QB365

Important Questions - Dual Nature of Matter and Radiation

12th Standard CBSE

Physics Reg.No. :

Time : 01:00:00 Hrs

Total Marks : 50

Section-A

1) The work function of lithium and copper are 2.3eV and 4.0eV respectively. Which of these metals will be useful for the photoelectric cell working with visible light? Explain. **1**

2) What determines the maximum velocity of the photoelectrons? **1**

3) Define space charge. What is its effect on the emission of photoelectrons from a metal surface? **1**

4) Two metals A and B have work functions 4eV and 10eV respectively. Which metal has higher threshold wavelength? **1**

5) Two beams one of red light and other of blue light of the same intensity are incidents on a metallic surface to emit photoelectrons. Which one of the two beam emits photoelectrons. Which one of the two beam emits electrons of greater kinetic energy? **1**

6) The photoelectric current at a distance $r_1 and r_2$ of light source from the photoelectric cell is respectively $I_1 and I_2$. Find the value of. I_1/I_2 **1**

Section-B

7) Explain the term stopping potential and a threshold frequency. **2**

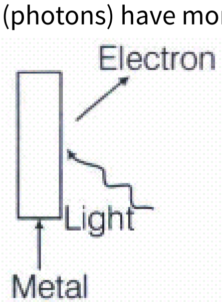
8) Is photoelectric emission possible at all frequencies? Give reasons for your answer. **2**

9) Green light ejects photoelectrons from a given photosensitive surface whereas yellow light does not. What will happen in the case of violet and red light? Give a reason for your answer. **2**

10) A particle with rest mass is m_0 moving with velocity c. What is the de-Broglie wavelength associated with it? **2**

11) Two monochromatic radiations, blue and violet, of the same intensity are incident on a photosensitive surface and cause photoelectric emission. Would **2**
(i) the number of electrons emitted per second and
(ii) the maximum kinetic energy of the electrons be equal in the two cases? Justify your answer.

12) Consider figure for photoemission. How would you reconcile with momentum conservation? Note light (photons) have momentum in a different direction than the emitted electrons. **2**



Section-C

13) 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? **3**

14) Estimating the following two numbers should be interesting.The first number will tell you why radio engineers do not need to worry much about photons.The second number tells you why our eye can never count photons,even in barely detectable light. (a) The number of photons emitted per second by an MW transmitter of 10 kW power emitting radio waves of wavelength 500 m. (b)The number of photons entering the pupil of our eye per second corresponding to the minimum intensity of while light that we humans can perceive ($\sim$ $(10^{-10} Wm^{-2})$ .Take the area of the pupil to be white light to be about 0.4 cm^2 and the average frequency of white light to be about $6 * 10^{14}$ **3**

15) Crystal diffraction experiments can be performed using X-rays,or electrons accelerated through appropriate voltage.Which probe has greater energy?(For quantitative comparison,take the wavelength of the probe equal to $1\overset{\circ}{A}$,which is of the order of inter-atomic spacing in the lattice),($m_e = 9.11 * 10^{-31} kg.$) **3**

16) Find the typical de-Broglie wavelength associated with a He atom in helium gas at room temperature $(27^{\circ}c)$ and 1 atm pressure , and compare it with the mean separation between two atoms under these conditions. **3**

Section-D

17) According to Plank's constant quantum theory of light, every source of radiation emits photons(i.e., packets of energy) which travel in all directions with the same speed(i.e., speed of light).Each photon is of energy $E = hv = \frac{hc}{\lambda}$ where h is plank's constant, v is the frequency and λ is wavelength of radiation emitted.The photons emitted from different sources of radiation are different. **5**

Read the above passage and answer the following questions:

(i) On what factors does the number of photons emitted per second from a source of radiation depend?

(ii) Why are the high energy photons not visible to eye?

(iii) Which basic values do you learn from this study?

18) Ram knows that red light has greater and so it is much bright, but in case of photoelectric emission it cannot produce the emission of electrons from a clean zinc surface, while even weak ultraviolet radiation can do so. He could not know specific cause of such thing. Then he went to his friend Shyam for its specific explanation. Shyam explained him that the photoemission of electron does not depend on the intensity while it depends on the frequency and thus on the energy of photon of incident light. The energy of photon of red light cannot emit photoelectrons. Similarly, the energy of photon of ultraviolet light is greater than the work function of zinc, so ultraviolet light can emit photoelectrons. **5**

(a) What values are noticed in Shyam?

(b) The work functions of lithium and copper are 2.3eV and 4eV respectively. Which of these metals are useful for the photoelectric cell working with visible light? Explain.

19) Shivam had knowledge that energy and momentum of an electron are related to frequency and wavelength of an electron are related to frequency and wavelength of the associated matter (de-Broglie) wave by the relations, E = hv, $p = \frac{h}{\lambda}$. But when he heard from his friend that value of λ is physically significance but the value of frequency v has no physical significance. Shivam requested Shubham to explain such thing clearly. Shubham said to him that according to de-Broglie a particle behavies as a wave, but it is now established that a particle cannot be equivalent to a single wave, but it is equivalent to a group of waves or a wave packet. As $p = \frac{h}{\lambda}$ so in the discussion of matter waves, a wave packet is significant and hence only wavelength, λ is significant. As a single wave is insignificant, so phase velocity (velocity of a single wave, v = vλ) is insignificant and thus, frequency v is also insignicant. **5**

(a) What are the values shown by Shubham?

(b) Calculate the

(i) momentum and

(ii) de Broglie wavelength of the electrons accelerated throught a potential difference of 56 V.

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Calculate the (i) momentum and (ii) de Broglie wavelength of the electrons accelerated throught a potential difference of 56 V.

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Section-A

1) Lithium, because its work function is less than the energy of the visible light photons. **1**

2) The frequency of the incident radiations and work function of the metallic surface. **1**

3) **1**

Space charge is the region or space around a metal surface in which the photoelectrons emitted from it get struck up when the anode is not given any positive potential. The creation of space charge decreases the probability of the emitted photoelectrons reaching the anode.

4) **1**

Work function, $\phi_0 = \frac{hc}{\lambda_0}$ where isλ_0 the threshold wavelength. So, $\lambda_0 \alpha \frac{1}{\phi_0}$. It means a metal with lower work function has higher threshold wavelength.

5) **1**

The energy of blue light $(hv)_{blue}$ is greater than the energy of red light. $(hv)_{red}$ In photoelectric emission, max K.E. of emitted electron $= hv - \phi_0, \quad i.e., max \quad K.E \alpha (hv)$ So, K.E of emitted electrons is more with blue light than that of red light.

6) $I \alpha \frac{I}{r^2} \quad so \quad \frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ **1**

Section-B

7) **2**

It is the minimum negative potential given to the anode in a photocell for which the photoelectric current becomes zero. If v_0 is the stopping potential, then maximum K.E. of emitted photoelectron is

$(K.E)_{max} = eV_0 = hv - \phi_0$

$V_0 = \frac{hv}{e} - \frac{\phi_0}{e}$

Threshold frequency It is the minimum frequency of the incident radiation for which just emission of photoelectrons takes place from a metal surface without any K.E. If V_0 is the threshold frequency, then using Einstein's photoelectric equation

$0 = hv_0 - \phi_0 \quad or \quad V_0 = \frac{\phi_0}{h}$

8) **2**

The photoelectric emission is possible if the energy of the incident photon is more than the work function of the metal, i.e., the energy required to just liberate an electron from the surface of the metal. If the energy of the incident photon is less than the work function of a metal, no emission of photoelectron will take place from a metal surface. The energy of a photon depends upon the frequency of the incident light. Thus the radiations of all frequencies whose photons are of energy more than the work function of a metal will cause photoelectric emission but the radiations of frequency less than threshold frequency will not cause photoelectric emission.

9) **2**

The photoelectrons can be emitted from a metal surface if the frequency of incident radiation is more than the threshold frequency, i.e., more than that of green light for the given surface. As the frequency of violet light is more than that of green light, hence violet light will eject photoelectrons. But the frequency of red light is less than that of the green light, hence red light can not eject photoelectrons from the given surface.

10) $\lambda = \frac{h}{mv} = \frac{h\sqrt{1-v^2/c^2}}{m_0 v} = \frac{h\sqrt{1-c^2/c^2}}{m_0 c} = 0$ **2**

11) **2**

(i) The intensities for both ejected in two cases are same because it depends on the number of incident photons.

(ii) As, $KE_{max} = hv - \phi_0$

[Einstein's photoelectric equation]

The KE_{max} of violet radiation will be more.

12) 2

During photelectric emission, the momentum of incident photon is transferred to the metal. At microscopic level, atoms of a metal absorb the photon and its momentum is transferred mainly to the nucleus and electrons.

The excited electron is emitted. Therefore, the conservation of momentum is to be considerd as the momentum of incident photon transferred to the nucleus and electrons.

Section-C

13) 3

(a) m=0.040 kg, $v=1.0km/s=1000ms^{-1}$ $\lambda=\frac{h}{mv}=\frac{6.62*10^{-34}}{0.04*1000}$ or $\lambda=0.1655*10^{-34}m$ $= = 1.7*10^{-35}m$ (b) $m=0.060kg, v=1.0ms^{-1}$ $\therefore$ $\lambda=\frac{h}{mv}=\frac{6.62*10^{-34}}{0.06*1}$ = $1.1*10^{-32}m$ (c) m=$1.0*10^{-9}kg, v=2.2ms^{-1}$ $\therefore$ $\lambda=\frac{h}{mv}=\frac{6.62*10^{-34}}{10^{-9}*2.2}$ = $3.0*10^{-23}m$

14) 3

Here, Energy emitted per sec = 10kW E=10*10^3 Js^{-1} $\lambda=500m$

Number of photons emitted per sec,n=? From relation,c=$c=v\lambda$ Frequency of photon, $v=\frac{c}{\lambda}=\frac{3*10^8}{500}$ $=6*10^5Hz$

Energy of each photon=hv Number of photon's emitted per sec, $n=\frac{E}{hv}$ = $\frac{10*10}{6.626*10*6*10}$ $=2.52*10^{31}$ per sec We see that the energy of a radio photon is very small and the number of photons emitted per second in a radio beam is very large.There is therefore, negligible error involved in ignoring the existence of a minimum quantum energy (photon) and treating the total energy of a radio wave as continuous. (b)Energy entering the pupil of eye per sec, E=intensity*area =$10^{-10}*0.4*10^{-4}$ =$4*10^{-15}J/s$ Number of photons entering pupil per sec $n=\frac{E}{hv}$ $=\frac{4*10^{-15}}{6.626*10^{-34}*6*10^5}$ =10^4 per sec. Though this number is not as large as in(a) above,it is large enough for us never to 'sense' or 'count' individual photons by our

15) 3

$\lambda=1\mathring{A}=10^{-10}m$ $1*10^{-10}=\frac{6.625*10^{-34}}{\sqrt{2*9.1*10^{-33}*E}}$ or E = 150 eV This gives the

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

energy of electron. Energy of photon, E = $\frac{hc}{\lambda}$ $=\frac{6.625*10^{-34}*3*10^8}{1*10^{-10}*1.6*10^{-19}}$

=12.4*10^3 eV =12.4 keV. Thus for the same wavelength, a photon has much greater energy then an electron.

16) 3

Using $\lambda = \frac{h}{\sqrt{3mkT}}$ $M_{He} = \frac{Mol.wt.}{Avogadro \quad no.}$ This gives

$= \frac{4*10^{-3}}{6*10^{23}} kg = 6.67 * 10^{-27} kg$

$\lambda = \frac{6.62*10^{-34}}{\sqrt{3*6.67*10^{-27}*1.38*10^{-23}*300}}$ $=0.73*10^{-10} m$ Mean separation $r = \left(\frac{V}{N}\right)^{1/3}$ For

T=300 k, $p = \frac{2}{3V} * \frac{3}{2} RT = \frac{RT}{V} = \frac{kNT}{V}$ $\therefore$ $r = \left(\frac{kT}{P}\right)^{1/3}$

$= 1.01 * 10^5 Pa$

$=\left(\frac{1.38*10^{-25}*300}{1.01*10.5}\right)^{1/3}$ r $=3.4 * 10^{-9} m.$ We find r>λ

Section-D

17) 5

(i) The number of photons emitted per second from a source of radiation on its temperature, nature and area of radiating surface.

(ii) The ratina of our eye is sensitive to visible light whose frequency range is $4 \times 10^{14} Hz \quad to \quad 8 \times 10^{14} Hz$High energy photons are frequency much higher than $8 \times 10^{14} Hz$They do not produce any sensation on our ratina.Hence, they cannot be seen by our eyes.

(iii) We have learnt that every source emits radiations(i.e., photons) The different source emits radiations of different energies, which have different effects on the exposed bodies.The radiations of holy persons cultivate in us the good qualities and radiations of criminals develop bad qualities.Therefore, we must live in a company of good people for better and peaceful life.

18) (a) The values noticed in Shyam are: 5

(i) High degree of general awareness.

(ii) Concern for his friend.

(iii) Helping and caring nature.

(b) The threshold wavelength, $\lambda_0 = \frac{hc}{W}$

For lithium, $\lambda_0 = \frac{12375}{2.3} \overset{0}{A} = 5380 \overset{0}{A}$

For copper, $\lambda_0 = \frac{12375}{4} \overset{0}{A} = 3094 \overset{0}{A}$

The wavelength 5380 $\overset{0}{A}$ lies in visible region, thus lithium will be useful for photoelectric cell.

19) (a) The values shown by Shubham are: 5

(i) High degree of general awarness.

(ii) High order of thinking skills.

(iii) Concern for his friend.

(iv) Helping and caring nature.

(b) Mass of electron, $m = 9.1 \times 10^{-31} kg$

(i) Momentum, $p = \sqrt{2mE_k} = \sqrt{2meV}$

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

$= 4.04 \times 10^{-24} kgms^{-1}$

(ii) de Broglie wavelength,

$= \frac{h}{p} = \frac{6.63 \times 10^{-34}}{4.04 \times 10^{-24}}$

$= 1.64 \times 10^{-10} m = 0.164 nm$

20) Mass of electron, $m = 9.1 \times 10^{-31} kg$ **5**

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