UNIT – VII DUAL NATURE OF MATTER AND RADIATIONS (4marks)

VERY SHORT ANSWER TYPE QUESTIONS:-

1. An electron and photon have same wavelength. Which one of the two has more energy?
Relativistic energy of a particle, E= $(m_0c^4+p^2c^2)^{½}$
Hence the electron has more energy than photon.

2. If wavelength of electromagnetic waves are doubled what will happen to energy of photon?
E = hν□
=hc/λ = E ∝ 1/λ energy of proton reduces to half.

3.Alkali metals are most suitable for photoelectric emission. Why?
Alkali metals have too low work functions. Even visible light can eject electrons from them.

4. Out of microwaves, UV, IR which radiation will be most effecting for emission of electrons from a metallic surface?
UV are most effective since they have highest frequency hence more energetic.

5. If the intensity of incident radiation on a metal is doubled what happens to the K.E of electrons emitted?
K.E of photons remains unaffected since they do not depend

6. What is the value of stopping potential between the cathode and anode of photocell? If the max K.E of electrons emitted is 5eV?
Stopping potential $V_0 = K_{max}/e$ = 5ev/e =5 V

7. It is easier to remove an electron from sodium than from copper, which has a higher value of threshold wavelength?

$w_0 = h\nu_0 = hc/\lambda_0$

$\therefore \lambda_0 \propto 1/ w_0$

Since sodium has lower work functions than copper it is easier for electron ejection. As it is lower work function, higher wavelength.

8. An electron and proton possessing same K.E. Which one will have greater wavelength?

$1/2\ mv^2 = (m^2 v^2)/2m = p^2/2m$

$\lambda_e > \lambda_p$

electrons have greater De broglie wavelength than proton .

9. In Davisson – Germer experiment if the angle of diffraction is 52^0 find Glancing angle?

$\theta = 90 - \phi/2$

$= 90 – 52/2 = 64°$

10. What is the effect on the velocity photo electrons, if the wavelength of incident light is decreased?

KE of photoelectrons is given by Einstein's photoelectric equation.

$E_k = 1/2\ mv^2$

$= h\upsilon - w_0$

$V \ \alpha\ 1/\sqrt{\lambda}$

As wavelength decreases velocity increases.

11. The stopping potential for some material is 1.2 V. What is the energy range of the emitted photoelectrons?

The range of energies of the emitted photoelectrons will be from 0 to 1.2 eV.

12.The intensity of incident radiations in a photoelectric experiment is doubled. How the stopping is potential affected?

The stopping potential will remain unaffected because it does not depend on the intensity of the incident light.

13. If the intensity of the incident radiation on a metal is doubled, what happens to the kinetic energy of the emitted photoelectrons?

There is no change in the kinetic energy of the emitted electrons. This K.E. is independent of the intensity of the incident radiation as long as its frequency remains the same.

14. The frequency (υ) of incident radiation is greater than threshold frequency (υ_q) in a photocell. How will the stopping potential vary if frequency (υ) is increased, keeping other factors constant?

When, ($\upsilon > \upsilon_o$) stopping potential will be increased.

15.What is the energy and wavelength of a thermal neutron ?

Kinetic energy of a thermal neutron = $f/2\ k_BT$.

Since degree of freedom of a thermal neutron is three.

$K.E = 3/2\ k_BT = 6.06 \times 10^{-21}$ J

Wave length , $\lambda_e = h/(2mK.E)^{1/2}$ = , $\lambda_e = h/(3m\ k_BT)^{1/2} = 0.147$nm.

16. An X –ray tube produces a continuous spectrum of radiation with its shots wavelength end 0.45 °A. What is the maximum energy of a photon in the radiation in electron volt?(ii) From your answer to (i) what order of accelerating voltage (fo0r electron) is required in such a tube?.

$E = h\upsilon = hc/\lambda = 27.6 \times 10^3$ eV

(ii)In this case energy of X-rays photon is 27.6 KeV, the striking electron must be of energy higher than 27.6 KeV. Therefore an accelerating voltage of the order of 30 KV is required.

17. It is difficult to remove free electrons from metal X as compare to metal Y . What you infer?

Work function of metal X is higher than metal Y.

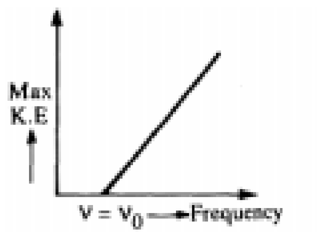
18. A particle behaves like a wave. What determine the wavelength of the wave?

Momentum of the moving particle.

19. Draw a graph giving variation of maximum kinetic energy of photoelectrons with frequency of incident radiations. What is the slope of this graph?

The equation of this straight line is

K.E. $= 1/2mv^2_{max} = h(\upsilon - \upsilon_o)$



20. The wavelength of radiations incident on a material is decreased. Does the maximum velocity of photoelectrons increase or decrease?

A decrease in wavelength implies an increase in frequency. Since an increase in frequency increases the maximum K.E. of the emitted photoelectrons, the maximum velocity would increase.

21. For photoelectric effect in sodium, the figure shows the plot of cut off voltage versus frequency of incident radiation. Calculate the threshold frequency (υ_0) the work function for sodium

(ii)The work function (W) is related to the threshold frequency (υ_0) by the relation.

$W_o = h\upsilon_o$ **= 6.6 x 10-34 x 4.5 x 1014 J**

= 29.7 xl0-20J = 2.97 xl0-i9J

$$= \frac{2.97 \times 10^{-19}}{1.6 \times 10^{-19}} eV \approx 1.856 eV$$

22. Suppose the photoelectric effect occurs in a gaseous target rather than a solid. Will photoelectrons be produced at all frequencies of the incident photons?

No; we are likely to get photoemission only for those frequencies whose photons have an energy equal to or more than the (minimum) ionization energy for the gas concerned.

23. Yellow light does not eject photoelectrons from a given photosensitive surface, whereas green light does. What shall be situation in case of red and violet light?

We will not get any photoemission with red light since its frequency is less than that of yellow light. We will, however, get photoemission with violet light since its frequency is more than that of green light.

24. By what factor does the maximum velocity of the emitted photoelectrons change when the wavelength "the incident radiation is increased four times? (Given that the initial frequency used is five times the threshold frequency)

When the wavelength is increased four times, the frequency goes down by a factor of four.

$$\frac{1}{2}mv_1^2=h(\nu_1-\nu_0) \quad and \quad \frac{1}{2}mv_2^2=h(\nu_2-\nu_0)$$

$$\frac{v_1^2}{v_2^2}=\frac{\nu_1-\nu_0}{\nu_2-\nu_0}$$

Now,

$$\frac{v_1^2}{v_2^2}=\frac{5\nu_0-\nu_0}{{}^5\!/_4\nu_0-\nu_0}=\frac{4\nu_0}{{}^1\!/_4\nu_0}=16 \qquad \frac{v_1}{v_2}=4$$

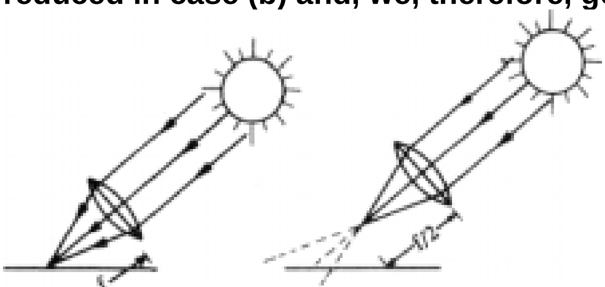
Thus, the maximum velocity goes down by a factor of 4.

25. A cesium photocell, with a steady potential difference of 90 volt across it, is illuminated by a small bright light placed one metre away. The number of electrons that cross the photocell is n. What will be the number of electrons crossing the photocell when the same light is placed half metre away?

When the light is brought to a distance of 0.5 m, the intensity of the light falling on the photocell goes up four times. Since the number of photoelectrons emitted is directly proportional to the intensity of incident light, the new number of photoelectrons emitted would become 4n.

26. The sun rays are focused on a metal surface , and it produces a current. The lens forming the image is then replaced by another lens of the same diameter but only half in focal length. What will be the effect on the photoelectric current?

Hence, the intensity of light falling on the metal surface gets reduced in case (b) and, we, therefore, get a reduced photoelectric current.



27. To work functions 2ev and 5ev for two metals x and y respectively. Which metal will emit electrons, when it is irradiated with light and wave length 400nm and why?

$\lambda = 400 \times 10^{-9} m = 4 \times 10^{-7} m$

$E = h\,c/\lambda = (6.6 \times 10^{-34} \times 3 \times 10^{8}) / (4 \times 10^{-7}) = 4.98 \times 10^{-19}$ j

$E = (4.98 \times 10^{-19}) / (1.6 \times 10^{-19}) = 3ev$

Hence, metal x will emit electrons.

28. A photon and an electron have same de-broglie wavelength. Which has greater total energy. Explain ?

For a photon $E_1 = hc/\lambda$

For an electron $\lambda = h/mv$ or $m = h/\lambda v$

$E_2 = mc^2$

$= (h/\lambda v) \times c^2$

$E_2/E_1 = c/v > 1$

Therefore, $E_2 > E_1$**.thus, electron has total energy greater then that of photon.**

29. The de-broglie wave length of a photon is same as the wave length of electron. Show that K.E. of a photon is 2mcλ/h times K.E. of electron. Where 'm' is mass of electron, c is velocity of light.

$\lambda_{ph} = \lambda_e = \lambda = h/mv$

K.E. of photon $E_{ph} = h\nu = hc/\lambda$

K.E. of electrons $E = 1/2mv^2 = 1/2\ m\ [h/m\lambda]^2$

$= h^2/2m\lambda^2$

$E_{ph}/E_e = (hc/\lambda) \times 2m\lambda^2/h^2$

$= 2mc\lambda/h$

$\therefore\quad E_{ph} = E_e(2mc\lambda/h)$

30. How may photons are required for emission of one photo electron if frequency of incident radiation is

less than threshold frequency.

More than threshold frequency.

(i)No photo – electron will be emitted and photons are absorbed by electrons.

ii)One photon will emit one photo electron.

31. State the dependence of work function on the kinetic energy of electrons emitted in a photocell. If the intensity of incident radiation is

doubled, what changes occur in the stopping potential and the photoelectric current?

According to Einstein theory of photoelectric effect, kinetic energy of emitted electron is

$$Ek = \frac{1}{2} m V_{max}^{2} = h\nu - W_0$$

Greater the work function of the metal, lesser the kinetic energy of the photoelectron. on doubling the intensity of the incident radiation stopping potential remains the same, whereas photoelectric current is doubled.

32. Using Davisson and Germer Experiment to establish the existence of de Broglie waves.

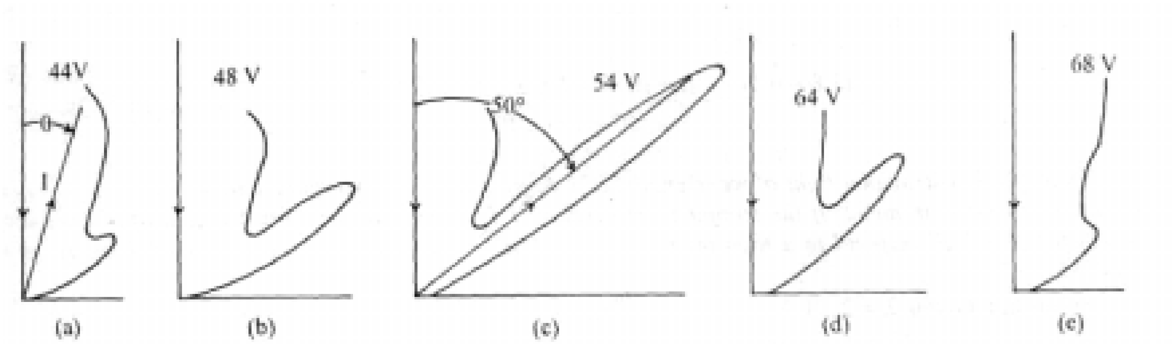
The experimental set up consists of an electron gun connected to a low tension battery. The electrons emitted by the gun are accelerated to a desired velocity by applying a suitable potential difference V using a high tension battery. Value of V can be varied.

Using Bragg's law of diffraction of light through crystal lattices, the wavelength of the wave showing diffraction peak at 50° was calculated as 1.65 A.

The predicted de Broglie wavelength of electrons accelerated through 54 V is

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2meV}} = \frac{12.27^{\circ}}{\sqrt{V}} A^{\circ} = \frac{12.27^{\circ}}{\sqrt{54}} A^{\circ} = 1.66 A^{\circ}$$

The excellent agreement between theoretical and experimental values of de Broglie wavelength confirms the wave nature of electrons and hence the existence of the de Broglie waves.



33. Through what potential difference an electron be accelerated so that it may have de – broglie wavelength 0.5Å?

Let v = potential through which electron is accelerated.

Therefore, Energy = $\frac{1}{2}mv^2 = eV$

=> $\lambda = h/(2mE)^{1/2} = h/(2mev)^{1/2}$

=> $v = h^2/2me\lambda^2$

here, $h = 6.625 \times 10^{-34}$ Js

$m = 9.1 \times 10^{-31}$ kg

$e = 1.6 \times 10^{-19}$ C

$\lambda = 0.5 \times 10^{-10}$ m

hence $v = 6.03 \times 10^4$ V

34. An e^- and photon have the same energy of 100eV. Which has greater associated wavelength?

Here, $\lambda_e = h/(2mEe)^{1/2}$

=> $E_e = h^2/2m\lambda_e^2$ ………………………………………….(1)

Now,

$E_p = hc/\lambda_p$ => $E_p^2 = \dfrac{h^2c^2}{\lambda_p^2}$ ……………………………….(2)

as $E_e = E_p = E = 100eV$ ……………………………………….(3)

Dividing equation (1) by (2) and using equation (3) we get

$$E = \frac{h^2c^2/\lambda_p^2}{h^2/2m\lambda_e^2}$$

$$\Rightarrow \quad E = \frac{2mc^2\lambda_e^2}{\lambda_p^2}$$

$$\lambda_e/\lambda_p = (E/2mc^2)^{1/2}$$

as E = 100eV

=> $2mc^2 \approx 1MeV$

therefore $E << 2mc^2$

ie $\lambda_e < \lambda_p$

Therefore the wavelength associated with a photon is greater than an electron for the same energy.

35. the frequency of the light falling on the metal is doubled, what will be the effect on photocurrent & the maximum Kinetic Energy?

The photo current does not depend on the frequency of incident radiation as:

$E_k = h\upsilon - W$

If the frequency is doubled

$E_k' = 2h\upsilon - W$

=> $E_k'/E_k = (2h\upsilon - W)/(h\upsilon - W) = (2h\upsilon - 2W + W)/(h\upsilon - W)$

$= 2 + W/(h\upsilon - W) > 2$

i.e. maximum KE will increase slightly more than double.

36.e work function of 'Li' and 'Cu' are 2.3eV & 4eV. Which of these metals will be useful for the photoelectric cells working with the visible light?

The threshold wavelength of a metal is:

$\lambda_o = hc/W = {}^{12475}/_{(W \text{ in eV})}$ Ǻ

=> ${}_{Li}\lambda_o = {}^{12375}/_{2.3}$ Ǻ = 5380 Ǻ

and ${}_{Cu}\lambda_0 = {}^{12375}/_{4}$ Ǻ = 3094 Ǻ

The wavelength 5380Ǻ lies in the visible region, hence 'Li' will be useful for the photoelectric cell.

37. An e^- has a speed of $5 \times 10^6\ {}^{m}/_{s}$ in a magnetic field of 10^{-4} T. What is the acceleration of e^- if ${}^{e}/_{m} = 1.76 \times 10^{11}\ {}^{C}/_{kg}$.

$BeV = mv^2$ as the force due to magnetic field provides the necessary centripetal force.

=> $v^2/r = {}^{Bev}/_{m}$

as acceleration = v^2/r

=> $a = B({}^{e}/_{m})$

=> $a = v^2/r = 10^{-4} \times 1.76 \times 10^{11} \times 5 \times 10^6$

=> $a = 8.8 \times 10^{13}\ ms^{-2}$.

38. Assume that the potential difference between cathode and anode is the same as that between two deflecting plates. If this potential difference is doubled, calculate by what factor the magnetic field should changed to keep the electron beam undeflected?

${}^{e}/_{m} = E^2/2vB^2$ But $E = {}^{V}/_{d}$

${}^{e}/_{m} = v^2/2vB^2d^2 = v/2B^2d^2$

or, $B^2 = \dfrac{v}{2({}^{e}/_{m})d^2}$.

or $B^2 \alpha v$ => $B \alpha \sqrt{v}$

if v is doubled, then

$B^{/}/B = (2)^{1/2}$ or $B^{/} = (2)^{1/2}B$

Thus, the magnetic field should be increased by a factor of $(2)^{1/2}$

39. Work function of the metals:

Na : 1.92 eV ; k : 2.15 ev ; Mo :4.17 ; Ni : 5.0;

Which of these willnot give photo electric emission for a radiation of wavelength 3300Å from a He-Cd laser placed 1m away ? What happens if laser is brought nearer and placed 50 cm away ?

Sol: Wavelength of the incident radiation , λ= 3300 Å

Frequency of radiation = $c/\lambda = 3*10^8/3300*10^{-10} = 9.1*10^{14}$ Hz

Threshold frequencies for different metals ;

v_0 (Na)= $1.92*1.6*10^{-19}/6.3*10^{-34} = 4.6*10^{14}$ Hz

v_0 (K)= $5.2 *10^{14}$ Hz

v_0 (Mo) =$1.0 * 10^{15}$ Hz

v_0 (Ni)= $1.2 *10^{15}$ Hz

Thus, the incident frequency ,v is greater than v_0 (Na) and v_0 (K) but less than v_0 (Mo) and v_0 (Ni) , therefore Mo and Ni will not give photo electric emission.

If the laser is brought closer , intensity decreases. This does not effect the result regarding Mo and Ni but photoelectric current will increase for Na and K.

40. a) show that a free e^- at rest can not absorb a photon and thereby acquire K.E. equal to the energy of the photon. Would the conclusion change if the e^- has a constant velocity.

b) If the absorption of a photon by a free e^- as proved in (a) , how does photo electric takes place?

Ans: a) the total energy of an e^- , $E = (m_0^2c^4+p^2c^2)^{1/2}$

$= m_0c^2+h\, v$

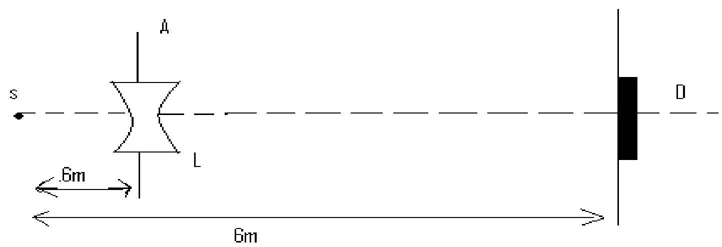
Squaring both the sides $p^2c^2+2m_0c^2pc= p^2c^2$

Or $2m_0c^2pc=0$

This is impossible

b) we have shown in (a) that $e^-+\gamma$ gives e^-. however, for an e^- a lattice the momentum of the incident photon can be shared by both the e^- and the lattice while the lattice due to large mass does not share the energy of the photon. Thus, e^- + γ +lattice gives e^- +lattice is not forbidden.

41. A monochromatic point source, S radiating wavelength 6000 Å with power 2W, an aperture A of diameter .1m are placed , area A = .5 cm^2, efficiency = .9 , h = $6.63*10^{-34}$js, c= $3*10^8$, e= $1.6*10^{-9}$C .
calculate the photon flux at the center of the screen and photo current in the detector if a concave lens L of focal length .6m is inserted in the aperture find the new values of photon flux and photocurrent , uniform average transmission is 80% .If the work function of the photo emissive surface is 1eV , calculate the values of the stopping potential.



Sol : Energy of each photon , E = hc/ λ = $6.63*10^{-34}*3*10^{8}/6*10^{-7}$ J

$=3.315*10^{-19}$J

Therefore number of photon emitted= power / energy of each photon

= $6.03*10^{18}$s -1

Number of photons passing through the aperture of diameter .1m

$N_A = 6.03*10^{18}s^{-1}/4\pi\ (.6)^2$ * $\pi*(.05)^2=1.047*10^{16}s^{-1}$

Now the screen is at a distance of 6m from the source let the area of the screen iluminated by the light from be a, therefore, a /$\pi*(.05)^2$ or a= .25π m^2

The number n_s = 1.33 *10^{16} photons

Number of photoelectrons = .6*10^{12} electrons

Photocurrent = .096 microA

b) 1/v = 1/f+ 1/u and thus, v= -.3m

photons transmitted through the lens n' = .838* 10^{16} s^{-1}

area illuminated = a' = .9025 π m^2

photon flux = n'/a'= 2.95*10^{15} photons

therefore photocurrent = .012 microA

42: Standing distance of the waves = 2 Å , d increased to 2.5 Å . energy of the electrons = ? . least value of d for which wave is defined ?

Ans: n λ = 2d (for standing wave)

Therefore n = $2d_1$/ λ and n+1 = $2d_2$/ λ

Therefore n+1-n = $2d_2$/ λ -$2d_1$/ λ

For least value of d, n is 1

Thus λ = $2d_{min}$

Energy of the electron E = p^2/2me

Now p=h /λ

Therefore E= 150.95 eV