CHAPTER 17

Dual Nature of Matter and Radiation

1. Two electrons are moving with non-relativistic speeds perpendicular to each other. If corresponding de Broglie wavelengths are λ_1 and λ_2, their de Broglie wavelength in the frame of reference attached to their centre of mass is

(a) $\lambda_{CM} = \dfrac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}$ (b) $\lambda_{CM} = \lambda_1 = \lambda_2$

(c) $\lambda_{CM} = \left(\dfrac{\lambda_1+\lambda_2}{2}\right)$ (d) $\dfrac{1}{\lambda_{CM}} = \dfrac{1}{\lambda_1} + \dfrac{1}{\lambda_2}$

(Online 2018)

2. If the de Broglie wavelengths associated with a proton and an α-particle are equal, then the ratio of velocities of the proton and the α-particle will be

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

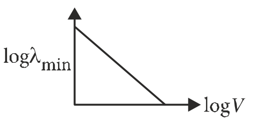
(Online 2018)

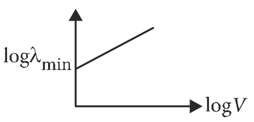
3. The de-Broglie wavelength (λ_B) associated with the electron orbiting in the second excited state of hydrogen atom is related to that in the ground state (λ_G) by

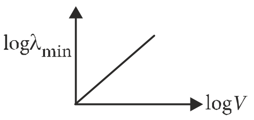
(a) $\lambda_B = \lambda_G/3$ (b) $\lambda_B = 3\lambda_G$

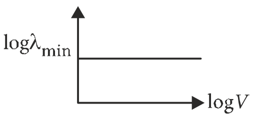
(c) $\lambda_B = \lambda_G/2$ (d) $\lambda_B = 2\lambda_G$ *(Online 2018)*

4. 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 $\log\lambda_{min}$ with $\log V$ is correctly represented in

(a) 

(b) 

(c) 

(d) 

(2017)

5. A particle A of mass m and initial velocity v collides with a particle B of mass $\dfrac{m}{2}$ which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is

(a) $\dfrac{\lambda_A}{\lambda_B} = \dfrac{1}{3}$ (b) $\dfrac{\lambda_A}{\lambda_B} = 2$

(c) $\dfrac{\lambda_A}{\lambda_B} = \dfrac{2}{3}$ (d) $\dfrac{\lambda_A}{\lambda_B} = \dfrac{1}{2}$ *(2017)*

6. The maximum velocity of the photoelectrons emitted from the surface is v when light of frequency n falls on a metal surface. If the incident frequency is increased to $3n$, the maximum velocity of the ejected photoelectrons will be

(a) more than $\sqrt{3}v$ (b) less than $\sqrt{3}v$

(c) v (d) equal to $\sqrt{3}v$

(Online 2017)

7. A Laser light of wavelength 660 nm is used to weld Retina detachment. If a Laser pulse of width 60 ms and power 0.5 kW is used, the approximate number of photons in the pulse are
[Take Planck's constant h = 6.62×10^{-34} J s]

(a) 10^{19} (b) 10^{22}

(c) 10^{18} (d) 10^{20} *(Online 2017)*

8. Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to $\dfrac{8\lambda}{9}1$ the speed of the fastest emitted electron will be

(a) $> \left(\dfrac{9}{8}\right)^{647}$ (b) $< \left(\dfrac{9}{8}\right)^{647}$

(c) $= \left(\dfrac{9}{8}\right)^{647}$ (d) $= \left(\dfrac{8}{9}\right)^{647}$ *(2016)*

9. When photons of wavelength λ_1 are incident on an isolated sphere, the corresponding stopping potential is found to be V. When photons of wavelength λ_2 are used, the corresponding stopping potential was thrice that of the above value. If light of wavelength λ_3 is used then find the stopping potential for this case

(a) $\dfrac{hc}{e}\left[\dfrac{1}{\lambda_3}+\dfrac{1}{\lambda_2}-\dfrac{1}{\lambda_1}\right]$ (b) $\dfrac{hc}{e}\left[\dfrac{1}{\lambda_3}+\dfrac{1}{2\lambda_2}-\dfrac{1}{\lambda_1}\right]$

(c) $\dfrac{hc}{e}\left[\dfrac{1}{\lambda_3}-\dfrac{1}{\lambda_2}-\dfrac{1}{\lambda_1}\right]$ (d) $\dfrac{hc}{e}\left[\dfrac{1}{\lambda_3}+\dfrac{1}{2\lambda_2}-\dfrac{3}{2\lambda_1}\right]$

(Online 2016)

10. A photoelectric surface is illuminated successively by monochromatic light of wavelengths λ and $\dfrac{\lambda}{2}$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the surface is

(a) $\dfrac{hc}{2\lambda}$ (b) $\dfrac{hc}{\lambda}$ (c) $\dfrac{hc}{3\lambda}$ (d) $\dfrac{3hc}{\lambda}$

(Online 2016)

11. Match List-I (Fundamental Experiment) with List-II (its conclusion) and select the correct option from the choices given below the list.

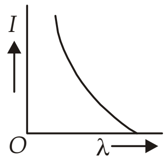
	List-I		List-II
P.	Franck-Hertz Experiment	(i)	Particle nature of light
Q.	Photo-electric Experiment	(ii)	Discrete energy levels of atom
R.	Davisson-Germer Experiment of electron	(iii)	Wave nature
		(iv)	Structure of atom

(a) P - (ii), Q - (i), R - (iii)
(b) P - (iv), Q - (iii), R - (ii)
(c) P - (i), Q - (iv), R - (iii)
(d) P - (ii), Q - (iv), R - (iii) *(2015)*

12. de-Broglie wavelength of an electron accelerated by a voltage of 50 V is close to ($|e| = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ J s)
(a) 0.5 Å (b) 1.2 Å (c) 1.7 Å (d) 2.4 Å *(Online 2015)*

13. The de-Broglie wavelength associated with the electron in the $n = 4$ level is
(a) two times the de-Broglie wavelength of the electron in the ground state
(b) four times the de-Broglie wavelength of the electron in the ground state
(c) half of the de-Broglie wavelength of the electron in the ground state
(d) $1/4^{th}$ of the de-Broglie wavelength of the electron in the ground state. *(Online 2015)*

14. 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

(a)


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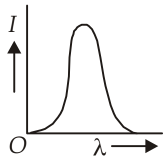

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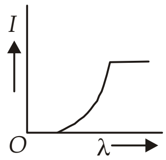

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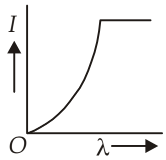


(2013)

15. This question has Statement 1 and Statement 2. Of the four choices given after the statements, choose the one that best describes the two statements.
Statement 1 : Davisson - Germer experiment established the wave nature of electrons.
Statement 2 : If electrons have wave nature, they can interfere and show diffraction.
(a) Statement 1 is true, Statement 2 is false.
(b) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation for Statement 1.
(c) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.
(d) Statement 1 is false, Statement 2 is true. *(2012)*

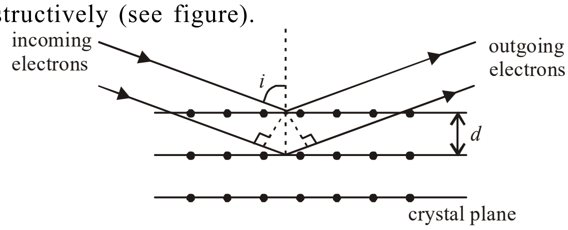
16. This question has Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.
Statement-1 : A metallic surface is irradiated by a monochromatic light of frequency $\upsilon > \upsilon_0$ (the threshold frequency). The maximum 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.
(a) Statement-1 is true, statement-2 is false.
(b) Statement-1 is true, Statement-2 is true, Statement-2 is the correct explanation of Statement-1.
(c) Statement-1 is true, Statement-2 is true, Statement-2 is not the correct explanation of Statement-1.
(d) Statement-1 is false, Statement-2 is true. *(2011)*

17. If a source of power 4 kW produces 10^{20} photons/second, the radiation belongs to a part of the spectrum called
(a) γ-rays (b) X-rays
(c) ultraviolet rays (d) microwaves *(2010)*

18. This question has Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.
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.
(a) Statement-1 is true, Statement-2 is false.
(b) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(c) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(d) Statement-1 is false, Statement-2 is true. *(2010)*

19. The surface of a metal is illuminated 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 (hc = 1240 eV nm)
(a) 3.09 eV (b) 1.41 eV
(c) 1.51 eV (d) 1.68 eV *(2009)*

Directions : Questions 20, 21 and 22 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).

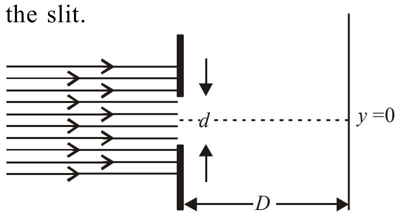


20. Electrons accelerated by potential V are diffracted from a crystal. If d = 1 Å and $i = 30°$, V should be about ($h = 6.6 \times 10^{-34}$ J s, $m_e = 9.1 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C)
(a) 1000 V (b) 2000 V
(c) 50 V (d) 500 V

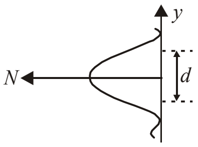
21. If a strong diffraction peak is observed when electrons are incident at an angle i from the normal to the crystal planes with distance d between them (see figure), de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer)

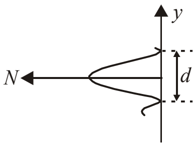
(a) $d \cos i = n\lambda_{dB}$ (b) $d \sin i = n\lambda_{dB}$
(c) $2d \cos i = n\lambda_{dB}$ (d) $2d \sin i = n\lambda_{dB}$

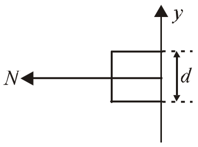
22. In an experiment, electrons are made to pass through a narrow slit of width d comparable to their de Broglie wavelength. They are detected on a screen at a distance D from the slit.

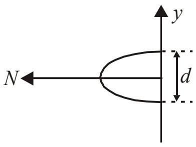


Which of the following graphs can be expected to represent the number of electrons N detected as a function of the detector position y ($y = 0$ corresponds to the middle of the slit)?

(a) 

(b) 

(c) 

(d) 

(2008)

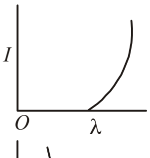
23. If g_E and g_M are the accelerations due to gravity on the surfaces of the earth and the moon respectively and if Millikan's oil drop experiment could be performed on the two surfaces, one will find the ratio

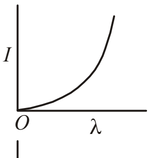
$$\frac{\text{electronic charge on the moon}}{\text{electronic charge on the earth}} \text{ to be}$$

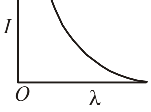
(a) g_M/g_E (b) 1
(c) 0 (d) g_E/g_M *(2007)*

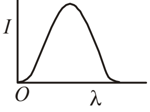
24. Photon of frequency υ has a momentum associated with it. If c is the velocity of light, the momentum is
(a) $h\upsilon/c$ (b) υ/c
(c) $h\upsilon c$ (d) $h\upsilon/c^2$ *(2007)*

25. 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

(a) 

(b) 

(c) 

(d) 

(2006)

26. 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 5 V. The incident radiation lies in
(a) X-ray region (b) ultra-violet region
(c) infra-red region (d) visible region *(2006)*

27. The time by a photoelectron to come out after the photon strikes is approximately
(a) 10^{-1} s (b) 10^{-4} s
(c) 10^{-10} s (d) 10^{-16} s *(2006)*

28. If the kinetic energy of a free electron doubles, its de Broglie wavelength changes by the factor
(a) $1/\sqrt{2}$ (b) $\sqrt{2}$ (c) 1/2 (d) 2 *(2005)*

29. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed (1/2) m away, the number of electrons emitted by photocathode would
(a) decrease by a factor of 2
(b) increase by a factor of 2
(c) decrease by a factor of 4
(d) increase by a factor of 4 *(2005)*

30. A charged oil drop is suspended in a uniform field of 3×10^4 V/m so that it neither falls nor rises. The charge on the drop will be (take the mass of the charge $= 9.9 \times 10^{-15}$ kg and $g = 10$ m/s^2)
(a) 3.3×10^{-18} C (b) 3.2×10^{-18} C
(c) 1.6×10^{-18} C (d) 4.8×10^{-18} C *(2004)*

31. 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
(a) 540 nm (b) 400 nm
(c) 310 nm (d) 220 nm *(2004)*

32. 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
(a) depends on the nature of the metal used
(b) depends on the intensity of the radiation
(c) depends both on the intensity of the radiation and the metal used
(d) is the same for all metals and independent of the intensity of the radiation. *(2004)*

33. Two identical photocathodes receive light of frequencies f_1 and f_2. If the velocities of the photoelectrons (of mass m) coming out are respectively v_1 and v_2, then
(a) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$ (b) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{\frac{1}{2}}$
(c) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$ (d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{\frac{1}{2}}$
(2003)

34. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to
(a) 1 : 2 (b) 4 : 1 (c) 2 : 1 (d) 1 : 4
(2002)

ANSWER KEY

1. (a)	**2.** (d)	**3.** (b)	**4.** (a)	**5.** (b)	**6.** (a)	**7.** (d)	**8.** (a)	**9.** (d)	**10.** (a)	**11.** (a)	**12.** (c)
13. (b)	**14.** (a)	**15.** (b)	**16.** (d)	**17.** (b)	**18.** (a)	**19.** (b)	**20.** (c)	**21.** (c)	**22.** (a)	**23.** (b)	**24.** (a)
25. (c)	**26.** (b)	**27.** (c)	**28.** (a)	**29.** (d)	**30.** (a)	**31.** (c)	**32.** (d)	**33.** (a)	**34.** (c)		

Explanations

1. **(a)** : Momentum of two electrons are $\frac{h}{\lambda_1}\hat{i}$ and $\frac{h}{\lambda_2}\hat{j}$.

Velocity of centre of mass $\vec{V}_{\text{CM}} = \frac{h}{2m\lambda_1}\hat{i} + \frac{h}{2m\lambda_2}\hat{j}$

Velocity of first electron about centre of mass is

$$\vec{V}_{1\text{CM}} = \frac{h}{2m\lambda_1}\hat{i} - \frac{h}{2m\lambda_2}\hat{j}$$

$$\lambda_{\text{CM}} = \frac{h}{\sqrt{\frac{h^2}{4\lambda_1^2} + \frac{h^2}{4\lambda_2^2}}} = \frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2 + \lambda_2^2}}$$

2. **(d)** : $\lambda_p = \frac{h}{p_p} = \frac{h}{m_p v_p}$ and $\lambda_\alpha = \frac{h}{m_\alpha v_\alpha}$

As, $\lambda_p = \lambda_\alpha$ or $\frac{h}{m_p v_p} = \frac{h}{m_\alpha v_\alpha}$ $\therefore$ $\frac{v_p}{v_\alpha} = \frac{m_\alpha}{m_p} = \frac{4m_p}{m_p} = \frac{4}{1}$

3. **(b)** : As de Brogile wavelength is given by

$\lambda = \frac{h}{p}$ $\therefore$ $\frac{\lambda_B}{\lambda_G} = \frac{p_G}{p_B} = \frac{mv_G}{mv_B}$

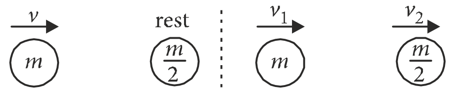
As $v \propto \frac{Z}{n}$; so $\frac{\lambda_B}{\lambda_G} = \frac{n_B}{n_G} = \frac{3}{1}$ or $\lambda_B = 3\ \lambda_G$

4. **(a)** : Minimum possible wavelengthof X-rays is $\lambda_{\text{min}} = \frac{hc}{eV}$

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

This is the equation of a straight line with negative slope and positive intercept on the y-axis ($\log\lambda_{\text{min}}$).

5. **(b)** : Velocity of the particle before and after the collision is shown in figure.



before collision after collision

Applying momentum conservation, we get

$$mv = mv_1 + \frac{m}{2}v_2; \quad v = v_1 + \frac{v_2}{2}$$

$$2v = 2v_1 + v_2 \qquad \text{... (i)}$$

Also, coefficient of restitution,

$$e = \frac{\text{velocity of separation}}{\text{velocity of approach}} = \frac{v_2 - v_1}{v - 0}$$

For elastic collision, $e = 1$

$$v = v_2 - v_1 \qquad \text{... (ii)}$$

Solving eqns. (i) and (ii), we get $v_1 = \frac{v}{3}$, $v_2 = \frac{4v}{3}$

Now, $\lambda = \frac{h}{p} = \frac{h}{mv}$ *i.e.* $\lambda \propto \frac{1}{mv}$

$$\therefore \frac{\lambda_A}{\lambda_B} = \frac{m_B v_B}{m_A v_A} = \frac{m_B v_2}{m_A v_1} \Rightarrow \frac{\lambda_A}{\lambda_B} = \frac{m}{2m}\left(\frac{4v}{3}\right)\left(\frac{3}{v}\right) = 2$$

6. **(a)** : $E_1 = \frac{1}{2}mv^2 = hn - \phi$

If incident frequency is increased to $3n$

$$E_2 = \frac{1}{2}mv'^2 = 3hn - \phi = 3(hn - \phi) + 2\phi = 3 \times \frac{1}{2}mv^2 + 2\phi$$

$$v'^2 = 3v^2 + 4\phi/m; \ v' > v\sqrt{3}$$

7. **(d)** : Here, $\lambda = 660$ nm $= 660 \times 10^{-9}$ m

$t = 60$ ms $= 60 \times 10^{-3}$ s; $P = 0.5$ kW $= 500$ W

$h = 6.62 \times 10^{-34}$ J s, $n = ?$

As, $P = \frac{E}{t} = \frac{nhc}{\lambda t}$; $\therefore n = \frac{P\lambda t}{hc}$

$$n = \frac{500 \times 660 \times 10^{-9} \times 60 \times 10^{-3}}{6.62 \times 10^{-34} \times 3 \times 10^{8}} \quad \therefore n \approx 10^{20}$$

8. **(a)** : According to Einstein's photoelectric effect maximum kinetic energy of a photoelectron, $\text{RL} = \frac{6}{7}\ {}^{7} = \frac{}{\lambda} - \phi$

According to question, for incident radiation of wavelength λ maximum speed of photoelectron is v.

$$\therefore \frac{6}{7}\ {}^{7} = \frac{}{\lambda} - \phi \qquad \text{...(i)}$$

Assume speed of fastest photoelectron is v' when incident photon has wavelength $\frac{3}{4}\lambda$.

$$\therefore \frac{6}{7}\ {}^{\prime 7} = \frac{9}{8\lambda} - \phi \ \{\sim \frac{6}{7}\ {}^{\prime 7} = \frac{9}{8}\left(\frac{6}{7}\ {}^{7} + \phi\right) - \phi$$

$$\{\sim \frac{6}{7}\ {}^{\prime 7} = \frac{7}{8}\ {}^{7} + \frac{\phi}{8} \ \{\sim\ {}' = \sqrt{\frac{9}{8}\ {}^{7} + \frac{7\phi}{8}} \therefore\ {}' > \sqrt{\frac{9}{8}}$$

9. **(d)** : Let the threshold wavelength for sphere be λ_0. According to Einstein's photoelectric equation

$$eV_s = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} \qquad \therefore\ eV = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_0} \qquad \text{...(i)}$$

$$3eV = \frac{hc}{\lambda_2} - \frac{hc}{\lambda_0} \qquad \text{...(ii)}$$

$$eV' = \frac{hc}{\lambda_3} - \frac{hc}{\lambda_0} \qquad \text{...(iii)}$$

From eqns. (i) and (ii)

$$\frac{2hc}{\lambda_0} = \frac{3hc}{\lambda_1} - \frac{hc}{\lambda_2} \text{ or } \frac{hc}{\lambda_0} = \frac{3hc}{2\lambda_1} - \frac{hc}{2\lambda_2}$$

Substituting in eqn. (iii)

$$eV' = \frac{hc}{\lambda_3} - \frac{3hc}{2\lambda_1} + \frac{hc}{2\lambda_2} \text{ or } V' = \frac{hc}{e}\left[\frac{1}{\lambda_3} - \frac{3}{2\lambda_1} + \frac{1}{2\lambda_2}\right]$$

10. **(a)** : According to Einstein's photoelectric equation, Maximum energy of photoelectrons

$(\text{KE})_{\text{max}} = h\upsilon - \phi_0$

$$(KE)_{max} = \frac{hc}{\lambda} - \phi_0$$

First case, $K = \frac{hc}{\lambda} - \phi_0$ ...(i)

Second case, $3K = \frac{2hc}{\lambda} - \phi_0$ ...(ii)

From equations (i) and (ii)

$$3\left(\frac{hc}{\lambda} - \phi_0\right) = \frac{2hc}{\lambda} - \phi_0 \Rightarrow 2\phi_0 = \frac{3hc}{\lambda} - \frac{2hc}{\lambda} = \frac{hc}{\lambda} \therefore \phi_0 = \frac{hc}{2\lambda}$$

11. (a) : Franck-Hertz Experiment - Discrete energy levels of atom.
Photo-electric experiment - Particle nature of light.
Davisson-Germer Experiment - Wave nature of electron.

12. (c) : Momentum, $p = \sqrt{2mE}$ and $E = eV$

So, de-Broglie wavelength of the electron is given by,

$$\lambda = \frac{}{} = \frac{}{\sqrt{7\ \ b}} = \frac{}{\sqrt{7\ \ \ s}} = \frac{;3\times 65^{-89}}{\sqrt{7\times >36\times 65^{-86}\times 63\times 65^{-6>}\times :5}}$$

$= 1.7 \times 10^{-10}$ m $= 1.7$ Å

13. (b) : de-Broglie wavelength of electron, $\lambda = \frac{}{}$

$$\text{Hx\{} \qquad = \frac{}{7\pi}$$

$$\lambda = \frac{7\pi}{} \quad \because\ r \propto n^2 \ \therefore \lambda \propto n$$

For $n = 4$, $\lambda_4 = 4\lambda_1$ *i.e,* the de-Broglie wavelength is four times that of ground state.

14. (a)

15. (b) : Davisson-Germer experiment showed that electron beams can undergo diffraction when passed through atomic crystals. This shows the wave nature of electrons as waves can exhibit interference and diffraction.

16. (d) : The maximum kinetic energy of the electron
$K_{max} = h\upsilon - h\upsilon_0$
Here, υ_0 is threshold frequency.
The stopping potential is $eV_0 = K_{max} = h\upsilon - h\upsilon_0$
Therefore, if υ is doubled K_{max} and V_0 is not doubled.

17. (b) : Here, power of a source, $P = 4$ kW $= 4 \times 10^3$ W

Number of photons emitted per second, $N = 10^{20}$

Energy of photon, $E = h\upsilon = \frac{hc}{\lambda}$

$$\because\ E = \frac{P}{N} \qquad \therefore \frac{hc}{\lambda} = \frac{P}{N}$$

or $\lambda = \frac{Nhc}{P} = \frac{10^{20} \times 6.63 \times 10^{-34} \times 3 \times 10^8}{4 \times 10^3}$

$= 4.972 \times 10^{-9}$ m $= 49.72$ Å

It lies in the X-ray region.

18. (a) : According to Einstein's photoelectric equation
$K_{max} = h\upsilon - \phi_0$
where, υ = frequency of incident light
ϕ_0 = work function of the metal
Since $K_{max} = eV_0$

$V_0 = \frac{h\upsilon}{e} - \frac{\phi_0}{e}$ As $\upsilon_{\text{X-rays}} > \upsilon_{\text{Ultraviolet}}$

Therefore, both K_{max} and V_0 increase when ultraviolet light is replaced by X-rays.

Statement-2 is false.

19. (b) : The wavelength of light illuminating the photoelectric surface = 400 nm.

i.e., $h\upsilon = \frac{1240 \text{ eV nm}}{400 \text{ nm}} = 3.1 \text{ eV}$

Max. kinetic energy of the electrons = 1.68 eV
$h\upsilon = W_\phi$ + kinetic energy
$\therefore$ W_ϕ, the work function $= h\upsilon$ – kinetic energy
$= 3.1 - 1.68$ eV $= 1.42$ eV

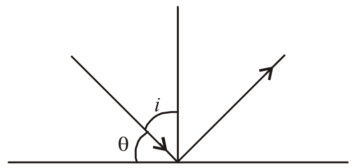
20. (c) : For electron diffraction, $d = 1$ Å, $i = 30°$
i.e., grazing angle $\theta = 60°$, $h = 6.6 \times 10^{-34}$ J s
$m_e = 9.1 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C
Bragg's equation for X-rays, which is also used in electron diffraction gives $n\lambda = 2d \sin\theta$

$\therefore\ \lambda = \frac{2 \times 1(\text{Å}) \times \sin 60°}{1}$ (assuming first order)

$\lambda = \sqrt{3}$ Å, $\sqrt{V} = \frac{(12.27 \times 10^{-10})}{\sqrt{3} \times 10^{-10}}$

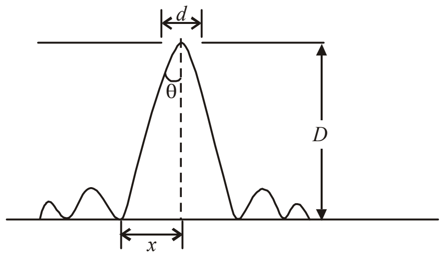
$V = 50.18$ Volt $\simeq 50$ V

21. (c) : Bragg's relation $n\lambda = 2d \sin\theta$ for having an intensity maximum for diffraction pattern.



But as the angle of incidence is given,
$n\lambda = 2d \cos i$ is the formula for finding a peak.

22. (a) : The electron diffraction pattern from a single slit will be as shown below.



$d \sin\theta = \frac{\lambda}{2\pi}$

The line of maximum intensity for the zeroth order will exceed d very much.

23. (b) : Since electronic charge (1.6×10^{-19} C) universal constant. It does not depend on g.
$\therefore$ Electronic charge on the moon = electronic charge on the earth

or $\frac{\text{electronic charge on the moon}}{\text{electronic charge on the earth}} = 1$

24. (a) : Energy of a photon $E = h\upsilon$ ... (i)
Also $E = pc$ ... (ii)
where p is the momentum of a photon

From (i) and (ii), we get $h\upsilon = pc$ or $p = \frac{h\upsilon}{c}$

25. (c) : The graph (c) depicts the variation of λ with I.

26. (b) : For photo-electron emission,
(Incident energy E) = (K.E.)$_{max}$ + (Work function ϕ)
or $E = K_m + \phi$
or $E = 5 + 6.2 = 11.2$ eV $= 11.2 \times (1.6 \times 10^{-19})$ J

$\therefore \quad \frac{hc}{\lambda} = 11.2 \times 1.6 \times 10^{-19}$ or $\lambda = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{11.2 \times 1.6 \times 10^{-19}}$ m

or $\lambda = 1110 \times 10^{-10}$ m $= 1110$ Å
The incident radiation lies in ultra violet region.

27. (c) : Emission of photo-electron starts from the surface after incidence of photons in about 10^{-10} sec.

28. (a) : de Broglie wavelength, $\lambda = h/p = h/\sqrt{(2mK)}$

$\therefore \quad \lambda = \frac{h}{\sqrt{2mK}}$ where K = kinetic energy of particle

$\therefore \quad \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{K_1}{2K_1}} = \frac{1}{\sqrt{2}}$

29. (d) : $I = \frac{P \text{ of source}}{4\pi(\text{distance})^2} = \frac{P}{4\pi d^2}$

Here, we assume light to spread uniformly in all directions. Number of photo-electrons emitted from a surface depend on intensity of light I falling on it. Thus the number of electrons emitted n depends directly on I. P remains constant as the source is the same.

$\therefore \quad \frac{I_2}{I_1} = \frac{n_2}{n_1} \Rightarrow \frac{P_2}{P_1}\left(\frac{d_1}{d_2}\right)^2 = \frac{n_2}{n_1} \therefore \frac{n_2}{n_1} = \left(\frac{P}{P}\right)\left(\frac{1}{1/2}\right)^2 = \frac{4}{1}$

30. (a) : For equilibrium of charged oil drop,
$qE = mg$

$\therefore \quad q = \frac{mg}{E} = \frac{(9.9 \times 10^{-15}) \times 10}{(3 \times 10^4)} = 3.3 \times 10^{-18}$ C

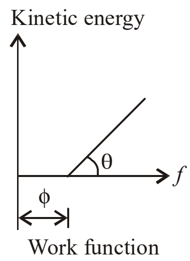
31. (c) : Let λ_m = Longest wavelength of light

$\therefore \quad \frac{hc}{\lambda_m} = \phi$ (work function)

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

or $\lambda_m = 310$ nm

32. (d) : According to Einstein's equation,
Kinetic energy $= hf - \phi$ where kinetic energy and f (frequency) are variables, compare it with equation, $y = mx + c$
$\therefore$ slope of line $= h$
h is Planck's constant.
Hence the slope is same for all metals and independent of the intensity of radiation.
Option (d) represents the answer.



33. (a) : For photoelectric effect, according to Einstein's equation,
Kinetic energy of emitted electron $= hf$ – (work function ϕ)

$\therefore \quad \frac{1}{2}mv_1^2 = hf_1 - \phi \quad \frac{1}{2}mv_2^2 = hf_2 - \phi$

$\therefore \quad \frac{1}{2}m(v_1^2 - v_2^2) = h(f_1 - f_2) \therefore \quad v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

34. (c) : Work function $= hc/\lambda$

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