**PHYSICS CLASS-XII –DUAL NATURE & RADIATION**

**Unit VII: Dual Nature of Radiation and Matter**            **08 Periods**

### Chapter–11: Dual Nature of Radiation and Matter

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light.

Matter waves-wave nature of particles, de-Broglie relation, Davisson-Germer experiment (experimental details should be omitted; only conclusion should be explained).

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701. What is Photoelectric effect ? **CBSE (AI)-2007,2004,(D)-2002**
 [ **Ans**. **Photoelectric effect** : When an electromagnetic radiation (such as U.V rays, x-rays etc.) of suitable frequency is incident on a metal surface, electrons are emitted from the surface. This phenomenon is called photoelectric effect

702. Define the term Work function of a photoelectric surface. **CBSE (AI)-2007,2004,(D)-2002**
 [ **Ans**. **(i) Work function (W)** : The minimum energy required to by an electron to just eject out from the metallic surface is called work function of that surface

$$W = h\nu_0 = \frac{hc}{\lambda_0}$$

703. Define the term (i) cut off frequency & (ii) Threshold wavelength in photoelectric emission.
 **CBSE (F) -2016,2011,(D)-2004,(AI)-2002**
 [ **Ans**. **(i) Cut off frequency ($\nu_0$)** :The minimum frequency of incident radiation, **below which** photoelectric emission is **not** possible, is called cut off frequency or threshold frequency

 **(ii) Threshold Wavelength ($\lambda_0$):** The maximum wavelength of incident radiation, **above which** photoelectric emission is **not** possible, is called threshold wavelength

704. Define the term 'intensity of radiation' in photon picture and write its S.I. unit. **CBSE (AI)-2016,2015**
 [ **Ans**. **Intensity of radiation** : Number of photons incident per unit area per second normal to the surface, is defined as the intensity of radiation. Its S.I. unit is Watt/ $m^2$

705. Define the term "stopping potential" or "Cut-off Potential" in relation to photoelectric effect.
 [ **Ans**. **Stopping potential or Cut-off Potential ($V_0$)** : **CBSE (AI) -2011,2008,2002, (D) -2005,2002**
 The minimum negative potential of anode at which photoelectric current becomes zero is called stopping potential

706. Name the phenomenon which shows the quantum nature of electromagnetic radiation. **CBSE (AI)-2017**
 [ **Ans**. Photoelectric effect

707. What is the stopping potential applied to a photocell if the maximum kinetic energy of a photoelectron is 5 eV ?
 [ **Ans**. $V_0 = -5 V$ ] **CBSE (AI) -2009, 2008, (D)-2001**

708. The stopping potential in an experiment is 1.5 V. What is the maximum K.E. of photoelectrons emitted ?
 [ **Ans**. $E_{k_{max}} = 1.5$ eV ] **CBSE (AI)-2009**

709. Two metals A and B have work functions 4 eV and 10 eV respectively. Which metal has the highest threshold wavelength ? **CBSE (AI) -2004, (F)-2005**
 [ **Ans**. **Metal A** has highest threshold wavelength as W= $\frac{hc}{\lambda_0}$

710. Two metals X and Y, when illuminated with appropriate radiations emit photoelectrons. The work function of X is higher than that of Y. Which metal will have higher value of cut off frequency & why ? **CBSE (AIC)-2001**
 [ **Ans**. **Metal X** has the higher cut off frequency because $\nu_0 = W/h$ & $W_X > W_Y$

711. A photosensitive surface emits photoelectrons when red light falls on it. Will the surface emit photoelectrons when blue light is incident on it ? Give reason. **CBSE (F)-2017**
 [ **Ans**. **Yes,** **Reason :** $\nu_{Blue} > \nu_{Red}$ $\Rightarrow (h\nu)_{Blue} > (h\nu)_{Red}$

712. For a photosensitive surface, threshold wavelength is $\lambda_0$, Does photoemission occure, if the wavelength ($\lambda$) of the incident radiation is (i) more than $\lambda_0$ (ii) less than $\lambda_0$. Justify your answer. **CBSE (AI)-2010, (AIC)-2001**
 [ **Ans**. **(i) No (ii) yes** as for photoelectric emission $\frac{hc}{\lambda} \geq \frac{hc}{\lambda_0}$ hence $\lambda \leq \lambda_0$ ]

713. Electrons are emitted from a photosensitive surface when it is illuminated by green light but does not take place by yellow light. Will the electrons be emitted when the surface is illuminated by (i) red light, and (ii) blue light ?
 [ **Ans**.**(i) No (ii) yes** as $\lambda_0$ is for wavelength of green light ] **CBSE (AI)-2012,2007, (D)-2005**

714. Red light however bright is it, cannot produce the emission of electrons from a clean zinc surface but even a weak Ultraviolet radiation can do so. Why ? **CBSE (AI)-2004, (AIC)-2003**
 [ **Ans**. The energy of photon of red light is less than work function of zinc surface and the energy of photon of Ultraviolet radiation is more than the work function of zinc surface

715. Work function of sodium is 2.3 eV. Does sodium show photoelectric emission for light of wavelength 6800 A$^0$ ?
 [ **Ans**. $E = \frac{hc}{\lambda} = \frac{6.6 \, X 10^{-34} \, X 3 \, X 10^8}{6800 \, X \, 10^{-10} \, X \, 1.6 \, X \, 10^{-19}} \, eV = 1.8 \, eV$ **CBSE (D)-2001**
 $\Rightarrow E$ W, Hence photoelectric emission will **not** take place

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716. If the intensity of the incident radiation on a photosensitive surface is doubled, how does the kinetic energy of emitted electrons get affected ?  **CBSE (F) -2005**

[ **Ans. No change** as $E_{k_{max}}$ does not depend on intensity ]

717. Ultraviolet light is incident on two photosensitive materials having work functions $W_1$ and $W_2 (W_1 > W_2)$. In which case will the kinetic energy of the emitted electrons be greater ? Why ?  **CBSE (AI)-2005**

[ **Ans.** K.E. of electrons emitted by the metal having work function $W_2$ will be greater as $E_{k_{max}} = h\nu - W$ ]

718. Ultraviolet radiations of different frequencies $\nu_1$ and $\nu_2$ are incident on two photosensitive materials having work functions $W_1$ and $W_2 (W_1 > W_2)$ respectively. The kinetic energy of the emitted electrons is same in both the cases. Which one of the two radiations will be of higher frequency and why?  **CBSE (AI)-2007**

[ **Ans.** $\nu_1 > \nu_2$   as   $h\nu = E_{k_{max}} + W$ ]

719. The threshold frequency of a metal is f. When the light of frequency 2f is incident on the metal plate, the maximum velocity of photo-electrons is $v_1$. When the frequency of the incident radiation is increased to 5f, the maximum velocity of photo-electrons is $v_2$. Find the ratio $v_1 : v_2$.  **CBSE (F)-2016, (D) -2004**

[ **Ans.**   $E_{K_{max}} = h\nu - W$   &   $W = hf$

$\Rightarrow \quad \dfrac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \dfrac{h\nu_1 - W}{h\nu_2 - W} = \dfrac{h(2f) - hf}{h(5f) - hf} = \dfrac{hf}{4hf} = \dfrac{1}{4} \quad \Rightarrow \quad \dfrac{v_1^2}{v_2^2} = \dfrac{1}{4} \quad \Rightarrow \quad v_1 : v_2 = 1 : 2$ ]
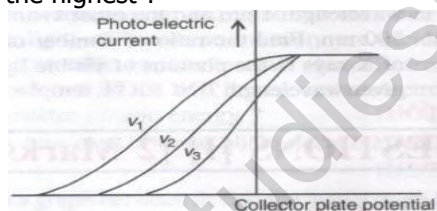
720. The graph below shows variation of photocurrent with collector plate potential for different frequencies of incident radiation.
    (i) Which physical parameter is kept constant for the three curves ?  **CBSE (F) -2009**
    (ii) Which frequency  ($\nu_1$, $\nu_2$ or $\nu_3$ ) is the highest ?  [ **Ans.** (i) Intensity (ii) $\nu_1$ is highest ]



721. The given graph shows the variation of photoelectric  current (I) with applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify the pair of curves that corresponds to
    (i) different materials but same intensity of incident radiation  **CBSE (AI)-2016,(D)-2013**
    (ii) different intensities but same material.  [ **Ans.** (i) (1,2) and (3,4)  (ii) (1,3) and (2,4) ]
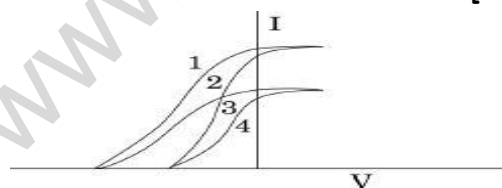


722. (i) Plot a graph showing the variation of photoelectric current with intensity of light.
    (ii) Show the variation of photocurrent with collector plate potential for different intensity but same frequency of incident radiation
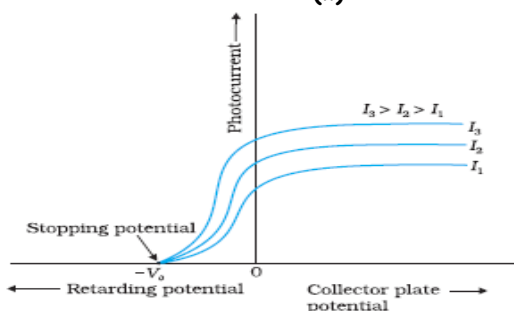    (iii) Show the variation of photocurrent with collector plate potential for different frequency but same intensity of incident radiation
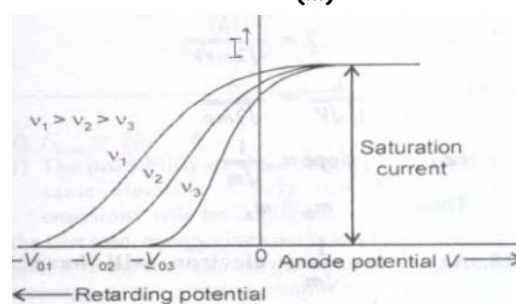    [ **Ans.**  **CBSE (F) -2016,(D)-2014,(AI)-2010,(AIC)-2011**
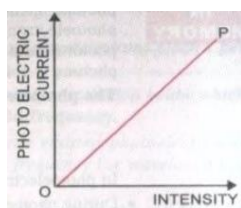
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723. Two monochromatic beams, one red and other blue, have the same intensity. In which case- **CBSE (AI)-2015**
(i) the number of photons per unit area per second is larger,
(ii) the maximum kinetic energy of the photoelectrons is more ? Justify your answer.
[ **Ans.** (i) number of photons per unit area per second is same because both red and blue light has the same intensity

(ii) blue light, because $E_{k_{max}} = \dfrac{hc}{\lambda} - W$ & $\lambda_{blue} < \lambda_{red}$

724. How does the stopping potential in photoelectric emission depends upon- **CBSE (AI)-2011,2008,(D)-2005**
(i) intensity of the incident radiation
(ii) frequency of incident radiation
(iii) distance between light source and cathode in a photocell ?
[ **Ans.** (i) stopping potential does not depend on intensity
(ii) stopping potential $\propto$ frequency
(iii) stopping potential does not depend on the distance between the light source and the cathode in a photocell

725. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons :-
(i) Do the emitted photoelectrons have the same kinetic energy ? **CBSE (F)-2015**
(ii) Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation ?
(iii) On what factors does the number of emitted photoelectrons depend ?
[ **Ans.** (i) No, all the emitted photoelectrons do not have same K.E. The reason is that different electrons are bound with different forces in different layers of metals. More tightly bound electron will emerge with less K.E.
(ii) No, kinetic energy of the emitted electrons does not depend on the intensity of incident radiation.
(iii) number of emitted photoelectrons depends on intensity of incident radiation provided that energy $h\nu > W$

726. Write two characteristic features observed in photoelectric effect which support the photon picture of electromagnetic radiation.
[ **Ans.** (i) number of photoelectrons emitted is proportional to the intensity of incident radiation **CBSE (F) -2012**
(ii) maximum kinetic energy of photoelectrons increases with frequency of incident radiation

727. State three important properties of photon which are used to write Einstein's photoelectric equation.
[ **Ans.** (i) for a radiation of frequency ν , the energy of each photon is hν. **CBSE (AI)-2016,2013, (D)-2013**
(ii) During the collision of a photon, with an electron, the total energy of photon gets absorbed by the electron
(iii) Intensity of light depends on the number of photons crossing per unit area per unit time

728. Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation. **CBSE (AI)-2017,(D)-2016**
[ **Ans.** (i) Instantaneous emission of photoelectrons
(ii) Existence of threshold frequency
(iii) Maximum Kinetic energy of emitted photoelectrons is independent of intensity of incident light

729. Sketch the graphs showing variation of stopping potential with frequency of incident radiations for two Photosensitive materials A and B having threshold frequencies $\nu_A > \nu_B$. **CBSE (AI) -2016**
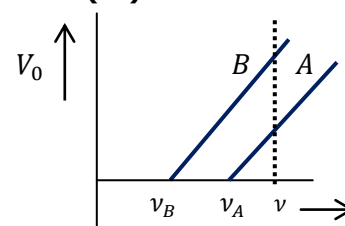(i) in which case is the stopping potential more and why ?
(ii) Does the slope of graph depend on the nature of material used ? Explain.
[ **Ans.** (i) $V_0$ is more for material B

**Reason :** $eV_0 = h(\nu - \nu_0) \quad \Rightarrow \quad V_0 = \dfrac{h}{e}(\nu - \nu_0)$

$V_0$ is more for lower value of $\nu_0$
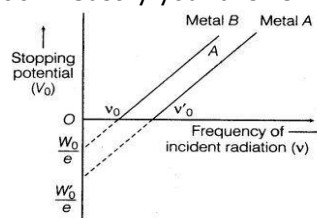(ii) No, slope = h/e, which is constant



730. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which of the two has higher value of work function ? Justify your answer. **(AI) -2014**
[ **Ans. Metal A has higher work function**
**Justification :** As $(\nu_0)_A > (\nu_0)_B$
$\Rightarrow (h\nu_0)_A > (h\nu_0)_B$
$\Rightarrow W_A > W_B$

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731. State de-Broglie hypothesis. **CBSE (D)-2012**

[ **Ans.** **de-Broglie hypothesis** : Whenever a material particle such as electron, proton etc is in motion, a wave is always associated with it, known as de-Broglie wave or matter wave and has the wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

732. What reasoning led de-Broglie to put forward the concept of matter waves ? **CBSE (Sample Paper)-2012**

[ **Ans**. Nature is symmetrical and that the two basic physical entities, matter and energy, must have symmetrical character So, if radiation shows dual nature, matter should also show it
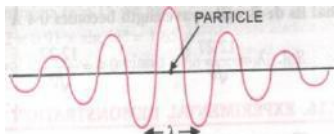
733. Name the two quantities which determine the wavelength and frequency of de-Broglie wave associated with moving electron.

[ **Ans**. Energy and momentum **CBSE (D)-2003**

734. Draw a schematic diagram of a localized wave describing the wave nature of moving electron. **CBSE (F)-2009**

[ **Ans**.



734. Why are de-Broglie waves associated with a moving football not visible ? **CBSE (D)-2003**

[ **Ans**. Since mass of a football is quite large, hence de-Broglie wave length ( $\lambda = \frac{h}{mv}$ ) associated with it is quite small and is not visible

735. In what manner wave velocity of matter waves is different from that of light ? **CBSE (D)-2003**

[ **Ans**. Wave velocity of matter waves ($v_w = \frac{h}{2m\lambda}$) depends upon the wavelength even if the particle is moving in vacuum. But light waves which moves in vacuum with the same velocity regardless of wavelength

736. de-Broglie waves are also called matter waves. Why ? **CBSE (AIC)-2004**

[ **Ans**. because to be associated with a de-Broglie wave, a particle need not have a charge

737. de-Broglie waves cannot be electromagnetic waves. Why ? **CBSE (AIC)-2009**

[ **Ans**. because de-Broglie waves are associated with every moving material particle whether charged or uncharged, whereas electromagnetic waves are associated with accelerated charged particles only

738. In what way wave nature of electrons helps us to increase the resolving limit of electron microscope ? **CBSE (D)-2003**

[ **Ans**. An electron accelerated through a potential difference of 50KV will have a de-Broglie wavelength of 0.0055nm, which is about $10^5$ times smaller than that of visible light. In this way wave nature of electron helps us to increase the resolving limit of electron microscope up to 0.0055 nm

739. (i) Name an experiment which shows wave nature of electrons. **CBSE (F)-2011, (AIC)-2006,2004**
(ii) Which phenomenon was observed in this experiment using electron beam ?
(iii) Also name the important hypothesis that was confirmed by this experiment.

[ **Ans**. **(i)** Davison- Germer experiment
**(ii)** Diffraction
**(iii)** de-Broglie hypothesis

740. Write briefly the underlying principle used in Davison-Germer experiment to verify wave nature of electrons experimentally. **CBSE (AI)-2016**

[ **Ans**. Diffraction effects are observed for beams of electrons scattered by the crystals using Bragg's diffraction law

741. Mention the significance of Davisson and Germer experiment. **CBSE (F)-2008, (AI)-2005**

**OR**

With what purpose was famous Davisson- Germer experiment with electrons performed ? **CBSE (D) -2006**

[ **Ans**. This experiment proves existence of de-Broglie waves associated with electrons in motion. Which proves the wave nature of material particles

742. Write the expression for the de-Broglie wavelength associated with a charged particle having charge q and mass m, when it is accelerated by potential V. **CBSE (AI)-2013,2006,2004,(F)-2009**

[ **Ans.** $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$

743. If the potential difference used to accelerate electrons is doubled, by what factor does the de-Broglie wavelength associated with the electron changed ? **CBSE (AI)-2013,2006,2004**

[ **Ans.** becomes $\frac{1}{\sqrt{2}}$ times as $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ $\Rightarrow \lambda \propto \frac{1}{\sqrt{V}}$
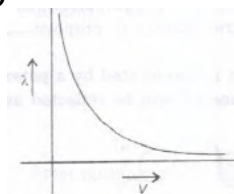
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744. (i) Show on a graph the variation of the de-Broglie wavelength ($\lambda$) associated with an electron with the square root of accelerating potential V. **CBSE (F)-2012**

(ii) Show graphically the variation of the de-Broglie wavelength ($\lambda$) with the potential (V) through which an electron is accelerated from rest. **CBSE (D) -2011**
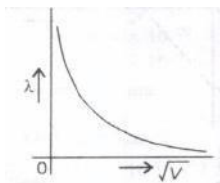
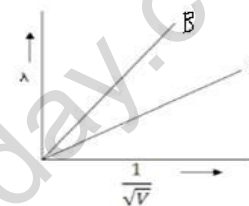[ **Ans**.  **(i)**                                         **(ii)**

745. (i) Plot a graph showing variation of de-Broglie wavelength $\lambda$ versus $\frac{1}{\sqrt{V}}$, where $V$ is accelerating potential for two particles $A$ and $B$ carrying same charge but of masses $m_1$, $m_2 (m_1 > m_2)$.

(ii) Which one of the two graphs represents a particle of smaller mass and why ? **CBSE (D)-2016,(AI)-2008**

[ **Ans. (ii) B** represents smaller mass ($m_2$) because its slope is more

$$\text{slope} = \frac{\lambda}{1/\sqrt{V}} = \lambda \sqrt{V} = \frac{h}{\sqrt{2\,m\,q}} \qquad\qquad [\because \lambda = \frac{h}{\sqrt{2\,m\,qV}}]$$

$$\Rightarrow \quad \text{slope} \propto \frac{1}{\sqrt{m}}$$

746. An electron is accelerated through a potential difference of 100 Volts. What is the de-Broglie wavelength associated with it ? To which part of the electromagnetic spectrum does this value of wavelength corresponds ?

[ **Ans**. $\lambda = \frac{12.27}{\sqrt{V}} A^0 = \frac{12.27}{\sqrt{100}} A^0 = 1.227 A^0$ , X-rays **CBSE (D)-2010,(F)-2006**

747. What is the de-Broglie wavelength of an electron with kinetic energy (K.E.) 120 eV ? **CBSE (AI)-2016,(F)-2015**

[ **Ans**. $E_K = 120$ eV    $\Rightarrow V = 120$ Volts

$\Rightarrow \lambda = \frac{12.27}{\sqrt{V}} A^0 = \frac{12.27}{\sqrt{120}} A^0 = 1.12 A^0$

748. An $\alpha$ −particle and a proton are accelerated from rest through the same potential difference $V$. Find the ratio of Their de-Broglie wavelengths associated with them. **CBSE(AI)-2010,2005,(F)-2008**

[ **Ans**. $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

$\Rightarrow \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p}{m_\alpha}} \, \text{X} \, \sqrt{\frac{q_p}{q_\alpha}} = \sqrt{\frac{m_p}{4m_p}} \, \text{X} \, \sqrt{\frac{q_p}{2q_p}} = \frac{1}{2\sqrt{2}}$

749. A proton and electron have same kinetic energy. Which one has greater de-Broglie wavelength and why ?

[ **Ans**. $\lambda = \frac{h}{\sqrt{2\,m\,E_k}}$ & $E_k$ = same **CBSE (AI) -2012, (AIC)-2005**

$\Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$ as $m_e < m_p$ hence $\lambda_e > \lambda_p$

Thus electron will have the greater de-Broglie wavelength

750. An electron, an alpha particle and a proton have the same kinetic energy. Which one of these particles has the largest/ shortest de-Broglie wavelength ? **CBSE (D) -2007, (DC) -2003**

[ **Ans**. $\lambda = \frac{h}{\sqrt{2\,m\,E_k}}$ & $E_k$ = same

$\Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$ as $m_e < m_p < m_\alpha$ hence $\lambda_e > \lambda_p > \lambda_\alpha$

Thus electron will have the largest de-Broglie wavelength & alpha particle has shortest de-Broglie wavelength

751. An electron and alpha particle have the same de-Broglie wavelength associated with them. How are their kinetic energies related to each other ? **CBSE (D) -2008**

[ **Ans**. $\lambda = \frac{h}{\sqrt{2\,m\,E_k}}$ & $\lambda$ = same

$\Rightarrow E_k \propto \frac{1}{m^2}$ as $m_e < m_\alpha$ hence $E_{k_{electron}} > E_{k_{alpha\,particle}}$

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752. Matter waves are associated with the material particles only if they are in motion. Why ?    **CBSE (DC)-2008**

[ **Ans**. If v = 0, $\lambda = \infty$ , it means, matter waves are associated with the material particles only if they are in motion

753. State the laws of photoelectric emission.    **CBSE (AI)-2010,(AIC)-2012**

[ **Ans.** (i) For a given photosensitive surface, photoelectric current is directly proportional to the intensity of incident light

(ii) The maximum kinetic energy of photoelectrons does not depend on intensity but it depends on frequency of incident radiation and is directly proportional to it

(iii) For a given photosensitive surface, there exists a certain minimum frequency of incident radiation, called threshold frequency ($v_0$) below which no photoelectric emission takes place, whatever may be the intensity of incident radiation

(iv) The photoelectric emission is an instantaneous process

754. Why photoelectric effect cannot be explained on the basis of wave nature of light ? Give reasons. **CBSE (D) -2013**

[ **Ans.**(i) According to wave theory, Kinetic energy of photoelectrons must increase as the intensity of light is increased. But, experimental observations show that, K.E. of photoelectrons does not depend on intensity of incident light

(ii) According to wave theory, if the intensity of incident radiation is sufficient photoelectron emission should take place, whatever may be the frequency. But, experimental observations shows that, if $v < v_0$, no emission of photo electrons takes place, whatever may be the intensity

(iii) According to wave theory, the electron should take appreciable time before it acquires sufficient energy to come out from the metal surface. But, experimental observations show that, there is no time lag between the incidence of radiation and emission of photoelectrons

755. (i) Using photon picture of light, show how Einstein's photoelectric equation can be established.

(ii) Write three salient features observed in photoelectric effect which can be explained using this equation.

**CBSE (AI)-2017,2013,(D)-2012**

[ **Ans. (i)** In the photon picture, energy of light is assumed to be in the form of photons, each carrying an energy h$v$ Einstein assumed that-

(a) Photoelectric emission is the result of interaction of a photon of incident radiation and a bound electron of metal surface

(b) When a photon falls on a metal surface, the energy h$v$ of a photon is completely absorbed by an electron and is partly used as work function and rest is carried as its kinetic energy

i,e,     ,h$v = W + E_{K_{max}}$

$\Rightarrow \quad E_{K_{max}} = h v - W = h v - h v_0 \qquad [ \because W = h v_0 ]$

$\Rightarrow \quad E_{K_{max}} = h (v - v_0) \qquad$ This is Einstein's photoelectric equation

**(ii) Three salient features explained by the Einstein's photoelectric equation**

(a) Existence of threshold frequency     In the equation   $E_{k_{max}} = h (v - v_0)$

If $v < v_0, E_{k_{max}}$ will be negative, which is not possible. Hence $v$ must be greater than $v_0$.

(b) The K.E. of photoelectrons is independent of intensity of incident light.

(c) The K.E. of photoelectrons increases with the frequency of incident light

756. (i) Plot a graph showing the variation of photocurrent versus collector potential for three different intensities $I_1 > I_2 > I_3$, two of which ($I_1$ and $I_2$) have the same frequency $v$ and the third has frequency $v_1 > v$.

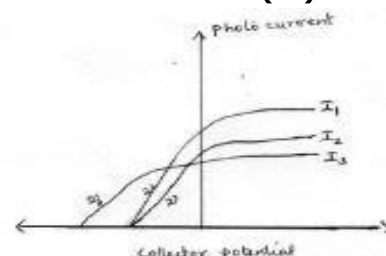(ii) Explain the nature of curves on the basis of Einstein's equation.    **CBSE (AI)-2016**

[ **Ans.**  (i) graph is shown below



(ii) as per the Einstein's equation

$eV_0 = h (v - v_0)$   which concludes

(a) the stopping potential is same for $I_1$ and $I_2$ as they have the same frequency.

(b) the saturation currents are as shown, because $I_1 > I_2 > I_3$.

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757. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive Metals A and B. Which of the two has higher threshold frequency ? Justify your answer. **CBSE (AI) -2014**

**[ Ans. Metal A has higher threshold frequency**
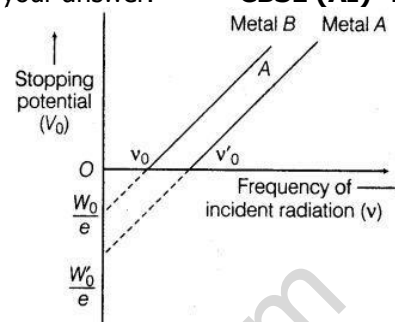
**Justification :** $eV_0 = h\nu - W$

$\Rightarrow \quad \dfrac{V_0}{e} = \left(\dfrac{h}{e}\right)\nu - \dfrac{W}{e}$

$\Rightarrow \quad \dfrac{W}{e} = $ **Intercept on y-axis**

But, $(\text{Intercept})_A > (\text{Intercept})_B$

$\Rightarrow \quad W_A > W_B \quad \Rightarrow \quad (h\nu_0)_A > (h\nu_0)_B$

$\Rightarrow (\nu_0)_A > (\nu_0)_B$

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758. In a photoelectric effect experiment, the graph between the stopping potential ($V_0$) and frequency ($\nu$) of the incident radiation on two different metal plates P & Q are shown in figure. Explain. **CBSE (AIC)-2005**

(i) Which of the metal plates P & Q has greater value of work function ?

(ii) What does the slope of lines depict ?

**[ Ans. (i) Metal Q has greater work function**

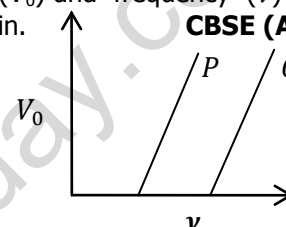**Reason :** As, $(\nu_0)_Q > (\nu_0)_P$

$\Rightarrow \quad (h\nu_0)_Q > (h\nu_0)_P$

$\Rightarrow \quad W_Q > W_P$

**(ii) slope** $= \left(\dfrac{h}{e}\right)$

**Reason :** $eV_0 = h\nu - W$

$\Rightarrow \quad \dfrac{V_0}{e} = \left(\dfrac{h}{e}\right)\nu - \dfrac{W}{e}$

On comparing with $y = mx + c \quad \Rightarrow \quad$ **slope** $= \left(\dfrac{h}{e}\right)$

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759. The following graph shows the variation of stopping potential ($V_0$) with frequency ($\nu$) of the incident radiation for two photosensitive surfaces X and Y. **CBSE (AI)-2015,2009,2008**

(i) Which of the metals has larger threshold wavelength ? Give reason.

(ii) Explain giving reason, which metal gives out electrons having larger kinetic energy, for the same wavelength of incident radiation ?

(iii) If the distance between the light source and metal X is halved, how will the kinetic energy of emitted from it change ? Give reason.

**[ Ans. (i) Metal X has larger threshold wavelength**

**Reason :** $(\nu_0)_X < (\nu_0)_Y$

$\Rightarrow \quad \left(\dfrac{c}{\lambda_0}\right)_X < \left(\dfrac{c}{\lambda_0}\right)_Y$

$\Rightarrow \quad (\lambda_0)_X > (\lambda_0)_Y$

**(ii) Metal X** will emit electrons of larger kinetic energy
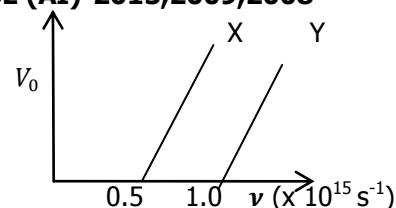
**Reason :** $(\nu_0)_X < (\nu_0)_Y$

$\Rightarrow \quad (h\nu_0)_X < (h\nu_0)_Y$

$\Rightarrow \quad W_X < W_Y$

Hence from, $E_{k_{max}} = \dfrac{hc}{\lambda} - W$

metal X will emit electrons of larger kinetic energy

**(iii)** K.E. will not change as it does not depend on the distance between light source and metal surface

**PHYSICS CLASS-XII –DUAL NATURE & RADIATION**

760. An electron is accelerated from rest through a potential V. Obtain the expression for the de-Broglie wavelength.

[ **Ans**. As the electron is accelerated through a potential $V$      **CBSE (F)-2014,(AI)-2012,2010,2007,(D)-2005**

$\Rightarrow$    $E_k = e\,V = \frac{1}{2}mv^2$

$\Rightarrow$    $v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2\,e\,V}{m}}$

de-Broglie wavelength,

$\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2\,e\,V}{m}}} = \frac{h}{\sqrt{2meV}}$

$\Rightarrow \lambda = \frac{h}{\sqrt{2meV}} = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19}V}} = \frac{12.27 \times 10^{-10}}{\sqrt{V}}$

$\Rightarrow \boldsymbol{\lambda = \frac{12.27}{\sqrt{V}} A^0}$

761. Describe briefly how Davisson-Germer experiment demonstrated the wave nature of electrons.    **CBSE (F)-2014**

[ **Ans**. **Davisson – Germer experiment** : It provides first experimental proof of concept of wave nature of electrons

**Principle** : Electron beam can be diffracted through crystal lattice, using Bragg's diffraction condition,

$2d\,\sin\theta = n\,\lambda$

**Working:**

Maximum intensity of scattered electron beam is obtained at 54 V and $\phi = 50^0$. This is due to the constructive interference of electron beams scattered from different layers of the regularly spaced atoms of the crystals.

We have,   $\theta + \phi + \theta = 180^0$

$\Rightarrow$    $\theta = \frac{1}{2}(180^0 - \phi) = \frac{1}{2}(180^0 - 50^0) = 65^0$

From Bragg's diffraction condition,

$2d\,\sin\theta = n\,\lambda$

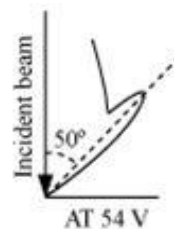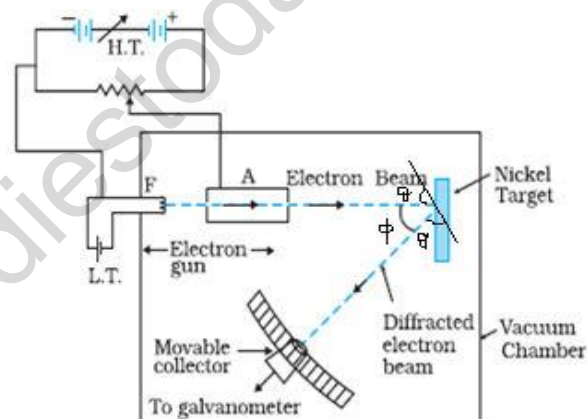$2 \times 0.91 \times \sin 65^0 = 1\lambda$

$\Rightarrow$    $\lambda = 1.65 \; A^0$    ----------(1)

Now the de-Broglie wavelength

$\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 1.66 \; A^0$    ----------(2)

From (1) & (2) it is obvious that theoretical and the experimental value of $\lambda$ are same. Hence, this experiment confirms the wave nature of electrons and the de Broglie hypothesis.



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762. The wavelength $\lambda$ of a photon and the de-Broglie wavelength of an electron have the same value. Show that the energy of a photon is $(2\lambda mc/h)$ times the kinetic energy of electron. Where $m$, $c$ and h have their usual meaning.

[ **Ans**. Energy of photon, $E = h\nu = \frac{h\,c}{\lambda}$      **CBSE (F) -2016, (D)-2003**

de-Broglie wavelength of electron, $\lambda = \frac{h}{p}$    $\Rightarrow p = \frac{h}{\lambda}$

Kinetic energy of electron    $E_k = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$

$\Rightarrow \frac{E}{E_k} = \frac{hc/\lambda}{h^2/2m\lambda^2} = \frac{2m\lambda c}{h}$

$\Rightarrow E = \left(\frac{2m\lambda c}{h}\right) E_k$

**PHYSICS CLASS-XII –DUAL NATURE & RADIATION**

763. X-rays of wavelength '$\lambda$' fall on a photo sensitive surface, emitting electrons. Assuming that the work function of surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be $\sqrt{\frac{h\lambda}{2mc}}$ **CBSE (AIC)-2017,(AI)-2004**

**OR**

An electromagnetic wave of wavelength $\lambda$ is incident on a photosensitive surface of negligible work function. If the photoelectrons emitted from this surface have the de-Broglie wavelength $\lambda_1$, Prove that, $\lambda = \left(\frac{2mc}{h}\right)\lambda_1^2$ **CBSE (D)-2008**

**[ Ans.** As, $W$ is negligible

$\Rightarrow \quad E_{K_{max}} = h\nu - W = h\nu - 0 = h\nu = \frac{hc}{\lambda}$

Now de-Broglie wavelength,

$$\lambda_1 = \frac{h}{\sqrt{2\,m\,E_k}} = \frac{h}{\sqrt{2\,m\,X\,\frac{hc}{\lambda}}} = \sqrt{\frac{h\lambda}{2mc}} \qquad \Rightarrow \lambda_1^2 = \frac{h\lambda}{2mc} \quad \Rightarrow \lambda = \left(\frac{2mc}{h}\right)\lambda_1^2$$

764. A proton and an $\alpha-particle$ are accelerated through the same potential difference. Which on of the two has

(i) greater de-Broglie wavelength, and **CBSE (AI)-2016,(D)-2014,2010,2009**

(ii) less kinetic energy ? Justify your answer.

**[ Ans. (i)** $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

$\Rightarrow \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}} X \sqrt{\frac{q_\alpha}{q_p}} = \sqrt{\frac{4\,m_p}{m_p}} X \sqrt{\frac{2e}{e}} = 2\sqrt{2} \qquad \Rightarrow \lambda_{proton} > \lambda_{\alpha-particle}$

(ii) $E_k = qV \Rightarrow E_k \propto q$

**As** $q_{proton} < q_{\alpha-particle} \qquad \Rightarrow E_{k_{proton}} < E_{k_{\alpha-particle}}$

765. A deuteron and an $\alpha-particle$ are accelerated with the same accelerating potential. Which one of the two has -

(i) greater value of de-Broglie wavelength associated with it, it, and **CBSE (AI)-2015,(D) -2014**

(ii) less kinetic energy ? Explain.

**[ Ans. (i)** $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

$\Rightarrow \frac{\lambda_d}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_d}} X \sqrt{\frac{q_\alpha}{q_d}} = \sqrt{\frac{4\,m_p}{2\,m_p}} X \sqrt{\frac{2e}{e}} = 2:1 \Rightarrow \lambda_{deutron} > \lambda_{\alpha-particle}$

(ii) $E_k = qV \Rightarrow E_k \propto q$

**As** $q_{deutron} < q_{\alpha-particle} \qquad \Rightarrow E_{k_{deutron}} < E_{k_{\alpha-particle}}$

766. A proton and an $\alpha-particle$ have the same de-Broglie wavelength. Determine the ratio of-

(i) their accelerating potentials, and  (ii) their speeds. **CBSE (D) -2015, (DC)-2009**

**[ Ans. (i)** $\lambda = \frac{h}{\sqrt{2\,m\,qV}} \Rightarrow V = \frac{h^2}{2mq\,\lambda^2}$ & $\lambda$ = same

$\Rightarrow \frac{V_P}{V_\alpha} = \frac{m_\alpha}{m_P} X \frac{q_\alpha}{q_P} = \frac{4\,m_P}{m_P} X \frac{2q_P}{q_P} = 8 : 1$

(ii) $\lambda = \frac{h}{m\,v} \Rightarrow v = \frac{h}{m\,\lambda} \Rightarrow v \propto 1/m$

$\Rightarrow \frac{v_P}{v_\alpha} = \frac{m_\alpha}{m_P} = \frac{4\,m_P}{m_P} = 4:1$

767. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has –

(i) greater value of de-Broglie wavelength associated with it, it, and **CBSE (D)-2014**

(ii) less momentum ? Give reasons to justify your answer.

**[ Ans. (i)** $\lambda = \frac{h}{\sqrt{2\,m\,qV}}$ & V = same

$\Rightarrow \frac{\lambda_p}{\lambda_d} = \sqrt{\frac{m_d}{m_p}} X \sqrt{\frac{q_d}{q_p}} = \sqrt{\frac{2\,m_p}{m_p}} X \sqrt{\frac{2\,e}{e}} = 2$

$\Rightarrow \lambda_{proton} > \lambda_{deutron}$ thus proton has the greater de-Broglie wavelength

(ii) $\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} \Rightarrow p \propto \frac{1}{\lambda}$

**As** $\lambda_{proton} > \lambda_{deutron}$ hence $p_{proton} < p_{deutron}$ Thus proton has less momentum

**PHYSICS CLASS-XII –DUAL NATURE & RADIATION**

768. Two metals X and Y have work functions 2 eV & 5 eV respectively. Which metal will emit electrons, when it is radiated with light of wavelength 400 nm & why ? **CBSE (AIC)-2010**

[**Ans. metal X,** as $E = \dfrac{hc}{\lambda} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9} \times 1.6 \times 10^{-19}}$ $eV = 3.09$ eV $\Rightarrow E > W_X$ & $E < W_Y$

769. Monochromatic light of frequency $6.0 \times 10^{14}$ Hz is produced by a laser. The power emitted is $2.0 \times 10^{-3}$ W.
 (a) What is the energy of a photon in the light beam ? **NCERT-2017**
 (b) Estimate the number of photons emitted per second on an average by the source. **CBSE (AI)-2015,(D)-2014**

[ **Ans. (a)** $E = h\nu = 6.6 \times 10^{-34} \times 6 \times 10^{14} = 3.98 \times 10^{-19}$ J

 **(b)** number of photons, $n = \dfrac{P}{E} = \dfrac{P}{h\nu} = \dfrac{2 \times 10^{-3}}{6.6 \times 10^{-34} \times 6 \times 10^{14}} = \dfrac{100 \times 10^{15}}{6.6 \times 3} = 5 \times 10^{15}$

770. The work function for the following metals is given : **CBSE (F)-2016**
$$Na : 2.75 \ eV \text{ and } Mo : 4.175 \ eV$$
 (i) Which of these will not give photoelectron emission from a radiation of wavelength 3300 $A^0$ from a laser beam ?
 (ii) What happens if the source of laser beam is brought closer ?

[ **Ans.** (i) for $\lambda = 3300$ $A^0$, energy of photon, $\dfrac{hc}{\lambda} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10} \times 1.6 \times 10^{-19}}$ $eV = 3.75 \ eV < 4.175$ eV

 Hence **Mo will not** give photoelectric emission as $\dfrac{hc}{\lambda} < W$

 (ii) In case of Na, photocurrent will increase but in case of Mo no effect

771. The work function of Cesium metal is 2.14 eV. When light of frequency $6.0 \times 10^{14}$ $Hz$ is incident on metal surface, photoemission of electron occurs. What is the **CBSE (AIC)-2010,NCERT-2017**
 (i) maximum kinetic energy of emitted electrons
 (ii) stopping potential, and
 (iii) maximum speed of emitted photoelectrons

[**Ans.** (i) $E_{k_{max}} = h\nu - W = 6.6 \times 10^{-34} \times 6 \times 10^{14} - 2.14 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-19} (2.48 - 2.14)$ J $= 0.34$ eV

 (ii) $e V_0 = E_{k_{max}} = 0.34 \ eV$ $\Rightarrow$ $V_0 = 0.34 \ V$

 (iii) $\dfrac{1}{2} m v_{max}{}^2 = E_{k_{max}} = 0.34 \ eV = 0.34 \times 1.6 \times 10^{-19}$ J $\Rightarrow$ $V_{max} = 345.8 \times 10^3 \ m/s$

772. Light of wavelength 2000 $A^0$ falls on a metal surface of work function 4.2 eV. **CBSE (F)-2011**
 (i) What is the kinetic energy (in eV) of the (a) fastest and (b) slowest electrons emitted from the surface ?
 (ii) What will be the change in the energy of the emitted electrons if the intensity of light with same wavelength is doubled ?
 (iii) If the same light falls on another surface of work function 6.5 eV, what will be the energy of emitted electrons ?
 [**Ans.** (i) (a) K.E. of fastest electron

$$E_{k_{max}} = \dfrac{hc}{\lambda} - W = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{2000 \times 10^{-10}} - 4.2 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-19} (6.2 - 4.2) \text{ J} = 2.0 \text{ eV}$$

 (b) K.E. of slowest electron = 0 eV (ii) **No change** in the energy of emitted electrons as it does not depend on intensity
 (iii) **no emission** as $E(6.2 \ eV) < W(6.5 \ eV)$ ]

773. Ultraviolet light of wavelength 2271 $A^0$ from a 100W mercury source irradiated a photocell made of Molybdenum metal. If the stopping potential is $-1.3$ V, estimate the work function of the metal. How would the photocell respond when the source is replaced by another source of high intensity ($10^5$ W/m$^2$) red light of wavelength 6328 $A^0$. Justify your answer. **CBSE (AI)-2015,(F)-2013,(D)-2005**

[ **Ans.** $eV_0 = \dfrac{hc}{\lambda} - W$

 $\Rightarrow W = \dfrac{hc}{\lambda} - eV_0 = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{2271 \times 10^{-10}} - 1.3 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-19} (5.5 - 1.3)$ J $= 4.2$ eV

 Also, $W = \dfrac{hc}{\lambda_0}$ $\Rightarrow \lambda_0 = \dfrac{hc}{W} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 4.2 \times 10^{-19}} = 2.977 \times 10^{-7} \ m = 2977 \ A^0$

 As $\lambda (= 6328 \ A^0) > \lambda_0 (= 2977 \ A^0)$

 Hence, photocell **will not respond** to source of high intensity ($10^5$ W/m$^2$) red light of wavelength 6328 $A^0$

**PHYSICS CLASS-XII –DUAL NATURE & RADIATION**

774. Calculate the-                                                                                    **NCERT-2017**
     (a) momentum, and
     (b) de Broglie wavelength of the electrons accelerated through a potential difference of 56 V.

[ **Ans**. (a) $p = \sqrt{2\, m\, E_k} = \sqrt{2\, m\, eV} = \sqrt{2 \text{ X } 9.1 \text{ X } 10^{-31} \text{ X } 1.6 \text{ X} 10^{-19} \text{X } 56} = 4.04 \text{ X } 10^{-24}\, Kg\, m/s$

   (b) $\lambda = \dfrac{h}{p} = \dfrac{6.6 \text{ X } 10^{-34}}{4.04 \text{ X } 10^{-24}} = 0.164 \text{ X } 10^{-9} m$

775. The wavelength of light from the spectral emission line of Sodium is 589 $nm$. Find the kinetic energy of electron
     for which it would have the same de-Broglie wavelength.                                    **CBSE (AI)-2015**

[ **Ans**.  $\lambda = \dfrac{h}{\sqrt{2\, m\, E_k}} \Rightarrow E_K = \dfrac{h^2}{2m\lambda^2} = \dfrac{\left(6.6 \text{ X } 10^{-34}\right)^2}{2 \text{ X } 9.1 \text{ X } 10^{-31} X\, (589 \text{ X } 10^{-9})^2} = 6.96 \text{ X } 10^{-25}$ J

776. An electron and a photon each have a wavelength 2.00 nm. Find-                              **CBSE (D)-2011**

   (i) their momenta
   (ii) the energy of photon, and
   (iii) the kinetic energy of electron

[ **Ans**. (i) momentum of electron = momentum of photon = $\dfrac{h}{\lambda}$ = $\dfrac{6.6 \text{ X } 10^{-34}}{2.0 \text{ X } 10^{-9}} = 3.3 \text{ X } 10^{-25}$ kgm/s

   (ii) energy of photon = $\dfrac{hc}{\lambda} = \dfrac{6.6 \text{ X } 10^{-34} \text{ X} 3 \text{ X } 10^8}{2.0 \text{ X } 10^{-9}}$ = 9.945 X$10^{-17}$ J.

   (iii) K.E. of electron = $\dfrac{p^2}{2m} = \dfrac{\left(3.3 \text{ X } 10^{-25}\right)^2}{2 \text{ X } 9.1 \text{ X } 10^{-31}} = 6.0314 \text{ X } 10^{-20}$ J

777. An electron and a proton each has de-Broglie wavelength of 1.6 nm.                          **CBSE (F)-2013**
   (i) write the ratio of their linear momenta
   (ii) compare the kinetic energy of the proton with that of the electron.

[ **Ans**. (i) momentum of electron = momentum of proton = $\dfrac{h}{\lambda} \Rightarrow \dfrac{momentum\ of\ electron}{momentum\ of\ photon} = 1:1$

   (ii) $\lambda = \dfrac{h}{\sqrt{2\, m\, E_k}} \Rightarrow E_K = \dfrac{h^2}{2m\lambda^2} \Rightarrow E_K \propto \dfrac{1}{m}$  As $m_e < m_p \Rightarrow E_{K_e} > E_{K_p}$

778. Given the ground state energy $E_0 = -13.6$ eV and Bohr radius $a_0 = 0.53$ A$^0$. Find out how the de-Broglie
     wavelength associated with the electron orbiting in the ground state would change when it jump in to the first
     excited state ?

[ **Ans**. $E_{K_n} = \dfrac{13.6}{n^2}\, eV$ & for ground state $n = 1$, for first excited state $n = 2$                    **CBSE (AI)-2015**

   Now, as $\lambda = \dfrac{h}{mv} \Rightarrow \lambda \propto \dfrac{1}{v}$ but $v \propto \dfrac{1}{n} \Rightarrow \lambda \propto n$

   $\Rightarrow \dfrac{\lambda_2}{\lambda_1} = \dfrac{n_2}{n_1} = \dfrac{2}{1} \Rightarrow \lambda_2 = 2\,\lambda_1$

   Hence, de-Broglie wavelength will become double

779. When an electron orbiting in hydrogen atom in its ground state moves to third excited state, show how the
     de-Broglie wavelength associated with it would be affected ?                              **CBSE (AI)-2015**

[ **Ans**. for ground state $n = 1$, for third excited state $n = 4$

   Now, as $\lambda = \dfrac{h}{mv} \Rightarrow \lambda \propto \dfrac{1}{v}$ but $v \propto \dfrac{1}{n} \Rightarrow \lambda \propto n$

   $\Rightarrow \dfrac{\lambda_2}{\lambda_1} = \dfrac{n_2}{n_1} = \dfrac{4}{1} \Rightarrow \lambda_2 = 4\,\lambda_1$

   Hence, de-Broglie wavelength will become four times

780. When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the
     de-Broglie wavelength associated with the electron change ? Justify your answer.          **CBSE (AI)-2015**

[ **Ans**. for third excited state $n = 4$, for ground state $n = 1$

   Now, as $\lambda = \dfrac{h}{mv} \Rightarrow \lambda \propto \dfrac{1}{v}$ but $v \propto \dfrac{1}{n} \Rightarrow \lambda \propto n$

   $\Rightarrow \dfrac{\lambda_2}{\lambda_1} = \dfrac{n_2}{n_1} = \dfrac{1}{4} \Rightarrow \lambda_2 = \lambda_1/4$

   Hence, de-Broglie wavelength will decrease to one fourth of its value in third excited state

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