# CHAPTER 18
# DAWN OF MODERN PHYSICS

1. $E = mc^2$

2. $L = L_o \sqrt{1 - \frac{v^2}{c^2}}$

3. $t = \frac{t_o}{\sqrt{1 - \frac{v^2}{c^2}}}$

4. $m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$

5. $\lambda_{max} T =$ Wein's constant $(0.2898 \times 10^{-2}\ mK)$

6. Stefann - Boltsmann Law

$E = \sigma T^4$

$\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$

7. $E = hf$

8. $E = \frac{hc}{\lambda}$

9. $K.E = eV$

Day:

10 $K.E_{max} = hf - hf_o$

$hf_o = \phi$ : Work function

11 $\lambda' - \lambda = \frac{h}{m_o c}(1-\cos\theta)$

12 $\frac{1}{f'} = \frac{1}{f} + \frac{h}{m_o c^2}(1-\cos\theta)$

13 $\lambda = \frac{h}{p}$ $p = \frac{h}{\lambda}$ $p = \frac{hf}{c}$

$\lambda = \frac{h}{mv}$ or $\lambda = \frac{h}{\sqrt{2mqV}}$

14. $(\Delta p)(\Delta x) \approx h$

15 $(\Delta E)(\Delta t) \approx h$

16 $p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$

17 $E_{max} = E_{photon} - \phi$

18 Stopping Potential $= \frac{E_{max}}{e}$

# INERTIAL REFERENCE FRAME

Inertial Reference frames are reference frames in which Newton's first law of physics holds i.e an object at rest and an object in motion remains in motion unless acted by a net force. An inertial reference frame is either at rest or moves with a constant velocity

# NON INERTIAL REFERENCE FRAME

A non-inertial reference frame is a reference frame that is accelerating, either in linear fashion or rotating around same axis.

## EXAMPLES:

* INERTIAL

  A train moving with constant velocity

* NON-INERTIAL

  1. A rotating merry-go round
  2. A turning car with constant speed
  3. The rotating earth

Date:

Day: M T W T F S S

* If object moves with 1/2 speed of light:

$\ell = 86.6\% \, \ell_o$

* If $v = c$

$t = \infty$ mean time will stop

* If $v = c$

$\ell = 0$, $t = \infty$, $m = \infty$

* RELEIGH-JEAN THEORY:

can predict long wavelength region

* WEIN'S THEORY:

can predict short wavelength region

* COMPTON'S SHIFT:

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

$\theta$: angle at which X-Rays photons were scattered

* COMPTON'S WAVELENGTH:

$$\frac{h}{m_o c} = 0.00243 \text{ nm}$$



* We don't observe Compton's effect for visible light bcz for Compton's effect to occur high energy and high frequency is required eg X-Rays

* At which angle Compton's shift ($\Delta\lambda$) equals to Compton's wavelength?

Ans : $90^\circ$

$$\Delta\lambda = \frac{h}{m_0 c}(1-\cos 90)$$

$$\Delta\lambda = \frac{h}{m_0 c}$$

* At which angle Compton's shift equals to half Compton's wavelength?

Ans : $60^\circ$

$$\Delta\lambda = \frac{h}{m_0 c}(1-\cos 60)$$

$$= \frac{h}{m_0 c}(1-\tfrac{1}{2})$$

$$\Delta\lambda = \frac{1}{2}\frac{h}{m_0 c}$$



* In Compton scattering from stationary electrons, the largest change in wavelength occurs when photon is scattered through:

Ans : $180^\circ$

* Suppose an electron is accelerated through a potential difference then the wavelength $\lambda$ associated with it related to V as:

$$\lambda \propto \frac{1}{\sqrt{V}}$$

* De-Broglie wavelength of electron moving with a typical speed of $10^6$ m/s?

$$\lambda = \frac{h}{mv} = 7.3 \times 10^{-10} \text{ m} = 7.3 \text{ A}^\circ$$

* ENERGY REQUIREMENTS
  1. For photoelectric effect $E < 0.1$ MeV
  2. For Compton effect $0.1 \text{ MeV} < E < 1 \text{ MeV}$
  3. For Pair production $E > 1$ MeV

* Contraction of length is observed only along the direction of motion. No such contraction would be observed perpendicular to the direction of motion.

* Classical Theory Fail to explain photoelectric effect bcz:
  1. Maximum K.E of photoelectrons doesnot depend on intensity of incident radiation
  2. The existence of a threshold frequency or wavelength.

* The radiant energy from the sun incident normally at the surface of earth is 20 kcal/m$^2$ min. What would have been the radiant energy, incident normally on the earth, if the sun had temperature twice of the present one?

Sol:

$$E \propto T^4$$

$$\frac{E_1}{E_2} = \frac{T_1^4}{T_2^4}$$

$$\frac{20}{E_2} = \frac{T^4}{2^4 T^4}$$

$$E_2 = 320 \text{ kcal/m}^2\text{min}$$

* For electron:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$$

* For photon

$$E = \frac{hc}{\lambda}$$



$$\lambda = \frac{hc}{E}$$

Date:

Day: M T W T F S S

* The mass of an object will be double at speed?

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

For $m = 2m_0$ denominator must be equal to 0.5

$$1 - \frac{v^2}{c^2} = 0.5^2$$

$$v^2/c^2 = 0.25 - 1$$

$$v^2/c^2 = 0.75$$

$$v^2 = 0.75c^2$$

$$v = (0.75)^{1/2} c$$

* The mass of a particle is $m_0$. In order for its total energy to be twice its rest energy, its momentum must be:

✓(a) $mc/2$ (b) $mc/\sqrt{2}$ (c) $mc$

Sol:

$$E = 2E_0$$

$$mc^2 = 2m_0c^2$$

$$mc^2 = 2m_0c \cdot c$$

$$mc = 2P$$

$$P = \frac{mc}{2}$$

* Stopping potential is independent of the distance of metal surface from the source.

* The stopping potential is found to be changing linearly with frequency of incident light, being more negative for high frequency. An increase in frequency of the incident light increases the kinetic energy for emitted electrons, so greater retarding potential is required to stop them completely.

MCQ: A particle with rest mass $m_o$ is moving with speed c. The De Broglie wavelength associated with it will be:

✓(a) zero (b) Infinity (c) $hf/m_oc$ (d) $m_oc/h$

Reason:

$$m = \infty \quad \text{when} \quad v = c$$

As

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

$$\lambda = \frac{h}{\infty} = 0$$

Day: M T W T F S S

* RELATION BETWEEN WAVELENGTH AND MASS (WHEN K.E SAME)

$$\lambda \propto \frac{1}{\sqrt{m}}$$

* An electron and a proton have the same De-Broglie wavelength. Then the K.E of electron is greater than the K.E of proton.

* $\Delta p \approx \frac{h}{\lambda}$ ($\Delta p$: uncertainty in momentum)

$\Delta x \approx \lambda$



* MCQ: The life time of an electron in an excited state is about $10^{-8}$ sec. What is its uncertainty in energy during this time?

Sol:

$$(\Delta E)(\Delta t) \approx h$$

$$\Delta E = \frac{h}{\Delta t}$$

$$= \frac{6.63 \times 10^{-34}}{10^{-8}}$$

$$\Delta E = 6.63 \times 10^{-26} J$$