Dual Nature of Matter & Radiation

2012

1. **A 200 W sodium street lamp emits yellow light of wavelength 0.6 μm. assuming it to be 25% efficient in converting electrical energy to light, the number of photons of yellow light it emits per second is**

   a) 1.5×10^{20} b) 6×10^{18} c) 62×10^{20} d) 3×10^{19}

2. **Monochromatic radiation emitted when electron on hydrogen atom jumps from first excited to the ground state potential is measured to be 3.57V. The threshold frequency of the material is**

   a) 4×10^{15} Hz b) 5×10^{15} Hz c) 1.6×10^{15} Hz d) 2.5×10^{15} Hz

3. **An α-particle moves in a circular path of radius 0.83 cm in the presence of a magnetic field of 0.25 Wb/m^2. The de Broglie wavelength associated with the particle will be**

   a) $1\ \overset{0}{A}$ b) $0.1\ \overset{0}{A}$ c) $10\ \overset{0}{A}$ d) $0.01\ \overset{0}{A}$

4. **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) 400 P c) $\frac{P}{200}$ d) 100 P

5. **Two radiations of photons energies 1 eV and 2.5 eV, successively illuminate a photosensitive metallic surface of work function 0.5 eV. The ratio of the maximum speeds of the emitted electrons is**

   a) 1:4 b) 1:2 c) 1:1 d) 1:5

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6. **Photoelectric emission occurs only when the incident light has more than a certain minimum**

   a) Power b) Wavelength c) Intensity d) Frequency

7. **In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by**

a) Increasing the potential difference between the anode and filament

b) Increasing the filament current

c) Decreasing the filament current

d) Decreasing the potential difference between the anode and filament

8. **Light of two different frequencies whose photons have energies 1 eV and 2.5 eV respectively illuminate a metallic surface whose work function is 0.5 eV successively. Ratio of maximum speeds of emitted electrons will be**

a) 1:4 b) 1:2 c) 1:1 d) 1:5

9. **Electrons used in an electron microscope are accelerated by a voltage of 25 kV. If the voltage is increased to 100 kV then the de-Broglie wavelength associated with the electrons would**

a) Increase by 2 times b) Decrease by 2 times

c) Decrease by 4 times d) Increase by 4 times

10. **In photoelectric emission process from a metal of work function 1.8 eV the kinetic energy of most energetic electrons is 0.5eV. The corresponding stopped potential is**

a) 1.8 V b) 1.3 V c) 0.5 V d) 2.3 V

11. **The threshold frequency for a photosensitive metal of 3.3 x 10^{14} Hz. If light of frequency 8.2 x 10^{14} Hz is incident on this metal, the cu-off voltage for the photoelectron emission is nearly**

a) 1 V b) 2 V c) 3 V d) 5 V

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12. **A beam of cathode rays is subjected to crossed electric (E) and magnetic fields (B). The fields are adjusted such that the beam is not deflected. The specific charge of the cathode rays is given by**

a) $\frac{B^2}{2VE^2}$ b) $\frac{2VB^2}{E^2}$ c) $\frac{2VE^2}{B^2}$ d) $\frac{E^2}{2VB^2}$

(Where V is the potential difference between cathode and anode)

13. **A source S_1 is producing, 10^{15} photons per second of wavelength 5000 $\overset{0}{A}$. Another source S_2 is producing 1.02 x 10^{15} photons per second of wavelength 5100 $\overset{0}{A}$. Then, (power of S_2)/(power of S_1) is equal to**

a) 1.00 b) 1.02 c) 1.04 d) 0.98

14. **The potential difference that must be applied to stop the fastest photoelectrons emitted by a nickel surface having work function 5.01 eV when ultraviolet light of 200nm falls on it, must be**

a) 2.4 V b) -1.2 V c) -2.4 V d) 1.2 V

15. **When monochromatic radiation of intensity I falls on a metal surface, the number of photoelectrons and their maximum kinetic energy are N and T respectively. If the intensity of radiations is 2I, the number of emitted electrons and their maximum kinetic energy are respectively**

a) N and 2T b) 2N and T c) 2N and 2T d) N and T

16. **The electron in the hydrogen atom jumps from excited state (n=-3) to its ground state (n=1) and the photons thus emitted irradiate a photosensitive material. If the work function of the material is 5.1 eV, the stopping potential is estimated to be (the energy of the electron in nth state $E = -\frac{13.6}{n^2}$ eV)**

a) 5.1 V b) 12.1 V c) 17.2 V d) 7 V

Previous examination questions key

1. a	**2. c**	**3.d**	**4.a**	**5. b**	**6. d**	**7. a**
8. b	**9.b**	**10.c**	**11.b**	**12.d**	**13.a**	**14.b**
15.b	**16.d**					

Solutions

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1. (a)

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

$= \frac{(6.6\times10^{-34} J\,s)(3\times10^{8} ms^{-1})}{0.6\times10^{-6} m}$

$= 33 \times 10^{-20}$ J

Number of photons emitted per second is

$N = \frac{\frac{25}{100}P}{E} = \frac{\frac{25}{100}\times200W}{33\times10^{-20}J} = 1.5\times10^{20}$

2. (c)

For hydrogen atom, $E_n = -\frac{13.6}{n^2} eV$

For ground state, n = 1

$\therefore E_1 = -\frac{13.6}{1^2} = -13.6eV$

For first excited state, n = 2

$\therefore E_2 = -\frac{13.6}{2^2} = -3.4eV$

$h\upsilon = E_2 - E_1 = -3.4eV$ -(-13.6eV) = 10.2 eV

Maximum kinetic energy

$K_{max} = eV_s = e \times 3.57\ V = 3.57\ eV$

According to Einstein's photoelectric equation

$K_{max} = h\upsilon - \phi_0$

3. (d)

Radius of the circular path of charged particles in a magnetic field is given by

$R = \frac{m\upsilon}{Bq}$

Or $m\upsilon = RBq$

de Broglie wavelength,

$$\lambda = \frac{h}{m\upsilon} = \frac{6.6\times10^{-34}}{0.83\times10^{-2}\times0.25\times2\times1.6\times10^{-19}} = 0.01\overset{0}{A}$$

4. (a)

De Broglie wavelength associated with aN electron is

$$P = \frac{h}{\lambda}$$

$$\therefore \frac{\Delta P}{P} = -\frac{\Delta\lambda}{\lambda}$$

$$\frac{P}{P_{initial}} = \frac{0.5}{100}$$

$P_{inital} = 200P$

5. (b)

According to Einstein's photoelectric equation

$$\frac{1}{2}m\upsilon_{\max}^2 = h\upsilon - \phi_0$$

$$\therefore \frac{1}{2}m\upsilon_{\max_1}^2 = 1eV - 0.5eV = 0.5eV \quad \text{............... (i)}$$

$$\therefore \frac{1}{2}m\upsilon_{\max_2}^2 = 2.5eV - 0.5eV = 2eV \quad \text{............... (ii)}$$

Divide (i) and (ii), we get

$$\frac{\upsilon_{\max_1}^2}{\upsilon_{\max_2}^2} = \frac{0.5}{2}$$

$$\frac{\upsilon_{\max_1}}{\upsilon_{\max_2}} = \sqrt{\frac{0.5}{2}} = \frac{1}{2}$$

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6. (d) According to Einstein's photoelectric equation

$$K_{\max} = h\upsilon - h\upsilon_0$$

Since $K_{\max}$ is +ve, the photoelectric emission occurs only if

$$h\upsilon > h\upsilon_0 \text{ Or } \upsilon > \upsilon_0$$

The photoelectric emission occurs only when the incident light has more than a certain minimum frequency. The minimum frequency is called threshold frequency.

7. (a)

8. (b) Here, work function, $\phi_0 = 0.5eV$

According to Einstein's photoelectric equation

Maximum kinetic energy of the emitted electrons = Incident photon energy – Work function

$\therefore \quad K_{\max_1} = 1eV - 0.5eV = 0.5eV$ ….. (i)

and $K_{\max_2} = 2.5eV - 0.5eV = 2eV$ …..(ii)

Divide (i) by (ii), we get

$$\frac{K_{\max_1}}{K_{\max_2}} = \frac{0.5eV}{2eV} = \frac{1}{4}$$

$$\frac{\frac{1}{2}m\upsilon^2{}_{\max_1}}{\frac{1}{2}m\upsilon^2{}_{\max_2}} = \frac{1}{4} \qquad \text{Or } \frac{\upsilon_{\max_1}}{\upsilon_{\max_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

9. (b) The de Broglie wavelength λ associated with the electrons is

$$\lambda = \frac{1.227}{\sqrt{V}} nm$$

Where V is the accelerating potential in volts

Or $\lambda \propto = \frac{1}{\sqrt{V}}$

$$\therefore \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_2}} = \sqrt{\frac{100\times10^3}{25\times10^3}} = 2 \quad \text{Or } \lambda_2 = \frac{\lambda_1}{2}$$

10. (c) The stopping potential V_s is related to the maximum kinetic energy of the emitted electrons K_{max} through the relation

$$K_{max} = eV_s$$

$$0.5 \text{ eV} = eV_S \text{ or } V_S = 0.5 \text{ V}$$

11. (b) According to Einstein's photoelectric equation

$eV_0 = h\upsilon - h\upsilon_0$

Where, υ = Incident frequency

υ_0 = Threshold frequency

V_0 = Cut-off or stopping potential

or $V_0 = \frac{h}{e}(\upsilon - \upsilon_0)$

Substituting the given values, we get

$$V_0 = \frac{6.63\times10^{-34}\left(8.2\times10^{14} - 3.3\times10^{14}\right)}{1.6\times10^{-19}} = 2V$$

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12. (d) When a beam of cathode rays (or electrons) are subjected to crossed electric (E) and magnetic (B) fields, then beam is not deflected, if Force on electron due to Magnetic field = Force on electron due to electric field

$$Be\upsilon = eE$$

Or $\upsilon = \frac{E}{B}$ …. (i)

If V is the potential difference between the anode and the cathode, then

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

$$\frac{e}{m} = \frac{\upsilon^2}{2V}$$

Specific charge of the cathode rays $\frac{e}{m} = \frac{E^2}{2VB^2}$

13. (a) For a source S_1,

Wavelength, $\lambda_1 = 5000\,\overset{0}{A}$

Number of photons emitted per second, $N_1 = 10^{15}$

Energy of each photon, $E_1 = \frac{hc}{\lambda_1}$

Power of sources $S_1, P_1 = E_1 N_1$

$$= \frac{N_1 hc}{\lambda_1}$$

For a source S_2,

Wavelength, $\lambda_2 = 5100\,\overset{0}{A}$

Number of photons emitted per second, $N_2 = 1.02 \times 10^{15}$

Energy of each photon, $E_2 = \frac{hc}{\lambda_2}$

Power of source $S_2, P_2 = E_2 N_2 = \frac{N_2 hc}{\lambda_2}$

$$\therefore \frac{Power\ of\ S_2}{Power\ of\ S_1} = \frac{P_2}{P_1} = \frac{\frac{N_2 hc}{\lambda_2}}{\frac{N_1 hc}{\lambda_1}} = \frac{N_2 \lambda_1}{N_1 \lambda_2}$$

$$= \frac{\left(1.02\times10^{15}\ photons/s\right)\times\left(5000\ \overset{0}{A}\right)}{\left(10^{15}\ photons/s\right)\times\left(5100\ \overset{0}{A}\right)} = \frac{51}{51} = 1$$

14. (b)

Incident wavelength, λ =200nm

Work function, ϕ_0 =5.01 eV

According to Einstein's photoelectric equation

$$eV_s = h\upsilon - \phi_0$$

$$eV_s = \frac{hc}{\lambda} - \phi_0$$

Where V_s is the stopping potential

$$eV_s = \frac{(1240eV\ nm)}{(200\ nm)} - 5.01eV$$

= 6.2 eV - 5.01 eV = 1.2 eV

Stopping potential, V_s = 1.2 eV

The potential difference that must be applied to stop photoelectrons = $-V_s$ = -1.2 V

15. (b) The number of photoelectrons ejected is directly proportional to the intensity of incident light. Maximum kinetic energy is independent of intensity of incident light but depends upon the frequency of light.

16. (d) Energy released when electron in the atom jumps from excited state (n = 3) to ground state

(n = 1) is

$$E = h\upsilon = E_3 - E_1 = \frac{-13.6}{3^2} - \left(\frac{-13.6}{1^2}\right)$$

$$= \frac{-13.6}{9} + 13.6 = 12.1 eV$$

Therefore, stopping potential

$$eV_0 = h\upsilon - \phi_0$$

$= 12.1 – 5.1$ [$\because$ work function $\phi_0 = 5.1$]

$V_0 = 7V$