CHAPTER 25

Dual Nature of Radiation and Matter

1. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to **[2002]**

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

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

2. Formation of covalent bonds in compounds exhibits **[2002]**

(a) wave nature of electron

(b) particle nature of electron

(c) both wave and particle nature of electron

(d) none of these

3. Two identical photocathodes receive light of frequencies f_1 and f_2. If the velocites of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then **[2003]**

(a) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

(b) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$

(c) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$

(d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$

4. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is **[2004]**

(a) Ec (b) $2E/c$

(c) E/c (d) E/c^2

5. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal vs the frequency, of the incident radiation gives a straight line whose slope **[2004]**

(a) depends both on the intensity of the radiation and the metal used

(b) depends on the intensity of the radiation

(c) depends on the nature of the metal used

(d) is the same for the all metals and independent of the intensity of the radiation

6. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately **[2004]**

(a) 310 nm (b) 400 nm

(c) 540 nm (d) 220 nm

7. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would **[2005]**

(a) increase by a factor of 4

(b) decrease by a factor of 4

(c) increase by a factor of 2

(d) decrease by a factor of 2

8. If the kinetic energy of a free electron doubles, it's deBroglie wavelength changes by the factor **[2005]**

(a) 2 (b) $\frac{1}{2}$

(c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

9. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5 V. The incident radiation lies in **[2006]**

(a) ultra-violet region
(b) infra-red region
(c) visible region
(d) X-ray region

10. The time taken by a photoelectron to come out after the photon strikes is approximately **[2006]**

(a) 10^{-4} s (b) 10^{-10} s
(c) 10^{-16} s (d) 10^{-1} s

11. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows **[2006]**

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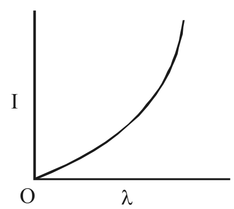

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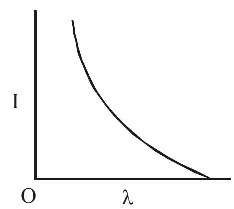

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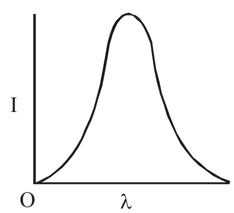

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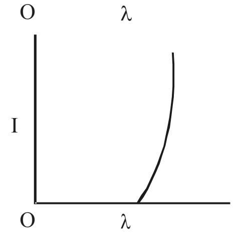
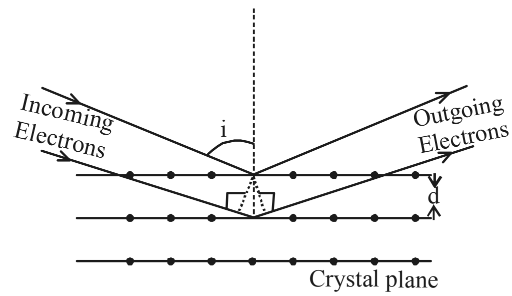


12. Photon of frequency ν has a momentum associated with it. If c is the velocity of light, the momentum is **[2007]**

(a) $h\nu / c$ (b) ν / c
(c) $h \nu c$ (d) $h\nu / c^2$

Directions: Question No. 13 and 14 are based on the following paragraph.

Wave property of electrons implies that they will show diffraction effects. Davisson and Germer demonstrated this by diffracting electrons from crystals. The law governing the diffraction from a crystal is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructively (see figure).



13. Electrons accelerated by potential V are diffracted from a crystal. If d = 1Å and i = 30°, V should be about **[2008]**

($h = 6.6 \times 10^{-34}$ Js, $m_e = 9.1 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C)

(a) 2000 V (b) 50 V
(c) 500 V (d) 1000 V

14. If a strong diffraction peak is observed when electrons are incident at an angle 'i' from the normal to the crystal planes with distance 'd' between them (see figure), de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer) **[2008]**

(a) $d \sin i = n\lambda_{dB}$ (b) $2d \cos i = n\lambda_{dB}$
(c) $2d \sin i = n\lambda_{dB}$ (d) $d \cos i = n\lambda_{dB}$

15. The surface of a metal is illuminted with the light of 400 nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is : **[2009]**

(hc = 1240 eV.nm)

(a) 1.41 eV (b) 1.51 eV
(c) 1.68 eV (d) 3.09 eV

Question (16–18) has Statement – 1 and Statement – 2. Of the four choices given after the statements, choose the one that best describes these two statements. **[2011]**

(a) Statement -1 is true, Statement -2 is true ; Statement -2 is the correct explanation of Statement -1.
(b) Statement -1 is true, Statement -2 is true; Statement -2 is **not** the correct explanation of Statement -1
(c) Statement -1 is false, Statement -2 is true.
(d) Statement -1 is true, Statement -2 is false.

16. **Statement -1 :** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max} .When the ultraviolet light is replaced by X-rays, both V_0 and K_{max} increase.

Statement -2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light. **[2010]**

17. **Statement – 1:** A metallic surface is irradiated by a monochromatic light of frequency $v > v_0$ (the threshold frequency). The maximum kinetic energy and the stopping potential are $K_{\max}$ and V_0 respectively. If the frequency incident on the surface is doubled, both the $K_{\max}$ and V_0 are also doubled.

Statement – 2 : The maximum kinetic energy and the stopping potential of photoelectrons emitted from a surface are linearly dependent on the frequency of incident light.

18. **Statement 1:** Davisson-Germer experiment established the wave nature of electrons.

Statement 2 : If electrons have wave nature, they can interfere and show diffraction. **[2012]**

(a) Statement 1 is false, Statement 2 is true.
(b) Statement 1 is true, Statement 2 is false
(c) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of statement 1
(d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1

19. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows : **[2013]**

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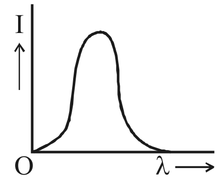

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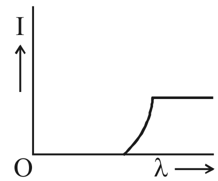

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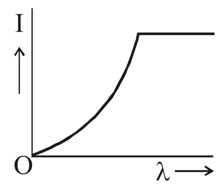

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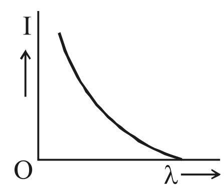


20. The radiation corresponding to $3 \rightarrow 2$ transition of hydrogen atom falls on a metal surface to produce photoelectrons. These electrons are made to enter a magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by these electrons is 10.0 mm, the work function of the metal is close to: **[2014]**

(a) 1.8 eV (b) 1.1 eV
(c) 0.8 eV (d) 1.6 eV

21. Match **List - I** (Fundamental Experiment) with **List - II** (its conclusion) and select the correct option from the choices given below the list: **[2015]**

List-I	List-II
A. Franck-Hertz Experiment	(i) Particle nature of light
B. Photo-electric experiment	(ii) Discrete energy levels of atom
C. Davison-Germer experiment	(iii) Wave nature of electron
	(iv) Structure of atom

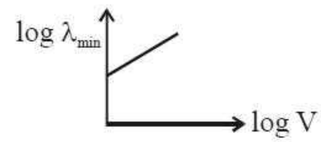
(a) (A)-(ii); (B)-(i); (C)-(iii)
(b) (A)-(iv); (B)-(iii); (C)-(ii)
(c) (A)-(i); (B)-(iv); (C)-(iii)
(d) (A)-(ii); (B)-(iv); (C)-(iii)

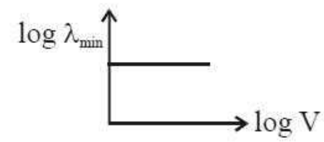
22. Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be: **[2016]**

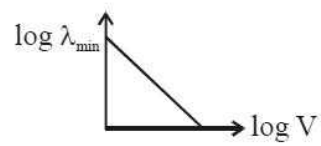
(a) $v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (b) $v\left(\frac{3}{4}\right)^{\frac{1}{2}}$

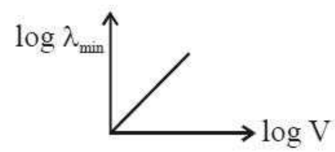
(c) $> v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (d) $< v\left(\frac{4}{3}\right)^{\frac{1}{2}}$

23. An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the smallest possible wavelength of X-ray in the spectrum, the variation of log λ_{min} with log V is correctly represented in : **[2017]**

(a) 

(b) 

(c) 

(d) 

Answer Key

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(c)	(a)	(a)	(b)	(d)	(a)	(a)	(d)	(a)	(b)	(b)	(a)	(b)	(b)	(a)
16	17	18	19	20	21	22	23							
(d)	(c)	(c)	(d)	(b)	(a)	(c)	(c)							

SOLUTIONS

1. **(c)** We know that work function is the energy required and energy $E = h\upsilon$

$$\therefore \frac{E_{Na}}{E_{Cu}} = \frac{h\upsilon_{Na}}{h\upsilon_{Cu}} = \frac{\lambda_{Cu}}{\lambda_{Na}}$$

$$\left[\because \upsilon \propto \frac{1}{\lambda} \text{ for light}\right]$$

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

2. **(a)** Formation of covalent bond is best explained by molecular orbital theory.

3. **(a)** For one photocathode

$$hf_1 - W = \frac{1}{2}mv_1^2 \qquad \text{....(i)}$$

For another photo cathode

$$hf_2 - W = \frac{1}{2}mv_2^2 \qquad \text{....(ii)}$$

Subtracting (ii) from (i) we get

$$(hf_1 - W) - (hf_2 - W) = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2$$

$$\therefore h(f_1 - f_2) = \frac{m}{2}(v_1^2 - v_2^2)$$

$\therefore\ v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

4. **(b)** Momentum of photon $= \frac{E}{c}$

Change in momentum $= \frac{2E}{c}$

= momentum transferred to the surface (the photon will reflect with same magnitude of momentum in opposite direction)

5. **(d)** From Equation $K.E = h\nu - \phi$

slope of graph of K.E & ν is h (Plank's constant)

which is same for all metals

6. **(a)** For the longest wavelength to emit photo electron

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

$$\Rightarrow \lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{40\times1.6\times10^{-16}} = 310\,\text{nm}$$

7. **(a)** $I \propto \frac{I}{r^2};\ \frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2 = \frac{1}{4}$

$I_2 \to 4$ times I_1

When intensity becomes 4 times, no. of photoelectrons emitted would increase by 4 times, since number of electrons emitted per second is directly proportional to intensity.

8. **(d)** de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(\text{K.E})}}$$

$$\therefore\ \lambda \propto \frac{1}{\sqrt{\text{K.E}}}$$

If K.E is doubled, wavelength becomes $\frac{\lambda}{\sqrt{2}}$

9. **(a)** $\phi = 6.2\text{ eV} = 6.2\times1.6\times10^{-19}$ J

$V = 5$ volt

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

$$\Rightarrow \lambda = \frac{hc}{\phi + eV_0}$$

$$= \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}(6.2+5)} \approx 10^{-7}\text{ m}$$

This range lies in ultra violet range.

10. **(b)** The order of time is nano second.

11. **(b)** As λ decreases, y increases and hence the speed of photoelectron increases. The chances of photo electron to meet the anode increases and hence photo electric current increases.

12. **(a)** Energy of a photon of frequency ν is given by $E = h\nu$.

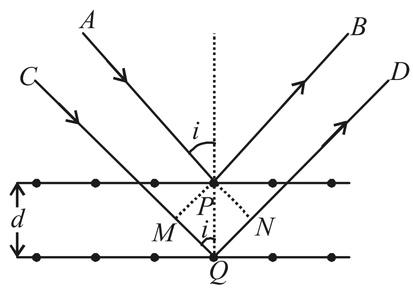
Also, $E = mc^2$, $mc^2 = h\nu$

$$\Rightarrow mc = \frac{h\nu}{c} \quad \Rightarrow p = \frac{h\nu}{c}$$

13. **(b)** The path difference between the rays APB and CQD is

$\Delta x = \text{MQ} + \text{QN} = d\cos i + d\cos i$

$\Delta x = 2d\cos i$



We know that for constructive interference the path difference is $n\lambda$

$\therefore\quad n\lambda = 2d\cos i$

Also by de-broglie concept

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m\text{K.E}}} = \frac{h}{\sqrt{2meV}}$$

$$\therefore\ \frac{nh}{\sqrt{2meV}} = 2d\cos i$$

Here $n = 1$: $V = \frac{h^2}{8med^2\cos^2 i}$

$$= \frac{(6.6\times10^{-34})^2}{8\times9.1\times10^{-31}\times1.6\times10^{-19}\times(10^{-10})^2\times\cos^2 30}$$

$= 50\,V$

14. **(b)** $2d\cos i = n\lambda_{dB}$

15. **(a)** $\lambda = 400$ nm, $hc = 1240$ eV.nm, K.E. $= 1.68$ eV

We know that,

$$\frac{hc}{\lambda} - W = K.E \Rightarrow W = \frac{hc}{\lambda} - K.E$$

$$\Rightarrow W = \frac{1240}{400} - 1.68 = 3.1 - 1.68 = 1.42\text{ eV}$$

16. **(d)** We know that

$$eV_0 = K_{\max} = h\nu - \phi$$

where, ϕ is the work function .

Hence, as ν increases (note that frequency of X-rays is greater than that of U.V. rays), both V_0 and K_{max} increase. So statement - 1 is correct

17. **(c)** By Einstein photoelectric equation,

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

When ν is doubled, $K_{\max}$ and V_0 become more than double.

18. **(c)**

19. **(d)** As λ is increased, there will be a value of λ above which photoelectrons will be cease to come out so photocurrent will become zero. Hence (d) is correct answer.

20. **(b)** Radius of circular path followed by electron is given by,

$$r = \frac{m\upsilon}{qB} = \frac{\sqrt{2meV}}{eB} = \frac{1}{B}\sqrt{\frac{2m}{e}V}$$

$$\Rightarrow \quad V = \frac{B^2 r^2 e}{2m} = 0.8V$$

For transition between 3 to 2.

$$E = 13.6\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{13.6\times5}{36} = 1.88eV$$

Work function $= 1.88$ eV $- 0.8$ eV $= 1.08$ eV ≈ 1.1 eV

21. **(a)** Frank-Hertz experiment - Discrete energy levels of atom Photoelectric effect - Particle nature of light

Davison - Germer experiment - wave nature of electron.

22. **(c)** $h\nu_0{}^2 - h\nu_0 = \frac{1}{2}mv^2$

$$\therefore \frac{4}{3}h\nu_0 - h\nu_0 = \frac{1}{2}mv'^2$$

$$\therefore \frac{v'^2}{v^2} = \frac{\frac{4}{3}\nu - \nu_0}{\nu - \nu_0} \quad \therefore v' = v\sqrt{\frac{\frac{4}{3}\nu - \nu_0}{\nu - \nu_0}}$$

$$\therefore v' > v\sqrt{\frac{4}{3}}$$

23. **(c)** In X-ray tube, $\lambda_{\min} = \frac{hc}{eV}$

$$\text{In } \lambda_{\min} = In\left(\frac{hc}{e}\right) - InV$$

Clearly, log $\lambda_{\min}$ versus log V graph slope is negative hence option (c) correctly depicts.