modern physics: rest of important questions

1 Mark Questions

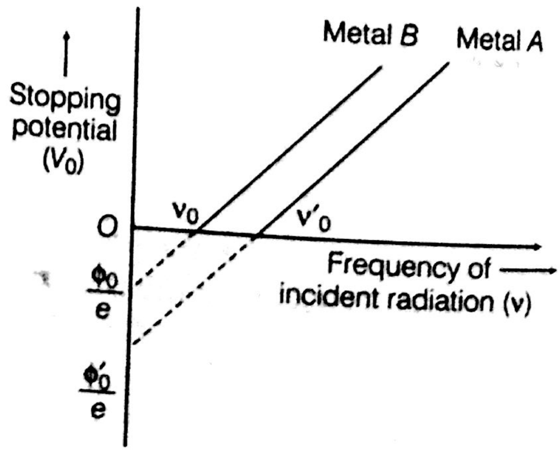
1. Define the term threshold frequency, in the context of photoelectric emission.

2. Define the term intensity in photon picture of electromagnetic radiation.

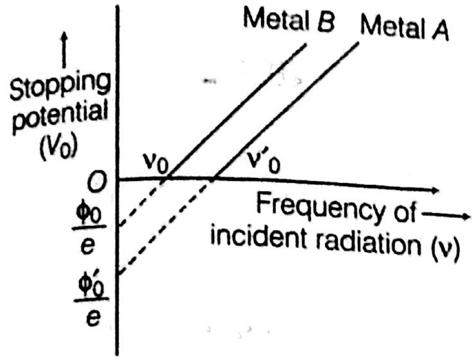
3. Draw graphs showing variation of photoelectric current with applied voltage for two incident radiations of equal frequency and different intensities. Mark the graph for the radiation of higher intensity

4. Define intensity of radiation on the basis of photon picture of light. Write its SI unit.

5. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals *A* and *B*. Which one of the two has higher value of work function? Justify your answer.

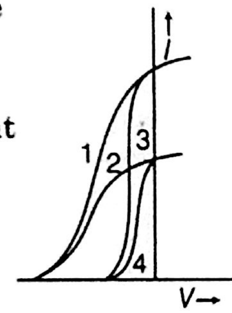


6. The graph shows variation of stopping potential V_0 *versus* frequency of incident radiation ν for two photosensitive metals *A* and *B*. Which one of the two metals has higher threshold frequency and why?



7. In photoelectric effect, why should the photoelectric current increase as the intensity of monochromatic radiation incident on a photosensitive surface is increased? Explain.

8. The given graph shows the variation of photoelectric current (*I*) *versus* applied voltage (*V*) for two different photosensitive materials and for two different intensities of the incident radiations. Identify the pairs of curves that corresponds to different materials but same intensity of incident radiation.



9. Show on a plot the nature of variation of photoelectric current with the intensity of radiation incident on a photosensitive surface.

10. Why is photoelectric emission not possible at all frequencies?

11. For a given photosensitive material and with a source of constant frequency of incident radiation, how does the photocurrent vary with the intensity of incident light?

12. Define the term stopping potential in relation to photoelectric effect.

13. Show the variation of photoelectric current with collector plate potential for different frequencies but same intensity of incident radiation.

14. Show the variation of photoelectric current with collector plate potential for different intensities but same frequency of incident radiation.

2 Marks Questions

15. Why is wave theory of electromagnetic radiation not able to explain photoelectric effect ? How does photon picture resolve this problem?

16. Explain with the help of Einstein's photoelectric equation any two observed features in photoelectric effect with cannot be explained by wave theory.

17. (a) Define the terms (i) threshold frequency and (ii) stopping potential in photoelectric effect.
    (b) Plot a graph of photocurrent *versus* anode potential for a radiation of frequency ν and intensities I_1 and $I_2 (I_1 < I_2)$.

18. If light of wavelength 412.5 nm is incident on each of the metals given below, which ones will show photoelectric emission and why?

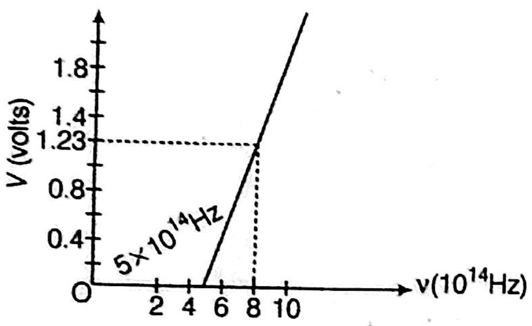
Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

19. Find the frequency of light which ejects electrons from a metal surface, fully stopped by a retarding potential of 3.3 V. If photoelectric emission begins in this metal at a frequency of 8×10^{14} Hz, calculate the work function (in eV) for this metal.

20. Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-3} W. Calculate the (i) energy of a photon in the light beam and (ii) number of photons emitted on an average by the source.

21. In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

22. Using the graph shown in the figure for stopping potential *versus* the incident frequency of photons, calculate Planck's constant.



23. (i) Monochromatic light of frequency 6.0×10^{14} Hz is produced by a laser. The power emitted is 2.0×10^{-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 given photosensitive surface

Or (i) Monochromatic light of frequency 5.0×10^{14} Hz is produced by laser. The power emitted is 3.0×10^{-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 given photosensitive surface.

24. Write three basic properties of photons which are used to obtain Einstein's photoelectric equation. Use this equation to draw a plot of maximum kinetic energy of the electrons emitted *versus* frequency of incident radiation.

25. (i) Define the term stopping potential.

(ii) Plot a graph showing the variation of photoelectric current as a function of anode potential for two light beams of same intensity but of different frequencies ν_1 and ν_2 $(\nu_2 > \nu_1)$.

26. (i) Define the term threshold frequency as used in photoelectric effect.

(ii) Plot a graph showing the variation of photoelectric current as a function of anode potential for two light beams having the same frequency $h\nu$ different intensities I_1 and $I_2 (I_1 > I_2)$.

27. Two monochromatic radiations of frequencies ν_1 and $\nu_2 (\nu_1 > \nu_2)$ and having the same intensity are in turn, incident on a photosensitive surface to cause photoelectric emission.

Explain giving reason in which case (i) more number of electrons will be emitted and (ii) maximum kinetic energy of the emitted photoelectrons will be more.

28. Two monochromatic radiations, blue and violet of the same intensity are incident on a photosensitive surface and cause photoelectric emission. Would (i) the number of electrons emitted per second and (ii) the maximum kinetic energy of the electrons be equal in the two cases? Justify your answer.

29. Write Einstein's photoelectric equation. State clearly the three salient features observed in photoelectric effect which can be explained on the basis of above equation.

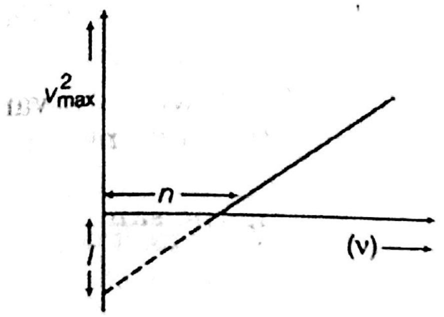
30. Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work-functions ϕ_1 and ϕ_2 ($\phi_1 > \phi_2$). On what factors does the

(i) slope and

(ii) intercept of the lines depend?

3 Marks Questions

31. State Einstein's photoelectric explaining the symbols used.



Light of frequency ν incident is on a photosensitive surface. A graph of the square of the maximum speed of the electrons (v^2_{max}) *versus* ν is obtained as shown in the figure. Using Einstein's photoelectric equation, obtain expressions for (i) Planck's constant and (ii) work function of the given photosensitive material in terms of parameters l, n and mass of the electron m.

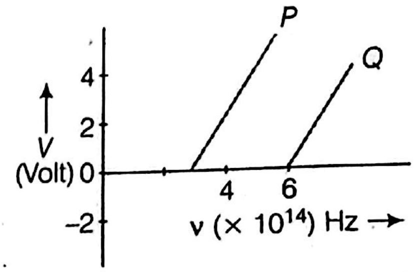
32. (i) How does one explain the emission of electrons from a photosensitive surface with the help of Einstein's photoelectric equation?

(ii) The work function of the following metals is given as Na = 2.75 eV, K = 2.3 eV, Mo = 4.17 eV and Ni = 5.15 eV. Which of these metals will not cause photoelectric emission for radiation of wavelength 3300 Å from a laser source placed 1 m away from these metals? What happens if the laser source is brought nearer and placed 50 cm away?

33. (i) State two important features of Einstein's photoelectric equation.

(ii) Radiation of frequency 10^{15} Hz is incident on two photosensitive surfaces P and Q. There is no photoemission from surface P. Photoemission occurs from surface Q but photoelectrons have zero kinetic energy. Explain these observations and find the value of work function for surface Q.

34. In the study of a photoelectric effect, the graph between the stopping potential V and frequency ν of the incident radiation on two different metals P and Q is shown below.



(i) Which one of the two metals has higher threshold frequency?

(ii) Determine the work function of the metal which has greater value.

(iii) Find the maximum kinetic energy of electron emitted by light of frequency 8×10^{14} Hz for this metal.

35. Sketch the graphs showing variation of stopping potential with frequency of incident radiations for two photosensitive materials A and B having threshold frequencies $\nu_A > \nu_B$.

(i) In which case, is the stopping potential more and why?

(ii) Does the slope of the graph depend on the nature of the material used? Explain.

36. Plot a graph showing the variation of photoelectric current with intensity of light. The work function for the following metals is given. Na : 2.75 eV and Mo : 4.175 eV. Which of these will not give photoelectron emission from a radiation of wavelength 3300 Å from a laser beam?

What happens if the source of laser beam is brought closer?

37. Define the term "cut-off frequency" in photoelectric emission. The threshold frequency of a metal is f. When the light of frequency $2f$ is incident on the metal plate, the maximum velocity of photoelectron is v_1. When the frequency of the incident radiation is increased to $5f$, the maximum velocity of photoelectrons is v_2. Find the ratio $v_1 : v_2$.

38. Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.

39. (i) Write the important properties of photons which are used to establish Einstein's photoelectric equation.

(ii) Use this equation to explain the concept of (a) threshold frequency and (b) stopping potential.

40. (i) Describe briefly three experimentally observed features in the phenomenon of photoelectric effect.

(ii) Discuss briefly how wave theory of light cannot explain these features.

41. 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 light incident 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.

42. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons.

(i) Do the emitted photoelectrons have the same kinetic energy?

(ii) Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation?

(iii) On what factors does the number of emitted photoelectrons depend?

43. Write Einstein's photoelectric equation and point out any two characteristic properties of photons on which this equation is based. Briefly explain three observed features which can be explained by this equation. All

44. (i) State three important properties of photons which describe the particle picture of electromagnetic radiation.

(ii) Use Einstein's photoelectric equation to define the terms :

(a) Stopping potential and

(b) Threshold frequency.

45. (i) Why photoelectric effect cannot be explained on the basis of wave nature of light? Give reasons.

(ii) Write the basic features of photon picture of electromagnetic radiation on which Einstein's photoelectric equation is based.

46. Draw a graph between the frequency of incident radiation (ν) 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.

47. Write two characteristic features observed in photoelectric effect which supports the photon pictures of electromagnetic radiation. Draw a graph between the frequency of incident radiation (ν) 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 the

(i) Planck constant and

(ii) work function of the material?

48. 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.

49. Define the terms cut-off voltage and 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.

50. Light of wavelength 2000 Å falls on a metal surface of work function 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 function 6.5 eV, what will be the energy of emitted electrons?

51. Draw a plot showing the variation of photoelectric current with collector plate potential for two different frequencies, $\nu_2 > \nu_1$ of incident radiation having the same intensity. In which case will the stopping potential be higher? Justify your answer.

52. (i) Ultraviolet light of wavelength 2271 Å from a 100 W mercury source is incident on a photocell made of molybdenum metal. If the stopping potential is 1.3 V, estimate the work function of the metal.

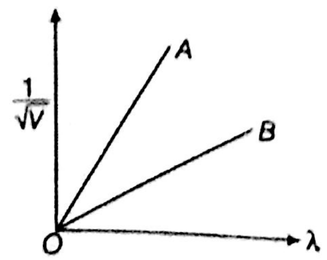
(ii) How would the photocell respond to high intensity (10^5 W/m^2) red light of wavelength 6328 Å produced by a He-Ne laser?

53. 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?

1 Mark Questions

1. Draw a plot showing the variation of de-Broglie wavelength of electron as a function of its KE.
2. Figure shows a plot of $1/\sqrt{V}$, where V is the accelerating potential *versus* the de-Broglie wavelength λ in the case of two

particles having same charge q but different masses m_1 and m_2. Which line (A or B) represents a particle of large mass?



3. 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.

4. State de-Broglie hypothesis.

5. A proton and an electron have same kinetic energy. Which one has greater de-Broglie wavelength and why?

6. A particle is moving three times as fast as an electron. The ratio of the de Broglie wavelength of the particle to that of the electron is 8.3×10^{-4}. Calculate the particle's mass and identify the particle. All

7. Write the relationship of de-Broglie wavelength λ associated with a particle of mass m in terms of its kinetic energy E.

8. Show graphically, the variation of de-Broglie wavelength (λ) with the potential (V) through which an electron is accelerated from rest.

9. Name an experiment which shows wave nature of the electron. Which phenomenon was observed in this experiment using an electron beam?

2 Marks Questions

10. A photon and a proton have the same de-Broglie wavelength λ. Prove that the energy of the photon is $(2m\lambda c/h)$ times the kinetic energy of the proton.

11. The wavelength of light from the spectral emission line of sodium is 590 nm. Find the kinetic energy at which the electron would have the same de-Broglie wavelength.

12. Plot a graph showing variation of de-Broglie wavelength (λ) associated with a charged particle of mass m *versus* $\frac{1}{\sqrt{V}}$, where V is the potential difference through which the particle is accelerated. How does this graph give us the information regarding the magnitude of the charge of the particle?

13. (a) Plot a graph showing variation of de-Broglie wavelength (λ) associated with a charged particle of mass m *versus* $\sqrt{V}$, where V is the accelerating potential.
(b) An electron, a proton and an alpha particle have the same kinetic energy. Which one has the shortest wavelength?

14. An α-particle and a proton are accelerated through the same potential difference. Find the ratio of their de-Broglie wavelengths.

15. The wavelength λ of a photon and the de-Broglie wavelength of an electron have the same value. Show that energy of a photon is $(2\lambda\ mc/h)$ times the kinetic energy of electron, where m, c and h have their usual meaning.

16. A proton and an α-particle have the same de-Broglie wavelength. Determine the ratio of (i) their accelerating potentials (ii) their speeds.

17. 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.

18. A deuteron and an α-particle are accelerated with the same accelerating potential. Which one of the two has

(i) greater value of de-Broglie wavelength, associated with it and

(ii) less kinetic energy? Explain.

19. X-rays fall on a photosensitive surface to cause photoelectric emission. Assuming that the work-function of the surface can be neglected, find the relation between the de-Broglie wavelength (λ) of the electrons emitted to the energy (E) of the incident photons. Draw of the graph for λ as function of E.

20. An electron is revolving around the nucleus with a constant speed of 2.2×10^8 m/s.

Find the de-Broglie wavelength associated with it.

21. 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?

Or An electron is accelerated through a potential difference of 144 V. What is the de-Broglie wavelength associated with it? To which part of electromagnetic spectrum does this wavelength correspond?

Or An electron is accelerated through a potential difference of 64 V. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond?

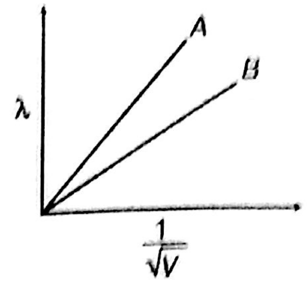
22. Find the ratio of de-Broglie wavelengths associated with

(i) protons, accelerated through a potential of 128 V and

(ii) α-particles, accelerated through a potential of 64 V.

23. The ratio between the de-Broglie wavelengths associated with protons, accelerated through a potential of 512 V and α-particles, accelerated through a potential of X volt is found to be one. Find the value of X.

24. The two lines marked A and B in the given figure, show a plot of de-Broglie wavelength λ *versus* $1/\sqrt{V}$, where V is the accelerating potential for two nuclei ^2_1H and ^3_1H.



(i) What does the slope of the lines represent?

(ii) Identify which of the lines corresponded to these nuclei.

3 Marks Questions

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

Taking other factors, such as numerical aperture, etc., to be same, how does the resolving power of an electron microscope compare with that of an optical microscope which uses yellow light?

26. (i) Describe briefly how the Davisson-Germer experiment demonstrated the wave nature of electrons.

(ii) An electron is accelerated from rest through a potential V, obtain the expression for the de-Broglie wavelength associated with it.

27. (i) Determine the de-Broglie wavelength of a proton whose kinetic energy is equal to the rest mass energy of an electron. Mass of a proton 1836 times that of electron.

(ii) In which region of electromagnetic spectrum does this wavelength lie?

28. (i) The mass of a particle moving with velocity 5×10^6 m/s has de-Broglie wavelength associated with it to be 0.135 nm. Calculate its mass.

(ii) In which region of the electromagnetic spectrum does this wavelength lie?

29. (i) A particle is moving three times as fast as an electron. The ratio of the de-Broglie wavelength of the particle to that of the electron is 1.813×10^{-4}. Calculate the particle's mass and identify the particle.

(ii) An electron and a proton have the same kinetic energy. Which of the two will have larger de-Broglie wavelength? Give reason.

30. An electron and a photon each have a wavelength 1nm. Find

(i) their momenta

(ii) the energy of the photon and

(iii) the kinetic energy of electron.

Objective Questions

(For Complete Chapter)

1 Mark Questions

1. Momentum of photon is

(a) $\frac{h\nu}{c^2}$ (b) $\frac{h\nu}{c^3}$ (c) $\frac{h\nu}{c}$ (d) $\frac{h}{c}$

2. 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

3. The curve drawn between velocity and frequency of photon in vacuum will be a

(a) straight line parallel to frequency axis
(b) straight line parallel to velocity axis
(c) straight line passing through origin and making an angle of 45° with frequency axis
(d) hyperbola

4. Choose the correct statement.

(a) Photoelectric effect can take place from bound electrons.
(b) Photoelectric effect can take place from free electrons.
(c) Photoelectric effect can take place from bounded or free electrons.
(d) None of the above

5. Photoelectric effect is an example of

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

6. The work function of a substance is 4 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately

(a) 540 nm (b) 400 nm
(c) 310 nm (d) 220 nm

7. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then, the ratio of their threshold wavelengths is nearest to

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

8. The energy of photon of light is 3 eV. Then, the wavelength of photon must be

(a) 4125 nm (b) 412.5 nm
(c) 41.250 nm (d) 4 nm

9. What is the de-Broglie wavelength of the electron accelerated through a potential difference of 1000 V?

(a) 12.27 Å (b) 1.227 Å
(c) 0.1227 Å (d) 0.001227 Å

10. If the momentum of an electron is changed by p, then the de-Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be

(a) $200p$ (b) $400p$
(c) $\frac{p}{200}$ (d) $100p$

11. If the particles listed below all have the same kinetic energy, which one would possess the shortest de-Broglie wavelength?

(a) Deuteron (b) α-particle
(c) Proton (d) Electron

12. An electron and a proton are moving in the same direction with same kinetic energy. The ratio of the de-Broglie wavelength associated with these particles is

(a) $\frac{m_e}{m_p}$ (b) $\frac{m_p}{m_e}$

(c) $\sqrt{\frac{m_p}{m_e}}$ (d) $m_p m_e$

Explanations

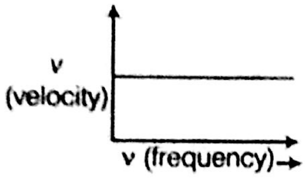
1. *(c)* Momentum of photon, $p = m \times c = \frac{E}{c} = \frac{h\nu}{c}$

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

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

$$\approx 2955 \text{ Å}$$

3. *(a)* The curve drawn between velocity and frequency of photon in vacuum will be a straight line parallel to frequency axis as velocity is constant and it iindependent of frequency.



4. (b) Photoelectric effect can take place only from free electrons.

5. (b) Photoelectric effect is an example of inelastic collision as in this phenomena, the momentum is not conserved after collision and as a result electron get ejected.

6. *(c)* Given, work function, $\phi = 4$ eV

Longest wavelength of light = λ_m

$$\therefore \quad \frac{hc}{\lambda_m} = \phi$$

$$\therefore \lambda_m = \frac{hc}{\phi} = \frac{(6.63 \times 10^{-34} \times 3 \times 10^8)}{4.0 \times 1.6 \times 10^{-19}} = 310 \text{ nm}$$

7. *(b)* We know that, work function $= \frac{hc}{\lambda}$

$$\frac{\phi_{Na}}{\phi_{Cu}} = \frac{hc/\lambda_{Na}}{hc/\lambda_{Cu}} = \frac{hc}{\lambda_{Na}} \times \frac{\lambda_{Cu}}{hc}$$

$$= \frac{\lambda_{Cu}}{\lambda_{Na}} = \frac{2.3}{4.5} = \frac{1}{2}$$

$$\therefore \quad \lambda_{Na} : \lambda_{Cu} = 2:1$$

8. *(b)* Given, $E = 3$ eV $= 3 \times 1.6 \times 10^{-19}$ J

We know that, $E = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3 \times 1.6 \times 10^{-19}}$$

$$= \frac{19.8 \times 10^{-26}}{4.8 \times 10^{-19}} = 4.125 \times 10^{-7}$$

$$= 412.5 \times 10^{-9} = 412.5 \text{ nm}$$

9. *(c)* de-Broglie wavelength of an electron is given by

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

where, h = Planck's constant, m = mass of electron

e = electronic charge and V = potential difference with which electron is accelerated.

$$\lambda = \frac{12.27}{\sqrt{10000}} = \frac{12.27}{100} = 0.1227 \text{ Å}$$

10. *(a)* We know that, $\lambda = \frac{h}{p}$

Here, $\left|\frac{\Delta\lambda}{\lambda}\right| = \left|\frac{\Delta p}{p}\right| \Rightarrow \frac{0.5}{100} = \frac{p}{p_i} \Rightarrow p_i = 200p$

11. *(b)* KE $= \frac{1}{2}mv^2$ (same for all particles) know,

de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m(\text{KE})}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$$

Here, mass of α-particle is highest, hence it has lowest wavelength.

12. *(c)* de-Broglie wavelength,

$$\lambda_e = \frac{h}{\sqrt{2m_e E}}$$

and $$\lambda_p = \frac{h}{\sqrt{2m_p E}} \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$$