UNIT 11

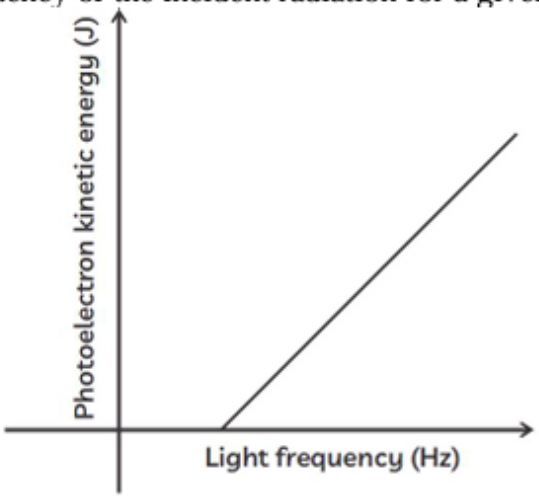
DUAL NATURE OF RADIATION & MATTER

SECTION – A

Questions 1 to 10 carry 1 mark each.

1. The quantum nature of light explains the observations on photoelectric effect as:
(a) there is a minimum frequency of incident radiation below which no electrons are emitted.
(b) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.
(c) when the metal surface is illuminated, electrons are ejected from the surface after sometime.
(d) the photoelectric current is independent of the intensity of incident radiation.

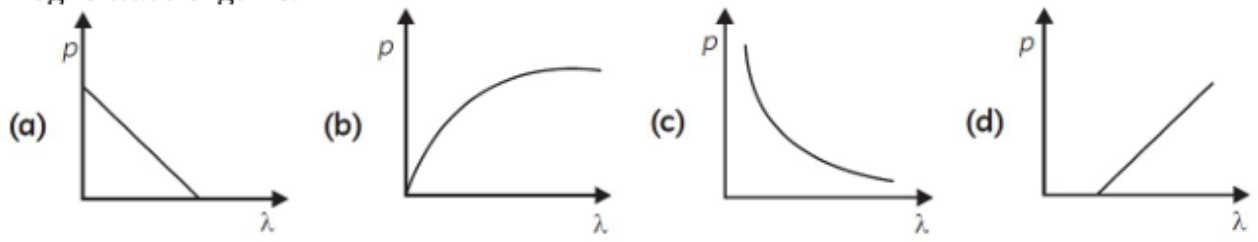
2. The graph below shows the variation of the maximum kinetic energy of the emitted photoelectron with the frequency of the incident radiation for a given metal.



Which of the following gives the work function of the metal?
(a) x-intercept (b) y-intercept (c) the slope of the graph (d) the area under the graph

3. A photon of wavelength 663 nm is incident on a metal surface. The work function of the metal is 1.50 eV. The maximum kinetic energy of the emitted photoelectrons is:
(a) 3.0×10^{-20} J (b) 6.0×10^{-20} J (c) 4.5×10^{-20} J (d) 9.0×10^{-20} J

4. The graph showing the correct variation of linear momentum (p) of a charge particle with its de-Broglie wavelength is.



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5. A metallic plate exposed to white light emits electrons. For which of the following colours of light, the stopping potential will be maximum?
(a) Blue (b) Yellow (c) Red (d) Violet

6. The work function for a metal surface is 4.125 eV. The threshold wavelength for this metal surface is:
(a) 4125 Å (b) 2062.5 Å (c) 3000 Å (d) 6000 Å

7. A photocell connected in an electrical circuit is placed at a distance d from a source of light. As a result, I current flows in the circuit. What will be the current in the circuit when then the distance is reduced to d/2 ?
(a) I (b) 2I (c) 4I (d) I/2

8. If photons of frequency ν are incident on surfaces of metal A and B of threshold frequencies ν/2 and ν/3 respectively, the ratio of the maximum kinetic energy of electrons emitted from A to that from B is:
(a) 2 : 3 (b) 3 : 4 (c) 1 : 3 (d) $\sqrt{3} : \sqrt{2}$

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** The photoelectrons produced by a monochromatic light beam incident on a metal surface have a spread in their kinetic energies.
Reason (R): The energy of electrons emitted from inside the metal surface, is lost in collision with the other atoms in the metal.

10. **Assertion (A):** The kinetic energy of photoelectrons emitted by a photosensitive surface depends upon the frequency of incident photon.
Reason (R): The ejection of electrons from metallic surface is possible with frequency of incident photon below the threshold frequency.

SECTION – B

Questions 11 to 14 carry 2 marks each.

11. Define the terms: (a) Threshold frequency, and (b) Stopping potential in photoelectric effect

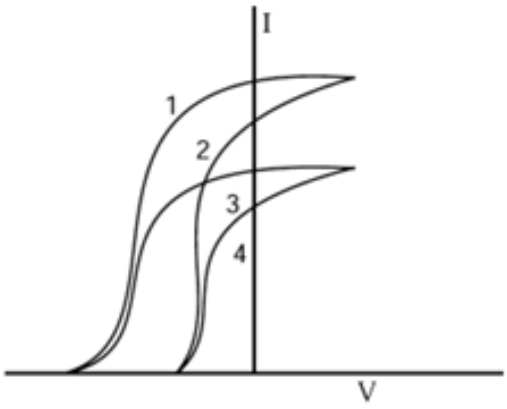
OR

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.

12. Write Einstein's photoelectric equation. State clearly the three salient features observed in photoelectric effect which can explain on the basis of this equation.

13. The de Broglie wavelengths associated with an electron and a proton are equal. Prove that the kinetic energy of the electron is greater than that of the proton.

14. The given graph shows the variation of photo-electric current (I) with the applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify and explain using Einstein's photo electric equation for the pair of curves that correspond to (i) different materials but same intensity of incident radiation, (ii) different intensities but same materials.



OR

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?

SECTION – C

Questions 15 to 17 carry 3 marks each.

15. Light of wavelength 2000 Å falls on a metal surface of work function 4.2 eV.

(a) What is the kinetic energy (in eV) of the fastest electrons emitted from the surface?

(b) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled?

(c) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons?

OR

(a) Explain de-Broglie argument to propose his hypothesis. Show that de-Broglie wavelength of photon equals electromagnetic radiation.

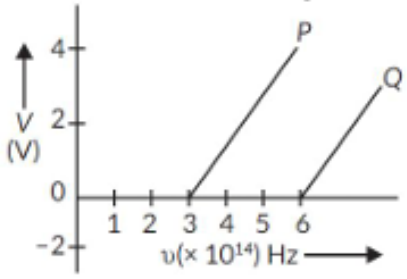
(b) If, deuterons and alpha particle are accelerated through same potential, find the ratio of the associated de-Broglie wavelengths of two.

16. Calculate the wavelength of de Broglie waves associated with a proton having energy. How will the wavelength be affected for an alpha particle having the same energy.

OR

Using photon picture of light, show how Einstein's photoelectric equation can be established. Write two features of photoelectric effect which cannot be explained by wave theory.

17. 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 × 1014 Hz for this metal.

OR

Explain briefly the reasons why wave theory of light is not able to explain the observed features of photo-electric effect.

SECTION – D

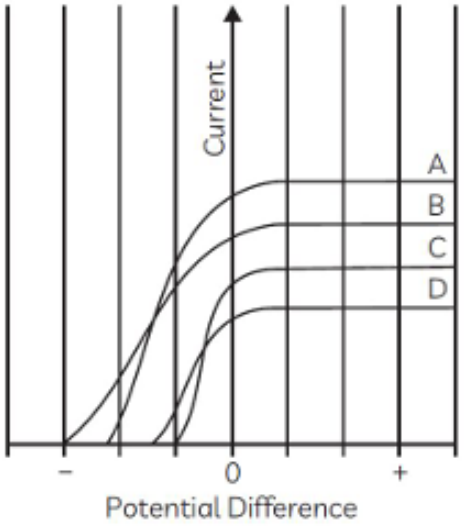
Questions 18 carry 5 marks.

18. Derive Einstein's photoelectric equation $\frac{1}{2}mv^2 = hv - hv_0$.

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. Figure shows the variation of photoelectric current measured in a photo cell circuit as a function of the potential difference between the plates of the photo cell when light beams A, B, C and D of different wavelengths are incident on the photo cell. Examine the given figure and answer the following questions:



(i) Which light beam has the highest frequency?

(a) A (b) B (c) C (d) D

(ii) Which light beam ejects photoelectrons will maximum momentum?

(a) D (b) C (c) B (d) A

(iii) The stopping potential of a photocell, in which electrons with a maximum kinetic energy of 6 eV are emitted will be

(a) –6V (b) 6V (c) 3V (d) –3V

(iv) 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) 1 : 4 (c) 2 : 1 (d) 4 : 1

20. All these photosensitive substances emit electrons when they are illuminated by light. After the discovery of electrons, these electrons were termed as photoelectrons. The phenomenon is called photoelectric effect.

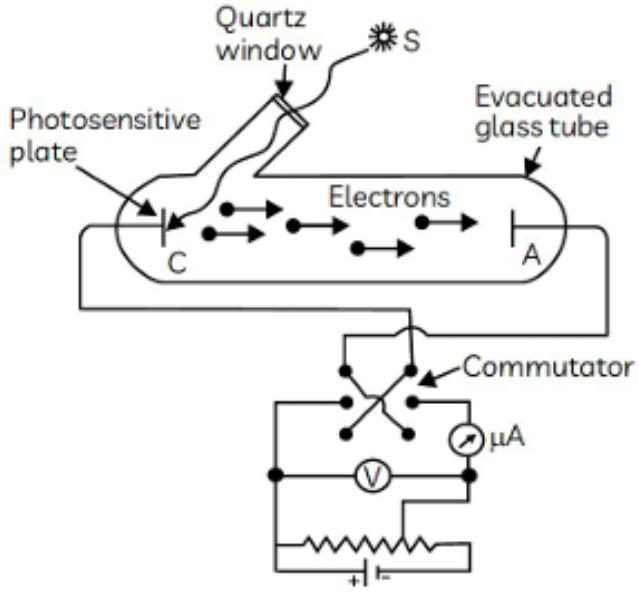


Figure depicts a schematic view of the arrangement used for the experimental study of the photoelectric effect. It consists of an evacuated glass or quartz tube having a thin photosensitive plate C and another metal plate A. Monochromatic light from the source S of sufficiently short wavelength passes through the window W and falls on the photosensitive plate C (emitter). A transparent quartz window is sealed on to the glass tube, which permits ultraviolet radiation to pass through it and irradiate the photosensitive plate C. The electrons are emitted by the plate C and are collected by the plate A (collector), by the electric field created by the battery. The battery maintains the potential difference between the plates C and A, that can be varied. The polarity of the plates C and A can be reversed by a commutator. Thus, the plate A can be maintained at a desired positive or negative potential with respect to emitter C.

(i) With the increase in the intensity of incident radiation, the:
(a) Kinetic energy of the emitted photoelectrons increase
(b) Photoelectric current decreases
(c) Kinetic energy of the emitted photoelectrons decreases
(d) Photoelectric current increases

(ii) The time taken by a photoelectron to come out after the photon strikes is approximately:
(a) 10^{-4} s (b) 10^{-10} s (c) 10^{-16} s (d) 10^{-1} s

(iii) In photoelectric effect, the electrons are ejected from metals, if the incident light has a certain minimum:
(a) amplitude (b) wavelength (c) frequency (d) angle of incidence

(iv) Photoelectron emission rate is a direct function of radiation:
(a) frequency (b) speed (c) intensity (d) energy

OR

(v) Consider a beam of electrons (each electron 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 an 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.