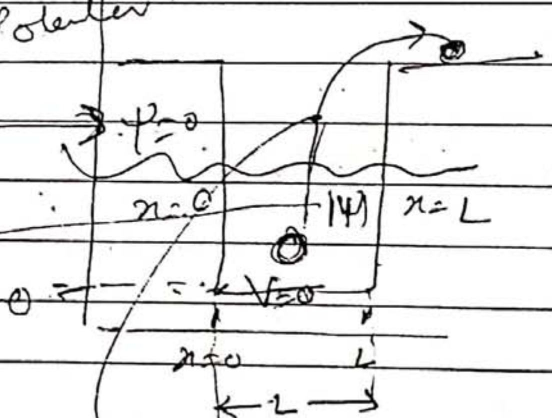
1) Particle in a 1-Dimensional Box : Infinite Potential Barrier



• particle is located here

and for
x>L } potential=∞
x<0 }

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi = E\psi \quad (1)$$



• it require infinite amount of energy to be here

• particle is confined only in the Box

• So magnitude of ψ ~~ψ=0~~ ~~(Amplitude)~~ should be zero outside the box

• Nature of wave function inside the Box is to be determined.