CHAPTER : 11

DUAL NATURE OF RADIATION AND MATTER

STUDY NOTES

- **Photoelectric emission:** Electrons are emitted from a metal surface when suitable electromagnetic radiations illuminate it.
- **Work function:** The minimum amount of energy required by an electron to just escape from the metal surface is known as work function of the metal. It is denoted by W_0.
- **Kinetic energy gained by an electron:** When an electron is accelerated from rest through a potential difference of V volts, the gain in its kinetic energy is

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

- **Electron volt (eV):** It is the kinetic energy gained by an electron when it is accelerated through a potential difference of 1 volt.

  $1eV = 1.6 \times 10^{-19}$J, $1\ MeV = 1.6 \times 10^{-13}$ J.

  The work function of a metal is generally measured in electron volt (eV).
- **Photons:** According to Planck's quantum theory of radiation, an electromagnetic wave travels in the form of discrete packets of energy called quanta. One quantum of light radiation is called a photon.
- **Photoelectric effect:** The phenomenon of emission of electrons from a metal surface, when electromagnetic radiations of sufficiently high frequency are incident on it, is called photoelectric effect. The photo (light)-generated electrons are called photoelectrons.

  Alkali metals like Li, Na, K, Ce show photoelectric effect with visible light. Metals like Zn, Cd, Mg respond to ultraviolet light.

  Photoelectric effect involves the conversion of light energy into electrical energy. It follows the law of conservation of energy. It is an instantaneous process.
- **Photoelectric current:** The current constituted by photoelectrons is called photoelectric current. Its value depends on :

  (i) the intensity of light,

  (ii) the potential difference applied between the two electrodes, and

  (iii) the nature of the cathode material.
- **Cut off or stopping potential:** It is the minimum value of the negative potential that must be applied to the anode of photocell to make the photoelectric current zero. It is denoted by V. Its value depends on: (i) the frequency of incident light, and (ii) the nature of the cathode material. For a given frequency of incident light, it is independent of its intensity. The stopping potential is directly related to the kinetic energy of the emitted electrons.

$$K_{max} = \frac{1}{2}mv^2{}_{max} = eV_0$$

- **Threshold frequency:** The minimum value of the frequency of incident radiation below which the photoelectric emission stops altogether is called threshold frequency. It is denoted by v_0 and is a characteristic of the metal.
- **Laws of photoelectric effect:** (i) For a given metal and a radiation of fixed frequency, the rate of emission of photoelectrons is proportional to the intensity of incident radiation. (ii) For every metal, there is a certain minimum

frequency below which no photoelectrons are emitted, howsoever high is the intensity of incident radiation. This frequency is called threshold frequency. (iii) For the radiation of frequency higher than the threshold frequency, the maximum kinetic energy of the photoelectrons is directly proportional to the frequency of incident radiation and is independent of the intensity of incident radiation. (iv) The photoelectric emission is an instantaneous process.

- **Einstein's theory of photoelectric effect:** Einstein explained photoelectric effect with the help of Planck's quantum theory. When a radiation of frequency v is incident on a metal surface, it is absorbed in the form of discrete packets of energy called quanta or photons. A part of energy hv of a photon is used in removing the electron from the metal surface and remaining energy is used in giving kinetic energy to the photoelectron. Einstein's photoelectric equation is

$$K_{max} = \frac{1}{2}mv^2{}_{max} = eV_0 = hv - W_0$$

Where W_0 is the work function of the metal and v_0 is the threshold frequency. All the experimental observations can be explained on the basis of Einstein's photoelectric equation.

- **Dual nature of radiation:** Light has dual nature. It shows wave like phenomenon in diffraction, interference, polarization, etc., while it shows particle like nature in photoelectric effect, Compton scattering, etc.
- **Dual nature of matter:** As there is complete equivalence between matter (mass) and radiation (energy) and nature always manifests the principle of symmetry, de Broglie suggested that moving particles like protons, neutrons, electrons, etc., should be associated with waves known as de Broglie waves and their wavelength is called de Broglie wavelength. This is known as de Broglie hypothesis.
- The de Broglie wavelength of a particle of mass m moving with velocity v is given by

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

where h is the Planck's constant. The de Broglie wavelength is independent of the charge and nature of the material particles. It has significantly measurable values for sub-atomic particles like electrons, protons, etc., due to their small masses. For macroscopic objects of everyday life, the de-Broglie wavelength is extremely small, quite beyond measurement.

- **Davisson and Germer experiment:** This electron diffraction experiment has verified and confirmed the wave-nature of electrons.
- **de Broglie wavelength of an electron:** The wavelength associated with an electron beam accelerated through a potential difference of V volts is given by

$$\lambda = \frac{h}{\sqrt{2meV}} = \frac{1.227}{\sqrt{V}} nm$$

QUESTION BANK

MULTIPLE CHOICE QUESTIONS

1. 1.An electromagnetic wave of wavelength 'λ_1' is incident on a photosensitive surface of negligible work function. If 'm' is the mass of photoelectron emitted from the surface has de-Broglie wavelength λ_2 then:

   (a) $\lambda_1 = \left(\frac{2m}{hc}\right)\lambda_2^2$ (b) $\lambda_2 = \left(\frac{2mc}{h}\right)\lambda_1$ (c) $\lambda_1 = \left(\frac{2h}{mc}\right)\lambda_2^2$ (d) $\lambda_1 = \left(\frac{2mc}{h}\right)\lambda_2^2$

2. An argon-ion laser produces monochromatic light with a wavelength of 514 nm. If the optical power in the beam is 1 watt, at what rate is the laser emitting photons?

   (a) 8.7×10^9 s^{-1} (b) 4.1×10^{17} s^{-1} (c) 3.2×10^{12} s^{-1} (d) 2.6×10^{18} s^{-1}

3. In a photo emissive cell with exciting wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to 3λ/4 the speed of the fastest emitted electron will be

(a) $v\left(\frac{3}{4}\right)^{\frac{1}{2}}$ (b) Less than $\left(\frac{4}{3}\right)^{\frac{1}{2}}v$ (c) $v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (d) Greater than $\left(\frac{4}{3}\right)^{\frac{1}{2}}v$

4. When a point source of monochromatic light is at a distance of 0.2m from a photo electric cell, the cut off voltage and the saturation current are 0.6 volt and 18 mA respectively. If the same source is placed 0.6 m away from the photelectric cell then

(a) The stopping potential will be 0.2 V (b) The stopping potential will be 0.6 V
(c) The saturation current will be 6 mA (d) The saturation current will be 18 mA

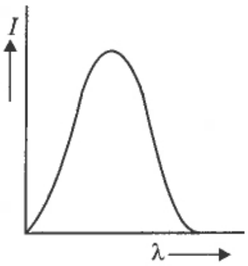
5. In an experiment a proton, a neutron, an electron and an α particle are ejected with same energy then their de-Broglie wavelength compare as

(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$ (b) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$ (d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

6. 3 mW of 400 nm light is incident on a photoelectric cell. If 10% of the photons are contributing in ejection of electrons, then the current in the cell is

(a) 0.48 μA (b) insufficient data (c) zero (d) 0.96 μA

7. In an physics experiment Ram kept the anode voltage of a photocell fixed and then gradually changed the wavelength of the light falling on the cathode. Then the observed variation between the plate current I of the photocell is

(a)


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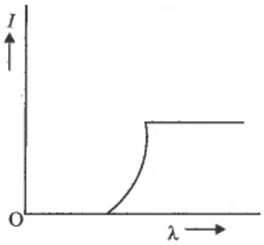
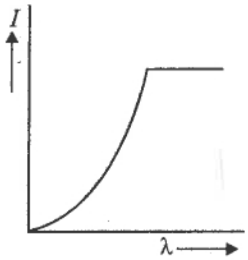
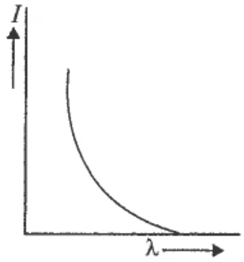


(c)


(d)


8. Two identical photo cathodes receive light of frequencies f_1, and f_2. If the velocities of the photoelectrons of mass m coming out are respectively v_1 and v_2 then:

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

(c) $v_1 - v_2 = \sqrt{\left[\frac{2h}{m}(f_1 - f_2)\right]}$ (d) $v_1 + v_2 = \sqrt{\left[\frac{2h}{m}(f_1 + f_2)\right]}$

9. Minimum light intensity that can be perceived by normal human eye is about 10^{-10} Wm^{-2}. What is the minimum number of photons of wavelength 660 nm that must enter the pupil in 1s for one to see the object? Area of cross-section of the pupil is 10^{-4} m^2.

(a) 3.3×10^2 (b) 3.3×10^4 (c) 3.3×10^3 (d) 3.3×10^5

10. The work functions of metals A and B are in the ratio 1: 2. If light of frequencies f and $2f$ are incident on the surfaces of A and B respectively, the ratio of the maximum kinetic energies of photoelectrons emitted is (f is greater than threshold frequency of A, $2f$ is greater than threshold frequency of B)

(a) 1:1 (b) 1:2 (c) 1:3 (d) 1:4

11. The de-Broglie wavelength of electron in ground state of an hydrogen atom is:

(a) 1.52 Å (b) 3.33 Å (c) 0.53 Å (d) 1.06 Å

12. One milliwatt of light of wavelength of 4560 Å is incident on a cesium surface. Calculate the electron current liberated. Assume a quantum efficiency of 0.5%.

(a) 0.184 μA (b) 184 μA (c) 1.84 μA (d) Can't be determined

13. If the frequency of light in a photoelectric experiment is doubled the stopping potential will

(a) be doubles
(b) become more than double
(c) be halved
(d) become less than double

14. In photoelectric effect, the photoelectric current:

(a) increases when frequency of incident photons increases
(b) decreases when frequency of incident photons increases
(c) does not depend on photon frequency but only on intensity of incident beam
(d) depends both on intensity and frequency of incident beam.

15. 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 = Plank constant = 6.6×10^{-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

16. 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) $\frac{m_p}{m_e}$

17. 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

18. Light of wavelength 330 nm falling on a piece of metal ejects electrons with sufficient energy with requires voltage V, to prevent them from reaching a collector. In the same setup, light of wavelength 220 nm, ejects electrons which require twice the voltage V_o to stop them in reaching a collector. The numerical value of voltage V, is

(a) $\frac{16}{15}$V
(b) $\frac{15}{16}$ V
(c) $\frac{8}{15}$ V
(d) $\frac{15}{8}$ V

19. Maximum KE of a photoelectron is E when the wavelength of incident light is λ. If energy becomes four times when wavelength is reduced to one-third, then work function of the metal is

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

20. Photoelectric effect is an example of

(a) elastic collision
(b) inelastic collision
(c) oblique collision
(d) two-dimensional collision

21. Let K_1 be the maximum kinetic energy of photoelectrons emitted by light of wavelength λ_1 and K_2 corresponding to wavelength λ_2. If $\lambda_1 = 2\lambda_2$ then

(a) $2K_1 = K_2$
(b) $K_1 = 2K_2$
(c) $K_1 < \frac{K_2}{2}$
(d) $K_1 > 2K_2$

22. The de-Broglie wavelength of a neutron at 927°C is λ. What will be its wavelength at 27°C?

(a) λ
(b) λ/2
(c) 2λ
(d) 4λ

23. In photoelectric effect if the intensity of light is doubled then maximum kinetic energy of photoelectrons will become

(a) double
(b) half
(c) no change
(d) four times

24. Monochromatic light of frequency f is incident on emitter having threshold frequency *f*. The kinetic energy of ejected electron is given by

(a) hf
(b) $h(f - f_0)$
(c) hf_0
(d) $h(f + f_0)$

25. A radio transmitter radiates 1 kW power at a wavelength 198.6 m. How many photons does it emit per second?

(a) 10^{10} (b) 10^{20} (c) 10^{40} (d) 10^{30}

26. The photons in a radio wave of wavelength 3×10^4 cm have energy

(a) 6.62×10^{-10} (b) 19.86×10^{-23} (c) 6.62×10^{-28} (d) 22×10^{-35}

27. The work function of a metal is 4.2 eV, its threshold wavelength will be

(a) 4000 Å (b) 3500 Å (c) 2955 Å (d) 2500 Å

28. The number of photoelectrons emitted per second metal surface increases when

(a) the energy of incident photons increases (b) the frequency of incident light increases

(c) the wavelength of the incident light increases (d) the intensity of the incident light increases

29. The work function of a metal is 1 eV. Light of wavelength 3000 Å is incident on this metal surface. The velocity of emitted photoelectrons will be

(a) 10 m/s (b) 1×10^3 m/s (c) 1×10^1 m/s (d) 1×10^6 m/s

30. X-rays are deflected by:

(a) electric field (b) magnetic field

(c) both electric and magnetic field (d) neither electric nor magnetic field

31. The kinetic energy of the photo electron is E when the incident wavelength is λ. When the incident wavelength is decreased to $\frac{\lambda}{3}$, the kinetic energy is doubled. The work function of the metal is:

(a) $\frac{-hc}{\lambda}$ (b) $\frac{-2hc}{\lambda}$ (c) $4hc$ (d) $\frac{3hc}{\lambda}$

32. Photons of 5.5 eV energy fall on the surface of the metal emitting photoelectrons of maximum kinetic energy 4.0 eV. The stopping voltage required for these electrons are :

(a) 5.5 V (b) 1.5 V (c) 9.5 V (d) 4.0 V

33. X–ray of wavelength $\lambda = 2$ Å is emitted from the target metal. The potential difference applied across the cathode and the metal target is:

(a) 6200 V (b) 2000 V (c) 7000 V (d) 3500 V

34. The lowest frequency of light that will cause the emission of photoelectrons from the surface of a metal (for which work function is 1.65 eV) will be :

(a) 4×10^{10} Hz (b) 4×10^{11} Hz (c) 4×10^{14} Hz (d) 4×10^{-10} Hz

35. The work function for tungsten and sodium are 4.5 eV and 2.3 eV respectively. If the threshold wavelength for sodium is 5460 Å, the value of λ for tungsten is

(a) 5893 Å (b) 10683 Å (c) 2791 Å (d) 528 Å

36. In photoelectric effect when photons of energy hv fall on a photosensitive surface (work function hv) electrons are emitted from the metallic surface with a kinetic energy. It is possible to say that:

(a) All ejected electrons have same kinetic energy equal to $(hv - hv_0)$

(b) The ejected electrons have a distribution of kinetic energy from zero to $(hv - hv_0)$

(c) The most energetic electrons have kinetic energy equal to hv

(d) All ejected electrons have kinetic energy hv_0

37. Light of two different frequencies, whose photons have energies 1 eV and 2.5 eV respectively, successively illuminates a metal of work function 0.5 eV. The ratio of maximum speeds of the emitted electrons will be:

(a) 1:5 (b) 1:4 (c) 1:2 (d) 1:1.

38. When light of certain frequency and intensity is incident on an emitter of photoelectrons. How will the velocity of the photoelectrons will change when the frequency is doubled and the intensity is halved?

(a) Increase (b) Decrease (c) Remain the same

(d) Increase or decrease depending on the exact values of the new frequency and intensity

39. A non-monochromatic light is used in an experiment on photoelectric effect. The stopping potential is

(a) related to the mean wavelength (b) related to the longest wavelength
(c) related to the shortest wavelength (d) not related to the wavelength

40. An X-ray tube is operated at 50 kV. The minimum wavelength produced is

(a) 0.75Å (b) 0.5 Å (c) 0.25 Å (d) 1 Å

41. How can we increase the intensity of the emitted X-rays in X-ray tube?

(a) By increasing the filament current (b) By decreasing the filament current
(c) Increasing the target potential (d) Decreasing the target potential

42. In which of the following emission of the electrons does not take place?

(a) Thermionic emissions (b) X-ray emission
(c) Photoelectric emission (d) Secondary emission

43. A photo-cell is illuminated by a point 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

(a) remain the same (b) become two times
(c) become four times (d) become one-fourth

44. The photoelectric threshold wavelength for silver is λ_0. The energy of the electron ejected from the surface of silver by an incident wavelength λ ($\lambda < \lambda_0$) will be

(a) $hc\,(\lambda - \lambda_0)$ (b) $\dfrac{hc}{\lambda_0 - \lambda}$ (c) $\dfrac{h}{c}\left(\dfrac{\lambda_0 - \lambda}{\lambda_0\lambda}\right)$ (d) $hc\left(\dfrac{\lambda_0 - \lambda}{\lambda_0\lambda}\right)$

45. The maximum kinetic energy of the photoelectrons varies

(a) inversely with the intensity and is independent of the frequency of the incident radiation
(b) inversely with the frequency and is independent of the intensity of the incident radiation
(c) linearly with the frequency and the intensity of the incident radiation
(d) linearly with the frequency and is independent of the intensity of the incident radiation

46. 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) decrease by 2 times (b) increase by 4 times
(c) increase by 2 times (d) decrease by 4 times

47. The maximum wavelength of radiation that can produce photoelectric effect in a certain metal is 200 nm. The maximum kinetic energy acquired by electron due to radiation of wavelength 100 nm will be

(a) 12.4 eV (b) 6.2 eV (c) 100 eV (d) 200 eV

48. In photoelectric effect if the intensity of light is doubled then maximum kinetic energy of photoelectrons will become

(a) double (b) half (c) four times (d) no change

49. A particle which has zero rest mass and non-zero energy and momentum must travel with a speed

(a) equal to c the speed of light in vacuum (b) greater than c
(c) less than e (d) tending to infinity

50. A particle of mass 1 mg has the same wavelength as an electron moving with velocity 3×10^{-6} m/s, the velocity of the particle is

(a) 2.7×10^{-8} m/s (b) 9×10^{-2} m/s (c) 3×10^{-31} m/s (d) 2.7×10^{-9} m/s

51. The de Broglie wavelength of an electron moving with speed of 6.6×10^5 m/s is nearly equal to :

(a) 11Å (b) 211Å (c) 121Å (d) 311Å

52. The de-Broglie wavelength of an electron moving with a velocity of 1.5×10^8m/s is equal to that of a photon. The ratio of kinetic energy of the electron to that of the photon ($c = 3 \times 10^8$ m/s):

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

53. How will the de Broglie wavelength of the electron which is placed in a uniform electric field changes as it moves?
(a) Increase
(b) Decrease
(c) Remain constant
(d) First increase and then decrease

54. An X-ray tube operates at 10 kV. The ratio of X-ray wavelength to that of de Broglie wavelength is:
(a) 10 :1
(b) 1:10
(c) 1:100
(d) 100:1.

55. The de Broglie wavelength of an electron in the first Bohr orbit is:
(a) Equal to twice the circumference of Bohr orbit
(b) Equal to the circumference of the first Bohr orbit
(c) Equal to one forth the circumference of first Bohr orbit
(d) Equal to half the circumference of the first Bohr orbit.

56. The energy of electron is 3×10^{-19} joule. Its momentum is
(a) 10^{-27} kg ms^{-1}
(b) 9×10^{-11} kg ms^{-1}
(c) 10^{-8} kg ms^{-1}
(d) 3×10^{-7} kg ms^{-1}

57. The speed of an electron having a wavelength of 10^{-10} m is
(a) 7.25×10^{6} m/s
(b) 6.26×10^{6} m/s
(c) 5.25×10^{6} m/s
(d) 4.24×10^{6} m/s

58. In de Broglie equation wavelength λ depends upon mass *m* and energy *E* according to the relation represented as
(a) $mE^{1/2}$
(b) $m^{-1/2}E^{1/2}$
(c) $m^{-1/2}E^{-1/2}$
(d) $m^{1/2}E^{-1/2}$

59. 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) $\frac{\lambda m}{M}$
(b) $\lambda\sqrt{\frac{m}{M}}$
(c) $\frac{\lambda M}{m}$
(d) $\lambda\sqrt{\frac{M}{m}}$

60. Consider a proton moving with kinetic energy *E*. Its de Broglie wavelength is given by:
(a) $\frac{hc}{\sqrt{2ME}}$
(b) $\frac{h}{q\sqrt{ME}}$
(c) $\frac{h}{\sqrt{2ME}}$
(d) $\frac{\sqrt{2MEq}}{hc}$

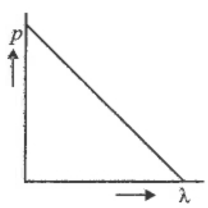
61. Neglecting variation of mass with velocity, the wavelength associated with an electron having the kinetic energy E is proportional to
(a) $E^{1/2}$
(b) $E^{-1/2}$
(c) E
(d) E^{-2}

62. An electron and a proton are accelerated through the same potential difference. The ratio of their de Broglie wavelength is
(a) $(m_p/m_e)^{1/2}$
(b) m_p/m_e
(c) m_e/m_p
(d) $(m_e/m_p)^{1/2}$

63. A proton accelerated through a potential difference of 100 V, has de-Broglie wavelength λ_0. The de-Broglie wavelength of an α-particle, accelerated through 800 V is
(a) $\frac{\lambda_o}{\sqrt{2}}$
(b) $\frac{\lambda_o}{2}$
(c) $\frac{\lambda_o}{4}$
(d) $\frac{\lambda_o}{8}$

64. Matter waves
(a) are longitudinal waves
(b) are electromagnetic waves in nature
(c) always travel with the speed of light
(d) show diffraction

65. Which of the following graphs represents the variation of the wavelength?

(a)


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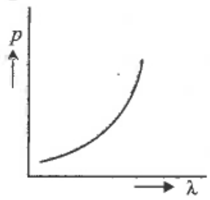

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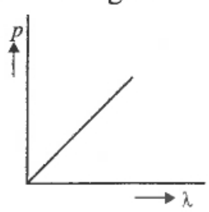

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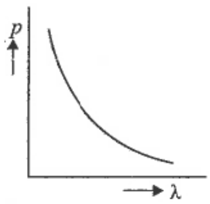


66. **Assertion :** A charged and an uncharged particle each have the same momentum and same de Broglie wavelength.
Reason: de Broglie wavelength does not depend upon the charge.
(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are true but Reason is not correct explanation of Assertion.

(c) If Assertion is true but Reason is false.

(d) If Assertion is false but Reason is true.

67. Proton and α particle have the same de Broglie wavelength. What is same for both?

(a) Time period (b) Energy (c) Frequency (d) Momentum

68. 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) 0.6 V (b) 1.3V (c) 0.133 V (d) 0.06 V

69. 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) 2 λ (b) 4 λ (c) 8 λ (d) 6 λ

70. 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) $\frac{16}{9}E$

71. When a metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V. If the same surface is illuminated with radiation of wavelength 2 λ, the stopping potential is V/4. The threshold wavelength for the metallic surface is

(a) $\frac{5}{2}\lambda$ (b) 3 λ (c) 4 λ (d) 5 λ

72. 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

73. Assuming the nitrogen molecule is moving with r.ms. 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

(a) 0.44 Å (b) 0.34 Å (c) 0.20 Å (d) 0.24 Å

74. 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 :

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

75. A silver sphere of radius 1 cm and work function 4.7 eV is suspended from an insulating thread in free-space. It is under continuous illumination of 200 nm wavelength of light. As photoelectrons are emitted, the sphere gets charged and acquires a potential. The maximum number of photoelectrons emitted from the sphere is $A \times 10^{Z}$ (where $1 < A < 10$). The value of 'Z' is

(a) 6 (b) 7 (c) 8 (d) 9

76. 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 :

(a) 1/500 (b) 500 (c) 250 (d) 1/250

77. 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 :.

(a) 1.02 eV (b) 0.81 eV (c) 0.61 eV (d) 0.52 eV

78. A parallel beam of light of intensity 'I' and cross-section area 'S' incident on a plate at normal incidence. The photoelectric emission efficiency is 100%, the frequency of beam is ν and the work function of the plate is ϕ(hv

> ϕ). Assume all the electrons are ejected normal to the plane and with same maximum possible speed. The net force exerted on the plate only due to striking of photons and subsequent emission of electrons is

(a) $\frac{IS}{h\nu}\left(\frac{2h}{\lambda}+\sqrt{2m(h\nu-\phi)}\right)$ (b) $\frac{2IS}{h\nu}\left(\frac{h}{\lambda}+\sqrt{2m(h\nu-\phi)}\right)$

(c) $\frac{IS}{h\nu}\left(\frac{h}{\lambda}+\sqrt{2m(h\nu-\phi)}\right)$ (d) $\frac{2IS}{h\nu}\left(\frac{h}{\lambda}+\sqrt{m(h\nu-\phi)}\right)$

79. The de-Broglie wavelength of a neutron at 927° C is λ. Its wavelength at 27° C is:

(a) $\frac{\lambda}{2}$ (b) λ (c) 2λ (d) 4λ

80. A quartz lamp with iodine vapour releases ultraviolet light which falls on a photoelectric cell. If a thick glass plate is now introduced between the lamp and photoelectric cell then :

(a) the photoelectric current increases
(b) the maximum kinetic energy of photoelectrons decreases
(c) the photoelectric current decreases
(d) the maximum kinetic energy of photoelectrons increases

INPUT TEXT BASED MCQs

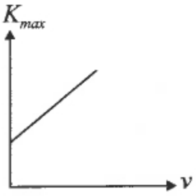
1. *In 1905, Albert Einstein (1879-1955) proposed a radically new picture of electromagnetic radiation to explain photoelectric effect. In this picture, photoelectric emission does not take place by continuous absorption of energy from radiation. Radiation energy is built up of discrete units–the so called quanta of energy of radiation. Each quantum of radiant energy has energy hv, where h is Plank's constant and v the frequency of light. In photoelectric effect, an electron absorbs a quantum of energy (hv) of radiation. If this quantum of energy absorbed exceeds the minimum energy needed for the electron to escape from the metal surface (work function ϕ_0), the electron is emitted with maximum kinetic energy.*

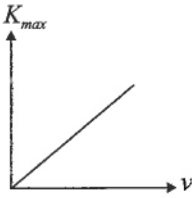
$$K_{max} = h\nu - \phi_0$$

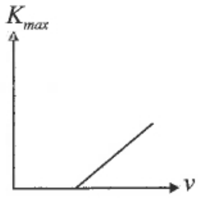
(i) A metal of work function 3.3 eV is illuminated by light of wavelength 300 mm. The maximum kinetic energy of photoelectrons is (taking $h = 6.6 \times 10^{-14}$ Js)

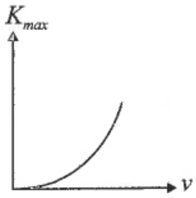
(a) 0.413 eV (b) 0.825 eV (c) 1.65 eV (d) 1.32 eV

(ii) The variation of maximum kinetic energy (K_{max}) of the emitted photoelectrons with frequency (ν) of the incident radiations can be represented by

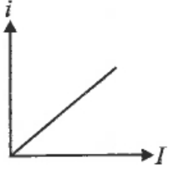
(a) 

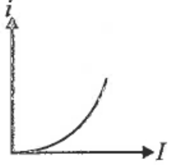
(b) 

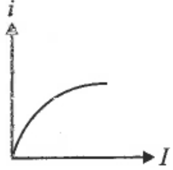
(c) 

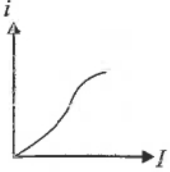
(d) 

(iii) The variation of photoelectric current (i) with the intensity of the incident radiation (I) can be represented by

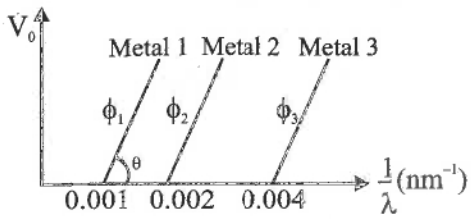
(a) 

(b) 

(c) 

(d) 

(iv) The graph between the stopping potential (V_0) and $\frac{1}{\lambda}$ is shown in the figure, ϕ_1, ϕ_2, ϕ_3 are work function. Which of the following options is correct?

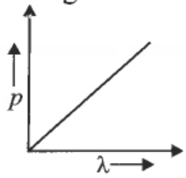


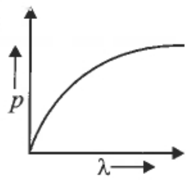
(a) $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 3$
(b) $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$

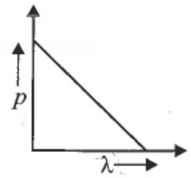
(c) $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

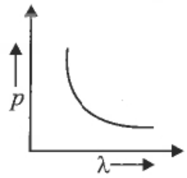
(d) Ultraviolet light can be used to emit photoelectrons from metal 2 and metal 3 only

(v) Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?

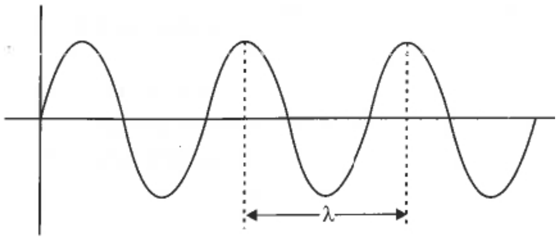
(a)


(b)


(c)


(d)


2. *According to de-Broglie, a moving material particle sometimes acts as a wave and sometimes as a particle or a wave associated with moving material particle which controls the particle in every respect. The wave associated with moving particle is called matter wave or de-Broglie wave. de Broglie proposed that the wave length λ associated with a particle of momentum p is given as*



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

Where m is the mass of the particle and v its speed. Above equation is known as the de Broglie relation and the wavelength λ of the matter wave is called de Broglie wavelength.

(i) If a proton and an electron have the same de Broglie wavelength, then

(a) kinetic energy of electron < kinetic energy of proton

(b) kinetic energy of electron = kinetic energy of proton

(c) momentum of electron = momentum of proton

(d) momentum of electron < momentum of proton

(ii) Which of these particles having the same kinetic energy has the largest de Broglie wavelength?

(a) Electron (b) Alpha particle (c) Proton (d) Neutron

(iii) Two particles A_1 and A_2 of masses m_1, m_2 $(m_1 > m_2)$ have the same de Broglie wavelength. Then

(a) their momenta are the same (b) their energies are the same

(c) momentum of A_1 is less than the momentum of A_2. (d) energy of A_1 is more than the energy of A_2.

(iv) When the velocity of an electron increases, its de Broglie wavelength

(a) increases (b) decreases

(c) remains same (d) may increase or decrease

(v) Proton and α-particle have the same de-Broglie wavelength. What is same for both of them?

(a) Time period (b) Energy (c) Frequency (d) Momentum

ANSWERS

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

Input Text Based MCQs

1. (i) (b), (ii) (c), (iii) (a), (iv) (c), (v) (d) **2.** (i) (c), (ii) (a), (iii) (a), (iv) (b), (v) (d)