INDIAN SCHOOL AL WADI AL KABIR

Class: XII	Department: SCIENCE 2025-2026 SUBJECT: PHYSICS	Date: 10/11/2025
Worksheet No: 11	Topic: DUAL NATURE OF RADIATION AND MATTER.	Note: A4 FILE FORMAT
NAME OF THE STUDENT-	CLASS & SECTION	ROLL NO.

Multiple choice type questions;

1. Two beams, A and B whose photon energies are 3·3 eV and 11·3 eV respectively, illuminate a metallic surface (work function 2·3 eV) successively. The ratio of maximum speed of electrons emitted due to beam A to that due to beam B is:

(A) 3 (B) 9 (C)1/3 (D)1/9

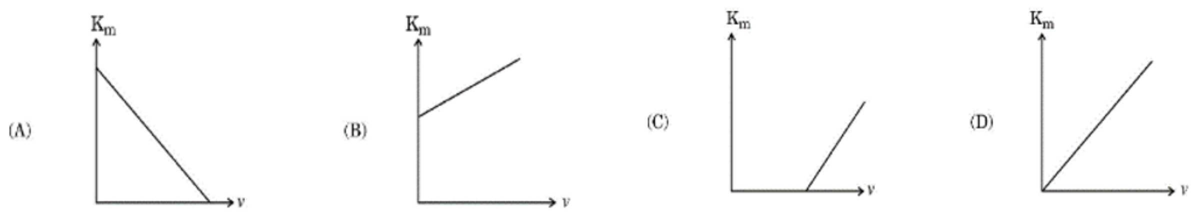
2. The waves associated with a moving electron and a moving proton have the same wavelength. It implies that they have the same:

(A) momentum (B) angular momentum (C) speed (D) energy

3. The work function for a photosensitive surface is 3·315 eV. The cut-off wavelength for photoemission of electrons from this surface is:

(A) 150 nm (B) 200 nm (C) 375 nm (D) 500 nm

4. Which one of the following is the correct graph between the maximum kinetic energy (Km) of the emitted photoelectrons and the frequency of incident radiation (v) for a given photosensitive surface?



5. 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 K.E 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 electron current is independent of the intensity of incident radiation

6. The photoelectric effect can be explained on the basis of

(a) Corpuscular theory (b) Wave theory
(c) electromagnetic theory (d) quantum theory

7. Which of the following has minimum stopping potential?

(a) Blue (b) Yellow (c) Violet (d) Red

8. When radiation is incident on a photoelectron emitter, the stopping potential is found to be 9 V. If e/m for the electron is $1{\cdot}8 \times 10^{11}$ C/kg, the maximum velocity of the ejected electron is

(a) 6×10^5 m/s (b) 8×10^5 m/s
(c) 10^6 ms^{-1} (d) $1{\cdot}8 \times 10^6$ ms^{-1}

9. Two photons, each of energy 2·5 eV are simultaneously incident on the metal surface. If the work function of the metal is 4·5 eV, then from the surface of metal

(a) one electron will be emitted with energy 0·5 *eV*
(b) two electrons will be emitted with energy 0·25 eV

(c) more than two electrons will be emitted
(d) not a single electron will be emitted

10. The maximum velocity of an electron emitted by light of wavelength λ incident on the surface of a metal of work function φ, is [h = Planck's constant, *c* = speed of light and *m* = mass of electron]

(a) $\left[\frac{2(hc+\lambda\varphi)}{m\lambda}\right]^{1/2}$ (b) $\frac{2(hc-\lambda\varphi)}{m\lambda}$ (c) $\left[\frac{2(hc-\lambda\varphi)}{m\lambda}\right]^{1/2}$ (d) $\left[\frac{2(hc-\varphi)}{m}\right]^{1/2}$

11. The photoelectric work function for a metal surface is 4· 125 e V. The cut off wavelength for this surface is

(a) 4125 Å (b) 2062.5 Å (c) 3000 Å (d) 6000 Å

12. The slope of frequency of incident light and stopping potential for a given surface will be

(a) h (b) h/e (c) eh (d) e

13. The threshold wavelength for a metal having work function φ_o is λ_o· What is the threshold wavelength for a metal whose work function is $\varphi_o/2$?

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

14. The work function for metals A, B and C are respectively 1 ·92 e V, 2·0 e V and 5·0 e V. According to Einstein's equation, the metals which will emit photoelectrons for a radiation of wavelength 4100 Å is/are

(a) none (b) A only (c) A and B only (d) B and c only

15. The wavelength of matter wave is independent of

(a) mass (b) velocity (c) momentum (d) charge

Assertion and Reason type questions;

DIRECTIONS. In each of the following questions, read the two statements and choose if
(A) both Assertion and Reason are true and the Reason is correct explanation of the Assertion.
(B) both Assertion and Reason are true, but the Reason is not a correct explanation of the Assertion.
(C) Assertion is true and Reason is false.
(D) both, Assertion and Reason are false.

16. **Assertion**: Light of frequency 1 ·5 times the threshold frequency is incident on photo-sensitive material. If the frequency is halved and intensity is doubled, the photo current remains unchanged.
Reason: The photo electric current varies directly with the intensity of light and frequency of light.

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

17. **Assertion**: Photoelectric effect demonstrates the wave nature of light.
Reason: The number of photoelectrons is proportional to the frequency of light.

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

18. **Assertion** An electron microscope can achieve better resolving power than an optical microscope.
Reason: The de-Broglie wavelength of the electrons emitted from an electron gun with velocity 500 m/s is much less than 500 nm.

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

19. **Assertion**: The de-Broglie wavelength of a neutron when. its kinetic energy is k is λ. Its wavelength is 2λ when its kinetic energy is 4 *k*.
Reason: The de-Broglie wavelength λ is proportional to square root of the kinetic energy. ·

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

20. **Assertion**: The de-Broglie wavelength equation has significance for any microscopic or submicroscopic particles.
Reason: The de-Broglie wavelength is inversely proportional to the mass of the object if velocity is constant.

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

ANSWERS OF MCQs; -(1).(c), 2.(a), 3.(c), 4.(c), 5.(a),6. (d),7. (d), 8. (d), 9. (d), 10. (c), 11. (c), 12. (b), 13. (b), 14. (c), 15. (d), 16. (d), 17. (d), 18. (c), 19. (d), 20. (a)

Short answers type questions;

1. **There are materials which absorb photons of shorter wavelength and emit photons of longer wavelength. Can there be stable substances which absorb photons of larger wavelength and emit light of shorter wavelength.**

Ans. In the first case, the energy of the incident photon on a material is high and the energy of emitted photon is low. In the second case, the energy of the incident photon is low and the energy of emitted photon is high. It means in second case the material has to supply the energy for the emission of photon. This cannot happen for stable substances.

2. **Do all the electrons that· absorb a photon come out as photoelectrons**?

Ans. No, most electrons get scattered into the metal by absorbing a photon. Only a few come out of the surface of metal whose energy becomes greater than the work function of metal.

3. **Why is this fact (two photon absorption) not taken into consideration in our discussion of the stopping potential**?

Ans. The probability of absorbing 2 photons by the same electron is very low. Hence such emission will be negligible.

4. **On what principle is an electron microscope based**?

Ans. An electron microscope is based on de-Broglie hypothesis. According to it, a beam of electrons behaves as a wave which can be converged or diverged by magnetic or electric field lenses like a beam of light using optical lenses.

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

Ans. De-Broglie wavelength $\lambda = h/mv$, i.e., De-Broglie wavelength of electron is more than that of proton.

2/3 marks questions

1. Calculate the

(a) momentum, and, (b) de Broglie wavelength of the electrons accelerated through a potential difference of 56 V.

Solution: -

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

$$v^2 = \frac{2eV}{m}$$

$$\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 56}{9.1 \times 10^{-31}}}$$

\

$$= \sqrt{19.69 \times 10^{12}} = 4.44 \times 10^6 \text{ m/s}$$

After this momentum, can be calculated.

For de-Broglie wavelength

$$\lambda = \frac{12.27}{\sqrt{V}} \text{ Å}$$

2. What is the

(a) momentum,

(b) speed, and

(c) de Broglie wavelength of an electron with kinetic energy of 120 eV.

Solution; - same as previous question,

3. The wavelength of light from the spectral emission line of sodium is 589 nm. Find the kinetic energy at which (a) an electron, and (b) a neutron, would have the same de Broglie wavelength.

Solution; -

$$K = \frac{1}{2}m_e v^2 \qquad \ldots (1)$$

$$\lambda = \frac{h}{m_e v}$$

$$\therefore v^2 = \frac{h^2}{\lambda^2 m_e^2} \qquad \ldots (2)$$

$$K = \frac{1}{2}\frac{m_e h^2}{\lambda^2 m_e^2} = \frac{h^2}{2\lambda^2 m_e} \qquad \text{... (3)}$$

$$= \frac{\left(6.6 \times 10^{-34}\right)^2}{2 \times \left(589 \times 10^{-9}\right)^2 \times 9.1 \times 10^{-31}}$$

$$\approx 6.9 \times 10^{-25} \text{ J}$$

$$= \frac{6.9 \times 10^{-25}}{1.6 \times 10^{-19}} = 4.31 \times 10^{-6} \text{ eV} = 4.31 \mu\text{eV}$$

In the same way KE of neutron can be calculated.

4. What is the de-Broglie wavelength of
(a) a bullet of mass 0.040 kg travelling at the speed of 1.0 km/s,
(b) a ball of mass 0.060 kg moving at a speed of 1.0 m/s, and
(c) a dust particle of mass 1.0×10^{-9} kg drifting with a speed of 2.2 m/s?

(a) $$\lambda = \frac{h}{mv}$$

$$= \frac{6.6 \times 10^{-34}}{0.040 \times 1000} = 1.65 \times 10^{-35} \text{ m}$$

In the same way other 2 can be calculated**.**
5. An electron and a photon each have a wavelength of 1.00 nm. Find
(a) their momenta,
(b) the energy of the photon, and
(c) the kinetic energy of electron.

(a) $$p = \frac{h}{\lambda} \qquad \therefore p = \frac{6.63 \times 10^{-34}}{1 \times 10^{-9}} = 6.63 \times 10^{-25} \text{ kg m s}^{-1}$$

(b) $$E = \frac{hc}{\lambda} \qquad \therefore E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$$= 1243.1 \text{ eV} = 1.243 \text{ keV}$$

(c) $$K = \frac{1}{2}\frac{p^2}{m}$$

$$\therefore K = \frac{1}{2} \times \frac{\left(6.63 \times 10^{-25}\right)^2}{9.1 \times 10^{-31}} = 2.415 \times 10^{-19} \text{ J}$$

$$= \frac{2.415 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.51 \text{ eV}$$

[6]] An electron and alpha particle have the same de-Broglie wavelength associated with them. How are their kinetic energies related to each other?

$$E_K = \frac{p^2}{2m} \quad \text{where} \begin{cases} E_K = \text{Kinetic energy} \\ p = \text{momentum} \\ m = \text{mass of the particle} \end{cases}$$

de-Broglie wavelength, $\lambda = \frac{h}{p}$

...where [h = Planck's constant

$\therefore \quad \lambda = \frac{h}{\sqrt{2mE_K}}$

$\because$ Both the particles have the same de-Broglie wavelength ...[Given

$\therefore \quad \frac{h}{\sqrt{2m_e E_{Ke}}} = \frac{h}{\sqrt{2m_\alpha E_{K\alpha}}}$

$$\text{or} \quad \frac{m_e}{m_\alpha} = \frac{E_{K\alpha}}{E_{Ke}} \quad \text{where} \begin{cases} m_e = \text{mass of electron} \\ m_\alpha = \text{mass of } \alpha\text{ - particle} \\ E_{Ke} = \text{K.E. of electron} \\ E_{K\alpha} = \text{K.E. of } \alpha\text{- particle} \end{cases}$$

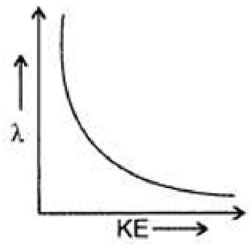
As $m_\alpha > m_e$ $\quad \therefore$ K.$E_{Ke} > E_{K\alpha}$

Q.7] An electron is revolving around the nucleus with a constant speed of 2.2 × 108 m/s. Find the de-Broglie wavelength associated with it.

$$\text{de-Broglie wavelength } (\lambda) = \frac{h}{mv}$$

$$= \frac{6.63 \times 10^{-34}}{(9.1 \times 10^{-31}) \times (2.2 \times 10^{8})} = \mathbf{3.31 \times 10^{-12}\ m}$$

Q.8] Draw a plot showing the variation of de Broglie wavelength of electron as a function of its K.E.



Q.9] An electron is accelerated through a potential difference of 64 volts. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond?

According to de-Broglie wavelength,

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm} = \frac{1.227}{\sqrt{64}} = \frac{1.227}{8} = 0.1533 \text{ nm}$$

This wavelength is associated with X-rays.

Q.10] An a-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de-Broglie wavelengths.

Answer:

de-Broglie wavelength of a charged (q)

Particle accelerated through a potential 'V' is

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

Ratio of their de-Broglie wavelengths for an α-particle and a proton is $\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{q_p m_p}{q_\alpha m_\alpha}}$

As $q_\alpha = 2\, q_p,\ m_\alpha = 4\, m_p$

$$\therefore \quad \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\left(\frac{1}{2}\right)\left(\frac{1}{4}\right)} = \frac{1}{2\sqrt{2}}.$$

Q.11] Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work functions W1 and W2 (W1 > W2). On what factors does the

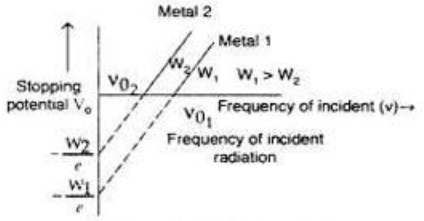
(i) slope and

(ii) intercept of the lines depends?

(*i*) As $eV_0 = hv - W_0 \qquad V_0 = \left(\frac{h}{e}\right)v - \frac{W_0}{e}$

$\therefore$ Slope of $V_0 - v$ graph $= \frac{h}{e}$

Slope depends on the Planck's constant and electronic charge (*e*).



(*ii*) Intercept $= \frac{\text{Work function}}{e} = \frac{-W_0}{e}$

Therefore, Intercept depends upon the work function (threshold frequency) and electronic charge (*e*).

CASE-STUDY BASED QUESTIONS; -

1. Photoelectric effect is the phenomenon of emission of electrons from a metal surface, when radiations of suitable frequency fall on them. The emitted electrons are called photoelectrons and the current so produced is called photoelectric current.

(i) With the increase of intensity of incident radiations on photoelectrons emitted by a photo tube, the number of photoelectrons emitted per unit time is

(a) increases **(b) decreases**

(c) remains same **(d) none of these**

(ii) It is observed that photoelectron emission stops at a certain time t after the light source is switched on. The stopping potential (V) can be represented as

(a) 2(KE_{max}/e) **(b) (KE_{max}/e)**

(c) (KE_{max}/3e) **(d) (KE_{max}/2e)**

(iii) A point source of light of power 3.2 x 10^{-3} W emits monoenergetic photons of energy 5.0 eV and work function 3.0 eV. The efficiency of photoelectron emission is 1 for every 10^6 incident photons. Assume that photoelectrons are instantaneously swept away after emission. The maximum kinetic energy of photon is

(a) 4 eV **(b) 5 eV**

(c) 2 eV **(d) Zero**

(iv) Which of the following device is the application of Photoelectric effect?

(a) Light emitting diode **(b) Diode**

(c) Photocell **(d) Transistor**

(v) If the frequency of incident light falling on a photosensitive metal is doubled, the kinetic energy of the emitted photoelectron is

(a) unchanged **(b) halved**

(c) doubled **(d) more than twice its initial value**

Sol; - **(i) (a):** With the increase of intensity of the incident radiation the number of photoelectrons emitted per un't time increases.

(ii) (b): As eV = KE_{max}

$\therefore \quad V = \left(\frac{KE_{max}}{e}\right)$

(iii) (c) : From Einstein's photoelectric equation,

$KE_{max} = hv - \phi = (5-3) = 2\text{eV}$

(iv) (c): A photocell is a technological application of the photoelectric effect.

(v) (d): According to Einstein's photoelectric equation, the kinetic energy of the emitted photoelectron is

$K = hv - \phi_n$

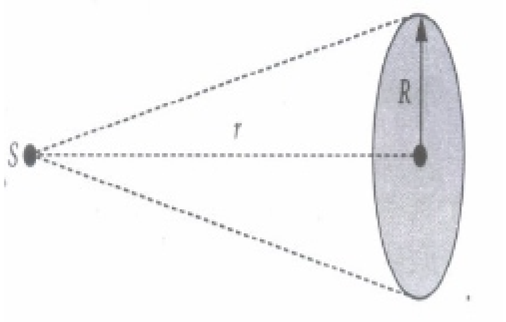
where v is the frequency of incident radiation and ϕ_0 is a work function of the metal.If the frequency of incident radiation is doubled, then

$K' = 2hv - \phi_0 = 2(hv - \phi_0) + \phi_0 = 2K + \phi_0$ (Using (i))

$K' > 2K$

2

A point source S of power 6.4 x 10^{-3}W emits mono energetic photons each of energy 6.0 eV. The source is located at a distance of 0·8 m from the centre of a stationary metallic sphere of work function 3·0 eV and of radius 1.6 x 10^{-3} m as shown in figure. The sphere is isolated and initially neutral and photoelectrons are instantly taken away from sphere after emission. The efficiency of photoelectric emission is one for very 10^5 incident photons.



(i) The'power received by the sphere through radiations is

(a) $\frac{4R^2}{Pr}$ (b) $\frac{PR^2}{4r^2}$ (c) $\frac{p^2R}{2\pi r}$ (d) $\frac{PR}{4r}$

(ii) Number of photons striking the metal sphere per second is

(a) 6.7 x 10^9 (b) 3.3 x 10^9 (c) 6.7 x 10^{10} (b) 3.3 x 10^{10}

(iii) The number of photoelectrons emitted per second is about

(a) 3.3 x 10^4 (b) 6.7 x 10^4 (c) 6.7 x 10^{15} (d) 3.3 x 10^{15}

(iv) The photoelectric emission stops when the sphere acquires a potential about

(a) 2 V (b) 3 V (c) 4 V (d) 6 V

(v) If the distance of source becomes double from the centre of the metal sphere then the power received by the sphere

(a) $\frac{PR^2}{4r^2}$ (b) $\frac{PR^2}{16r^2}$ (c) $\frac{PR^2}{4r}$ (d) $\frac{P^2R^2}{16r^2}$

Sol: -

(i) (b): Let R be the radius of the metallic sphere and r be its distance from the source S_0. The power received at the sphere is

$P' = \frac{P \times \pi R^2}{4\pi r^2} = \frac{PR^2}{4r^2}$

(ii) (a): Number of photons striking the metal sphere per second is

$n' = \frac{P'}{E} = \frac{6 \cdot 4 \times 10^{-9}}{6 \cdot 0 \times 1 \cdot 6 \times 10^{-19}} = 6 \cdot 7 \times 10^9 \text{ s}^{-1}$

(iii) (b): Number of photoelectrons emitted from metal sphere,

$\frac{n'}{10^5} = \frac{6 \cdot 7 \times 10^{-9}}{10^5} = 6 \cdot 7 \times 10^4$

(iv) (b): Kinetic energy of the fastest photoelectrons is $K_{max} = 6 \cdot 0 - 3 \cdot 0 = 3 \cdot 0\text{eV}$

$\therefore$ Stopping potential, $V_s = \frac{K_{max}}{e} = \frac{3 \cdot 0\text{eV}}{e} = 3.0 \text{ V}$

(v) (b): When r = 2r, then power received by the sphere

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