



Dual Nature of Radiation and Matter

Numerical

Q.1 The K_{α} X-ray of molybdenum has wavelength 0.071 nm. If the energy of a molybdenum atoms with a K electron knocked out is 27.5 keV, the energy of this atom when an L electron is knocked out will be _____ keV. (Round off to the nearest integer)

$$[h = 4.14 \times 10^{-15} \text{ eVs}, c = 3 \times 10^8 \text{ ms}^{-1}]$$

27th July Evening Shift 2021

Q.2 A transistor is connected in common emitter circuit configuration, the collector supply voltage is 10 V and the voltage drop across a resistor of 1000Ω in the collector circuit is 0.6 V. If the current gain factor (β) is 24, then the base current is _____ μA . (Round off to the Nearest Integer)

27th July Morning Shift 2021

Q.3 A radioactive sample has an average life of 30 ms and is decaying. A capacitor of capacitance $200 \mu\text{F}$ is first charged and later connected with resistor 'R'. If the ratio of charge on capacitor to the activity of radioactive sample is fixed with respect to time then the value of 'R' should be _____ Ω .

27th July Morning Shift 2021

Q.4 A light beam of wavelength 500 nm is incident on a metal having work function of 1.25 eV, placed in a magnetic field of intensity B. The electrons emitted perpendicular to the magnetic

field B, with maximum kinetic energy are bent into circular arc of radius 30 cm. The value of B is _____ $\times 10^{-7}$ T.

Given $hc = 20 \times 10^{-26}$ J-m, mass of electron = 9×10^{-31} kg

25th July Evening Shift 2021

Q.5 A certain metallic surface is illuminated by monochromatic radiation of wavelength λ . The stopping potential for photoelectric current for this radiation is $3V_0$. If the same surface is illuminated with a radiation of wavelength 2λ , the stopping potential is V_0 . The threshold wavelength of this surface for photoelectric effect is _____ λ .

20th July Evening Shift 2021

Q.6 If 2.5×10^{-6} N average force is exerted by a light wave on a non-reflecting surface of 30 cm^2 area during 40 minutes of time span, the energy flux of light just before it falls on the surface is _____ W/cm^2 . (Round off to the Nearest Integer)

(Assume complete absorption and normal incidence conditions are there)

17th Mar Morning Shift 2021

Q.7 Two stream of photons, possessing energies equal to twice and ten times the work function of metal are incident on the metal surface successively. The value of ratio of maximum velocities of the photoelectrons emitted in the two respective cases is $x : y$. The value of x is _____.

26th Feb Evening Shift 2021

Numerical Answer Key

1. Ans. (10)
2. Ans. (25)
3. Ans. (150)
4. Ans. (125)
5. Ans. (4)
6. Ans. (150)
7. Ans. (1)

Numerical Explanation

Ans 1.

$$E_{k_{\alpha}} = E_k - E_L$$

$$\frac{hc}{\lambda_{k_{\alpha}}} = E_k - E_L$$

$$E_L = E_k - \frac{hc}{\lambda_{k_{\alpha}}}$$

$$= 27.5 \text{ KeV} - \frac{12.42 \times 10^{-7} \text{ eVm}}{0.071 \times 10^{-9} \text{ m}}$$

$$E_L = (27.5 - 17.5) \text{ keV}$$

$$= 10 \text{ keV}$$

Ans 2.

$$\beta = \frac{I_C}{I_B} = 24;$$

$$R_C = 1000$$

$$\Delta V = 0.6$$

$$I_C = \frac{0.6}{1000}$$

$$I_C = 6 \times 10^{-4}$$

$$I_B = \frac{I_C}{\beta} = \frac{6 \times 10^{-4}}{24} = 25 \mu A$$

Ans 3.

$$T_m = 30 \text{ ms}$$

$$C = 200 \mu F$$

$$\frac{q}{N} = \frac{Q_0 e^{-t/RC}}{N_0 e^{-\lambda t}} = \frac{Q_0}{N_0} e^{t\left(\lambda - \frac{1}{RC}\right)}$$

Since q/N is constant hence

$$\lambda = \frac{1}{RC}$$

$$R = \frac{1}{\lambda C} = \frac{T_m}{C} = \frac{30 \times 10^{-3}}{200 \times 10^{-6}} = 150 \Omega$$

Ans 4. By photoelectric equation

$$\frac{hc}{\lambda} - \phi = k_{\max}$$

$$k_{\max} = \frac{1240}{500} - 1.25 \approx 1.25$$

$$r = \frac{\sqrt{2mk}}{eB}$$

$$B = \frac{\sqrt{2mk}}{er}$$

$$= 125 \times 10^{-7} T$$

Ans 5.

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

$$e(3V_0) = \frac{hc}{\lambda} - \phi \dots (i)$$

$$eV_0 = \frac{hc}{2\lambda} - \phi \dots (ii)$$

Using (i) & (ii)

$$\phi = \frac{hc}{4\lambda_0} = \frac{hc}{\lambda_t}$$

$$\lambda_t = 4\lambda_0$$

Ans 6.

$$\text{Pressure} = \frac{\text{Intensity}}{C} \text{ (for absorbing surface)}$$

$$I = P \times C$$

$$I = \frac{2.5 \times 10^{-6}}{30 \text{ cm}^2} \text{ N} \times 3 \times 10^8 \text{ m/s}$$

$$I = 25 \text{ W/cm}^2$$

Ans 7.

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

$$\frac{1}{2}mv^2 = hv - \phi$$

$$v = \sqrt{\frac{2(hv - \phi)}{m}}$$

$$\text{Given } hv_1 = 2\phi$$

$$hv_2 = 10\phi$$

$$\therefore \frac{v_1}{v_2} = \sqrt{\frac{hv_1 - \phi}{hv_2 - \phi}}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{2\phi - \phi}{10\phi - \phi}} = \frac{1}{3} = \frac{x}{y}$$

$$\therefore x = 1$$

MCQ (Single Correct Answer)

Q.1 The half life period of radioactive element x is same as the mean life time of another radioactive element y. Initially they have the same number of atoms. Then :

- ☐ A x-will decay faster than y.
- ☐ B y-will decay faster than x.
- ☐ C x and y have same decay rate initially and later on different decay rate.
- ☐ D x and y decay at the same rate always.

1st Sep Evening Shift 2021

Q.2 The temperature of an ideal gas in 3-dimensions is 300 K. The corresponding de-Broglie wavelength of the electron approximately at 300 K, is :

[m_e = mass of electron = 9×10^{-31} kg, h = Planck constant = $6.6 \times 6.6 \times 10^{-34}$ Js, k_B = Boltzmann constant = 1.38×10^{-23} JK $^{-1}$]

A 6.26 nm

B 8.46 nm

C 2.26 nm

D 3.25 nm

1st Sep Evening Shift 2021

Q.3 Consider two separate ideal gases of electrons and protons having same number of particles. The temperature of both the gases are same. The ratio of the uncertainty in determining the position of an electron to that of a proton is proportional to :-

A $\left(\frac{m_p}{m_e}\right)^{3/2}$

B $\sqrt{\frac{m_e}{m_p}}$

C $\sqrt{\frac{m_p}{m_e}}$

D $\frac{m_p}{m_e}$

31st Aug Evening Shift 2021

Q.4 A free electron of 2.6 eV energy collides with a H^+ ion. This results in the formation of a hydrogen atom in the first excited state and a photon is released. Find the frequency of the emitted photon. ($h = 6.6 \times 10^{-34}$ Js)

A 1.45×10^{16} MHz

B 0.19×10^{15} MHz

C 1.45×10^9 MHz

D 9.0×10^{27} MHz

31st Aug Evening Shift 2021

Q.5 A monochromatic neon lamp with wavelength of 670.5 nm illuminates a photo-sensitive material which has a stopping voltage of 0.48 V. What will be the stopping voltage if the source light is changed with another source of wavelength of 474.6 nm?

A 0.96 V

B 1.25 V

C 0.24 V

D 1.5 V

27th Aug Evening Shift 2021

Q.6 In a photoelectric experiment, increasing the intensity of incident light :

A increases the number of photons incident and also increases the K.E. of the ejected electrons

B increases the frequency of photons incident and increases the K.E. of the ejected electrons

C increases the frequency of photons incident and the K.E. of the ejected electrons remains unchanged

D increases the number of photons incident and the K.E. of the ejected electrons remains unchanged

27th Aug Morning Shift 2021

Q.7 The de-Broglie wavelength of a particle having kinetic energy E is λ . How much extra energy must be given to this particle so that the de-Broglie wavelength reduces to 75% of the initial value?

A $\frac{1}{9}E$

B $\frac{7}{9}E$

C E

D $\frac{16}{9}E$

26th Aug Evening Shift 2021

Q.8 In a photoelectric experiment ultraviolet light of wavelength 280 nm is used with lithium cathode having work function $\phi = 2.5$ eV. If the wavelength of incident light is switched to 400 nm, find out the change in the stopping potential.

($h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8$ ms $^{-1}$)

A 1.3 V

B 1.1 V

C 1.9 V

D 0.6 V

26th Aug Morning Shift 2021

Q.9 If ' f ' denotes the ratio of the number of nuclei decayed (N_d) to the number of nuclei at $t = 0$ (N_0) then for a collection of radioactive nuclei, the rate of change of ' f ' with respect to time is given as :

[λ is the radioactive decay constant]

☐ A $-\lambda (1 - e^{-\lambda t})$

☐ B $\lambda (1 - e^{-\lambda t})$

☐ C $\lambda e^{-\lambda t}$

☐ D $-\lambda e^{-\lambda t}$

27th July Morning Shift 2021

Q.10 When radiation of wavelength λ is incident on a metallic surface, the stopping potential of ejected photoelectrons is 4.8 V. If the same surface is illuminated by radiation of double the previous wavelength, then the stopping potential becomes 1.6 V. The threshold wavelength of the metal is :

☐ A 2λ

☐ B 4λ

☐ C 8λ

☐ D 6λ

25th July Evening Shift 2021

Q.11

The half-life of ^{198}Au is 3 days. If atomic weight of ^{198}Au is 198 g/mol then the activity of 2 mg of ^{198}Au is [in disintegration/second] :

A 2.67×10^{12}

B 6.06×10^{18}

C 32.36×10^{12}

D 16.18×10^{12}

25th July Morning Shift 2021

Q.12 Some nuclei of a radioactive material are undergoing radioactive decay. The time gap between the instances when a quarter of the nuclei have decayed and when half of the nuclei have decayed is given as:

(where λ is the decay constant)

A $\frac{1}{2} \frac{\ln 2}{\lambda}$

B $\frac{\ln 2}{\lambda}$

C $\frac{2 \ln 2}{\lambda}$

D $\frac{\ln \frac{3}{2}}{\lambda}$

25th July Morning Shift 2021

Q.13 An electron having de-Broglie wavelength λ is incident on a target in a X-ray tube. Cut-off wavelength of emitted X-ray is :

A 0

B $\frac{2m^2c^2\lambda^2}{h^2}$

C $\frac{2mc\lambda^2}{h}$

D $\frac{hc}{mc}$

20th July Evening Shift 2021

Q.14 The radiation corresponding to $3 \rightarrow 2$ transition of a hydrogen atom falls on a gold surface to generate photoelectrons. The electrons are passed through a magnetic field of 5×10^{-4} T. Assume that the radius of the largest circular path followed by these electrons is 7 mm, the work function of the metal is: (Mass of electron = 9.1×10^{-31} kg)

20th July Morning Shift 2021

Q.15 Two identical photocathodes receive the light of frequencies f_1 and f_2 respectively. If the velocities of the photo-electrons coming out are v_1 and v_2 respectively, then

A $v_1 - v_2 = \left[\frac{2h}{m} (f_1 - f_2) \right]^{\frac{1}{2}}$

B $v_1^2 + v_2^2 = \frac{2h}{m} [f_1 + f_2]$

C $v_1 + v_2 = \left[\frac{2h}{m} (f_1 + f_2) \right]^{\frac{1}{2}}$

D $v_1^2 - v_2^2 = \frac{2h}{m} [f_1 - f_2]$

17th Mar Evening Shift 2021

Q.16 The stopping potential in the context of photoelectric effect depends on the following property of incident electromagnetic radiation :

A Phase

B Frequency

C Amplitude

D Intensity

16th Mar Morning Shift 2021

Q.17 The recoil speed of a hydrogen atom after it emits a photon in going from $n = 5$ state to $n = 1$ state will be :

A 4.34 m/s

B 2.19 m/s

C 3.25 m/s

D 4.17 m/s

26th Feb Evening Shift 2021

Q.18 Given below are two statements: one is labeled as Assertion A and the other is labelled as Reason R.

Assertion A: An electron microscope can achieve better resolving power than an optical microscope.

Reason R: The de Broglie's wavelength of the electrons emitted from an electron gun is much less than wavelength of visible light.

In the light of the above statements, choose the correct answer from the options given below:

A A is false but R is true.

B Both A and R are true but R is NOT the correct explanation of A.

C Both A and R are true and R is the correct explanation of A.

D A is true but R is false.

26th Feb Morning Shift 2021

Q.19 The stopping potential for electrons emitted from a photosensitive surface illuminated by light of wavelength 491 nm is 0.710 V. When the incident wavelength is changed to a new value, the stopping potential is 1.43 V. The new wavelength is :

A 400 nm

B 329 nm

C 309 nm

D 382 nm

25th Feb Morning Shift 2021

Q.20 The wavelength of the photon emitted by a hydrogen atom when an electron makes a transition from $n = 2$ to $n = 1$ state is :

A 194.8 nm

B 490.7 nm

C 913.3 nm

D 121.8 nm

25th Feb Evening Shift 2021

Q.21 An α particle and a proton are accelerated from rest by a potential difference of 200V. After this, their de Broglie wavelengths are λ_α and λ_p respectively. The

ratio $\frac{\lambda_p}{\lambda_\alpha}$ is :

A 8

B 2.8

C 7.8

D 3.8

25th Feb Morning Shift 2021

Q.22 According to Bohr atom model, in which of the following transitions will the frequency be maximum?

A $n = 2$ to $n = 1$

B $n = 3$ to $n = 2$

C $n = 4$ to $n = 3$

D $n = 5$ to $n = 4$

24th Feb Evening Shift 2021

Q.23 Match List - I with List - II.

	List I		List II
(a)	Source of microwave frequency	(i)	Radioactive decay of nucleus
(b)	Source of infrared frequency	(ii)	Magnetron
(c)	Source of Gamma Rays	(iii)	Inner shell electrons
(d)	Source of X-rays	(iv)	Vibration of atoms and molecules
		(v)	LASER
		(vi)	RC circuit

Choose the correct answer from the options given below :

A (a)-(vi), (b)-(v), (c)-(i), (d)-(iv)

B (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)

C (a)-(ii), (b)-(iv), (c)-(vi), (d)-(iii)

D (a)-(vi), (b)-(iv), (c)-(i), (d)-(v)

24th Feb Evening Shift 2021

Q.24 An X-ray tube is operated at 1.24 million volt. The shortest wavelength of the produced photon will be :

A 10^{-2} nm

B 10^{-1} nm

C 10^{-3} nm

D 10^{-4} nm

24th Feb Evening Shift 2021

Q.25 Given below are two statements :

Statement I : Two photons having equal linear momenta have equal wavelengths.

Statement II : If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.

In the light of the above statements, choose the correct answer from the options given below.

A Statement I is false but Statement II is true

B Both Statement I and Statement II are false

C Both Statement I and Statement II are true

D Statement I is true but Statement II is false

MCQ Answer Key

1. Ans. (b)

2. Ans. (a)

10. Ans. (b)

11. Ans. (d)

19. Ans. (d)

20. Ans. (d)

- | | | |
|-------------|--------------|--------------|
| 3. Ans. (c) | 12. Ans. (d) | 21. Ans. (b) |
| 4. Ans. (c) | 13. Ans. (c) | 22. Ans. (a) |
| 5. Ans. (b) | 14. Ans. (c) | 23. Ans. (b) |
| 6. Ans. (d) | 15. Ans. (d) | 24. Ans. (c) |
| 7. Ans. (b) | 16. Ans. (b) | 25. Ans. (d) |
| 8. Ans. (a) | 17. Ans. (d) | |
| 9. Ans. (c) | 18. Ans. (c) | |

MCQ Explanation

Ans 1.

Given, $(\tau_{1/2})_x = (\tau)_y$

Here, $\tau_{1/2}$ = half-life period of radioactive element and τ = mean life period of radioactive element.

As we know the expression,

Half-life of the radioactive element x,

$$\tau_{1/2} = \frac{\ln(2)}{\lambda_x}$$

Mean life of the radioactive element y,

$$\tau = \frac{1}{\lambda_y}$$

Substituting the values in Eq. (i), we get

$$\frac{\ln 2}{\lambda_x} = \frac{1}{\lambda_y} \Rightarrow \lambda_x = 0.693\lambda_y$$

Initially they have same number of atoms,

$$N_x = N_y = N_0$$

As we know that,

$$\text{Activity, } A = \lambda N$$

$$\text{As, } \lambda_x < \lambda_y \Rightarrow A_x < A_y$$

Therefore, y will decay faster than x.

Ans 2.

Given, Planck's constant, $h = 6.6 \times 10^{-34}$ Js

Boltzmann constant, $k_B = 1.38 \times 10^{-23}$ J/K

Mass of an electron, $m_e = 9 \times 10^{-31}$ kg

Temperature of an ideal gas, $T = 300$ K

As we know that, de-Broglie wavelength,

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

Here, E is the kinetic energy,

$$E = \frac{3K_B T}{2}$$

Substituting value of E in Eq. (i), we get

$$\lambda = \frac{h}{\sqrt{3mK_B T}}$$

Substituting the given values in the above equation, we get

$$\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{3 \times 9 \times 10^{-31} \times 1.38 \times 10^{-23} \times 300}}$$

$$= 6.26 \text{ nm}$$

∴ The corresponding de-Broglie wavelength of an electron approximately at 300 K is 6.26 nm.

Ans 3.

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x = \frac{h}{4\pi m \Delta v}$$

$$v = \sqrt{\frac{3KT}{m}}$$

$$\frac{\Delta x_e}{\Delta x_p} = \sqrt{\frac{m_p}{m_e}}$$

Ans 4.

For every large distance P.E. = 0

& total energy = 2.6 + 0 = 2.6 eV

Finally in first excited state of H atom total energy = -3.4 eV

Loss in total energy = 2.6 - (-3.4) = 6 eV

It is emitted as photon

$$\lambda = \frac{1240}{6} = 206 \text{ nm}$$

$$f = \frac{3 \times 10^8}{206 \times 10^{-9}} = 1.45 \times 10^{15} \text{ Hz}$$

$$= 1.45 \times 10^9 \text{ Hz}$$

Ans 5.

$$kE_{\max} = \frac{hc}{\lambda_i} + \phi$$

$$\text{or } eV_o = \frac{hc}{\lambda_i} + \phi$$

when $\lambda_i = 670.5 \text{ nm}$; $V_o = 0.48$

when $\lambda_i = 474.6 \text{ nm}$; $V_o = ?$

So,

$$e(0.48) = \frac{1240}{670.5} + \phi \dots (1)$$

$$e(V_o) = \frac{1240}{474.6} + \phi \dots (2)$$

$$(2) - (1)$$

$$e(V_o - 0.48) = 1240 \left(\frac{1}{474.6} - \frac{1}{670.5} \right) eV$$

$$V_o = 0.48 + 1240 \left(\frac{670.5 - 474.6}{474.6 \times 670.5} \right) \text{ Volts}$$

$$V_o = 0.48 + 0.76$$

$$V_o = 1.24 \text{ V} \approx 1.25 \text{ V}$$

Ans 6.

→ Increasing intensity means number of incident photons are increased.

→ Kinetic energy of ejected electrons depend on the frequency of incident photons, not the intensity.

Ans 7.

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}, mv = \sqrt{2mE}$$

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

$$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{E_1}{E_2}} = \frac{3}{4}, \lambda_2 = 0.75\lambda_1$$

$$\frac{E_1}{E_2} = \left(\frac{3}{4} \right)^2$$

$$E_2 = \frac{16}{9} E_1 = \frac{16}{9} E \quad (E_1 = E)$$

$$\text{Extra energy given} = \frac{16}{9} E - E = \frac{7}{9} E$$

Ans 8.

$$KE_{\max} = eV_s = \frac{hc}{\lambda} - \phi$$

$$\Rightarrow eV_s = \frac{1240}{280} - 2.5 = 1.93 \text{ eV}$$

$$\Rightarrow V_{s1} = 1.93 \text{ V} \dots (i)$$

$$\Rightarrow eV_{s2} = \frac{1240}{400} - 2.5 = 0.6 \text{ eV}$$

$$\Rightarrow V_{s2} = 0.6 \text{ V} \dots (ii)$$

$$\Delta V = V_{s1} - V_{s2} = 1.93 - 0.6 = 1.33 \text{ V}$$

Ans 9.

$$N = N_0 e^{-\lambda t}$$

$$N_d = N_0 - N$$

$$N_d = N_0 (1 - e^{-\lambda t})$$

$$\frac{N_d}{N_0} = f = 1 - e^{-\lambda t}$$

$$\Rightarrow \frac{df}{dt} = \lambda e^{-\lambda t}$$

Ans 10.

$$V_s = hv - \phi$$

$$4.8 = \frac{hc}{\lambda} - \phi \dots (i)$$

$$1.6 = \frac{hc}{2\lambda} - \phi \dots (ii)$$

Using above equation (i) - (ii)

$$3.2 = \frac{hc}{\lambda} - \frac{hc}{2\lambda}$$

$$3.2 = \frac{hc}{2\lambda} \dots (iii)$$

Put in equation (ii)

$$\phi = 1.6$$

$$\frac{hc}{\lambda_{th}} = 1.6$$

$$\lambda_{th} = \frac{hc}{1.6}$$

$$= \left(\frac{hc}{6.4} \right) \times 4 = 4\lambda$$

Ans 11.

$$A = \lambda N$$

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{3 \times 24 \times 60 \times 60} \text{sec}^{-1} = 2.67 \times 10^{-6} \text{sec}^{-1}$$

N = Number of atoms in 2 mg Au

$$= \frac{2 \times 10^{-3}}{198} \times 6 \times 10^{23} = 6.06 \times 10^{15}$$

$$A = \lambda N = 1.618 \times 10^{13} = 16.18 \times 10^{12} \text{ dps}$$

Ans 12.

$$\frac{3N_0}{4} = N_0 e^{-\lambda t_1}$$

$$\frac{N_0}{2} = N_0 e^{-\lambda t_2}$$

$$\ln(3/4) = -\lambda t_1 \dots (i)$$

$$\ln(1/2) = -\lambda t_2 \dots (i)$$

$$\ln(3/4) - \ln(1/2) = \lambda(t_2 - t_1) \dots (i)$$

$$\Delta t = \frac{\ln(3/2)}{\lambda}$$

Ans 13.

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

$$\text{kinetic energy, } \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_c}$$

$$\lambda_c = \frac{2mc\lambda^2}{h}$$

Ans 15.

$$\frac{1}{2}mv_1^2 = hf_1 - \phi \text{ (1)}$$

$$\frac{1}{2}mv_2^2 = hf_2 - \phi \text{ (2)}$$

Subtracting equation (1) by equation (2)

$$\frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2 = hf_1 - hf_2$$

$$v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$$

Ans 16. Stopping potential depends on frequency, according to Einstein's photoelectric equation.

$$hv - hv_0 = eV$$

$$\Rightarrow V = \frac{h}{e}v - \frac{h}{e}v_0$$

Ans 17. (ΔE) Releases when photon going from $n = 5$ to $n = 1$

$$\Delta E = (13.6 - 0.54) \text{ eV} = 13.06 \text{ eV.}$$

$P_i = P_f$ (By linear momentum conservation)

$$0 = \frac{h}{\lambda} - Mv = V_{\text{Recoil}} = \frac{h}{\lambda M} \text{ (i)}$$

$$\& \Delta E = \frac{hc}{\lambda} = \frac{hc}{\lambda M} \times M = McV_{\text{Recoil}}$$

$$V_{\text{Recoil}} = \frac{\Delta E}{Mc} = \frac{13.06 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27} \times 3 \times 10^8} = 4.17 \text{ m/sec}$$

Ans 18.

$$\text{Resolution limit } (\Delta\theta) = \frac{1.22\lambda}{d}$$

$$\text{Resolution power} = \frac{1}{\text{Resolution limit}}$$

$$\therefore \text{Resolution power} \propto \frac{1}{\lambda}$$

Since, wavelength of electron is much less than visible light, its resolving power will be much more.

Ans 19. From the photoelectric effect equation

$$\frac{hc}{\lambda} = \phi + ev_s$$

$$\text{SO, } ev_{s_1} = \frac{hc}{\lambda_1} - \phi \dots\dots(i)$$

$$ev_{s_2} = \frac{hc}{\lambda_2} - \phi \dots\dots(ii)$$

Subtract equation (i) from equation (ii)

$$ev_{s_1} - ev_{s_2} = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$$

$$v_{s_1} - v_{s_2} = \frac{hc}{e} \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2} \right)$$

$$(0.710 - 1.43) = 1240 \left(\frac{1}{491} - \frac{1}{\lambda_2} \right)$$

$$\frac{-0.72}{1240} = \frac{1}{491} - \frac{1}{\lambda_2}$$

$$\frac{1}{\lambda_2} = \frac{1}{491} + \frac{0.72}{1240}$$

$$\frac{1}{\lambda_2} = 0.00203 + 0.00058$$

$$\frac{1}{\lambda_2} = 0.00261$$

$$\lambda_2 = 383.14$$

$$\lambda_2 \simeq 382 \text{ nm}$$

Ans 20.

$$\Delta E = 10.2 \text{ eV}$$

$$\frac{hc}{\lambda} = 10.2 \text{ eV}$$

$$\lambda = \frac{hc}{(10.2)e}$$

$$= \frac{12400}{10.2} \text{ \AA}$$

$$= 121.56 \text{ nm}$$

$$\simeq 121.8 \text{ nm}$$

Ans 21. We know,

$$qv = \frac{p^2}{2m}$$

$$\Rightarrow p = \sqrt{2mqv}$$

$$\therefore \lambda = \frac{h}{\sqrt{2mqv}}$$

$$\therefore \frac{\lambda_p}{\lambda_\alpha} = \frac{\sqrt{2m_\alpha q_\alpha v}}{\sqrt{2m_p q_p v}}$$

$$= \frac{\sqrt{2(4m)(2e)}}{\sqrt{2me}}$$

$$= \sqrt{8}$$

$$= 2\sqrt{2}$$

Ans 22. Let, n_f , n_i be the final and initial orbit.

As we know that,

$$\frac{1}{\lambda} = 1.09 \times 10^7 \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]$$

Now, checking for each option, we get

$$(a) \frac{1}{\lambda} \propto \left[\frac{1}{3^2} - \frac{1}{4^2} \right] = \left[\frac{1}{9} - \frac{1}{16} \right] = 0.05 \dots (i)$$

$$(b) \frac{1}{\lambda} \propto \left[\frac{1}{1} - \frac{1}{4} \right] = 0.75 \dots (ii)$$

$$(c) \frac{1}{\lambda} \propto \left[\frac{1}{16} - \frac{1}{25} \right] = 0.0225 \dots (iii)$$

$$(d) \frac{1}{\lambda} \propto \left[\frac{1}{4} - \frac{1}{9} \right] = 0.14 \dots (iv)$$

The option (b) has highest value.

Since, frequency, $f = \frac{c}{\lambda} \Rightarrow f \propto \frac{1}{\lambda}$

$\therefore$ Frequency will be maximum for transition $n = 2$ to $n = 1$.

Ans 23.

(a) Source of microwave frequency - (ii) Magnetron

(b) Source of infra red frequency - (iv) Vibration of atom and molecules

(c) Source of gamma ray - (i) Radio active decay of nucleus

(d) Source of X-ray - (iii) inner shell electron

Ans 24.

Given, $V = 1.24$ million volt $= 1.24 \times 10^6$ volt

Since, energy (E) = eV

where, e is the charge of electron $= 1.6 \times 10^{-19}$ C

$$\therefore E = 1.6 \times 10^{-19} \times 1.24 \times 10^6 \dots (i)$$

As we know that,

$$\text{Energy of photon, } E = \frac{hc}{\lambda} \dots (ii)$$

Here, Planck's constant, $h = 6.67 \times 10^{-34}$ J-s,

c = speed of light in free space, $c = 3 \times 10^8$ ms⁻¹

Equating Eqs. (i) and (ii), we get

$$1.6 \times 10^{-19} \times 1.24 \times 10^6 = \frac{6.67 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$$\Rightarrow \lambda = \frac{20.01 \times 10^{-13}}{1.6 \times 1.24} = 10.09 \times 10^{-13}$$

$$= 1.009 \times 10^{-12} \simeq 10^{-3} \times 10^{-9}$$

$$= 10^{-3} \text{ nm}$$

Ans 25.

$$\text{As we know, } \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

If linear momenta of two photons are equal, then their wavelengths is also equal.

Also, if the wavelength is decreased, then the momentum and energy of photon will increase.

Hence, option (d) is correct.

TOPIC 1 Matter Waves, Cathode and Positive Rays



- An electron, a doubly ionized helium ion (He^{++}) and a proton are having the same kinetic energy. The relation between their respective de-Broglie wavelengths λ_e , $\lambda_{\text{He}^{++}}$ and λ_p is : **[Sep. 06, 2020 (I)]**
 - $\lambda_e > \lambda_{\text{He}^{++}} > \lambda_p$
 - $\lambda_e < \lambda_{\text{He}^{++}} = \lambda_p$
 - $\lambda_e > \lambda_p > \lambda_{\text{He}^{++}}$
 - $\lambda_e < \lambda_p < \lambda_{\text{He}^{++}}$
- Assuming the nitrogen molecule is moving with r.m.s. velocity at 400 K, the de-Broglie wavelength of nitrogen molecule is close to :
(Given : nitrogen molecule weight : 4.64×10^{-26} kg, Boltzman constant : 1.38×10^{-23} J/K, Planck constant : 6.63×10^{-34} J.s) **[Sep. 06, 2020 (II)]**
 - 0.24 Å
 - 0.20 Å
 - 0.34 Å
 - 0.44 Å
- Particle A of mass $m_A = \frac{m}{2}$ moving along the x-axis with velocity v_0 collides elastically with another particle B at rest having mass $m_B = \frac{m}{3}$. If both particles move along the x-axis after the collision, the change $\Delta\lambda$ in de-Broglie wavelength of particle A, in terms of its de-Broglie wavelength (λ_0) before collision is : **[Sep. 04, 2020 (I)]**
 - $\Delta\lambda = \frac{3}{2}\lambda_0$
 - $\Delta\lambda = \frac{5}{2}\lambda_0$
 - $\Delta\lambda = 2\lambda_0$
 - $\Delta\lambda = 4\lambda_0$
- A particle is moving 5 times as fast as an electron. The ratio of the de-Broglie wavelength of the particle to that of the electron is 1.878×10^{-4} . The mass of the particle is close to : **[Sep. 02, 2020 (II)]**
 - 4.8×10^{-27} kg
 - 9.1×10^{-31} kg
 - 1.2×10^{-28} kg
 - 9.7×10^{-28} kg

- A particle moving with kinetic energy E has de Broglie wavelength λ . If energy ΔE is added to its energy, the wavelength become $\frac{\lambda}{2}$. Value of ΔE , is: **[9 Jan. 2020 I]**
 - E
 - 4E
 - 3E
 - 2E
- An electron of mass m and magnitude of charge |e| initially at rest gets accelerated by a constant electric field E. The rate of change of de-Broglie wavelength of this electron at time t ignoring relativistic effects is: **[9 Jan. 2020 II]**
 - $-\frac{h}{|e|E\sqrt{t}}$
 - $\frac{|e|Et}{h}$
 - $-\frac{h}{|e|Et}$
 - $\frac{-h}{|e|Et^2}$
- An electron (mass m) with initial velocity $\vec{v} = v_0\hat{i} + v_0\hat{j}$ is in an electric field $\vec{E} = -E_0\hat{k}$. If λ_0 is initial de-Broglie wavelength of electron, its de-Broglie wave length at time t is given by: **[8 Jan. 2020 II]**
 - $\frac{\lambda_0\sqrt{2}}{\sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}}$
 - $\frac{\lambda_0}{\sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}}$
 - $\frac{\lambda_0}{\sqrt{1 + \frac{e^2 E^2 t^2}{2m^2 v_0^2}}}$
 - $\frac{\lambda_0}{\sqrt{2 + \frac{e^2 E^2 t^2}{m^2 v_0^2}}}$
- A particle 'P' is formed due to a completely inelastic collision of particles 'x' and 'y' having de-Broglie wavelengths ' γ_x ' and ' γ_y ' respectively. If x and y were moving in opposite directions, then the de-Broglie wavelength of 'P' is: **[9 Apr. 2019 II]**
 - $\frac{\gamma_x \gamma_y}{\gamma_x + \gamma_y}$
 - $\frac{\gamma_x \gamma_y}{|\gamma_x - \gamma_y|}$
 - $\gamma_x - \gamma_y$
 - $\gamma_x + \gamma_y$

9. Two particles move at right angle to each other. Their de Broglie wavelengths are λ_1 and λ_2 respectively. The particles suffer perfectly inelastic collision. The de Broglie wavelength λ , of the final particle, is given by:

[8 April 2019 I]

(a) $\frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$ (b) $\lambda = \sqrt{\lambda_1 \lambda_2}$
 (c) $\lambda = \frac{\lambda_1 + \lambda_2}{2}$ (d) $\frac{2}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

10. A particle A of mass 'm' and charge 'q' is accelerated by a potential difference of 50V. Another particle B of mass '4m' and charge 'q' is accelerated by a potential difference of 2500V. The ratio of de-Broglie wavelength $\frac{\lambda_A}{\lambda_B}$ is

[12 Jan. 2019 I]

(a) 10.00 (b) 0.07
 (c) 14.14 (d) 4.47

11. If the deBroglie wavelength of an electron is equal to 10^{-3} times the wavelength of a photon of frequency 6×10^{14} Hz, then the speed of electron is equal to :

(Speed of light = 3×10^8 m/s)Planck's constant = 6.63×10^{-34} J.sMass of electron = 9.1×10^{-31} kg) [11 Jan. 2019 I]

(a) 1.1×10^6 m/s (b) 1.7×10^6 m/s
 (c) 1.8×10^6 m/s (d) 1.45×10^6 m/s

12. In an electron microscope, the resolution that can be achieved is of the order of the wavelength of electrons used. To resolve a width of 7.5×10^{-12} m, the minimum electron energy required is close to: [10 Jan. 2019 I]

(a) 500 keV (b) 100 keV (c) 1 keV (d) 25 keV

13. Two electrons are moving with non-relativistic speeds perpendicular to each other. If corresponding de Broglie wavelengths are λ_1 and λ_2 , their de Broglie wavelength in the frame of reference attached to their centre of mass is:

[Online April 15, 2018]

(a) $\lambda_{CM} = \lambda_1 = \lambda_2$ (b) $\frac{1}{\lambda_1} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$
 (c) $\lambda_{CM} = \frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2 + \lambda_2^2}}$ (d) $\lambda_{CM} = \left(\frac{\lambda_1 + \lambda_2}{2} \right)$

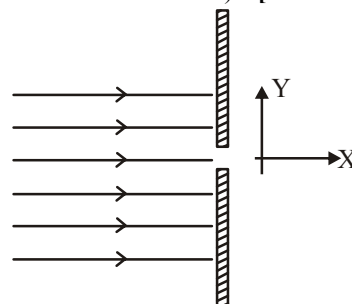
14. If the de Broglie wavelengths associated with a proton and an α -particle are equal, then the ratio of velocities of the proton and the α -particle will be: [Online April 15, 2018]

(a) 1 : 4 (b) 1 : 2 (c) 4 : 1 (d) 2 : 1

15. A particle A of mass m and initial velocity v collides with a particle B of mass $\frac{m}{2}$ which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is [2017]

(a) $\frac{\lambda_A}{\lambda_B} = \frac{2}{3}$ (b) $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$
 (c) $\frac{\lambda_A}{\lambda_B} = \frac{1}{3}$ (d) $\frac{\lambda_A}{\lambda_B} = 2$

16. A parallel beam of electrons travelling in x-direction falls on a slit of width d (see figure). If after passing the slit, an electron acquires momentum p_y in the y-direction then for a majority of electrons passing through the slit (h is Planck's constant) : [Online April 10, 2015]



(a) $|P_y|d > h$ (b) $|P_y|d < h$
 (c) $|P_y|d \approx h$ (d) $|P_y|d >> h$

17. de-Broglie wavelength of an electron accelerated by a voltage of 50 V is close to ($|e| = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ Js) : [Online April 10, 2015]

(a) 2.4 Å (b) 0.5 Å (c) 1.7 Å (d) 1.2 Å

18. For which of the following particles will it be most difficult to experimentally verify the de-Broglie relationship?

[Online April 9, 2014]

(a) an electron (b) a proton
 (c) an α -particle (d) a dust particle

19. Electrons are accelerated through a potential difference V and protons are accelerated through a potential difference 4 V. The de-Broglie wavelengths are λ_e and λ_p for electrons

and protons respectively. The ratio of $\frac{\lambda_e}{\lambda_p}$ is given by : (given m_e is mass of electron and m_p is mass of proton).

[Online April 23, 2013]

(a) $\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$ (b) $\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_e}{m_p}}$
 (c) $\frac{\lambda_e}{\lambda_p} = \frac{1}{2} \sqrt{\frac{m_e}{m_p}}$ (d) $\frac{\lambda_e}{\lambda_p} = 2 \sqrt{\frac{m_p}{m_e}}$

20. If the kinetic energy of a free electron doubles, its de-Broglie wavelength changes by the factor [2005]

(a) 2 (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

21. Formation of covalent bonds in compounds exhibits [2002]

(a) wave nature of electron
 (b) particle nature of electron
 (c) both wave and particle nature of electron
 (d) none of these

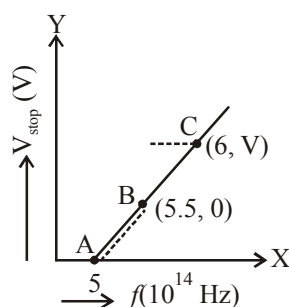
TOPIC 2 Photon, Photoelectric Effect X-rays and Davisson-Germer Experiment



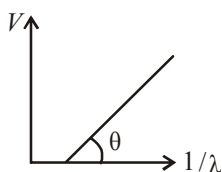
22. A beam of electrons of energy E scatters from a target having atomic spacing of $1\text{ \AA}$. The first maximum intensity occurs at $\theta = 60^\circ$. Then E (in eV) is _____.

(Plank constant $h = 6.64 \times 10^{-34}\text{ Js}$, $1\text{ eV} = 1.6 \times 10^{-19}\text{ J}$, electron mass $m = 9.1 \times 10^{-31}\text{ kg}$) [NA Sep. 05, 2020 (I)]

23. The surface of a metal is illuminated alternately with photons of energies $E_1 = 4\text{ eV}$ and $E_2 = 2.5\text{ eV}$ respectively. The ratio of maximum speeds of the photoelectrons emitted in the two cases is 2. The work function of the metal (in eV) is _____. [NA Sep. 05, 2020 (II)]
24. Given figure shows few data points in a photo electric effect experiment for a certain metal. The minimum energy for ejection of electron from its surface is : (Plancks constant $h = 6.62 \times 10^{-34}\text{ J.s}$) [Sep. 04, 2020 (I)]



- (a) 2.27 eV (b) 2.59 eV
(c) 1.93 eV (d) 2.10 eV
25. In a photoelectric effect experiment, the graph of stopping potential V versus reciprocal of wavelength obtained is shown in the figure. As the intensity of incident radiation is increased : [Sep. 04, 2020 (II)]



- (a) Straight line shifts to right
(b) Slope of the straight line get more steep
(c) Straight line shifts to left
(d) Graph does not change
26. When the wavelength of radiation falling on a metal is changed from 500 nm to 200 nm , the maximum kinetic energy of the photoelectrons becomes three times larger. The work function of the metal is close to : [Sep. 03, 2020 (I)]
- (a) 0.81 eV (b) 1.02 eV
(c) 0.52 eV (d) 0.61 eV

27. Two sources of light emit X-rays of wavelength 1 nm and visible light of wavelength 500 nm , respectively. Both the sources emit light of the same power 200 W . The ratio of the number density of photons of X-rays to the number density of photons of the visible light of the given wavelengths is : [Sep. 03, 2020 (II)]

(a) $\frac{1}{500}$ (b) 250 (c) $\frac{1}{250}$ (d) 500

28. When radiation of wavelength λ is used to illuminate a metallic surface, the stopping potential is V . When the same surface is illuminated with radiation of wavelength

3λ , the stopping potential is $\frac{V}{4}$. If the threshold

wavelength for the metallic surface is $n\lambda$ then value of n will be _____. [NA Sep. 02, 2020 (I)]

29. Radiation, with wavelength $6561\text{ \AA}$ falls on a metal surface to produce photoelectrons. The electrons are made to enter a uniform magnetic field of $3 \times 10^{-4}\text{ T}$. If the radius of the largest circular path followed by the electrons is 10 mm , the work function of the metal is close to: [9 Jan. 2020 I]

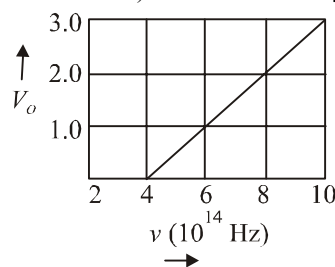
(a) 1.1 eV (b) 0.8 eV
(c) 1.6 eV (d) 1.8 eV

30. When photon of energy 4.0 eV strikes the surface of a metal A , the ejected photoelectrons have maximum kinetic energy $T_A\text{ eV}$ and de-Broglie wavelength λ_A . The maximum kinetic energy of photoelectrons liberated from another metal B by photon of energy 4.50 eV is $T_B = (T_A - 1.5)\text{ eV}$. If the de-Broglie wavelength of these photoelectrons $\lambda_B = 2\lambda_A$, then the work function of metal B is: [8 Jan. 2020 I]

(a) 4 eV (b) 2 eV
(c) 1.5 eV (d) 3 eV

31. A beam of electromagnetic radiation of intensity $6.4 \times 10^{-5}\text{ W/cm}^2$ is comprised of wavelength, $\lambda = 310\text{ nm}$. It falls normally on a metal (work function $\phi = 2\text{ eV}$) of surface area of 1 cm^2 . If one in 10^3 photons ejects an electron, total number of electrons ejected in 1 s is 10^x . ($hc = 1240\text{ eVnm}$, $1\text{ eV} = 1.6 \times 10^{-19}\text{ J}$), then x is _____. [NA 7 Jan. 2020 I]

32. The stopping potential V_0 (in volt) as a function of frequency (ν) for a sodium emitter, is shown in the figure. The work function of sodium, from the data plotted in the figure, will be : (Given : Planck's constant (h) = $6.63 \times 10^{-34}\text{ Js}$, electron charge $e = 1.6 \times 10^{-19}\text{ C}$) [12 Apr. 2019 I]



(a) 1.82 eV (b) 1.66 eV (c) 1.95 eV (d) 2.12 eV

33. In a photoelectric effect experiment the threshold wavelength of light is 380 nm. If the wavelength of incident light is 260 nm, the maximum kinetic energy of emitted electrons will be:

Given E (in eV) = [10 Apr. 2019 I]

- (a) 1.5 eV (b) 3.0 eV (c) 4.5 eV (d) 15.1 eV

34. A 2 mW laser operates at a wavelength of 500 nm. The number of photons that will be emitted per second is :

[Given Planck's constant $h = 6.6 \times 10^{-34}$ Js, speed of light $c = 3.0 \times 10^8$ m/s] [10 Apr. 2019 II]

- (a) 5×10^{15} (b) 1.5×10^{16}
(c) 2×10^{16} (d) 1×10^{16}

35. The electric field of light wave is given as

$$\vec{E} = 10^3 \cos\left(\frac{2\pi x}{5 \times 10^{-7}} - 2\pi \times 6 \times 10^{14} t\right) \hat{x} \frac{N}{C}$$

This light falls on a metal plate of work function 2 eV. The stopping potential of the photo-electrons is:

Given, E (in eV) = $\frac{12375}{\lambda \text{ (in Å)}}$ [9 April 2019 I]

- (a) 2.0 V (b) 0.72 V (c) 0.48 V (d) 2.48 V

36. When a certain photosensitive surface is illuminated with monochromatic light of frequency ν , the stopping potential for the photo current is $-V_0/2$. When the surface is illuminated by monochromatic light of frequency $\nu/2$, the stopping potential is $-V_0$. The threshold frequency for photoelectric emission is : [12 Jan. 2019 II]

- (a) $\frac{5\nu}{3}$ (b) $\frac{4}{3}\nu$ (c) 2ν (d) $\frac{3\nu}{2}$

37. In a Frank-Hertz experiment, an electron of energy 5.6 eV passes through mercury vapour and emerges with an energy 0.7 eV. The minimum wavelength of photons emitted by mercury atoms is close to : [12 Jan. 2019 II]

- (a) 1700 nm (b) 2020 nm
(c) 220 nm (d) 250 nm

38. In a photoelectric experiment, the wavelength of the light incident on a metal is changed from 300 nm to 400 nm. The decrease in the stopping potential is close to : [11 Jan. 2019 II]

$$\left(\frac{hc}{e} = 1240 \text{ nm-eV}\right)$$

- (a) 0.5 V (b) 1.5 V
(c) 1.0 V (d) 2.0 V

39. A metal plate of area $1 \times 10^{-4} \text{ m}^2$ is illuminated by a radiation of intensity 16 mW/m^2 . The work function of the metal is 5 eV. The energy of the incident photons is 10 eV and only 10% of it produces photo electrons. The number of emitted photo electrons per second and their maximum energy, respectively, will be:

[1 eV = 1.6×10^{-19} J] [10 Jan. 2019 II]

- (a) 10^{14} and 10 eV (b) 10^{12} and 5 eV
(c) 10^{11} and 5 eV (d) 10^{10} and 5 eV

40. Surface of certain metal is first illuminated with light of wavelength $\lambda_1 = 350 \text{ nm}$ and then, by light of wavelength $\lambda_2 = 540 \text{ nm}$. It is found that the maximum speed of the photo electrons in the two cases differ by a factor of (2). The work function of the metal (in eV) is close to:

$$\left(\text{Energy of photon} = \frac{1240}{\lambda \text{ (in nm)}} \text{ eV}\right) \quad [9 \text{ Jan. 2019 I}]$$

- (a) 1.8 (b) 2.5 (c) 5.6 (d) 1.4

41. The magnetic field associated with a light wave is given at the origin by

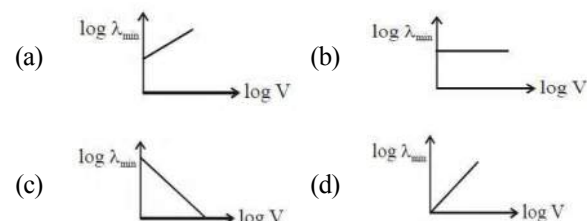
$$B = B_0 [\sin(3.14 \times 10^7)ct + \sin(6.28 \times 10^7)ct].$$

If this light falls on a silver plate having a work function of 4.7 eV, what will be the maximum kinetic energy of the photoelectrons? [9 Jan. 2019 II]

($c = 3 \times 10^8 \text{ ms}^{-1}$, $h = 6.6 \times 10^{-34} \text{ J-s}$)

- (a) 6.82 eV (b) 12.5 eV
(c) 8.52 eV (d) 7.72 eV

42. An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If $\lambda_{\min}$ is the smallest possible wavelength of X-ray in the spectrum, the variation of $\log \lambda_{\min}$ with $\log V$ is correctly represented in : [2017]



43. A Laser light of wavelength 660 nm is used to weld Retina detachment. If a Laser pulse of width 60 ms and power 0.5 kW is used the approximate number of photons in the pulse are : [Take Planck's constant $h = 6.62 \times 10^{-34}$ Js] [Online April 9, 2017]

- (a) 10^{20} (b) 10^{18} (c) 10^{22} (d) 10^{19}

44. The maximum velocity of the photoelectrons emitted from the surface is v when light of frequency n falls on a metal surface. If the incident frequency is increased to $3n$, the maximum velocity of the ejected photoelectrons will be : [Online April 8, 2017]

- (a) less than $\sqrt{3}v$ (b) v
(c) more than $\sqrt{3}v$ (d) equal to $\sqrt{3}v$

45. Radiation of wavelength λ , is incident on a photocell. The fastest emitted electron has speed v . If the wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be: [2016]

- (a) $= v \left(\frac{4}{3}\right)^{\frac{1}{2}}$ (b) $= v \left(\frac{3}{4}\right)^{\frac{1}{2}}$
(c) $> v \left(\frac{4}{3}\right)^{\frac{1}{2}}$ (d) $< v \left(\frac{4}{3}\right)^{\frac{1}{2}}$

46. A photoelectric surface is illuminated successively by monochromatic light of wavelengths λ and $\frac{\lambda}{2}$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the surface is : [Online April 10, 2016]

(a) $\frac{hc}{2\lambda}$ (b) $\frac{hc}{\lambda}$
(c) $\frac{hc}{3\lambda}$ (d) $\frac{3hc}{\lambda}$

47. When photons of wavelength λ_1 are incident on an isolated sphere, the corresponding stopping potential is found to be V . When photons of wavelength λ_2 are used, the corresponding stopping potential was thrice that of the above value. If light of wavelength λ_3 is used then find the stopping potential for this case : [Online April 9, 2016]

(a) $\frac{hc}{e} \left[\frac{1}{\lambda_3} + \frac{1}{\lambda_2} - \frac{1}{\lambda_1} \right]$
(b) $\frac{hc}{e} \left[\frac{1}{\lambda_3} + \frac{1}{2\lambda_2} - \frac{1}{\lambda_1} \right]$
(c) $\frac{hc}{e} \left[\frac{1}{\lambda_3} - \frac{1}{\lambda_2} - \frac{1}{\lambda_1} \right]$
(d) $\frac{hc}{e} \left[\frac{1}{\lambda_3} + \frac{1}{2\lambda_2} - \frac{3}{2\lambda_1} \right]$

48. Match **List - I** (Fundamental Experiment) with **List - II** (its conclusion) and select the correct option from the choices given below the list: [2015]

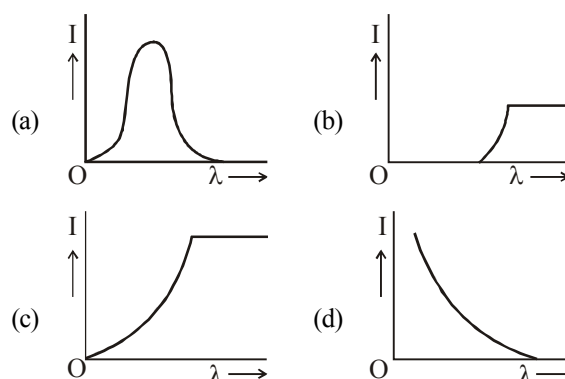
List-I	List-II
A. Franck-Hertz Experiment	(i) Particle nature of light
B. Photo-electric experiment	(ii) Discrete energy levels of atom
C. Davis on-Germer experiment	(iii) Wave nature of electron
	(iv) Structure of atom

- (a) (A)-(ii); (B)-(i); (C)-(iii)
(b) (A)-(iv); (B)-(iii); (C)-(ii)
(c) (A)-(i); (B)-(iv); (C)-(iii)
(d) (A)-(ii); (B)-(iv); (C)-(iii)
49. A beam of light has two wavelengths of $4972\text{\AA}$ and $6216\text{\AA}$ with a total intensity of $3.6 \times 10^{-3} \text{ Wm}^{-2}$ equally distributed among the two wavelengths. The beam falls normally on an area of 1 cm^2 of a clean metallic surface of work function 2.3 eV . Assume that there is no loss of light by reflection and that each capable photon ejects one electron. The number of photoelectrons liberated in 2s is approximately: [Online April 12, 2014]
- (a) 6×10^{11} (b) 9×10^{11}
(c) 11×10^{11} (d) 15×10^{11}

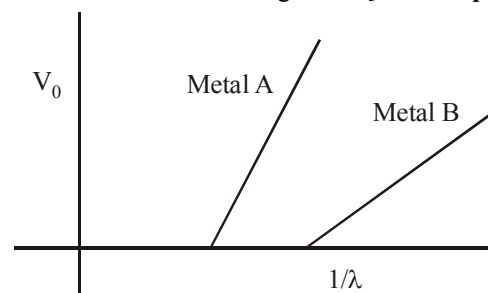
50. A photon of wavelength λ is scattered from an electron, which was at rest. The wavelength shift $\Delta\lambda$ is three times of λ and the angle of scattering θ is 60° . The angle at which the electron recoiled is ϕ . The value of $\tan \phi$ is : (electron speed is much smaller than the speed of light)

[Online April 11, 2014]

- (a) 0.16 (b) 0.22 (c) 0.25 (d) 0.28
51. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows : [2013]



52. In an experiment on photoelectric effect, a student plots stopping potential V_0 against reciprocal of the wavelength λ of the incident light for two different metals A and B. These are shown in the figure. [Online April 25, 2013]



Looking at the graphs, you can most appropriately say that:

- (a) Work function of metal B is greater than that of metal A
(b) For light of certain wavelength falling on both metal, maximum kinetic energy of electrons emitted from A will be greater than those emitted from B.
(c) Work function of metal A is greater than that of metal B
(d) Students data is not correct
53. A copper ball of radius 1 cm and work function 4.47 eV is irradiated with ultraviolet radiation of wavelength $2500 \text{\AA}$. The effect of irradiation results in the emission of electrons from the ball. Further the ball will acquire charge and due to this there will be a finite value of the potential on the ball. The charge acquired by the ball is :

[Online April 25, 2013]

(a) $5.5 \times 10^{-13} \text{ C}$ (b) $7.5 \times 10^{-13} \text{ C}$
(c) $4.5 \times 10^{-12} \text{ C}$ (d) $2.5 \times 10^{-11} \text{ C}$

54. This equation has statement 1 and statement 2. Of the four choices given after the statements, choose the one that describes the two statements.

Statement 1: Davisson-Germer experiment established the wave nature of electrons.

Statement 2 : If electrons have wave nature, they can interfere and show diffraction. [2012]

- (a) Statement 1 is false, Statement 2 is true.
 (b) Statement 1 is true, Statement 2 is false
 (c) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of statement 1
 (d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1
55. Photoelectrons are ejected from a metal when light of frequency ν falls on it. Pick out the wrong statement from the following. [Online May 26, 2012]
- (a) No electrons are emitted if ν is less than W/h , where W is the work function of the metal
 (b) The ejection of the photoelectrons is instantaneous.
 (c) The maximum energy of the photoelectrons is $h\nu$.
 (d) The maximum energy of the photoelectrons is independent of the intensity of the light.

56. This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: A metallic surface is irradiated by a monochromatic light of frequency $\nu > \nu_0$ (the threshold frequency). If the incident frequency is now doubled, the photocurrent and the maximum kinetic energy are also doubled.

Statement 2: The maximum kinetic energy of photoelectrons emitted from a surface is linearly dependent on the frequency of the incident light. The photocurrent depends only on the intensity of the incident light. [Online May 19, 2012]

- (a) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.
 (b) Statement 1 is false, Statement 2 is true.
 (c) Statement 1 is true, Statement 2 is false.
 (d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.
57. This question has Statement – 1 and Statement – 2. Of the four choices given after the statements, choose the one that best describes the two statements. [2011]

Statement – 1: A metallic surface is irradiated by a monochromatic light of frequency $\nu > \nu_0$ (the threshold frequency). The maximum kinetic energy and the stopping potential are $K_{\max}$ and V_0 respectively. If the frequency incident on the surface is doubled, both the $K_{\max}$ and V_0 are also doubled.

Statement – 2 : The maximum kinetic energy and the stopping potential of photoelectrons emitted from a surface are linearly dependent on the frequency of incident light.

- (a) Statement–1 is true, Statement–2 is true, Statement – 2 is the correct explanation of Statement – 1.
 (b) Statement–1 is true, Statement–2 is true, Statement – 2 is not the correct explanation of Statement – 1.
 (c) Statement – 1 is false, Statement – 2 is true.
 (d) Statement – 1 is true, Statement – 2 is false.

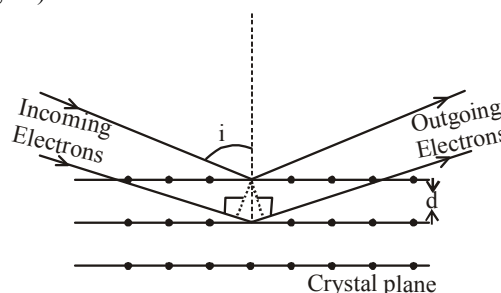
58. **Statement -1 :** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is $K_{\max}$. When the ultraviolet light is replaced by X-rays, both V_0 and $K_{\max}$ increase.

Statement -2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light. [2010]

- (a) Statement -1 is true, Statement -2 is true ; Statement -2 is the correct explanation of Statement -1.
 (b) Statement -1 is true, Statement -2 is true; Statement -2 is **not** the correct explanation of Statement -1
 (c) Statement -1 is false, Statement -2 is true.
 (d) Statement -1 is true, Statement -2 is false.
59. The surface of a metal is illuminated with the light of 400 nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is : ($hc = 1240 \text{ eV}\cdot\text{nm}$) [2009]
- (a) 1.41 eV (b) 1.51 eV
 (c) 1.68 eV (d) 3.09 eV

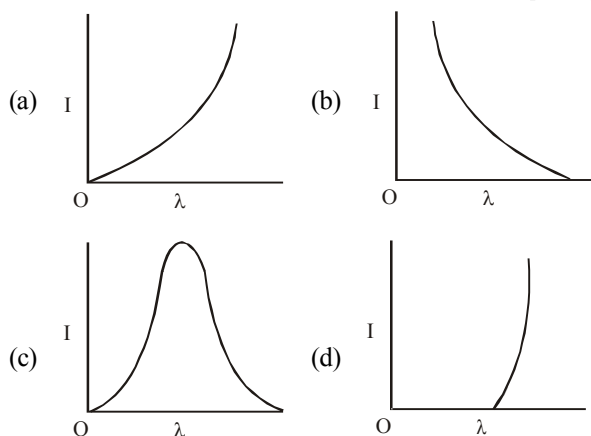
Directions: Question No. 60 and 61 are based on the following paragraph.

Wave property of electrons implies that they will show diffraction effects. Davisson and Germer demonstrated this by diffracting electrons from crystals. The law governing the diffraction from a crystal is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructively (see figure).



60. Electrons accelerated by potential V are diffracted from a crystal. If $d = 1 \text{ \AA}$ and $i = 30^\circ$, V should be about [2008]
 ($h = 6.6 \times 10^{-34} \text{ Js}$, $m_e = 9.1 \times 10^{-31} \text{ kg}$, $e = 1.6 \times 10^{-19} \text{ C}$)
 (a) 2000 V (b) 50 V (c) 500 V (d) 1000 V
61. If a strong diffraction peak is observed when electrons are incident at an angle ' i ' from the normal to the crystal planes with distance ' d ' between them (see figure), de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer) [2008]
- (a) $d \sin i = n\lambda_{dB}$ (b) $2d \cos i = n\lambda_{dB}$
 (c) $2d \sin i = n\lambda_{dB}$ (d) $d \cos i = n\lambda_{dB}$

62. Photon of frequency ν has a momentum associated with it. If c is the velocity of light, the momentum is [2007]
 (a) $h\nu/c$ (b) ν/c (c) $h\nu c$ (d) $h\nu/c^2$
63. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5 V. The incident radiation lies in [2006]
 (a) ultra-violet region (b) infra-red region
 (c) visible region (d) X-ray region
64. The time taken by a photoelectron to come out after the photon strikes is approximately [2006]
 (a) 10^{-4} s (b) 10^{-10} s (c) 10^{-16} s (d) 10^{-1} s
65. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows [2006]



66. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would [2005]
 (a) increase by a factor of 4
 (b) decrease by a factor of 4

- (c) increase by a factor of 2
 (d) decrease by a factor of 2
67. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is [2004]
 (a) Ec (b) $2E/c$ (c) E/c (d) E/c^2
68. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal Versus the frequency, of the incident radiation gives a straight line whose slope [2004]
 (a) depends both on the intensity of the radiation and the metal used
 (b) depends on the intensity of the radiation
 (c) depends on the nature of the metal used
 (d) is the same for the all metals and independent of the intensity of the radiation
69. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately [2004]
 (a) 310 nm (b) 400 nm (c) 540 nm (d) 220 nm
70. Two identical photocathodes receive light of frequencies f_1 and f_2 . If the velocities of the photo electrons (of mass m) coming out are respectively v_1 and v_2 , then [2003]
 (a) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$
 (b) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2) \right]^{1/2}$
 (c) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$
 (d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2) \right]^{1/2}$
71. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to [2002]
 (a) 1 : 2 (b) 4 : 1 (c) 2 : 1 (d) 1 : 4



Hints & Solutions



1. (c) de-Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m(\text{KE})}}$

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

As $m_{\text{He}^{++}} > m_p > m_e$

$$\lambda_{\text{He}^{++}} > \lambda_p > \lambda_e \text{ or } \lambda_e > \lambda_p > \lambda_{\text{He}^{++}}$$

2. (a) Rms speed of gas molecule, $V_{\text{rms}} = \sqrt{\frac{3kT}{m}}$

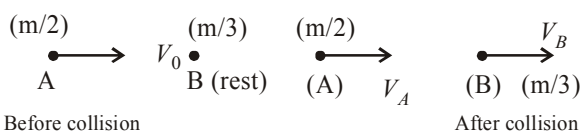
de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}}$

$$\therefore \lambda = \frac{h}{\sqrt{2m \times \frac{1}{2} m V_{\text{rms}}^2}} = \frac{h}{\sqrt{m \times \frac{3}{2} kT}} = \frac{h}{\sqrt{3mkT}}$$

Substituting the respective values we get

$$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{3 \times 4.64 \times 10^{-26} \times 1.38 \times 10^{-13} \times 400}} = 0.24 \text{ \AA}$$

3. (d)



Before collision

Applying momentum conservation

$$\frac{m}{2} \times V_0 + \frac{m}{3} \times (0) = \frac{m}{2} V_A + \frac{m}{3} V_B$$

$$= \frac{V_0}{2} = \frac{V_A}{2} + \frac{V_B}{3} \quad \dots(i)$$

Since, collision is elastic

$$e = 1 = \frac{V_B - V_A}{V_0} \Rightarrow V_0 = V_B - V_A \quad \dots(ii)$$

On solving equations (i) and (ii): $V_A = \frac{V_0}{5}$

Now, de-Broglie wavelength of A before collision :

$$\lambda_0 = \frac{h}{m_A V_0} = \frac{h}{\left(\frac{m}{2}\right) V_0} \Rightarrow \lambda_0 = \frac{2h}{m V_0}$$

Final de-Broglie wavelength :

$$\lambda_f = \frac{h}{m_A V_0} = \frac{h}{\frac{m}{2} \times \frac{V_0}{5}} \Rightarrow \lambda_f = \frac{10h}{m V_0}$$

$$\therefore \Delta\lambda = \lambda_f - \lambda_0 = \frac{10h}{m V_0} - \frac{2h}{m V_0}$$

$$\Rightarrow \Delta\lambda = \frac{8h}{m V_0} \Rightarrow \Delta\lambda = 4 \times \frac{2h}{m V_0}$$

$$\therefore \Delta\lambda = 4\lambda_0$$

4. (d) de Broglie wavelength

$$\lambda = \frac{h}{mv} \Rightarrow m = \frac{h}{\lambda v}$$

Clearly, $m \propto \frac{1}{\lambda v}$

If λ and v be the wavelength and velocity of electron and λ' and v' be the wavelength and velocity of the particle then

$$\Rightarrow \frac{m'}{m} = \frac{v\lambda}{v'\lambda'} = \frac{1}{5} \times \frac{1}{1.878} \times 10^{-4}$$

$$\Rightarrow m = 9.7 \times 10^{-28} \text{ kg}$$

5. (c) As per question, when KE of particle E , wavelength λ and when KE becomes $E + \Delta E$ wavelength becomes $\lambda/2$

Using, $\lambda = \frac{h}{\sqrt{2mKE}}$

$$\frac{\lambda}{2} = \frac{h}{\sqrt{2m(KE + \Delta E)}}$$

$$\Rightarrow \frac{\lambda}{\lambda/2} = \sqrt{\frac{KE + \Delta E}{KE}}$$

$$\Rightarrow 4 = \frac{KE + \Delta E}{KE}$$

$$\Rightarrow 4KE - KE = \Delta E$$

$$\therefore \Delta E = 3KE = 3E$$

6. (d) Acceleration of electron in electric field, $a = \frac{eE}{m}$

Using equation

$$v = u + at$$

$$\Rightarrow v = 0 + \frac{eE}{m} t$$

$$\Rightarrow v = \frac{eEt}{m} \quad \dots (i)$$

De-Broglie wavelength λ is given by

$$\lambda = \frac{h}{mv} = \frac{h}{m\left(\frac{eEt}{m}\right)} \quad [\text{using (i)}]$$

$$\Rightarrow \lambda = \frac{h}{eEt}$$

Differentiating w.r.t. t

$$\frac{d\lambda}{dt} = \frac{d\left(\frac{h}{eEt}\right)}{dt} \Rightarrow \frac{d\lambda}{dt} = \frac{-h}{eEt^2}$$

7. (c) Given, Initial velocity, $u = v_0\hat{i} + v_0\hat{j}$

$$\text{Acceleration, } a = \frac{qE_0}{m} = \frac{eE_0}{m}$$

Using $v = u + at$

$$v = v_0\hat{i} + v_0\hat{j} + \frac{eE_0}{m}t\hat{k}$$

$$\therefore |\vec{v}| = \sqrt{2v_0^2 + \left(\frac{eE_0t}{m}\right)^2}$$

$$\text{de-Broglie wavelength, } \lambda = \frac{h}{p}$$

$$\Rightarrow \lambda = \frac{h}{mv} \quad (\because p = mv)$$

$$\text{Initial wavelength, } \lambda_0 = \frac{h}{mv_0\sqrt{2}}$$

Final wavelength,

$$\lambda = \frac{h}{m\sqrt{2v_0^2 + \left(\frac{eE_0t}{m}\right)^2}}$$

$$\frac{\lambda}{\lambda_0} = \frac{1}{\sqrt{1 + \left(\frac{eE_0t}{\sqrt{2}mv_0}\right)^2}}$$

$$\Rightarrow \lambda = \frac{\lambda_0}{\sqrt{1 + \frac{e^2 E_0^2 t^2}{2m^2 v_0^2}}}$$

8. (b) $P_1 - P_2 = (P_1 + P_2) = P$

$$\text{As } P \propto \frac{1}{\lambda}$$

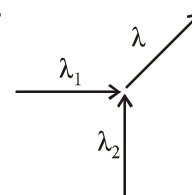
$$\text{or } \frac{1}{\lambda_x} - \frac{1}{\lambda_y} = \frac{1}{\lambda}$$

$$\text{or } \frac{\lambda_y - \lambda_x}{\lambda_x \lambda_y} = \frac{1}{\lambda}$$

9. (a) From the de-Broglie relation,

$$p_1 = \frac{h}{\lambda_1}$$

$$p_2 = \frac{h}{\lambda_2}$$



Momentum of the final particle (p_f) is given by

$$\therefore p_f = \sqrt{p_1^2 + p_2^2}$$

$$\Rightarrow \frac{h}{\lambda} = \sqrt{\frac{h^2}{\lambda_1^2} + \frac{h^2}{\lambda_2^2}}$$

$$\Rightarrow \frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$$

10. (c) de Broglie wavelength (λ) is given by $K = qV$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}} \quad (\because p = \sqrt{2mK})$$

Substituting the values we get

$$\begin{aligned} \therefore \frac{\lambda_A}{\lambda_B} &= \frac{\sqrt{2m_B q_B V_B}}{\sqrt{2m_A q_A V_A}} = \sqrt{\frac{4m.q.2500}{m.q.50}} \\ &= 2\sqrt{50} = 2 \times 7.07 = 14.14 \end{aligned}$$

11. (d) de-Broglie wavelength,

$$\lambda = \frac{h}{mv} = 10^{-3} \left(\frac{3 \times 10^8}{6 \times 10^{14}} \right) \quad \left[\because \lambda = \frac{c}{v} \right]$$

$$v = \frac{6.63 \times 10^{-34} \times 6 \times 10^{14}}{9.1 \times 10^{-31} \times 3 \times 10^5}$$

$$v = 1.45 \times 10^6 \text{ m/s}$$

12. (d) Using, $\lambda = \frac{h}{p}$ {given: $\lambda = 7.5 \times 10^{-12}$ }

$$\Rightarrow P = \frac{h}{\lambda}$$

Minimum energy required,

$$KE = \frac{p^2}{2m} = \frac{(h/\lambda)^2}{2m} = \frac{\left\{ \frac{6.6 \times 10^{-34}}{7.5 \times 10^{-12}} \right\}^2}{2 \times 9.1 \times 10^{-31}} \text{ J} = 25 \text{ keV}$$

13. (c) Momentum (p) of each electron $\frac{h}{\lambda_1} \hat{i}$ and $\frac{h}{\lambda_2} \hat{j}$

Velocity of centre of mass

$$V_{cm} = \frac{h}{2m\lambda_1} \hat{i} + \frac{h}{2m\lambda_2} \hat{j} \quad (\because p = mv)$$

Velocity of 1st particle about centre of mass

$$V_{1cm} = \frac{h}{2m\lambda_1} \hat{i} - \frac{h}{2m\lambda_2} \hat{j}$$

$$\lambda_{cm} = \frac{h}{\sqrt{\frac{h^2}{4\lambda_1^2} + \frac{h^2}{4\lambda_2^2}}} = \frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2 + \lambda_2^2}} \quad \left(\because \lambda = \frac{h}{p} \right)$$

14. (c) According to question, $\lambda_p = \lambda_\alpha$

$$\text{Using, } \lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\text{So, } \frac{h}{m_p \times v_p} = \frac{h}{m_\alpha \times v_\alpha}$$

$$\Rightarrow \frac{v_p}{v_\alpha} = \frac{m_\alpha}{m_p} = \frac{4m_p}{m_p}$$

($\because$ mass of α -particle is 4 times of mass of proton)

$$\text{So, } \frac{v_p}{v_\alpha} = \frac{4}{1}; \text{ i.e., } 4:1$$

15. (d) From question, $m_A = M; m_B = \frac{m}{2}$

$$u_A = V \quad u_B = 0$$

Let after collision velocity of A = V_1 and

velocity of B = V_2

Applying law of conservation of momentum,

$$mu = mv_1 + \left(\frac{m}{2}\right)v_2$$

$$\text{or, } 24 = 2v_1 + v_2 \dots (i)$$

By law of collision

$$e = \frac{v_2 - v_1}{u - 0}$$

$$\text{or, } u = v_2 - v_1 \dots (ii)$$

[$\because$ collision is elastic, $e = 1$]

using eqns (i) and (ii)

$$v_1 = \frac{4}{3} \text{ and } v_2 = \frac{4}{3}u$$

$$\text{de-Broglie wavelength } \lambda = \frac{h}{p}$$

$$\therefore \frac{\lambda_A}{\lambda_B} = \frac{P_B}{P_A} = \frac{\frac{m}{2} \times \frac{4}{3}u}{m \times \frac{4}{3}} = 2$$

16. (a) From Bragg's equation

$$d \sin \theta = \lambda$$

$$\sin \theta = \frac{\lambda}{d} < 1 \quad \therefore \lambda < d$$

$$\frac{h}{|p_y|} < d \quad \left[\because \lambda = \frac{h}{|p_y|} \right]$$

$$\therefore h < |p_y| d$$

17. (c) de-Broglie wavelength,

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

$$\text{or, } \lambda = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 50}} = 1.7 \text{ \AA}$$

18. (d) Among the given particles most difficult to experimentally verify the de-broglie relationship is for a dust particle.

19. (d) Energy in joule (E)

= charge $\times$ potential diff. in volt

$$E_{\text{electron}} = q_e V \text{ and } E_{\text{proton}} = q_p 4V$$

$$\text{de-Broglie wavelength } \lambda = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$$

$$\lambda_e = \frac{h}{\sqrt{2m_e eV}} \text{ and } \lambda_p = \frac{h}{\sqrt{2m_p e4V}} \quad (\because q_e = q_p)$$

$$\therefore \frac{\lambda_e}{\lambda_p} = \frac{\frac{h}{\sqrt{2m_e eV}}}{\frac{h}{\sqrt{2m_p e4V}}} = \sqrt{\frac{2m_p e4V}{2m_e eV}} = 2\sqrt{\frac{m_p}{m_e}}$$

20. (d) de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{mv} \quad \dots (i)$$

$$\text{but } K.E = \frac{1}{2}mv^2$$

$$\Rightarrow K.E = \frac{(mv)^2}{2m}$$

$$\Rightarrow mv = \sqrt{2m K.E}$$

$$\lambda = \frac{h}{\sqrt{2m K.E}}$$

$$\therefore \lambda \propto \frac{1}{\sqrt{K.E}}$$

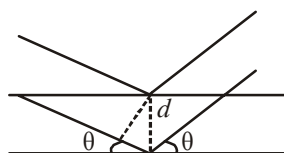
So, if K.E. is doubled, wavelength becomes $\frac{\lambda}{\sqrt{2}}$

21. (a) Covalent bonds are formed by sharing of electrons with different compounds. Formation of covalent bond is best explained by molecular orbital theory.

22. (50)

From Bragg's equation $2d \sin \theta = \lambda$ and de-Broglie

wavelength, $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$



$$2d \sin \theta = \lambda = \frac{h}{\sqrt{2mE}}$$

$$\Rightarrow 2 \times 10^{-10} \times \frac{\sqrt{3}}{2} = \frac{6.6 \times 10^{-34}}{\sqrt{2mE}}$$

$$[\because \theta = 60^\circ \text{ and } d = 1 \text{ \AA} = 1 \times 10^{-10} \text{ m}]$$

$$\therefore E = \frac{1}{2} \times \frac{6.64^2 \times 10^{-48}}{9.1 \times 10^{-31} \times 3 \times 1.6 \times 10^{-19}} \approx 50 \text{ eV}$$

23. 2

From the Einstein's photoelectric equation

Energy of photon

= Kinetic energy of photoelectrons + Work function

$\Rightarrow$ Kinetic energy = Energy of Photon – Work Function

Let ϕ_0 be the work function of metal and v_1 and v_2 be the velocity of photoelectrons. Using Einstein's photoelectric equation we have

$$\frac{1}{2}mv_1^2 = 4 - \phi_0 \quad \dots(i)$$

$$\frac{1}{2}mv_2^2 = 2.5 - \phi_0 \quad \dots(ii)$$

$$\Rightarrow \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{4 - \phi_0}{2.5 - \phi_0}$$

$$\Rightarrow (2)^2 = \frac{4 - \phi_0}{2.5 - \phi_0} \Rightarrow 10 - 4\phi_0 = 4 - \phi_0$$

$$\phi_0 = 2 \text{ eV}$$

24. (a) Graph of V_s and f given at B (5.5, 0)
Minimum energy for ejection of electron
= Work function (ϕ).

$$\phi = hV \text{ joule or } \phi = \frac{hV}{e} \text{ eV (for } V=0)$$

$$\therefore \phi = \frac{6.62 \times 10^{-34} \times 5.5 \times 10^{14}}{1.6 \times 10^{-19}} \text{ eV} = 2.27 \text{ eV}$$

25. (d) According to Einstein's photoelectric equation

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

$$\Rightarrow eV_s = \frac{hc}{\lambda} - \phi_0$$

$$\Rightarrow V_s = \frac{hc}{\lambda e} - \frac{\phi_0}{e}$$

where λ = wavelength of incident light

ϕ_0 = work function

V_s = stopping potential

Comparing the above equation with $y = mx + c$, we get

$$\text{slope} = \frac{hc}{e}$$

Increasing the frequency of incident radiation has no effect on work function and frequency. So, graph will not change.

26. (d) Using equation, $= \frac{hc}{\lambda} - \phi$

$$KE_{\max} = \frac{hc}{\lambda} - \phi = \frac{hc}{500} - \phi \quad \dots(1)$$

$$\text{Again, } 3KE_{\max} = \frac{hc}{200} - \phi \quad \dots(2)$$

Dividing equation (2) by (1),

$$\frac{3KE_{\max}}{KE_{\max}} = \frac{3}{1} = \frac{\frac{hc}{200} - \phi}{\frac{hc}{500} - \phi}$$

Putting the value of $hc = 1237.5$ and solving we get, work function, $\phi = 0.61 \text{ eV}$.

27. (a) Given,

Wavelength of X-rays, $\lambda_1 = 1 \text{ nm} = 1 \times 10^{-9} \text{ m}$

Wavelength of visible light, $\lambda_2 = 500 \times 10^{-9} \text{ m}$

The number of photons emitted per second from a source of monochromatic radiation of wavelength λ and power P is given as

$$n = \frac{P}{E} = \frac{P}{h\nu} = \frac{P\lambda}{hc} \quad (\because E = h\nu \text{ and } \nu = \frac{c}{\lambda})$$

$\Rightarrow$ Clearly $n \propto \lambda$

$$\Rightarrow \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{500}$$

28. (9)

When radiation of wavelength λ_A is used to illuminate, stopping potential $V_A = V$

$$\frac{hc}{\lambda} = \phi + eV \quad \dots(i)$$

When radiation of wavelength B , λ_B is used to illuminate,

stopping potential, $V_B = \frac{V}{4}$

$$\frac{hc}{3\lambda} = \phi + \frac{eV}{4} \quad \dots(ii)$$

From eq. (i) – (ii),

$$\frac{hc}{\lambda} \left(1 - \frac{1}{3}\right) = \frac{3}{4} eV$$

$$\Rightarrow \frac{hc}{\lambda} \frac{2}{3} = \frac{3}{4} eV \Rightarrow eV = \frac{8}{9} \frac{hc}{\lambda}$$

$$\frac{hc}{\lambda} = \phi + \frac{8}{9} \frac{hc}{\lambda}$$

$$\therefore \phi = \frac{hc}{9\lambda} = \frac{hc}{n\lambda}, \text{ so, } n = 9.$$

29. (a) Using Einstein's photoelectric equation,

$$E = \omega_0 + KE_{\max}$$

$$\Rightarrow \omega_0 = KE_{\max} - E$$

$$p = \sqrt{2mKE} \Rightarrow KE = \frac{p^2}{2m}$$

$$r = \frac{p}{eB} \Rightarrow p = reB$$

$$K_{\max} = \frac{r^2 e^2 B^2}{2m} \quad KE_{\max} = \frac{12420}{\lambda} - \omega_0$$

$$\Rightarrow \omega_0 = \frac{12420}{6561} - \frac{r^2 e^2 B^2}{2m} \text{ (In eV)}$$

$$= 1.89 \text{ (eV)} - \frac{(10^{-4})(1.6 \times 10^{-19})^2 \times 9 \times 10^5}{2 \times 9.07 \times 10^{-31}}$$

$$= 1.89 \text{ (eV)} - \frac{(10^{-4})(1.6 \times 10^{-19})^2 \times 9 \times 10^5}{2 \times 9.07 \times 10^{-31}}$$

$$= (1.89 - 0.79) \text{ eV} = 1.1 \text{ eV}$$

30. (a) de-Broglie wavelength (λ),

$$\text{Momentum, } mv = \frac{h}{\lambda} = p = \sqrt{2m(KE)}$$

$$\therefore \lambda = \frac{h}{\sqrt{2mKE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{KE}}$$

$$\therefore \frac{\lambda_A}{\lambda_B} = \sqrt{\frac{K_B}{K_A}} = \sqrt{\frac{T_A - 1.5}{T_A}} \quad (\text{as given})$$

$$\text{Also, } \frac{\lambda_A}{\lambda_B} = \frac{1}{2}$$

On solving we get, $T_A = 2 \text{ eV}$

$$\therefore KE_B = T_A - 1.5 = 2 - 1.5 = 0.5 \text{ eV}$$

$\therefore$ Work function of metal B is

$$\phi_B = E_B - KE_B = 4.5 - 0.5 = 4 \text{ eV}$$

31. (11.00) Energy of proton

$$E = \frac{hc}{\lambda} = \frac{1240}{310} = 4 \text{ eV} > 2 \text{ eV } [= \phi]$$

(so emission of photoelectron will take place)

$$= 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19} \text{ joule}$$

$$N = \frac{6.4 \times 10^{-5} \times 1}{4 \times 6.4 \times 10^{-19}} = 10^{14}$$

No. of photoelectrons emitted per second

$$= \frac{10^{14}}{10^3} = 10^{11} \quad (\because 1 \text{ in } 10^3 \text{ photons ejects an electron})$$

$\therefore$ Value of $X = 11.00$

32. (b) $f_0 = 4 \times 10^{14} \text{ Hz}$

$$W_0 = hf_0 = 6.63 \times 10^{-34} \times (4 \times 10^{14}) \text{ J}$$

$$= \frac{(6.63 \times 10^{-34}) \times (4 \times 10^{14})}{1.6 \times 10^{-19}}$$

$$= 1.66 \text{ eV}$$

33. (a) $KE_{\max} = E - \phi_0$

(where E = energy of incident light ϕ_0 = work function)

$$= \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$= 1237 \left[\frac{1}{260} - \frac{1}{380} \right]$$

$$= \frac{1237 \times 120}{380 \times 260} = 1.5 \text{ eV}$$

34. (a) Energy of photon (E) is given by

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

Number of photons of wavelength λ emitted in t second from laser of power P is given by

$$n = \frac{Pt\lambda}{hc}$$

$$\Rightarrow n = \frac{2 \times \lambda}{hc} = \frac{2 \times 10^{-3} \times 5 \times 10^{-7}}{2 \times 10^{-25}} \quad (\because t = 1 \text{ S})$$

$$\Rightarrow n = 5 \times 10^{15}$$

35. (c) Here $w = 2\pi \times 6 \times 10^{14}$ or $f = 6 \times 10^{14} \text{ Hz}$

$$\text{Wavelength } \lambda = \frac{c}{f} = \frac{3 \times 10^8}{6 \times 10^{14}} = 0.5 \times 10^{-6} \text{ m} = 5000 \text{ \AA}$$

$$\text{Now } E = \frac{12374}{5000} = 2.48 \text{ eV}$$

Using $E = w + eV_s$

$$2.48 = 2 + eV_s \text{ or } V_s = 0.48 \text{ V}$$

36. (BONUS)

37. (d) Using, wavelength, $\lambda = \frac{12375}{\Delta E}$

$$\text{or, } \lambda = \frac{12375}{4.9} \approx 250 \text{ nm}$$

38. (c) Let ϕ = work function of the metal,

$$\frac{hc}{\lambda_1} = \phi + eV_1 \quad \dots (i)$$

$$\frac{hc}{\lambda_2} = \phi + eV_2 \quad \dots (ii)$$

Subtracting (ii) from (i) we get

$$hc \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2} \right) = e(V_1 - V_2)$$

$$\Rightarrow V_1 - V_2 = \frac{hc}{e} \left(\frac{\lambda_2 - \lambda_1}{\lambda_1 \lambda_2} \right) \left[\begin{array}{l} \lambda_1 = 300 \text{ nm} \\ \lambda_2 = 400 \text{ nm} \\ \frac{hc}{e} = 1240 \text{ nm} \cdot \text{V} \end{array} \right]$$

$$= (1240 \text{ nm} \cdot \text{V}) \left(\frac{100 \text{ nm}}{300 \text{ nm} \times 400 \text{ nm}} \right)$$

$$= 1.03 \text{ V} \approx 1 \text{ V}$$

39. (c) using, intensity $I = \frac{nE}{At}$

n = no. of photoelectrons

$$\Rightarrow 16 \times 10^{-3} = \left(\frac{n}{t} \right) \times \frac{10 \times 1.6 \times 10^{-19}}{10^{-4}} \quad \text{or, } \frac{n}{t} = 10^{12}$$

So, effective number of photoelectrons ejected per unit time = $10^{12} \times 10/100 = 10^{11}$

40. (a) From Einstein's photoelectric equation,

$$\frac{hc}{\lambda_1} = \phi + \frac{1}{2} m (2v)^2 \quad \dots (i)$$

$$\text{and } \frac{hc}{\lambda_2} = \phi + \frac{1}{2} mv^2 \quad \dots (ii)$$

As per question, maximum speed of photoelectrons in two cases differ by a factor 2

From eqn. (i) & (ii)

$$\Rightarrow \frac{\frac{hc}{\lambda_1} - \phi}{\frac{hc}{\lambda_2} - \phi} = 4 \Rightarrow \frac{hc}{\lambda_1} - \phi = \frac{4hc}{\lambda_2} - 4\phi$$

$$\Rightarrow \frac{4hc}{\lambda_2} - \frac{hc}{\lambda_1} = 3\phi \Rightarrow \phi = \frac{1}{3} hc \left(\frac{4}{\lambda_2} - \frac{1}{\lambda_1} \right)$$

$$= \frac{1}{3} \times 1240 \left(\frac{4 \times 350 - 540}{350 \times 540} \right) = 1.8 \text{ eV}$$

41. (d) According to question, there are two EM waves with different frequency,

$$B_1 = B_0 \sin(\pi \times 10^7 c)t$$

$$\text{and } B_2 = B_0 \sin(2\pi \times 10^7 c)t$$

To get maximum kinetic energy we take the photon with higher frequency

$$\text{using, } B = B_0 \sin \omega t \text{ and } \omega = 2\pi\nu \Rightarrow \nu = \frac{\omega}{2\pi}$$

$$B_1 = B_0 \sin(\pi \times 10^7 c)t \Rightarrow \nu_1 = \frac{10^7}{2} \times c$$

$$B_2 = B_0 \sin(2\pi \times 10^7 c)t \Rightarrow \nu_2 = 10^7 c$$

where c is speed of light $c = 3 \times 10^8 \text{ m/s}$

Clearly, $\nu_2 > \nu_1$

so KE of photoelectron will be maximum for photon of higher energy.

$$\nu_2 = 10^7 c \text{ Hz}$$

$$h\nu = \phi + \text{KE}_{\text{max}}$$

energy of photon

$$E_{\text{ph}} = h\nu = 6.6 \times 10^{-34} \times 10^7 \times 3 \times 10^8$$

$$E_{\text{ph}} = 6.6 \times 3 \times 10^{-19} \text{ J}$$

$$= \frac{6.6 \times 3 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 12.375 \text{ eV}$$

$$\text{KE}_{\text{max}} = E_{\text{ph}} - \phi$$

$$= 12.375 - 4.7 = 7.675 \text{ eV} \approx 7.7 \text{ eV}$$

42. (c) In X-ray tube, $\lambda_{\text{min}} = \frac{hc}{eV}$

$$\ln \lambda_{\text{min}} = \ln \left(\frac{hc}{e} \right) - \ln V$$

Clearly, $\log \lambda_{\text{min}}$ versus $\log V$ graph

slope is negative hence option (c) correctly depicts.

43. (a) Given, $\lambda = 660 \text{ nm}$, Power = 0.5 kW , $t = 60 \text{ ms}$

$$\text{Power } P = \frac{nhc}{\lambda t} \Rightarrow n = \frac{P\lambda t}{hc}$$

$$= 0.5 \times 10^3 \times \frac{660 \times 10^{-9} \times 60 \times 10^{-3}}{6.6 \times 10^{-34} \times 3 \times 10^8}$$

$$= 100 \times 10^{18} = 10^{20}$$

44. (c) As the metal surface is same, work function (ϕ) is same for both the case.

$$\text{Initially } \text{KE}_{\text{max}} = nh - \phi \quad \dots (i)$$

After increase

$$\text{KE}'_{\text{max}} = 3nh - \phi \quad \dots (ii)$$

For work function ϕ – not to be –ve or zero, $\nu' > \sqrt{3}\nu$

45. (c) $h \frac{c}{\lambda} - h\nu_0 = \frac{1}{2}mv^2$

$$\therefore \frac{4}{3} \frac{hc}{\lambda} - h\nu_0 = \frac{1}{2}mv'^2$$

$$\therefore \frac{v'^2}{v^2} = \frac{\frac{4}{3}v - v_0}{v - v_0} \therefore v' = v \sqrt{\frac{\frac{4}{3}v - v_0}{v - v_0}}$$

$$\therefore v' > v \sqrt{\frac{4}{3}}$$

46. (a) From Einstein's photoelectric equation

$$K.E._\lambda = \frac{hc}{\lambda} - \phi \quad \dots(i)$$

(for monochromatic light of wavelength λ)

where ϕ is work function

$$K.E._{\lambda/2} = \frac{hc}{\lambda/2} - \phi \quad \dots(ii)$$

(for monochromatic light of wavelength $\lambda/2$)

From question,

$$K.E._{\lambda/2} = 3(K.E._\lambda) \Rightarrow \frac{hc}{\lambda/2} - \phi = 3\left(\frac{hc}{\lambda} - \phi\right)$$

$$\frac{2hc}{\lambda} - \phi = 3\frac{hc}{\lambda} - 3\phi$$

$$\Rightarrow 2\phi = \frac{hc}{\lambda} \therefore \phi = \frac{hc}{2\lambda}$$

47. (None)

From Einstein's photoelectric equation, we have

$$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_0} + eV \quad \dots(1)$$

$$\frac{hc}{\lambda_2} = \frac{hc}{\lambda_0} + eV \quad \dots(2)$$

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_0} + 3eV' \quad \dots(3)$$

From equation (1) & (2)

$$\frac{3}{2\lambda_1} - \frac{2}{2\lambda_2} = \frac{1}{\lambda_0}$$

$$\frac{hc}{\lambda_1} - hc \left[\frac{3}{2\lambda_1} - \frac{1}{2\lambda_2} \right] = eV'$$

$$\frac{hc}{e} \left[\frac{1}{\lambda_3} - \frac{3}{2\lambda_1} + \frac{1}{2\lambda_2} \right] = V'$$

48. (a) Frank-Hertz experiment - Discrete energy levels of atom, Photoelectric effect - Particle nature of light.
Davison - Germer experiment - wave nature of electron.

49. (b) Given, $\lambda_1 = 4972 \text{ \AA}$

and $\lambda_2 = 6216 \text{ \AA}$

and $I = 3.6 \times 10^{-3} \text{ Wm}^{-2}$

Intensity associated with each wavelength

$$= \frac{3.6 \times 10^{-3}}{2}$$

$$= 1.8 \times 10^{-3} \text{ Wm}^{-2}$$

work function $\phi = h\nu$

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

$$= \frac{(6.62 \times 10^{-34})(3 \times 10^8)}{\lambda}$$

$$= \frac{12.4 \times 10^3}{\lambda} \text{ eV}$$

for different wavelengths

$$\phi_1 = \frac{12.4 \times 10^3}{\lambda_1} = \frac{12.4 \times 10^3}{4972} = 2.493 \text{ eV} = 3.984 \times 10^{-19} \text{ J}$$

$$\phi_2 = \frac{12.4 \times 10^3}{\lambda_2} = \frac{12.4 \times 10^3}{6216} = 1.994 \text{ eV} = 3.184 \times 10^{-19} \text{ J}$$

J

Work function for metallic surface $\phi = 2.3 \text{ eV}$ (given)

$\phi_2 < \phi$

Therefore, ϕ_2 will not contribute in this process.

Now, no. of electrons per $\text{m}^2\text{-s}$ = no. of photons per $\text{m}^2\text{-s}$

$$\text{no. of electrons per } \text{m}^2\text{-s} = \frac{1.8 \times 10^{-3}}{3.984 \times 10^{-19}} \times 10^{-4}$$

$$\left(\because 1 \text{ cm}^2 = 10^{-4} \text{ m}^2 \right) = 0.45 \times 10^{12}$$

So, the number of photo electrons liberated in 2 sec.

$$= 0.45 \times 10^{12} \times 2$$

$$= 9 \times 10^{11}$$

50. (b)

51. (d) As λ is increased, there will be a value of λ above which photoelectrons will cease to come out so photocurrent will become zero. Hence (d) is correct answer.

52. (d) $\frac{hc}{\lambda} - \phi = eV_0$

$$v_0 = \frac{hc}{e\lambda} - \frac{\phi}{e}$$

For metal A

For metal B

$$\frac{\phi_A}{hc} = \frac{1}{\lambda}$$

$$\frac{\phi_B}{hc} = \frac{1}{\lambda}$$

As the value of $\frac{1}{\lambda}$ (increasing and decreasing) is not specified hence we cannot say that which metal has comparatively greater or lesser work function (ϕ).

53. (a)

54. (a) Davisson Germer experiment showed that electron beams can undergo diffraction when passed through atomic crystal. This established wave nature of electron as waves can exhibit interference and diffraction.

55. (c) According to photo-electric equation :
 $K.E_{\max} = h\nu - h\nu_0$ (Work function)
 Some sort of energy is used in ejecting the photoelectrons.
56. (b) The maximum kinetic energy of photoelectrons depends upon frequency on incident light and photo current depends upon intensity of incident light.
57. (c) By Einstein photoelectric equation,
 $K_{\max} = eV_0 = h\nu - h\nu_0$
 When ν is doubled, $K_{\max}$ and V_0 become more than double.
58. (d) We know that
 $eV_0 = K_{\max} = h\nu - \phi$
 where, ϕ is the work function.
 X-rays have higher frequency (ν) than ultraviolet rays. Therefore as ν increases $K.E$ and V_0 both increases.
 The kinetic energy ranges from zero to maximum because of loss of energy due to subsequent collisions before getting ejected.
59. (a) Wavelength of incident light, $\lambda = 400 \text{ nm}$ $hc = 1240 \text{ eV}\cdot\text{nm}$
 $K.E = 1.68 \text{ eV}$
 Using Einstein's photoelectric equation

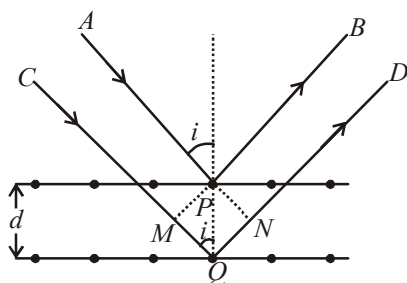
$$\frac{hc}{\lambda} - W = K.E$$

$$\Rightarrow W = \frac{hc}{\lambda} - K.E$$

$$\Rightarrow W = \frac{1240}{400} - 1.68$$

$$= 3.1 - 1.68$$

$$= 1.41 \text{ eV}$$
60. (b) The path difference between the rays APB and CQD is
 $\Delta x = MQ + QN = d \cos i + d \cos i$
 $\Delta x = 2d \cos i$



For constructive interference the path difference is integral multiple of wavelength

$$\therefore n\lambda = 2d \cos i$$

From de-broglie concept

Wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK.E}} = \frac{h}{\sqrt{2meV}}$$

$$\therefore \frac{nh}{\sqrt{2meV}} = 2d \cos i$$

Squaring both side

$$\frac{n^2 h^2}{2meV} = 4d^2 \cos^2 i$$

For first order interference $n = 1$

$$\therefore V = \frac{h^2}{8med^2 \cos^2 i}$$

$$= \frac{(6.6 \times 10^{-34})^2}{8 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times (10^{-10})^2 \times \cos^2 30}$$

$$= 50 \text{ V}$$

61. (b) For constructive interference,
 $2d \cos i = n\lambda_{dB}$
62. (a) Energy of a photon of frequency ν is given by
 $E = h\nu$.
 Also, $E = mc^2$, $mc^2 = h\nu$
 $\Rightarrow mc = \frac{h\nu}{c} \Rightarrow p = \frac{h\nu}{c}$
63. (a) Work function, $\phi = 6.2 \text{ eV} = 6.2 \times 1.6 \times 10^{-19} \text{ J}$
 Stopping potential, $V = 5 \text{ volt}$
 From the Einstein's photoelectric equation

$$\frac{hc}{\lambda} - \phi = eV_0$$

$$\Rightarrow \lambda = \frac{hc}{\phi + eV_0}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} (6.2 + 5)} \approx 10^{-7} \text{ m}$$

This range lies in ultra violet range.

64. (b) The photoelectric emission is an instantaneous process without any apparent time lag. It is known that emission starts in the time of the order of 10^{-9} second. So, the approximate time taken by a photoelectron to come out after the photon strikes is 10^{-10} second.
65. (b) As λ decreases, y increases and hence the speed of photoelectron increases. The chances of photo electron to meet the anode increases and hence photo electric current increases.
66. (a) $I \propto \frac{I}{r^2}$; $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2 = \frac{1}{4}$
 $I_2 \rightarrow 4 \text{ times } I_1$
 When intensity becomes 4 times, no. of photoelectrons emitted would increase by 4 times, since number of electrons emitted per second is directly proportional to intensity.

67. (b) Momentum of photon of energy E is $= \frac{E}{c}$

When a photon hits a perfectly reflecting surface, it reflects back in opposite direction with same energy and momentum.

$$\therefore \text{Change in momentum} = \frac{E}{C} - \left(\frac{-E}{C} \right) = \frac{2E}{C}$$

This is equal to momentum transferred to the surface.

68. (d) From the Einstein photoelectric equation $K.E. = h\nu - \phi$

Here, ϕ = work function of metal

h = Planck's constant

slope of graph of $K.E.$ & ν is h (Planck's constant) which is same for all metals.

69. (a) Work function of metal (ϕ) is given by

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

$$\Rightarrow \lambda = \frac{hc}{\phi}$$

$$\Rightarrow \lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4 \times 1.6 \times 10^{-19}} = 310 \text{ nm}$$

70. (a) Let work function be W and ν_1 and ν_2 be the velocity of electrons for frequencies f_1 and f_2 .

Using Einstein's photo electric equation for one photodiode, we get

$$hf_1 - W = \frac{1}{2} m \nu_1^2 \quad \dots(i)$$

Using Einstein's photo electric equation for another photodiode we get,

$$hf_2 - W = \frac{1}{2} m \nu_2^2 \quad \dots(ii)$$

Subtracting (ii) from (i) we get

$$(hf_1 - W) - (hf_2 - W) = \frac{1}{2} m \nu_1^2 - \frac{1}{2} m \nu_2^2$$

$$\therefore h(f_1 - f_2) = \frac{m}{2} (\nu_1^2 - \nu_2^2)$$

$$\therefore \nu_1^2 - \nu_2^2 = \frac{2h}{m} (f_1 - f_2)$$

71. (c) We know that work function,

$$E = h\nu = \frac{hC}{\lambda}$$

where

h = Planck's constant

C = velocity of light

λ = wavelength of light

$$\therefore \frac{E_{\text{Na}}}{E_{\text{Cu}}} = \frac{\lambda_{\text{Cu}}}{\lambda_{\text{Na}}}$$

$$\Rightarrow \frac{\lambda_{\text{Na}}}{\lambda_{\text{Cu}}} = \frac{E_{\text{Cu}}}{E_{\text{Na}}} = \frac{4.5}{2.3} \approx \frac{2}{1}$$