My Physics notes

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Contents

Chapter 1

Quantum mechanics

1.1 De Broglie relations

$$\begin{aligned} E = \hbar\omega = \hbar f = \frac{\hbar}{\lambda} \\ p = \hbar k \\ \lambda = \frac{h}{p} \\ p = \frac{h}{\lambda} \\ k = \frac{1}{\lambda} \end{aligned} \quad (1.1)$$

where

E= energy
p=momentum
k=wave number
λ =wave length
$\hbar$ =Reduced Planck constant

ω =angular velocity
f=frequency˙

1.2 Schrodinger

Time independent version[TISE]
For a plane wave we have:

$$\Psi = e^{i(kx-\omega t)} \tag{1.2}$$

Differentiating with respect to x we get:

$$\frac{\partial\Psi}{\partial x} = ike^{i(kx-\omega t)} = ik\Psi \tag{1.3}$$

Differentiating once more we get:

$$\frac{\partial^2\Psi}{\partial x^2} = (ik)^2\Psi \tag{1.4}$$

Plank reduced or Dirac constant:

$$\hbar = \frac{h}{2\pi} \tag{1.5}$$

De Broglie relations:

$$p = \frac{h}{\lambda} \implies \lambda = \frac{h}{p} \implies \frac{1}{\lambda} = \frac{p}{h} \tag{1.6}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi p}{h} = \frac{p}{\hbar} \tag{1.7}$$

$$p = k\hbar \tag{1.8}$$

where:
k=wavenumber
λ=wavelength
p=momentum
In equation 1.4 by substituting k from 1.7 we finally get:

$$\frac{\partial^2\Psi}{\partial x^2} = -(\frac{p}{\hbar})^2\Psi \tag{1.9}$$

and

$$-\hbar^2\frac{\partial^2\Psi}{\partial x^2} = p^2\Psi \tag{1.10}$$

If E = energy, E_k=kinetic energy,u=potential energy

$$E = E_k + u \tag{1.11}$$

From equation 1.30 we get:

$$E = \frac{p^2}{2m} + u \tag{1.12}$$

and from 1.10($-\hbar^2 = p^2$)

$$E\Psi = -\frac{\hbar^2}{2m}\frac{d^2\Psi}{dx^2} + u\Psi\text{[TISE]} \tag{1.13}$$

Time dependant version [TDSE]

$$\Psi = e^{i(kx-\omega t)} \tag{1.14}$$

$$\frac{\partial\Psi}{\partial t} = -i\omega e^{i(kx-\omega t)} = -i\omega\Psi \tag{1.15}$$

$$\frac{\partial\Psi}{\partial t} = -i\frac{E}{\hbar}\Psi \tag{1.16}$$

$$\hat{E}\Psi = \frac{\partial\Psi}{\partial t}\frac{\hbar}{-i} = i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{d^2\Psi}{dt^2} + u\Psi\text{[TDSE]} \tag{1.17}$$

$$\hat{E} = i\hbar\frac{\partial}{\partial t} \tag{1.18}$$

1.2.1 Hamiltonian operator $\hat{H}$

$$\hat{H} = \hat{T} + \hat{V} \tag{1.19}$$

For 3-dimensional space the Laplacian operator $\hat{\nabla}$ is engaged.

$$\hat{\nabla} = \hat{e}_x\frac{\partial}{\partial x} + \hat{e}_y\frac{\partial}{\partial y} + \hat{e}_z\frac{\partial}{\partial z} \tag{1.20}$$

From 1.9-1.13 we get:

$$\hat{T} = -\frac{\hbar^2}{2m}\hat{\nabla}^2 \tag{1.21}$$

$$\hat{V} = V(\hat{r}, \hat{t}) \tag{1.22}$$

so from 1.9

$$\hat{H} = -\frac{\hbar^2}{2m}\hat{\nabla}^2 + V(\hat{r}, \hat{t}) \tag{1.23}$$

and finally:

$$\hat{E} = \hat{H}\Psi \tag{1.24}$$

Massless element

$$E = pc \tag{1.25}$$

$$E^2 = (pc)^2 + (mc)^2 \tag{1.26}$$

$$pc = \hbar ck \implies p = \hbar k = \frac{\hbar 2\pi}{\lambda} = \text{hf} \tag{1.27}$$

From De' Broglie relations above(1.1):

$$\lambda = \frac{\hbar}{p} \implies p = \frac{\hbar}{\lambda} \tag{1.28}$$

Quantized angular momentum

$$L = \sqrt{l(l+1)\hbar} \tag{1.29}$$

1.3 Energy Momentum relation

$$E = \frac{1}{2}mv^2 = \frac{1}{2}m(\frac{p}{m})^2 = \frac{1}{2}m\frac{p^2}{m^2} = \frac{p^2}{2m} \tag{1.30}$$

$$
\begin{aligned}
\Psi &= e^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)}\\
\nabla\Psi = e_x\frac{\partial\Psi}{\partial x} + e_y\frac{\partial\Psi}{\partial y} + e_z\frac{\partial\Psi}{\partial z} &\implies \\
\nabla\Psi = ik_x\Psi e_x + ik_y\Psi e_y + ik_z\Psi e_z\\
\frac{i}{\hbar}(p_x e_x + p_y e_y + p_z e_z) = \frac{i}{\hbar}\hat{p}
\end{aligned}
\tag{1.31}
$$

$$
\begin{aligned}
\nabla\Psi &= \frac{i}{\hbar}(p_x e_x + p_y e_x + p_z e_z)\Psi\\
\frac{\nabla\Psi}{\Psi} &= \frac{i}{\hbar}(p_x e_x + p_y e_x + p_z e_z)\\
\nabla &= \frac{i}{\hbar}\hat{\mathbf{p}} \implies \hat{\mathbf{p}} = -i\hbar\nabla
\end{aligned}
\tag{1.32}
$$

$$
\begin{aligned}
\mathbf{E} = \mathbf{H} &= \mathbf{T} + \mathbf{V}\\
\hat{\mathbf{T}} &= \frac{\hat{\mathbf{p}} \bullet \hat{\mathbf{p}}}{2m}\\
\hat{\mathbf{E}}\Psi &= \hat{\mathbf{H}}\Psi\\
i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = \hat{\mathbf{H}}\Psi(\mathbf{r},t) &=\\
= -\frac{\hbar^2}{2m}\nabla^2 &+ V(\mathbf{r},t)
\end{aligned}
\tag{1.33}
$$

where:

∇ =The differential operator

∇^2 =The Laplacian operator

H =The Hamiltonian operator
T=Kinetic energy
Ψ =The wave equation
m=The mass
e=Euler number, the base of the natural logarithms≈ 2.71828183

1.4 Lagrangian function

The problem:
To maximize f(x,y) subject to g(x,y)=c

$$L(x,y,\lambda)=f(x,y)-\lambda(f(x,y)-c) \tag{1.34}$$

Derivatives of L must be zero.So
you must solve:

$$\nabla_{x,y,\lambda}L(x,y,\lambda)=0 \tag{1.35}$$

1.5 Hamilton Jacobi equation

$$H+\frac{\partial S}{\partial t}=0 \tag{1.36}$$

where

$$H=H(q_1,q_2,....Q_N;\frac{\partial S}{q_1},\frac{\partial S}{q_2},...\frac{\partial S}{q_N};t) \tag{1.37}$$

and

$$S = S(q_1, q_2, q_N, t) \tag{1.38}$$

1.6 Action

$$S = \int_{t_1}^{t_2} L dt \tag{1.39}$$

where L is the Lagrangian and in units:

$$[S] = [ET] = [\textbf{energy}][\textbf{time}] \tag{1.40}$$

1.7 Hydrogen atom energies and forces

1.7.1 Centripetal

Coulomb law states:

$$F_{electrostatic} = k_e \frac{q_1 q_2}{r^2} \tag{1.41}$$

and by Newton's 2nd law:

$$F_{centripetal} = F_{electrostatic} \tag{1.42}$$

and from 1.41

$$F_p = \frac{mv^2}{r} = k_e \frac{q_1 q_2}{r^2} \tag{1.43}$$

$$F_p = \frac{mv^2}{r} = k_e \frac{Ze.e}{r^2} \tag{1.44}$$

or:

$$F_p = \frac{mv^2}{r} = k_e \frac{Ze^2}{r^2} \tag{1.45}$$

1.7.2 E potential

$$V = k\frac{q_1 q_2}{r} = -k\frac{Ze2}{r} \tag{1.46}$$

1.7.3 E kinetic

$$E_k = \frac{1}{2}mv^2 = k\frac{Ze^2}{2r} \tag{1.47}$$

1.7.4 E total

$$E = E_p + E_k \rightarrow E = -2E_k + E_k \rightarrow E = -E_k \rightarrow E = -k\frac{Ze^2}{2r} \tag{1.48}$$

1.8 Quantum superposition

1.9 Hilbert space,bra cket notation

1.10 The concept of eigen vectors and eigen values

1.11 The light duality

1.12 The double slit experiment

1.13 Fermi level, valence-conduction bands

1.14 Quantum tunneling

1.15 The uncertainty principle

1.16 Interpretations of quantum mechanics

Chapter 2

Electronic configurations of atoms and the Bohr model

2.1 Particle collisions

2.1.1 Photon - electron collision

The photon - electron collision when electron is free, is widely known as the Compton effect.
When a photon hits an electron the photon's energy increases and changes its path at an angle, while the electron gets some energy and is emitted in the medium with a larger wavelength (photoelectric effect). Within an atom if the energy of the photon is enough can free an electron from the outer shell or knock an an electron in an inner shell(Balmier sheries)

$$\lambda - \lambda' = \frac{h}{m_e c}(1 - cos\theta) \tag{2.1}$$

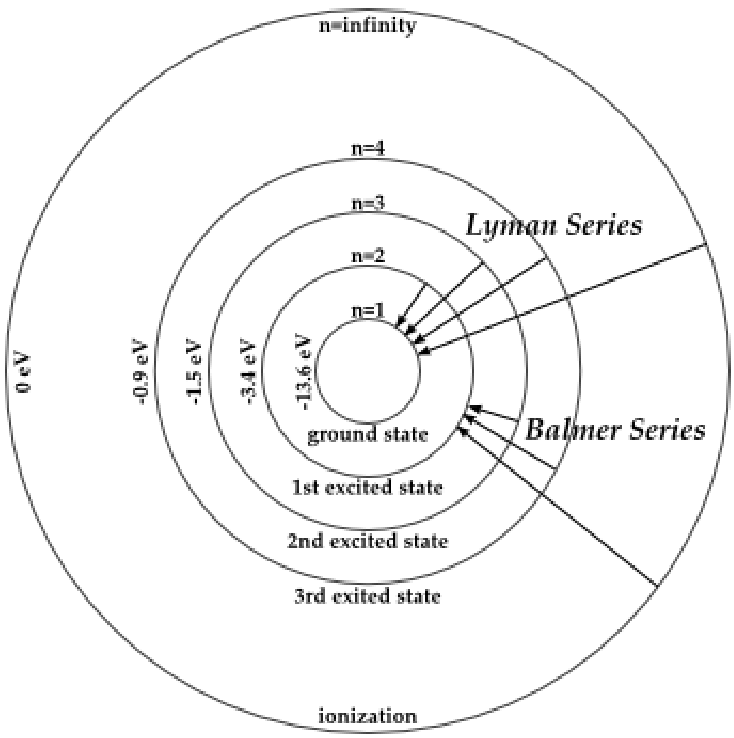

Figure 2.1: Balmier series emission spectrum Bit [2017]

where
λ is the initial wavelength,
λ' is the wavelength after scattering,
h is the Planck constant,
m_e is the electron rest mass,
c is the speed of light, and
θ is the scattering angle.

Chapter 3

Special and General Relativity

The Special and General relativity theory formulated by Albert Einstein in 1900's was the theory merging together Newtonian physics and time, introducing the space-time continuum, the fabric of the universe in the macroscopic point of view. In this fabric gravity is the main actor and the cause of matter to tell space how to curve and space to tell matter how to move. Time is not an actual 4th dimension as called because it is not part of the human senses, but only part of his perception, used to do our computations in a 4-dimensional matrix, as the Minkowski space-time grid.

Figure 3.1: Albert Einstein around 1905, the year his "Annus Mirabilis papers" Einstein [1905]

3.1 Ricci curvature, Riemann, Minkowski spaces

3.2 Lorentz transformations

Lorentz transformations is the conversion from non-relativistic to relativistic measurements. Lorentz factor is the factor which actually imposes this conversion. It is denoted using the Greek letter γ and is defined to be equal to the reciprocal square root of 1 minus the square rate of the relative velocity to the speed of light:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{3.1}$$

where:
v=relative velocity
c=speed of light
Sometimes in favor of our convenience we are using the rate standalone, as the rate of the relative velocity to the speed of light, denoted with Greek letter β.

$$\beta = \frac{v}{c} \tag{3.2}$$

and so equation 3.1 can be rewritten as

$$\gamma = \frac{1}{\sqrt{1 - \beta^2}} \tag{3.3}$$

Chapter 4

Electromagnetism

4.1 Maxwell equations

Chapter 5

Quantum computers

Chapter 6

Black holes, wormholes

Chapter 7

Correlation , entanglement

Chapter 8

Closed Timelike curves

8.1 Time travel

CTCs is the source for time travel. Time travel based in Einstein's theory, could create paradoxes like the grandfather's paradox.

According to a David Deutches model in 1991, paradoxes can be avoided. Deutsches insight was to postulate self-consistency in the quantum realm. In 2009 Seth Lloyd, a theorist at Massachusetts Institute of Technology, proposed an alternative, less radical model of CTCs that resolves the grandfather paradox using quantum teleportation and a technique called post-selection, rather than Deutsche's quantum self-consistency.

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