Physics Board Questions

Class: 12

Dual Nature of Light

Important Formula

1. $\phi_0 = h\nu_0$
2. $E = h\nu = \frac{hc}{\lambda}$
3. $K_{max} = \frac{1}{2}mv_{max}^2 = eV_0$
4. $K_{max} = h\nu - \phi_0 = h(\nu - \nu_0) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$
5. $\lambda = \frac{h}{p} = \frac{h}{mv}$
6. $\lambda = \frac{h}{\sqrt{2mqV}} = \frac{h}{\sqrt{2mK}}$

where

$\phi_0 - work\ function$

$h - planck's\ const.$

$v - velocity$

$\nu - frequency$

$V - potential$

$K - Kinetic\ energy$

Delhi 2016

1. Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1, m_2 ($m_1 > m_2$).
   Which one of the two represents a particle of smaller mass and why?
2. Write three characteristic features in photoelectric effect which can't be explained on the basis of wave theory of light but can be explained only using Einstein's equation.

All India 2016

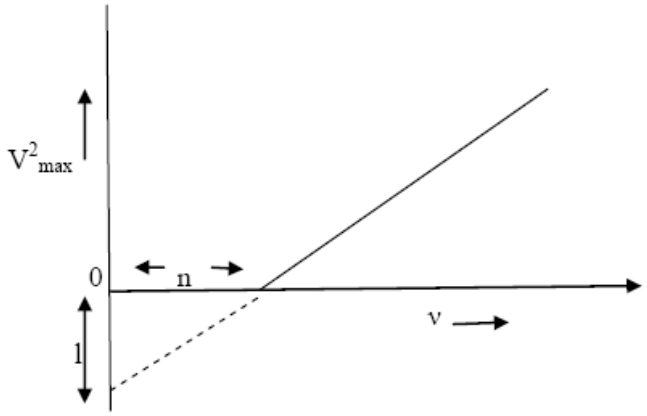
1. A proton and an α- particle are accelerated through the same potential difference. Which one of the two has (i) greater de-Broglie wavelength, and (ii) less kinetic energy? Justify your answer. [(i)$\lambda_p > \lambda_\alpha$ (ii) proton]
2. State two important properties of photon which are used to write Einstein's photoelectric equation.
   Define (i) stopping potential and (ii) threshold frequency, using Einstein's equation and drawing necessary plot between relevant quantities.

Delhi 2015

1. A proton and an α- particle have the same greater de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speed. [(i) V_p: V_α= 8:1 (ii) v_p: v_α = 4:1]
2. Write Einstein's photoelectric equation and mention which important features in photoelectric effect can be explained with the help of this equation.
   The maximum kinetic energy of the photoelectrons gets doubled when the wavelength of incident light on the surface changes from λ_1 to λ_2. Derive the expressions for the threshold wavelength λ_0 and work function for the metal surface. $\phi_0 = \frac{hc(2\lambda_2 - \lambda_1)}{\lambda_1\lambda_2}$

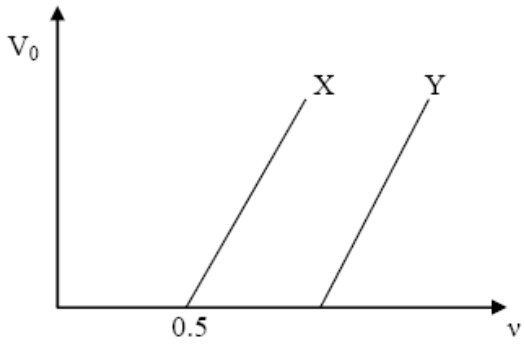
All India 2015

1. Define the terms 'stopping potential' and threshold frequency' in relation to photoelectric effect. How does one determine these physical quantities using Einstein's equation?
2. (a)Describe briefly three experimentally observed features in the phenomenon of photoelectric effect.
   (b) Discuss briefly how wave theory of light cannot explain these features.
3. (a) Write the important properties of photons which are used to establish Einstein's photoelectric equation.
   (b) Use this equation to explain the concept of (i)threshold frequency and (ii) stopping potential
4. Define the term 'intensity of radiation' in photon picture of light.
   Ultraviolet light of wavelength 2270 A^0 from 100W mercury source irradiates a photo cell made of a given metal. If the stopping potential is -1.3V, estimate the work function of the metal. How would the photocell respond to a high intensity (~10^5 Wm^{-2}) red light of wavelength 6300 A^0 produced by a laser?
   [1.973eV, no emission]
5. Set up Einstein's photoelectric equation using the photon picture of electromagnetic radiation. Explain briefly how this equation accounts for all the observations in the photoelectric effect.
6. (a) Give brief description of basic elementary process involved in photoelectric emission of Einstein's picture.
   (b) When a photosensitive material is irradiated with the light of frequency ν, the maximum speed of electrons is given by V_{max} . A plot of V^2_{max} is found to vary with frequency ν as shown in the figure.



   Use Einstein's photoelectric equation to find the expressions for
   (i) Planck's constant and
   (ii) work function of the given material, in terms of the parameters l, n and mass m of the electron.
   [(i) h = ml/2n (ii) ml/2)]

7. (a) Monochromatic light of frequency 6×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3}W. How many photons per second on an average are emitted by the source?
   (b) Fig. shows a variation of stopping potential V_0 vs. frequency ν of incident radiation for two metals X & Y. Which metal will emit electrons of larger kinetic energy for same wavelength of incident radiation? Explain.



[(a) 5×10^{15} photons per sec. (b) X]

8. Light of intensity 'I' and frequency 'ν' is incident on a photosensitive surface and causes photoelectric emission. What will be the effect on anode current when (i) the intensity of light is gradually increased, (ii) the frequency of incident radiation is increased, and (iii) the anode potential is increased? In each case, all other factors remain the same. Explain, giving justification in each case.
9. The equivalent wavelength of a moving electron has the same value as that of a photon of energy 6×10^{-17}J. Calculate the momentum of the electron. [2×10^{-25} kgm/s]
10 (a) Define the term 'intensity of radiation' in terms of photon picture of light.
   (b) Two monochromatic beams, one red and the other blue, have the same intensity. In which case (i) the number of photons per unit area per second is larger, (ii) the maximum kinetic energy of the photoelectrons is more? Justify your answer. [(i) Red (ii) Blue]

Foreign 2015

1. The kinetic energy of the electron orbiting in the first excited state of hydrogen atom is 3.4 eV. Determine the de Broglie wavelength associated with it. [0.67 nm]
2. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons:
   (a) Do the emitted photoelectrons have the same kinetic energy?
   (b) Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation?
   (c) On what factors does the number of emitted photoelectrons depend?

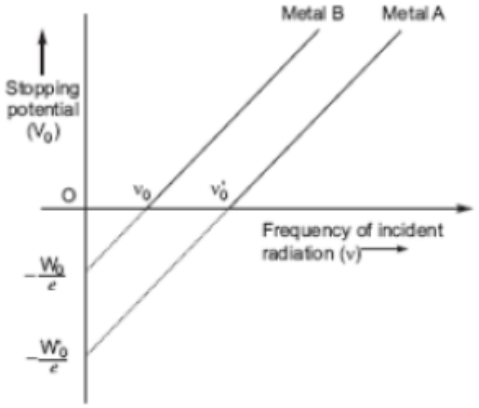
Delhi 2014

1. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has
   (*i*) greater value of de-Broglie wavelength associated with it, and (*ii*) less momentum?
   Give reasons to justify your answer. [(i)$\lambda_p > \lambda_d$ (ii) proton]
2. (*i*) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3} W. Estimate the number of photons emitted per second on an average by the source.
   (*ii*) Draw a plot showing the variation of photoelectric current versus the intensity of incident radiation on a photosensitive surface. [5×10^{15}]
3. A proton and an alpha particle are accelerated through the same potential. Which one of the two has
   (*i*) greater value of de-Broglie wavelength associated with it and (*ii*) less kinetic energy?
   Give reasons to justify your answer. [(i)$\lambda_p > \lambda\alpha$ (ii) proton]

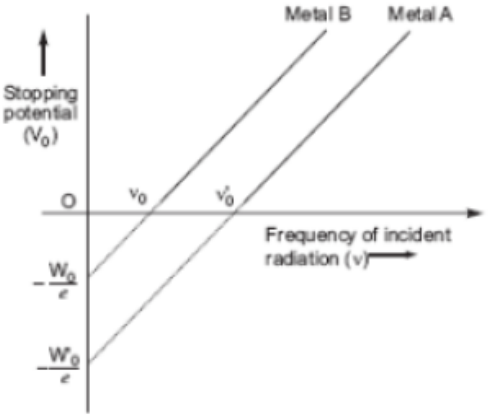
4. A deuteron and an alpha particle are accelerated with the same accelerating potential. Which one of the 2 has
(*a*) greater value of de-Broglie wavelength, associated with it and
(*b*) less kinetic energy? Explain. [(i)$\lambda_d > \lambda_a$ (ii) deuteron]

All India 2014

1. Define intensity of radiation on the basis of photon picture of light. Write its SI unit. [W/m^2 or $J/s\text{-}m^2$]
2. The graph shows the variation of stopping potential with frequency of incident radiation for 2 photosensitive metals A and B. Which one of the two has higher value of work-function? Justify your answer. [A]



3 The graph shows variation of stopping potential V_0 versus frequency of incident radiation ν for 2 photosensitive metals A and B. Which of the two metals has higher threshold frequency and why? [A]

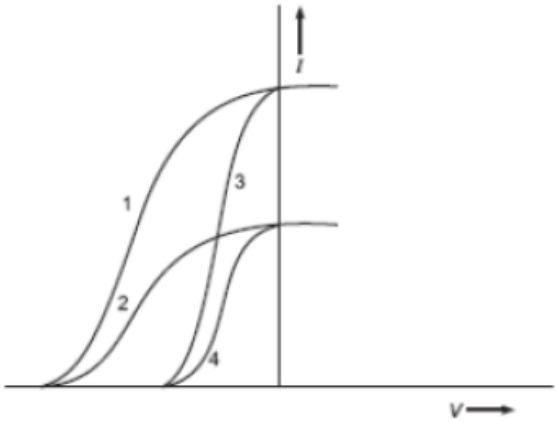


Foreign 2014

1. In photoelectric effect, why should the photoelectric current increase as the intensity of monochromatic radiation incident on a photosensitive surface is increased? Explain.
2. (*a*) Describe briefly how Davisson – Germer experiment demonstrated the wave nature of electrons.
(*b*) An electron is accelerated from rest through a potential V. Obtain the expression for the de-Broglie wavelength associated with it. [$\lambda = h/\sqrt{2meV}$]
3. Plot a graph showing variation of photoelectric current with collector plate potential at a given frequency and intensity of incident radiation. What does the intercept of the graph with potential axis signify? [stopping potential]
4. Plot a graph showing the variation of photoelectric current with collector plate potential at a given frequency but for two different intensities I_1 and I_2, where $I_2 > I_1$.

Delhi 2013

1. The given graph shows the variation of photo-electric current (I) versus applied voltage (V) for two different photosensitive materials and for two different intensities of the incident radiation. Identify the pairs of curves that correspond to different materials but same intensity radiation. [(1, 3) & (2, 4)]



2. (a) Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.
   (b) Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

All India 2013

1. Write the expression for the de Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V. [$\lambda = h/\sqrt{2mqV}$]
2. Write Einstein's photoelectric equation and point out any two characteristic properties of photons on which this equation is based.
   Briefly explain the three observed features which can be explained by this equation.

Foreign 2013

1. Ultraviolet light of wavelength 2271 A° from 100 W mercury source irradiates a photocell made of molybdenum metal. If the stopping potential is –1.3 V, estimate the work function of the metal. How would the photocell respond when the source is replaced by another source of high intensity (~10^5 Wm^{-2}) red light of wavelength 6328 A°. Justify your answer. [4.2eV]
2. An electron and a proton, each have de Broglie wavelength of 1.00 nm.
   (a) Find the ratio of their momenta.
   (b) Compare the kinetic energy of the proton with that of the electron. [(a) 1:1 (b) $K_p : K_e = 5.4 \times 10^{-4}$]

Delhi 2012

1. State de-Broglie hypothesis.
2. Write Einstein's photoelectric equation. State clearly how this equation is obtained using the photon picture of electromagnetic radiation.
   Write the three salient features observed in photoelectric effect which can be explained using this equation.

All India 2012

1. A proton & an electron have same kinetic energy. Which has greater de-Broglie wavelength & why? [$\lambda_e > \lambda_p$]
2. Define the terms (*i*) 'cut-off voltage' and (*ii*) 'threshold frequency' in relation to the phenomenon of photoelectric effect.
   Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of a suitable plot/graph.
3. A proton & an electron have same velocity. Which one has greater de-Broglie wavelength and why? [$\lambda_p < \lambda_e$]

Foreign 2012

1. Show on a graph the variation of the de Broglie wavelength (λ) associated with an electron, with the square root of accelerating potential (V).
2. Write two characteristic features observed in photoelectric effect which support the photon picture of electromagnetic radiation.
   Draw a graph between the frequency of incident radiation (v) and the maximum kinetic energy of the electrons emitted from the surface of a photosensitive material. State clearly how this graph can be used to determine (*i*) Planck's constant and (*ii*) work function of the material.
3. Show on a graph variation of the de-Broglie wavelength (λ) associated with the electron versus $1/\sqrt{V}$, where V is the accelerating potential for the electron.
4. Write the relation between de-Broglie wavelength (λ) associated with the electron & its kinetic energy E.
   [$\lambda = h/\sqrt{2mE}$]

Delhi 2011

1. Show graphically, the variation of the de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest.
2. An electron and a photon each have a wavelength 1.00 nm. Find
   (*i*) their momenta,
   (*ii*) the energy of the photon and
   (*iii*) the kinetic energy of electron [(i) 6.63×10^{-25} kgms^{-1} (ii)1.24 keV (iii) 1.51eV]
3. An electron and a photon each have a wave length of 1.50 nm. Find
   (*i*) their momenta,
   (*ii*) the energy of the photon and
   (*iii*) kinetic energy of the electron. [(i) 4.42×10^{-25} kgms^{-1} (ii)828.7eV (iii) 0.67eV]
4. An electron and a photon each have a wavelength of 2 nm. Find
   (*i*) their momenta
   (*ii*) the energy of the photon
   (*iii*) the kinetic energy of the electron. [(i) 3.32×10^{-25} kgms^{-1} (ii)0.62 keV (iii) 0.38eV]

All India2011

1. Define the term 'stopping potential' in relation to photoelectric effect.
2. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_1 > \nu_2$, of incident radiation having the same intensity. In which case will the stopping potential be higher? Justify your answer. [ν_1]

Foreign 2011

1. Define the term 'threshold frequency' in relations to photoelectric effects.
2. Show the variation of photocurrent with collector plate potential for different frequencies but same intensity of incident radiation.
3. Show the variation of photocurrent with collector plate potential for different intensity but same frequency of incident radiation.
4. Light of wavelength 2000 $\AA$ falls on a metal surface of work functions 4.2 eV. What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?
   (*i*) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?
   (*ii*) If the same light falls on another surface of work functions 6.5 eV, what will be the energy of emitted electrons? [K = 2eV]

Delhi 2010

1. An electron is accelerated through a potential difference of 100 V. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond? [$\lambda = 1.227A^0$,X- ray]
2. Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$). On what factors does the (*i*) slope and (*ii*) intercept of the lines depend? [(i) h and e (ii) work function]
3. An electron is accelerated through a potential difference of 144 volts. What is the de-Broglie wavelength associated with it? To which part of the e-m spectrum does this wavelength correspond? [$1A^0$, X -ray]
4. An electron is accelerated through a potential diff. of 64 volts. What is the de-Broglie wavelength associated with it? To which part of the e-m spectrum does this value of wavelength correspond? [$1.53A^0$, X-ray]

All India 2010

1. An α-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de-Broglie wavelengths. [$\lambda_\alpha : \lambda_p = 1:2\sqrt{2}$]
2. Write Einstein's photoelectric equation. State clearly the three salient features observed in photoelectric effect, which can be explained on the basis of the above equation.

Foreign 2010

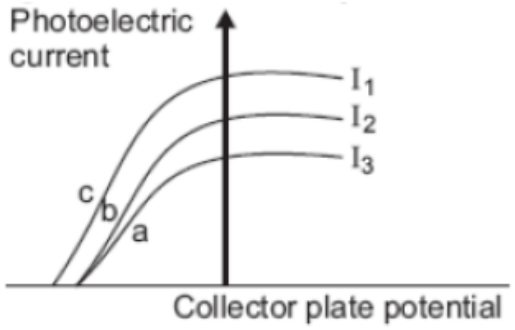
1. Name an experiment which shows wave nature of electrons. Which phenomenon was observed in this experiment using an electron beam? [Davisson-Germer experiment, diffraction]
2. Define the terms 'threshold frequency' and 'stopping potential' in the study of photoelectric emission. Explain briefly the reasons why wave theory of light is not able to explain the observed features in photoelectric effect.

Delhi 2009

1. A proton and an alpha particle are accelerated through the same potential. Which one of the two has
   (i) greater value of de-Broglie wavelength associated with it, and
   (ii) less kinetic energy? Justify your answers. . [(i) $\lambda_p > \lambda_\alpha$ (ii)proton]

2. An electron and a proton are accelerated through the same potential. Which one and the two has
(i) greater value of de-Broglie wavelength associated with it and
(ii) less momentum? Justify your answer. [(i) $\lambda_e > \lambda_p$ (ii)electron]

3. The figure shows a plot of three curves *a, b, c* showing the variation of photocurrent vs. collector plate potential for three different intensities I_1 , I_2 and I_3 having frequencies ν_1 , ν_2 and ν_3 respectively incident on a photosensitive surface.
Point out the two curves for which the incident radiations have same frequency but different intensities. [a, b]

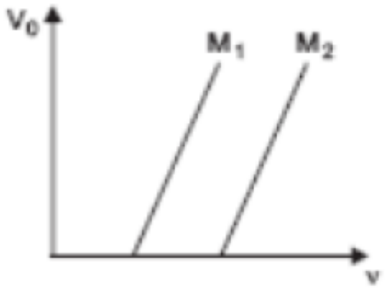


All India 2009

1. The stopping potential in an experiment on photoelectric effect is 1.5 V. What is the maximum kinetic energy of the photoelectrons emitted? [2. 4 x 10^{-19} J]
2. The maximum kinetic energy of a photoelectron is 3 eV. What is its stopping potential? [3V]
3. The stopping potential in an experiment on photoelectric effect is 2 V. What is the maximum kinetic energy of the photoelectrons emitted? [3.2 x 10^{-19} J]

Foreign 2009

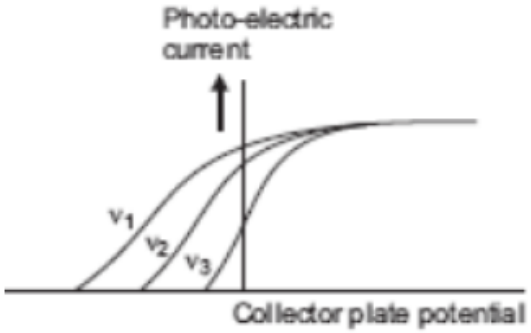
1. Derive an expression for the de-Broglie wavelength associated with an electron accelerated through a potential V. Draw a schematic diagram of a localised-wave describing the wave nature of the moving electron.
2. Fig. shows variation of stopping potential (V_0) with frequency (ν) for two photosensitive materials M_1 & M_2 .



(i) Why is the slope same for both lines?
(ii) For which material will the emitted electrons have greater kinetic energy for the incident radiations of the same frequency ? Justify your answer. [M_1]

3. (a) Draw a graph showing variation of photo-electric current (*I*) with anode potential (*V*) for different intensities of incident radiation. Name the characteristic of the incident radiation that is kept constant in this experiment.
(b) If the potential difference used to accelerate electrons is doubled, by what factor does the de-Broglie wavelength associated with the electrons change? [(a)frequency (b) decreases to $1/\sqrt{2}$ times]

4. The graph below shows variation of photo-electric current with collector plate potential for different frequencies of incident radiations.



(i) Which physical parameter is kept constant for the three curves?

(ii) Which frequency (ν_1, ν_2 or ν_3) is the highest? [(i) Intensity of incident radiations (ii) ν_1]

Delhi 2008

1. An electron and alpha particle have the same de Broglie wavelength associated with them. How are their kinetic energies related to each other? [$E_a : E_e = m_e : m_a$]
2. An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photo-electrons emitted from this surface have the de-Broglie wavelength λ_1, prove that $\lambda = (2mc/h)\ \lambda_1^2$
3. An electron and alpha particle have the same kinetic energy. How are the de-Broglie wavelengths associated with them related? [$\lambda_e = 86.5\ \lambda_a$]
4. An electron and a proton have the same de Broglie wavelength associated with them. How are their kinetic energy related to each other? [$K_e = 1840\ K_p$]

All India 2008

1. How does the stopping potential applied to a photocell change, if the distance between the light source and the cathode of the cell is doubled?
2. What is the stopping potential of a photocell, in which electrons with a maximum kinetic energy of 6 eV are emitted ? [6V(negative)]
3. What is the stopping potential applied to a photocell, if the max. Kinetic energy of electrons emitted is 5 eV? [5V(negative)]