CHAPTER NO. 19 (DAWN OF MODERN PHYSICS)

Question 19.1:- What are the measurements on which two observers in relative motion will always agree upon?

Answer:- The measurements on which two observers in relative motion will always agree upon are:-

1) Speed of light.
2) Magnitude of their relative velocity.

Question 19.2:- Does the dilation means that time really passes more slowing in moving system or that it only seems to pass more slowly?

Answer:- According to result of Einstein's special theory of relativity, time dilation is a physical phenomenon. Time is not an absolute quantity, rather it is relative. Time passes normally for any observer within his own frame of reference. Time actually passes more slowly i.e. time dilates when an observer in one frame of reference is in relativistic motion with respect to other frame of reference.

Question 19.3:- If you are moving in a space ship at very high speed relative to the earth, would you notice a difference (a) in your pulse rate (b) in pulse rate of people on earth?

Answer:- (a) No difference in his pulse rate will be measured by a person who is itself travelling in a spaceship.

(b) A person in spaceship will experience a change in pulse rate of the people on earth, according to the relation $t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}}$.

Question 19.4:- If the speed of light were infinite, what would the equations of special theory of relativity reduce to?

Answer:- If we take speed of light c as infinity, then the equations of special theory of relativity reduce to:-

Time dilation:- $t = \frac{t_o}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{t_o}{\sqrt{1-\frac{v^2}{\infty^2}}} = t_o$ i.e. Time in motion = Proper time

Length contraction:- $l = l_o\sqrt{1-\frac{v^2}{c^2}} = l_o\sqrt{1-\frac{v^2}{\infty^2}} = l_o$ i.e. Length in motion = Proper length

Mass variation:- $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_o}{\sqrt{1-\frac{v^2}{\infty^2}}} = m_o$ i.e. Mass in motion=Rest mass

Question 19.5:- Since mass is form of energy, can we conclude that a compressed spring has more mass than the same spring when it is not compressed?

Answer:- According to Einstein's special theory of relativity, mass is a form of energy. As compressed spring has more energy in the form of elastic potential energy, so there would be increase in mass of compressed spring according to the relation $\Delta m = \frac{\Delta E}{c^2}$. However, this increase in mass is negligible due to very high value of speed of light.

Question 19.6:- As a solid is heated and begins to glow, why does it first appear red?

Answer:- At lower temperature, a body emits radiation of low energy i.e. longer wavelength). Since longest wavelength in visible region is of red colour, so the object appears red first.

Question 19.7:- What happens to total radiation from a black body if its absolute temperature is doubled?

Answer:- According to Stephen Boltzmann law, $E = \sigma T^4$.

When absolute temperature of the body is doubled, $T_1 = 2T$ and $E_1 = \sigma T_1^4 = \sigma (2T)^4 = 16 (\sigma T^4) = 16 E$.

Thus, if absolute temperature is doubled, the total radiation emitted by black body increases 16 times.

Question 19.8:- A beam of red light and a beam of blue light have exactly the same energy. Which beam contains the greater number of photons?

Answer:- The energy of a beam of photon is given as $E = nhf$ where n is number of photons in the beam. We can conclude that $n = E/hf$. The number of photons will be inversely proportional to frequency provided energy is constant. Therefore, two color beams having same energy will contain different number of photons.

The blue light, having photon of comparatively larger frequency contains less number of photons.

The red light, having photon of comparatively smaller frequency contains greater number of photons

Question 19.9:- Which photon, red, green or blue carries the most (a) energy and (b) momentum?

Answer:- **Energy** According to the relation E = $\frac{hc}{\lambda}$, the photons of blue light having shorter wavelength must have larger energy as compared to photons of red or green color light.

Momentum According to the relation P = $\frac{h}{\lambda}$, the photons of blue light having shorter wavelength must have larger momentum as compared to photons of red or green color light.

Question 19.10:- Which has the lower energy quanta? Radiowaves or X-rays.

Answer:- According to the relation E = $\frac{hc}{\lambda}$, the quanta of X-rays having shorter wavelength must have larger energy as compared to quanta of radiowaves.

Question 19.11:- Does the brightness of a beam of light primarily depend on the frequency of photons or the number of photons?

Answer:- The brightness of a beam depends upon intensity (number of photons) and not on the frequency of light. Thus, brightness increases with intensity of light.

Question 19.12:- When ultraviolet light falls on certain dyes, visible light is emitted. Why does this not happen when infrared light falls on these dyes?

Answer:- Ultraviolet (UV) light consists of photons having energy greater than energy of visible light photons. When UV light falls on dyes, atoms initially become excited and then de-excited by emitting lower energy photons, which may be detectable by normal human eyes.

Infrared (IR) light consists of photons having energy lower than energy of visible light photons. When IR light falls on dyes, atoms initially become excited and then de-excited by emitting lower energy photons, which do not lie in the visible spectrum of electromagnetic radiation.

Question 19.13:- Will bright light eject more electrons from metal surface than dimmer light of same color?

Answer:- We know that number of photoelectrons ejected from a metal surface depend upon the intensity of light i.e. number of photons. Therefore, bright light being more intense will eject more electrons from a metal surface than dimmer light of same color.

Question 19.14:- Will higher frequency light eject greater number of electrons than lower frequency light?

Answer:- No, the higher frequency light will not eject greater number of electrons than low frequency light. It is because of the reason that number of electrons emitted from metal surface depends upon intensity of light i.e. number of photons and not on frequency of light.

Question 19.15:- When light shines on a surface, is momentum transferred to the metal surface?

Answer:- When light falls on the surface, incident light energy is absorbed in each reflection. Light beam consists of photons, which carry both energy and momentum. Hence, momentum and energy is transferred to the metal surface when it is exposed to light.

Question 19.16:- Why can red light be used in photographic dark room when developing films, but a blue or white light cannot?

Answer:- The frequency of red light is less as compared to blue or white light, so red light has less energy as compared to blue or white light. Therefore, photographic films and the material concerned are less affected in the presence of red light.

Question 19.17:- Photon A has twice the energy of photon B. What is the ratio of the momentum to A to that of B?

Answer:- Given that the energy of photon A is twice the energy of photon B i.e. $E_A = 2\ E_B$.

$$\frac{E_A}{E_B} = 2$$

Momentum of photon A = $P_A = E_A/c$

Momentum of photon B = $P_B = E_B/c$

$$\frac{P_A}{P_B} = \frac{E_A/c}{E_B/c} = \frac{E_A}{E_B} = 2$$

So, photon A has twice the momentum of photon B.

Question 19.18:- Why don't we observe Compton effect with visible light?

Answer:- Compton's effect is mostly observed in semimetals**.** The electrons in semimetals such as graphite are semi loosely bound and their energy levels lie in X-ray region. Therefore, we don't observe Compton effect with visible light because photons of visible light have smaller energy than the photons of X-rays.

Question 19.19:- Can pair production take place in vacuum? Explain.

Answer:- No, pair production cannot take place in vacuum because, in vacuum, there is no heavy nucleus present. Presence of heavy nucleus is necessary for pair production because recoil energy is absorbed by the heavy nucleus.

The electron and positron created as a result of pair production always move in opposite direction (their net momentum is zero), so a heavy nucleus should always be there which can absorb the momentum of incident γ-ray photon. Pair production in the absence of heavy nucleus is against the law of conservation of momentum and hence cannot take place.

Question 19.20:- Is it possible to create a single electron from energy? Explain.

Answer:- No, it is not possible to create a single electron from energy. The creation of single electron from energy is violation of law of conservation of electric charge. Whenever pair production takes place, the electrons and positrons are created at the same time.

Question 19.21:- If electrons behaved only like particles, what pattern would you expect on the screen after the electron passes through double slit?

Answer:- If electron behave only like particles then, after passing through the double slit, only those parts of the screen are affected which are in front of the slits. Two spots on the screen each in front of both slits will be observed as no diffraction effects are visible.

Question 19.22:- If an electron and proton have the same de Broglie wavelength, which particle has greater speed?

Answer:- The de Broglie wavelength associated with moving particle is given by expression $\lambda = \frac{h}{mv}$ which may be rearranged as $v = \frac{h}{m\lambda}$. Speed is inversely proportional to mass provided wavelength is same. As the wavelength is same for both electron and proton, therefore speed of electron is greater due to smaller mass of electron than proton.

Question 19.23:- We don't notice the de Broglie wavelength for a pitched cricket. Explain why?

Answer:- The de Broglie wavelength associated with moving particle is given by expression $\lambda = \frac{h}{mv}$. Due to large mass and small speed, the wavelength associated with moving cricket ball is very small. Therefore, it is impossible to measure de Broglie wavelength for a pitched cricket ball.

For a cricket ball of m = 200 g = 0.2 kg moving with a speed of v = 10 m s^{-1}, the de Broglie wavelength is λ = $\frac{6.63\ x\ 10^{-34}}{0.2\ x\ 10}$ = 3.31 x 10^{-34} m. The wavelength is of the order of 10^{-34} m and too short to be detected.

Question 19.24:- If the following particles have the same energy, which has the shortest wavelengths? Electron, alpha particle, neutron, proton.

Answer:- The de Broglie wavelength associated with moving particle is given by expression λ = $\frac{h}{\sqrt{2mE}}$. For same energy of all the particles, de Broglie wavelength is inversely proportional to mass. Thus, alpha particle being the massive particle has the shorter wavelength.

Question 19.25:- When does light behave as a wave? When does it behave as a particle?

Answer:- Light behaves as a wave in the phenomenon of (i) Interference (ii) Diffraction (iii) Polarization (iv) Reflection (v) Refraction (vi) Dispersion (vii) Scattering.

Light behaves as a particle in the phenomenon of (i) Photoelectric effect (ii) Compton's effect (iii) Pair production (iv) Black body radiation.

Question 19.26:- What advantages an electron microscope has over an optical microscope?

Answer:- The magnifying and resolving power of electron microscope is thousand times greater than an optical microscope. The internal structure of an object can also be obtained by an electron microscope which is not possible with optical microscope.

Question 19.27:- If measurement shows a precise position for an electron, can those measurements show precise momentum also? Explain.

Answer:- According to Heisenberg's uncertainty principle, it is impossible that measure both position and momentum of an atomic particle precisely at the same time. Mathematically, Δx Δp = $\frac{h}{2\pi}$. Thus, if position is determined with precision, the momentum cannot be measured precisely.