C H A P T E R

11

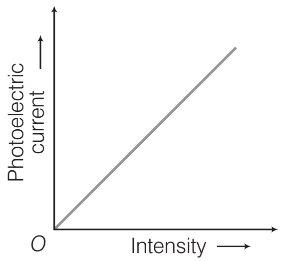
Dual Nature of Radiation and Matter

A Quick Recapitulation of the Chapter

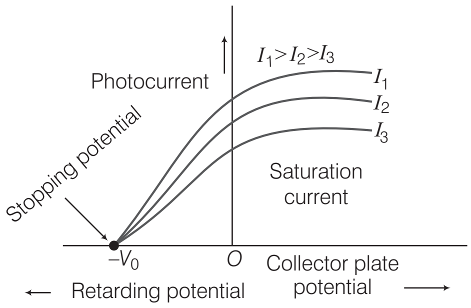
1. The minimum amount of energy required to just eject an electron from the outermost surface of metal is known as **work function** of the metal.

   Also, work function, $W = h\nu_0 = \frac{hc}{\lambda_0}$

   where, ν_0 and λ_0 are the threshold frequency and threshold wavelength, respectively.
2. **Photoelectric emission** is the phenomenon of emission of electrons from the surface of metal when light radiations of suitable frequency fall on it.
3. The phenomenon of emission of photoelectron from the surface of metal, when a light beam of suitable frequency is incident on it, is called **photoelectric effect**. The emitted electrons are called photoelectrons and the current so produced is called photoelectric current.
4. **Effect of Intensity of Light on Photocurrent** For a fixed frequency of incident radiation, the photoelectric current increases linearly with increase in intensity of incident light.



5. **Effect of Potential on Photoelectric Current** For a fixed frequency and intensity of incident light, the photoelectric current increases with increase in the potential applied to the collector. When all the photoelectrons reach the plate *A*, current becomes maximum it is known as **saturation current.**



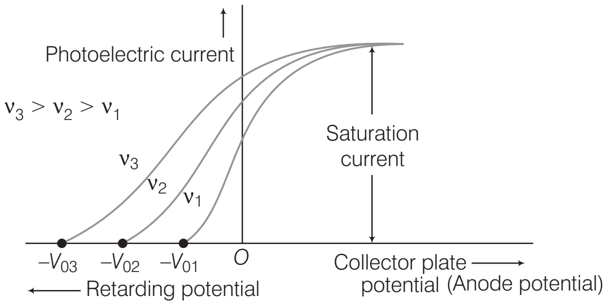
6. For a particular frequency of incident radiation, the minimum negative (retarding) potential V_0 given to plate for which the photoelectric current becomes zero is called **cut-off** or **stopping potential**.

$$KE_{max} = eV_0$$

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

7. **Effect of Frequency of Incident Radiation on Stopping Potential** We take radiations of different frequencies but of same intensity. For each radiation,

we study the variation of photoelectric current against the potential difference between the plates.



8. The minimum frequency of light which can emit photoelectrons from a material is called **threshold frequency** or **cut-off frequency** of that material.
9. The maximum wavelength of light which can emit photoelectrons from a material is called **threshold wavelength** or **cut-off wavelength** of that material.
10. According to Planck's quantum theory, light radiations consist of tiny packets of energy is called **quanta.** One quantum of light radiation is called a photon which travels with the speed of light.
11. **Einstein Photoelectric Equation** Energy quantum of radiation, $K_{max} = h\nu - \phi_0$

    where, $h\nu$ = energy of photon and ϕ = work-function
12. **Relation between Stopping Potential (V_0) and Threshold Frequency (ν_0)**

    We know that $h\nu = \text{KE}_{\text{max}} + W_0$

    where, W_0 = work function

    $$\text{KE}_{max} = h\nu - W_0 \quad \text{also, } W_0 = h\nu_0$$
    $$\text{KE}_{max} = h\nu - h\nu_0 \Rightarrow \text{KE}_{max} = h(\nu - \nu_0)$$
    $$eV_0 = h(\nu - \nu_0)$$
    $$\Rightarrow V_0 = \frac{h}{e}(\nu - \nu_0) \quad (\because \text{KE}_{max} = eV_0)$$
    $$\nu = \frac{c}{\lambda} \text{ and } \nu_0 = \frac{c}{\lambda_0}$$
    $$V_0 = \frac{h}{e}\left[\frac{c}{\lambda} - \frac{c}{\lambda_0}\right] \Rightarrow$$
    $$V_0 = \left(\frac{hc}{e}\right)\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

    For photoelectric emission $\lambda < \lambda_0$ and $\nu > \nu_0$.
13. Energy of each photon is given by $E = h\nu = \frac{hc}{\lambda}$
14. Momentum of each photon is given by $p = \frac{h}{\lambda} = \frac{h\nu}{c}$
15. Energy $E = mc^2 \Rightarrow m = \frac{E}{c^2} = \frac{h\nu}{c^2} = \frac{h}{c\lambda}$
16. de-Broglie wavelength is given by

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

    where, $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$,

    m_0 being the rest mass of the particle and c is the speed of light.

    E is the kinetic energy.

    For an electron, $\lambda = \frac{12.27}{\sqrt{V}}$ Å

    where, V is potential difference.
17. Electron diffraction experiments by Davisson and Germer, and by GP Thomson have verified and confirmed the wave nature of electrons.

Objective Questions Based on NCERT Text

Topic 1
Electron Emission

1. Gases are non-conductor at NTP. They are most conducting at
(a) low temperature and low pressure
(b) low temperature and high pressure
(c) high temperature and low pressure
(d) high temperature and high pressure

2. When electric field is applied between cathode and anode at pressure of about 0.001 mm of mercury in a discharge tube, following is observed.
(a) There is no discharge in the tube
(b) A *zig-zag* thin red spark runs from cathode to anode
(c) Whole of tube is filled with bright light
(d) A fluorescent glow appeared

3. Colour of glow in a discharge tube at a pressure of 0.001 mm of mercury column depends on
(a) nature of gas in the discharge tube
(b) potential diference between cathode and anode
(c) nature of material of cathode
(d) nature of glass of the discharge tube

4. Glow in discharge tube is due to

(a) X-rays (b) positive rays
(c) cathode rays (d) collision of gas ions

5. Cathode rays are

(a) streams of positive ions
(b) streams of negatively charged particles
(c) streams of nuclei
(d) streams of neutrons

6. Cathode rays are streams of fast moving negatively charged particles. Their speed range is (consider $c \approx 3 \times 10^8$ ms^{-1})

(a) 0.1 c to 0.2 c
(b) c
(c) greater than c
(d) around $10^{-5} c$ to $10^{-3} c$

7. Specific charge of electrons is

(a) 1.76×10^{11} C kg^{-1} (b) 1.6×10^{-19} C kg^{-1}
(c) 9.11×10^{-31} C kg^{-1} (d) 1.67×10^{-27} C kg^{-1}

8. Value of e/m (specific charge) of the cathode ray particles

(a) depends on potential difference of cathode and anode
(b) depends on nature of gas in the discharge tube
(c) is independent of material of cathode or gas in tube
(d) depends on nature of metal used for cathode

9. The specific charge of a proton is 9.6×10^7 kg^{-1}. The specific charge of an α-particle will be

(a) 9.6×10^7 C kg^{-1} (b) 19.2×10^7 C kg^{-1}
(c) 4.8×10^7 C kg^{-1} (d) 2.4×10^7 C kg^{-1}

10. RA Millikan during his oil-drop experiment on electron found that the charge on an oil drop is

(a) a fraction of 1.6×10^{-19} C
(b) an even multiple of 1.6×10^{-19} C
(c) an odd multiple of 1.6×10^{-19} C
(d) an integral multiple of 1.6×10^{-19} C

11. Which of the following wavelengths falls in X-ray region?

(a) 0.5 Å (b) 10^3 Å
(c) 10^{-3} Å (d) 10^2 Å

12. X-ray can be deflected by applying

(a) a magnetic field (b) an electric field
(c) Both (a) and (b) (d) None of these

13. An electron is accelerated through a potential difference of 1000 V, its velocity is nearly

(a) 3.8×10^7 ms^{-1} (b) 1.9×10^6 ms^{-1}
(c) 1.9×10^7 ms^{-1} (d) 5.7×10^7 ms^{-1}

14. Mass of a particle is 400 times than that of an electron and charge is double that of an electron. The particle is accelerated by a potential difference of 5 V. If particle is initially at rest, then its final KE will be

(a) 5 eV (b) 10 eV
(c) 100 eV (d) 2000 eV

15. Gases begin to conduct electricity at low pressure because

(a) at low pressure gases turn to plasma
(b) colliding electrons can acquire higher kinetic energy due to increased mean path leading to ionisation of atoms
(c) atom break into ions and electrons
(d) the electrons in atoms can move freely at low pressure

16. Cathode rays are produced when the pressure is of order of

(a) 2 cm of Hg (b) 0.1 cm of Hg
(c) 0.001 mm of Hg (d) 10 cm of Hg

17. An electron initially at rest is accelerated through a potential difference of 200 V, so that it acquires a velocity of 8.4×10^6 ms^{-1}. The value of e/m of electron is

(a) 2.76×10^{12} C kg^{-1} (b) 1.76×10^{11} C kg^{-1}
(c) 0.76×10^{12} C kg^{-1} (d) 2.76×10^{11} C kg^{-1}

18. Which of the following orders of specific charge of proton, α-particle and electron is correct

(a) $e > p > \alpha$ (b) $p > \alpha > e$
(c) $e > \alpha > p$ (d) $p > e > \alpha$

19. In Millikan's oil drop experiment an oil drop having charge q gets stationary on applying a potential difference V between two plates separated by a distance d. The weight of the drop is

(a) qVd (b) $q\dfrac{d}{V}$ (c) $\dfrac{q}{Vd}$ (d) $q\dfrac{V}{d}$

20. Free electrons cannot normally escape out of metal surface because

(a) free electrons are bounded to one or other ion core
(b) free electrons lie deep inside atom
(c) free electrons are held in metal lattice by attraction force of protons
(d) if an electron attempts to come out of metal, the metal surface acquires a positive charge and pulls the electron back to metal

21. Work-function is

(a) maximum possible energy acquired by an electron
(b) energy of electrons in valence shell
(c) minimum energy required by an electron to move out of metal surface
(d) maximum energy which is given to electron to move it out of metal surface

22. Work-function for a metal will change
(a) if it is heated (b) if it is cooled
(c) if it is coated (d) All of these

23. Work-function is least for
(a) caesium (b) aluminium
(c) silver (d) platinum

24. When light of suitable high frequency falls on a metal surface, it emits electrons this process is called
(a) field emission (b) electron emission
(c) thermionic emission (d) photoemission

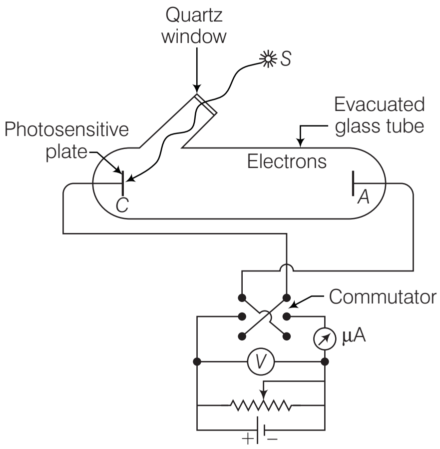
25. Kinetic energy of emitted electron depends on
(a) amount of energy acquired from an external source
(b) work function of an electron
(c) Both (a) and (b)
(d) it does not depend on any physical quantity

26. For moving elementary charged particles,
(a) q/m value is measured and not q or m separately
(b) only q or m can be measured and these are more important than q/m
(c) q/m value is not measured
(d) q/m value is important only for electrons

Topic 2
Photoelectric Effect and Wave Theory

27. Photoelectric effect supports quantum nature of light because
(a) there is a minimum frequency of light below which no photoelectrons are emitted
(b) the maximum kinetic energy of photoelectrons do not depends on the frequency of light and not on its intensity
(c) when the metal surface is faintly illuminated, the photoelectrons will not leave the surface immediately
(d) electric charge of the photoelectrons is quantised

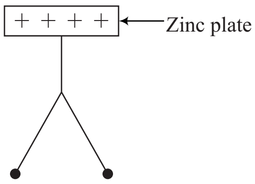
28. Lenard observed that when UV-radiations were allowed to fall on the emitter plate of an evacuated glass tube enclosing two electrodes, current flows in the circuit as shown in figure. Reason is



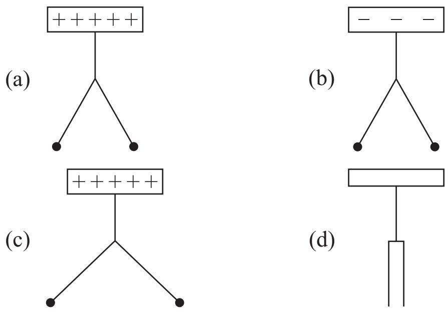
(a) UV-light ionises the traces of gas left after evacuation
(b) UV-light produces ionisation of cathode and anode
(c) UV-light causes ionisation of cathode
(d) UV-light causes ejection of electrons from the emitter plate

29. Which one among the following shows particle nature of light?
(a) Photoelectric effect (b) Interference
(c) Refraction (d) Polarization

30. A positively charged zinc plate is connected to an electroscope.



It is then irradiated by UV-light. Result is



31. Lenard observed that no electrons are emitted when frequency of light is less than a certain minimum frequency. This minimum frequency depends on
(a) potential difference of emitter and collector plates
(b) distance between collector and the emitter plate
(c) size (area) of the emitter plate
(d) material of the emitter plate

32. Photoelectric effect involves
(a) conversion of nuclear energy into electrical energy
(b) conversion of atomic energy into electrical energy
(c) conversion of electronic energy into electrical energy
(d) conversion of light energy into electrical energy

33. Photoemission with visible light is possible in
(a) alkali metals (b) alkaline earth metals
(c) metalloids (d) semiconductors

34. When yellow light is incident over a metal surface, no electrons are emitted while green light can emit electrons. If red light is incident over the surface, then
(a) no electrons are emitted
(b) more electrons are emitted
(c) electrons of higher energy are emitted
(c) electrons of lower energy are emitted

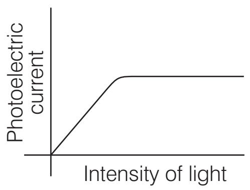
35. When ultraviolet rays are incident on a metal surface the photoelectric effect does not occur. It may occur by the incidence of
(a) X-rays (b) radiowave
(c) infrared rays (d) sound waves

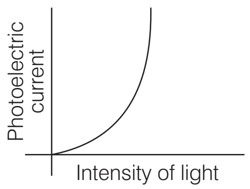
36. In the experimental study of photoelectric effect, light used is
(a) monochromatic light
(b) white light
(c) polychromatic light
(d) light from a tungsten filament lamp

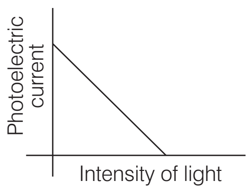
37. Light used to emit electrons from metal plate is
(a) short wavelength (b) long wavelength
(c) polarised light (d) low speed

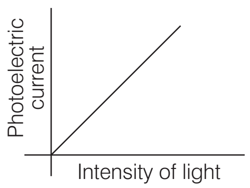
38. While studying, effect of variation of intensity on the photocurrent, intensity of light is changed in a photocell by
(a) using a prism in the path of light beam
(b) using a thick glass sheet
(c) tilting the cathode
(d) changing the distance of light source from the emitter

39. Variation of photoelectric current with intensity of light is

(a)


(b)


(c)


(d)


40. Number of photoelectrons emitted per second is proportional to the
(a) intensity of incident radiation
(b) colour of incident radiation
(c) angle of incidence of incident radiation
(d) potential difference of collector and emitter plates

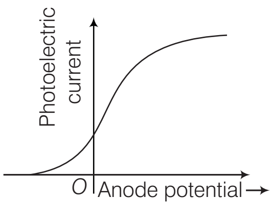
41. To measure the effect of potential on photoelectric current
(a) intensity and frequency of incident light is kept fixed
(b) only intensity is kept fixed
(c) only frequency is kept fixed
(d) only potential of collector plate is kept fixed

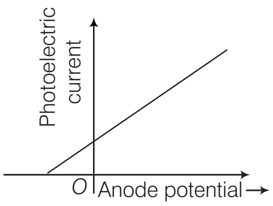
42. With the increase in potential difference of emitter and collector, the photoelectric current
(a) increases
(b) decreases
(c) remains constant
(d) increases initially and then become constant

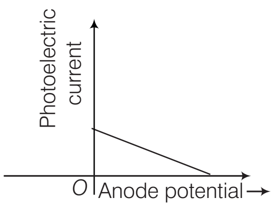
43. At certain positive potential of collector plate, photocurrent becomes maximum or saturates. Saturation current corresponds to the case when
(a) half of photoelectrons emitted by emitter plate reaches collector
(b) more than half of photoelectrons emitted by emitter plate reaches collector
(c) less than half of photoelectrons emitted by emitter plate reaches collector
(d) All of the photoelectrons emitted by emitter plate reaches the collector plate

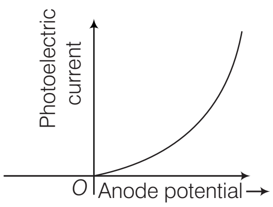
44. When polarity of collector plate is reversed,
(a) only slow electrons reach collector
(b) only very fast electrons reach collector
(c) no electron can reach collector
(d) all electrons move towards emitter

45. Variation of photoelectric current with anode potential is shown below. Choose the correct option.

(a)


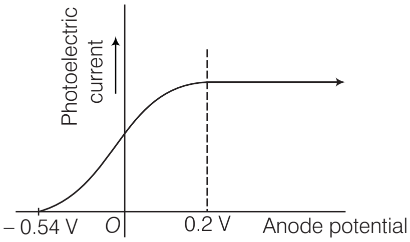
(b)


(c)


(d)


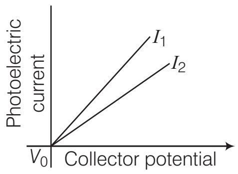
46. Stopping potential is
(a) maximum possible negative potential of anode
(b) minimum possible negative potential of anode for which photoelectric current is zero
(c) anode potential for which photoelectric current is saturated at constant intensity
(d) None of the above

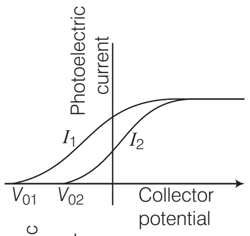
47. Obtain the value of stopping potential from the given graph is

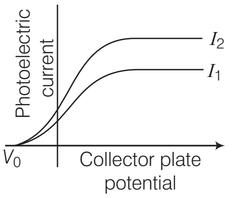


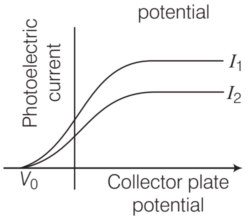
(a) -0.54 V (b) 0.54 V (c) 0.2 V (d) -0.2 V

48. Variation of photoelectric current with collector plate potential for different intensities $(I_1 > I_2)$ at a fixed frequency is

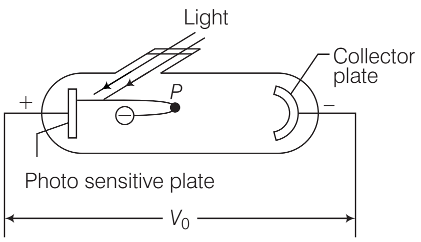
(a)


(b)


(c)


(d)


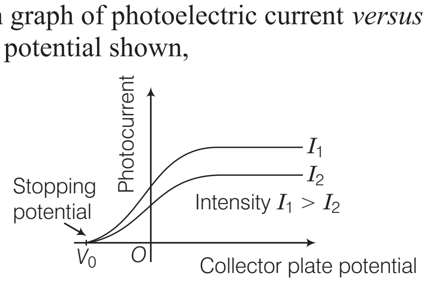
49. If collector plate is made negative with respect to emitter, at certain potential V_0, photocurrent is zero.



If K indicates kinetic energy of an emitted photoelectron, then at point P;

(a) $K > eV_0$ (b) $K < eV_0$
(c) $K = eV_0$ (d) $0 \leq K \leq eV_0$

50. From graph of photoelectric current *versus* collector plate potential shown,



We conclude that

(a) maximum KE of photoelectrons is independent of intensity
(b) maximum KE of photoelectrons depends on intensity
(c) minimum KE of photoelectrons is independent of nature of material
(d) minimum KE of photoelectrons depends on intensity

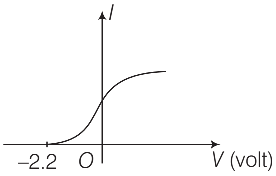
51. Maximum KE of photoelectrons depends on

(a) accelerating potential and light source
(b) only accelerating potential
(c) light source and emitter plate material
(d) only emitter plate material

52. Stopping potential is more negative for

(a) higher frequency of incident radiation
(b) lower frequency of incident radiation
(c) higher intensity of incident radiation
(d) lower intensity of incident radiation

53. In a photoelectric experiment the relation between applied potential difference between cathode and anode V and the photoelectric current I was found to be shown in graph below. If Planck's constant $h = 6.6 \times 10^{-34}$ Js, the frequency of incident radiation would be nearly (in s^{-1})($\phi = 1$eV)



(a) 0.436×10^{18} (b) 0.436×10^{17}
(c) 0.775×10^{15} (d) 0.775×10^{16}

54. An electron gun with its anode at a potential difference of 120 V fires out electron in a spherical bulb containing hydrogen gas at low pressure (10^{-2} mm of Hg). A magnetic field of 2.5×10^{-4}T curves the path of the electron in a circular orbit of radius 13 cm. The *e/m* ratio is

(a) 2.27×10^{-11} C kg^{-1}
(b) 2.27×10^{8} C kg^{-1}
(c) 2.27×10^{-8} C kg^{-1}
(d) 2.27×10^{11} C kg^{-1}

55. In an experiment on photoelectric effect, the slope of the cut-off voltage *versus* frequency of incident light is found to be 12×10^{-15} V-s. Calculate the value of Planck's constant.

(a) 6.0×10^{-34} Js
(b) 0.63×10^{-34} Js
(c) 6.59×10^{-34} Js
(d) 0

56. Photoelectrons are emitted from a metal surface when light of suitable frequency is incident over a metal surface. Then, all of emitted photoelectrons

(a) do not have same kinetic energy
(b) have same momentum
(c) have same velocity
(d) do not have kinetic energy

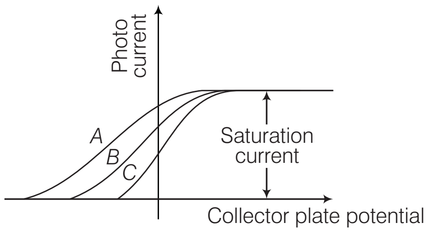
57. Photoelectric current in an experimental study of photoelectric effect is made zero by making anode negative with respect to cathode. If stopping potential is V_0, then

(a) kinetic energy of emitted photoelectron is $K = eV_0$
(b) for every emitted photoelectron kinetic energy $K \geq eV$
(c) maximum kinetic energy of emitted electrons $K_{\max} = eV_0$
(d) sum of kinetic energies of emitted photoelectrons is $\Sigma K = eV_0$

58. When intensity of incident radiation is changed to study the effect of intensity on stopping potential, it is found that,

(a) stopping potential increases with increase in intensity
(b) stopping potential decreases with increase in intensity
(c) stopping potential remains same even when intensity is increased
(d) stopping potential first decreases, then increases with increase in intensity

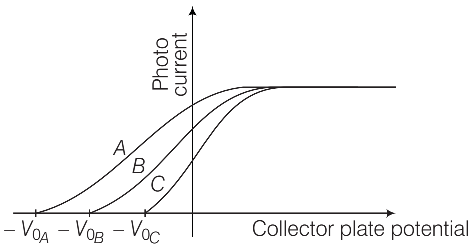
59. For the graph of collector plate potential *versus* photo electric current shown,



If I denotes intensity of incident radiation, then

(a) $I_A > I_B > I_C$ (b) $I_A < I_B < I_C$
(c) $I_A = I_B = I_C$ (d) $I_B > I_A$ and $I_B < I_C$

60. For the graph shown,



If f denotes frequency of incident light

(a) $f_A > f_B > f_C$ (b) $f_A < f_B < f_C$
(c) $f_A = f_B = f_C$ (d) $f_B > f_C$ and $f_B > f_A$

61. Greater the frequency of incident light

(a) lesser is the maximum kinetic energy of emitted electrons
(b) lesser is the minimum kinetic energy of emitted electrons
(c) greater is the maximum kinetic energy of emitted electrons
(d) greater is the minimum kinetic energy of emitted electrons

62. Which of the following is true for a photosensitive material?

(a) All materials shows photosensitivity to some or more extent
(b) Different photosensitive materials have same sensitivity
(c) Same photosensitive substance gives different response to light of different wavelengths
(d) All photosensitive materials give response to green light

63. Photoelectric emission is observed from a metallic surface for frequencies ν_1 and ν_2 of the incident light $(\nu_1 > \nu_2)$. If the maximum values of kinetic energy of the photoelectrons emitted in the two cases are in the ratio $1 : n$, then the threshold frequency of the metallic surface is

(a) $\frac{(\nu_1 - \nu_2)}{(n-1)}$ (b) $\frac{(n\nu_1 - \nu_2)}{(n-1)}$
(c) $\frac{(n\nu_2 - \nu_1)}{(n-1)}$ (d) $\frac{(\nu_1 - \nu_2)}{n}$

64. In a photoelectric experiment, for different incident frequencies of same intensities, we have

(a) same saturation current but different stopping potentials
(b) same stopping potential but different value of saturation current
(c) same saturation current value and same stopping potential value
(d) both saturation current and stopping potential are different for different frequencies

65. Energy of emitted photoelectrons depends on

(a) intensity of incident radiation
(b) frequency of incident radiation
(c) both on intensity and frequency of incident radiation
(d) does not depends on frequency or intensity of incident radiation

66. Photoemission of electrons

(a) is instantaneous process with a time lag of less than nano second
(b) is slow with a large time lag
(c) shows a time lag of around 1 s
(d) time lag of less than 1 s cannot be calculated

67. A beam of wavelength λ and intensity I falls over a clean surface of sodium metal. If N photoelectrons are emitted with kinetic energy E, then

(a) $N \propto I$ and $E \propto I$ (b) $N \propto I$ and $E \propto \frac{1}{\lambda}$

(c) $N \propto \lambda$ and $E \propto I$ (d) $N \propto \frac{1}{\lambda}$ and $E \propto \frac{1}{I}$

68. 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 change are I_1 and I_2, all other conditions remaining unchanged and assuming ($E_1 > W_2$), then

(a) $I_1 = I_2$ (b) $I_1 < I_2$ (c) $I_1 > I_2$ (d) $\frac{W_1}{W_2} = \frac{I_1}{I_2}$

69. If light is considered a wave, then time delay for photoemission is of hours because

(a) metal surface reflects the wave
(b) metal surface may not be in resonance with the wave
(c) metal surface has many electrons
(d) energy carried by a wave is very less

70. Phenomena of interference, diffraction and polarisation are explained by

(a) wave theory of light
(b) particle theory of light
(c) Newton's Corpuscular theory
(d) Einstein's mass-energy relation

71. Light is an electromagnetic wave consisting of electric and magnetic fields with

(a) uniform distribution of electrons
(b) continuous distribution of energy
(c) no distribution of energy
(d) discrete distribution of energy

72. When a light wave is incident over a metal surface, light energy is

(a) absorbed by free electrons of the metal surface
(b) reflected completely back into first medium
(c) refracted completely through the metal
(d) absorbed by the nuclei of surface atoms

73. According to wave theory of light,

(a) maximum KE of electrons increases with frequency
(b) maximum KE of electrons increases with intensity
(c) maximum KE of electrons increases with decrease in frequency
(d) maximum KE of electrons does not depend on intensity

74. According to wave theory of light,

(a) frequency less than threshold frequency is required for photoemission
(b) frequency greater than threshold frequency is required for photoemission
(c) frequency equal to that of threshold frequency is required
(d) a beam of sufficient high intensity is required

75. According to wave theory, time required for photoemission is

(a) less than 10 s (b) around 10^{-9} s
(c) around 1s (d) around few hours

76. Photoelectric effect can be explained by

(a) Corpuscular theory of light
(b) Wave nature of light
(c) Bohr's theory
(d) Quantum theory of light

77. Light of intensity 10^{-5} Wm^{-2} falls on sodium photo cell of surface area 2 cm^2 and work function 2 eV. Assuming that, only top 5 layers of sodium absorbs the incident energy and effective atomic area of sodium atom is 10^{-20} m^2, the time required for photoemission in wave picture of light is nearly

(a) $10\frac{1}{2}$ s (b) $\frac{1}{2}$ s (c) $\frac{1}{2}$ h (d) $\frac{1}{2}$ yr

Topic 3
Einstein's Photoelectric Equation and Energy Quantum of Radiation

78. According to Albert Einstein, photoelectric emission does not takes place by …*A*…of energy from radiation. Radiation energy is build up of discrete units called …*B*… of energy of radiation. Here, *A* and *B* refer to

(a) radiation, bundle
(b) incidence, packet
(c) emission, thrust
(d) continuous absorption, quanta

79. The photoelectric threshold frequency of a metal is ν. When light of frequency 6ν is incident on the metal, the maximum kinetic energy of the emitted photo electron is

(a) $4h\nu$ (b) $5h\nu$ (c) $3h\nu$ (d) $(3/2)\,h\nu$

80. Electrons emitted due to absorption of energy of radiation will have a maximum kinetic energy

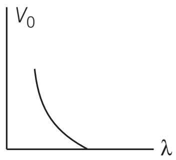
(a) $K_{max} = h\nu - \phi_0$ (b) $K_{max} = \phi_0 - h\nu$
(c) $K_{max} > h\nu - \phi_0$ (d) $K_{max} < h\nu - \phi_0$

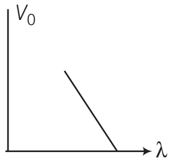
81. Maximum kinetic energy K_{max} of emitted photoelectrons is determined by
(a) total number of photons absorbed
(b) rate of photons incident over surface
(c) energy of each photon
(d) distance of source from the surface

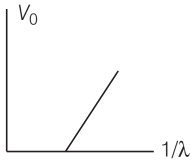
82. Einstein's photoelectric equation is
(a) $K_{max} = \frac{1}{2}mv^2$
(b) $K_{max} = eV_0$
(c) $K_{max} = h\nu - \phi_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$
(d) $K_{max} = mc^2$

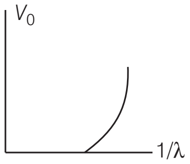
83. Einstein's photoelectric equation is based on
(a) conservation of momentum
(b) de-Broglie's matter wave
(c) conservation of energy
(d) mass-energy relation

84. For photoelectric effect with incident photon wavelength λ, the stopping potential is V. Identify the correct variations of V_0 with λ_0 and $\frac{1}{\lambda}$. **[JEE Advanced 2015]**

(a)


(b)


(c)


(d)


85. According to Einstein's equation $K_{max} \propto \nu$ because
(a) an electron is emitted after absorption of few photons when absorbed energies exceeds certain value
(b) an electron is emitted after number of photons falling over surface exceeds of critical volume
(c) an electron is emitted only if it is present on the surface
(d) an electron is emitted after absorption of a single photon of sufficient energy

86. An electron is emitted from a metal surface, when
(a) $h\nu > \phi_0$ (b) $h\nu < \phi_0$ (c) $h\nu = \phi_0$ (d) $0 < h\nu < \phi_0$

87. Energy E of emitted photoelectrons ranges from
(a) $h\nu < E < K_{max}$ (b) $\phi_0 < E < K_{max}$
(c) $K_{max} > E > \infty$ (d) $0 < E < K_{max}$

88. As kinetic energy (K_{max}) is always positive, so
(a) $h\nu = \phi_0$ (b) $h\nu > \phi_0$
(c) $h\nu < \phi_0$ (d) None of these

89. Intensity of light is
(a) number of photons falling over an area is 1 s
(b) number of photons falling over an area
(c) number of photons falling over unit area in unit time
(d) number of photons emitted by source in 1 s

90. According to Einstein, photoemission occurs only, when
(a) incident radiation must be very intense
(b) metal surface must be smooth
(c) incident radiation must falls over surface for a sufficient time
(d) frequency of incident radiation exceeds threshold frequency

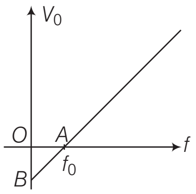
91. For incident frequency greater than threshold frequency, photocurrent is proportional to
(a) intensity (b) work-function
(c) distance of source (d) initial energy of electron

92. In photoemission, if intensity of radiation falling over surface is very low, then
(a) time required will be large
(b) time required will be small
(c) process in instantaneous whether intensity is low or high
(d) photoemission does not occurs

93. V_0 *versus* ν curve is a
(a) straight line with slope = ϕ_0
(b) straight line with slope = ϕ_0 / e
(c) straight line with slope = h/e
(d) straight line with zero slope

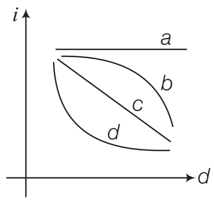
94. Stopping potential *versus* frequency graph for a metal surface is a straight line. Planck's constant is given by
(a) slope of line
(b) product of slope of the line and charge of electron
(c) product of y intercept and mass of electron
(d) product of slope and mass of electron

95. In an experiment on photoelectric effect, the frequency f of incident light is plotted against the stopping potential V_0. The work-function of the photoelectric surface is given by



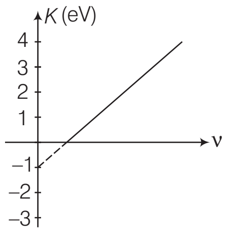
(a) $OB \times e$ (in eV) (b) OB (in volts)
(c) OA (in eV) (d) the slope of line AB

96. A point source of light is used in an experiment on photoelectric effect. Which of the following curves best represents the variation of photoelectric current i with distance d of the source from the emitter?



(a) a (b) b
(c) c (d) d

97. Figure represents a graph of kinetic energy K of photoelectrons and frequency ν for a metal used or cathode in photoelectric experiment. The work function of metal is



(a) 1 eV (b) 1.5 eV
(c) 2 eV (d) 3 eV

98. 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 wavel ength 2λ, the stopping potential is $\frac{V}{4}$. The threshold wavelength for the metallic surface is **[NEET 2016]**

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

99. Light of wavelength 0.6 mm from a sodium lamp falls on a photocell and causes the emission of photoelectrons for which the stopping potential is 0.5 V and with the light of wavelength 0.4 mm from a sodium lamp, the stopping potential is 1.5 V with this data, the value of h/e is

(a) 4×10^{-59} Vs (b) 0.25×10^{15} Vs
(c) 4×10^{-15} Vs (d) 4×10^{-8} Vs

100. A metallic surface is irradiated by a monochromatic light of frequency ν_1 and stopping potential is found to be V_1. If the light of frequency ν_2 irradiates the surface. The stopping potential will be

(a) $V_1 + \frac{h}{e}(\nu_1 + \nu_2)$ (b) $V_1 + \frac{h}{e}(\nu_1 - \nu_2)$
(c) $V_1 + \frac{e}{h}(\nu_2 - \nu_1)$ (d) $V_1 - \frac{h}{e}(\nu_1 + \nu_2)$

101. The work function of platinum is 6.35 eV. The threshold frequency of platinum is

(a) 15.32×10^{14} Hz (b) 15.32×10^{16} Hz
(c) 15.32×10^{19} Hz (d) 15.32×10^{18} Hz

102. For a certain metal, incident frequency ν is five times of threshold frequency ν_0 and the maximum velocity of coming out photoelectrons is 8×10^6 ms^{-1} if $\nu = 2\nu_0$, the maximum velocity of photoelectrons will be

(a) 4×10^6 ms^{-1} (b) 6×10^6 ms^{-1}
(c) 8×10^6 ms^{-1} (d) 1×10^6 ms^{-1}

103. Two identical photo cathodes receive light of frequencies ν_1 and ν_2. If the velocities of the photo electrons (of mass m) coming out are v_1 and v_2 respectively, then

(a) $v_1^2 - v_2^2 = \frac{2h}{m}(\nu_1 - \nu_2)$ (b) $v_1 - v_2 = \left[\frac{2h}{m}(\nu_1 + \nu_2)\right]^{1/2}$
(c) $v_1^2 - v_2^2 = \frac{2h}{m}(\nu_1 + \nu_2)$ (d) $v_1 - v_2 = \left[\frac{2h}{m}(\nu_1 - \nu_2)\right]^{1/2}$

104. In experimenting with rubidium photocell, the following lines from a mercury source were used $\lambda_1 = 3650$ Å, $\lambda_2 = 4047$ Å, $\lambda_3 = 4358$ Å, $\lambda_4 = 5461$ Å, $\lambda_5 = 6907$ Å and stopping potentials respectively are $V_{01} = 1.28$ V, $V_{02} = 0.95$ V, $V_{03} = 0.74$ V, $V_{04} = 0.16$ V, $V_{05} = 0$ V.

Threshold frequency and work-function of metal are

(a) 4×10^{14} Hz, 1.5 eV (b) 4.3×10^{14} Hz, 1.8 eV
(c) 4×10^{14} Hz, 3 eV (d) 1.5×10^{14} Hz, 5 eV

105. Every metal has a definite work-function. Then, all photoelectrons do not come out with same kinetic energy, if incident radiation is monochromatic because

(a) KE of emitted electron depends on number of photons absorbed
(b) KE of emitted electron depends on energy of absorbed photon and each photon may be of different energy
(c) all electrons in an atom do not have the same energy level
(d) all electrons have same kinetic energy

106. The work-function of caesium metal is 2.14 eV. When light of frequency 6×10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. What is the

(i) stopping potential and
(ii) maximum speed of the emitted photoelectrons?

(a) $V_0 = 0.35$ V, $V_{max} = 350.7$ kms^{-1}
(b) $V_0 = .2$ V, $V_{max} = 250$ kms^{-1}
(c) $V_0 = 1.2$ V, $V_{max} = 250$ kms^{-1}
(d) None of the above

107. A photoelectric surface is illuminated successively by monochromatic light of wavelengths λ and $\lambda/2$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times than in the first case, the work function of the surface of the material is **[CBSE AIPMT 2015]**

(h = Planck's constant, c = speed of light)

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

108. 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 **[JEE Main 2016]**

(a) $> v\left(\frac{4}{3}\right)^{1/2}$ (b) $< v\left(\frac{4}{3}\right)^{1/2}$

(c) $= v\left(\frac{4}{3}\right)^{1/2}$ (d) $= v\left(\frac{3}{4}\right)^{1/2}$

109. Monochromatic radiation of wavelength 640.2 nm ($1 \text{ nm} = 10^{-9}$ m) from a neon lamp irradiates photosensitive material made of caesium on tungsten. The stopping voltage is measured to be 0.54 V. The source is replaced by an iron source and its 427.2 nm line irradiates the same photocell. Predict the new stopping voltage.

(a) 1.51 V (b) 3.5 V

(c) 0.05 V (d) 2.03 V

110. Light of wavelengths λ_A and λ_B falls on two identical metal plates A and B respectively. The maximum kinetic energy of photoelectrons is K_A and K_B respectively, then which one of the following relations is true? ($\lambda_A = 2\lambda_B$)

(a) $K_A < \frac{K_B}{2}$ (b) $2K_A = K_B$

(c) $K_A = 2K_B$ (d) $K_A > 2K_B$

Topic 4
Particle Nature of Light : The Photon

111. Millikan proved validity of Einstein's photoelectric equation by

(a) finding work-function (ϕ_0)
(b) finding Planck's constant (h)
(c) finding change of electron (e)
(d) finding mass of electron (m)

112. Einstein's picture of photoelectric effect was accepted using

(a) the hypothesis of light quantas
(b) the experimental determination of values of h and ϕ_0
(c) Both (a) and (b)
(d) Neither (a) nor (b)

113. Photoelectric effect gave evidence that light in interaction with matter,

(a) is converted into particles of same size
(b) is converted into particles of same energy
(c) is converted into mass following $E = mc^2$
(d) behaves as if it was made of packets of energy, each of energy $h\nu$

114. Particle like behaviour of light arises from the fact that each quanta of light has definite ...A... and a fixed value of ...B... just like a particle. Here, A and B refer to

(a) frequency, energy
(b) shape, volume
(c) energy, frequency
(d) energy, momentum

115. Definite value of energy possessed by quantum of radiation is called

(a) proton (b) photon
(c) deutron (d) lapton

116. Particle like behaviour of light is confirmed by

(a) α-particle scattering
(b) scattering of electrons by a metal target
(c) scattering of X-rays from electrons
(d) scattering of neutrons

117. All photons present in a light beam of single frequency have

(a) same frequency but different momentum
(b) same momentum but different frequency
(c) different frequency and different momentum
(d) same frequency and same momentum

118. When intensity of a light beam is increased,

(a) energy of photons present increases
(b) momentum of photons present increases
(c) wavelength of photons present increases
(d) number of photons crossing a unit area per second increases

119. An electric eye is

(a) an LED (b) a photocell
(c) a solar cell (d) a photo diode

120. Which of the following is 'incorrect' statement regarding 'photon'?

(a) Photon exerts no pressure
(b) Photon energy is $h\nu$
(c) Photon rest mass is zero
(d) Photons can rebound from a metal surface

121. In an electron-photon collision, which is not true?

(a) Photon-electron collision is elastic
(b) Photons can rebound from an electron
(c) In an photoelectron collision, number of photons is not conserved
(d) Photons are deflected by a strong electric field

122. The wavelength of light from the spectral emission line of sodium is 589 nm. Find the kinetic energy at which
(i) an electron and
(ii) a neutron would have the same de-Broglie wavelength.
(a) $KE_e = 5 \times 10^{-25}$ J, $KE_n = 6.5 \times 10^{-28}$ J
(b) $KE_e = 6.96 \times 10^{-25}$ J, $KE_n = 3.81 \times 10^{-28}$ J
(c) $KE_e = 1.25 \times 10^{-25}$ J $KE_n = 6.23 \times 10^{-28}$ J
(d) $KE_e = 3.26 \times 10^{+25}$ J, $KE_n = 4.06 \times 10^{+28}$ J

123. In an accelerator experiment on high-energy collisions of electrons with positrons, a certain event is interpreted as annihilation of an electron-positron pair of total energy 10.2 eV into two γ-rays of equal energy. What is the wavelength associated with each γ-ray?
(a) 2.436×10^{-7} m (b) 1.436×10^{-7} m
(c) $2.436 \times 10^{+7}$ m (d) $1.436 \times 10^{+7}$ m

124. Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The energy of a photon in the light beam is
(a) 5×10^{-15} J (b) 3.98×10^{-19} J
(c) 2.54×10^{-14} J (d) 5.16×10^{-14} J

125. A laser beam of frequency 6.0×10^{14} Hz is emitted from a source of 2×10^{-3} W. Number of photons emitted per second is
(a) 3.98×10^{-19} (b) 5.16×10^{14}
(c) 3.98×10^{19} (d) 5×10^{15}

126. Work-function of caesium is 2.14 eV. Threshold frequency of caesium is
(a) 5.14×10^{14} Hz (b) 6×10^{14} Hz
(c) 3×10^{14} Hz (d) 5.16×10^{14} Hz

127. The wavelength of light in the visible region is about 760 nm for red colour. The energy of photon in eV at the red end of the visible spectrum is
(a) 6.63 (b) 3.62 (c) 7.61 (d) 1.64

128. The energy flux of sunlight reaching the surface of the earth is 1.52×10^3 Wm^{-2}. The photons in the sunlight have an average wavelength of 520 nm. How many photons per square metre are incident on the earth per second?
(a) 4×10^{21} (b) 4×10^{34}
(c) 4×10^{31} (d) 4×10^{28}

129. An X-ray tube produces a continuous spectrum of radiation with its short wavelength end at 0.55Å. The maximum energy of a photon in the radiation is
(a) 32.6 eV (b) 22.6 keV
(c) 15.2 keV (d) 12.8 keV

130. The linear momentum of a 6 MeV photon is
(a) 0.01 eV sm^{-1}
(b) 0.02 eV sm^{-1}
(c) 0.03 eV sm^{-1}
(d) 0.04 eV sm^{-1}

Topic 5
Wave Nature of Matter

131. de-Broglie hypothesis is
(a) wave can behave like a particle
(b) a stationary particle can behave like a wave
(c) a travelling wave can behave like a particle
(d) a moving particle of matter can display wave like properties

132. de-Broglie hypothesis is a conclusion drawn from
(a) photoelectric effect
(b) convertibility of mass into energy
(c) symmetry of matter and energy
(d) compton effect

133. Macroscopic objects like a moving cricket ball does not shows any wave like properties because
(a) de-Broglie's hypothesis is not true
(b) de-Broglie's hypothesis is true only for electrons
(c) de-Broglie's hypothesis is true only for photons
(d) wavelength associated with a macroscopic object is small

134. A photocell converts
(a) change in current into change in light intensity
(b) change in intensity of light into change in current
(c) change in current into change in voltage
(d) change in intensity into change in potential difference

135. A photocell cannot be used
(a) for reproduction of sound in motion pictures
(b) in burglar alarms
(c) as a fire alarm
(d) to illuminate a room

136. If an electron is accelerated from rest through a potential of V volts, then kinetic energy K gained by it
(a) $K = eV$ (b) $K = \frac{1}{2} eV$
(c) $K = \frac{2}{3} eV$ (d) $K = 0$

137. The phenomenon of image formation by our eye,
(a) can be described using wave theory
(b) can be described using photon theory
(c) can be described using any of the wave or photon theory
(d) can be described fully by using both wave and photon theory

138. The de-Broglie wavelength λ
(a) is proportional to mass
(b) is proportional to momentum
(c) inversely proportional to momentum
(d) does not depends on momentum

139. de-Broglie wavelength of a body of mass m and kinetic energy E is given by
(a) $\lambda = \frac{h}{mE}$ (b) $\lambda = \frac{\sqrt{2mE}}{h}$
(c) $\lambda = \frac{h}{2mE}$ (d) $\lambda = \frac{h}{\sqrt{2mE}}$

140. An electron of mass m and charge e initially at rest gets accelerated by a constant electric field E. The rate of change of de-Broglie wavelength of the electron at time t ignoring relativistic effect is
(a) $\frac{-h}{e\,Et^2}$ (b) $\frac{-eEt}{E}$ (c) $\frac{-mh}{e\,Et^2}$ (d) $\frac{-h}{eE}$

141. de-Broglie wavelength associated with an electron, accelerating through a potential difference of 100 V lies in the region of
(a) Gamma rays (b) X-rays
(c) Ultraviolet (d) Visible region

142. Wavelength of an electromagnetic wave is
(a) more than de-Broglie wavelength of its photon
(b) less than de-Broglie wavelength of its photon
(c) there is not relation between wavelength of a radiation and de-Broglie wavelength of its photon
(d) wavelength of radiation is equal to de-Broglie wavelength of its photon

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

144. The number of photons entering the pupil of our eye per second, when a light beam of intensities of 10^{-10} Wm^{-2} enters pupil of our eye of area 0.4 cm^2 with frequency 6×10^{14} Hz is
(a) around 1×10^4 in 1 s (b) around 100 in 1 s
(c) around 1000 in 1 s (d) only 1 in 1 s

145. The de-Broglie wavelength associated with an electron moving with a speed of $5.4\times10^6\ \text{ms}^{-1}$ is
(a) 0.135 nm (b) 0.125 nm
(c) 0.150 nm (d) 0.145 nm

146. A proton and an α-particle are accelerated through the same potential difference. The ratio of de-Broglie wavelength λ_p to that of λ_α is
(a) $\sqrt{2}:1$ (b) $\sqrt{4}:1$ (c) $\sqrt{6}:1$ (d) $\sqrt{8}:1$

147. The de-Broglie wavelength of a particle of KE, K is λ. What will be the wavelength of the particle, if it's kinetic energy is $\frac{K}{9}$?
(a) λ (b) 2λ (c) 3λ (d) 4λ

148. There are two sources of light, each emitting with a power of 200 W. One emits X-rays of wavelength 2 nm and the other visible light of 400 nm. The ratio of number of photons of X-rays to the photons of visible light of the given wavelength is
(a) 1:100 (b) 1:200 (c) 1:500 (d) 1:300

149. If alpha particle, proton and electron move with the same momentum, then their respective de-Broglie wavelengths $\lambda_\alpha, \lambda_p, \lambda_e$ are related as
(a) $\lambda_\alpha = \lambda_p = \lambda_e$ (b) $\lambda_\alpha < \lambda_p < \lambda_e$
(c) $\lambda_\alpha > \lambda_p > \lambda_e$ (d) $\lambda_p > \lambda_e > \lambda_\alpha$

150. Electrons with de-Broglie wavelength λ fall on the target in an X-ray tube. The cut-off wavelength 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) $\lambda_0 = \lambda$

151. 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) decrease by 4 times
(c) increase by 4 times (d) increase by 2 times

152. If h is Planck's constant, the momentum of a photon of wavelength 1 Å is
(a) $10^{10}\,h$ (b) h
(c) $10^2\,h$ (d) $10^{12}\,h$

153. 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 **[NEET 2013]**
(a) 25 (b) 75
(c) 60 (d) 50

154. The work function for aluminium surface is 4.2 eV. The cut-off wavelength for the photoelectric effect is

(a) 2955 Å (b) 4200 Å
(c) 2000 Å (d) 1000 Å

155. Ultraviolet light of wavelength 200 nm is incident on polished surface of Fe (iron). Work function of the surface is 4.71 eV. What will be its stopping potential?

(a) 0.5 V (b) 2.5 V
(c) 1.5 V (d) None of these

156. An electron, an α-particle and a proton have the same kinetic energy. Shortest de-Broglie wavelength is associated with

(a) electron
(b) α-particle
(c) proton
(d) all produces same wavelength

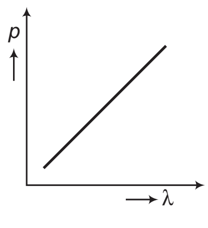
157. A particle is moving three times as fast that of an electron. The ratio of de-Broglie wavelength of particle to that of the electron is 1.83×10^{-4}. Then, the particle is

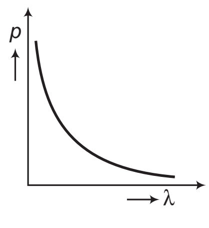
(a) a meuon (b) a proton
(c) a neutron (d) Either neutron or a proton

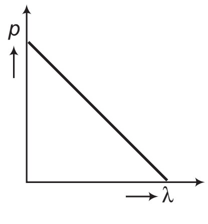
158. Calculate the
(i) momentum and
(ii) de-Broglie wavelength of electrons accelerated through a potential difference of 56 V.

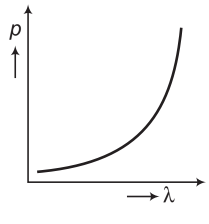
(a) $p = 4.02 \times 10^{-24}$ kg ms^{-1}, $\lambda = 0.164$ nm.
(b) $p = 2.5 \times 10^{22}$ kg ms^{-1}, $\lambda = 1$ nm
(c) $p = 1.25 \times 10^{-22}$ kg ms^{-1}, $\lambda = 0.5$ nm
(d) None of the above

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

(a)


(b)


(c)


(d)


160. What is the basic idea behind experimental verification of de-Broglie hypothesis?

(a) Wavelength associated with electrons is of same order as spacing of atomic planes in crystal
(b) Wavelength associated with electrons is much larger than spacing of atomic planes in crystal
(c) Wavelength associated with electrons is much smaller than spacing of atomic planes in crystal
(d) It was taken from diffraction of X-rays from crystal planes

161. Wave is associated with matter

(a) when it is stationary
(b) when it is in motion with velocity of light
(c) when it is in motion with any velocity
(d) never associated with matter

162. 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 c
(d) tending to infinity

163. According to Heisenberg's uncertainty principle, it is not possible to measure

(a) exact momentum of an electron
(b) exact position of an electron
(c) both exact position and momentum of an electron at same time
(d) exact velocity of electron

164. If Δx is uncertainty in the specification of position and Δp is the uncertainty in specification of momentum of an electron, then the product Δx and Δp is of the order of $\hbar$ such that $\hbar$

(a) $h/2\pi$ (b) 10^{-2}
(c) 10^{-19} (d) 10^{-31}

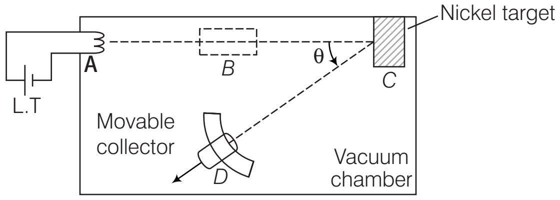
165. An electron is confined to a 1 nm wide region. Find the uncertainty in momentum using Heisenberg uncertainty principle. (Take $h = 6.63 \times 10^{-34}$ J-s)

(a) 1.05×10^{-25} kg ms^{-1}
(b) 2.03×10^{-31} kg ms^{-1}
(c) 3.05×10^{-34} kg ms^{-1}
(d) 2.49×10^{-32} kg ms^{-1}

166. Davisson-Germer experiment verified

(a) particle nature of radiation
(b) particle nature of electrons
(c) wave nature of electrons
(d) transverse nature of electromagnetic radiation

167. Davisson-Germer's electron diffraction arrangement is as shown



Correct labelling is

(a) A-electron source, B-metal crystal, C-reflector, D-detector
(b) A-electron source, B-hollow tube, C-wall, D-reflector
(c) A-electron gun, B-electron accelerator, C-detector, D- counter
(d) A-electron gun, B-collimating and accelerating tube, C-metal target, D -movable collector

168. In Davisson-Germer experiment, at accelerating voltage of 54 V, intensity of scattered electrons is maximum at an scattering angle of 50°. The appearance of the peak in a particular direction is due to

(a) resonance caused by scattered electrons
(b) destructive interference of electrons scattered from different layers of atoms of crystal
(c) constructive interference of electrons scattered from different layers of atoms of crystal
(d) constructive interference of electrons scattered by same atom of crystal

169. Davisson-Germer experiment confirms de-Broglie relation by

(a) converting electrons into waves
(b) converting light into particles
(c) varying angle of incidence of an electron beam over a metal target and observing scattering pattern
(d) comparing theoretical value of wavelength associated with moving electrons and practical value of wavelength measured by observing diffraction pattern produced by electrons

170. de-Broglie hypothesis is true for

(a) particles which are very light like electrons
(b) only subatomic particles
(c) only for photons and electrons
(d) fast moving particles, lighter like electrons and also for particles much-much heavier than electrons

171. Wave nature of electrons is exploited in

(a) mass-spectrometer (b) coolidge tube
(c) synchrotrons (d) electron microscope

172. In Davisson-Germer experiment, the wavelength associated with nickel crystal is

(a) 1.66 Å (b) 2Å
(c) 2.3 Å (d) 3.86 Å

173. 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

174. An electron microscope uses electrons accelerated by a voltage of 50 kV. Determine the de-Broglie wavelength associated with the electrons.

(a) 2.5×10^{-12} m (b) 1.5×10^{-12} m
(c) 5.5×10^{-12} m (d) 0 m

Special Format Questions

I. Assertion and Reason

■ **Directions** (Q. Nos. 175-182) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion
(c) Assertion is correct but Reason is incorrect
(d) Assertion is incorrect but Reason is correct

175. Assertion Cathode rays produce fluorescence in glass and colour of glow depends on nature of glass.

Reason Cathode rays excite glass electrons and they on de-excitation emits radiation in visible region.

176. Assertion In photoelectric effect, cathode or emitter plate is usually coated with barium oxide, barium sulphide or strontium oxide.

Reason Coating prevents cathode from erosion.

177. Assertion According to wave theory of light, if intensity of incident radiation is increased, then energy of emitted photoelectrons increases.

Reason Energy of a wave is proportional to its intensity.

178. Assertion Photoelectric current depends on the intensity of incident light.

Reason Number of photoelectrons emitted per second is directly proportional to the intensity of incident radiation.

179. Assertion Photosensitivity of a metal is high if its work-function is small.

Reason Work-function $= h\nu_0$ where, ν_0 is the threshold frequency.

180. Assertion In photon particle collision the total energy and total momentum are conserved.

Reason The number of photons are conserved in a collision.

181. Assertion Photocell is also called electric eye.

Reason Photocell can see the things placed in front of it.

182. Assertion In Davisson-Germer experiment wavelength associated with the beam decreases with increases of speed of electrons.

Reason Wavelength associated with electron beam in Davisson-Germer experiment is given by $\lambda = \dfrac{h}{\sqrt{2mK}}$.

II. Statement Based Questions Type I

■ **Directions** (Q. Nos. 183-185) *In the following questions, a Statement I is followed by a corresponding Statement II. Of the following Statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I
(c) Statement I is correct but Statement II is incorrect
(d) Statement I is incorrect but Statement II is correct

183. Statement I The energy (E) and momentum (p) of a photon are related $p = E/c$

Statement II The photon behaves like a particle.

184. Statement I In Millikan experiment for the determination of charge on an electron, oil drop of any size can be used.

Statement II Millikan's experiment determines the charge of electron, by simply measuring the terminal velocity.

185. Statement I In photoemissive cell inert gas is used.

Statement II Inert gas in the photoemissive cell is given greater current.

Statement Based Questions Type II

186. Maxwell's equations are

I. Gauss's law for electrostatics.
II. Gauss's law for magnetism.
III. Faraday law of electromagnetic induction.
IV. Ampere's circuital law with Maxwell's addition.

(a) I and II (b) I II and III
(c) Only IV (d) All of these

187. Energy required by an electron for electron emission can be supplied to a free electron by

I. hammering the metal surface.
II. heating the metal surface.
III. applying electric field.
IV. applying magnetic field.

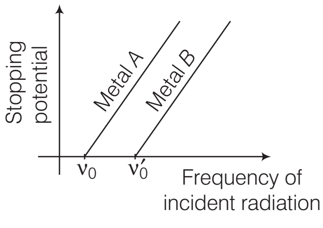
(a) Only I (b) I, II and IV
(c) II, III and IV (d) II and III

188. To observe the effect of intensity of light on photocurrent,

I. collector is maintained at positive potential with respect to emitter.
II. frequency of incident light is kept fixed.
III. accelerating potential is fixed.
IV. distance of source from emitter is kept constant.

(a) I and II are correct (b) II and III are correct
(c) III and IV are correct (d) I II and III are correct

189. Variation of stopping potential V_0 with frequency ν of incident radiation for photosensitive materials A and B are shown



From graph we conclude that

I. maximum kinetic energy of photoelectrons varies linearly with frequency.
II. a frequency lower than a certain frequency photoemission is not possible.
III. density of metal A is more than that of B.
IV. metal A contains more electrons than that of B.

(a) I and II (b) I and IV (c) III and IV (d) II and III

190. Experimental study of photoelectric effect shows that

I. photocurrent $\propto$ intensity of light.
II. saturation current $\propto$ intensity of light.
III. photoemission occurs only at frequency greater than threshold frequency.
IV. photoemission is an instantaneous process.

(a) I and II are correct
(b) I, II and III are correct
(c) I, III and IV are correct
(d) All I, II, III and IV are correct

191. Which of the following statements are true?

I. In the interaction with matter, radiation behaves as if it is made up of particles called photons.
II. Each photon has energy $E = h\nu$ and momentum $p = h\nu/c$.
III. Photons are electrically neutral and are not deflected by electric and magnetic fields.
IV. In a photon-particle collision, photon number is conserved.

(a) I and II
(b) I, II and III
(c) I, III and IV
(d) I, II and IV

192. If de-Broglie wavelength of

I. a bullet of mass 0.40 kg travelling with speed of 1.0 kms^{-1} is λ_1.
II. a ball of mass 0.60 kg moving at a speed of 1.0 ms^{-1} is λ_2.
III. a dust particle of mass 1.0×10^{-9} kg drifting with a speed of 2.2 ms^{-1} is λ_3.

Then,

(a) $\lambda_1 > \lambda_2 > \lambda_3$
(b) $\lambda_2 > \lambda_1 > \lambda_3$
(c) $\lambda_1 < \lambda_2 < \lambda_3$
(d) $\lambda_3 > \lambda_1 > \lambda_2$

III. Matching Type

193. Work-function for caesium metal is 2.14 eV. Let a beam of light of frequency 6×10^{14} Hz is incident over the metal surface.

Now, match the following columns and choose the correct option from codes given.

Column I	Column II
A. Maximum KE of emitted photoelectrons (in eV)	1. 332.3 kms^{-1}
B. Minimum KE of emitted photoelectrons (in eV)	2. 345 mV
C. Stopping potential of material (in mV) is	3. 0.345 eV
D. Maximum speed of the emitted photoelectrons (in kms^{-1})	4. 0

	A	B	C	D
(a)	4	3	2	1
(b)	3	4	2	1
(c)	3	1	4	2
(d)	2	1	4	3

194. Match the quantities of Column I with their values in Column II and choose the correct option from the codes given below.

Column I	Column II
A. Maximum number of photons absorbed by an electron	1. $\frac{\phi_0}{\nu_0}$
B. Number of photons emitted by a source per second	2. $\frac{P}{E}$
C. Energy of a photon	3. $h\nu$
D. Planck's constant	4. 1

	A	B	C	D
(a)	2	4	1	3
(b)	4	2	3	1
(c)	2	4	3	1
(d)	3	1	2	4

195. Match the following.

List-I	List-II
A. Planck constant	1. $\frac{h}{p}$
B. Stopping potential	2. $E - K_{high}$
C. Work-function	3. $V_0 = K_{high}/c$
D. de-Broglie wavelength	4. $\frac{E}{v}$

	A	B	C	D
(a)	4	3	2	1
(b)	4	2	3	1
(c)	2	4	3	1
(d)	3	1	2	4

196. Match List-I (Fundamental Experiment) with List-II (its conclusion) and select the correct option from the choice given below the list.

List-I	List-II
A. Frank-Hertz experiment.	1. Particle nature of light
B. Photoelectric experiment.	2. Discrete energy levels of atom
C. Davisson-Germer experiment	3. Wave nature of electron
	4. Structure of atom

	A	B	C
(a)	2	1	3
(b)	4	2	3
(c)	2	4	3
(d)	3	1	2

IV. Passage Based Questions

■ **Directions** (Q. Nos. 197-199) *These questions are based on the following situation. Choose the correct options from those given below.*

When a beam of 10.6 eV photons of intensity 2.0 Wm^{-2} falls on a surface of platinum of surface area $1.0 \times 10^{-4} m^2$ and the work-function of the material is 5.6 eV. Given that, 0.53% of the incident photons eject photoelectrons.

197. Find number of photoelectrons emitted per second.
(a) 7×10^{11} (b) 6.25×10^{11} .
(c) 9×10^{10} (d) 11×10^{11}

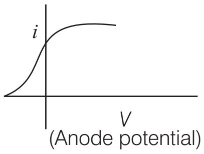
198. Find maximum energy of photoelectrons emitted.
(a) 5.0 eV (b) 6.0 eV (c) 2.5 eV (d) 0 eV

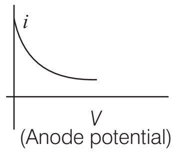
199. Find minimum energy of photoelectrons emitted.
(a) 6.0 eV (b) 5.0 eV (c) 5.8 eV (d) 0 eV

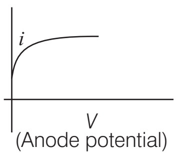
■ **Directions** (Q. Nos. 200-201) *These questions are based on the following situation. Choose the correct options from those given below.*

In a photoelectric experiment set-up, photons of energy 5 eV fall on the cathode having work function 3 eV. If the saturation current is found to be 4×10^{-6} A for intensity of 10^{-5} Wm^{-2}, then

200. Graph between anode potential and current will be

(a) 

(b) 

(c) 

(d) None of these

201. When intensity is doubled,
(a) saturation current remain as it is
(b) saturation current will be doubled
(c) saturation current will be four times
(d) saturation current will be halved

■ **Directions** (Q. Nos. 202-204) *These questions are based on the following situation. Choose the correct options from those given below.*

Assume that the de-Broglie wave associated with an electron can form a standing wave between the atoms arranged in a one-dimensional array with nodes at each of the atomic sites. It is found that one such standing wave is formed, if the distance *d* between the atoms of the array is 2Å. A similar standing wave is again formed, if *d* is increased to 2.5 Å but not for any intermediate value of *d*.

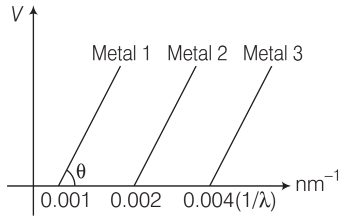
202. Find wavelength of the beam.
(a) 1Å (b) 2Å (c) 3Å (d) 0.5Å

203. The energy of the electron is
(a) 160 eV (b) 150.8 eV
(c) 145 eV (d) 100 eV

204. The least of *d* for which the standing wave of the type described can form
(a) 0.8 Å (b) 0.5 Å (c) 1Å (d) 2.5 Å

V. More than One Option Correct

205. The graph between $1/\lambda$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photoelectric effect is plotted as shown in the figure. Which of the following option(s) is/are correct? (Here, λ is the wavelength of the incident ray)



(a) Ratio of work function $\phi_1 : \phi_2 : \phi_3 = 1:2:4$
(b) Ratio of work function $\phi_1 : \phi_2 : \phi_3 = 4:2:1$
(c) tan θ is directly proportional to hc/e, where *h* is Planck's constant and *c* is the speed of light
(d) The violet colour light can eject photoelectrons from metals 2 and 3.

206. When photon of energy 4.25 eV strike the surface of a metal *A*, the ejected photoelectron have maximum kinetic energy T_A eV and de-Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal *B* by photon of energy 4.70 eV is $T_B = (T_A - 1.5)$ eV. If the de-Broglie wavelength of these photoelectron is $\lambda_B = 2\lambda_A$. Then
(a) the work function of *A* is 2.25 eV
(b) the work function of *B* is 4.20 eV
(c) $T_A = 2.00$ eV
(d) $T_B = 2.75$ eV

207. Relativistic corrections become necessary when the expression for the kinetic energy $\frac{1}{2}mv^2$, becomes comparable with mc^2, where *m* is the mass of the electron. At what de-Broglie wavelength, will relativistic corrections become important for an electron?
(a) $\lambda = 10$ nm
(b) $\lambda = 10^{-1}$ nm
(c) $\lambda = 10^{-4}$ nm
(d) $\lambda = 10^{-6}$ nm

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

209. The de-Broglie wavelength of a photon is twice, the de-Broglie wavelength of an electron. The speed of the electron is $v_e = \frac{c}{100}$. Then,

(a) $\frac{E_e}{E_p} = 10^{-4}$ (b) $\frac{E_e}{E_p} = 10^{-2}$ (c) $\frac{p_e}{m_e c} = 10^{-2}$ (d) $\frac{p_e}{m_e c} = 10^{-4}$

210. A particle moves in a closed orbit around the origin, due to a force which is directed towards the origin. The de-Broglie wavelength of the particle varies cyclically between two values λ_1, λ_2 with $\lambda_1 > \lambda_2$. Which of the following statement are true?

(a) The particle could be moving in a circular orbit with origin as centre
(b) The particle could be moving in an elliptic orbit with origin as its focus
(c) When the de-Broglie wavelength is λ_1, the particle is nearer the origin than when its value is λ_2
(d) When the de-Broglie wavelength is λ_2, the particle is nearer the origin than when its value is λ_1

NCERT & NCERT Exemplar Questions

NCERT

211. The minimum wavelength of X-rays produced by 30 kV electrons will be

(a) 0.0414 nm (b) 0.414 nm
(c) 4.14 nm (d) 41.4 nm

212. The work function of caesium metal is 2.14 eV. When light of frequency 6×10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. What is the maximum kinetic energy of the emitted electrons?

(a) 0.65 eV (b) 0.35 eV (c) 0.50 eV (d) 0.56 eV

213. The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photoelectrons emitted?

(a) 4.4×10^{-19} J (b) 5.4×10^{-19} J
(c) 2.4×10^{-19} J (d) 3.4×10^{-19} J

214. Monochromatic light of wavelength 632.8 nm is produced by a helium-neon laser. The power emitted is 9.42 mW. The energy and momentum of each photon in the light beam will be

(a) 3.14×10^{-19} J, 1.05×10^{-27} kg ms^{-1}
(b) 2.4×10^{-19} J, 2.05×10^{-27} kg ms^{-1}
(c) 4.2×10^{-19} J, 3×10^{16} kg ms^{-1}
(d) 4.2×10^{-18} J, 1.05×10^{-26} kg ms^{-1}

215. The energy flux of sunlight reaching the surface of the earth is 1.388×10^3 W/m^2. How many photons (nearly) per square metre are incident on the earth per second? Assume that the photons in the sunlight have an average wavelength of 550 nm.

(a) 10^{21} (b) 10^{20} (c) 10^{10} (d) 10^{40}

216. A 100 W sodium lamp radiates energy uniformly in all directions. The lamp is located at the centre of a large sphere that absorbs all the sodium light which is incident on it. The wavelength of the sodium light is 589 nm. At what rate are the photons delivered to the sphere?

(a) 3×10^{21} photon/s (b) 3×10^{20} photon/s
(c) 3×10^{22} photon/s (d) 3×10^{24} photon/s

217. The threshold frequency for a certain metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on the metal, predict the cut-off voltage for the photoelectric emission.

(a) 2.03 V (b) 4.04 V
(c) 5.04 V (d) 6.04 V

218. Light of frequency 7.21×10^{14} Hz is incident on a metal surface. Electrons with a maximum speed of 6.0×10^5 m/s are ejected from the surface. What is the threshold frequency for photoemission of electrons?

(a) 4.74×10^{14} Hz (b) 5.47×10^{14} Hz
(c) 6.47×10^{14} Hz (d) 6.47×10^{14} Hz

219. Light of wavelength 488 nm is produced by an argon laser, which is used in the photoelectric effect. When light from this spectral line is incident on the emitter, the stopping (cut-off) potential of photoelectrons is 0.38 V. Find the work function of the material from which the emitter is made.

(a) 3.17 eV (b) 2.17 eV (c) 4.17 eV (d) 5.17 eV

NCERT Exemplar

220. A particle is dropped from a height H. The de-Broglie wavelength associated with particle is proportional to

(a) H (b) $H^{1/2}$ (c) H^0 (d) $H^{-1/2}$

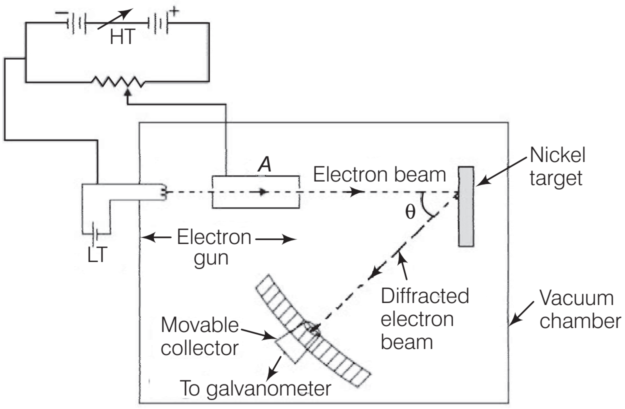
221. Wavelengths of a photon needed to remove a proton from a nucleus which is bound to the nucleus with 1 meV energy is nearly

(a) 1.2 nm (b) 1.2×10^{-3} nm
(c) 1.2×10^{-6} nm (d) 1.2×10^{1} nm

222. Consider a beam of electrons (each with energy E_0) incident on a metal surface kept in an evacuated chamber. Then,

(a) no electrons will be emitted as only photons can emit electrons
(b) electrons can be emitted but all with energy E_0
(c) electrons can be emitted with any energy, with a maximum of $E_0 - \phi$ (ϕ is the work-function)
(d) electrons can be emitted with any energy, with a maximum of E_0

223. Consider figure given below. Suppose the voltage applied to A is increased. The diffracted beam will have the maximum at a value of θ that



(a) will be larger than the earlier value
(b) will be the same as the earlier value
(c) will be less than the earlier value
(d) will depend on the target

224. A proton, a neutron, an electron and an α-particle have same energy. Then, their de-Broglie wavelengths 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) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

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

(a) remains constant (b) increases with time
(c) decreases with time (d) first increases decreases

226. An electron (mass m) with an initial velocity $\mathbf{v} = v_0\hat{\mathbf{i}}$ ($v_0 > 0$) is in an electric field $\mathbf{E} = E_0\hat{\mathbf{i}}$ ($E_0 = \text{constant} > 0$) field. It's de-Broglie wavelength at time t is given by

(a) $\dfrac{\lambda_0}{\left(1 + \dfrac{eE_0}{m}\dfrac{t}{v_0}\right)}$ (b) $\lambda_0\left(1 + \dfrac{eE_0 t}{mv_0}\right)$
(c) λ_0 (d) $\lambda_0 t$

227. An electron (mass m) with an initial velocity $\mathbf{v} = v_0\hat{\mathbf{i}}$ is in an electric field $\mathbf{E} = E_0\hat{\mathbf{j}}$. If $\lambda_0 = h/mv_0$, it's de-Broglie wavelength at time t is given by

(a) λ_0 (b) $\lambda_0\sqrt{1 + \dfrac{e^2E_0^2t^2}{m^2v_0^2}}$
(c) $\dfrac{\lambda_0}{\sqrt{1 + \dfrac{e^2E_0^2\,t^2}{m^2v_0^2}}}$ (d) $\dfrac{\lambda_0}{\left(1 + \dfrac{e^2E_0^2\,t^2}{m^2v_0^2}\right)}$

Answers

1.	(c)	2.	(d)	3.	(d)	4.	(c)	5.	(b)	6.	(a)	7.	(a)	8.	(c)	9.	(c)	10.	(d)	11.	(c)	12.	(d)	13.	(c)	14.	(b)	15.	(c)
16.	(c)	17.	(b)	18.	(a)	19.	(d)	20.	(d)	21.	(c)	22.	(d)	23.	(a)	24	(d)	25.	(c)	26.	(a)	27.	(a)	28.	(d)	29.	(a)	30.	(c)
31.	(d)	32.	(d)	33.	(a)	34.	(a)	35.	(a)	36.	(a)	37.	(a)	38.	(d)	39.	(d)	40.	(a)	41.	(a)	42.	(d)	43.	(d)	44.	(b)	45.	(a)
46.	(b)	47.	(a)	48.	(d)	49.	(c)	50.	(a)	51.	(c)	52.	(a)	53.	(c)	54.	(d)	55.	(c)	56.	(a)	57.	(c)	58.	(c)	59.	(c)	60.	(a)
61.	(c)	62.	(c)	63.	(b)	64.	(a)	65.	(b)	66.	(a)	67.	(b)	68.	(a)	69.	(c)	70.	(a)	71.	(b)	72.	(a)	73.	(b)	74.	(d)	75.	(d)
76.	(d)	77.	(d)	78.	(d)	79.	(b)	80.	(a)	81.	(c)	82.	(c)	83.	(c)	84.	(a,c)	85.	(d)	86.	(a)	87.	(d)	88.	(b)	89.	(c)	90.	(d)
91.	(a)	92.	(c)	93.	(c)	94.	(b	95.	(a)	96.	(d)	97.	(a)	98.	(c)	99	(c)	100.	(b)	101.	(a)	102.	(a)	103.	(a)	104.	(b)	105.	(c)
106.	(a)	107.	(a)	108.	(a)	109.	(a)	110.	(a)	111.	(b)	112.	(c)	113.	(d)	114.	(d)	115.	(b)	116.	(c)	117.	(d)	118.	(d)	119.	(b)	120.	(a)
121.	(d)	122.	(b)	123.	(a)	124.	(b)	125.	(d)	126.	(d)	127.	(d)	128.	(a)	129.	(b)	130.	(b)	131.	(d)	132.	(c)	133.	(d)	134.	(b)	135.	(b)
136.	(a)	137.	(d)	138.	(c)	139.	(d)	140.	(a)	141.	(b)	142.	(d)	143.	(d)	144.	(a)	145.	(a)	146.	(d)	147.	(c)	148.	(b)	149.	(a)	150.	(a)
151.	(a)	152.	(a)	153.	(b)	154.	(a)	155.	(c)	156.	(b)	157.	(d)	158.	(a)	159.	(b)	160.	(a)	161.	(c)	162.	(a)	163.	(c)	164.	(a)	165.	(a)
166.	(c)	167.	(d)	168.	(c)	169.	(d)	170.	(d)	171.	(d)	172.	(a)	173.	(a)	174.	(c)	175.	(a)	176.	(c)	177.	(a)	178.	(a)	179.	(b)	180.	(c)
181.	(c)	182.	(a)	183.	(a)	184.	(d)	185.	(b)	186.	(d)	187.	(d)	188.	(d)	189.	(a)	190.	(d)	191.	(b)	192.	(c)	193.	(b)	194.	(b)	195.	(a)
196.	(a)	197.	(b)	198.	(a)	199.	(d)	200.	(a)	201.	(b)	202.	(a)	203.	(b)	204.	(b)	205.	(a,c)	206.	(a,b,c)	207.	(c,d)	208.	(a,c)	209.	(b,c)	210.	(b,d)
211.	(a)	212.	(b)	213.	(c)	214.	(a)	215.	(a)	216.	(b)	217.	(a)	218.	(a)	219.	(b)	220.	(d)	221.	(b)	222.	(d)	223.	(c)	224.	(b)	225.	(a)

Hints *and* Explanations

1. (*c*) At low pressure and high temperature, free electrons are generated and positively charged atom (or molecule) which is called an ion is created. Hence, conduction is possible.

2. (*d*) It was found that at sufficiently low pressure of about 0.001 mm of mercury column, a discharge tube place between the two electrodes an applying the electric field to the gas.
A fluorescent glow appeared opposite to cathode.

3. (*d*) In the discharge tube a fluorescent glow is seen on the glass opposite to cathode. The colour of glow of the glass depended on the type of glass, it being yellowish-green for soda glass.

4. (*c*) Glow is due to the radiation which appeared to be coming from the cathode.

5. (*b*) Cathode rays are streams of negatively charged particles.

6. (*a*) The particles speed ranges from $0.1c$ to $0.2c$. Here, c is the speed of light in vacuum which is $3\times10^8\ \text{ms}^{-1}$.

7. (*a*) Specific charge is $1.76\times10^{11}\ \text{C kg}^{-1}$. By applying mutually perpendicular electric and magnetic fields across the discharge tube, JJ Thomson was the first to determine the speed and the specific charge [Charge to mass ratio (e/m)] of the cathode ray particles.

8. (*c*) The value of e/m was found to be independent of the nature of the material/metal used as the cathode (emitter) or the gas introduced in the discharge tube.

9. (*c*) For proton,

Specific charge $= \dfrac{e}{m} = 9.6\times10^7\text{C kg}^{-1}$

For alpha particle,

Specific charge $= \dfrac{2e}{4m} = \dfrac{1}{2}\dfrac{e}{m} = \dfrac{1}{2}\times 9.6\times10^7$

$= 4.8\times10^7\text{C kg}^{-1}$

10. (*d*) It is found that the charge on an oil-droplet was always an integral multiple of an elementary charge, 1.6×10^{-19} C.
Millikan's experiment established that electric charge is quantised. From the values of charge (e) and specific charge (e/m), the mass (m) of the electron could be determined.

11. (*c*) X-rays region lies from wavelengths 10^{-8} m (= 10 or 100 A) to 10^{-19} m (= 10^{-14}nm or 10^{-3} Å)

12. (*d*) X-rays does not have charge particle they are simple electromagnetic radiation, hence, it cannot be deflected by applying electric and magnetic fields.

13. (*c*) When an electron is accelerated by a potential difference of V volts, then

or $\quad eV = U$

This potential energy is converted into KE of electron,

$$\text{KE} = U$$

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

$$\Rightarrow \quad v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times1000}{9.1\times10^{-31}}}$$

$$= 1.875\times10^7 \approx 1.9\times10^7\ \text{ms}^{-1}$$

14. (*b*) Change in KE = work done by electric field due to potential difference applied

$$\text{KE}_f - \text{KE}_i = qV \quad\Rightarrow\quad \text{KE}_f - 0 = qV$$

or $\quad \text{KE}_f = qV \qquad (q = 2e)$

$\Rightarrow \quad \text{KE} = 2e\times5 = 10\,\text{eV}$

15. (*c*) Atom break into proton and electron at low pressure.

16. (*c*) Pressure is of the order of 10^{-2} mm of Hg.

17. (*b*) Initially energy of electron = eV

and finally, energy $= \dfrac{1}{2}mv^2 \quad\Rightarrow\quad eV = \dfrac{1}{2}mv^2$

or $\quad e/m = \dfrac{v^2}{2V} \qquad$ ...(i)

On substituting the values in Eq. (i), we get

$\Rightarrow \quad e/m = 1.76\times10^{11}\ \text{C kg}^{-1}$

18. (*a*) Use $m_e = 9.1\times10^{-31}$ kg, $e = 1.6\times10^{-19}$ C

$m_p = 1.67\times10^{-27}$, $e = 1.6\times10^{-19}$ C

$m_\alpha = 4\times m_p$, $q_\alpha = 2\times1.6\times10^{-19}$C

For electron $\quad \dfrac{e}{m_e} = \dfrac{1.6\times10^{-19}\text{c}}{9.1\times10^{-31}\text{kg}} = 0.176\times10^{12}\text{C kg}^{-1}$

For proton $\quad \dfrac{e}{m_p} = \dfrac{1.6\times10^{-19}\text{c}}{1.67\times10^{-27}\text{kg}}$

$= 0.95\times10^8\ \text{C kg}^{-1}$

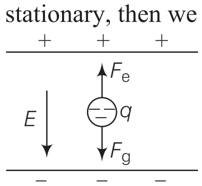
For α-particle $\quad q_\alpha / m_\alpha = \dfrac{2e}{4m_p} = \dfrac{1}{2}\dfrac{e}{m_p} = 0.475\times10^8\text{C kg}^{-1}$

Therefore, order of specific charge is

$$\left(\frac{e}{m_e}\right) > \left(\frac{e}{m_p}\right) > \left(\frac{q_\alpha}{m_\alpha}\right)$$

$$\Rightarrow \quad e > p > \alpha$$

19. (*d*) As the drop is stationary, then we can say that



$$F_e = F_g$$

$\Rightarrow \quad qE = F_g \qquad (F_g = \text{weight})$

$\Rightarrow \quad \text{Weight} = qE = q\dfrac{V}{d}$

20. (*d*) If an electron attempts to come out of the metal, the metal surface acquires a positive charge and pulls the electron back to the metal.
Consequently, the electron can come out of the metal surface only if it has got sufficient energy to overcome the attractive pull.

21. (*c*) The minimum energy required by an electron to escape from the metal surface is called the work function of the metal.

22. (*d*) The work function (ϕ_0) depends on the properties of the metal and the nature of its surface. The work function also depends on presence of surface impurities and it also depends on temperature of the surface.

23. (*a*) The work function of platinum is the highest ($\phi_0 = 5.65$ eV) while it is the lowest ($\phi_0 = 2.14$ eV) for caesium.

24. (*d*) Electrons absorbs light energy and electrons are emitted, so the process is called photoemission.

25. (*c*) Kinetic energy of electron is the excess energy remained after the electron moves out of metal surface. So, it depends on work function and also energy acquired from external source.

26. (*a*) We can measure charge by mass ratio only. *i.e.,* $\frac{q}{m}$ is measured.

27. (*a*) Below a minimum frequency no photoelectrons will be emitted.

28. (*d*) When ultraviolet radiations fall on the emitter plate, electrons are ejected from it which are attracted towards the positive collector plate by the electric field. The electrons flow through the evacuated glass tube, resulting in the current flow.

30. (*c*) Positive charge on a positively charged zinc plate was found to be further enhanced when it was illuminated by ultraviolet light. So, leaves of electroscope will move further apart.

31. (*d*) Hallwachs and Lenard also observed that when ultraviolet light fell on the emitter plate, no electrons were emitted at all when the frequency of the incident light was smaller than a certain minimum value, called the threshold frequency. This minimum frequency depends on the nature of the material of the emitter plate.

32. (*d*) Photoemission involves conversion of light energy into electrical energy.It is observed that many metals emit electrons when light shines upon them.

33. (*a*) Some alkali metals such as, lithium, sodium, potassium, caesium and rubidium are sensitive even to visible light. All these photosensitive substances emit electrons when they are illuminated by light.

34. (*a*) For photoemission a minimum frequency called threshold frequency is required. As green light can emit electrons and yellow light does not, so red light also shows no photoemission as the frequency of red light is least of all three colours.

35. (*a*) Frequency of X-rays is much higher than ultraviolet-light, so photoemission might be possible with X- rays. For photoemission, a minimum frequency called threshold frequency is required. Below threshold frequency photoemission does not occurs.

36. (*a*) In the experiment study of photoelectric effect, light is monochromatic, consisting of only one wavelength.

37. (*a*) Short wavelength light have high frequency and photoemission occurs.

Since, $c = \nu\lambda$ or $\nu = \frac{c}{\lambda}$

For constant wave velocity (as in case of electromagnetic radiation in vacuum, $c = 3\times10^8 \text{ms}^{-1}$), the frequency is inversely proportional to wavelength. High frequency light carries more energy $[E = h\nu]$ and hence photoemission easily occurs.

38. (*d*) Intensity of light reaching a surface is inversely proportional to square of its distance from source.

$$\text{Intensity} \propto \frac{1}{(\text{Distance})^2}$$

39. (*d*) Photocurrent varies linearly with intensity. The photocurrent is directly proportional to the number of photoelectrons emitted per second. This implies that the number of photoelectrons emitted per second is directly proportional to the intensity of incident radiation.

40. (*a*) As photocurrent increases with increase in intensity, so we can say that number of photoelectrons emitted per second is proportional to intensity of radiation.

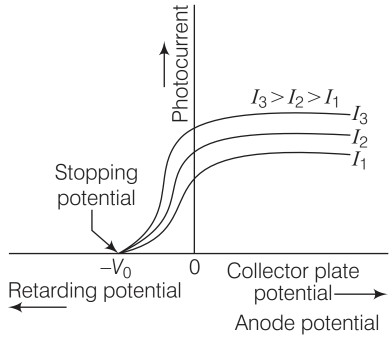
41. (*a*) Intensity and frequency are kept fixed and collector plate potential is gradually changed. Since, intensity and frequency may effect photocurrent, these parameter are kept fixed to observe, the effect of then change in third parameter.

42. (*d*) With the increase in collector potential it is found that the photoelectric current increases with increase in accelerating (positive) potential and finally saturates.

43. (*d*) The maximum value of the photoelectric current is called saturation current. Saturation current corresponds to the case when all the photoelectrons emitted by the emitter plate C reach the collector plate A.

44. (*b*) When polarity of collector plate is reversed only the most energetic electrons are able to reach the collector A.

45. (*a*)



46. (*b*) For a particular frequency of incident radiation, the minimum negative (retarding) potential V_0 given to the plate *A* for which the photocurrent stops or becomes zero is called the cut-off or stopping potential.

47. (*a*) From figure, 0 to $V_0 = -0.54\,V$.

48. (*d*) For greater intensity (I_1), more photoelectrons are emitted and hence saturation current is more. Thus, graph corresponding to I_1 will be above that of I_2. The stopping potential is independent of intensity, hence the graphs converge at same value of V_0 (stopping potential).

49. (*c*) The maximum kinetic energy of photoelectrons depends on the frequency of light source and the emitter plate material but is independent of intensity of incident radiation. Loss in KE = Gain in PE.

50. (*a*) Maximum KE is independent of intensity of light.

51. (*c*) Maximum KE will depend upon the frequency of light source and emitter plate material.

52. (*a*) Stopping potential is more negative for higher frequency.

53. (*c*) From the graph, stopping potential $= V_0 = -\ 3.2\,V$

For photoelectric effect, $KE_{max} = h\nu - \phi$

$$h\nu = 2.2 + 1 = 3.2\,eV$$

The frequency of incident radiation

$$\nu = \frac{1.6\times 10^{-19} \times 3.2}{6.6 \times 10^{-34}} = 0.775 \times 10^{15}\ \text{Hz}$$

54. (*d*) Here, $B = 2.5 \times 10^{-4}$ T

$V = 120\,V$

$r = 13\,\text{cm} = 13 \times 10^{-2}$ m

When electrons are accelerated through V volts.

The change in kinetic energy of the electron is

$$\frac{1}{2} mv^2 = eV \quad \Rightarrow \quad v^2 = \frac{2\,eV}{m} \qquad ...(i)$$

as $$evB = \frac{mv^2}{r} \quad \text{or} \quad v = \frac{eBr}{m}$$

$$\Rightarrow \quad v^2 = \frac{e^2B^2r^2}{m^2} \qquad ....(ii)$$

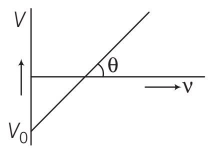
From Eqs. (i) and (ii), we get

$$\frac{2eV}{m} = \frac{e^2B^2r^2}{m^2}$$

or $$\frac{e}{m} = \frac{2V}{r^2B^2} = \frac{2\times 120}{(13\times 10^{-2})^2 \times (2.5\times 10^{-4})^2}$$

$$= 2.27\times 10^{11}\ \text{C kg}^{-1}$$

55. (*c*) Given, slope of graph, $\tan\theta = 4.12\times 10^{-15}$ V-s and charge on electron $e = 1.6\times 10^{-19}$ C



For slope of graph, $\tan\theta = \dfrac{\Delta V}{\Delta \nu}$

$$eV = h\nu - \phi$$

$$\Rightarrow \quad \frac{\Delta V}{\Delta \nu} = \frac{h}{e}$$

$$\therefore \quad \frac{h}{e} = 4.12\times 10^{-15}$$

$$h = 1.6\times 10^{-19} \times 4.12\times 10^{-15}$$

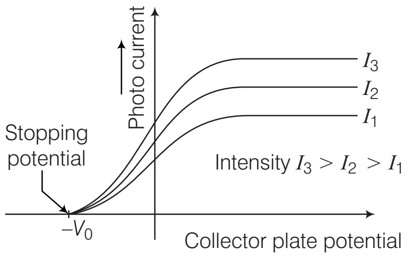
$$= 6.592\times 10^{-34}\ \text{J-s}$$

56. (*a*) All the photoelectrons emitted from the metal do not have the same energy. Electrons near the surface acquires more KE and electrons lying in deep layers are ejected with less energy. Range of KE of emitted electrons is zero to a maximum (K_{max}).

57. (*c*) Photoelectric current is zero when the stopping potential is sufficient to repel even the most energetic photoelectrons, with the maximum kinetic energy (K_{max}), so that

$$K_{max} = eV_0$$

58. (*c*) With incident radiation of the same frequency but of higher intensity I_2 and I_3 ($I_3 > I_2 > I_1$), the saturation currents are found to attain higher values. This shows that more electrons are being emitted per second, proportional to the intensity of incident radiation. But the stopping potential remains the same as KE of ejected electrons does not change.



59. (*c*) Intensities will be equal as the saturation current is same. To study the variation of photocurrent with collector plate potential at different frequencies the intensity is kept same.

60. (*a*) Stopping potential is more negative for higher frequency of incident radiation and *vice-versa.* Thus, from graph

$$\nu_{0A} > \nu_{0B} > \nu_{0C}$$

$$\Rightarrow \quad f_A > f_B > f_C$$

61. (*c*) When frequency of incident radiation increases, the maximum kinetic energy of emitted electrons also increases.

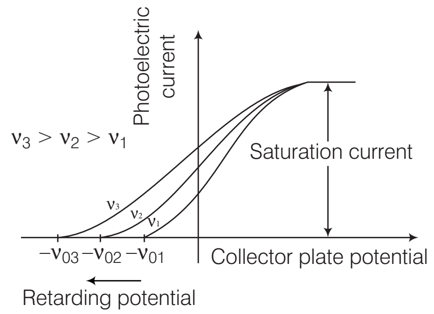
62. (*c*) Different photosensitive materials respond differently to light. Selenium is more sensitive than zinc or copper. The same photosensitive substance gives different response to light of different wavelengths. *e.g.,* Ultraviolet light gives rise to photoelectric effect in copper while green or red light does not.

63. (*b*) By using equation, $h\nu - h\nu_0 = K_{max}$

$$h(\nu_1 - \nu_0) = K_1 \quad \text{and} \quad h(\nu_2 - \nu_0) = K_2$$

$$\therefore \quad \frac{\nu_1 - \nu_0}{\nu_2 - \nu_0} = \frac{K_1}{K_2} = \frac{1}{n} \quad \text{or} \quad \nu_0 = \frac{(n\nu_1 - \nu_2)}{(n-1)}$$

64. (*a*) We obtain different values of stopping potential but the same value of the saturation current for incident radiation of different frequencies of same intensities.



65. (*b*) Energy of emitted photoelectrons depends on frequency of incident radiation.

66. (*a*) Experimentally, it is found that, if frequency of the incident radiation exceeds the threshold frequency, the photoelectric emission starts instantaneously without any apparent time lag, even if the incident radiation is very dim. It is now known that emission starts in a time of the order of 10^{-9} s or less.

67. (*b*) $N \propto I$

As, $f \cdot \lambda$ = speed of light (Here, f is frequency)

$\therefore \quad f \propto \dfrac{1}{\lambda}$

Also, $E \propto f \Rightarrow E \propto \dfrac{1}{\lambda}$

68. (*a*) Photocurrent depends only on intensity of light. As in given problem, only work function is changed, so current values are same.

69. (*c*) In metals many free electrons are present on the surface.

70. (*a*) The wave nature of light was well established by the end of the nineteenth century the phenomena of interferences, diffraction and polarisation were explained in a natural and satisfactory way as the wave picture of light.

71. (*b*) According to wave theories, light is an electromagnetic wave consisting of electric and magnetic fields with continuous distribution of energy over the region of space over which the wave is extended.

72. (*a*) According to the wave picture of light, the free electrons at the surface of the metal (over which the beam of radiation falls) absorb the radiant energy continuously.

73. (*b*) The greater the intensity of radiation, the greater are the amplitude of electric and magnetic fields. Consequently, the greater the intensity, the greater should be the energy absorbed by each electron. The maximum kinetic energy of the photoelectrons on the surface is then expected to increase with increase in intensity.

74. (*d*) According to wave theory we will require beam of sufficient high intensity.

75. (*d*) In the wave picture, the absorption of energy by electron takes place continuously over entire wavefront of the radiation. Since a large number of electrons absorb energy, the energy absorbed per electron per unit time turns out to be small. Explicit calculations estimate that it can take hours or more for a single electron to pick up sufficient energy to overcome the work function and come out of the metal.

76. (*d*) Photoelectric effect is based on quantum theory. The wave picture is unable to explain the most basic features of photoelectric emission. In quantum theory, the radiation energy is considered to be built up of discrete units and it is considered that photoelectric emission does not take place by continuous absorption of energy from radiation.

77. (*d*) Incident power of light = Intensity × Area

$$P = IA = 10^{-5} \times 2 \times 10^{-4} = 2 \times 10^{-9}\ \text{W}$$

Number of layers absorbing light is 5, each sodium atom with effective atomic area of $10^{-20}\ \text{m}^2$.

Number of electrons absorbing energy

$$= n' = n \times \frac{A}{A_e} = 5 \times \frac{2 \times 10^{-4}}{10^{-20}} = 10^{17}$$

where, A_e = effective area of sodium atom

Energy absorbed per second by each electron

$$E = P/n' = 2 \times 10^{-9} / 10^{17} = 2 \times 10^{-26}\ \text{Js}^{-1}$$

$\therefore$ Time required for protoemission in wave picture of light

$$\phi_0 / E = \frac{2 \times 1.6 \times 10^{-19}\ \text{J}}{2 \times 10^{-26}\ \text{Js}^{-1}} = 1.6 \times 10^{7}\text{s} = 0.507\ \text{yr}$$

$$= \frac{1}{2}\ \text{yr}$$

78. (*d*) Einstein's photoelectric equation depends on the basic idea of quantisation of energy. Each quanta of energy is called a photon with energy $h\nu$, where h = Planck's constant and ν is the frequency of light.

79. (*b*) The maximum kinetic energy of the emitted electron is given by

$$K_{\max} = h\nu - \phi_0 = h(6\nu) - h(\nu) = 5\,h\nu$$

80. (*a*) In photoelectric effect, an electron absorbs a quantum of energy ($h\nu$) 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

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

81. (*c*) According to Einstein's experimental results, $K_{\max}$ depends linearly on ν and is independent of intensity of radiation. It is determined by energy of each photon.

82. (*c*) Maximum kinetic energy of emitted photoelectron is given by $K_{\max} = h\nu - \phi_0$

This is Einstein's photoelectric equation.

As we can write, $\phi_0 = h\nu_0$

where, ν_0 = threshold frequency

The above equation can be expressed in following form

$$K_{max} = h\nu - \phi_0 \quad \Rightarrow \quad eV_0 = h\nu - h\nu_0$$

$$K_{max} = eV_0, \text{ where } V_0 = \text{stopping potential}$$

$$\Rightarrow \quad K_{max} = eV_0 = h\frac{c}{\lambda} - \frac{hc}{\lambda_0} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

where, $\lambda_0 =$ threshold wavelength

84. (*a, c*) $eV_0 = \frac{hc}{\lambda} - W$

$$V_0 = \left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}\right) - \frac{W}{e}$$

V_0 *versus* $\frac{1}{\lambda}$ graph is in the form $y = mx - c$

Therefore, option (c) is correct.

Clearly, V_0 *versus* λ graph is not a straight line but V_0 decreases with increase in λ and V_0 becomes zero when $\frac{hc}{\lambda} = W$.

i.e., $\lambda = \lambda_0$ (Threshold wavelength)

$\therefore$ Option (a) is also correct.

85. (*d*) When photon of sufficient energy is absorbed, electron will be emitted.

86. (*a*) Einstein's photoelectric equation is

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

where, K_{max} = maximum KE of emitted electrons,

h = Planck's constant, ν = frequency of incident radiation,

ϕ_0 = work function of metal.

Since, K_{max} must be non-negative.

So, photoelectric emission is possible only, if

$$h\nu > \phi_0 \quad \text{or} \quad \nu > \nu_0,$$

where, $\nu_0 = \frac{\phi_0}{h}$

87. (*d*) More tightly bound electrons will emerge with kinetic energies less than the maximum value.

Kinetic energy of emitted photoelectrons lies between 0 to K maximum value, where $K_{max} = h\nu - \phi_0$

88. (*b*) We know that, $K_{max} = h\nu - \phi_0$ and hence if $K_{max} > 0$

$$\Rightarrow \quad h\nu - \phi_0 > 0 \text{ or } h\nu > \phi_0$$

89. (*c*) Intensity of light of a given frequency is determined by the number of energy quanta (photon) per unit area per unit time.

90. (*d*) From Einstein's equation, $\nu > \frac{\phi_0}{h}$. So, the greater the work function ϕ_0, the higher the threshold frequency ν_0 needed to emit photoelectrons. Thus, there exists a threshold frequency ν_0 $(= \phi_0/h)$ for the metal surface, below which no photoelectric emission is possible, no matter how intense the incident radiation may be or how long it falls on the surface.

91. (*a*) The greater the number of energy quanta available, the greater is the number of electrons absorbing the energy quanta and therefore greater number of electrons coming out of the metal (for $\nu > \nu_0$). Hence, photoelectric current is proportional to intensity.

92. (*c*) In Einstein's picture, the basic elementary process involved in photoelectric effect is the absorption of light quantum by an electron. This process is instantaneous. Thus, whatever may be the intensity *i.e.,* the number of quanta of radiation per unit area per unit time, photoelectric emission is instantaneous.

93. (*c*) The photoelectric equation can be written as

$$eV_0 = h\nu - \phi_0, \text{ for } \nu \geq \nu_0 \quad \text{or} \quad V_0 = \frac{h}{e}\nu - \frac{\phi_0}{e}$$

This is an important result. It predicts that the V_0 *versus* ν curve is a straight line with slope $= (h/e)$, independent of the nature of the material.

94. (*b*) As slope of graph of stopping potential *versus* frequency is h/e. So,

$$\therefore \quad \text{Slope} = \frac{h}{e} \quad \text{or} \quad h = e \times \text{slope}$$

95. (*a*) By Einstein's equation,

we have $eV_0 = h\nu - \phi_0$ or $V_0 = \frac{h}{e}\nu - \frac{\phi_0}{e}$

Above is a equation of straight line $(y = mx + c)$ with slope $\frac{h}{e}$ and y-intercept $= \frac{\phi_0}{e}$

$\therefore$ Work function, $\phi_0 = e \times$ intercept (eV)

96. (*d*) As the distance of source from the surface increases, intensity of radiation decreases.

Intensity $= \frac{1}{(\text{distance})^2}$ and photocurrent $\propto$ Intensity

97. (*a*) $K_{max} = h\nu - \phi_0$ (Einstein's photoelectric equation)

Above equation is equation of a straight line with y-intercept ϕ_0, so from graph, work function is 1 eV.

98. (*c*) In Ist case, when a metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V.

So, photoelectric equation can be written as

$$eV = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} \quad \ldots\text{(i)}$$

In IInd case, when the same surface is illuminated with radiation of wavelength 2λ, the stopping potential is $\frac{V}{4}$.

So, photoelectric equation can be written as

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

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

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

$$\Rightarrow \quad \frac{1}{\lambda} - \frac{1}{\lambda_0} = \frac{2}{\lambda} - \frac{4}{\lambda_0} \quad \Rightarrow \quad \lambda_0 = 3\lambda$$

99. (*c*) Here, $eV = \frac{hc}{\lambda} - W_0$

$$0.5e = \frac{hc}{6 \times 10^{-7}} - W_0$$

$$\Rightarrow \quad 0.5 = \frac{h}{e}\left(\frac{c}{6\times 10^{-7}}\right) - \frac{W_0}{e} \quad \text{...(i)}$$

Similarly, $$1.5 = \frac{h}{e}\left(\frac{c}{4\times 10^{-7}}\right) - \frac{W_0}{e} \quad \text{...(ii)}$$

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

$$1 = \frac{h}{e}\frac{c}{10^{-7}}\left[\frac{1}{4} - \frac{1}{6}\right]$$

$$\Rightarrow \quad \frac{h}{e} = \frac{12\times 10^{-7}}{3\times 10^{8}}$$

$$\frac{h}{e} = 4\times 10^{-15}\ \text{Vs}$$

100. (*b*) Maximum kinetic energy,

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

where, V_0 is the stopping potential.

According to Einstein's photoelectric equation

$$h\nu_1 = \phi_0 + eV_1$$

$$h\nu_2 = \phi + eV_2$$

$$\therefore \quad h(\nu_1 - \nu_2) = e(V_1 - V_2)$$

$$\frac{h}{e}(\nu_1 - \nu_2) = V_1 - V_2$$

or $$V_2 = V_1 + \frac{h}{e}(\nu_1 - \nu_2)$$

101. (*a*) Work-function $\phi_0 = hv_0$

Then threshold frequency

$$v_0 = \frac{\phi_0}{h} = \frac{6.35\times 1.6\times 10^{-19}}{6.63\times 10^{-34}} = 15.32\times 10^{14}\ \text{Hz}$$

102. (*a*) According to Einstein's photoelectric equation,

$$h\nu = h\nu_0 + \frac{1}{2}mv_{\max}^2 \quad \text{or} \quad \frac{1}{2}mv_{\max}^2 = h\nu - h\nu_0$$

According to the given problem

$$\frac{1}{2}m(8\times 10^6)^2 = h(5\nu_0 - \nu_0) \quad \text{...(i)}$$

$$\frac{1}{2}mv_{\max}^2 = h(2\nu_0 - \nu_0) \quad \text{...(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{(8\times 10^6)^2}{v_{\max}^2} = \frac{4\nu_0}{\nu_0}$$

$$v_{\max}^2 = \frac{(8\times 10^6)^2}{4}$$

$$v_{\max} = \frac{8\times 10^6}{2} = 4\times 10^6\ \text{ms}^{-1}$$

103. (*a*) According to Einstein's equation

Kinetic energy of emitted electron

$$= h\nu - (\text{work-function } \phi_0)$$

$$\therefore \quad \frac{1}{2}mv_1^2 = h\nu_1 - \phi$$

$$\frac{1}{2}mv_2^2 = h\nu_2 - \phi$$

$$\therefore \quad \frac{1}{2}m(v_1^2 - v_2^2) = h(\nu_1 - \nu_2)$$

$$v_1^2 - v_2^2 = \frac{2h}{m}(\nu_1 - \nu_2)$$

104. (*b*) Frequency of lines can be found by using $\nu = \frac{c}{\lambda}$ and they are listed in tabular form as

$f\times 10^{14}$ Hz	8.219	7.412	6.884	5.493	4.343
V_0	1.28	0.95	0.74	0.16	0

From the table, frequency $f_0 = 4.343\times 10^{14}$ Hz

Work function $= \phi_0 = h\nu f_0 \approx 1.8$ eV

105. (*c*) When an electron absorbs sufficient energy, it is emitted and carries remaining energy as its KE. Part of energy absorbed is spent in overcoming attraction from metal surface and in collision.

$$\text{KE}_{\max} = 4v - \phi = 0.35\ \text{eV}$$

106. (*a*) Given, work-function of caesium metal $\phi_0 = 2.14$ eV

Frequency of light $\nu = 6\times 10^4$ Hz

$$\text{KE}_{\max} = h\nu - \phi = 0.35\ \text{eV}$$

(i) Let stopping potential be V_0

We know that

$$\text{KE}_{\max} = eV_0$$

$$0.35\ \text{eV} = eV_0$$

$$V_0 = 0.35\ \text{V}$$

(ii) Maximum kinetic energy $\text{KE}_{\max} = \frac{1}{2}mv_{\max}^2$

$$0.35\ \text{eV} = \frac{1}{2}mv_{\max}^2$$

(where, $v_{\max}$ is the maximum speed and m is the mass of electron)

or $$\frac{0.35\times 2\times 1.6\times 10^{-19}}{9.1\times 10^{-31}} = v_{\max}^2 \ (\because e = 1.6\times 10^{-19})$$

or $$v_{\max}^2 = 0.123\times 10^{12}$$

or $$v_{\max} = 350713.55\ \text{ms}^{-1}$$

$$v_{\max} = 350.7\ \text{kms}^{-1}$$

107. (*a*) According to Einstein photoelectric equation

$$E = K_{\max} + \phi$$

where, $K_{\max}$ is maximum kinetic energy of emitted electron and ϕ is work function of an electron

$$K_{\max} = E - \phi = h\nu - \phi$$

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

Similarly, in second case, maximum kinetic energy of emitted electron is 3 times that in first case, we get

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

Solving Eqs. (i) and (ii), we get work function of an emitted electron from a metal surface

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

108. (*a*) According to Einstein's photoelectric emission of light,

$$E = (\text{KE})_{\max} + \phi \text{ as } \frac{hc}{\lambda} = (\text{KE})_{\max} + \phi$$

If the wavelength of radiation is changed to $\frac{3\lambda}{4}$, then

$$\Rightarrow \quad \frac{4}{3}\frac{hc}{\lambda} = \left(\frac{4}{3}(\text{KE})_{\max} + \frac{\phi}{3}\right) + \phi$$

For fastest emitted electron, $(\text{KE})_{\max} = \frac{1}{2}mv'^2 + \phi$

$$\Rightarrow \quad \frac{1}{2}mv'^2 = \frac{4}{3}\left(\frac{1}{2}mv^2\right) + \frac{\phi}{3}$$

i.e., $$v' > v\left(\frac{4}{3}\right)^{1/2}$$

109. (*a*) Given, for neon lamp wavelength of monochromatic radiation, $\lambda = 640.2\,\text{nm} = 640.2 \times 10^{-9}$ m

Stopping voltage $V_0 = 0.54$ V

Let ϕ_0 be the work-function.

$$\therefore \quad eV_0 = \frac{hc}{\lambda} - \phi_0$$

Work-function of photosensitive material,

$$\phi_0 = \frac{hc}{\lambda} - eV_0$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{640.2 \times 10^{-9}} - 1.6 \times 10^{-19} \times 0.54$$

$$= 3.1 \times 10^{-19} - 0.864 \times 10^{-19} = 2.236 \times 10^{-19}$$

$$= \frac{2.236 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.4 \text{ eV}$$

For iron; given work-function, $\phi_0 = 1.4$ eV

Wavelength $\lambda = 427.2$ nm $= 427.2 \times 10^{-9}$ m

Let V_0' be the new stopping potential.

$$eV_0' = \frac{hc}{\lambda} - \phi_0$$

$$= \frac{6.63 \times 10^{-34} \times 10^8 \times 3}{427.2 \times 10^{-9} \times 1.6 \times 10^{-19}} - 1.4 = 1.51\,\text{eV}$$

Required stopping potential, $V_0' = 1.51$ V

110. (*a*) According to Einstein photoelectric equation,

$$K_A = \frac{hc}{\lambda_A} - \phi \Rightarrow 2K_A = \frac{2hc}{\lambda_A} - 2\phi$$

or $$2K_A + \phi = \frac{2hc}{\lambda_A} - \phi$$

Wavelength of metal B is half of metal A, therefore

$$K_B = \frac{2hc}{\lambda_A} - \phi \Rightarrow 2K_A + \phi = K_B \Rightarrow K_A < \frac{K_B}{2}$$

111. (*b*) Millikan performed a series of experiments on photoelectric effect. He measured the slope of the straight line obtained for sodium. Using the known value of e, he determined the value of Planck's constant h. This value was close to the value of Planck's constant ($= 6.626 \times 10^{-34}$ Js) determined in an entirely different context.

112. (*c*) The successful explanation of photoelectric effect using the hypothesis of light quanta and the experimental determination of values of h and ϕ_0 in agreement with values obtained from other experiments, led to the acceptance of Einstein's picture of photoelectric effect.

113. (*d*) Photoelectric effect gives the evidence to the strange fact that light in interaction with matter behaved as if it was made of quanta or packets of energy, each of energy $h\nu$.

114. (*d*) Einstein arrived at the important result that the light quantum can also be associated with momentum ($h\nu/c$). A definite value of energy as well as momentum is a strong sign that the light quantum can be associated with a particle.

115. (*b*) The quantum possessing energy is called photon.

116. (c) Behaviour of light was further confirmed, in 1924 by the experiment of AH. Compton (1892-1962) on scattering of X-rays from electrons.

117. (*d*) Momentum of a photon $= \frac{h}{\lambda} = \frac{h\nu}{c}$

So, all have same momentum.

118. (*d*) Intensity of a light beam = Number of photons falling on a unit area in 1s.

119. (*b*) It is a photocell. As a photocell converts variation of intensity of light into variation of current, we can say it is sensitive to intensity of light like an eye. It is based on the application of photoelectric effect.

120. (*a*) Photons can exerts pressure. Pressure of electromagnetic waves is called radiation pressure.

121. (*d*) Photons are electrically neutral and so are not deflected by strong electric or magnetic field.

122. (*b*) Given, wavelength of light = 589 nm $= 589 \times 10^{-9}$ m

Mass of electron, $m_e = 9.1 \times 10^{-31}$ kg

Mass of neutron, $m_n = 1.67 \times 10^{-27}$ kg

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

(i) Using of formula, $\lambda = \frac{h}{\sqrt{2\text{KE}m_e}}$

Kinetic energy of electron,

$$\text{KE}_e = \frac{h^2}{2\lambda^2 m_e} = \frac{(6.63 \times 10^{-34})^2}{2 \times (589 \times 10^{-9})^2 \times 9.1 \times 10^{-31}}$$

$$= 6.96 \times 10^{-25} \text{ J}$$

(ii) Kinetic energy of neutron

$$\text{KE}_n = \frac{h^2}{2\lambda^2 m_n} = \frac{(6.63 \times 10^{-34})^2}{2 \times (589 \times 10^{-9})^2 \times 1.66 \times 10^{-27}}$$

$$= 3.81 \times 10^{-28} \text{ J}$$

123. (*a*) Given, energy of γ-rays = 10.2 eV = 10.2 eV (2γ-rays)

Energy of one γ-ray $= \frac{10.2}{2} = 5.1 \text{ eV} = 5.1 \times 1.6 \times 10^{-9}$ J

$= 8.16 \times 10^{-19}$ J

Let λ be the wavelength.

Energy of each ray

$$E = \frac{hc}{\lambda} \quad \text{or} \quad \lambda = \frac{hc}{E}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{8.16 \times 10^{-19}} = 2.436 \times 10^{-7} \text{ m}$$

124. (*b*) Energy of photons $= h\nu$

$$= (6.626 \times 10^{-34} \text{Js}) \times (6 \times 10^{14} \text{ s}^{-1})$$
$$= 3.98 \times 10^{-19} \text{ J}$$

125. (*d*) Number of photons emitted per second

= Power of the source/ Energy of one photon

$$= \frac{2 \times 10^{-3}}{3.98 \times 10^{-19}} = 5 \times 10^{15} \text{ Photons per second.}$$

126. (*d*) Work function, $\phi_0 = h\nu_0'$

∴ Threshold frequency,

$$\nu_0 = \frac{\phi_0}{h} = \frac{2.14 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34}} = 5.16 \times 10^{14} \text{Hz}$$

127. (*d*) For red light, $\lambda = 760$ nm

Energy, $E = h\nu = \frac{hc}{\lambda}$

Hence $E = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{760 \times 10^{-9}} = 2.62 \times 10^{-19}$ J

$$= \frac{2.62 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV} = 1.64 \text{ eV}$$

128. (*a*) Here, $I = 1.52 \times 10^{3} \text{ Wm}^{-2}$

$$\lambda = 520 \times 10^{-9} \text{ m} \Rightarrow h = 6.63 \times 10^{-34} \text{ Js}$$

Number of photons incident on earth's surface per second per square metre is

$$n = \frac{I}{E} = \frac{I}{hc}\lambda \qquad \left[\because E = \frac{hc}{\lambda}\right]$$

$$n = \frac{1.52 \times 10^{3} \times 520 \times 10^{-9}}{6.63 \times 10^{-34} \times 3 \times 10^{8}}$$

$= 4 \times 10^{21}$ Photons per m^2 per second.

129. (*b*) Here, $\lambda_{min} = 0.55 \text{ Å} = 0.55 \times 10^{-10}$ m, $c = 3 \times 10^{8} \text{ ms}^{-1}$

Maximum energy of X-ray photon is

$$E_{max} = h\nu_{max} = \frac{hc}{\lambda_{min}}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{0.55 \times 10^{-10} \times 1.6 \times 10^{-19}} \text{ eV}$$

$= 22.6 \times 10^{3}$ eV = 22.6 keV

130. (*b*) Energy of a photon, $E = 6 \text{ MeV} = 6 \times 10^{6}$ eV

Linear momentum of the photon

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

$$P = \frac{6 \times 10^{6} \text{ eV}}{3 \times 10^{8} \text{ ms}^{-1}} = 2 \times 10^{-2} \text{ eVs m}^{-1} = 0.02 \text{ eVs m}^{-1}$$

131. (*d*) According to de-Broglie, a moving particles of matter should display wave-like properties under the condition that particle is having some momentum under the frame of reference of observation. So, a moving particle may exhibit wave like properties.

132. (*c*) de-Broglie reasoned that nature was symmetrical and that the two basic physical entities-matter and energy, must have symmetrical character. If radiation shows dual aspects, so should matter.

133. (*d*) λ is smaller for a heavier particle (large *m*) or more energetic particle (large *v*).

This wavelength is so small that it is beyond any measurement. This is reason why macroscope objects in our daily life do not show wavelike properties.

134. (*b*) In photocell, light energy (intensity) is converted into electrical energy (current). It converts a change in intensity of illumination into a change in photocurrent. This current can be used to operate control systems and in light measuring device.

135. (*b*) In burglar alarm, ultraviolet light is continuously made to fall on a photocell installed at the doorway.

136. (*a*) For an electron (mass *m*, charge *e*) accelerated from rest through a potential V. The kinetic energy K of the electron equals to work done (eV) on it by the electric field

⇒ $K = eV$

137. (*d*) In the familiar phenomenon of seeing an object by our eye, both descriptions are important. The gathering and focussing mechanism of light by the eye-lens is well described in the wave picture. But its absorption by the rods and cones (of the retina) requires the photon picture of light.

138. (*c*) $\because \lambda = \frac{h}{p}$

$\Rightarrow \lambda \propto \frac{1}{p}$ or λ is inversely proportional to momentum.

139. (*d*) If v = velocity of particle

Then, $E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$, so that

$$p = \sqrt{2mE} = \sqrt{2meV}$$

The de-Broglie wavelength λ of the electron is then

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2meV}}$$

140. (*a*) Here, $u = 0$; $a = \frac{eE}{m}$; $v = ?$, $t = t$

∴ $v = u + at = 0 + \frac{eE}{m}t$ (from equation of motion) de-Broglie wavelength,

$$\lambda = \frac{h}{mv} = \frac{h}{m\,(eEt/m)} = \frac{h}{eEt}$$

Rate of change of de-Broglie wavelength,

$$\frac{d\lambda}{dt} = \frac{h}{eE}\left(-\frac{1}{t^2}\right) = \frac{-h}{eEt^2}$$

141. (*b*) $\lambda = \frac{1.227}{\sqrt{V}}\text{nm} = \frac{1.227}{\sqrt{100}} = 0.123$ nm

which is in X-ray region.

142. (*d*) Momentum of a photon of energy $h\nu$

$$p = \frac{h\nu}{c} = \frac{h}{\lambda} \Rightarrow \lambda = \frac{h}{p} \quad \ldots\text{(i)}$$

Also, by de-Broglie wavelength formula,

$$\lambda = \frac{h}{p} \quad \ldots\text{(ii)}$$

Both agrees to same value.

143. (*d*) Since, it is given that electron has mass *m*. de-Broglie's wavelength for an electron will be given as

$$\lambda_e = \frac{h}{p} \quad \ldots\text{(i)}$$

where, h = Planck's constant
p = Linear momentum of electron

As kinetic energy of electron, $E = \frac{p^2}{2m}$

$$\Rightarrow \quad p = \sqrt{2\,mE} \quad \ldots\text{(ii)}$$

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

$$\lambda_e = \frac{h}{\sqrt{2mE}} \quad \ldots\text{(iii)}$$

Energy of a photon can be given as

$$E = h\nu$$

$$\Rightarrow \quad E = \frac{hc}{\lambda_p} \Rightarrow \lambda_p = \frac{hc}{E} \quad \ldots\text{(iv)}$$

Hence, λ_p = de-Broglie's wavelength of photon.
Now, dividing Eq. (iii) by Eq. (iv), we get

$$\frac{\lambda_e}{\lambda_p} = \frac{h}{\sqrt{2mE}}\cdot\frac{E}{hc} \Rightarrow \frac{\lambda_e}{\lambda_p} = \frac{1}{c}\cdot\sqrt{\frac{E}{2m}}$$

144. (*a*) Energy per unit area per unit time = Intensity
Number of photons per unit area per unit time = N

$$\therefore \quad \frac{\text{Intensity}}{\text{Energy of a photon}} = \frac{I}{h\nu}$$

So, number of photons entering our eye

$= N \times$ Area of pupil $= \frac{I}{h\nu} \times A = 1.008 \times 10^4$ photons s^{-1}.

145. (*a*) For the electron,
Mass, $m = 9.11 \times 10^{-31}$ kg, speed $v = 5.4 \times 10^{-6}\text{ms}^{-1}$
Then, momentum
$p = mv = 9.11 \times 10^{-31} \times 5.4 \times 10^6 = 4.92 \times 10^{-24}\text{kg ms}^{-1}$

de-Broglie wavelength, $\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}\text{ Js}}{4.92 \times 10^{-24}\text{kgms}^{-1}}$

$= 0.135$ nm

146. (*d*) As $\lambda = \frac{h}{\sqrt{2\,mqv}}$

$$\therefore \quad \lambda \propto \frac{1}{\sqrt{mq}}$$

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \frac{\sqrt{m_\alpha q_\alpha}}{\sqrt{m_p q_p}} \quad (m_\alpha = 4m_p,\ q_\alpha = 2q_p)$$

$$\frac{\lambda_p}{\lambda_\alpha} = \frac{\sqrt{4m_p \times 2e}}{\sqrt{m_p \times e}} = \sqrt{8} : 1$$

147. (*c*) de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mK}}$ ...(i)

When the KE is $\frac{K}{9}$, then

$$\lambda' = \frac{h}{\sqrt{2m\left(\frac{K}{9}\right)}} = \frac{3h}{\sqrt{2mK}} = 3\lambda \quad \text{[using Eq. (i)]}$$

148. (*b*) Here, $P = 200$ W, $\lambda_1 = 2$ nm, $\lambda_2 = 400$ nm
Let n_1 and n_2 be the number of photons of X-rays and visible light emitted from the two sources.

$$\therefore \quad n_1\frac{hc}{\lambda_1} = n_2\frac{hc}{\lambda_2} \text{ or } \frac{n_1}{\lambda_1} = \frac{n_2}{\lambda_2}$$

$$\Rightarrow \quad \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{2}{400} = \frac{1}{200} = 1:200$$

149. (*a*) de-Broglie wavelength, $\lambda = h/p$

$$\because \quad p_\alpha = p_p = p_e \quad \therefore \quad \lambda_\alpha = \lambda_p = \lambda_e$$

150. (*a*) Momentum of striking electrons, $p = \frac{h}{\lambda}$

$\therefore$ Kinetic energy of striking electrons

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

This is also, maximum energy of X-ray photons.

Therefore, $\frac{hc}{\lambda_0} = \frac{h^2}{2m\lambda^2}$ or $\lambda_0 = \frac{2m\lambda^2 c}{h}$

151. (*a*) We have, $\lambda = \frac{12.27}{\sqrt{V}}$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}} \text{ or } \lambda_2 = \lambda_1\sqrt{\frac{V_1}{V_2}}$$

$$\lambda_2 = \lambda_1\sqrt{\frac{25}{100}} \Rightarrow \lambda_2 = \lambda_1\sqrt{\frac{1}{4}} = \frac{\lambda_1}{2}$$

152. (*a*) Momentum of photon, $p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$

$$p = \frac{h}{\lambda} = \frac{h}{1 \times 10^{-10}} = 10^{10}\,h$$

153. (*b*) For de-Broglie wavelength

$$\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mK}} \quad \ldots(i)$$

$$\lambda_2 = \frac{h}{\sqrt{2m\,16K}} = \frac{h}{4\sqrt{2mK}} = \frac{\lambda_1}{4} \quad \ldots(ii)$$

$$\lambda_2 = 25\% \text{ of } \lambda_1$$

There is 75% change in the wavelength

154. (*a*) If λ_0 is threshold wavelength, then work function

$$\phi_0 = \frac{hc}{\lambda_0} \Rightarrow \lambda_0 = \frac{hc}{\phi_0} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.2 \times 1.6 \times 10^{-19}} \approx 2955 \text{ Å}$$

155. (*c*) Given that, the wavelength of incident light

$$(\lambda) = 200 \text{ nm} = 200 \times 10^{-9} \text{ m}$$

From Einstein's photoelectric equation,

$$KE_{max} = h\nu - \phi \quad \ldots(i)$$

But $KE_{max} = eV_0$

$\therefore$ $eV_0 = h\nu - \phi$ (V_0 = stopping potential)

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

$$\therefore 1.6 \times 10^{-19}\, V_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{200 \times 10^{-9}} - 4.71 \times 1.6 \times 10^{-19}$$

$$V_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2 \times 10^{-7} \times 1.6 \times 10^{-19}} - \frac{4.71 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-19}}$$

$$V_0 = (6.19 - 4.71) = 1.48 \approx 1.50 \text{ V}$$

156. (*b*) $K = \frac{1}{2} mv^2$

$\Rightarrow$ $2mK = p^2$ and $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$

So, for same kinetic energy, $\lambda \propto \frac{1}{\sqrt{m}}$.

As heaviest is α-particle, λ is smallest for α.

157. (*d*) Given, $\frac{\lambda_p}{\lambda_e} = 1.83 \times 10^{-4}$ (where, λ_p and λ_e are de-Broglie's wavelengths associated with particle and electron, respectively) and $\frac{v_p}{v_e} = 3$ (where, v_p and v_e are velocities of the particle and electron, respectively.)

Since, $\lambda = \frac{h}{mv}$ or $m = \frac{h}{\lambda v}$ ...(i)

Using Eq. (i), $\frac{m_e}{m_p} = \frac{\lambda_p v_p}{\lambda_e v_e} = 5.49 \times 10^{-4}$

or $\frac{m_p}{m_e} = \frac{1}{5.49 \times 10^{-4}}$

$\Rightarrow$ $m_p = \frac{9.1 \times 10^{-31}}{5.49 \times 10^{-4}} \approx 1.66 \times 10^{-27}$ kg

So, particle may be proton or a neutron.

158. (*a*) Given, potential difference, $V = 56$ V

(i) Use the formula for kinetic energy

$$eV = \frac{1}{2} mv^2 \Rightarrow \frac{2eV}{m} = v^2 \Rightarrow v = \sqrt{\frac{2\,eV}{m}}$$

where, m is mass and v is velocity of electron.

Momentum associated with accelerated electron,

$$p = mv = m\sqrt{\frac{2eV}{m}} = \sqrt{2\,eVm}$$

$$= \sqrt{2 \times 1.6 \times 10^{-19} \times 56 \times 9 \times 10^{-31}}$$

$$= 4.02 \times 10^{-24} \text{ kg-ms}^{-1}$$

(ii) de-Broglie wavelength of electron,

$$\lambda = \frac{12.27}{\sqrt{V}} \text{ Å} = \frac{12.27}{\sqrt{56}} = 0.164 \times 10^{-9} \text{ m} = 0.164 \text{ nm}$$

159. (*b*) The de-Broglie wavelength is given by

$$\lambda = h/p \Rightarrow p\lambda = h$$

This equation is in the form of $yx = c$, which is the equation of a rectangular hyperbola. Hence, the graph given in option (b) is the correct one.

160. (*a*) If an electron is accelerated through a potential difference of V volts, then wavelength associated with electron is $\lambda = \frac{1.227}{\sqrt{V}}$ nm, where, V is the magnitude of accelerating potential in volts. For a 120 V accelerating potential, above equation gives $\lambda = 0.112$ nm. This wavelength is of the same order as the spacing between the atomic planes in crystals.

161. (*c*) As $\lambda = \frac{\hbar}{p}$ and p = momentum

$\therefore$ If $p = 0, \lambda = \infty$ (not defined)

Hence, $p \neq 0 \Rightarrow v$ = finite and non-zero.

162. (*a*) Photons have zero rest mass and non-zero energy and they are moving with a speed of light.

163. (*c*) The matter wave picture elegantly incorporated the Heisenberg's uncertainty principle. According to the principle, it is not possible to measure both the position and momentum of an electron (or any other particle) at the same time exactly.

164. (*a*) There is always some uncertainty (Δx) in the specification of position and some uncertainty (Δp) in the specification of momentum. The product of Δx and Δp is of the order of $\hbar$ (with $\hbar = h/2\pi$) *i.e.*, $\Delta x \Delta p \approx \hbar$

165. (*a*) Here, $\Delta x = 1 \text{ nm} = 10^{-9}$ m

By Heisenberg uncertainty principle

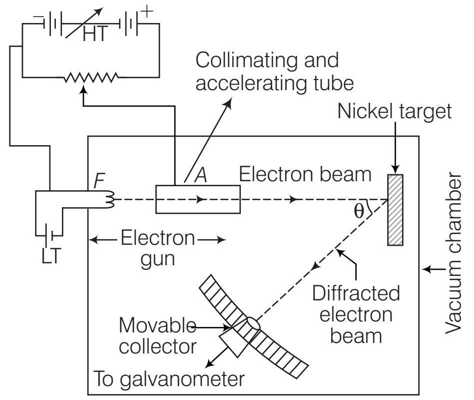
$$\Delta x \, \Delta p = \hbar$$

$$\therefore \quad \Delta p = \frac{\hbar}{\Delta x} = \frac{h}{2\pi\,\Delta x} \quad \left(\because \hbar = \frac{h}{2\pi}\right)$$

$$= \frac{6.63 \times 10^{-34}}{2 \times \pi \times 10^{-9}} < 1.05 \times 10^{-25} \text{ kg ms}^{-1}$$

166. (*c*) The wave nature of electrons was first experimentally verified by CJ Davisson and LH Germer in 1927.

167. (*d*)



168. (*c*) The appearance of the peak in a particular direction is due to the constructive interference of electrons scattered from different layers of the regularly spaced atoms of the crystals.

170. (*d*) For heavy or slow particles, wavelength associated is not measurable. But for a fast and light particle, wavelength is observable.

171. (*d*) The de-Broglie hypothesis beam basic to the development of modern quantum mechanics. It has also led to the field of electron optics. The wave properties of electrons have been utilised in the design of electron microscope which is a great improvement, with higher resolution, over the optical microscope.

172. (*a*) For the nickel crystal, the interatomic separation is

$$d = 0.91\,\text{Å}$$

According to Bragg's law, for first order diffraction maxima $(n = 1)$, we have

$$2\,d\,\sin\theta = 1\times\lambda$$

$$\therefore \quad \lambda = 2\times 0.91\times\sin\,65° = 1.65\,\text{Å}$$

173. (*a*) The experimental arrangement used by Davisson and Germer consists of an electron gun which comprises of a tungsten filament *F*, coated with barium oxide and heated by a low voltage power supply. Electrons emitted by the filament are accelerated to a desired velocity by applying suitable potential/voltage from a high voltage power supply.

174. (*c*) Given, voltage of electron microscope $= 50\,\text{kV} = 50000\,\text{V}$

de-Broglie wavelength, $\lambda = \dfrac{12.27}{\sqrt{V}}\,\text{Å} = \dfrac{12.27}{\sqrt{50000}} = 0.055\,\text{Å}$

$$= 5.5\times 10^{-12}\ \text{m}$$

175. (*a*) Cathode ray particles when strike the electrons of glass atom, the electrons of glass atom are excited and move to higher energy levels. On de-excitation, they fall to their ground state and release energy. As energy levels are characteristics of glass, glow depends on glass.

176. (*c*) Sensitivity of a photoelectric materials greatly depends on its surface characteristics. When emitter plate is coated with a materials of low work function, photoemission occurs even at low frequency.

177. (*a*) We know that intensity is energy per unit area per unit time.

178. (*a*) The number of photoelectrons emitted per second is directly proportional to the intensity of incident radiation and kinetic energy of photoelectrons depends on frequency of incident radiation.

179. (*b*) Work function is the minimum energy required to eject the photoelectron from photosensitive metal. Hence for metal to be photosensitive, the work-function should be small.

Work function $= h\nu_0$

where ν_0 is the threshold frequency.

180. (*c*) In a photon-particle collision such as photon-electron collision, the total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

181. (*c*) Photocell is a technical application of the photoelectric effect. It is a device which converts light energy into electric energy. It is also called an electric eye. Photocell are used in the reproduction of sound in motion picture and in the television camera.

182. (*a*) In Davisson and Germer experiment, de-Broglie wavelength associated with electron beam is

$$\lambda = \frac{h}{\sqrt{2mK}}$$

where, K is KE and m is mass of electron.

183. (*a*) Momentum of a photon is given by $p = h/c$

Also the photon is a form of energy photon behaves as a particle having energy $E = \dfrac{hc}{\lambda}$ so $p = \lambda\,\dfrac{E}{c}$.

185. (*b*) The photo emissive cell contain an inert gas at low pressure. An inert gas in the cell is given greater current but causes a time lag in the response of the cell to very rapid change of radiation which may make it unsuitable for some purpose.

186. (*d*) Maxwell's equations and Lorentz force formula forms the basic foundation of electrodynamics Maxwell's equations describes how electric and magnetic fields are generated and altered by each other. X-ray is a form of electromagnetic radiation.

187. (*d*) The minimum energy required for the electron emission from the metal surface can be supplied to the free electrons by anyone of the following physical processes.

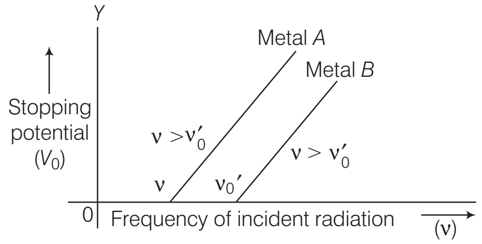
(i) **Thermionic emission** By suitably heating, sufficient thermal energy can be imparted to the free electrons to enable them to come out of the metal.

(ii) **Photoelectric emission** When light of suitable frequency illuminates a metal surface, electrons are emitted from the metal surface. These photo (light)-generated electrons are called photoelectrons.

(iii) **Field emission** By applying a very strong electric field (of the order of $10^8\ \text{Vm}^{-1}$) to a metal, electrons can be pulled out of the metal, as in a spark plug.

188. (*d*) To study effect of intensity, the collector C is maintained at a positive potential with respect to emitter E so that electrons ejected from E are attracted towards collector C. Keeping the frequency of the incident radiation and the accelerating potential fixed, the intensity of light is varied and the resulting photoelectric current is measured each time. It is found that the photocurrent increases linearly with intensity of incident light.

189. (*a*) (i) The graph shows that the stopping potential V_0 varies linearly with the frequency of incident radiation for a given photosensitive material.



Variation of stopping potential V_0 with frequency ν of incident radiation for a given photosensitive material.

(ii) There exists a certain minimum cut-off frequency ν_0 for which the stopping potential is zero.
These observations have two implications.

(iii) The maximum kinetic energy of the photoelectrons varies linearly with the frequency of incident radiation, but is independent of its intensity.

(iv) For a frequency ν of incident radiation lower than the cut-off frequency ν_0, no photoelectric emission is possible even if the intensity is large.
This minimum, cut-off frequency ν_0, is called the threshold frequency. It is different for different metals.

190. (*d*) (i) For a given photosensitive material and frequency of incident radiation (above the threshold frequency), the photoelectric current is directly proportional to the intensity of incident light, till saturation.

(ii) Saturation current is found to be proportional to the intensity of incident radiation whereas the stopping potential is independent of its intensity.

(iii) A certain minimum cut-off frequency of the incident radiation, called the threshold frequency, below which no emission of photoelectrons takes place, no matter how intense the incident light is. Above the threshold frequency, the stopping potential or equivalently the maximum kinetic energy of the emitted photoelectrons increases linearly with the frequency of the incident radiation but is independent of its intensity.

(iv) The photoelectric emission is an instantaneous process without any apparent time lag ($\sim 10^{-9}$ or less), even when the incident radiations is made exceedingly dim.

191. (*b*) (i) In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.

(ii) Each photon has energy $E\ (= h\nu)$ and momentum $p\ (= h\nu/c)$ where c is the speed of light.

(iii) Photons are electrically neutral and are not deflected by electric and magnetic fields.

(iv) In photon-particle collision (such as photoelectron collision), the total energy and total momentum are conserved.

192. (*c*) Using $\lambda = \dfrac{h}{p}$ and $p = mv$,

we get, $\lambda_1 < \lambda_2 < \lambda_3$

$$p_1 = m_1 v_1 = (0.4\ \text{kg} \times 1\ \text{kms}^{-1}) = 400\ \text{kg ms}^{-1}$$

$$p_2 = m_2\ v_2 = (0.6\ \text{kg} \times 1\ \text{ms}^{-1}) = 0.6\ \text{kg ms}^{-1}$$

$$p_3 = m_3 v_3 = (1.0 \times 10^{-9} \times 2.2) = 2.2 \times 10^{-9}\ \text{kgms}^{-1}$$

$$p_1 > p_2 > p_3$$

$$\lambda_1 < \lambda_2 < \lambda_3 \qquad \left(\because \lambda \propto \frac{1}{p}\right)$$

193. (*b*) $A \to 3, B \to 4, C \to 2, D \to 1$

Maximum KE is given by

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

$$= \frac{6.62 \times 10^{-34} \times 6 \times 10^{14}}{1.6 \times 10^{-19}} - 2.14$$

$$= 2.485 - 2.140 = 0.345\ \text{eV}$$

$$K_{\text{min}} = 0,\ (\text{so } B \to 4)$$

Stopping potential, $V_0 = \dfrac{K_{\text{max}}}{e} = \dfrac{0.345\ \text{eV}}{e}$

or $\quad V_0 = 0.345\ \text{V} = 345\ \text{mV}$

Maximum speed of emitted electrons,

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

or $\quad v_{\text{max}} = \sqrt{\dfrac{2K_{\text{max}}}{m}} = \sqrt{0.1104 \times 10^{12}}$

$$= 3.323 \times 10^5\ \text{ms}^{-1} = 332\ \text{kms}^{-1}$$

194. (*b*) $A \to 4, B \to 2, C \to 3, D \to 1$

A. An electron absorbs a single photon of light and if the energy carried by photon is more than work function of the metal, the electron is emitted.

B. From source,
Total emitted power $= P$ (total energy per second)
Energy carried by each photon $= E$
So, number of photons emitted by the source $= P / E$

C. Energy of a photons $= E = h\nu$

D. For the cut-off or threshold frequency, the energy $h\nu_0$ of the incident radiation must be equal to work function ϕ_0, so that $h\nu_0 = \phi_0$

$$\Rightarrow \qquad h = \frac{\phi_0}{\nu_0}$$

196. (*a*) $A \to 2, B \to 1, C \to 3$

Frank-Hertz experiment $\to$ Discrete energy levels of atoms.
Photoelectric experiment $\to$ Particle nature of light
Davisson-Germer experiment $\to$ Wave nature of electron.

197. (*b*) Energy of the incident photons,

$$E_i = 10.6 \text{ eV}$$
$$= 10.6 \times 1.6 \times 10^{-19}$$
$$E_i = 16.96 \times 10^{-19} \text{ J}$$

Energy incident per unit area per unit time (intensity) = 2 J

$\therefore$ Number of photons incident on unit area in unit time

$$= \frac{2}{16.96 \times 10^{-19}} = 1.18 \times 10^{18}$$

Therefore, number of photons incident on given area $(1.0 \times 10^{-4} \text{ m}^2)$

$$= (1.18 \times 10^{18})(1.0 \times 10^{-4})$$
$$= 1.18 \times 10^{14}$$

But only 0.53% of incident photons emit photoelectrons.

$\therefore$ Number of photoelectrons emitted per second (n),

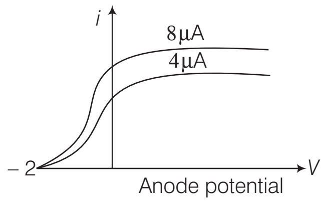
$$n = \left(\frac{0.53}{100}\right)(1.18 \times 10^{14}) = 6.25 \times 10^{11}$$

198. (*a*) $K_{\text{max}} = E_i -$ work-function $= (10.6 - 5.6) = 5.0$ eV

199. (*d*) $K_{\text{min}} = 0$, kinetic energy of photoelectrons varies from 0 $(\text{KE})_{\text{max}}$. Hence, minimum possible KE of any photoelectron is zero.

200. (*a*) Maximum kinetic energy of the photoelectrons would be

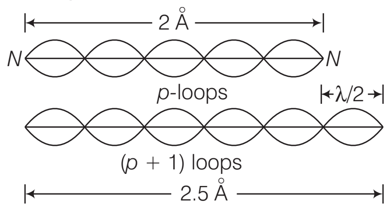
$$K_{\text{max}} = E - W = 5 - 3 = 2 \text{ eV}$$



Therefore, the stopping potential is 2 V. Saturation current depends on the intensity of light incident. Therefore, option (a) is correct.

201. (*b*) When the intensity is doubled the saturation current will also become double.

202. (*a*) From the figure, it is clear that



$$p \cdot (\lambda/2) = 2\text{Å} \quad \Rightarrow \quad (p+1) \cdot \lambda/2 = 2.5 \text{ Å}$$

$\therefore \quad \lambda/2 = (2.5 - 2.0) \text{ Å} = 0.5 \text{ Å} \quad \text{or} \quad \lambda = 1 \text{ Å}$

203. (*b*) de-Broglie wavelength is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2Km}}$$

Here, K = Kinetic energy of electron

$$\therefore \quad K = \frac{h^2}{2m\lambda^2} = \frac{(6.63 \times 10^{-34})^2}{2(9.1 \times 10^{-31})(10^{-10})^2} = 2.415 \times 10^{-17} \text{ J}$$

$$K = \left(\frac{2.415 \times 10^{-17}}{1.6 \times 10^{-19}}\right) = 150.8 \text{ eV}$$

204. (*b*) The least value of d will be, when only one loop is formed.

$$\therefore \quad d_{\text{min}} = \lambda/2 = \frac{1}{2} \quad \Rightarrow \quad d_{\text{min}} = 0.5 \text{ Å}$$

205. (*a,c*) $\frac{hc}{\lambda} - \phi = eV$

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

For plate I	Plate 2	Plate 3
$\frac{\phi_1}{hc} = 0.001$	$\frac{\phi_2}{hc} = 0.002$	$\frac{\phi_3}{hc} = 0.004$

$\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

For plate 2, threshold wavelength

$$\lambda = \frac{hc}{\phi_2} = \frac{hc}{0.002hc} = \frac{1000}{2} = 500 \text{ nm}$$

For plate 3, threshold wavelength

$$\gamma = \frac{hc}{\phi_3} = \frac{hc}{0.004hc} = \frac{1000}{4} = 250 \text{ nm}$$

Since, violet colour light will eject photoelectrons from plate 2 not from 3.

206. (*a,b,c*) $K_{\text{max}} = E - W_0$

$$T_A = 4.25 - (W_0)_A \quad \ldots\text{(i)}$$
$$T_B = (T_A - 1.5)$$
$$T_B = 4.70 - (W_0)_B \quad \ldots\text{(ii)}$$

Eqs. (i) and (ii) gives

$$(W_0)_B - (W_0)_A = 1.95 \text{ eV}$$

de-Broglie wavelength

$$\lambda = \frac{h}{2mV} \quad \Rightarrow \quad \lambda \propto \frac{1}{\sqrt{K}}$$

$$\frac{\lambda_B}{\lambda_A} = \sqrt{\frac{K_A}{K_B}} \quad \Rightarrow \quad 2 = \sqrt{\frac{T_A}{T_A - 1.5}}$$

$$\Rightarrow \quad T_A = 2 \text{ eV}$$

From Eqs. (i) and (ii),

$$W_A = 2.25 \text{ eV and } W_B = 4.20 \text{ eV}$$

207. (*c,d*) de-Broglie wavelength

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

Here, $\quad h = 6.6 \times 10^{-34}$ Js

and for electron, $m = 9 \times 10^{-31}$ kg

Now consider each option one by one

(a) $\lambda_1 = 10 \text{ nm} = 10 \times 10^{-9} \text{ m} = 10^{-8} \text{ m}$

$$\Rightarrow \quad v_1 = \frac{6.6 \times 10^{-34}}{(9 \times 10^{-31}) \times 10^{-8}} = \frac{2.2}{3} \times 10^5 \approx 10^5 \text{ ms}^{-1}$$

(b) $\lambda_2 = 10^{-1}$ nm $= 10^{-1} \times 10^{-9}$ m $= 10^{-10}$ m

$$\Rightarrow \quad v_2 = \frac{6.6 \times 10^{-34}}{(9 \times 10^{-31}) \times 10^{-10}} \approx 10^7 \text{ ms}^{-1}$$

(c) $\lambda_3 = 10^{-4}$ nm $= 10^{-4} \times 10^{-9}$ m $= 10^{-13}$ m

$$\Rightarrow \quad v_3 = \frac{6.6 \times 10^{-34}}{(9 \times 10^{-31}) \times 10^{-13}} \approx 10^{10} \text{ ms}^{-1}$$

(d) $\lambda_4 = 10^{-6}$ nm $= 10^{-6} \times 10^{-9}$ m $= 10^{-15}$ m

$$\Rightarrow \quad v_4 = \frac{6.6 \times 10^{-34}}{9 \times 10^{-31} \times 10^{-15}} \approx 10^{12} \text{ ms}^{-1}$$

Thus, options (c) and (d) are correct as v_3 and v_4 is greater than 3×10^8 ms^{-1}.

208. (*a, c*) de-Broglie wavelength, $\lambda = \frac{h}{mv}$

where, $mv = p$ (momentum)

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

Here, h is a constant.

So, $p \propto \frac{1}{\lambda} \Rightarrow \frac{p_1}{p_2} = \frac{\lambda_2}{\lambda_1}$

But $(\lambda_1 = \lambda_2) = \lambda$

Then, $\frac{p_1}{p_2} = \frac{\lambda}{\lambda} = 1 \Rightarrow p_1 = p_2$

Thus, their momenta is same.

Also, $E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{mv^2 \times m}{m} = \frac{1}{2}\frac{m^2v^2}{m} = \frac{1}{2}\frac{p^2}{m}$

Here, p is constant $E \propto \frac{1}{m}$

$\therefore \quad \frac{E_1}{E_2} = \frac{m_2}{m_1} < 1 \Rightarrow E_1 < E_2$

209. (*b, c*) Suppose, mass of electron $= m_e$, mass of photon $= m_p$,

Velocity of electron $= v_e$ and velocity of photon $= v_p$

Thus, for electron, de-Broglie wavelength

$$\lambda_e = \frac{h}{m_e v_e} = \frac{h}{m_e(c/100)} = \frac{100\,h}{m_e c} \text{ (given)} \quad \ldots\text{(i)}$$

Kinetic energy, $E_e = \frac{1}{2}m_e v_e^2$

$$\Rightarrow \quad m_e v_e = \sqrt{2E_e m_e}$$

so, $\lambda_e = \frac{h}{m_e v_e} = \frac{h}{\sqrt{2m_e E_e}}$

$$\Rightarrow \quad E_e = \frac{h^2}{2\lambda_e^2 m_e} \quad \ldots\text{(ii)}$$

For photon of wavelength λ_p, energy

$$E_p = \frac{hc}{\lambda_p} = \frac{hc}{2\lambda_e} \quad [\because \lambda_p = 2\lambda_e]$$

$$\therefore \quad \frac{E_p}{E_e} = \frac{hc}{2\lambda_e} \times \frac{2\lambda_e^2 m_e}{h^2}$$

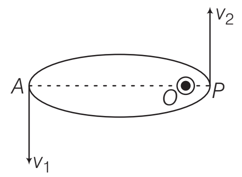
$$= \frac{\lambda_e m_e c}{h} = \frac{100h}{m_e c} \times \frac{m_e c}{h} = 100$$

So, $\frac{E_e}{E_p} = \frac{1}{100} = 10^{-2}$

For electron, $p_e = m_e v_e = m_e \times c/100$

So, $\frac{p_e}{m_e c} = \frac{1}{100} = 10^{-2}$

210. (*b, d*) The de-Broglie wavelength of the particle can be varying cyclically between two values λ_1 and λ_2, if particle is moving in an elliptical orbit with origin as its one focus. *Consider the figure given below*



Let v_1, v_2 be the speed of particle at A and B, respectively and origin is at focus O. If λ_1, λ_2 are the de-Broglie wavelengths associated with particle while moving at A and B respectively. Then,

$$\lambda_1 = \frac{h}{mv_1} \quad \text{and} \quad \lambda_2 = \frac{h}{mv_2}$$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{v_2}{v_1}$$

Since $\lambda_1 > \lambda_2$

$\therefore \quad v_2 > v_1$

By law of conservation of angular momentum, the particle moves faster when it is closer to focus.

From figure, we note that origin O is closed to P than A.

211. (*a*) Given, voltage $V = 30$ kV $= 30 \times 10^3$ V and $e = 1.6 \times 10^{-19}$ C

Using formula for energy

$$E = eV = h\nu$$

$$\nu = \frac{eV}{h} = \frac{1.6 \times 10^{-19} \times 30 \times 10^3}{6.63 \times 10^{-34}} = 7.24 \times 10^{18} \text{ Hz}$$

Maximum frequency $\nu = 7.24 \times 10^{18}$ Hz

Minimum wavelength of X-ray.

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{7.24 \times 10^{18}}$$

where, $c = 3 \times 10^8$ m/s (speed of light)

$$\lambda = 0.414 \times 10^{-10} = 0.0414 \times 10^{-9} \text{ m} = 0.0414 \text{ nm}$$

212. (*b*) Given, work function of caesium metal $\phi_0 = 2.14$ eV

Frequency of light $\nu = 6 \times 10^{14}$ Hz

Maximum kinetic energy of emitted electrons (Einstein's photoelectric equation)

$$KE_{max} = h\nu - \phi_0 = \frac{6.63\times10^{-34}\times6\times10^{14}}{1.6\times10^{-19}} - 2.14 = 0.35\,\text{eV}$$

213. (*c*) Given, cut-off voltage $V_0 = 1.5$ V

Use the formula for maximum kinetic energy

$$KE_{max} = eV_0 = 1.5\,\text{eV} = 1.5\times1.6\times10^{-19} = 2.4\times10^{-19}\ \text{J}$$

214. (*a*) Given, wavelength of monochromatic light, $\lambda = 632.8$ nm $= 632.8\times10^{-9}$ m

Power $= 9.42$ mW $= 9.42\times10^{-3}$ W

Energy of each photon, $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^8}{632.8\times10^{-9}}$

$= 3.14\times10^{-19}$ J

We know that momentum of each photon, $p = \frac{h}{\lambda}$

$$p = \frac{6.63\times10^{-34}}{632.8\times10^{-9}} = 1.05\times10^{-27}\ \text{kg-m/s}$$

215. (*a*) Given, energy per unit area per second,

$$P = 1.388\times10^3\ \text{W/m}^2$$

Let n be the number of photons incident on the earth per square metre. Wavelength of each photon $= 550$ nm $= 550\times10^{-9}$ m

Energy of each photon, $E = hc/\lambda$ (where, h is the Planck's constant)

$$= \frac{6.63\times10^{-34}\times3\times10^8}{550\times10^{-9}} = 3.616\times10^{-19}\ \text{J}$$

Number of photons incident on the earth's surface

$$n = \frac{P}{E} = \frac{1.388\times10^3}{3.616\times10^{-19}} = 3.838\times10^{21}$$

$= 3.838\times10^{21}$ photon/m^2 -s

216. (*b*) Given, power of lamp, $P = 100$ W

Wavelength of the sodium light, $\lambda = 589$ nm $= 589\times10^{-9}$ m

Planck constant $h = 6.63\times10^{-34}$ J-s

Energy of each photon

$$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^8}{589\times10^{-9}} \quad (\because c = 3\times10^8\ \text{m/s})$$

$= 3.38\times10^{-19}$ J

$$= \frac{3.38\times10^{-19}}{1.6\times10^{-19}} = 2.11\,\text{eV}$$

Let n photons are delivered per second.

$$\therefore \quad n = \frac{\text{Power}}{\text{Energy of each photon}} \quad (\text{from } P = En)$$

$$= \frac{100}{3.38\times10^{-19}} = 3\times10^{20}\ \text{photon/s}$$

$= 3\times10^{20}$ photon/s are delivered

217. (*a*) Given, threshold frequency for a metal, $\nu_0 = 3.3\times10^{14}$ Hz

Frequency of light, $\nu = 8.2\times10^{14}$ Hz

Let V_0 be the cut-off voltage.

Using the formula for kinetic energy,

$$KE = eV_0 = h\nu - h\nu_0$$

$$V_0 = \frac{h(\nu-\nu_0)}{e} = \frac{6.63\times10^{-34}(8.2\times10^{14} - 3.3\times10^{14})}{1.6\times10^{-19}}$$

$$= \frac{6.63\times10^{-34}\times10^{14}\times4.9}{1.6\times10^{-19}} = 2.03\ \text{V}$$

218. (*a*) Given, frequency of light, $\nu = 7.21\times10^{14}$ Hz

Mass of electron, $m = 9.1\times10^{-31}$ kg

Maximum speed of electrons, $v_{max} = 6\times10^5$ m/s

Let ν_0 be the threshold frequency.

Use the formula for kinetic energy

$$KE = \frac{1}{2}mv_{max}^2 = h\nu - h\nu_0$$

i.e., $\frac{1}{2}\times9.1\times10^{-31}\times6\times10^5\times6\times10^5$

$= 6.63\times10^{-34}\,(\nu-\nu_0)$

or $\nu - \nu_0 = \frac{36\times9.1\times10^{-21}}{2\times6.63\times10^{-34}} = 2.47\times10^{14}$

$\nu_0 = 7.21\times10^{14} - 2.47\times10^{14} \quad (\because \nu = 7.21\times10^{14}\ \text{Hz})$

$= 4.74\times10^{14}$ Hz

219. (*b*) Given, wavelength of light, $\lambda = 488$ nm $= 488\times10^{-9}$ m

Cut-off potential $V_0 = 0.38$ V, $e = 1.6\times10^{-19}$ C

Planck constant $h = 6.62\times10^{-34}$ J-s

Velocity of light $c = 3\times10^8$ m/s

Let ϕ_0 be the work function.

Use the formula for kinetic energy,

$$KE = eV_0 = \frac{hc}{\lambda} - \phi_0$$

$$1.6\times10^{-19}\times0.38 = \frac{6.63\times10^{-34}\times3\times10^8}{488\times10^{-9}} - \phi_0$$

or $6.08\times10^{-20} = 40.75\times10^{-20} - \phi_0$

or $\phi = (40.75 - 6.08)\times10^{-20} = 34.67\times10^{-20}$ J

or $= \frac{34.67\times10^{-20}}{1.6\times10^{-19}}\ \text{eV} = 2.17\,\text{eV}$

220. (*d*) Velocity gained by particle

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

$$\therefore \quad \lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{m\sqrt{2gH}} \Rightarrow \lambda \propto H^{-1/2}$$

221. (*b*) Energy of a photon,

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{1240\ \text{eV-nm}}{1\ \text{MeV}} = 1.2\times10^{-3}\ \text{nm}$$

222. (*d*) When an electron with energy E_0 strikes another electron, it is one of the possibility that it replaces one of e^- of metal by transferring complete energy. As there is no change in total number of electrons, no work has to be done as no attraction is produced by metal atoms.

$\therefore$ Electrons will be emitted with maximum energy $= E_0$

223. (c) In Davisson-Germer experiment, the de-Broglie wavelength associated with electron is

$$\lambda = \frac{12.27}{\sqrt{V}} \text{ Å} \quad \text{...(i)}$$

where, V is the applied voltage.

If there is a maxima of the diffracted electrons at an angle θ, then

$$2d \sin\theta = \lambda \quad \text{...(ii)}$$

i.e., V will increase with the decrease in the λ.
So, with the decrease in λ, θ will also decrease.

Thus, when the voltage applied to A is increased. The diffracted beam will have the maximum at a value of θ that will be less than the earlier value.

224. (b) We know that the relation between λ and K is given by

$$\lambda = \frac{h}{\sqrt{2mK}}$$

Here, for the given value of energy K, $\frac{h}{\sqrt{2K}}$ is a constant.

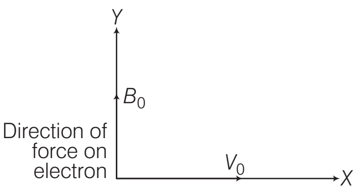
Thus, $\lambda \propto \frac{1}{\sqrt{m}}$

$\therefore$ $\lambda_p : \lambda_n : \lambda_e : \lambda_\alpha$

$\Rightarrow$ $= \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{m_n}} : \frac{1}{\sqrt{m_e}} : \frac{1}{\sqrt{m_\alpha}}$

Since, $m_p = m_n$, hence $\lambda_p = \lambda_n$
As, $m_\alpha > m_p$, therefore $\lambda_\alpha < \lambda_p$
As, $m_e < m_n$, therefore $\lambda_e > \lambda_n$
Hence, $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$

225. (a) Given, $\mathbf{v} = v_0 \hat{\mathbf{i}}$, $\mathbf{B} = B_0 \hat{\mathbf{j}}$



Force on charged particle moving in external magnetic field $= q(\mathbf{v} \times \mathbf{B})$

or $\mathbf{F} = q(v_0 \hat{\mathbf{i}} \times B_0 \hat{\mathbf{j}})$

or $\mathbf{F} = q B_0 v_0 \hat{\mathbf{k}}$

$\because q$ is negative, force is in direction of $-\hat{\mathbf{k}}$. (into the plane of paper) For force perpendicular to velocity, the particle executes uniform circular motion. Since, magnitude of velocity v_0 is constant.

de-Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{mV_0} =$ constant

226. (a) Initial de-Broglie wavelength of electron,

$$\lambda_0 = \frac{h}{mv_0} \quad \text{...(i)}$$

Force on electron in electric field,

$$\mathbf{F} = -e\mathbf{E} = -e[-E_0 \hat{\mathbf{i}}] = eE_0 \hat{\mathbf{i}}$$

Acceleration of electron, $\mathbf{a} = \frac{\mathbf{F}}{m} = \frac{eE_0 \hat{\mathbf{i}}}{m}$

Velocity of electron after time t,

$$v = v_0 \hat{\mathbf{i}} + \left(\frac{eE_0 \hat{\mathbf{i}}}{m}\right) t \quad \text{(using, } v = u + at)$$

$$= \left(v_0 + \frac{eE_0}{m} t\right) \hat{\mathbf{i}} = v_0 \left(1 + \frac{eE_0}{mv_0} t\right) \hat{\mathbf{i}}$$

de-Broglie wavelength associated with electron at time t is

$$\lambda = \frac{h}{mv} = \frac{h}{m\left[v_0 \left(1 + \frac{eE_0}{mv_0} t\right)\right]}$$

$$= \frac{\lambda_0}{\left[1 + \frac{eE_0}{mv_0} t\right]} \quad \left(\because \frac{h}{mv_0} = \lambda_0\right)$$

227. (c) Initial de-Broglie wavelength of electron,

$$\lambda_0 = \frac{h}{mv_0}$$

Force on electron in electric field,

$$\mathbf{F} = -eE = -eE_0 \hat{\mathbf{j}}$$

Acceleration of electron,

$$\mathbf{a} = \frac{\mathbf{F}}{m} = -\frac{eE_0}{m} \hat{\mathbf{j}}$$

It is acting along negative Y-axis.

The initial velocity of electron along X-axis $\mathbf{v}_{x0} = v_0 \hat{\mathbf{i}}$.

Initial velocity of electron along Y-axis, $\mathbf{v}_{y0} = 0$.

Velocity of electron after time t along X-axis, $\mathbf{v}_x = v_0 \hat{\mathbf{i}}$

(since, there is no acceleration of electron along X-axis)

Velocity of electron after time t along Y-axis,

$$\mathbf{v}_y = 0 + \left(-\frac{eE_0}{m} \hat{\mathbf{j}}\right) t = -\frac{eE_0}{m} t \hat{\mathbf{j}}$$

Magnitude of velocity of electron after time t is

$$|\mathbf{v}| = \sqrt{v_x^2 + v_y^2}$$

$$= \sqrt{v_0^2 + \left(\frac{-eE_0}{m} t\right)^2} = v_0 \sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}$$

de-Broglie wavelength,

$$\lambda = \frac{h}{mv} = \frac{h}{mv_0 \sqrt{\frac{1 + e^2 E_0^2 t^2}{(m^2 v_0^2)}}} \quad \left(\text{here, } \lambda_0 = \frac{h}{mv_0}\right)$$

$$= \frac{\lambda_0}{\left(1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}\right)^{1/2}}$$