CHAPTER 11

# Dual Nature of Radiation and Matter

## 11.1 Introduction

1. A beam of cathode rays is subjected to crossed electric ($E$) and magnetic fields ($B$). The fields are adjusted such that the beam is not deflected. The specific charge of the cathode rays is given by
(a) $\frac{B^2}{2VE^2}$ (b) $\frac{2VB^2}{E^2}$ (c) $\frac{2VE^2}{B^2}$ (d) $\frac{E^2}{2VB^2}$ *(2010)*
(Where $V$ is the potential difference between cathode and anode)

2. In the phenomenon of electric discharge through gases at low pressure, the coloured glow in the tube appears as a result of
(a) collisions between the charged particles emitted from the cathode and the atoms of the gas
(b) collision between different electrons of the atoms of the gas
(c) excitation of electrons in the atoms
(d) collision between the atoms of the gas. *(2008)*

3. In a discharge tube ionization of enclosed gas is produced due to collisions between
(a) neutral gas atoms/molecules
(b) positive ions and neutral atoms/molecules
(c) negative electrons and neutral atoms/molecules
(d) photons and neutral atoms/molecules. *(2006)*

4. J.J. Thomson's cathode-ray tube experiment demonstrated that
(a) cathode rays are streams of negatively charged ions
(b) all the mass of an atom is essentially in the nucleus
(c) the $e/m$ of electrons is much greater than the $e/m$ of protons
(d) the $e/m$ ratio of the cathode-ray particles changes when a different gas is placed in the discharge tube *(2003)*

5. Which of the following is not the property of cathode rays ?
(a) It produces heating effect.
(b) It does not deflect in electric field.
(c) It casts shadow.
(d) It produces fluorescence. *(2002)*

6. Who evaluated the mass of electron indirectly with help of charge?
(a) Thomson (b) Millikan
(c) Rutherford (d) Newton *(2000)*

7. In a discharge tube at 0.02 mm, there is formation of
(a) Crooke's dark space (b) Faraday's dark space
(c) both space partly (d) none of these. *(1996)*

## 11.2 Electron Emission

8. In which of the following, emission of electrons does not take place
(a) thermionic emission (b) $X$-rays emission
(c) photoelectric emission
(d) secondary emission *(1990)*

9. Thermions are
(a) protons (b) electrons
(c) photons (d) positrons. *(1988)*

## 11.4 Experimental Study of Photoelectric Effect

10. A source of light is placed at a distance of 50 cm from a photo cell and the stopping potential is found to be $V_0$. If the distance between the light source and photo cell is made 25 cm, the new stopping potential will be :
(a) $V_0/2$ (b) $V_0$ (c) $4V_0$ (d) $2V_0$
*(Karnataka NEET 2013)*

11. Photoelectric emission occurs only when the incident light has more than a certain minimum
(a) power (b) wavelength
(c) intensity (d) frequency *(2011)*

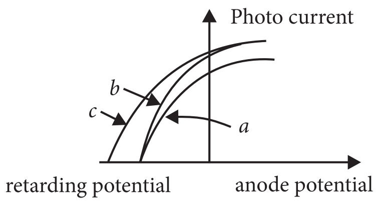
12. In photoelectric emission process from a metal of work function 1.8 eV, the kinetic energy of most energetic electrons is 0.5 eV. The corresponding stopping potential is
(a) 1.8 V (b) 1.3 V
(c) 0.5 V (d) 2.3 V *(2011)*

13. When monochromatic radiation of intensity $I$ falls on a metal surface, the number of photoelectrons

and their maximum kinetic energy are $N$ and $T$ respectively. If the intensity of radiation is $2I$, the number of emitted electrons and their maximum kinetic energy are respectively
(a) $N$ and $2T$ (b) $2N$ and $T$
(c) $2N$ and $2T$ (d) $N$ and $T$
*(Mains 2010)*

**14.** The number of photo electrons emitted for light of a frequency $\upsilon$ (higher than the threshold frequency $\upsilon_0$) is proportional to
(a) threshold frequency ($\upsilon_0$)
(b) intensity of light
(c) frequency of light ($\upsilon$)
(d) $\upsilon - \upsilon_0$ *(2009)*

**15.** The figure shows a plot of photo current versus anode potential for a photo sensitive surface for three different radiations. Which one of the following is a correct statement?




(a) Curves (a) and (b) represent incident radiations of same frequency but of different intensities.
(b) Curves (b) and (c) represent incident radiations of different frequencies and different intensities.
(c) Curves (b) and (c) represent incident radiations of same frequency having same intensity.
(d) Curves (a) and (b) represent incident radiations of different frequencies and different intensities
*(2009)*

**16.** A 5 watt source emits monochromatic light of wavelength 5000 Å. When placed 0.5 m away, it liberates photoelectrons from a photosensitive metallic surface. When the source is moved to a distance of 1.0 m, the number of photoelectrons liberated will be reduced by a factor of
(a) 8 (b) 16 (c) 2 (d) 4 *(2007)*

**17.** A photocell employs photoelectric effect to convert
(a) change in the frequency of light into a change in the electric current
(b) change in the frequency of light into a change in electric voltage
(c) change in the intensity of illumination into a change in photoelectric current
(d) change in the intensity of illumination into a change in the work function of the photocathode. *(2006)*

**18.** A photoelectric cell is illuminated by a point source of light 1 m away. When the source is shifted to 2 m then
(a) each emitted electron carries one quarter of the initial energy
(b) number of electrons emitted is half the initial number
(c) each emitted electron carries half the initial energy
(d) number of electrons emitted is a quarter of the initial number. *(2003)*

**19.** When ultraviolet rays incident on metal plate then photoelectric effect does not occur, it occurs by incidence of
(a) infrared rays (b) X-rays
(c) radio wave (d) micro wave. *(2002)*

**20.** A photo-cell is illuminated by a source of light, which is placed at a distance $d$ from the cell. If the distance become $d/2$, then number of electrons emitted per second will be
(a) remain same (b) four times
(c) two times (d) one-fourth. *(2001)*

**21.** As the intensity of incident light increases
(a) kinetic energy of emitted photoelectrons increases
(b) photoelectric current decreases
(c) photoelectric current increases
(d) kinetic energy of emitted photoelectrons decreases. *(1999)*

**22.** Which of the following statement is correct?
(a) The photocurrent increases with intensity of light.
(b) The stopping potential increases with increase of incident light.
(c) The current in photocell increases with increasing frequency.
(d) The photocurrent is proportional to the applied voltage. *(1997)*

**23.** Number of ejected photoelectrons increases with increase
(a) in intensity of light (b) in wavelength of light
(c) in frequency of light (d) never. *(1993)*

**24.** The cathode of a photoelectric cell is changed such that the work function changes from $W_1$ to $W_2$ ($W_2 > W_1$). If the current before and after changes are $I_1$ and $I_2$, all other conditions remaining unchanged, then (assuming $h\upsilon > W_2$)
(a) $I_1 = I_2$ (b) $I_1 < I_2$
(c) $I_1 > I_2$ (d) $I_1 < I_2 < 2I_1$ *(1992)*

## 11.5 Photoelectric Effect and Wave Theory of Light

**25.** Light of frequency 1.5 times the threshold frequency is incident on a photosensitive material. What will be the photoelectric current if the frequency is halved and intensity is doubled?
(a) Doubled (b) Four times
(c) One-fourth (d) Zero *(NEET 2020)*

## 11.6 Einstein's Photoelectric Equation : Energy Quantum of Radiation

**26.** The work function of a photosensitive material is 4.0 eV. The longest wavelength of light that can cause photon emission from the substance is (approximately)
(a) 3100 nm (b) 966 nm
(c) 31 nm (d) 310 nm
*(Odisha NEET 2019)*

**27.** When the light of frequency $2\upsilon_0$ (where $\upsilon_0$ is threshold frequency), is incident on a metal plate, the maximum velocity of electrons emitted is $v_1$. When the frequency of the incident radiation is increased to $5\upsilon_0$, the maximum velocity of electrons emitted from the same plate is $v_2$. The ratio of $v_1$ to $v_2$ is
(a) 1 : 2 (b) 1 : 4
(c) 4 : 1 (d) 2 : 1 *(NEET 2018)*

**28.** The photoelectric threshold wavelength of silver is $3250 \times 10^{-10}$ m. The velocity of the electron ejected from a silver surface by ultraviolet light of wavelength $2536 \times 10^{-10}$ m is [Given $h = 4.14 \times 10^{-15}$ eV s and $c = 3 \times 10^8$ m s$^{-1}$]
(a) $\approx 0.6 \times 10^6$ m s$^{-1}$ (b) $\approx 61 \times 10^3$ m s$^{-1}$
(c) $\approx 0.3 \times 10^6$ m s$^{-1}$ (d) $\approx 6 \times 10^5$ m s$^{-1}$
*(NEET 2017)*

**29.** Photons with energy 5 eV are incident on a cathode $C$ in a photoelectric cell. The maximum energy of emitted photoelectrons is 2 eV. When photons of energy 6 eV are incident on $C$, no photoelectrons will reach the anode $A$, if the stopping potential of $A$ relative to $C$ is
(a) +3 V (b) +4 V (c) −1 V (d) −3 V
*(NEET-II 2016)*

**30.** When a metallic surface is illuminated with radiation of wavelength $\lambda$, the stopping potential is $V$. If the same surface is illuminated with radiation of wavelength $2\lambda$, the stopping potential is $\frac{V}{4}$. The threshold wavelength for the metallic surface is
(a) $\frac{5}{2}\lambda$ (b) $3\lambda$ (c) $4\lambda$ (d) $5\lambda$
*(NEET-I 2016)*

**31.** A photoelectric surface is illuminated successively by monochromatic light of wavelength $\lambda$ and $\lambda/2$. 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 of the material is ($h$ = Planck's constant, $c$ = speed of light)
(a) $\frac{2hc}{\lambda}$ (b) $\frac{hc}{3\lambda}$ (c) $\frac{hc}{2\lambda}$ (d) $\frac{hc}{\lambda}$ *(2015)*

**32.** A certain metallic surface is illuminated with monochromatic light of wavelength, $\lambda$. The stopping potential for photoelectric current for this light is $3V_0$. If the same surface is illuminated with light of wavelength $2\lambda$, the stopping potential is $V_0$. The threshold wavelength for this surface for photoelectric effect is
(a) $\frac{\lambda}{4}$ (b) $\frac{\lambda}{6}$ (c) $6\lambda$ (d) $4\lambda$
*(2015 Cancelled)*

**33.** When the energy of the incident radiation is increased by 20%, the kinetic energy of the photoelectrons emitted from a metal surface increased from 0.5 eV to 0.8 eV. The work function of the metal is
(a) 0.65 eV (b) 1.0 eV
(c) 1.3 eV (d) 1.5 eV *(2014)*

**34.** For photoelectric emission from certain metal the cutoff frequency is $\upsilon$. If radiation of frequency $2\upsilon$ impinges on the metal plate, the maximum possible velocity of the emitted electron will be ($m$ is the electron mass)
(a) $\sqrt{\frac{2h\upsilon}{m}}$ (b) $2\sqrt{\frac{h\upsilon}{m}}$ (c) $\sqrt{\frac{h\upsilon}{(2m)}}$ (d) $\sqrt{\frac{h\upsilon}{m}}$
*(NEET 2013)*

**35.** Two radiations of photons energies 1 eV and 2.5 eV, successively illuminate a photosensitive metallic surface of work function 0.5 eV. The ratio of the maximum speeds of the emitted electrons is
(a) 1 : 4 (b) 1 : 2 (c) 1 : 1 (d) 1 : 5
*(Mains 2012, 2011)*

**36.** The threshold frequency for a photosensitive metal is $3.3 \times 10^{14}$ Hz. If light of frequency $8.2 \times 10^{14}$ Hz is incident on this metal, the cut-off voltage for the photoelectron emission is nearly
(a) 1 V (b) 2 V (c) 3 V (d) 5 V
*(Mains 2011)*

**37.** The potential difference that must be applied to stop the fastest photoelectrons emitted by a nickel surface, having work function 5.01 eV, when ultraviolet light of 200 nm falls on it, must be
(a) 2.4 V (b) −1.2 V (c) −2.4 V (d) 1.2 V
*(2010)*

**38.** The work function of a surface of a photosensitive material is 6.2 eV. The wavelength of the incident radiation for which the stopping potential is 5 V lies in the
(a) Infrared region (b) X-ray region
(c) Ultraviolet region (d) Visible region. *(2008)*

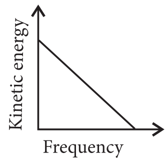
**39.** When photons of energy $h\upsilon$ fall on an aluminium plate (of work function $E_0$), photoelectrons of maximum kinetic energy $K$ are ejected. If the frequency of radiation is doubled, the maximum kinetic energy of the ejected photoelectrons will be
(a) $K + h\upsilon$ (b) $K + E_0$
(c) $2K$ (d) $K$ *(2006)*

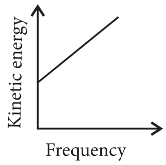
**40.** The work functions for metals $A$, $B$ and $C$ are respectively 1.92 eV, 2.0 eV and 5 eV. According to Einstein's equation the metals which will emit

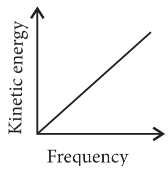
photoelectrons for a radiation of wavelength 4100 Å is/are
(a) *A* only (b) *A* and *B* only
(c) all the three metals (d) none. *(2005)*

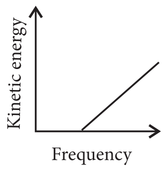
**41.** A photosensitive metallic surface has work function, $h\upsilon_0$. If photons of energy $2h\upsilon_0$ fall on this surface, the electrons come out with a maximum velocity of $4 \times 10^6$ m/s. When the photon energy is increased to $5h\upsilon_0$, then maximum velocity of photoelectrons will be
(a) $2 \times 10^7$ m/s (b) $2 \times 10^6$ m/s
(c) $8 \times 10^6$ m/s (d) $8 \times 10^5$ m/s *(2005)*

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

(a) 


(b) 


(c) 


(d) 


*(2004, 1996)*

**43.** The value of Planck's constant is
(a) $6.63 \times 10^{-34}$ J/sec (b) $6.63 \times 10^{-34}$ kg m$^2$/sec
(c) $6.63 \times 10^{-34}$ kg m$^2$ (d) $6.63 \times 10^{-34}$ J sec *(2002)*

**44.** By photoelectric effect, Einstein proved
(a) $E = h\upsilon$ (b) $\text{K.E.} = \frac{1}{2}mv^2$
(c) $E = mc^2$ (d) $E = \frac{-Rhc^2}{n^2}$ *(2000)*

**45.** The photoelectric work function for a metal surface is 4.125 eV. The cut-off wavelength for this surface is
(a) 3000 Å (b) 2062.5 Å
(c) 4125 Å (d) 6000 Å *(1999)*

**46.** In a photo-emissive cell, with exciting wavelength $\lambda$, the fastest electron has speed $v$. If the exciting wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be
(a) less than $v(4/3)^{1/2}$ (b) $v(4/3)^{1/2}$
(c) $v(3/4)^{1/2}$ (d) greater than $v(4/3)^{1/2}$ *(1998)*

**47.** When light of wavelength 300 nm (nanometer) falls on a photoelectric emitter, photoelectrons are liberated. For another emitter, however, light of 600 nm wavelength is sufficient for creating photoemission. What is the ratio of the work functions of the two emitters?
(a) 1 : 2 (b) 2 : 1
(c) 4 : 1 (d) 1 : 4 *(1993)*

**48.** Photoelectric work function of a metal is 1 eV. Light of wavelength $\lambda$ =3000 Å falls on it. The photo electrons come out with a maximum velocity
(a) 10 metres/sec (b) $10^2$ metres/ sec
(c) $10^4$ metres/sec (d) $10^6$ metres/sec *(1991)*

**49.** Ultraviolet radiations of 6.2 eV falls on an aluminium surface. Kinetic energy of fastest electron emitted is (work function = 4.2 eV)
(a) $3.2 \times 10^{-21}$ J (b) $3.2 \times 10^{-19}$ J
(c) $7 \times 10^{-25}$ J (d) $9 \times 10^{-32}$ J *(1989)*

**50.** The threshold frequency for photoelectric effect on sodium corresponds to a wavelength of 5000 Å. Its work function is
(a) $4 \times 10^{-19}$ J (b) 1 J
(c) $2 \times 10^{-19}$ J (d) $3 \times 10^{-19}$ J *(1988)*

## 11.7 Particle Nature of Light : The Photon

**51.** A 200 W sodium street lamp emits yellow light of wavelength 0.6 μm. Assuming it to be 25% efficient in converting electrical energy to light, the number of photons of yellow light it emits per second is
(a) $1.5 \times 10^{20}$ (b) $6 \times 10^{18}$
(c) $62 \times 10^{20}$ (d) $3 \times 10^{19}$ *(2012)*

**52.** A source $S_1$ is producing, $10^{15}$ photons per second of wavelength 5000 Å. Another source $S_2$ is producing $1.02 \times 10^{15}$ photons per second of wavelength 5100 Å. Then, (power of $S_2$)/(power of $S_1$) is equal to
(a) 1.00 (b) 1.02
(c) 1.04 (d) 0.98 *(2010)*

**53.** Monochromatic light of wavelength 667 nm is produced by a helium neon laser. The power emitted is 9 mW. The number of photons arriving per second on the average at a target irradiated by this beam is
(a) $3 \times 10^{16}$ (b) $9 \times 10^{15}$
(c) $3 \times 10^{19}$ (d) $9 \times 10^{17}$ *(2009)*

**54.** Monochromatic light of frequency $6.0 \times 10^{14}$ Hz is produced by a laser. The power emitted is $2 \times 10^{-3}$ W. The number of photons emitted, on the average, by the source per second is
(a) $5 \times 10^{16}$ (b) $5 \times 10^{17}$
(c) $5 \times 10^{14}$ (d) $5 \times 10^{15}$ *(2007)*

**55.** The momentum of a photon of energy 1 MeV in kg m/s will be
(a) $5 \times 10^{-22}$ (b) $0.33 \times 10^6$
(c) $7 \times 10^{-24}$ (d) $10^{-22}$ *(2006)*

**56.** If a photon has velocity $c$ and frequency $\upsilon$, then which of the following represents its wavelength?
(a) $\frac{h\upsilon}{c^2}$ (b) $h\upsilon$ (c) $\frac{hc}{E}$ (d) $\frac{h\upsilon}{c}$ *(1996)*

**57.** The velocity of photons is proportional to (where $\upsilon$ = frequency)
(a) $1/\sqrt{\upsilon}$ (b) $\upsilon^2$ (c) $\upsilon$ (d) $\sqrt{\upsilon}$ *(1996)*

**58.** Momentum of photon of wavelength $\lambda$ is
(a) $\frac{h\upsilon}{c}$ (b) zero (c) $\frac{h\lambda}{c^2}$ (d) $\frac{h\lambda}{c}$ *(1993)*

**59.** The wavelength of a 1 keV photon is $1.24 \times 10^{-9}$ m. What is the frequency of 1 MeV photon?
(a) $1.24 \times 10^{15}$ (b) $2.4 \times 10^{20}$
(c) $1.24 \times 10^{18}$ (d) $2.4 \times 10^{23}$ *(1991)*

**60.** A radio transmitter operates at a frequency 880 kHz and a power of 10 kW. The number of photons emitted per second is
(a) $1.72 \times 10^{31}$ (b) $1.327 \times 10^{25}$
(c) $1.327 \times 10^{37}$ (d) $1.327 \times 10^{45}$ *(1990)*

**61.** The momentum of a photon of an electromagnetic radiation is $3.3 \times 10^{-29}$ kg m s$^{-1}$. What is the frequency of the associated waves? [$h = 6.6 \times 10^{-34}$ J s ; $c = 3 \times 10^8$ m s$^{-1}$]
(a) $1.5 \times 10^{13}$ Hz (b) $7.5 \times 10^{12}$ Hz
(c) $6 \times 10^3$ Hz (d) $3 \times 10^3$ Hz *(1990)*

**62.** The energy of a photon of wavelength $\lambda$ is
(a) $hc\lambda$ (b) $\frac{hc}{\lambda}$ (c) $\frac{\lambda}{hc}$ (d) $\frac{\lambda h}{c}$ *(1988)*

## 11.8 Wave Nature of Matter

**63.** An electron is accelerated from rest through a potential difference of $V$ volt. If the de Broglie wavelength of the electron is $1.227 \times 10^{-2}$ nm, the potential difference is
(a) 10 V (b) $10^2$ V
(c) $10^3$ V (d) $10^4$ V *(NEET 2020)*

**64.** An electron is accelerated through a potential difference of 10,000 V. Its de Broglie wavelength is, (nearly) ($m_e = 9 \times 10^{-31}$ kg)
(a) 12.2 nm (b) $12.2 \times 10^{-13}$ m
(c) $12.2 \times 10^{-12}$ m (d) $12.2 \times 10^{-14}$ m *(NEET 2019)*

**65.** An electron of mass $m$ with an initial velocity $\vec{v} = v_0\hat{i}\ (v_0 > 0)$ enters an electric field $\vec{E} = -\vec{E}_0\hat{i}$ ($E_0$ = constant > 0) at $t = 0$. If $\lambda_0$ is its de-Broglie wavelength initially, then its de- Broglie wavelength at time $t$ is
(a) $\frac{\lambda_0}{\left(1+\frac{eE_0}{mv_0}t\right)}$ (b) $\lambda_0\left(1+\frac{eE_0}{mv_0}t\right)$
(c) $\lambda_0 t$ (d) $\lambda_0$ *(NEET 2018)*

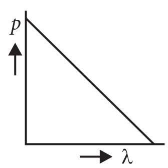
**66.** The de-Broglie wavelength of a neutron in thermal equilibrium with heavy water at a temperature $T$ (kelvin) and mass $m$, is
(a) $\frac{h}{\sqrt{3mkT}}$ (b) $\frac{2h}{\sqrt{3mkT}}$
(c) $\frac{2h}{\sqrt{mkT}}$ (d) $\frac{h}{\sqrt{mkT}}$ *(NEET 2017)*

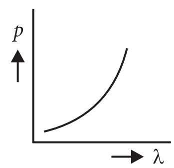
**67.** Electrons of mass $m$ with de-Broglie wavelength $\lambda$ fall on the target in an $X$-ray tube. The cutoff wavelength ($\lambda_0$) of the emitted $X$-ray is
(a) $\lambda_0 = \frac{2mc\lambda^2}{h}$ (b) $\lambda_0 = \frac{2h}{mc}$
(c) $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$ (d) $\lambda_0 = \lambda$ *(NEET-II 2016)*

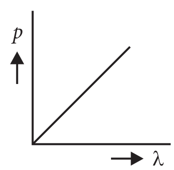
**68.** An electron of mass $m$ and a photon have same energy $E$. The ratio of de-Broglie wavelengths associated with them is
(a) $c(2mE)^{\frac{1}{2}}$ (b) $\frac{1}{c}\left(\frac{2m}{E}\right)^{\frac{1}{2}}$
(c) $\frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$ (d) $\left(\frac{E}{2m}\right)^{\frac{1}{2}}$
($c$ being velocity of light) *(NEET-I 2016)*

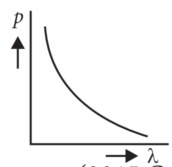
**69.** Light of wavelength 500 nm is incident on a metal with work function 2.28 eV. The de Broglie wavelength of the emitted electron is
(a) $\geq 2.8 \times 10^{-9}$ m (b) $\leq 2.8 \times 10^{-12}$ m
(c) $< 2.8 \times 10^{-10}$ m (d) $< 2.8 \times 10^{-9}$ m *(2015)*

**70.** Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?

(a) 


(b) 


(c) 


(d) 


*(2015 Cancelled)*

**71.** If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de Broglie wavelength of the particle is

(a) 25 (b) 75 (c) 60 (d) 50 *(2014)*

**72.** The wavelength $\lambda_e$ of an electron and $\lambda_p$ of a photon of same energy $E$ are related by

(a) $\lambda_p \propto \sqrt{\lambda_e}$ (b) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$

(c) $\lambda_p \propto \lambda_e^2$ (d) $\lambda_p \propto \lambda_e$. *(NEET 2013)*

**73.** The de-Broglie wavelength of neutrons in thermal equilibrium at temperature $T$ is

(a) $\frac{3.08}{\sqrt{T}}$ Å (b) $\frac{0.308}{\sqrt{T}}$ Å

(c) $\frac{0.0308}{\sqrt{T}}$ Å (d) $\frac{30.8}{\sqrt{T}}$ Å *(Karnataka NEET 2013)*

**74.** An α-particle moves in a circular path of radius 0.83 cm in the presence of a magnetic field of 0.25 Wb/m$^2$. The de Broglie wavelength associated with the particle will be

(a) 1 Å (b) 0.1 Å

(c) 10 Å (d) 0.01 Å *(2012)*

**75.** If the momentum of an electron is changed by $P$, then the de Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be

(a) 200$P$ (b) 400$P$

(c) $P$/200 (d) 100$P$ *(Mains 2012)*

**76.** Electrons used in an electron microscope are accelerated by a voltage of 25 kV. If the voltage is increased to 100 kV then the de-Broglie wavelength associated with the electrons would

(a) increase by 2 times (b) decrease by 2 times

(c) decrease by 4 times (d) increase by 4 times. *(2011)*

**77.** A particle of mass 1 mg has the same wavelength as an electron moving with a velocity of $3 \times 10^6$ m s$^{-1}$. The velocity of the particle is

(a) $3 \times 10^{-31}$ ms$^{-1}$ (b) $2.7 \times 10^{-21}$ ms$^{-1}$

(c) $2.7 \times 10^{-18}$ ms$^{-1}$ (d) $9 \times 10^{-2}$ ms$^{-1}$

(mass of electron = $9.1 \times 10^{-31}$ kg) *(2008)*

**78.** If particles are moving with same velocity, then which has maximum de Broglie wavelength?

(a) proton (b) α-particle

(c) neutron (d) β-particle *(2002)*

**79.** Which one among the following shows particle nature of light?

(a) photoelectric effect (b) interference

(b) refraction (d) polarization. *(2001)*

**80.** When a proton is accelerated through 1 V, then its kinetic energy will be

(a) 1 eV (b) 13.6 eV

(c) 1840 eV (d) 0.54 eV *(1999)*

**81.** The kinetic energy of an electron, which is accelerated in the potential difference of 100 volts, is

(a) 416.6 cal (b) 6.636 cal

(c) $1.602 \times 10^{-17}$ J (d) $1.6 \times 10^4$ J *(1997)*

**82.** An electron beam has a kinetic energy equal to 100 eV. Find its wavelength associated with a beam, if mass of electron = $9.1 \times 10^{-31}$ kg and 1 eV = $1.6 \times 10^{-19}$ J. (Planck's constant = $6.6 \times 10^{-34}$ Js)

(a) 24.6 Å (b) 0.12 Å

(c) 1.2 Å (d) 6.3 Å *(1996)*

**83.** An electron of mass $m$ and charge $e$ is accelerated from rest through a potential difference $V$ in vacuum. Its final velocity will be

(a) $\sqrt{\frac{2eV}{m}}$ (b) $\sqrt{\frac{eV}{m}}$

(c) $\frac{eV}{2m}$ (d) $\frac{eV}{m}$ *(1996)*

**84.** An electron of mass $m$, when accelerated through a potential difference $V$, has de Broglie wavelength λ. The de Broglie wavelength associated with a proton of mass $M$ accelerated through the same potential difference, will be

(a) $\lambda \frac{M}{m}$ (b) $\lambda \frac{m}{M}$ (c) $\lambda \sqrt{\frac{M}{m}}$ (d) $\lambda \sqrt{\frac{m}{M}}$ *(1995)*

**85.** If we consider electrons and photons of same wavelength, then they will have same

(a) momentum (b) angular momentum

(c) energy (d) velocity. *(1995)*

**86.** The de Broglie wave corresponding to a particle of mass $m$ and velocity $v$ has a wavelength associated with it

(a) $\frac{h}{mv}$ (b) $hmv$ (c) $\frac{mh}{v}$ (d) $\frac{m}{hv}$ *(1989)*

## 11.9 Davisson and Germer Experiment

**87.** In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by

(a) increasing the potential difference between the anode and filament

(b) increasing the filament current

(c) decreasing the filament current

(d) decreasing the potential difference between the anode and filament. *(2011)*

## ANSWER KEY

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.** | (d) | **2.** | (a) | **3.** | (c) | **4.** | (c) | **5.** | (b) | **6.** | (a) | **7.** | (a) | **8.** | (b) | **9.** | (b) | **10.** | (b) |
| **11.** | (d) | **12.** | (c) | **13.** | (b) | **14.** | (b) | **15.** | (a) | **16.** | (d) | **17.** | (c) | **18.** | (d) | **19.** | (b) | **20.** | (b) |
| **21.** | (c) | **22.** | (a) | **23.** | (a) | **24.** | (a) | **25.** | (d) | **26.** | (d) | **27.** | (a) | **28.** | (a,d) | **29.** | (d) | **30.** | (b) |
| **31.** | (c) | **32.** | (d) | **33.** | (b) | **34.** | (a) | **35.** | (b) | **36.** | (b) | **37.** | (b) | **38.** | (c) | **39.** | (a) | **40.** | (b) |
| **41.** | (c) | **42.** | (d) | **43.** | (d) | **44.** | (a) | **45.** | (a) | **46.** | (d) | **47.** | (b) | **48.** | (d) | **49.** | (b) | **50.** | (a) |
| **51.** | (a) | **52.** | (a) | **53.** | (a) | **54.** | (d) | **55.** | (a) | **56.** | (c) | **57.** | (*) | **58.** | (a) | **59.** | (b) | **60.** | (a) |
| **61.** | (a) | **62.** | (b) | **63.** | (d) | **64.** | (c) | **65.** | (a) | **66.** | (a) | **67.** | (a) | **68.** | (c) | **69.** | (a) | **70.** | (d) |
| **71.** | (b) | **72.** | (c) | **73.** | (d) | **74.** | (d) | **75.** | (a) | **76.** | (*) | **77.** | (c) | **78.** | (d) | **79.** | (a) | **80.** | (a) |
| **81.** | (c) | **82.** | (c) | **83.** | (a) | **84.** | (d) | **85.** | (a) | **86.** | (a) | **87.** | (a) | | | | | | |

# Hints & Explanations

**1. (d) :** When a beam of cathode rays (or electrons) are subjected to crossed electric ($E$) and magnetic ($B$) fields, the beam is not deflected, if

Force on electron due to magnetic field = Force on electron due to electric field

$$Bev = eE \quad \text{or} \quad v = \frac{E}{B} \qquad \text{...(i)}$$

If $V$ is the potential difference between the anode and the cathode, then

$$\frac{1}{2}mv^2 = eV \quad \text{or} \quad \frac{e}{m} = \frac{v^2}{2V} \qquad \text{...(ii)}$$

Substituting the value of $v$ from equation (i) in equation (ii),we get

$$\frac{e}{m} = \frac{E^2}{2VB^2}$$

Specific charge of the cathode rays $\frac{e}{m} = \frac{E^2}{2VB^2}$

**2. (a) :** Collisions of the charged particles with the atoms in the gas.

**3. (c)** **4. (c)**

**5. (b) :** Cathode rays are basically negatively charged particles (electrons). If the cathode rays are allowed to pass between two plates kept at a difference of potential, the rays are found to be deflected from the rectilinear path. The direction of deflection shows that the rays carry negative charges.

**6. (a)** **7. (a)**

**8. (b) :** Thermionic emission : When a metal is heated to a high temperature, the free electron gain kinetic energy and escape from the surface of the metal.

Secondary emission : When an electron strikes the surface of a metallic plate, it emits other electrons from the surface.

Photoelectric emission : Emission of electrons from the metal surface on irradiation with radiation of suitable frequency.

$X$-rays emission : They are due to transitions in the inner energy levels of the atom.

**9. (b) :** When a metal is heated, electrons are ejected out of it, which are called thermions.

**10. (b) :** By changing the position of source of light from photo cell, there will be a change in the intensity of light falling on photo cell.

As stopping potential is independent of the intensity of the incident light, hence stopping potential remains same *i.e.*, $V_0$.

**11. (d) :** The photoelectic emission occurs only when the incident light has more than a certain minimum frequency. This minimum frequency is called threshold frequency.

**12. (c) :** The stopping potential $V_s$ is related to the maximum kinetic energy of the emitted electrons $K_{max}$ through the relation

$$K_{max} = eV_s$$
$$0.5 \text{ eV} = eV_s \quad \text{or} \quad V_s = 0.5 \text{ V}$$

**13. (b) :** The number of photoelectrons ejected is directly proportional to the intensity of incident light. Maximum kinetic energy is independent of intensity of incident light but depends upon the frequency of light. Hence option (b) is correct.

**14. (b) :** The number of photoelectrons decide the photocurrent. Assuming that the number of electrons emitted depends on the number of photons incident, the number of photoelectrons depend on the intensity of light.

**15. (a)**

**16. (d) :** For a light source of power $P$ watt, the intensity at a distance $d$ is given by $I = \frac{P}{4\pi d^2}$

where we assume light to spread out uniformly in all directions *i.e.*, it is a spherical source.

$\therefore \quad I \propto \frac{1}{d^2}$ or $\frac{I_1}{I_2} = \frac{d_2^2}{d_1^2}$

or, $\frac{I_1}{I_2} = \left(\frac{1}{0.5}\right)^2$ or, $\frac{I_1}{I_2} = 4$ or, $I_2 = \frac{I_1}{4}$

In a photoelectric emission, the number of photoelectrons liberated per second from a photosensitive metallic surface is proportional to the intensity of the light. When a intensity of source is reduced by a factor of four, the number of photoelectrons is also reduced by a factor of 4.

**17. (c) :** The photoelectric current is directly proportional to the intensity of illumination. Therefore a change in the intensity of the incident radiation will change the photocurrent.

**18. (d) :** Photoelectric current $I \propto$ intensity of light and

intensity $\propto \frac{1}{(\text{distance})^2}$

$\therefore \quad I \propto \frac{1}{(\text{distance})^2}$

**19. (b)** **20. (b)**

**21. (c) :** If the intensity of light of a given frequency is increased, then the number of photons striking the surface per second will increase in the same ratio. This increased number of photons strikes more electrons of metals and hence number of photoelectrons emitted through the surface increase and hence photoelectric current increases.

**22. (a) :** Since the emission of photoelectrons is directly proportional to the intensity of the incident light, therefore photocurrent increases with the intensity of light.

**23. (a) :** Photoelectric current is directly proportional to the intensity of incident light.

**24. (a) :** The work function has no effect on photoelectric current so long as $h\upsilon > W_0$. The photoelectric current is proportional to the intensity of incident light. Since there is no change in the intensity of light, hence $I_1 = I_2$.

**25. (d) :** Initially, $\upsilon = 1.5\,\upsilon_0$

If the frequency is halved, $\upsilon' = \frac{\upsilon}{2} = \frac{1.5\,\upsilon_0}{2} < \upsilon_0$

Hence, no photoelectric emission will take place.

**26. (d) :** Required wavelength of light,

$$\lambda_0 = \frac{hc}{\phi} = \frac{1240 \text{ eV nm}}{4 \text{ eV}} \approx 310 \text{ nm}$$

**27. (a) :** According to the Einstein's photoelectric equation, $E = W_0 + \frac{1}{2}mv^2$

When frequency of incident light is $2\upsilon_0$.

$$h(2\upsilon_0) = h\upsilon_0 + \frac{1}{2}mv_1^2 \Rightarrow h\upsilon_0 = \frac{1}{2}mv_1^2 \quad \text{...(i)}$$

When frequency of incident light is $5\upsilon_0$

$$h(5\upsilon_0) = h\upsilon_0 + \frac{1}{2}mv_2^2 \Rightarrow 4h\upsilon_0 = \frac{1}{2}mv_2^2 \quad \text{...(ii)}$$

Dividing (i) by (ii), $\frac{1}{4} = \frac{v_1^2}{v_2^2}$ or $\frac{v_1}{v_2} = \frac{1}{2}$.

**28. (a, d) :** The maximum kinetic energy is given as

$$K_{max} = h\upsilon - \phi_0 = h\upsilon - h\upsilon_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

where $\lambda_0$ = threshold wavelength

or $\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

Here, $h = 4.14 \times 10^{-15}$ eV s, $c = 3 \times 10^8$ m s$^{-1}$

$\lambda_o = 3250 \times 10^{-10}$ m $= 3250$ Å

$\lambda = 2536 \times 10^{-10}$ m $= 2536$ Å,

$m = 9.1 \times 10^{-31}$ kg

$hc = 4.14 \times 10^{-15}$ eV s $\times 3 \times 10^8$ m s$^{-1}$ = 12420 eV Å

$$\therefore \quad \frac{1}{2}mv^2 = 12420\left[\frac{1}{2536} - \frac{1}{3250}\right]\text{eV} = 1.076 \text{ eV}$$

$$v^2 = \frac{2.152 \text{ eV}}{m} = \frac{2.152 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$\therefore \quad v \approx 6 \times 10^5$ m s$^{-1}$ $= 0.6 \times 10^6$ m s$^{-1}$

**Note:** Options (a) and (d) are same. So both are correct.

**29. (d) :** According to Einstein's photoelectric equation maximum kinetic energy of photoelectrons,

$KE_{max} = E_\nu - \phi$

or $2 = 5 - \phi \quad \therefore \quad \phi = 3$ eV

When $E_\nu = 6$ eV then, $KE_{max} = 6 - 3 = 3$ eV

or $e(V_{cathode} - V_{anode}) = 3$ eV

or $V_{cathode} - V_{anode} = 3\text{ V} = -V_{stopping}$

$\therefore \quad V_{stopping} = -3$ V

**30. (b) :** According to Einstein's photoelectric equation,

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

$\therefore$ As per question, $eV = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$ ...(i)

$$\frac{eV}{4} = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0} \quad \text{...(ii)}$$

From equations (i) and (ii), we get

$$\frac{hc}{2\lambda} - \frac{hc}{4\lambda} = \frac{hc}{\lambda_0} - \frac{hc}{4\lambda_0}$$

$$\Rightarrow \frac{hc}{4\lambda} = \frac{3hc}{4\lambda_0} \text{ or } \lambda_0 = 3\lambda$$

**31. (c) :** Let $\phi_0$ be the work function of the surface of the material.

According to Einstein's photoelectric equation, the maximum kinetic energy of the emitted photoelectrons in the first case is

$$K_{max_1} = \frac{hc}{\lambda} - \phi_0$$

and that in the second case is

$$K_{max_2} = \frac{hc}{\frac{\lambda}{2}} - \phi_0 = \frac{2hc}{\lambda} - \phi_0$$

But $K_{max_2} = 3K_{max_1}$ (given)

$$\therefore \quad \frac{2hc}{\lambda} - \phi_0 = 3\left(\frac{hc}{\lambda} - \phi_0\right); \ \frac{2hc}{\lambda} - \phi_0 = \frac{3hc}{\lambda} - 3\phi_0$$

$$3\phi_0 - \phi_0 = \frac{3hc}{\lambda} - \frac{2hc}{\lambda} \ \text{ or } \ 2\phi_0 = \frac{hc}{\lambda} \ \text{ or } \ \phi_0 = \frac{hc}{2\lambda}$$

**32. (d)**

**33. (b) :** According to Einstein's photoelectric equation, the kinetic energy of emitted photoelectrons is

$K = h\upsilon - \phi_0$

where $h\upsilon$ is the energy of incident radiation and $\phi_0$ is work function of the metal.

As per question,

$0.5 \text{ eV} = h\upsilon - \phi_0$ ... (i)

$0.8 \text{ eV} = 1.2h\upsilon - \phi_0$ ... (ii)

On solving eqns. (i) and (ii), we get

$\phi_0 = 1.0 \text{ eV}$

**34. (a) :** Work function, $\phi = h\upsilon$

According to Einstein's photoelectric equation

$$\frac{1}{2}mv_{max}^2 = h(2\upsilon) - h\upsilon \ \text{ or } \ \frac{1}{2}mv_{max}^2 = h\upsilon$$

$$v_{max}^2 = \frac{2h\upsilon}{m} \quad \Rightarrow \quad v_{max} = \sqrt{\frac{2h\upsilon}{m}}$$

**35. (b) :** According to Einstein's photoelectric equation

$$\frac{1}{2}mv_{max}^2 = h\upsilon - \phi_0$$

where $\frac{1}{2}mv_{max}^2$ is the maximum kinetic energy of the emitted electrons, $h\upsilon$ is the incident energy and $\phi_0$ is the work function of the metal.

$$\therefore \quad \frac{1}{2}mv_{max_1}^2 = 1 \text{ eV} - 0.5 \text{ eV} = 0.5 \text{ eV} \quad \text{...(i)}$$

$$\text{and} \quad \frac{1}{2}mv_{max_2}^2 = 2.5 \text{ eV} - 0.5 \text{ eV} = 2 \text{ eV} \quad \text{...(ii)}$$

Divide (i) and (ii), we get

$$\frac{v_{max_1}^2}{v_{max_2}^2} = \frac{0.5}{2} \ \text{ or } \ \frac{v_{max_1}}{v_{max_2}} = \sqrt{\frac{0.5}{2}} = \frac{1}{2}$$

**36. (b) :** According to Einstein's photoelectric equation

$eV_0 = h\upsilon - h\upsilon_0$

where, $\upsilon$ = Incident frequency

$\upsilon_0$ = Threshold frequency

$V_0$ = Cut-off or stopping potential

$$\text{or} \quad V_0 = \frac{h}{e}(\upsilon - \upsilon_0)$$

Substituting the given values, we get

$$V_0 = \frac{6.63\times10^{-34}(8.2\times10^{14} - 3.3\times10^{14})}{1.6\times10^{-19}} \approx 2 \text{ V}$$

**37. (b) :** Here, Incident wavelength, $\lambda = 200$ nm

Work function, $\phi_0 = 5.01$ eV

According to Einstein's photoelectric equation

$$eV_s = h\upsilon - \phi_0 \ \text{ or } \ eV_s = \frac{hc}{\lambda} - \phi_0$$

where $V_s$ is the stopping potential

$$eV_s = \frac{(1240 \text{ eV nm})}{(200 \text{ nm})} - 5.01 \text{ eV} = 6.2 \text{ eV} - 5.01 \text{ eV} = 1.2 \text{ eV}$$

Stopping potential, $V_s = 1.2$ V

The potential difference that must be applied to stop photoelectrons $= -V_s = -1.2$ V

**38. (c) :** $\phi_0 = 6.2$ eV

$K_{max} = 5$ eV $\quad \therefore \ h\upsilon = 11.2$ eV

$$\therefore \quad \lambda = \frac{hc}{E} = \frac{12400 \text{ eV Å}}{11.2 \text{ eV}} = 1107 \text{ Å}$$

This wavelength is in the ultraviolet region.

**39. (a) :** Let $K$ and $K'$ be the maximum kinetic energy of photoelectrons for incident light of frequency $\upsilon$ and $2\upsilon$ respectively.

According to Einstein's photoelectric equation,

$K = h\upsilon - E_0$ ... (i)

$K' = h(2\upsilon) - E_0 = 2h\upsilon - E_0 = h\upsilon + h\upsilon - E_0$ [using (i)]

$K' = h\upsilon + K$

**40. (b)**

**41. (c) :** K.E. $= h\upsilon - W$ *i.e.*, $\frac{1}{2}mv^2_{max} = h\upsilon - W$

$$\Rightarrow \quad \frac{1}{2}m\times(4\times10^6)^2 = 2h\upsilon_0 - h\upsilon_0$$

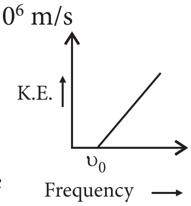
$$\text{or,} \quad \frac{1}{2}m\times(4\times10^6)^2 = h\upsilon_0$$

Another case, $2h\upsilon_0 \rightarrow 5h\upsilon_0$

$$\frac{1}{2}mv_{max}^2 = 4h\upsilon_0 \ \Rightarrow \ \frac{1}{2}mv_{max}^2 = 4\times\frac{1}{2}\times m\times(4\times10^6)^2$$

$$\Rightarrow \ v_{max}^2 = 64\times10^{12} \ \Rightarrow \ v_{max} = 8\times10^6 \text{ m/s}$$

**42. (d) :** The maximum kinetic energy of photoelectron ejected is given by




K.E. $= h\upsilon - W = h\upsilon - h\upsilon_0$

where work function depends on the type of material.

If the frequency of incident radiation is greater than $\upsilon_0$ only then the ejection of photoelectrons start. After that as frequency increases kinetic energy also increases.

**43. (d) :** The value of Planck's constant is $6.63\times10^{-34}$ J s.

**44. (a)**

**45. (a) :** $\phi = h\upsilon_0 = \frac{hc}{\lambda_0}$

$$\Rightarrow \quad \lambda_0 = \frac{hc}{\phi} = \frac{1242 \text{ eV nm}}{4.125 \text{ eV}} \approx 3000 \text{ Å}$$

**46. (d) :** According to Einstein's photoelectric equation,

$$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - W_0 \ \text{ or, } \ \frac{hc}{\lambda} = \frac{1}{2}mv^2 + W_0$$

$$\frac{1}{2}mv_1^2 = \frac{hc}{3\lambda/4} - W_0 = \frac{4}{3}\left(\frac{1}{2}mv^2 + W_0\right) - W_0$$

$$v_1^2 = \frac{4}{3}v^2 + \frac{2}{3}W_0$$

So, $v_1$ is greater than $v(4/3)^{1/2}$.

**47. (b) :** $W_0 = \frac{hc}{\lambda_0}$ or $W_0 \propto \frac{1}{\lambda_0}$

$$\Rightarrow \quad \frac{W_1}{W_2} = \frac{\lambda_2}{\lambda_1} = \frac{600}{300} = \frac{2}{1}$$

**48. (d) :** $h\upsilon = W + \frac{1}{2}mv^2$ or $\frac{hc}{\lambda} = W + \frac{1}{2}mv^2$

Here $\lambda$ = 3000 Å = $3000 \times 10^{-10}$ m
and $W$ = 1 eV = $1.6 \times 10^{-19}$ joule

$$\frac{(6.6\times10^{-34})(3\times10^{8})}{3000\times10^{-10}} = (1.6\times10^{-19}) + \frac{1}{2}\times(9.1\times10^{-31})v^2$$

Solving we get $v \cong 10^6$ m/s

**49. (b) :** Kinetic energy of fastest electron
$= E - W_0 = 6.2 - 4.2 = 2.0$ eV
$= 2 \times 1.6 \times 10^{-19}$ J $= 3.2 \times 10^{-19}$ J

**50. (a) :** $W_0 = \frac{hc}{\lambda_0}$

$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{5000\times10^{-10}} = 4\times10^{-19}\text{ J}$$

**51. (a) :** Energy of a photon,

$$= \frac{(6.6\times10^{-34}\text{ J s})(3\times10^{8}\text{ m s}^{-1})}{0.6\times10^{-6}\text{ m}} = 33\times10^{-20}\text{ J}$$

Number of photons emitted per second is

$$N = \frac{\frac{25}{100}P}{E} = \frac{\frac{25}{100}\times200\text{ W}}{33\times10^{-20}\text{ J}} = 1.5\times10^{20}$$

**52. (a) :** For a source $S_1$,

Wavelength, $\lambda_1$ = 5000 Å
Number of photons emitted per second, $N_1 = 10^{15}$

Energy of each photon, $E_1 = \frac{hc}{\lambda_1}$

Power of source $S_1$, $P_1 = E_1N_1 = \frac{N_1hc}{\lambda_1}$

For a source $S_2$,
Wavelength, $\lambda_2$ = 5100 Å
Number of photons emitted per second, $N_2 = 1.02 \times 10^{15}$

Energy of each photon, $E_2 = \frac{hc}{\lambda_2}$

Power of source $S_2$, $P_2 = N_2E_2 = \frac{N_2hc}{\lambda_2}$

$$\therefore \quad \frac{\text{Power of } S_2}{\text{Power of } S_1} = \frac{P_2}{P_1} = \frac{\frac{N_2hc}{\lambda_2}}{\frac{N_1hc}{\lambda_1}} = \frac{N_2\lambda_1}{N_1\lambda_2}$$

$$= \frac{(1.02\times10^{15}\text{ photons/s})\times(5000\text{ Å})}{(10^{15}\text{ photons/s})\times(5100\text{ Å})} = \frac{51}{51} = 1$$

**53. (a) :** $\lambda$ = 6670 Å

$$E\text{ of a photon} = \frac{12400\text{ eVÅ}}{6670\text{ Å}} = \frac{12400}{6670}\times1.6\times10^{-19}\text{ J.}$$

Energy emitted per second, power $P = 9 \times 10^{-3}$ J

$\therefore$ Number of photons incident $= \frac{\text{Power}}{\text{Energy}} = \frac{P}{E}$

$$= \frac{9\times10^{-3}\times6670}{12400\times1.6\times10^{-19}} = 3\times10^{16}$$

**54. (d) :** Power $P = 2 \times 10^{-3}$ W
Energy of one photon $E = h\upsilon = 6.63 \times 10^{-34} \times 6 \times 10^{14}$ J
Number of photons emitted per second, $N = P/E$

$$= \frac{2\times10^{-3}}{6.63\times10^{-34}\times6\times10^{14}} = 0.05\times10^{17} = 5\times10^{15}$$

**55. (a) :** Energy of photon $E$ = 1 MeV
Momentum of photon $p = E/c$

$$\therefore \quad p = \frac{E}{c} = \frac{1\times10^{6}\times1.6\times10^{-19}\text{ J}}{3\times10^{8}\text{ m s}^{-1}} = 0.53\times10^{-21}$$

$\approx 5 \times 10^{-22}$ kg m/s.

**56. (c) :** Energy of the photon $E = \frac{hc}{\lambda}$ or $\lambda = \frac{hc}{E}$, where $\lambda$ is the wavelength.

**57. (*) :** The velocity of a photon in vacuum is a constant. $c = \upsilon\lambda$. But $c$ = constant and one cannot say that it is proportional to $\upsilon$ or $\lambda$ but only $c = \upsilon\lambda$.
In media, for a particular medium, $\upsilon$ remain the same, velocity changes. Therefore $\lambda$ changes. The question is wrong.

**58. (a) :** Momentum of the photon $= \frac{h\upsilon}{c}$

**59. (b) :** Here, $\frac{hc}{\lambda} = 10^3$ eV and $h\upsilon = 10^6$ eV

$$\text{Hence, } \upsilon = \frac{10^3c}{\lambda} = \frac{10^3\times3\times10^8}{1.24\times10^{-9}} = 2.4\times10^{20}\text{ Hz}$$

**60. (a) :** No. of photons emitted per sec,

$$n = \frac{\text{Power}}{\text{Energy of photon}}$$

$$= \frac{P}{h\upsilon} = \frac{10000}{6.6\times10^{-34}\times880\times10^{3}} = 1.72\times10^{31}$$

**61. (a) :** Momentum of the photon $= \frac{h\upsilon}{c}$

$$\Rightarrow \quad \frac{c}{\upsilon} = \frac{h}{p} = \lambda$$

$$\upsilon = \frac{c}{\lambda} = \frac{cp}{h} = 3\times10^{8}\times\frac{3.3\times10^{-29}}{6.6\times10^{-34}} = 1.5\times10^{13}\text{ Hz}$$

**62. (b) :** Energy of a photon $E = h\upsilon = \frac{hc}{\lambda}$

**63. (d) :** Given : de-Broglie wavelength of electron
$\lambda = 1.227 \times 10^{-2}$ nm = 0.1227 Å

$$\because \quad \lambda = \frac{h}{\sqrt{2meV}} = \frac{12.27}{\sqrt{V}}\text{ Å}$$

We have, $\sqrt{V}=\dfrac{12.27}{0.1227}=100 \Rightarrow V=10^4$ V.

**64. (c) :** de Broglie wavelength of electron,

$$\lambda_e=\frac{12.27\text{ Å}}{\sqrt{V(\text{in V})}}$$

Here, $V$ = 10000 V

$$\therefore\quad \lambda_e=\frac{12.27}{\sqrt{10000}}\times 10^{-10}\text{ m} = 12.27\times 10^{-12}\text{ m}$$

**65. (a) :** Here, $\vec{E}=-E_0\,\hat{i}$; initial velocity $\vec{v}=v_0\,\hat{i}$

Force acting on electron due to electric field

$$\vec{F}=(-e)(-E_0\,\hat{i})=eE_0\,\hat{i}$$

Acceleration produced in the electron,

$$\vec{a}=\frac{\vec{F}}{m}=\frac{eE_0}{m}\,\hat{i}$$

Now, velocity of electron after time $t$,

$$\vec{v}_t=\vec{v}+\vec{a}\,t=\left(v_0+\frac{eE_0t}{m}\right)\hat{i}\quad\text{or}\quad |\vec{v}_t|=v_0+\frac{eE_0t}{m}$$

$$\text{Now, }\lambda_t=\frac{h}{mv_t}=\frac{h}{m\left(v_0+\frac{eE_0t}{m}\right)}=\frac{h}{mv_0\left(1+\frac{eE_0t}{mv_0}\right)}$$

$$=\frac{\lambda_0}{\left(1+\frac{eE_0t}{mv_0}\right)}\qquad\left(\because \lambda_0=\frac{h}{mv_0}\right)$$

**66. (a) :** Kinetic energy of a neutron in thermal equilibrium with heavy water at a temperature $T$ is given as

$$K=\frac{3}{2}kT \qquad\text{...(i)}$$

Also momentum ($p$) is, $p=\sqrt{2mK}$

From eqn. (i)

$$p=\sqrt{2m\cdot\frac{3}{2}kT}=\sqrt{3mkT}$$

Required de-Broglie wavelength is given as

$$\lambda=\frac{h}{p}=\frac{h}{\sqrt{3mkT}}$$

**67. (a) :** Kinetic energy of electrons

$$K=\frac{p^2}{2m}=\frac{(h/\lambda)^2}{2m}=\frac{h^2}{2m\lambda^2}$$

So, maximum energy of photon (X-ray) = $K$

$$\frac{hc}{\lambda_0}=\frac{h^2}{2m\lambda^2}\quad\therefore\quad \lambda_0=\frac{2mc\lambda^2}{h}$$

**68. (c) :** For electron of energy $E$,

$$\text{de-Broglie wavelength, }\lambda_e=\frac{h}{p}=\frac{h}{\sqrt{2mE}}$$

$$\text{For photon of energy, }E=h\upsilon=\frac{hc}{\lambda_p}\Rightarrow \lambda_p=\frac{hc}{E}$$

$$\therefore\quad \frac{\lambda_e}{\lambda_p}=\frac{h}{\sqrt{2mE}}\times\frac{E}{hc}=\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$$

**69. (a) :** According to Einstein's photoelectric equation, the maximum kinetic energy of the emitted electron is

$$K_{\max}=\frac{hc}{\lambda}-\phi_0$$

where $\lambda$ is the wavelength of incident light and $\phi_0$ is the work function.

Here, $\lambda$ = 500 nm, $hc$ = 1240 eV nm and $\phi_0$ = 2.28 eV

$$\therefore\quad K_{\max}=\frac{1240\text{ eV nm}}{500\text{ nm}}-2.28\text{ eV}$$

$$= 2.48\text{ eV} - 2.28\text{ eV} = 0.2\text{ eV}$$

The de Broglie wavelength of the emitted electron is

$$\lambda_{\min}=\frac{h}{\sqrt{2\,mK_{\max}}}$$

where $h$ is the Planck's constant and $m$ is the mass of the electron.

As $h = 6.6\times 10^{-34}$ J s, $m = 9\times 10^{-31}$ kg and $K_{\max}$ = 0.2 eV = $0.2\times 1.6\times 10^{-19}$ J

$$\therefore\quad \lambda_{\min}=\frac{6.6\times10^{-34}\text{ J s}}{\sqrt{2(9\times10^{-31}\text{kg})(0.2\times1.6\times10^{-19}\text{J})}}$$

$$=\frac{6.6}{2.4}\times10^{-9}\text{m}\approx 2.8\times10^{-9}\text{m}$$

So, $\lambda \geq 2.8\times 10^{-9}$ m

**70. (d) :** de-Broglie wavelength, $\lambda=\dfrac{h}{p}$

or $\lambda p$ = constant

This represents a rectangular hyperbola.

**71. (b) :** de Broglie wavelength,

$$\lambda=\frac{h}{\sqrt{2mK}}\qquad\text{...(i)}$$

where $m$ is the mass and $K$ is the kinetic energy of the particle.

When kinetic energy of the particle is increased to 16 times, then its de Broglie wavelength becomes,

$$\lambda'=\frac{h}{\sqrt{2m(16K)}}=\frac{1}{4}\frac{h}{\sqrt{2mK}}=\frac{\lambda}{4}\quad\text{(Using (i))}$$

% change in the de Broglie wavelength

$$=\frac{\lambda-\lambda'}{\lambda}\times100=\left(1-\frac{\lambda'}{\lambda}\right)\times100=\left(1-\frac{1}{4}\right)\times100=75\%$$

**72. (c) :** Wavelength of an electron of energy $E$ is

$$\lambda_e=\frac{h}{\sqrt{2m_eE}}\qquad\text{...(i)}$$

Wavelength of a photon of same energy $E$ is

$$\lambda_p=\frac{hc}{E}\quad\text{or}\quad E=\frac{hc}{\lambda_p}\qquad\text{...(ii)}$$

Squaring both sides of eq. (i), we get

$$\lambda_e^2=\frac{h^2}{2m_eE}\quad\text{or}\quad E=\frac{h^2}{2m_e\lambda_e^2}\qquad\text{...(iii)}$$

Equating (ii) and (iii), we get

$$\frac{hc}{\lambda_p}=\frac{h^2}{2m_e\lambda_e^2}\quad\text{or}\quad \lambda_p=\frac{2m_ec}{h}\lambda_e^2$$

$\lambda_p \propto \lambda_e^2$

**73. (d) :** de Broglie wavelength of neutrons in thermal equilibrium at temperature $T$ is

$\lambda = \frac{h}{\sqrt{2mk_BT}}$, where $m$ is the mass of the neutron

Here, $m = 1.67 \times 10^{-27}$ kg, $k_B = 1.38 \times 10^{-23}$ J K$^{-1}$
$h = 6.63 \times 10^{-34}$ J s

$$\therefore \quad \lambda = \frac{6.63\times10^{-34}}{\sqrt{2\times1.67\times10^{-27}\times1.38\times10^{-23}\times T}}$$

$$= \frac{3.08\times10^{-34}\times10^{25}}{\sqrt{T}} = \frac{30.8\times10^{-10}}{\sqrt{T}}\text{ m} = \frac{30.8}{\sqrt{T}}\text{ Å}$$

**74. (d) :** Radius of the circular path of a charged particle in a magnetic field is given by

$$R = \frac{mv}{Bq} \quad \text{or} \quad mv = RBq$$

Here, $R = 0.83$ cm $= 0.83 \times 10^{-2}$ m, $B = 0.25$ Wb m$^{-2}$
$q = 2e = 2 \times 1.6 \times 10^{-19}$ C
$\therefore \quad mv = (0.83 \times 10^{-2})(0.25)(2 \times 1.6 \times 10^{-19})$

de Broglie wavelength, $\lambda = \frac{h}{mv}$

$$= \frac{6.6\times10^{-34}}{0.83\times10^{-2}\times0.25\times2\times1.6\times10^{-19}}\times10^{-12}\text{ m} = 0.01\text{ Å}$$

**75. (a) :** de Broglie wavelength associated with an electron is

$$\lambda = \frac{h}{P} \quad \text{or} \quad P = \frac{h}{\lambda}$$

$$\therefore \quad \frac{\Delta P}{P} = -\frac{\Delta\lambda}{\lambda}\ ; \quad \frac{P}{P_{\text{initial}}} = \frac{0.5}{100}$$

$P_{\text{initial}} = 200P$

**76. (*) :** The de Broglie wavelength $\lambda$ associated with the electrons is

$$\lambda = \frac{1.227}{\sqrt{V}}\text{ nm}$$

where $V$ is the accelerating potential in volts.

$$\text{or} \quad \lambda \propto \frac{1}{\sqrt{V}}$$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}} = \sqrt{\frac{100\times10^3}{25\times10^3}} = 2 \text{ or } \lambda_2 = \frac{\lambda_1}{2}$$

*None of the given options is correct.

**77. (c) :** $\frac{h}{10^{-6}\text{ kg}\times v} = \frac{h}{9.1\times10^{-31}\text{ kg}\times3\times10^{6}\text{ m/s}}$

$\therefore \quad v = 2.7 \times 10^{-18}$ m/s

**78. (d) :** de Broglie wavelength for a particle is given by $\lambda = \frac{h}{p} = \frac{h}{mv}$, where $m$, $v$ and $p$ are the mass, velocity and momentum respectively. $h$ is Planck's constant. Now, since all the particles are moving with same velocity, the particle with least mass will have maximum de-Broglie wavelength. Out of the given four particles (proton, neutron, $\alpha$-particles, *i.e.*, He nucleus and $\beta$-particles, *i.e.*, electrons) $\beta$-particle has the lowest mass and therefore it has maximum wavelength.

**79. (a)**

**80. (a) :** K.E. $= 1.6 \times 10^{-19} \times 1$ J $= 1$ eV

**81. (c) :** Potential difference ($V$) = 100 volts.
Kinetic energy of an electron (K.E.)
$= eV = (1.6 \times 10^{-19}) \times 100 = 1.6 \times 10^{-17}$ J

**82. (c) :** Kinetic energy ($E$) = 100 eV;
Mass of electron ($m$) $= 9.1 \times 10^{-31}$ kg;
1 eV $= 1.6 \times 10^{-19}$ J and
Planck's constant ($h$) $= 6.6 \times 10^{-34}$ J s
Energy of an electron ($E$) $= 100 \times (1.6 \times 10^{-19})$ J

$$\text{or} \quad \lambda = \frac{h}{\sqrt{2mE}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times100\times1.6\times10^{-19}}}$$

$= 1.2 \times 10^{-10}$ m $= 1.2$ Å

**83. (a) :** The kinetic energy of an electron

$$\frac{1}{2}\times mv^2 = eV$$

or final velocity of electron ($v$) $= \sqrt{\frac{2eV}{m}}$

**84. (d) :** Momentum of electrons,

$(p_e) = \sqrt{2meV}$

Momentum for proton ($p_p$) $= \sqrt{2MeV}$

$$\text{Therefore,} \quad \frac{\lambda_p}{\lambda_e} = \frac{h/p_p}{h/p_e} = \frac{p_e}{p_p} = \frac{\sqrt{2meV}}{\sqrt{2MeV}} = \sqrt{\left(\frac{m}{M}\right)}$$

$$\text{Therefore,} \quad \lambda_p = \lambda\sqrt{\left(\frac{m}{M}\right)}$$

**85. (a) :** Wavelength ($\lambda$) $= \frac{h}{mv} = \frac{h}{p}$. Therefore for same wavelength of electrons and photons, the momentum should be same.

**86. (a) :** de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv}$

**87. (a)**

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