# 17 Dual Nature of Matter and Radiation

| Name of scientist | | Discovery |
|---|---|---|
| Jean perin | - | Discovered an electron |
| Milikan | - | Charge of an electron |
| J.J.Thomson | - | found the value of $\frac{e}{m}$ |
| Wilhem Rontgen | - | discovered X-rays |
| Henry Bacquerel and Madam curie | - | Radio activity |
| Hertz | - | photo electric effect |

**Methods of Emission of Electron :**

(1) Thermionic Emission : In this method, the current is passed through a filament of metal so that it gets heated sufficiently and electrons get emitted from the metal.

(2) Field Emission : when a metal is subjected to strong electic field of the order of $10^8\ Vm^{-1}$, electrons are pulled out of the metal surface.

(3) Photo electric emission : when an electromagnetic radiation of enough high frequeney is incident on a cleaned metallic surface, electrons can be liberated from the metal surface. This phenomenon is known as the photoelectric effect and electrons so emitted are known as photo electrons.

**Work function (Threshold energy)**

The minimum energy required to get emission of an electron ( to eject the free electrons from metallic surface) is defined as work function of that surface of metal ($\phi_0$ ).

$\phi_0 = hf_0 = \frac{hc}{\lambda_0}$ where $f_o$ = threshold frequency, $\lambda_0$ = threshold wavelength

Work function in electron volt, $\phi_0\,(eV) = \frac{hc}{e\lambda_o} = \frac{12375}{\lambda_0 \left(\overset{\circ}{A}\right)}$

(taking planck's constant, $h = 6.6 \times 10^{-34}$ Js )

**Threshold Frequency** $(f_0)$ : The minimum frequency of incindent light for the emission of photo electrons from metallic surface is defined as threshold frequency $(f_0)$.

for the emission of photo electrons, the frequency of the incident light $f \geq f_0$

**Threshold wave length** $(\lambda_0)$

For the emission of photo electrons from the given metallic surface, the wavelength of incident light should be some maximum or less than that maximum wavelength. This maximum wavelength is called the threshold wavelength $(\lambda_0)$

For emission of photo electrons, $\lambda \leq \lambda_0$

(1) **Effect of intensity of incident light :**

By Increasing the intensity of incident light (keeping frequency constant) the number of photo electrons emitted and hence photoelectric current increases. but the maximum kinetic energy of photo electrons do not change i.e. value of stopping potential remains unchanged.

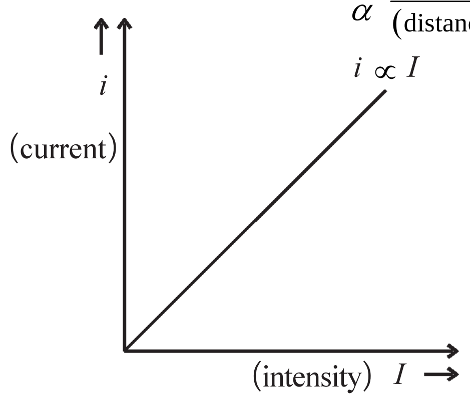
$\therefore$ Intensity $I \propto$ no. of incident photons

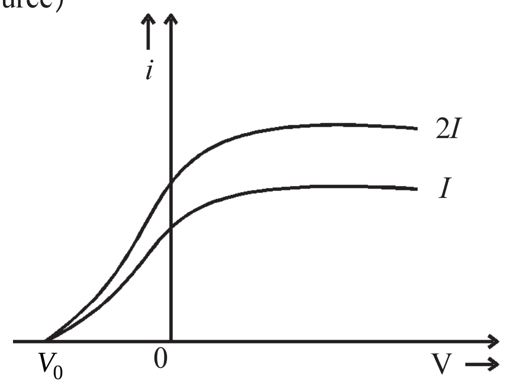
$\propto$ no. of emitted photo electrons in 1 second

$\alpha$ photo electric current

$\alpha \dfrac{1}{(\text{distance})^2}$ (for a point like source)

$\alpha \dfrac{1}{(\text{distance})}$ (for a linear source)




(2) **Effect of potential :**

- when collector C is kept positive with respect to photo sensitive surface S, the emitted photo electrons are attracted to collector C and amount of current passing through the micro ammeter. At certain value of positive potential difference, when all the emitted electrons are collected, increasing the potential difference further has no effect on the current. This current is known as saturation current.

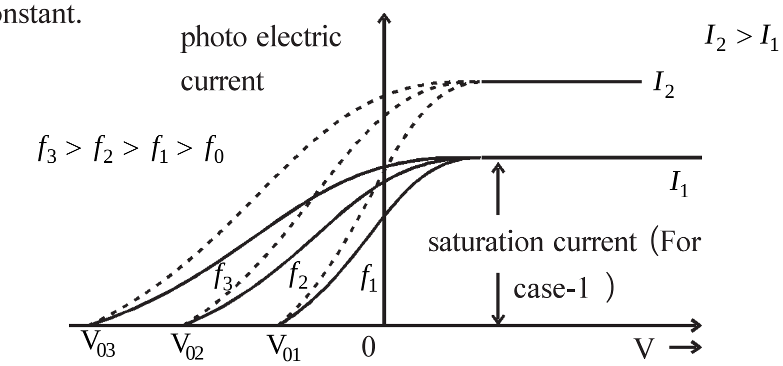
  when the C is made negative with respect to S, on increasing this negative potential, the number of photo electrons reaching the collector (value of photo electric current) gradually decreases.

- For some specific negative potential of the collector, even the most energetic electrons are unable to reach collector, then photo electric current becomes zero. This minimum specific negative potential of C with respect to S is known as stopping potential or cut off potential $\left(V_0\right)$
- If the value of stopping potantial is $V_0$, then the energy required for electron to cross this potential barrier is, $eV_0$

  If maximum speed of photo electron is $v_{max}$, then $eV_0 = \frac{1}{2} mv_{max}^2$

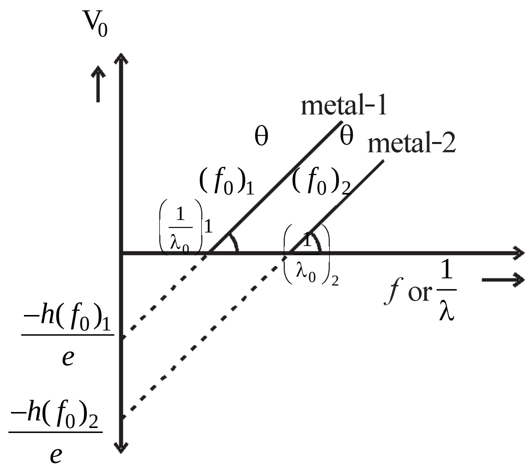
(3) **Effect of frequency :**

If frequency of incident light $\left(> f_0\right)$ is increased, the maximum kinetic energy of emitted photo electrons increased. i.e.the value of stopping potential is also increased but photo electric current remains constant.




(4) **Effect of photo sensitive surface :**

When the photo sensitive surface is changed by keeping frequency and intensity of incident light constant, the graph of stopping, potential $\left(V_0\right) \rightarrow$ frequency $(f)$ found to be straight line and pasallel to each other. which intersects the X-axis (frequency axis) and the Y-axis at different points. Which shows that the values of threshold frequencies are different for different metals but slope of the graph $\left(\frac{h}{e}\right)$ is equal for all the metals.




It is clear from the graphs, the value of threshold frequency and work function for metal–2 are more than for metal–1

- **Einstein's equation for photoelectric effect**

  The maximum kinetic energy of emitted photo electrons,

  $$K_{max} = hf - \phi_0$$

  $$\frac{1}{2}mv_{max}^2 = hf - hf_0 = h\left(f - f_0\right)$$

  $$\frac{1}{2}mv_{max}^2 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) \Rightarrow v_{max} = \sqrt{\frac{2hc}{m}\frac{(\lambda_0 - \lambda)}{\lambda\lambda_0}}$$

  This equation is called eEinstein's photo electric equation.

- **Relation between stopping potential and frequency** :

  According to definition of stopping potential,

  $$\frac{1}{2}mv_{max}^2 = eV_0$$

  $$\therefore \quad eV_0 = h\left(f - f_0\right) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

  $$\therefore \quad V_0 = \frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = 12375\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

  In the graph of $V_0 \to f$

  $$V_0 = \frac{h}{e}\left(f - f_0\right) = \frac{hf}{e} - \frac{hf_0}{e}$$

  comparing above equation with equation of straight line

  $y = mx + c$, slope is found to be $\frac{h}{e}$ and intercept on X-axis is $f_0$ and intercept on Y-axis is $\frac{-hf_0}{e}$ is obtained.

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(1) The work functions for tungsten and sodium are 4.6 eV and 2.3 eV respectively. If threshold wavelength for sodium is 5460 $\overset{\circ}{A}$, the value of threshold wavelength for tungsten is ________.

(A) 10682 $\overset{\circ}{A}$  (B) 2730 $\overset{\circ}{A}$  (C) 526 $\overset{\circ}{A}$  (D) 5892 $\overset{\circ}{A}$

(2) The maximum velocity of photo electron emitted from surface of metal is $5 \times 10^6\ ms^{-1}$. If specific charge of an electron is $1.8 \times 10^{11}\ Ckg^{-1}$ then the value of stopping potential is ________. (approximately)

(A) 2 V  (B) 3 V  (C) 7 V  (D) 4 V

(3) If the intensity of radiation incident on a photo cell be increased by four times, then the number of photoelectrons and maximum kinetic energy of photoelectrons emitted become ...... .

(A) Four times, doubled (B) Four times, remains unchanged

(C) Doubled, remains unchanged (D) Remains unchanged, Doubled

(4) In a photo cell, with exciting wave length $\lambda$ the maximum speed of emitted photoelectron is $v$. If the exciting wave length is changed to $\frac{3\lambda}{4}$ the maximum speed of emitted photo electron will be ......

(A) greater than $\sqrt{\frac{4}{3}}\, v$ (B) $\sqrt{\frac{4}{3}}\, v$ (C) less than $\sqrt{\frac{4}{3}}\, v$ (D) $\sqrt{\frac{3}{2}}\, v$

(5) Light of wave length $0.6\ \mu m$ falls on a surface of metal causes the emission of photoelectrons. for which the stopping potential is 0.5 V. With light of wavelength $0.4\ \mu m$ falls on the same surface the stopping potential found to be 1.5 V. then the work function of surface of metal is ________.

(A) 1.5 eV (B) 0.75 eV (C) 2.5 eV (D) 3 eV

(6) When a certain metallic surface is illuminated with light of wavelength $\lambda$, the stopping potential is $4\,V_0$. When the same surface is illuminated with light of wavelength $2\lambda$, the stopping potential is $V_0$. The threshold wavelength for the surface is ...... .

(A) $6\lambda$ (B) $8\lambda$ (C) $3\lambda$ (D) $\frac{\lambda}{4}$

(7) The frequency of incident light falling on a photosensitive surface is doubled, the value of stopping potential will be ...... .

(A) Doubled (B) More than doubled

(C) halved (D) less than doubled.

(8) Sodium surface is illuminated by ultraviolet and visible radiation successively and stopping potantial determined. This stopping potantial is ...... .

(A) Equal in both cases (B) More with visible light

(C) More with ultraviolet light (D) Varies randomly

(9) Light of two different frequencies whose photons have energies $1\,\text{eV}$ and $5\,\text{eV}$ respectively, successively illuminates a metal of work function $0.5\,\text{eV}$. The ratio of maximum speed of the emitted photo electron will be ...... .

(A) 1 : 4 (B) 1 : 1 (C) 1 : 3 (D) 4 : 1

(10) Light of wavelength $\lambda$ falls on a metal having work function $\frac{hc}{\lambda_0}$. Where $\lambda_0$ is threshold wavelength of surface of metal. Photo electric effect take place only if

(A) $\lambda \geq \lambda_0$ (B) $\lambda \leq \lambda_0$ (C) $\lambda = 4\lambda_0$ (D) $\lambda \geq 2\lambda_0$

(11) When the point like sousce is kept 1m away from a photocell, photo electric current 16 $mA$ is obtained. When the same surface is kept 4m away, the photo electric current will be...... .

(A) 1 $mA$ (B) 2 $mA$ (C) 4 $mA$ (D) 16 $mA$

(12) The threshold frequency for a metallic surface is $f_0$. When radiation of frequency $2f_0$ is incident on this surface,the maximum speed of emitted photoelectron is found $2\times10^6\ \mathrm{ms^{-1}}$. When the radiation with frequency $5f_0$ is incident on that, the maximum speed of the emitted photo electron will be ...... $\mathrm{ms^{-1}}$.

(A) $3\times10^6$ (B) $6\times10^6$ (C) $8\times10^6$ (D) $4\times10^6$

(13) The kinetic energies of photo electrons emitted from a metal are $K_1$ and $K_2$, when it is irradiated with lights of wavelength $\lambda_1$ and $\lambda_2$ respectively. The work function of the metal is

(A) $\dfrac{K_2\lambda_2 - K_1\lambda_1}{\lambda_1-\lambda_2}$ (B) $\dfrac{K_1K_2}{\lambda_1-\lambda_2}$ (C) $\dfrac{\lambda_1\lambda_2\left(K_1-K_2\right)}{\lambda_1-\lambda_2}$ (D) $\dfrac{\lambda_1\lambda_2\,K_2}{\left(\lambda_1-\lambda_2\right)K_1}$

(14) The work function for a metallic surface is $\phi_0$. Now this surface is successively illuminated with the radiations of energy $5\phi_0$ and $10\phi_0$ respectively. The ratio of maximum speed of emitted photo electrons will be ...... .

(A) 1 : 3 (B) 1 : 1 (C) 1 : 2 (D) 2 : 3

(15) The maximum kinetic energy of emitted photoelectron is $0.5\,\mathrm{eV}$ when the metal surface is illuminated with the radiation of frequency $8\times10^{14}\ H_z$. When the same surface is illuminated with radiation of frequency $12\times10^{14}\ H_z$, the maximum kinetic energy of emitted photoelectron is found to be 2eV. Then the work function of the metallic surface is ...... .

(A) 3.5 eV (B) 0.5 eV (C) 2.5 eV (D) 3.85 eV

(16) The maximum speed of emitted photoelectrons, when light of wavelength $\lambda$ is incident on a metallic surface having work function $\phi_0$ is ...... . where $h =$ planck's constant, $c =$ speed of light in vaccum, $\mathrm{m} =$ mass of electron.

(A) $\left(\dfrac{2hc+\lambda\phi_0}{\mathrm{m}\lambda}\right)^{\frac{1}{2}}$ (B) $\dfrac{2\left(hc-\lambda\phi_0\right)}{\mathrm{m}}$

(C) $\left[\dfrac{2\left(hc-\lambda\phi_0\right)}{\mathrm{m}\lambda}\right]^{\frac{1}{2}}$ (D) $\left[\dfrac{2\left(hc-\phi_0\right)}{\mathrm{m}}\right]^{\frac{1}{2}}$

(17) When a metallic surface is illuminated with light of wavelenght $\lambda$, the stopping potential is $3\,V_0$ When the same surface is illuminated with light of wavelength $2\lambda$, the stopping potential is $V_0$. The threhold wavelength for this surface is

(A) $4\lambda$ (B) $3\lambda$ (C) $6\lambda$ (D) $\dfrac{5}{3}\lambda$

(18) The work function for aluminium surface is $4.2 \text{ eV}$. The wavelength of incident light for which the value of stopping potential will be zero ......

$h = 6.6 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ ms$^{-1}$

(A) 2694 $\overset{\circ}{\text{A}}$ (B) 2946 $\overset{\circ}{\text{A}}$ (C) 1854 $\overset{\circ}{\text{A}}$ (D) 4268 $\overset{\circ}{\text{A}}$

(19) The value of threshold frequency for a certain metal is $3.3 \times 10^{14}$ Hz. If light of frequency $8.2 \times 10^{14}$ Hz is incident on this surface, the value of stopping potential is ________.

$h = 6.63 \times 10^{-34}$ Js, $e = 1.6 \times 10^{-19}$ C.

(A) 2.03 V (B) 3.68 V (C) 1.74 V (D) 4.06 $V$

(20) The frequency of incident light on a metallic surface is made three times, the maximum kinetic energy of the emitted photo electrons will become ________.

(A) three times (B) less than three times

(C) 1/3 times the earlier value (D) more than three times

(21) When the light of frequency $5 \times 10^{14}$ Hz is incident on a metallic surface having threshold frequency $4 \times 10^{14}$ Hz, the photoelectric current found to be 1.8 $m$A. When the frequency of incident light is halved and the intensity is made three times, the value of photoelectrics current will be ...... .

(A) 0.9 $m$A (B) 5.4 $m$A (C) 3.6 $m$A (D) zero

(22) The difference between the maximum kinetic energies of photoelectrons emitted from a metallic surface by light of wavelength 2000 $\overset{\circ}{\text{A}}$ and 5000 $\overset{\circ}{\text{A}}$ will be $h = 6.6 \times 10^{-34}$ Js

(A) 3.71 eV (B) 5.94 eV (C) 7.42 eV (D) 2.97 eV

(23) A light with frequency $6 \times 10^{14}$ Hz is incident on a metal surface whose work function is 1.59 eV .The maximum kinetic energy of photoelectrons emitted will be .....

$\left(h = 6.63 \times 10^{-34} \text{ Js}\right)$

(A) 0.49 eV (B) 0.90 eV (C) 1.26 eV (D) 1.08 eV

(24) The maximum wavelength of radiation that can produce photoelectric effect in certain metal having work function 3.2 eV will be ...... ($h = 6.625 \times 10^{-34}$ Js)

(A) 1988 $\overset{\circ}{\text{A}}$ (B) 2466 $\overset{\circ}{\text{A}}$ (C) 2953 $\overset{\circ}{\text{A}}$ (D) 3881 $\overset{\circ}{\text{A}}$

(25) The work function of a photo sensitive surface is 1.6 eV. In order to have the value of stopping potential equal to 1 V for that surface, the wavelength of the incident light will be in the region of ...... . ($h = 6.6 \times 10^{-34}$ Js)

(A) X-ray region (B) infrared region (C) ultraviolet region (D) visible region

(26) How many photons of radiation of wavelength 5000 $\overset{\circ}{\text{A}}$ have energy equals to the energy of a photons of $\gamma$. radiations of wavelength $2.5 \times 10^{-13}$m ?

(A) $2 \times 10^{6}$ (B) $4 \times 10^{6}$ (C) $8 \times 10^{6}$ (D) $0.5 \times 10^{6}$

**Ans. :** **1 (B), 2 (C), 3 (B), 4 (A), 5 (A), 6 (C), 7 (B), 8 (C), 9 (C), 10 (B), 11 (A), 12 (D), 13 (A), 14 (D), 15 (C), 16 (C), 17 (A), 18 (B), 19 (A), 20 (D), 21 (D), 22 (A), 23 (B), 24 (D), 25 (D), 26 (A)**

- **Particle like nature of light (photon nature)**

Photon is bundles or packet (quanta) of discrete energy. The energy of the smallest packet is equal to $hf$ .

**Properties of photon :**

(1) The speed of photon in vaccum is same as speed of light $\left(3\times10^{8}\ \text{ms}^{-1}\right)$.

(2) Energy of a photon of frequency $f$ is, $E = hf = \frac{hc}{\lambda}$

where $c =$ velocity of light in vaccum, plank's constant, $h = 6.6\times10^{-34}$ Js , $\lambda$ = wavelength of light.

$$E\ (\text{in eV}) = \frac{hc}{e\lambda} = \frac{12375}{\lambda\left(\overset{\circ}{A}\right)} \approx \frac{12400}{\lambda\left(\overset{\circ}{A}\right)} \quad \left(\text{taking } h = 6.625\times10^{-34}\ \text{Js}\right)$$

The energy of photon is not continuous but discrete like $hf$ $2hf$,... which shows the quantization of energy.

(3) Linear momentum of photon of frequency $f$ is

$$P = m\times c = \frac{E}{c^2}\times c = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$$

(4) Rest mass ($m_0$) of photon is zero, but effective mass,

$$m = \frac{E}{c^2} = \frac{hf}{c^2} = \frac{h}{c\lambda}$$

This mass is also known as kinetic mass of photon.

mass of particle moving with velocity $v$ is, $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$, where $m_0$ = rest mass

but speed of photon in vaccum $v$ = speed of light c

$$\therefore\ m_0 = m\left(\sqrt{1-\frac{v^2}{c^2}}\right) = 0$$

(5) Photon is electrically neutral.

(6) Photons are not effected by electric and magnetic field.

(7) Like a real particle, photon interacts with other particles obeying the law of conservation of energy and momentum..

**Number of emitted photons :**

The number of photons emitted per second from a source of monochromatic radiation of wavelength $\lambda$ and power P is given as,

$n = \frac{P}{E} = \frac{P}{hf} = \frac{P\lambda}{hc}$ ; where E = energy of each photon.

**Intensity of lght (I) :**

Energy crossing per unit area normally per second is called intensity $(I)$ of incident light

$\therefore I = \frac{E}{At} = \frac{P}{A} \quad \left(\because \frac{E}{t} = P = \text{ power}\right)$

At a distance *'r'* from a point source of power P, intensity is given by

$I = \frac{P}{A} = \frac{P}{4\pi r^2} \Rightarrow I \propto \frac{1}{r^2}$

For a linear source, $I = \frac{P}{2\pi rl} \Rightarrow I \propto \frac{1}{r}$

where $l =$ length of a cylinder at a distance $r$ from the source.

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(27) If the efficiency of an electric bulb of 2 W is 20 %, what is number of photons emitted by it in one second ? the wavelength of light emitted by it is 400 nm. ($h = 6.6 \times 10^{-34}$ Js)

(A) $3.46 \times 10^{16}$ (B) $4.67 \times 10^{17}$ (C) $2.52 \times 10^{17}$ (D) $8.08 \times 10^{17}$

(28) The monochromatic light of wavelength of 660 nm is produced from He–Ne LASER.Hence, output power of 6 mW is obtained. If this light is incident on the target, what will be the number of photons incident per second $\left(h = 6.6 \times 10^{-34} \text{ Js}\right)$

(A) $4 \times 10^{16}$ (B) $2 \times 10^{16}$ (C) $3 \times 10^{16}$ (D) $5.5 \times 10^{16}$

(29) A source $S_1$ is produsing $10^{14}$ photons per second of wavelength $3000\,\overset{\circ}{A}$. Another source $S_2$ is producing $1.04 \times 10^{14}$ photons per second of wavelength $3120\,\overset{\circ}{A}$. Then the ratio of powers of sources $S_1$ and $S_2$ respectively is ...... .

(A) 1 : 1 (B) 1 : 1.02 (C) 1.04 : 1 (D) 1 : 2

(30) $12 \times 10^{12}$ photons are incident on a surface in 10 s. This photons correspond to a wavelength $12\,\overset{\circ}{A}$. If the surface area of the given surface is $0.02\,m^2$. Find the intensity of incident radiations. Velocity of light, $c = 8 \times 10^8\ ms^{-1}$, $h = 6.6 \times 10^{-34}$ Js

(A) $2.19 \times 10^{-3}\ Wm^{-2}$ (B) $3.48 \times 10^{-3}\ Wm^{-2}$ (C) $9.9 \times 10^{-3}\ Wm^{-2}$ (D) $6.62 \times 10^{-2}\ Wm^{-2}$

(31) Monochromatic light of wavelength $6000\ \mathring{A}$ is incident normally on a surface of area $2\ cm^2$. If the intensity of light is $200\ mWm^{-2}$, find the number of photons being incident on this surface in one second.

$h = 6.6 \times 10^{-34}$ Js, $c = 3 \times 10^{8}\ ms^{-1}$

(A) $1.21 \times 10^{14}$ (B) $3.88 \times 10^{13}$ (C) $6.16 \times 10^{14}$ (D) $4.54 \times 10^{13}$

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|---|
| **Ans. : 27 (D), 28 (B), 29 (A), 30 (C), 31 (A)** |

- **Matter Wave (Wave like nature of particle)**

According to de-Broglie a moving material particle some times acts as a wave and some times as a particle.

The wave associated with moving particle is called matter wave or de-Broglie wave and it propagates in the form of wave packets with group velocity.

(1) de-Broglie wave length :

According to de Broglie theory, the wavelength of de-Broglie wave is given by,

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{P} \propto \frac{1}{v} \propto \frac{1}{\sqrt{E}}$$

where $h =$ planck's constant,

m = mass of the particle, $v =$ speed of the particle, E = kinetic energy of particle.

(2) de-Broglie wavelength associated with the charged particle :

The kinetic energy of a charged particle accelerated through a potential difference of V volt, $E = \frac{1}{2} mv^2 = qV$.

$\therefore$ Hence de-Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$

$$\lambda_{\text{electron}} = \frac{12.27}{\sqrt{V}}\ \mathring{A},\ \lambda_{\text{proton}} = \frac{0.286}{\sqrt{V}}\ \mathring{A}$$

$$\lambda_{\text{Deutron}} = \frac{0.202}{\sqrt{V}}\ \mathring{A},\ \lambda_{\propto-\text{Particle}} = \frac{0.101}{\sqrt{V}}\ \mathring{A}$$

(3) de-Broglie wavelength associated with uncharged (netural) particle :

$$\lambda_{\text{neutron}} = \frac{0.286 \times 10^{-10}}{\sqrt{E\ (\text{in eV})}}\ m = \frac{0.286}{\sqrt{E\ (\text{in eV})}}\ \mathring{A}$$

Energy of thermal neutron at ordinary temperature

$$E = \frac{3}{2} kT \Rightarrow \lambda\ \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{(2m)\left(\frac{3}{2}kT\right)}} = \frac{h}{\sqrt{3mkT}}$$

where T = Absolute temperature, $k =$ Boltzmann's constant $= 1.38 \times 10^{-23}\ JK^{-1}$

$$\therefore \lambda_{\text{thermal neutron}} = \frac{6.62 \times 10^{-34}}{\sqrt{3 \times 1.67 \times 10^{-27} \times 1.38 \times 10^{23}\ T}} = \frac{25.17}{\sqrt{T}}\ \mathring{A}$$

(4) Ratio of wavelength of photon and electron :

The wavelength of a photon of energy E is given by,, $\lambda_p = \frac{hc}{\mathrm{E}}$ $\left(\because \mathrm{E} = \frac{hc}{\lambda}\right)$

While the wavelength of an electron of kinetic energy K is given by,

$$\lambda_e = \frac{h}{\sqrt{2m\mathrm{K}}}$$

$$\therefore \frac{\lambda_p}{\lambda_e} = \frac{\mathrm{c}}{\mathrm{E}}\sqrt{2\mathrm{mK}} = \sqrt{\frac{2\mathrm{m}c^2\mathrm{K}}{\mathrm{E}^2}}$$

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(32) The de-Broglie wavelength of a neutron at 627° C is $\lambda$. What will be its wavelength at 127° C

(A) $\frac{2}{3}\lambda$ (B) $2\lambda$ (C) $\frac{3}{2}\lambda$ (D) $\frac{\lambda}{2}$

(33) If the kinetic energy of a free electron is made thrice, its de-Broglie wavelength will become.......

(A) $\frac{1}{\sqrt{3}}$ times (B) $\sqrt{3}$ times (C) 3 times (D) $\frac{1}{3}$ times

(34) The de-Broglie wavelength of a neutron having energy $8\,e\mathrm{V}$ is ...... .($h = 6.6 \times 10^{-34}$ Js , mass of neutron = $1.7 \times 10^{-27}$ kg )

(A) $1 \times 10^{-11}$ m (B) $1.8 \times 10^{-11}$ m (C) $2.2 \times 10^{-11}$ m (D) $0.6 \times 10^{-11}$ m

(35) A proton and a deutron have equal energies. The ratio of their de-Broglie wavelengths is ......

(A) 2 : 1 (B) 1 : 2 (C) $\sqrt{2}:1$ (D) $1:\sqrt{2}$

(36) A proton and an $\alpha$ −particle are accelerated through same potential difference of 200 V. If de-Broglie wavelength associated with proton is 5200 A°, then the de-Broglie wavelength associated with $\alpha$ −particle is ...... .

(A) $\frac{1300}{\sqrt{2}}$ $\mathring{\mathrm{A}}$ (B) $1300\sqrt{2}$ $\mathring{\mathrm{A}}$ (C) 2600 $\mathring{\mathrm{A}}$ (D) $2600\sqrt{2}$ $\mathring{\mathrm{A}}$

(37) The linear momentum of an electron intially at rest, accelerated through a potential difference of 25 V is

(A) $5.4 \times 10^{-24}$ $\mathrm{kgms}^{-1}$ (B) $2.7 \times 10^{-24}$ $\mathrm{kgms}^{-1}$

(C) $1.2 \times 10^{-24}$ $\mathrm{kgms}^{-1}$ (D) $3.2 \times 10^{-24}$ $\mathrm{kgms}^{-1}$

(38) If the kinetic energy of the particle is increased by 16 times, then the value of de Broglie wavelength of particle is ...... .

(A) decreased by 75 % (B) increased by 75 %

(C) decreased by 67 % (D) increased by 67 %

(39) The de-Broglie wavelength of a proton accelerated through a potential difference of 450 V is ($h = 6.6 \times 10^{-34}$ Js, charge of proton $= 1.6 \times 10^{-19}$ C, mass of proton $= 1.6 \times 10^{-27}$ kg)

(A) $0.14 \times 10^{-11}$ m (B) $0.2 \times 10^{-11}$ m (C) $0.26 \times 10^{-11}$ m (D) $0.09 \times 10^{-11}$ m

(40) The de Broglie wavelength of a particle moving with a velocity $2.25 \times 10^{8}$ ms$^{-1}$ is equal to the wavelength of photon. The ratio of kinetic energy of the particle to the energy of the photon is ...... . (velocity of light is $c = 3 \times 10^{8}$ ms$^{-1}$)

(A) $\frac{7}{8}$ (B) $\frac{5}{8}$ (C) $\frac{3}{8}$ (D) $\frac{1}{8}$

(41) The kinetic energy of electron and proton is equal. Then the relation between their de-Broglie wavelength is

(A) $\lambda_p > \lambda_e$ (B) $\lambda_p < \lambda_e$ (C) $\lambda_p = 2\lambda_e$ (D) $\lambda_p = \lambda_e$

(42) An electron and a proton have the same de-Broglie wavelength. Then the kinetic energy of the electron is ...... .

(A) greater than the kinetic energy of proton (B) less than the kinetic energy of proton.

(C) equal to kinetic energy of proton (D) zero

(43) A body of mass 0.5 kg is moving with a velocity of 1000 ms$^{-1}$. The de-Broglie wavelength of the body is ...... .

(A) $3.32 \times 10^{-27}$ Å (B) $1.32 \times 10^{-26}$ Å (C) $1.6 \times 10^{-27}$ Å (D) $0.132 \times 10^{-26}$ Å

(44) A particle of mass 1 $\mu$g has the same de-Broglie wavelength as an electron moving with a velocity of $2 \times 10^{6}$ ms$^{-1}$. The velocity of the particle is ________.

(A) $1.82 \times 10^{-15}$ ms$^{-1}$ (B) $3.6 \times 10^{-16}$ ms$^{-1}$ (C) $3.6 \times 10^{-21}$ ms$^{-1}$ (D) $9 \times 10^{-2}$ ms$^{-1}$

(45) The velocity of an electron having a wavelength of 10 Å is ...... .

(A) $7.25 \times 10^{6}$ ms$^{-1}$ (B) $7.25 \times 10^{5}$ ms$^{-1}$ (C) $5.25 \times 10^{6}$ ms$^{-1}$ (D) $4.25 \times 10^{5}$ ms$^{-1}$

(46) Two charged particle of mass 2m and 3m have charged $3q$ and $2q$ respectively. Now both particles are accelerated through a same potential difference.Then the ratio of their de-Broglie wavelength is ...... .

(A) $2:3$ (B) $3:2$ (C) $1:\sqrt{6}$ (D) $1:1$

(47) De Broglie wavelength of a proton and $\alpha$ −particle is same. If proton is accelerated through a potential difference of V volt, then $\alpha$ −particle should be accelerated through a potential difference of ...... volt.

(A) 1 (B) 8 (C) 2 (D) $\frac{1}{8}$

(48) The frequency of a photon is $1.5 \times 10^{14}$ Hz. Its momentum will be ...... . $kgms^{-1}$ Plank's constant $h = 6.6\,10^{-34}$ Js, velocity of light $c = 3 \times 10^{8}\ ms^{-1}$.

(A) $3.3 \times 10^{-28}\ kgms^{-1}$ (B) $3.3 \times 10^{-34}\ kgms^{-1}$ (C) $3.3 \times 10^{-30}\ kgms^{-1}$ (D) $6.6 \times 10^{-28}\ kgms^{-1}$

(49) An electron of mass m when accelerated through a potential diference of V volt has de-Broglie wavelength $\lambda$. The de-Broglie wavelength associated with a proton of mass M accelerated through the potential difference of 4 V will be ....... .

(A) $\frac{\lambda}{2}\sqrt{\frac{M}{m}}$ (B) $\frac{\lambda}{2}\sqrt{\frac{m}{M}}$ (C) $\lambda\sqrt{\frac{m}{2M}}$ (D) $\frac{\lambda}{4}\sqrt{\frac{m}{M}}$

(50) A photon of wavelength 1.4 $\overset{\circ}{A}$ collides with an electron. After the collision the wavelength of proton becomes 2.0 $\overset{\circ}{A}$. Then the energy of scattered electron will be ...... . (take $h = 6.63 \times 10^{-34}$ Js)

(A) $4.6 \times 10^{-15}$ J (B) $4.6 \times 10^{-16}$ J (C) $3.2 \times 10^{-16}$ J (D) $2.3 \times 10^{-16}$ J

(51) To reduce de-Broglie wavelength of an electron from $3 \times 10^{-10}$ m to $1 \times 10^{-10}$ m, its energy should be ...... .

(A) increased to 9 times (B) increased to 3 times

(C) decreased to third part (D) decreased to nineth part

(52) The rest mass of an electron is $m_0$. It is moving with the velocity of 0.6 c, its mass m will be ...... . where c = velocity of light in vaccum.

(A) $m_0$ (B) $\frac{5m_0}{4}$ (C) $\frac{4m_0}{5}$ (D) $\frac{m_0}{6}$

(53) The potential diference through which an electron should be accelerated so its wavelength will become 0.5 $\overset{\circ}{A}$ ...... .

(A) 466 V (B) 747.0 V (C) 941.0 V (D) 602.0 V

(54) The chargless particle neutron has mass of $1.67 \times 10^{-27}$ kg and its kinetic energy is 0.04 eV, then calculate de-Broglie wavelength of neutron. $h = 6.62 \times 10^{-34}$ Js

(A) 1.80 $\overset{\circ}{A}$ (B) 1.43 $\overset{\circ}{A}$ (C) 2.86 $\overset{\circ}{A}$ (D) 3.2 $\overset{\circ}{A}$

(55) De Broglie wavelength associated with an electron moving with the velocity of $10^{5}\ ms^{-1}$ is ...... . $h = 6.6 \times 10^{-34}$ Js, mass of electron $m = 9 \times 10^{-31}$ kg

(A) 73.33 $\overset{\circ}{A}$ (B) 7.33 $\overset{\circ}{A}$ (C) 46.2 $\overset{\circ}{A}$ (D) 146.66 $\overset{\circ}{A}$

**Ans. : 32 (C), 33 (A), 34 (A), 35 (C), 36 (B), 37 (B), 38 (C), 39 (A), 40 (C), 41 (B), 42 (A), 43 (B), 44 (A), 45 (B), 46 (D), 47 (D), 48 (A), 49 (B), 50 (B), 51 (A), 52 (B), 53 (D), 54 (B), 55 (A)**

**Davission and Germer Experiment :**

This experiment proves the wave like nature of an electron.

In this experiment using Bragg's law, from the formula $2d\sin\theta = n\lambda$, the wavelength found to be 1.67 $\mathring{A}$. which is near to the de Broglie wavelength of electron ($\lambda = 1.65\ \mathring{A}$). Which shows wave like nature of electron.

**Heisenberg's Uncertainty principle :**

According to Heisenberg's uncertainty principle, If the uncertainty in the $x$- cordinate of the position is $\Delta x$ and uncertainty in the $x$- cordinate of its momentum is $\Delta p$, then

$$\Delta x\ \Delta p \geq \frac{h}{2\pi} \quad \text{(in one dimension)}$$

$$\therefore\ \Delta x\ \Delta p \geq \hbar \ \text{ where } \frac{h}{2\pi} = \hbar$$

Now, If $\Delta x \to 0$, then $\Delta p \to \infty$

and $\Delta p \to 0$ then, $\Delta x \to \infty$

Similarly, the uncertainty in the measurements of Energy and time for a particle using above principle,

$$\Delta E\ .\ \Delta t \geq \hbar$$

- If the radius of the nucleus is $r$ then uncertainty in the position of proton inside the nucleus is

$$\Delta x = 2r = d$$

Hence the uncertainty in momentum of proton is.

$$\Delta p = \frac{\hbar}{\Delta x} = \frac{\hbar}{d} = \frac{\hbar}{2r} = \frac{h}{4\pi r}$$

For a particle if the uncertainties in the measurement of angular momentum and angular displacement are $\Delta L$ and $\Delta\theta$ respectively.then from Heisenberg's uncertainty principle,

$$\Delta L\ .\ \Delta\theta \geq \hbar$$

---

(56) The correctness of velocity of an electron moving with velocity 50 $ms^{-1}$ is 0.005 % The accuracy with which its position can be measured will be ...... .

(A) $46 \times 10^{-3}$ m (B) $46 \times 10^{-4}$ m (C) $46 \times 10^{-5}$ m (D) $46 \times 10^{-6}$ m

(57) A proton and electron are lying in a box having unpenitrable walls, the uncertainty in their momenta will be ...... .

(A) For proton is more, as compared to electron (B) For electron is more, as compared to the proton

(C) same for both the particles (D) directly proportional to their masses

(58) The maximum uncertainty in the position of proton is $6 \times 10^{-8}$ m, then the minimum uncertainty in its velocity will be ...... .($h = 6.625 \times 10^{-34}$ Js, mass of proton = $1.67 \times 10^{-27}$ kg)

(A) $1\ mms^{-1}$ (B) $1\ ms^{-1}$ (C) $1\ cms^{-1}$ (D) $100\ ms^{-1}$

(59) If the uncertainty in the position of an electron is $10^{-10}$ m, then the value of uncertainly in its momentum (in $kg\ ms^{-1}$) will be

(A) $1.054 \times 10^{-24}$ (B) $1.112 \times 10^{-24}$ (C) $1.054 \times 10^{-22}$ (D) $1.112 \times 10^{-22}$

**Ans. : 56 (A), 57 (C), 58 (B), 59 (A)**

**Assertion - Reason type Question :**

**Instruction : Read assertion and reason carefully, select proper option from given below.**

(a) Both assertion and reason are true and reason explains the assertion.

(b) Both assertion and reason are true but reason does not explain the assertion.

(c) Assertion is true but reason is false.

(d) Assertion is false and reason is true.

---

(60) **Assertion :** The work function of a metal is 2 eV. To have photo emission from the surface of the metal, the maximum wavelength of incident photon is 6200 A°.

**Reason :** Work function, $\Phi = \frac{hc}{\lambda_{max}}$

(A) a (B) b (C) c (D) d

(61) **Assertion :** Light with frequency which is1.3 times the threshold frequency is incident on a photo sensitive surface. Now, the frequency of incident light is halved and the intensity is doubled, the photo electric current remains unchanged.

**Reason :** Photo electric current is directly proportional to the intensity of incident light.

(A) a (B) b (C) c (D) d

(62) **Assertion :** Proton is nearly heavier by 1840 times than an electron. A proton is accelerated through a potential difference of 1 kV, Its kinetic energy becomes 1 keV

**Reason :** Kinetic energy gained = (charge) × (potential difference)

(A) a (B) b (C) c (D) d

(63) **Assertion:** The kinetic energy of photoelectrons emitted from the photo sensitive surface depends on the frequency of the incident light.

**Reason :** Kinetic energy of emitted photoelectrons changes with the change in the frequency of incident light.

(A) a (B) b (C) c (D) d

(64) **Assertion :** On increasing the frequency of incident light, the number of emitted photons remains constant.

**Reason :** the number of emitted photo electrons does not depend on the frequency of incident light, but depends on the intensity.

(A) a (B) b (C) c (D) d

(65) **Assertion :** An electron and a proton are accelerated through same potential difference. The de Broglie wavelength associated with an electron is more than the de- Broglie wavelength associated with proton.

**Reason :** The de-Broglie wavelength associated with the charged particle accelerated through a potential difference of V volt is given by, $\lambda = \frac{h}{\sqrt{2mqV}} \propto \frac{1}{\sqrt{m}}$ (for equal value of $qV$ ).

(A) a (B) b (C) c (D) d

(66) **Assertion :** A radiation of monochromatic light (with enough high frequency) is incident on a metallic surface. The kinetic energy of emitted photoelectrons is lying between 0 to $K_{max}$.

**Reason :** The value of work function changed with the depth from the surface of metal.

(A) a (B) b (C) c (D) d

(67) **Assertion :** The de-Broglie wavelength associated with molecules is inversely proportional to the square root of the absolute temperature.

**Reason :** The value of $v_{rms}$ for moleaules depends on the absolute temperature.

(A) a (B) b (C) c (D) d

**Ans : 60 (A), 61 (D), 62 (A), 63 (A), 64 (A), 65 (A), 66 (C) 67 (A)**

**Comprehension Type Questions :**

**paragraph :**

The work function of ceisium metal is $2.14\ eV$. When radiation of frequency $6 \times 10^{14}\ H_z$ is made incident on it, then photoelectrons are emitted. Answer the following questions :

(68) Maximum kinetic energy of photoelectron ...... .

(A) $5.58 \times 10^{-20}$ J (B) $3.34 \times 10^{-19}$ (C) $5.58 \times 10^{-18}$ J (D) $3.34 \times 10^{-20}$ J

(69) The value of stopping potential ...... .

(A) 0.236 V (B) 0.349 V (C) 1.03 V (D) 0.87 V

(70) maximum speed of photo electrons ...... .

(A) $155 \times 10^3\ ms^{-1}$ (B) $224 \times 10^3\ ms^{-1}$ (C) $3.50 \times 10^5\ ms^{-1}$ (D) $276 \times 10^3\ ms^{-1}$

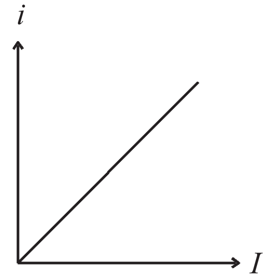
(71) The value of threshold wavelength ...... .

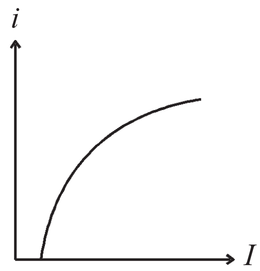
(A) 4647 $\mathring{A}$ (B) 3288 $\mathring{A}$ (C) 5789 $\mathring{A}$ (D) 6134 $\mathring{A}$

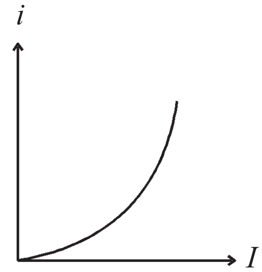
(72) The value of threshold frequency ...... .

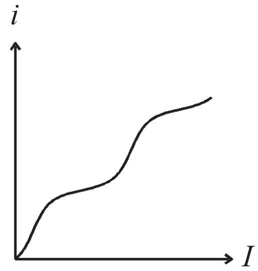
(A) $5.18 \times 10^{14}$ Hz (B) $4.44 \times 10^{14}$ Hz (C) $5.56 \times 10^{18}$ Hz (D) $4.89 \times 10^{14}$ Hz

(73) The variation of intensity $(I)$ of incident radiation with photo electric current $(i)$ can be shown by ...... .

(A) 


(B) 

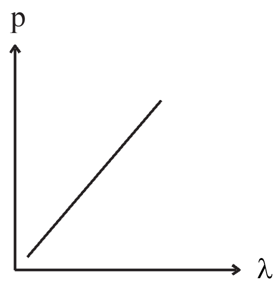

(C) 

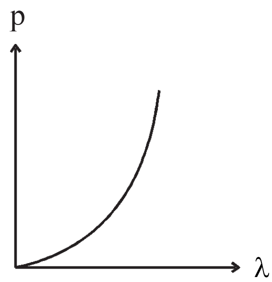

(D) 

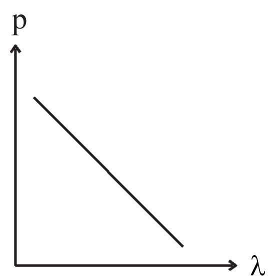

**Ans. : 68 (C), 69 (B), 70 (C), 71 (C), 72 (A), 73 (A)**

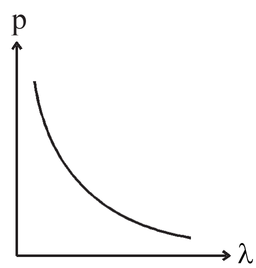
**Graphical questions :**

(74) Which of the following graph represents the variation of particle momentum and the associated de-Broglie wavelength

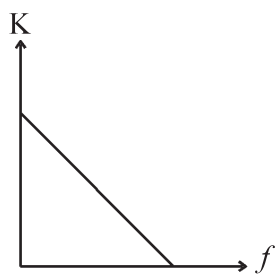
(A) 

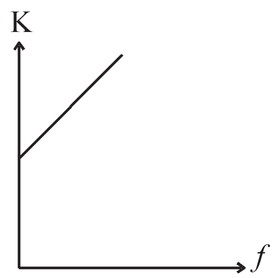

(B) 


(C) 

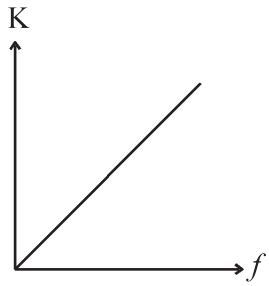

(D) 


(75) According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency light is

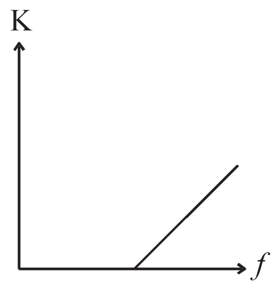
(A) 


(B) 

(C)

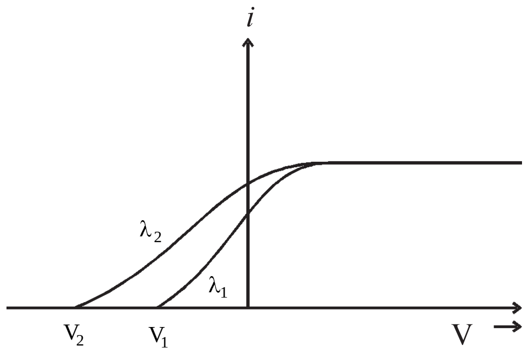



(D)




(76) In the graph shown below, $V_2 > V_1$ then ...... .

where $V =$ potential difference, $i \rightarrow$ photoelectric current

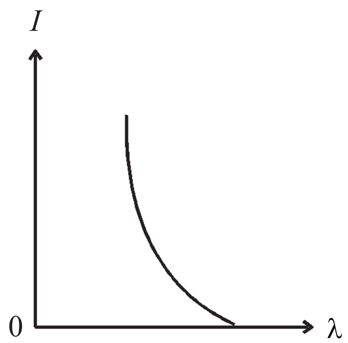



(A) $\lambda_1 = \sqrt{\lambda_2}$ (B) $\lambda_1 < \lambda_2$

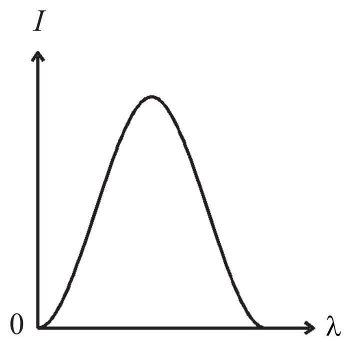
(C) $\lambda_1 = \lambda_2$ (D) $\lambda_1 > \lambda_2$

(77) The anode voltage of a photocell is kept fixed. The wavelength of the light falling on the cathode is gradually changed.The plate current ($I$) of the photocell varies as follows.

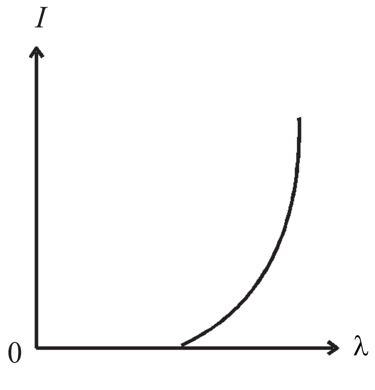
(A)



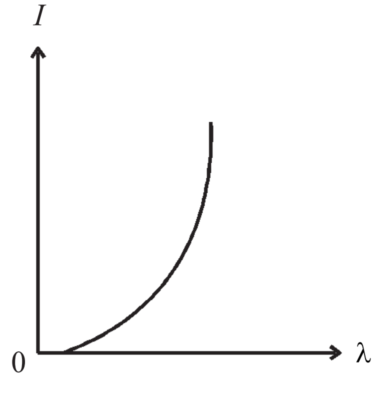

(B)




(C)




(D)




**Ans. : 74 (D), 75 (D), 76 (D) 77 (A)**

**Match the columns :**

(78) Methods for eomission of electron are shown in column-1 and in column-2 methods to obtain it are shown. Match the columns.

| column-1 | | column-2 | |
|---|---|---|---|
| (a) | Thermionic emission | (p) | By incidenting suitable light |
| (b) | photo electric emission | (q) | By heating (by passing current through filament) |
| (c) | Field emission | (r) | By colliding accelerated electron beam on the surface of the metal. |
| (d) | Secondary emission | (s) | By appying strong electric field. |

(A) $a \rightarrow q$ $b \rightarrow p$ $c \rightarrow s$ $d \rightarrow r$

(B) $a \rightarrow p$ $b \rightarrow q$ $c \rightarrow r$ $d \rightarrow s$

(C) $a \rightarrow r$ $b \rightarrow s$ $c \rightarrow p$ $d \rightarrow q$

(D) $a \rightarrow s$ $b \rightarrow r$ $c \rightarrow q$ $d \rightarrow p$

(79) In column-1 physical quantities related to photoelectric effect are shown. Join them with appropriate physical quantitces given in column-2.

| column-1 | | column-2 | |
|---|---|---|---|
| (a) | saturation current | (p) | Frequency of incident light |
| (b) | stopping potential | (q) | work function |
| (c) | de Broglie wavelength associated with photo electron | (r) | Area of photo sensitive surface |
| (d) | Force exerted on photo sensitive surface due to incident radiation. | (s) | Intensity of incident light (For constant frequency) |

(A) $a \rightarrow s$ $b \rightarrow p, q$ $c \rightarrow p, q$ $d \rightarrow p, r, s$

(B) $a \rightarrow r, p$ $b \rightarrow s, r$ $c \rightarrow r$ $d \rightarrow q$

(C) $a \rightarrow p$ $b \rightarrow r$ $c \rightarrow r, s$ $d \rightarrow s$

(D) $a \rightarrow s$ $b \rightarrow r$ $c \rightarrow q$ $d \rightarrow p$

**Ans. : 78 (A), 79 (A)**

●