

Dual Nature of Radiation

Question1

If we consider an electron and a photon of same de-Broglie wavelength, then they will have same

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Options:

- A. Angular momentum
- B. Energy
- C. Velocity
- D. Momentum

Answer: D

Solution:

They'll have the same momentum.

Reasoning (from de Broglie's relation):

$$\lambda = \frac{h}{p} \implies p = \frac{h}{\lambda}.$$

If an electron and a photon share the same λ , they share the same p .

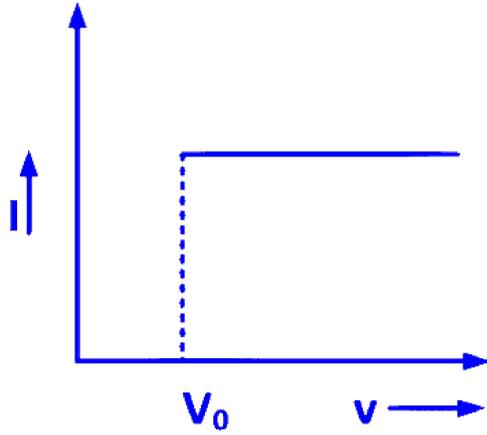
Question2

The anode voltage of a photocell is kept fixed. The frequency of the light falling on the cathode is gradually increased. Then the correct graph which shows the variation of photo current I with the frequency ν of incident light is

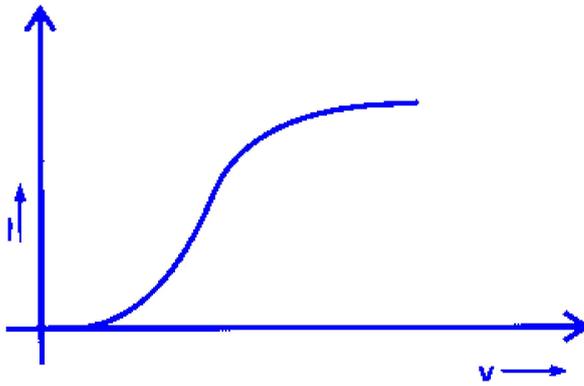
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Options:

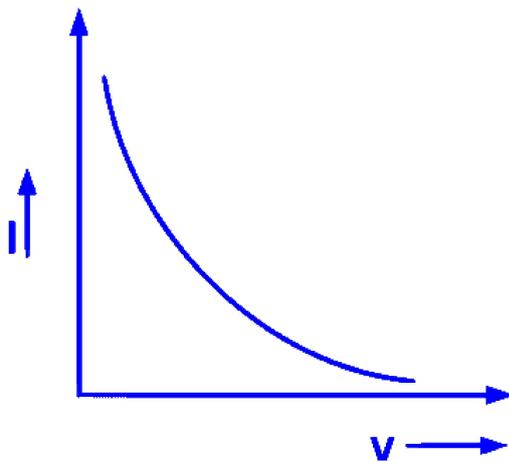
A.



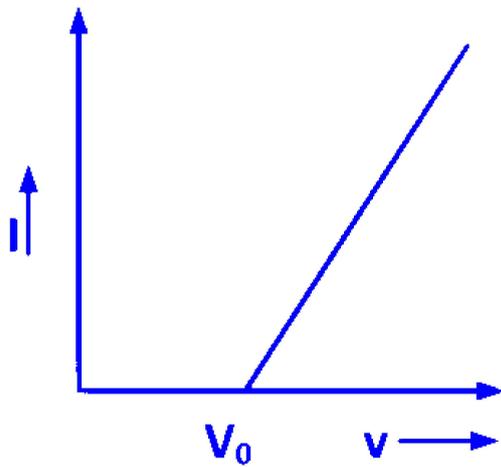
B.



C.

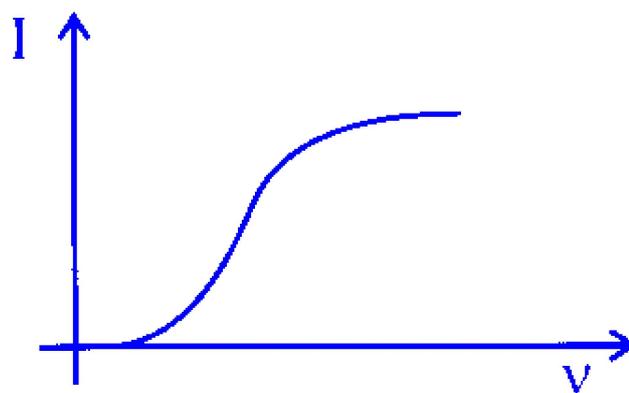


D.



Answer: A

Solution:



theoretical

Question3

Light of energy E falls normally on a metal of work function $\frac{E}{3}$. The kinetic energies K of the photo electrons are

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Options:

A. $K = \frac{2E}{3}$

B. $K = \frac{E}{3}$

C. $0 \leq K \leq \frac{2E}{3}$

D. $0 \leq K \leq \frac{E}{3}$

Answer: C

Solution:

Given, work function, $\phi_0 = E/3$

According to Einstein's photoelectric equation,

$$K_{\max} = E - \phi_0 = E - \frac{E}{3}$$
$$\Rightarrow K_{\max} = \frac{2E}{3}$$

\therefore Kinetic energy lies between 0 to $2E/3$



Question4

The photoelectric work function for photo metal is 2.4 eV . Among the four wavelengths, the wavelength of light for which photoemission does not take place is

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Options:

- A. 200 nm
- B. 300 nm
- C. 700 nm
- D. 400 nm

Answer: C

Solution:

Given, $\phi_0 = 24\text{eV}$

We know that, $\phi_0 = \frac{1240}{\lambda_0(\text{ in nm})}$

$$\Rightarrow \lambda_0(\text{ in nm}) = \frac{1240}{\phi_0} = \frac{1240}{24} = 516.6 \text{ nm}$$

\therefore For $\lambda = 700 \text{ nm}$, photoelectric emission does not take place.

Question5

A 60 W source emits monochromatic light of wavelength 662.5 nm. The number of photons emitted per second is



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Options:

A. 5×10^{17}

B. 2×10^{20}

C. 5×10^{26}

D. 2×10^{29}

Answer: B

Solution:

Given, $P = 60 \text{ W}$

$$\lambda = 662.5 \text{ nm} = 6.625 \times 10^{-7} \text{ m}$$

$$\text{Energy of 1 photon} = h\nu = h \frac{c}{\lambda}$$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{6.625 \times 10^{-7}} = 3 \times 10^{-19} \text{ J}$$

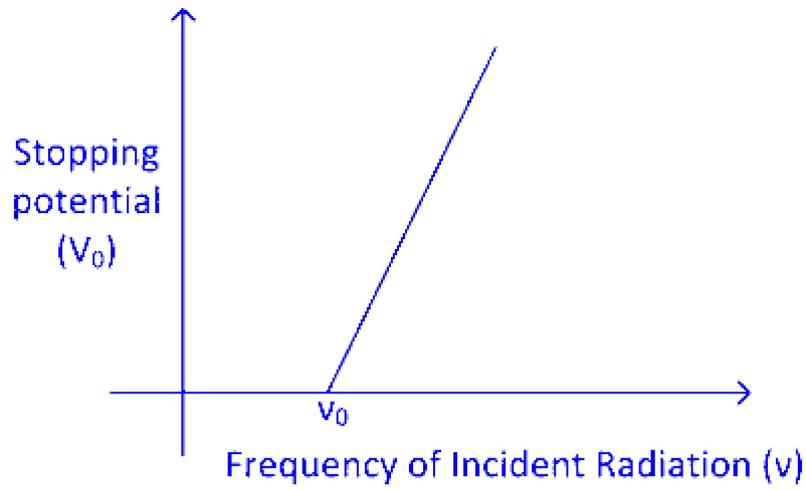
\therefore Number of photons emitted per second

$$\begin{aligned} &= \frac{\text{Power of source}}{\text{Energy of one photon}} \\ &= \frac{60}{3 \times 10^{-19}} \\ &= 20 \times 10^{19} \\ &= 2 \times 10^{20} \end{aligned}$$

Question6

In an experiment to study photoelectric effect the observed variation of stopping potential with frequency of incident radiation is as shown in the figure. The slope and y -intercept are respectively





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Options:

A. $\frac{h}{e}, -\frac{h\nu_0}{e}$

B. $\frac{h\nu}{e}, \nu_0$

C. $\frac{h\nu}{e}, -\frac{h}{e}$

D. $h\nu_1 - h\nu_0$

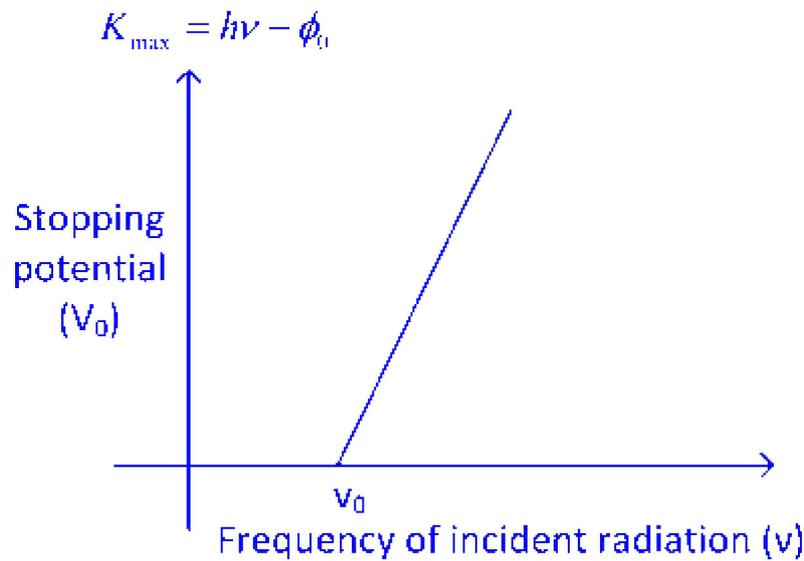
Answer: A

Solution:

The maximum kinetic energy of emitted photoelectrons is given as

$$K_{\max} = h\nu - \phi_0$$





$$\Rightarrow eV_0 = h\nu - \phi_0$$

$$\Rightarrow V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi_0}{e}$$

Comparing with $y = mx + c$, we get

$$m = \frac{h}{e} \text{ and } c = -\frac{\phi_0}{e} = -\frac{h\nu_0}{e}$$

$$\therefore \text{Slope} = m = \frac{h}{e}$$

$$\text{and } y\text{-intercept} = c = -\frac{h\nu_0}{e}$$

Question7

The energy gap of an LED is 2.4 eV. When the LED is switched ON, the momentum of the emitted photons is

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Options:

A. $1.28 \times 10^{-27} \text{ kg ms}^{-1}$

B. $2.56 \times 10^{-27} \text{ kg ms}^{-1}$

C. $1.28 \times 10^{-11} \text{ kg ms}^{-1}$

D. $0.64 \times 10^{-27} \text{ kg ms}^{-1}$

Answer: A

Solution:

To determine the momentum of the emitted photons from an LED with an energy gap of 2.4 eV, we need to use the relationship between energy and momentum for photons. The energy of a photon is given by:

$$E = pc$$

where:

- E is the energy of the photon
- p is the momentum of the photon
- c is the speed of light in a vacuum $\approx 3 \times 10^8$ m/s

First, let's convert the energy from electron volts (eV) to joules (J). The conversion factor is:

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

Thus, the energy in joules is:

$$E = 2.4 \text{ eV} \times 1.6 \times 10^{-19} \text{ J/eV} = 3.84 \times 10^{-19} \text{ J}$$

Now we can use the relationship $E = pc$ to find the momentum:

$$p = \frac{E}{c}$$

Substituting the known values:

$$p = \frac{3.84 \times 10^{-19} \text{ J}}{3 \times 10^8 \text{ m/s}} = 1.28 \times 10^{-27} \text{ kg m/s}$$

Therefore, the momentum of the emitted photons is:

Option A: $1.28 \times 10^{-27} \text{ kg ms}^{-1}$

Question8

The kinetic energy of the photoelectrons increases by 0.52 eV when the wavelength of incident light is changed from 500 nm to another wavelength which is approximately

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Options:

A. 400 nm

B. 1250 nm

C. 1000 nm

D. 700 nm

Answer: A

Solution:

Given, change in kinetic energy of photoelectrons,

$$\Delta K = 0.52 \text{ eV}$$

$$\lambda_1 = 500 \text{ nm}, \lambda_2 = ?$$

We know that, kinetic energy of emitted photoelectron (using Einstein's equation)

$$K = \frac{hc}{\lambda} - \phi$$

∴ At wavelength λ_1 ,

$$K_1 = \frac{hc}{\lambda_1} - \phi \dots \text{(i)}$$

At wavelength λ_2 ,

$$K_2 = \frac{hc}{\lambda_2} - \phi \dots \text{(ii)}$$

From Eqs. (i) and (ii), we have

$$\begin{aligned} K_2 - K_1 &= \frac{hc}{\lambda_2} - \frac{hc}{\lambda_1} \\ \Rightarrow \Delta K &= hc \left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1} \right) \\ \Rightarrow 0.52 &= 1242 \left(\frac{1}{\lambda_2} - \frac{1}{500} \right) \\ \Rightarrow \frac{0.52}{1242} &= \frac{1}{\lambda_2} - \frac{1}{500} \\ \Rightarrow \frac{1}{\lambda_2} &= \frac{0.52}{1242} + \frac{1}{500} \\ \Rightarrow \lambda_2 &\approx 400 \text{ nm} \end{aligned}$$

Question9

The de-Broglie wavelength of a particle of kinetic energy K is λ , the wavelength of the particle, if its kinetic energy $\frac{K}{4}$ is

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Options:

- A. 2λ
- B. $\frac{\lambda}{2}$
- C. 4λ
- D. λ

Answer: A

Solution:

de-Broglie wavelength (λ) of the particle in terms of kinetic energy K is given as

$$\lambda = \frac{h}{\sqrt{2mK}} \dots (i)$$

where, m is the mass of the particle and h is Planck's constant.

Let at wavelength λ' , kinetic energy of particle becomes $K' = \frac{K}{4}$

$$\begin{aligned} \text{i.e } \lambda' &= \frac{h}{\sqrt{2mK'}} = \frac{h}{\sqrt{2m \cdot \frac{K}{4}}} \\ &= \frac{h}{\frac{1}{2}\sqrt{2mK}} = 2 \frac{h}{\sqrt{2mK}} \\ \Rightarrow \lambda' &= 2\lambda \quad [\text{from Eq. (i)}] \end{aligned}$$

Question10

In a photo electric experiment, if both the intensity and frequency of the incident light are doubled, then the saturation photoelectric current

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Options:

- A. is halved
- B. is doubled



C. becomes four times

D. remains constant

Answer: B

Solution:

In photoelectric effect, saturation photocurrent is directly proportional to the intensity of incident radiation but independent of frequency of incident radiation. Hence, saturation current in photoelectric effect becomes double when both intensity and frequency of the incident light are doubled.

Question 11

The work-function of a metal is 1 eV. Light of wavelength $3000\overset{\circ}{\text{A}}$ is incident on this metal surface. The velocity of emitted photoelectrons will be

KCET 2021

Options:

A. 10 ms^{-1}

B. $1 \times 10^3 \text{ ms}^{-1}$

C. $1 \times 10^4 \text{ ms}^{-1}$

D. $1 \times 10^6 \text{ ms}^{-1}$

Answer: D

Solution:

Given, work-function, $\phi_0 = 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

Wavelength, $\lambda = 3000\overset{\circ}{\text{A}} = 3000 \times 10^{-10} \text{ m}$

As, we know that,



$$E = hv = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3000 \times 10^{-10}}$$

$$= 6.6 \times 10^{-19} \text{ J}$$

Also, $E = \phi_0 + \text{KE}$

$$\Rightarrow \text{KE} = E - \phi_0 \Rightarrow \frac{1}{2}mv^2 = E - \phi_0$$

$$v^2 = \frac{(6.6 \times 10^{-19} - 1.6 \times 10^{-19}) \times 2}{9.1 \times 10^{-31}}$$

$$= \frac{5 \times 10^{-19} \times 2}{9.1 \times 10^{-31}} = 1.1 \times 10^{12}$$

$$v = 1.01 \times 10^6$$

$$\approx 1 \times 10^6 \text{ m/s}$$

Question12

A proton moving with a momentum p_1 has a kinetic energy 1/8th of its rest mass-energy. Another light photon having energy equal to the kinetic energy of the possesses a momentum p_2 . Then, the ratio $\frac{p_1 - p_2}{p_1}$ is equal to

KCET 2021

Options:

- A. 1
- B. 1/4
- C. 1/2
- D. 3/4

Answer: D

Solution:

For proton, $v^2 = \frac{c^2}{4}$ ($\because v = \frac{c}{2}$)



$$p_1 = \sqrt{2mE_k}$$

$$= \sqrt{2 \times m \times \frac{1}{8}mc^2} \quad \left(\because E_k = \frac{1}{8}mc^2 \right)$$

$$p_1 = \frac{mc}{2}$$

For photon,

$$E = \text{KE}$$

$$\frac{hc}{\lambda} = \frac{1}{8}mc^2$$

$$\Rightarrow p_2 = \frac{h}{\lambda} = \frac{mc}{8}$$

$$\therefore \frac{p_1 - p_2}{p_1} = \frac{\frac{mc}{2} - \frac{mc}{8}}{\frac{mc}{2}} = \frac{4 - 1}{8} \times 2 = \frac{3}{4}$$

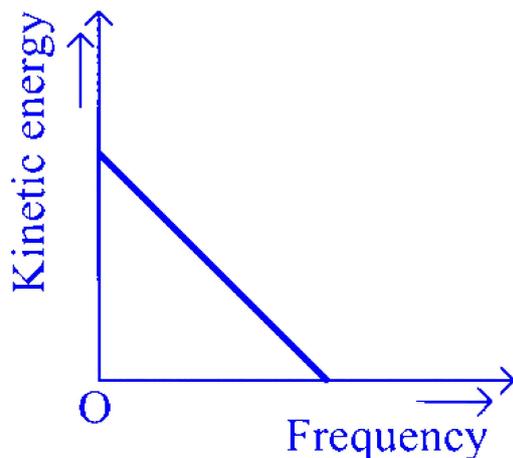
Question13

According to Einstein's photoelectric equation to the graph between kinetic energy of photoelectrons ejected and the frequency of incident radiation is

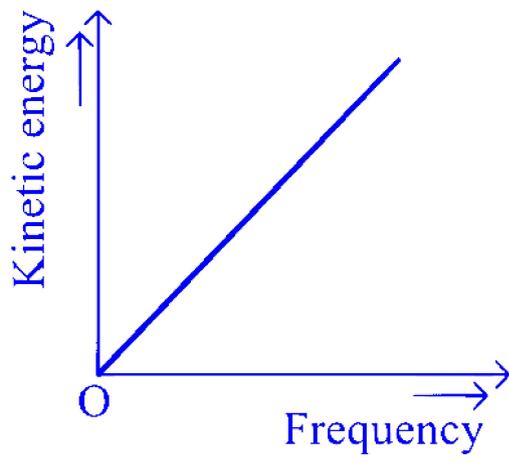
KCET 2021

Options:

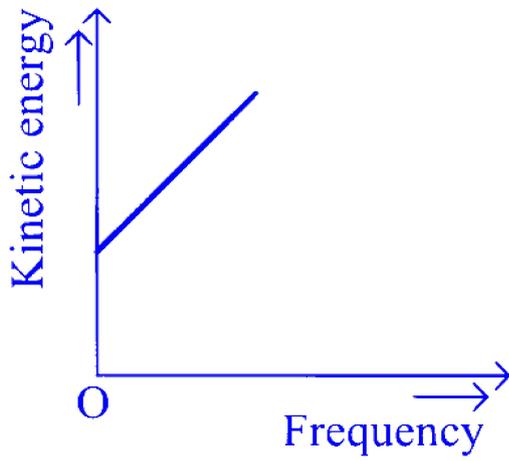
A.



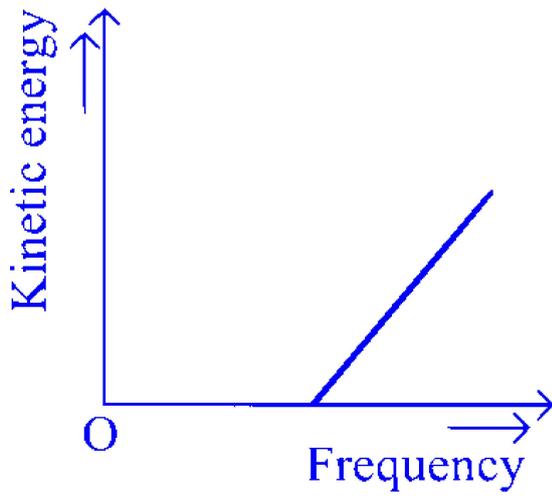
B.



C.



D.



Answer: D

Solution:

The maximum kinetic energy of photoelectron ejected is given by

$$KE = hv - \phi_0 = hv - hv_0 = h(v - v_0)$$

If the frequency of incident radiation is greater than threshold frequency v_0 , then the ejection of photoelectrons starts. After that as frequency increases, kinetic energy also increases linearly. It is shown in option (d).

Question14

A hot filament liberates an electron with zero initial velocity. The anode potential is 1200 V. The speed of the electron when it strikes the anode is

KCET 2020

Options:

A. $1.5 \times 10^5 \text{ ms}^{-1}$

B. $2.5 \times 10^6 \text{ ms}^{-1}$

C. $2.1 \times 10^7 \text{ ms}^{-1}$

D. $2.5 \times 10^8 \text{ ms}^{-1}$

Answer: C



Solution:

Given, anode potential, $V = 1200 \text{ V}$

Electron will accelerate with the effect of anode potential.

Hence, $\frac{1}{2}mv^2 = eV$

$$\begin{aligned}v &= \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 1200}{9.1 \times 10^{-31}}} \\&= \sqrt{421.98 \times 10^{12}} = 20.5 \times 10^6 \text{ ms}^{-1} \\&= 2.05 \times 10^7 \text{ ms}^{-1} \simeq 2.1 \times 10^7 \text{ ms}^{-1}\end{aligned}$$

Question15

The de-Broglie wavelength associated with electron of hydrogen atom in this ground state is

KCET 2020

Options:

A. 0.3 \AA

B. 3.3 \AA

C. 6.26 \AA

D. 10 \AA

Answer: B

Solution:



The angular momentum of electron in an orbit of radius r is,

$$mvr = \frac{nh}{2\pi}$$

So, momentum in ground state,

$$p = mv = \frac{h}{2\pi r} \quad \dots (i)$$

The de-Broglie wavelength associated with an electron is

$$\lambda = \frac{h}{mv} = \frac{h}{p} = 2\pi r \quad [\text{from Eq. (i)}]$$

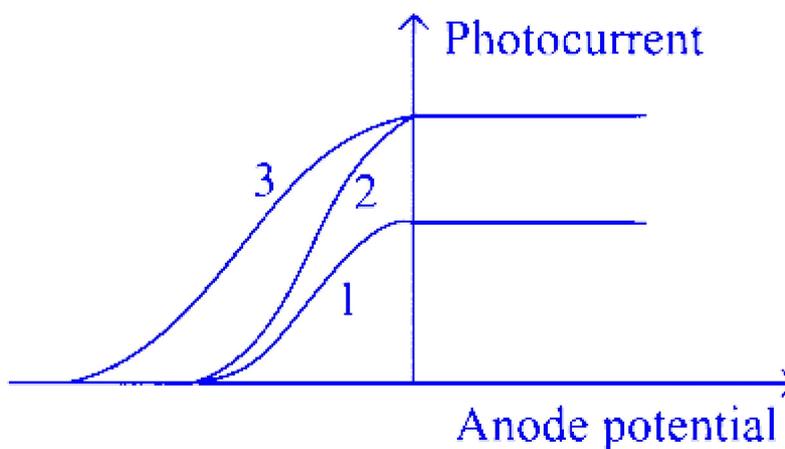
As we know, in ground state of hydrogen atom,

$$r = 0.53\text{\AA}$$

$$\Rightarrow \lambda = 2\pi \times 0.53\text{\AA} = 3.3\text{\AA}$$

Question16

The following graph represents the variation of photocurrent with anode potential for a metal surface. Here I_1 , I_2 and I_3 represents intensities and γ_1 , γ_2 , γ_3 represent frequency for curves 1, 2 and 3 respectively, then



KCET 2020

Options:

A. $\gamma_1 = \gamma_2$ and $I_1 \neq I_2$

B. $\gamma_1 = \gamma_3$ and $I_1 \neq I_3$



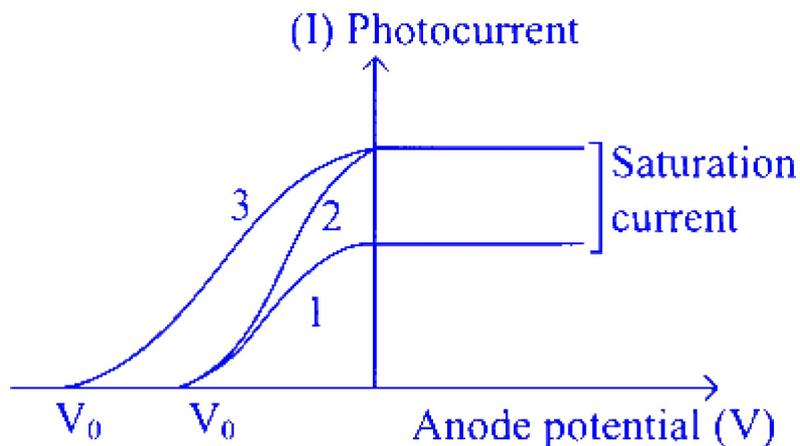
C. $\gamma_1 = \gamma_2$ and $I_1 = I_2$

D. $\gamma_2 = \gamma_3$ and $I_1 = I_3$

Answer: A

Solution:

The given figure can be shown as



From figure, we can see that the stopping potential (V_0) is same for curve 1 and 2. But for curve 3, it is greater than that for land 2.

As, we know that, $eV_0 = E_{\max} = h\gamma - \phi_0$ where, ϕ_0 is the work function.

Since, V_0 is same for 1 and 2, so from above equation, we have $r_1 = r_2$

Thus, for 1, 2 and 3

$$\gamma_1 = \gamma_2 \neq \gamma_3$$

Also, the saturation current of curve 2 is greater than of curve 1. But for curve 2 and 3 it is equal, so,

$$I_1 \neq I_2 = I_3$$

Question17

An electron is moving with an initial velocity $\mathbf{v} = v_0 \hat{i}$ and is in a uniform magnetic field $\mathbf{B} = B_0 \hat{j}$. Then its de-Broglie wavelength

KCET 2019

Options:

- A. remains constant
- B. increases with time
- C. decrease with time
- D. increase and decrease periodically

Answer: A

Solution:

Initial velocity of electron $\mathbf{v} = v_0 \hat{\mathbf{i}}$

Magnetic field, $\mathbf{B} = B_0 \hat{\mathbf{j}}$, when electron is moving in perpendicular direction of magnetic field, than it moves on circular path, and radius r of circular path is given by $r = \frac{mv_0}{B_0 e}$

$$\Rightarrow r = \frac{p}{B_0 e}$$

Where, $p =$ momentum. $p = r B_0 e$

\therefore de-Broglie wavelength associated with electron is

$$\lambda = \frac{h}{p} = \frac{h}{r B_0 e}$$

Since, h and e are constant and r is also constant for constant B_0 . Hence, de-Broglie wavelength associated with electron remains constant.

Question18

Light of certain frequency and intensity incident on a photosensitive material causes photoelectric effect. If both the frequency and intensity are doubled, the photoelectric saturation current becomes

KCET 2019

Options:

- A. quadruple
- B. doubled
- C. halved



D. unchanged

Answer: B

Solution:

Photoelectric saturation current i does not depend on frequency of incident radiation but it is directly proportional to the intensity I of incident radiation.

i.e. $i \propto I$

i.e. $\frac{i_1}{i_2} = \frac{I_1}{I_2}$

when, $I_2 = 2I_1$

then, $\frac{i_1}{i_2} = \frac{I_1}{2I_1} \Rightarrow i_2 = 2i_1$

Question19

The number of photons falling per second on a completely darkened plate to produce a force of 6.62×10^{-5} N is n . If the wavelength of the light falling is 5×10^{-7} m, then $n = \dots \times 10^{22}$. (Take, $h = 6.62 \times 10^{-34}$ J – s)

KCET 2018

Options:

A. 1

B. 5

C. 0.2

D. 3.3

Answer: B

Solution:

We can determine the number of photons striking the plate per second by equating the force (which is the rate of momentum transfer) to the product of the number of photons per second and the momentum lost by each photon.

Here's a step-by-step explanation:

Each photon of wavelength λ has an energy:

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

where

$$h = 6.62 \times 10^{-34} \text{ J}\cdot\text{s (Planck's constant),}$$

$$c \approx 3 \times 10^8 \text{ m/s (speed of light).}$$

The momentum of a photon is given by:

$$p = \frac{E}{c} = \frac{hc}{\lambda c} = \frac{h}{\lambda}.$$

For a completely dark (absorbing) plate, the photon transfers all its momentum upon absorption, so the momentum transfer per photon is $\frac{h}{\lambda}$.

If n photons hit the plate per second, the total momentum transferred per second (which is the force F) is:

$$F = n \times \frac{h}{\lambda}.$$

Solving for n , we have:

$$n = \frac{F\lambda}{h}.$$

Now, plugging in the values:

$$F = 6.62 \times 10^{-5} \text{ N,}$$

$$\lambda = 5 \times 10^{-7} \text{ m,}$$

$$h = 6.62 \times 10^{-34} \text{ J}\cdot\text{s,}$$

we get:

$$n = \frac{(6.62 \times 10^{-5}) \times (5 \times 10^{-7})}{6.62 \times 10^{-34}}.$$

Notice that the 6.62 in the numerator and denominator cancel:

$$n = \frac{5 \times 10^{-5-7}}{10^{-34}} = \frac{5 \times 10^{-12}}{10^{-34}}.$$

Dividing the exponents:

$$n = 5 \times 10^{-12+34} = 5 \times 10^{22}.$$

Therefore, the number of photons per second n is 5×10^{22} .

This corresponds to Option B.

Question20

The maximum kinetic energy of emitted photoelectrons depends on

KCET 2018



Options:

- A. intensity of incident radiation
- B. frequency of incident radiation
- C. speed of incident radiation
- D. number of photons in the incident radiation

Answer: B

Solution:

The maximum kinetic energy of emitted photoelectrons can be understood using the formula:

$$KE = \frac{1}{2}mv_{\max}^2 = h(v - v_0)$$

This can also be expressed as:

$$KE_{\max} = hv - hv_0$$

From this equation, it is clear that the maximum kinetic energy of the photoelectrons (KE_{\max}) depends on the frequency of the incident radiation. Here, h is Planck's constant, v is the frequency of the incident light, and v_0 is the threshold frequency. Therefore, the maximum kinetic energy is directly influenced by the frequency v of the incoming radiation.

Question21

A proton and an α -particle are accelerated through the same potential difference V . The ratio of their de-Broglie wavelength is

KCET 2018

Options:

- A. $\sqrt{2}$
- B. $2\sqrt{2}$
- C. $\sqrt{3}$
- D. $2\sqrt{3}$

Answer: B



Solution:

Let's work through the problem step by step.

When a charged particle is accelerated through a potential difference V , it gains kinetic energy equal to its charge times the potential difference:

$$K = qV.$$

The momentum of a non-relativistic particle with mass m and kinetic energy K is given by:

$$p = \sqrt{2mK}.$$

The de Broglie wavelength is:

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

where h is Planck's constant.

Now, let's apply these to both the proton and the α -particle.

• For a proton:

Charge: $q_p = e$.

Mass: $m_p = m$.

Kinetic energy: $K_p = eV$.

Momentum:

$$p_p = \sqrt{2m_p K_p} = \sqrt{2meV}.$$

de Broglie wavelength:

$$\lambda_p = \frac{h}{\sqrt{2meV}}.$$

• For an α -particle:

Charge: $q_\alpha = 2e$ (the α -particle has two protons).

Mass: $m_\alpha = 4m$ (approximately four times the mass of a proton).

Kinetic energy: $K_\alpha = 2eV$.

Momentum:

$$p_\alpha = \sqrt{2m_\alpha K_\alpha} = \sqrt{2(4m)(2eV)} = \sqrt{16meV} = 4\sqrt{meV}.$$

de Broglie wavelength:

$$\lambda_\alpha = \frac{h}{4\sqrt{meV}}.$$

Now, let's find the ratio of their de Broglie wavelengths:

$$\frac{\lambda_p}{\lambda_\alpha} = \frac{\frac{h}{\sqrt{2meV}}}{\frac{h}{4\sqrt{meV}}} = \frac{4\sqrt{meV}}{\sqrt{2meV}}$$

Notice that \sqrt{meV} cancels out, leaving:

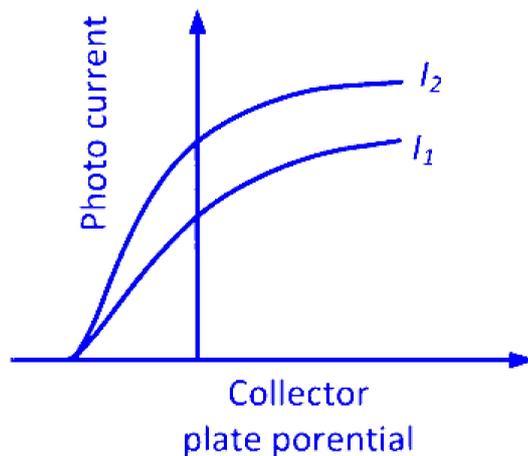
$$\frac{\lambda_p}{\lambda_\alpha} = \frac{4}{\sqrt{2}} = 2\sqrt{2}.$$

Thus, the ratio of the proton's de Broglie wavelength to that of the α -particle is $2\sqrt{2}$.

The correct option is: Option B $2\sqrt{2}$.

Question22

From the following graph of photo current against collector plate potential, for two different intensities of light I_1 and I_2 , one can conclude



KCET 2017

Options:

A. $I_1 = I_2$

B. $I_1 > I_2$

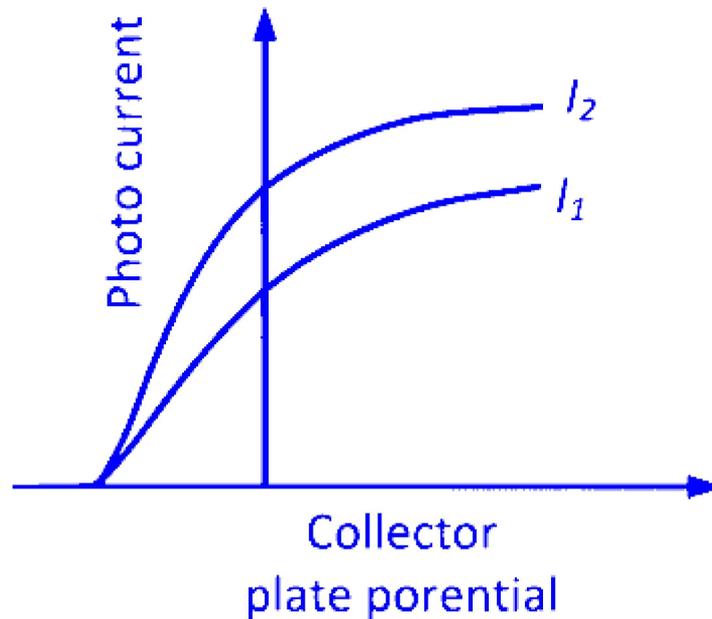
C. $I_1 < I_2$

D. Comparison is not possible

Answer: C

Solution:

The value of photo current depends on the intensity of incident light. Hence, when the intensity of incident light increases, then the value of photo current is increases. i.e. intensity of light (I) \propto photo current



From graph
 $I_1 < I_2$

Question23

A particle is dropped from a height H . The de-Broglie wavelength of the particle depends on height as

KCET 2017

Options:

A. $H^{-1/2}$

B. H°

C. $H^{1/2}$

D. H

Answer: A

Solution:

The de-Broglie wavelength λ of a particle is given by the formula:

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

Where:

h is the Planck's constant,

m is the mass of the particle,

v is the velocity of the particle.

When a particle is dropped from a height H , it accelerates due to gravity, and its velocity v becomes:

$$v = \sqrt{2gH}$$

Substituting this expression for velocity into the de-Broglie wavelength formula, we get:

$$\lambda = \frac{h}{m\sqrt{2gH}}$$

This shows that the de-Broglie wavelength λ is proportional to $H^{-1/2}$, meaning that as the height H increases, the wavelength decreases according to this relationship:

$$\lambda \propto H^{-1/2}$$

