arride learning

MODERN PHYSICS

Contents

Syllabus

Potoelectric effect ; Bohr's theory of hydrogen like atoms ;
Characteristic and continuous X-rays, Moseley's law ;
de Broglie wavelength of matter waves.

Name : ______________________________ Contact No. ____________________

ARRIDE LEARNING ONLINE E-LEARNING ACADEMY

A-479 indra Vihar, Kota Rajasthan 324005

Contact No. 8033545007

MODERN PHYSICS

1. CATHODE RAYS :

(a) Generated in a discharge tube in which a high vaccum is maintained .

(b) They are electrons accelerated by high potential difference (10 to 15 Kilo Volt)

(c) K.E. of C.R. particle accelerated by a p.d. V is eV = $\frac{1}{2}mv^2 = \frac{P^2}{2m}$.

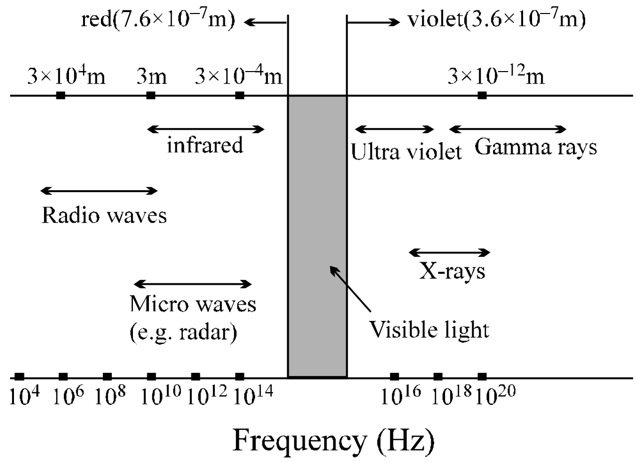
(d) Can be deflected by Electric & magnetic fields .

2. ELECTROMAGNETIC SPECTRUM :

Ordered arrangement of the big family of electro magnetic waves (EMW) either in ascending order of frequencies or of wave lengths

Speed of E.M.W. in vacuum

C = 3 × 10^8 m/s = $\nu \lambda$



3. PLANK'S QUANTUM THEORY :

A beam of EMW is a stream of discrete packets of energy called **PHOTONS** , each photon having a frequency ν and energy = E = h ν .

h = plank 's constant = 6.63 × 10^{-34} Js .

4. PHOTO ELECTRIC EFFECT :

The phenomenon of the emission of electrons, when metals are exposed to light (of a certain minimum frequency) is called photo electric effect.

Results :

(i) Can be explained only on the basis of the quantum theory (concept of photon) .

(ii) Electrons are emitted if the incident light has frequency $\nu \geq \nu_0$ (threshold frequency) emission of electrons is independent of intensity . The wave length corresponding to ν_0 is called threshold wave length λ_0 .

(iii) ν_0 is different for different metals .

(iv) Number of electrons emitted per second depends on the intensity of the incident light .

(v) **EINSTEINS PHOTO ELECTRIC EQUATION :**

Photon energy = K. E. of electron + work function .

$$h\nu = \frac{1}{2}mv^2 + \phi$$

ϕ = **Work function = energy needed by the electron in freeing itself from the atoms of the metal .**

$$\phi = h\nu_0$$

(vi) **STOPPING POTENTIAL OR CUT OFF POTENTIAL :**

The minimum value of the retarding potential to prevent electron emission is :

$$eV_{cut\ off} = (KE)_{max}$$

Note : The number of photons incident on a surface per unit time is called photon flux.

5. WAVE NATURE OF MATTER :

Beams of electrons and other forms of matter exhibit wave properties including interference and diffraction with a de Broglie wave length given by $\lambda = \frac{h}{p}$

(wave length of a praticle) .

6. ATOMIC MODELS :

(a) THOMSON MODEL : (PLUM PUDDING MODEL)

(i) Most of the mass and all the positive charge of an atom is uniformly distributed over the full size of atom (10^{-10} m).

(ii) Electrons are studded in this uniform distribution .

(iii) Failed to explain the large angle scattering α - particle scattered by thin foils of matter .

(b) RUTHERFORD MODEL : (Nuclear Model)

(i) The most of the mass and all the positive charge is concentrated within a size of 10^{-14} m inside the atom . This concentration is called the atomic nucleus .

(ii) The electron revolves around the nucleus under electric interaction between them in circular orbits.

(iii) An accelerating charge radiates the nucleus spiralling inward and finally fall into the nucleus, which does not happen in an atom. This could not be explained by this model.

(c) BOHR ATOMIC MODEL :

Bohr adopted Rutherford model of the atom & added some arbitrary conditions. These conditions are known as his postulates :

(i) The electron in a stable orbit does not radiate energy . i.e. $\frac{mv^2}{r} = \frac{kze^2}{r^2}$

(ii) A stable orbit is that in which the angular momentum of the electron about nucleus is an integral (n) multiple of $\frac{h}{2\pi}$. i.e. $mvr = n\frac{h}{2\pi}$; n = 1 , 2 , 3 , ...($n \neq 0$).

(iii) The electron can absorb or radiate energy only if the electron jumps from a lower to a higher orbit or falls from a higher to a lower orbit .

(iv) The energy emitted or absorbed is a light photon of frequency ν and of energy . $\mathbf{E = h\nu}$.

FOR HYDROGEN ATOM : (Z = atomic number = 1)

(i) L_n = angular momentum in the n^{th} orbit = $n\frac{h}{2\pi}$.

(ii) r_n = radius of n^{th} circular orbit = (0.529 A°) n^2 ; (1A° = 10^{-10} m) ; $r_n \alpha\ n^2$.

(iii) E_n Energy of the electron in the n^{th} orbit = $\frac{-13.6\ ev}{n^2}$ i.e. $E_n \alpha \frac{1}{n^2}$.

Note : Total energy of the electron in an atom is negative , indicating that it is bound .

Binding Energy $(BE)_n = -E_n = \frac{13.6\ ev}{n^2}$.

(iv) $E_{n2} - E_{n1}$ = Energy emitted when an electron jumps from n_2^{th} orbit to n_1^{th} orbit $(n_2 > n_1)$.

$$\Delta E = (13.6\ ev)\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] .$$

$\Delta E = h\nu$; ν = frequency of spectral line emitted .

$\frac{1}{\lambda}$ = wave no. [no. of waves in unit length (1m)] = $R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$.

Where R = Rydberg's constant, for hydrogen = $1.097 \times 10^7\ m^{-1}$.

(v) For hydrogen like atom/species of atomic number Z :

$r_{nz} = \frac{\text{Bohr radius}}{Z} n^2 = (0.529\ A°)\frac{n^2}{Z}$; $E_{nz} = (-13.6)\frac{Z^2}{n^2}$ ev

$R_z = RZ^2$ – Rydberg's constant for element of atomic no. Z .

Note : If motion of the nucleus is also considered , then m is replaced by μ .

Where μ = reduced mass of electron - nucleus system = mM/(m+M) .

In this case $E_n = (-13.6\ ev)\frac{Z^2}{n^2} \cdot \frac{\mu}{m_e}$

7. SPECTRAL SERIES :

(i) Lyman Series : (Landing orbit n = 1) .

Ultraviolet region $\bar{v}=R\left[\frac{1}{1^2}-\frac{1}{n_2^{\,2}}\right]$; $n_2 > 1$

(ii) Balmer Series : (Landing orbit n = 2)

Visible region $\bar{v}=R\left[\frac{1}{2^2}-\frac{1}{n_2^{\,2}}\right]$; $n_2 > 2$

(iii) Paschan Series : (Landing orbit n = 3)

In the near infrared region $\bar{v}=R\left[\frac{1}{3^2}-\frac{1}{n_2^{\,2}}\right]$; $n_2 > 3$

(iv) Bracket Series : (Landing orbit n = 4)

In the mid infrared region $\bar{v}=R\left[\frac{1}{4^2}-\frac{1}{n_2^{\,2}}\right]$; $n_2 > 4$

(v) Pfund Series : (Landing orbit n = 5)

In far infrared region $\bar{v}=R\left[\frac{1}{5^2}-\frac{1}{n_2^{\,2}}\right]$; $n_2 > 5$

In all these series n_2 = $n_1 + 1$ is the α line
= $n_1 + 2$ is the β line
= $n_1 + 3$ is the γ line .... etc . where n_1 = Landing orbit

8. EXCITATION POTENTIAL OF ATOM :

Excitation potential for quantum jump from $n_1 \longrightarrow n_2 = \frac{E_{n2}-E_{n1}}{\text{electron charge}}$.

9. IONIZATION ENERGY :

The energy required to remove an electron from an atom . The energy required to ionize hydrogen atom is = 0 – (– 13.6) = 13.6 eV .

10. IONIZATION POTENTIAL :

Potential difference through which a free electron is moved to gain ionization energy = $\frac{-E_n}{\text{electronic charge}}$

11. X - RAYS :

(i) Short wavelength (0.1 A° to 1 A°) electromagnetic radiation .

(ii) Are produced when a metal anode is bombarded by very high energy electrons .

(iii) Are not affected by electric and magnetic field .

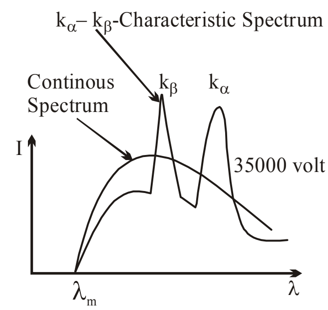
(iv) They cause photoelectric emission .

Characteristics equation $eV = h\nu_m$

e = electron charge ;

V = accelerating potential

ν_m = maximum frequency of X - radiation



(v) Intensity of X - rays depends on number of electrons hitting the target .

(vi) Cut off wavelength or minimum wavelength, where V (in volts) is the p.d. applied to the tube

$\lambda_{min} \cong \frac{12400}{V}$ A° .

(vii) Continuous spectrum due to retardation of electrons .

(viii) Characteristic Spectrum due to transition of electron from higher to lower

$v = a (z - b)^2$ **[MOSELEY's LAW]**

b = 1 for k_α transition

Note : **(i)** Binding energy = - [Total Mechanical Energy]

(ii) Velocity of electron in n^{th} orbit for hydrogen atom $\cong \frac{c}{137\,n}$; c = speed of light .

(iii) For x - rays $\frac{1}{\lambda}=R(z-b)^2\left(\frac{1}{n_1^{\,2}}-\frac{1}{n_2^{\,2}}\right)$

(iv) Series limit means minimum wave length of that series.

EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

* ***Marked Questions are having more than one correct option.***

SECTION (A) : PHOTOELECTRIC EFFECT

A-1. If the frequency of light in a photoelectric experiment is doubled then maximum kinetic energy of photoelectron
(A) be doubled (B) be halved
(C) become more than double (D) become less than double

A-2. When a centimeter thick surface is illuminated with light of wavelength λ, the stopping potential is V. When the same surface is illuminated by light of wavelength 2λ, the stopping potential is V/3. The threshold wavelength for the surface is
(A) $\frac{4\lambda}{3}$ (B) 4λ (C) 6λ (D) $\frac{8\lambda}{3}$

A-3.* If the wavelength of light in an experiment on photo electric effect is doubled :
(A) The photoelectric emission will not take place.
(B) The photoemission may or may not take place.
(C) The stopping potential will increase
(D) The stopping potential will decrease under the condition that energy of photon of doubled Wavelength is more than work function of metal.

A-4. Photons of wavelength 6620 Å are incident normally on a perfectly reflecting screen. Calculate the number of photons per second falling on the screen as total power of photons such that the exerted force is 1N :
(A) 5×10^{26} (B) 5×10^{25} (C) 1.5×10^{8} (D) None of these

A-5. Let n_r and n_b be respectively the number of photons emitted by a red bulb and a blue bulb of equal power in a given time.
(A) $n_r = n_b$ (B) $n_r < n_b$ (C) $n_r > n_b$ (D) data insufficient

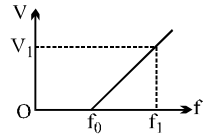
A-6. 10^{-3} W of 5000 Å light is directed on a photoelectric cell. If the current in the cell is 0.16 μA, the percentage of incident photons which produce photoelectrons, is
(A) 0.4% (B) .04% (C) 20% (D) 10%

A-7. The stopping potential for the photo electrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelength equal to that of incident radiation for the above photoelectric effect
(A) n = 3 to 1 (B) n = 3 to 2 (C) n = 2 to 1 (D) n = 4 to 1

A-8. The frequency and the intensity of a beam of light falling on the surface of photoelectric material are increased by a factor of two. Treating efficiency of photoelectron generation as constant, this will :
(A) increase the maximum energy of the photoelectrons, as well as photoelectric current by a factor of two.
(B) increase the maximum kinetic energy of the photo electrons and would increase the photoelectric current by a factor of two.
(C) increase the maximum kinetic energy of the photoelectrons by a factor of greater than two and will have no effect on the magnitude of photoelectric current produced.
(D) not produce any effect on the kinetic energy of the emitted electrons but will increase the photoelectric current by a factor of two.

A-9. A point source of ligth is used in a photoelectric effect. If the source is removed farther from the emitting metal, the stopping potential :
(A) will increase (B) will decrease
(C) will remain constant (D) will either increase or decrease.

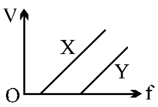
A-10. In a photoelectric experiment, the potential difference V that must be maintained between the illuminated surface and the collector so as just to prevent any electron from reaching the collector is determined for different frequencies f of the incident illumination. The graph obtained is shown. The maximum kinetic energy of the electrons emitted at frequency f_1 is

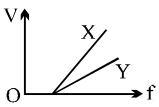


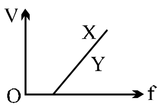
(A) hf_1 (B) $\frac{V_1}{(f_1 - f_0)}$ (C) $h(f_1 - f_0)$ (D) $eV_1(f_1 - f_0)$

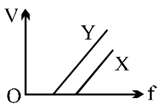
A-11. Cut off potentials for a metal in photoelectric effect for light of wavelength λ_1, λ_2 and λ_3 is found to be V_1, V_2 and V_3 volts if V_1, V_2 and V_3 are in Arithmetic Progression and λ_1, λ_2 and λ_3 will be:
(A) Arithmetic Progression (B) Geometric Progression
(C) Harmonic Progression (D) None of these

A-12. In a photoelectric experiment, electrons are ejected from metals X and Y by light of intensity I and frequency f. The potential difference V required to stop the electrons is measured for various frequencies. If Y has a greater work function than X ; which one of the following graphs best illustrates the expected results?

(A) 

(B) 

(C) 

(D) 

SECTION (B) : PHOTON EMISSION FROM A SOURCE ,RADIATION PRESSURE AND DE-BROGLIE WAVES

B-1. A photon of light enters a block of glass after travelling through vacuum. The energy of the photon on entering the glass block
(A) increases because its associated wavelength decreases
(B) Decreases because the speed of the radiation decreases
(C) Stays the same because the speed of the radiation and the associated wavelength do not change
(D) Stays the same because the frequency of the radiation does not change

B-2. The de Broglie wavelength of an electron moving with a velocity 1.5×10^8 ms^{-1} is equal to that of a photon. The ratio of the kinetic energy of the electron to that of the energy of photon is :
(A) 2 (B) 4 (C) $\frac{1}{2}$ (D) $\frac{1}{4}$

B-3. A particle of mass *M* at rest decays into two particles of masses m_1 and m_2, having non zero velocities. The ratio of the de Broglie wavelengths of the particles, λ_1/λ_2 is :
(A) $\frac{m_1}{m_2}$ (B) $\frac{m_2}{m_1}$ (C) 1 : 1 (D) $\sqrt{\frac{m_2}{m_1}}$

B-4. In order to have the same wavelength for the electron (mass m_e) and the neutron (mass m_n) their velocities should be in the ratio (electron velocity / neutron velocity) :
(A) m_n / m_e (B) $m_n \times m_e$ (C) m_e / m_n (D) one

B-5. An electron with initial kinetic energy of 100 eV is acceleration through a potential difference of 50 V. Now the de-Broglie wavelength of electron becomes
(A) 1 Å (B) $\sqrt{1.5}$ Å (C) $\sqrt{3}$ Å (D) 12.27 Å

SECTION (C) :BOHR'S ATOMIC MODEL OF H-ATOM & H-LIKE SPECIES (PROPERTIES)

C-1.* Let A_n be the area enclosed by the n^{th} orbit in a hydrogen atom. The graph of ℓn (A_n / A_1) against In(n)
(A) will pass through the origin
(B) will have certain points lying on a straight line with slope 4
(C) will be a monotonically increasing nonlinear curve
(D) will be a circle

C-2. Bohr's atomic model :
(A) assumes only certain valuesof angular momenta to be possible for orbital electron of hydrogen atom
(B) explains line spectra of elements having more thanone electgron in the outermost shell
(C) assumes that the electrons have wave properties
(D) could not explain hydrogen spectra completely

C-3. The energy gap between successive energy levels in a hydrogen atom :
(A) decreases as n increases (B) decreases as n decreases
(C) increases as n increases (D) either (A) or (B)

C-4. A hydrogen-like atoms has one electron revolving around a stationary nucleus. The energy required to excite the electron from the second orbit to the third orbit is 47.2 eV. The atomic number of the atom is :
(A) 3 (B) 4 (C) 5 (D) 6

C-5. In the spectrum of hydrogen atom, ratio of the longest wavelength in Lyman series to the longest wavelength in Balmer series is :
(A) $\frac{5}{27}$ (B) $\frac{1}{93}$ (C) $\frac{4}{9}$ (D) $\frac{3}{2}$

C-6. The electron in a hydrogen atom makes a transition $n_1 \rightarrow n_2$ where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is 8 times that in the final state. The possible values of n_1 and n_2 are
(A) $n_1 = 4, n_2 = 1$ (B) $n_1 = 8, n_2 = 2$ (C) $n_1 = 8, n_2 = 1$ (D) $n_1 = 6, n_2 = 3$

C-7.* The energy, the magnitude of linear momentum and orbital radius of an electron in a hydrogen atom corresponding to the quantum number n are E, P and r, according to the Bohr's theory of hydrogen atom:
(A) EPr is proportional to 1/n (B) P/E is proportional to n^0
(C) Er is not constant for all orbits (D) Pr is proportional to n.

C-8.* A hydrogen like atom of atomic number Z is an excited state of quantum number 2n. It can emit a maximum energy photon of 204 eV. It makes a transition to quantum state n, a photon of energy 40.8 eV is emitted, then
(A) Z = 2 (B) Z = 4 (C) n = 1 (D) n = 2

C-9. In a hypothetical system a particle of mass m and charge –3q is moving around a very heavy particle having charge q. Assuming Bohr's model to be true to this system, the orbital velocity of mass m when it is nearest to heavy particle is
(A) $\frac{3q^2}{2\varepsilon_0 h}$ (B) $\frac{3q^2}{4\varepsilon_0 h}$ (C) $\frac{3q}{2\varepsilon_0 h}$ (D) $\frac{3q}{4\varepsilon_0 h}$

C-10. In a hydrogen atom, the binding energy of the electron in the n^{th} state is E_n, then the frquency of revolutionof the electron in the nth orbits is:
(A) $2E_n$ /nh (B) $2E_n n$/h (C) E_n/nh (D) $E_n n$/h

SECTION (D) :ELECTRONIC TRANSITION IN THE H/H-LIKE ATOM/SPECIES OF EFFECT OF MOTION OF NUCLEUS AND ATOMIC COLLISIONS

D-1. Three photons coming from emission spectra of hydrogen sample are picked up. Their energies are 12.1eV, 10.2eV and 1.9eV. These photons must come from
(A) a single atom (B) two atoms
(C) three atom (D) either two atoms or three atoms

D-2. In a hypothetical atom, if transition from n = 4 to n = 3 produces visible light then the possible transition to obtain infrared radiation is :
(A) n = 5 to n = 3 (B) n = 4 to n = 2 (C) n = 3 to n = 1 (D) none of these

D-3. Energy levels *A*, *B* and *C* of a certain atom correspond to increasing values of energy, i.e. $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 are the wavelengths of radiations corresponding to transitions *C* to *B*, *B* to *A* and *C* to *A* respectively, which of the following relations is correct ?
(A) $\lambda_3 = \lambda_1 + \lambda_2$ (B) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$ (C) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (D) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

D-4. An electron with kinetic energy 10 eV is incident on a hydrogen atom in its ground state. The collision
(A) must be elastic (B) may be partially elastic
(C) must be completely inelastic (D) may be completely inelastic

D-5. When a hydrogen atom, initially at rest emits, a photon resulting in transition n = 5 $\rightarrow$ n = 1, its recoil speed is about :
(A) 10^{-4} m/s (B) 2×10^{-2} m/s (C) 4.2 m/s (D) 3.8×10^{-2} m/s

D-6.* A neutron collides head on with a stationary hydrogen atom in ground state
(A) If kinetic energy of the neutron is less than 13.6eV, collision must be elastic
(B) if kinetic energy of the neutron is less than 13.6eV, collision may be inelastic.
(C) inelastic collision may takes place when initial kinetic energy of neutron is greater than 13.6eV.
(D) perfectly inelastic collision may take place.

D-7. The electron in a hydrogen atom make a transition from an excited state to the ground state. Which of the following statement is true ?
(A) Its kinetic energy increases and its potential and total energies decrease
(B) Its kinetic energy decreases, potential energy increases and its total energy remains the same.
(C) Its kinetic and toal energies decrease and its potential energy increases.
(D) its kinetic potential and total energies decreases.

SECTION (E) : X-RAYS

E-1.* Consider a metal used to produced some charateristic X-rays. Energy of X-rays are given by E and wave-length as represented by λ. Then which of the following is true :
(A) $E(K_\alpha) > E(K_\beta) > E(K_\gamma)$ (B) $E(M_\alpha) > E(L_\alpha) > E(K_\alpha)$
(C) $\lambda(K_\alpha) > \lambda(K_\beta) > \lambda(K_\gamma)$ (D) $\lambda(M_\alpha) > \lambda(L_\alpha) > \lambda(K_\alpha)$

E-2. Which of the following wavelength will be absent from the X-ray spectrum if the X-ray tube is operated at 40,000 V?
(A) 0.2 Å (B) 0.5 Å (C) 1.0 Å (D) 2.0 Å

E-3.* In an X-ray tube, the intensity of the emitted X-ray beam is increased by
(A) increasing the filament current (B) decreasing the filament current
(C) increasing the target potential (D) decreasing the target potential

E-4. If a high speed electron hit a target :
(A) heat is produced and simultaneously continuous and characteristic X-rays are emitted
(B) only continuous X-ray are emitted
(C) only characteristic X-rays are emitted and continous X-rays are not emitted
(D) only heat is produced

E-5. The wavelength of K_α-line from an element of atomic number 41 is λ. Then the wavelength of K_α-line of an element of atomic number 21 is :
(A) 4λ (B) $\lambda/4$ (C) 3.08λ (D) $0.26\,\lambda$

E-6. The K_α X – ray emission line of tungsten occurs at λ = 0.021 nm. The energy difference between K and L levels in this atom is about
(A) 0.51 MeV (B) 1.2 MeV (C) 59 keV (C) 136 eV

E-7.* Regarding X ray spectrum which of the following statement/s is/are true
(A) The characteristic X ray spectrum is emitted due to excitation of inner electrons of atom
(B) Wavelength of characteristic spectrum depend on the potential difference across the tube.
(C) Wavelength of continuous spectrum is dependent on the potential difference across tube
(D) None of these

E-8. If the frequencies of K_α, K_β and L_α X-rays for a material ν_{K_α}, ν_{K_β}, ν_{L_α} respectively, then
(A) $\nu_{K_\alpha} = \nu_{K_\beta} + \nu_{L_\alpha}$ (B) $\nu_{L_\alpha} = \nu_{K_\alpha} + \nu_{K_\beta}$ (C) $\nu_{K_\beta} = \nu_{K_\alpha} + \nu_{L_\alpha}$ (D) none of these

PART - II : MISLLANEOUS QUESTIONS

1. COMPREHENSION TYPE

In quantum mechanics, some quantities are discrete and cannot be continuous. One of these quantities is the energy. Energy can only take certain values E_1, E_2, E_3, E_4......., which are called energy levels. The energy cannot take any values between E_1 and E_2, or E_2 and E_3 or E_3 and E_4 etc. Certain transitions from one energy level to another result in the emission of a photon of radiation, whereas others can only take place if a photon is absorbed. The energy levels in a newly discovered gas are expressed as:

$$E_n = \frac{-E_1 z^2}{n^2}$$

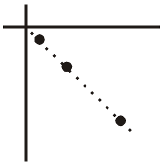
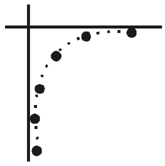
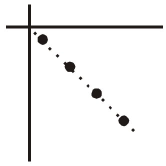
in which $-E_1z^2$ is the ground state energy. Take z = 1 for simplicity, but do not assume that the gas is hydrogen. An experiment is designed to measure the energy as a functions of the level. The results obtained are as follows :

n	E_n(eV)
2	–144
3	–64
4	–36

$$E_n = \frac{-E_1 z^2}{n^2}$$

1. The ionization energy of the gas must be :
(A) 244 eV (B) 576 eV (C) 144 eV (D) +13.6 eV

2. Which of the following shapes is most likely to represent the graph of E_n versus $1/n^2$?

(A)  (B)  (C)  (D) 

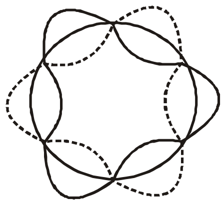
3. A transition from the n = 2 state to the n = 3 state results :
(A) in emission of a photon of energy 144 eV (B) in emission of a photon of energy 80 eV
(C) in emission of an ultraviolet photon (D) only accomplished if a photon is absorbed

COMPREHENSION # 2 :

Assuming that nature should exercise symmetry, prince Louis victor de broglie, in 1923, hypothesised that matter had a dual (wave-particle) nature like radiation. Duality of radiation was already established. Matter was earlier supposed to have only the 'particle' behaviour. de Broglie's idea of matter also as 'wave' did not find an experimental evidence at that time but it was soon established from the expreiments performed by davisson and germer and Thomson that electrons could be diffracted. These experiments verified de broglie's idea that matter had also a wave character. de Broglie further concluded that wavelength of matter wave associated with a moving object could be expressed as

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

Where P is the linear momentum of the object. Idea of duality of matter has some very improtant and immediate applications. It could explain quantisation of angular momentum and energy in the bohr model of the atom. In fact, bohr's model has many shortcomings. It was not immediately clear why should angular momentum or energy be quantised so that only discrete values of these quantities are allowed. de Brogile's concept, as applied to the motion of electron in an atom, treated electron as matter waves bent into a circle around the nucleus. It was suggested that allowed bohr's orbits arise if the electron matter waves interfere constructively and that it will result in a stationary wave that fits into the circular orbit as shown in Fig. Also it could be shown that quantisation of angular momentum ($m\nu r = nh/2\pi$) was then a natural consequence of such a visualisation of waves fitting in the orbits.



Answer the following questions.

4. For an allowed orbit, radius will be an intergal multiple of

(A) λ (B) $\frac{\lambda}{2}$ (C) $\frac{\lambda}{\pi}$ (D) $\frac{\lambda}{2\pi}$

5. Energy of the particle can be expressed as ($a = \pi r$; r = radius of orbit)

(A) $\frac{n^2m^2}{4h^2a^2}$ (B) $\frac{n^2h^2a^2}{8m^2}$ (C) $\frac{n^2h^2}{8ma^2}$ (D) $\frac{n^2m^2h^2}{4a^2}$

6. Minimum energy that will be require to excite the particle from the ground state to a higher state will be

(A) $\frac{3m^2}{4h^2a^2}$ (B) $\frac{3h^2a^2}{8m^2}$ (C) $\frac{3h^2}{8ma^2}$ (D) $\frac{3m^2h^2}{4a^2}$

2. MATCH THE COLUMN

7. Using Bohr's model, match the following. (Where the letters n and Z have usual meaning)

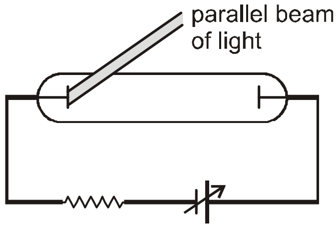
(A) Due to revolving electron, the magnetic field produced at its centre is proportional to — (P) n^{-5}

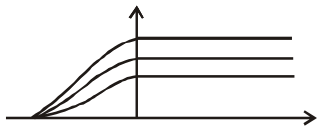
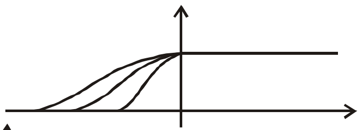
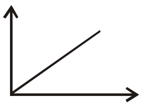
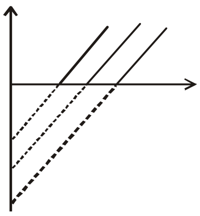
(B) Magnetic moment of revolving electron is proportional to — (Q) n

(C) De-Broglie wave length of revolving electron is proportional to — (R) Z^3

(D) Areal velocity of revolving electron about nucleus is proportional to — (S) independent of Z

8. In the shown experimental setup to study photoelectric effect, two conducting electrodes are enclosed in an evacuated glass-tube as shown. A parallel beam of monochromatic radiation, falls on photosensitive electrode. Assume that for each photons incident, a photoelectron is ejected if its energy is greater than work function of electrode. Match the statements in column I with corresponding graphs in column II.



Column-I	Column-II
(A) Photocurrent versus intensity of radiation is represented by	(p) 
(B) Maximum kinetic energy of ejected photoelectrons versus frequency for electrodes of different work function is represented by (frequency remain same)	(q) 
(C) Photo current versus applied voltage for different intensity of radiation is represented by (frequency remain same)	(r) 
(D) Photo current versus applied voltage at constant intensity of radiation for electrodes of different work function. (frequency remain same)	(s) 

3. True or False

9.
- **(i)** If an electron moves to a large orbit its total energy decreases.
- **(ii)** The wavelengths of 'hard' X-rays are larger than those of 'soft' X-rays.
- **(iii)** Some Frequencies of the Balmer lines of the hydrogen atom lie in the ultraviolet region.
- **(iv)** Characteristic X-rays depend on the nature of the target from which they are emitted.
- **(v)** Cathode rays are streams of particles travelling towards the cathode.
- **(vi)** Characteristic X-rays are emitted when the bombarding electrons knock out electrons from the inner shells of the target atoms and the outer electrons fall into these vacancies.

4. FILL IN THE BLANKS

10. **(i)** The energy of a photon of .... X-ray from a Coolidge tube comes from an atomic transition in the target
(ii) The photocurrent in an experiment on photoelectric effect increases if the intensity of the source is...........
(iii) The wavelength of the characteristic X - ray K_α line emitted by a hydrogen like element is 0.32 Å. The wavelength of the K_β line emitted by the element will be ________.
(iv) In an x-ray tube, electrons accelerated through a potential difference of 15000 V strike a copper target. The speed of the emitted x-rays inside the tube is ______ m/s.
(v) In the Bohr model of the hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in a quantum state n is _________.

EXERCISE # 2

PART - I : MIXED OBJECTIVE

* ***Marked Questions are having more than one correct option.***

SINGLE CORRECT ANSWER TYPE

1. If λ_{min} is minimum wavelength produced in X-ray tube and $\lambda_{k\alpha}$ is the wavelength of k_α line. As the operating tube voltage is increased.

(A) $(\lambda_k - \lambda_{min})$ increases
(B) $(\lambda_k - \lambda_{min})$ decreases
(C) $\lambda_{k\alpha}$ increases
(D) $\lambda_{k\alpha}$ decreases

2. An atom consists of three energy levels given by a ground state with energy $E_0 = 0$, the first excited state with energy $E_1 = K$ and the second excited state with energy $E_2 = 2K$ where $K > 0$. The atom is initially in the ground state. Light from a laser which emits photons with energy 1.5K is shined on the atom. Which of the following is/are correct ?
(A) The photons are absorbed, putting one atom in a state E_1 and one atom in a state E_2.
(B) A photon will always be absorbed, but half the time the atom will go into the state with energy K and the other half into the state with energy 2K. In this way, energy will be conserved on the average.
(C) The atom absorbs a photon, goes into the first excited state with energy K and emits a photon with energy 0.5 K to conserve energy.
(D) The atom does not absorb any photon and stays in the ground state.

3. The work function of a certain metal is $\frac{hC}{\lambda_0}$. When a monochromatic light of wavelength $\lambda < \lambda_0$ is incident such that the plate gains a total power P. If the efficiency of photoelectric emission is η% and all the emitted photoelectrons are captured by a hollow conducting sphere of radius R already charged to potential V, then neglecting any interaction between plate and the sphere, expression of potential of the sphere at time t is :

(A) $V + \frac{100\eta\lambda Pet}{4\pi\varepsilon_0 RhC}$ (B) $V - \frac{\eta\lambda Pet}{400\pi\varepsilon_0 RhC}$ (C) V (D) $\frac{\lambda Pet}{4\pi\varepsilon_0 RhC}$

4. In a Coolidge tube experiment, the minimum wavelength of the continuous X-ray spectrum is equal to 66.3 pm, then
(A) electrons accelerate through a potential difference of 12.75 kV in the Coolidge tube
(B) electrons accelerate through a potential difference of 18.7 kV in the Coolidge tube
(C) de-Broglie wavelength of the electrons reaching the anticathode is of the order of 10μm.
(D) de-Broglie wavelength of the electrons reaching the anticathode is 0.01Å.

5. An electron is in an excited state in hydrogen-like atom. It has a total energy of –3.4 eV. If the kinetic energy of the electron is E and its de-Broglie wavelength is λ, then

(A) E = 6.8 eV, $\lambda = 6.6 \times 10^{-10}$ m
(B) E = 3.4 eV, $\lambda = 6.6 \times 10^{-10}$ m
(C) E = 3.4 eV, $\lambda = 6.6 \times 10^{-11}$ m
(D) E = 6.8 eV, $\lambda = 6.6 \times 10^{-11}$ m

6. If radiation allow wavelengths from ultraviolet to infrared is passed through hydrogen gas at room temperature, absorption lines will be observed in the :

(A) Lyman series
(B) Balmer series
(C) both (A) and (B)
(D) neither (A) nor (B)

7. In the hydrogen atom, if the reference level of potential energy is assumed to be zero at the ground state level. Choose the incorrect statement.

(A) The total energy of the shell increases with increase in the value of n
(B) The total energy of the shell decrease with increase in the value of n.
(C) The difference in total energy of any two shells remains the same.
(D) The total energy at the ground state becomes 13.6 eV.

8. An electron in hydrogen atom first jumps from second excited state to first excited state and then, from first excited state to ground state. Let the ratio of wavelength, momentum and energy of photons in the two cases be x, y and z, then select the wrong answer/(s) :

(A) z = 1/x
(B) x = 9/4
(C) y = 5/27
(D) z = 5/27

MULTIPLE CORRECT ANSWER(S) TYPE

9. Select the correct alternative(s):
When photons of energy 4.25 eV strike the surface of a metal A, the ejected photo electrons have maximum kinetic energy T_A eV and de Broglie wave length $\lambda_{A.}$ The maximum kinetic energy of photo electrons liberated from another metal B by photons of energy 4.70 eV is $T_B = (T_A - 1.50)$ eV. If the de-Brogleie wave length of these photo electrons is $\lambda_B = 2\lambda_{A,}$ then:

(A) the work function of A is 2.25 eV
(B) the work function of B is 4.20 eV
(C) T_A = 2.00 eV
(D) T_B = 2.75 eV

10. Photoelectric effect supports particle nature of light because

(A) there is a minimum frequency below which no photoelectrons are emitted
(B) the maximum kinetic energy of photoelectrons depends only on the frequency of light and is independent of intensity.
(C) even when the metal surface is illuminated with very small intensity the photoelectrons (if $\nu \geq \nu_{th}$) leave the surface immediately
(D) electric charge of the photoelectrons is quantized

11. The potential difference applied to an X-ray tube is increased. As a result,in the emitted radiation.

(A) the intensity increases
(B) the minimum wavelength increases
(C) the intensity remains unchanged
(D) the minimum wavelength decreases

12. A hydrogen-like atoms has ground state binding energy 122.4 eV. Then :

(A) its atomic number is 3
(B) an electron of 90 eV can excite it to a higher state
(C) an 80 eV electron cannot excite it to a higher state
(D) an electron of 8.2 eV and a photon of 91.8 eV are emitted when a 100 eV electron interacts with it

13. X-rays

(A) cause ionisation of air when they pass through it
(B) can be deflected by electric and magnetic fields
(C) can be used to detect flaws in metal castings
(D) travel with the speed of light

14. The K shell ionisation energies for cobalt, copper and molybdenum are 7.8, 9.0 and 20.1 KeV respectively. If an X-ray tube operates at 15 kV with any of the above metals as targets, then :
(A) characteristic X-rays of K series will be emitted only from cobalt
(B) characteristic X-rays of K series will be emitted only from copper and cobalt
(C) characteristic X-rays of K series will be emitted from cobalt, copper and molybdenum.
(D) the shortest wavelength of continuous X-rays emitted is the same for the three metals.

15. According to Einstein's theory of relativity, mass can be converted into energy and vice-versa. The lightest elementary particle, taken to be the electron, has a mass equivalent to 0.51 MeV of energy, we can then say that :
(A) the minimum amount of energy available through conversion of mass into energy is 1.02 MeV.
(B) the least energy of a γ-ray photon than can be converted into mass is 1.02 MeV.
(C) the minimum energy released by conversion of mass into enegy is 0.51 MeV.
(D) None of these

16. Two electrons are moving with the same speed v. One electron enters a region of uniform electric field while the other enters a region of uniform magnetic field, then after sometime if the de–Broglie wavelengths of the two are λ_1 and λ_2, then which are possible:
(A) $\lambda_1 = \lambda_2$ (B) $\lambda_1 > \lambda_2$ (C) $\lambda_1 < \lambda_2$ (D) Data insufficient

17. A beam of ultraviolet light of all wavelengths passes through hydrogen gas at room temperature, in the x-direction. Assume that all photons emitted due to electron transition inside the gas emerge in the y-direction. Let A and B denote the lights emerging from the gas in the x and y directions respectively.
(A) Some of the incident wavelengths will be absent in A.
(B) Only those wavelengths will be present in B which are absent in A.
(C) B may contain some visible light.
(D) B may contain some infrared light.

18. A neutron collides head-on with a stationary hydrogen atom in ground state. Which of the following statements are correct (Assume that the hydrogen atom and neutron has same mass) :
(A) If kinetic energy of the neutron is less than 20.4 eV collision must be elastic.
(B) If kinetic energy of the neutron is less than 20.4 eV collision may be inelastic.
(C) Inelastic collision may be take place only when initial kinetic energy of neutron is greater than 20.4 eV.
(D) Perfectly inelastic collision can not take place.

19. A free hydrogen atom in ground state is at rest. A neutron of kinetic energy 'K' collides with the hydrogen atom. After collision hydrogen atom emits two photons in succession one of which has energy 2.55 eV. (Assume that the hydrogen atom and neutron has same mass)
(A) minimum value of 'K' is 25.5 eV. (B) minimum value of 'K' is 12.75 eV
(C) the other photon has energy 10.2 eV (D) the upper energy level is of excitation energy 12.75 eV.

PART - II : SUBJECTIVE QUESTIONS

1. A light beam of wavelength 400 nm is incident on a metal plate of work function 2.2 eV. A particular electron absorbs a photon and makes some collisions before coming out of the metal. Assuming that 10% of the instantaneous energy is lost to the metal in each collision.find the minimum number of collisions the electron can suffer before it becomes unable to come out of metal. (use hc = 12400 eV Å)

2. Consider Bohr's theory for hydrogen atom. The magnitude of angular momentum, orbit radius and frequency of the electron in n^{th} energy state in a hydrogen atom are ℓ, r & f respectively. Find out the value of 'x', if $(fr\ell)$ is directly proportional to n^x.

3. A sample of hydrogen atom gas contains 100 atoms. All the atoms are excited to the same n^{th} excited state. The total energy released by all the atoms is $\frac{4800}{49}$ Rch (where Rch = 13.6 eV), as they come to the ground state through various types of transitions and maximum total number of photons that can be emitted by this sample are 100m. Find n and m

4. Consider a system in which the electrons do not have spin and a spin quantum number does not exist. How many electrons can there be in the state with principal quantum number n = 3?

5. A hydrogen atom emits radiation of wavelength 102.5 nm. What are the n values of the two levels involved?

6. A beam of 5.0 nm wavelength X-rays is incident on a gas of unexcited hydrogen atoms. It expels the atomic photoelectrons from the hydrogen atoms.Their speed is 9.08×10^{x} m/s then find value of x.

7. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength 975Å. How many different lines are possible in the resulting spectrum ? You may assume the ionization energy for hydrogen atom as 13.6 eV.

8. To stop the flow of photoelectrons produced by electromagnetic radiation incident on a certain metal, a negative potential of 300 volts is required. If the photoelectric threshold of the metal is 1500Å, The frequency of the incident radiation is = 7.45×10^{4x} cycles/s then find value of x.

9. A monochromatic beam of light (λ = 4900 A°) incident normally upon a surface produces a pressure of 5×10^{-7} N/m^2 on it. Assuming that 25% of the light incident is reflected and the rest absorbed. The number of photons falling per second on a unit area of thin surface is 2.93×10^{4n}.then find value of n.

10. A gas of hydrogen like atoms can absorb radiations of 68 eV. Consequently, the atoms emit radiations of only three different wavelengths. All the wavelengths are equal or greater than that of the absorbed photon.
(A) Determine the initial state of the gas atoms.
(B) Identify the gas atoms.

11. The magnetic field at a point associated with a light wave is B = 2×10^{-6} Tesla sin [(3.0×10^{15} s^{-1})t] sin [(6.0×10^{15} s^{-1})t]. If this light falls on a metal surface having a work function of 2.0 eV , what will be the maximum kinetic energy of the photoelectrons ?

12. One milliwatt of light of wavelength λ = 4560 Å is incident on a cesium metal surface. Calculate the electron current liberated. Assume a quantum efficiency of η = 0.5 %. [work function for cesium = 1.89 eV]
Take hc = 12400 eV-Å.

13. A sodium lamp of power 10 W is emitting photons of wavelength 590 nm. Assuming that 60% of the consumed energy is converted into light, find the number of photons emitted per second by the lamp.

14. Photo electrons are liberated by ultraviolet light of wavelength 3000 Å from a metallic surface for which the photoelectric threshold wavelength is 4000 Å. Calculate the de Broglie wavelength of electrons emitted with maximum kinetic energy.

15. Find the temperature at which the average kinetic energy of the molecules of hydrogen equals the binding energy of its electron in ground state, assuming average kinetic energy of hydrogen gas molecule = $\frac{3}{2}kT$.

16. A monochromatic light source of frequency ν illuminates a metallic surface and ejects photoelectrons. The photoelectrons having maximum energy are just able to ionize the hydrogen atoms in ground state. When the whole experiment is repeated with an incident radiation of frequency $\left(\frac{5}{6}\right)\nu$ the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength of 1215 Å. Find the frequency ν.

17. Consider a gas of hydrogen like ions in a excited state A. It emits photons having wavelength equal to the wavelength of the first line of the lyman series together with photons of five other wavelengths. Identify the gas and find the principal quantum number of the state A.

18. From the condition of the foregoing problem, find how much (in %) the energy of the emitted photon differs from the energy of the corresponding transition in a hydrogen atom.

19. At what minimum kinetic energy must a hydrogen atom move for it's inelastic headon collision with another stationary hydrogen atom so that one of them emits a photon? Both atoms are supposed to be in the ground state prior to the collision.

20. On increasing the operating voltage in a x-ray tube by 1.5 times, the shortest wavelength decreases by 26 pm. Find the original value of operating voltage.

21. An X-ray tube operates at 20 kV. Suppose the electron converts 70% of its energy into a photon at each collision. Find the lowest three wavelength emitted from the tube. Neglect the energy imparted to the atom with which the electron collides.

22. Find the wavelength of the K_α line in copper (Z = 29), if the wave length of the K_α line in iron (Z = 26) is known to be equal to 193 pm. (Take b = 1)

EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

*** Marked Questions are having more than one correct option.**

1. **(a)** Electrons with energy 80keV are incident on the tungsten target of an X–ray tube. K shell electrons of tungsten have –72.5keV energy. X–rays emitted by the tube contain only

(A) a continuous X–ray spectrum (Bremsstrahlung) with a minimum wavelength of ~ 0.155Å.

(B) a continuous X–ray spectrum (Bremsstrahlung) with all wavelengths.

(C) the characteristic X–ray spectrum of tungsten.

(D) a continuous X–ray spectrum (Bremsstrahlung) with a minimum wavelength of ~ 0.155Å and the characteristic X–ray spectrum of tungsten. **[JEE '2000, Screening 1 + 1/35]**

(b) Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to

(A) 9/(5R) (B) 36/(5R) (C) 18/(5R) (D) 4/R

2. (a) A hydrogen – like atom of atomic number Z is in an excited state of quantum number 2 n. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. Find, n, Z and the ground state energy (in eV) for this atom. Also, calculate the minimum energy (in eV) that can be emitted by this atom during de–excitation. Ground state energy of hydrogen atom is – 13.6 eV. **[JEE '2000, Mains 6+4/100]**

(b) When a beam of 10.6 eV photons of intensity 2.0 W/m^2 falls on a platinum surface of area 1.0 ×10^{-4} m^2 and work function 5.6 eV, 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per second and their minimum and maximum energies (in eV). Take 1 eV = 1.6 × 10^{-19} J.

3. A hydrogen – like gas (described by the Bohr model) is observed to emit six wavelength, originating from all possible transitions between a group of levels. These levels have energies between a group of levels. These levels have energies between – 0.85 eV and – 0.544 eV (including both these values):

(a) Find the atomic number of the atom. **[JEE '2002, Mains, 4 + 1/60]**

(b) Calculate the smallest wavelength emitted in these transitions.

[Take hc = 1240 eV – nm, ground state energy of hydrogen atom = – 13.6 eV]

4. The attractive potential between electron and nucleus is given by $v = v_0 \ell n \frac{r}{r_0}$, v_0 and r_0 are constants and ' r ' is the radius. The radius ' r ' of the nth Bohr's orbit depends upon principal quantum number ' n ' as: **[JEE '2003, Scr. 3/84]**

(A) $r \propto n^2$ (B) $r \propto n$ (C) $r \propto \frac{1}{n}$ (D) $r \propto \frac{1}{n^2}$

5. If Bohr's theory is applicable to $_{100}Fm^{257}$, then radius of this atom in Bohr's unit is :**[JEE '2003, Scr. 3/84]**

(A) 4 (B) 1/4 (C) 100 (D) 200

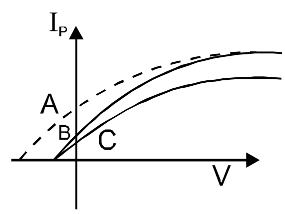
6. In a photoelectric effect experiment, photons of energy 5 eV are incident on the photocathode of work function 3 eV. For photon intensity $I_A = 10^{15}\ m^{-2}\ s^{-1}$, saturation current of 4.0 μ A is obtained. Sketch the variation of photocurrent i_p against the anode voltage V_a in the figure below for photon intensity I_A (curve A) and $I_B = 2 \times 10^{15}\ m^{-2}\ s^{-1}$ (curve B) (in JEE graph was to be drawn in the answer sheet itself.)

[JEE '2003, Mains 2/60]

7. Characteristic X-rays of frequency 4.2×10^{18} Hz are emitted from a metal due to transition from L-to K-shell. Find the atomic number of the metal using Moseley's law. Take Rydberg constant $R = 1.1 \times 10^7\ m^{-1}$.

[JEE '2003, Mains 2/60]

8. The graph is showing the photocurrent with the applied voltage of a photoelectric effect experiment. Then



(A) A & B will have same intensity and B & C have same frequency

(B) B & C have same intensity and A & B have same frequency

(C) A & B will have same frequency and B & C have same intensity

(D) A & C will have same intensity and B & C have same frequency **[JEE '2004, Scr.; 3/84]**

9. A proton and photon both have same energy of E = 100 K eV. The debroglie wavelength of proton and photon be λ_1 and λ_2 then λ_1/λ_2 is proportional to - **[JEE '2004, Scr. 3/84]**

(A) $E^{-1/2}$ (B) $E^{1/2}$ (C) E^{-1} (D) E

10. The photons from Balmer series in hydrogen spectrum having wavelength between 450 nm to 700 nm are incident on a metal surface of work function 2 eV. Find the maximum kinetic energy of one photo electron.

[JEE 2004 Mains, 4/60]

11. The wavelength of K_α X-ray of an element having atomic number z = 11 is λ. The wavelength of K_α X-ray of another element of atomic number z′ is 4λ. Then z′ is - **[JEE '2005, Scr, 3/84]**

(A) 11 (B) 44 (C) 6 (D) 4

12. A photon of 10.2 eV energy collides with a hydrogen atom in ground state inelastically. After few microseconds one more photon of energy 15 eV collides with the same hydrogen atom. Then what can be detected by a suitable detector.

(A) one photon of 10.2 eV and an electron of energy 1.4 eV

(B) 2 photons of energy 10.2 eV

(C) 2 photons of energy 3.4 eV

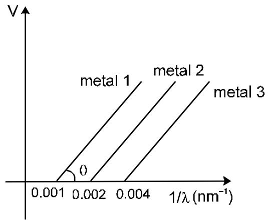
(D) 1 photon of 3.4 eV and one electron of 1.4 eV **[JEE (Scr.) 2005, 3/84]**

13. The potential energy of a mass 'm' is given by the following relation

$$U = E_0 \text{ for } 0 \le x \le 1$$
$$= 0 \text{ for } x > 1$$

If λ_1 and λ_2 are the de-broglie wavelengths of the mass in the region $0 \le x \le 1$ and for $x > 1$ respectively and the total energy be $2E_0$, then find the value of $\frac{\lambda_1}{\lambda_2}$? **[JEE (Mains) 2005, 2/60]**

14. The graph between $1/\lambda$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photo–electric effect is plotted as shown in the figure. Which of the following statement(s) is/are correct ? [Here λ is the wavelength of the incident ray]. **[JEE 2006, 5/184]**



(A) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$.
(B) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$.
(C) $\tan\theta$ is directly proportional to hc/e, where h is Planck's constant and c is the speed of light.
(D) The violet colour light can eject photoelectrons from metals 2 and 3.

15. If the wavelength of the n^{th} line of Lyman series is equal to the de-broglie wavelength of electron in initial orbit of a hydrogen like element (z = 11). Find the value of n. **[JEE 2006, 5/184]**

16. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is **[JEE 2007, 3/81]**
(A) 802 nm (B) 823 nm (C) 1882 nm (D) 1648 nm

17. **STATEMENT-1** **[JEE 2007, 3/81]**
If the accelerating potential in an X-ray tube is increased, the wavelengths of the characteristic X-rays do not change.
STATEMENT-2
When an electron beam strikes the target in an X-ray tube, part of the kinetic energy is converted into X-ray energy.
(A) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1
(B) Statement-1 is True, Statement-2 is True; Statement-2 **is NOT** a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True.

18. Electrons with de-Broglie wavelength λ fall on the target in an X-ray tube. The cut-off wavelength of the emitted X-rays is : **[JEE 2007, 3/81]**

(A) $\lambda_0 = \frac{2mc\lambda^2}{h}$ (B) $\lambda_0 = \frac{2h}{mc}$ (C) $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$ (D) $\lambda_0 = \lambda$

19. Which one of the following statements is WRONG in the context of X-rays generated from a X-ray tube? **[JEE 2008, 4/163]**
(A) Wavelength of characteristic X-rays decreases when the atomic number of the target increases
(B) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target
(C) Intensity of the characteristic X-rays depends on the electrical power given to the X-ray tube
(D) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

Paragraph :

In a mixture of H – He^+ gas (He^+ is singly ionized He atom), H atoms and He^+ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He^+ ions (by collisions). Assume that the Bohr model of atom is exactly valid. **[IIT-JEE 2008, 12/163]**

20. The quantum number n of the state finally populated in He^+ ions is :
(A) 2 (B) 3 (C) 4 (D) 5

21. The wavelength of light emitted in the visible region by He^+ ions after collisions with H atoms is
(A) 6.5×10^{-7} m (B) 5.6×10^{-7} m (C) 4.8×10^{-7} m (D) 4.0×10^{-7} m

22. The ratio of the kinetic energy of the n = 2 electron for the H atom to that of He^+ ion is :
(A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) 1 (D) 2

Paragraph for Question Nos. 23 to 25 **[IIT-JEE 2009, 3×4/160, –1]**

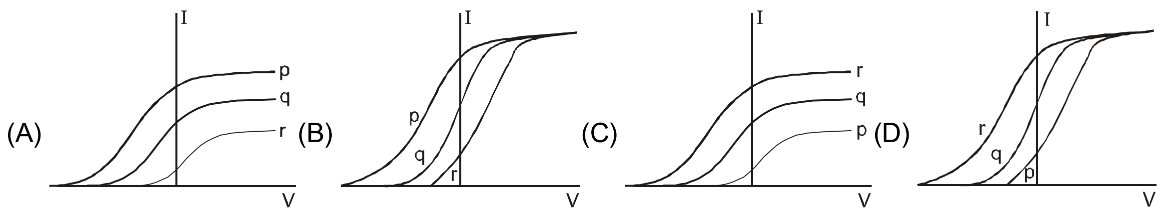
When a particle is restricted to move along x-axis between x = 0 and x = a, where a is of nanometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends x = 0 and x = a. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de-Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$.
Thus, the energy of the particle can be denoted by a quantum number 'n' taking values 1,2,3,......., (n = 1, called the ground state) corresponding to the number of loops in the standing wave.
Use the model described above to answer the following three questions for a particle moving in the line x = 0 to x = a. Take $h = 6.6 \times 10^{-34}$ J s and $e = 1.6 \times 10^{-19}$ C.

23. The allowed energy for the particle for a particular value of n is proportional to :
(A) a^{-2} (B) $a^{-3/2}$ (C) a^{-1} (D) a^2

24. If the mass of the particle is $m = 1.0 \times 10^{-30}$ kg and a = 6.6 nm, the energy of the particle in its ground state is closest to :
(A) 0.8 meV (B) 8 meV (C) 80 meV (D) 800 meV

25. The speed of the particle, that can take discrete values, is proportional to :
(A) $n^{-3/2}$ (B) n^{-1} (C) $n^{1/2}$ (D) n

26. Photoelectric effect experiments are performed using three different metal plates p, q and r having work functions $\phi_p = 2.0$ eV, $\phi_q = 2.5$ eV and $\phi_r = 3.0$ eV respectively. A light beam containing wavelengths of 550 nm, 450 nm and 350 nm with equal intensities illuminates each of the plates. The correct I-V graph for the experiment is [Take hc = 1240 eV nm] **[JEE 2009, 3/160, –1]**



27. An α-particle and a proton are accelerated from rest by a potential difference of 100V. After this, their de-Broglie wavelength are λ_α and λ_p respectively. The ratio $\frac{\lambda_p}{\lambda_\alpha}$, to the nearest integer, is : **[JEE 2010, 3/163]**

Paragraph for questions 28 to 30

The key feature of Bohr's theory of spectrum of hydrogen atom is the quantization of angular momentum when an electron is revolving around a proton. We will extent this to a general rotational motion to find quantized rotational energy of a diatomic molecule assuming it to be rigid. The rule to be applied is Bohr's quantization condition. **[JEE 2010, 3×3/163, –1]**

28. A diatomic molecule has moment of inertia I. By Bohr's quantization condition its rotational energy in the n^{th} level (n = 0 is not allowed) is :

(A) $\frac{1}{n^2}\left(\frac{h^2}{8\pi^2 I}\right)$ (B) $\frac{1}{n}\left(\frac{h^2}{8\pi^2 I}\right)$ (C) $n\left(\frac{h^2}{8\pi^2 I}\right)$ (D) $n^2\left(\frac{h^2}{8\pi^2 I}\right)$

29. It is found that the excitation frequency from ground to the first excited state of rotation for the CO molecule is close to $\frac{4}{\pi}\times 10^{11}$ Hz. Then the moment of inertia of CO molecule about its centre of mass is close to (Take h = $2\pi \times 10^{-34}$ J s)

(A) 2.76×10^{-46} kg m^2 (B) 1.87×10^{-46} kg m^2 (C) 4.67×10^{-47} kg m^2 (D) 1.17×10^{-47} kg m^2

30. In a CO molecule, the distance between C (mass = 12 a.m.u.) and O (mass = 16 a.m.u.), where 1 a.m.u. = $\frac{5}{3}\times 10^{-27}$ kg, is close to :

(A) 2.4×10^{-10} m (B) 1.9×10^{-10} m (C) 1.3×10^{-10} m (D) 4.4×10^{-11} m

31. The wavelength of the first spectral line in the Balmer series of hydrogen atom is 6561 Å. The wavelength of the second spectral line in the Balmer series of singly-ionized helium atom is : **[IIT-JEE 2011; 4/160 conducted by IIT Kanpur]**

(A) 1215 Å (B) 1640 Å (C) 2430 Å (D) 4687 Å

32. A silver sphere of radius 1 cm and work function 4.7 eV is suspended from an insulating thread in free-space. It is under continuous illumination of 200 nm wavelength light. As photoelectrons are emitted, the sphere -gets charged and acquires a potential. The maximum number of photoelectrons emitted from the sphere is A × 10^Z (where 1 < A < 10). The value of 'Z' is : **[IIT-JEE 2011; 4/160 conducted by IIT Kanpur]**

33. A proton is fired from very far away towards a nucleus with charge Q = 120 e, where e is the electronic charge. It makes a closest approach of 10 fm to the nucleus. The de Broglie wavelength (in units of fm) of the proton at its start is (take the proton mass, m_p = (5/3) × 10^{-27} kg; h/e = 4.2 × 10^{-15} J.s/C; $\frac{1}{4\pi\varepsilon_0}$ = 9 × 10^9 m/F; 1 fm = 10^{-15}m) **[JEE 2012 (3, –1)/136] [conducted by IIT Dehli]**

34. A particle of mass m is projected from the ground with an initial speed u_0 at an angle α with the horizontal. At the highest point of its trajectory, it makes a completely inelastic collision with another identical particle, which was thrown vertically upward from the ground with the same initial speed u_0. The angle that the composite system makes with the horizontal immediately after the collision is : **[IIT-JEE (Advanced) P-1 2013]**

(A) $\frac{\pi}{4}$ (B) $\frac{\pi}{4}+\alpha$ (C) $\frac{\pi}{2}-\alpha$ (D) $\frac{\pi}{2}$

35. The work function of Silver and Sodium are 4.6 and 2.3 eV, respectively. The ratio of the slope of the stopping potential versus frequency plot for Silver to that of Sodium is : **[IIT-JEE (Advanced) P-1 2013]**

36. The radius of the orbit of an electron in a Hydrogen-like atom is 4.5 a_0, where a_0 is the Bohr radius. Its orbital angular momentum is $\frac{3h}{2\pi}$. It is given that h is Planck constant and R is Rydberg constant. The possible wavelength(s), when the atom de-excites, is (are) **[IIT-JEE (Advanced) P-2 2013]**

(A) $\frac{9}{32R}$ (B) $\frac{9}{16R}$ (C) $\frac{9}{5R}$ (D) $\frac{4}{3R}$

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

*** Marked Questions are having more than one correct option.**

1. If 13.6 eV energy is required to Iionize the hydrogen atom, then the energy required to remove an electron from n = 2 is : **[AIEEE 2002 4/300]**
(1) 10.2 eV (2) 0 eV (3) 3.4 eV (4) 6.8 eV

2. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of threshold wavelengths is nearest to : **[AIEEE 2002 4/300]**
(1) 1 : 2 (2) 4 : 1 (3) 2 : 1 (4) 1 : 4

3. Formation of covalent bonds in compounds exhibits : **[AIEEE 2002 4/300]**
(1) wave nature of electron (2) particle nature of electron
(3) both wave and particle nature of electron (4) none of these

4. 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 : **[AIEEE 2003 4/300]**

(1) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$ (2) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$

(3) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 + f_2)$ (4) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$

5. Which of the following atoms has the lowest ionization potential? **[AIEEE 2003 4/300]**
(1) $^{14}_{7}N$ (2) $^{133}_{55}Cs$ (3) $^{40}_{18}Ar$ (4) $^{16}_{8}O$

6. The wavelength involved in the spectrum of deuterium $\left(^{2}_{1}D\right)$ are slightly different from that of hydrogen spectrum, because : **[AIEEE 2003 4/300]**
(1) size of the two nuclei are different
(2) nuclear forces are different in the two cases
(3) masses of the two nuclei are different
(4) attraction between the electron and the nucleus is different in the two cases

7. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{2+} is : **[AIEEE 2003 4/300]**
(1) 30.6 eV (2) 13.6 eV (3) 13.6 eV (4) 122.4 eV

8. In Bohr series of lines of hydrogen spectrum, the third line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits is an atom of hydrogen ? **[AIEEE 2003 4/300]**

(1) $3 \rightarrow 2$ (2) $5 \rightarrow 2$ (3) $4 \rightarrow 1$ (4) $2 \rightarrow 5$

9. The de Broglie wavelength of a tennis ball of mass 60 g moving with a velocity of 10 metres per second is approximately - (Planck's constant, h = 6.63×10^{-34} Js) **[AIEEE 2003 4/300]**

(1) 10^{-33} metre (2) 10^{-31} metre (3) 10^{-16} metre (4) 10^{-25} metre

10. The orbital angular momentum for an electron revolving in an orbit is given by $\sqrt{\ell(\ell+1)}\,\frac{h}{2\pi}$. This momentum for an s-electron will be given by - **[AIEEE 2003 4/300]**

(1) $+\frac{1}{2}.\frac{h}{2\pi}$ (2) zero (3) $\frac{h}{2\pi}$ (4) $\sqrt{2}.\frac{h}{2\pi}$

11. A radiation of energy E falls normally on a perfecting reflecting surface. The momentum transferred to the surface is: **[AIEEE 2004 4/300]**

(1) E/c (2) 2E/c (3) Ec (4) E/c^2

12. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photoelectrons from a metal Vs then frequency, of the incident radiation gives a straight line whose slope : **[AIEEE 2004 4/300]**

(1) depends on the nature of the metal used
(2) depends on the intensity of the radiation
(3) depends both on the intensity of the radiation and the metal used
(4) is the same for all metals and independent of the intensity of the radiation

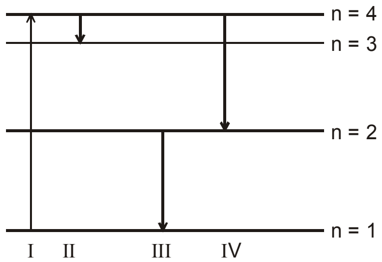
13. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately : **[AIEEE 2004 4/300]**

(1) 540 nm (2) 400 nm (3) 310 nm (4) 220 nm

14. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would : **[AIEEE 2005 4/300]**

(1) decrease by a factor of 4 (2) increase by a factor of 4
(3) decrease by a factor of 2 (4) increase by a factor of 2

15. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy? **[AIEEE 2005 4/300]**



(1) III (2) IV (3) I (4) II

16. If the kinetic energy of a free electron doubles, its de-Broglie wavelength changes by the factor :

(1) $\frac{1}{2}$ (2) 2 (3) $\frac{1}{\sqrt{2}}$ (4) $\sqrt{2}$ **[AIEEE 2005 4/300]**

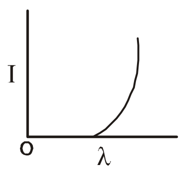
17. The time by a photoelectron to come out after the photon strikes is approximately **[AIEEE 2006 3/180]**
(1) 10^{-1} s (2) 10^{-4} s (3) 10^{-10} s (4) 10^{-16} s

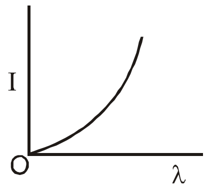
18. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to : **[AIEEE 2006 3/180]**
(1) $\frac{1}{Ze}$ (2) v^2 (3) $\frac{1}{m}$ (4) $\frac{1}{v^4}$

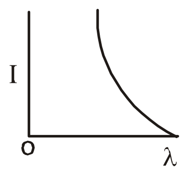
19. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV, and the stopping potential for a radiation incident on this surface 5 V. The incident radiation lies in **[AIEEE 2006 3/180]**
(1) X-ray region (2) ultra-violet region (3) infra-red region (4) visible region

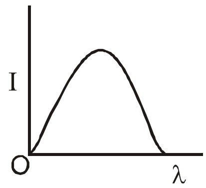
20. A solid which is transparent to visible light and whose conductivity increases with temperature is formed by **[AIEEE 2006 3/180]**
(1) Metallic binding (2) Ionic binding (3) Covalent binding (4) Van der Waals binding

21. The anode voltage of a photocell is kept fixed. The wavelength of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows : **[AIEEE 2006 3/180]**

(1) 

(2) 

(3) 

(4) 

22. Photon of frequency v has a momentum associated with it. If c is the velocity of light, the momentum is: **[AIEEE 2007 3/120, –1]**
(1) v/c (2) hvc (3) h v/c^2 (4) h v/c

23. Which of the following transitions in hydrogen atoms emit photons of highest frequency ? **[AIEEE 2007 3/120, –1]**
(1) n = 2 to n = 6 (2) n = 6 to n = 2 (3) n = 2 to n = 1 (4) n = 1 to n = 2

24. Suppose an electron is attracted towards the origin by a force $\frac{k}{r}$ where 'k' is a constant and 'r' is the distance of the electron from the origin. By applying Bohr model to this system, the radius of the nth orbital of the electron is found to be 'r_n' and the kinetic energy of the electron to be 'T_n'. Then which of the following is true?

(1) T_n independent of n, r_n , (2) $T_n \propto \frac{1}{n}$, $r_n \propto n$ **[AIEEE 2008 3/105, –1]**

(3) T_n μ $\frac{1}{n}$ n_1, $r_n \propto n^2$ (4) T_n μ $\frac{1}{n^2}$, $r_n \propto n^2$

25. The transition from the state n =4 to n =3 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from: **[AIEEE 2009 4/144, –1]**
(1) 3 → 2 (2) 4 → 2 (3) 5 → 4 (4) 2 → 1

26. 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 fuction of the metal is : (hc = 1240 eV.nm) **[AIEEE 2009 4/144, –1]**

(1) 1.41 eV (2) 1.51 eV (3) 1.68 eV (4) 3.09 eV

27. **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. **[AIEEE 2010, 4/144, –1]**

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.

(1) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.

(2) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1

(3) Statement-1 is false, Statement-2 is true.

(4) Statement-1 is true, Statement-2 is false.

28. If a source of power 4 kW produces 10^{20} photons/second, the radiation belongs to a part of the spectrum called: **[AIEEE 2010, 4/144, –1]**

(1) X-rays (2) ultraviolet rays (3) microwaves (4) γ-rays

29. This question has Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describe the two statements. **[AIEEE 2011, 4/144, –1]**

Statement-1 : A metallic surface is irradiated by a monochromatic light of frequency $v > v_0$ (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 froma surface are linearly dependent on the frequency of incident light.

(1) Statement .1 is true, statement .2 is false.

(2) Statement .1 is true, Statement .2 is true, Statement .2 is the correct explanation of Statement .1

(3) Statement .1 is true, Statement .2 is true, Statement .2 is not the correct explanation of Statement.1

(4) Statement.1 is false, Statement .2 is true

30. Enery required for the electron excitation in Li^{++} from the first to the third Bohr orbit is :

[AIEEE 2011, 4/144, –1]

(1) 12.1 eV (2) 36.3 eV (3) 108.8 eV (4) 122.4 eV

31. Hydrogen atom is excieted from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be : **[AIEEE 2012]**

(1) 2 (2) 3 (3) 5 (4) 6

32. This equation has statement 1 and Statement 2. Of the four choices given the Statements, choose the one that describes the two statements. **[AIEEE 2012]**

Statement 1 : Davisson-Germer experiment established the wave nature of electrons.

Statement 2 : If electrons have wave nature, they can interfere and show diffraction.

(1) Statement 1 is false, Statement 2 is true.

(2) Statement 1 is true, Statement 2 is false

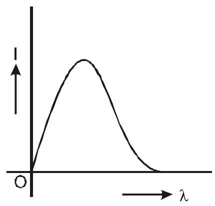
(3) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation for statement 1

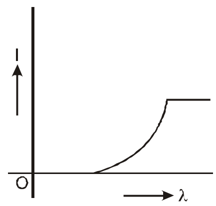
(4) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1

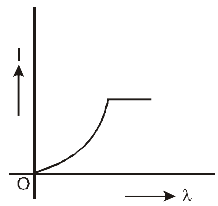
33. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r. If we calculate its rotational energy by applying Bohrís rule of angular momentum quantization, its energy will be given by : (n is an integer) **[AIEEE 2012]**

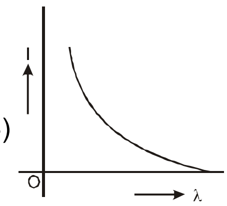
(1) $\frac{(m_1+m_2)^2 n^2 h^2}{2m_1^2 m_2^2 r^2}$ (2) $\frac{n^2 h^2}{2(m_1+m_2)r^2}$ (3) $\frac{2n^2 h^2}{(m_1+m_2)r^2}$ (4) $\frac{(m_1+m_2)n^2 h^2}{2m_1 m_2 r^2}$

34. The anode voltage of a photocell is kept fixed. The wavelength l of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows :

(1) 

(2) 

(3) 

(4) 

35. In a hydrogen like-atom electron makes transition from an energy level with quantum number n to another with quantum number (n – 1). If n >> 1, the frequency of radiation emitted is proportional to :

(1) $\frac{1}{n}$ (2) $\frac{1}{n^2}$ (3) $\frac{1}{n^{3/2}}$ (4) $\frac{1}{n^3}$

EXERCISE # 4

NCERT QUESTIONS

1. The photoelectric cut-off voltage in a certain experiment is 1.5 V. What is the maximum kinetic energy of photoelectrons emitted ?

2. Monochromatic light of wavelength 632.8 nm is produced by a helium-neon laser. The power emitted is 9.42 mW.
(a) Find the energy and momentum of each photon in the light beam,
(b) How fast does a hydrogen atom have to travel in order to have the same momentum as that of the photon?

3. The energy flux of sunlight reaching the surface of the earth is 1.388 x 10^3 W/m^2 . How many photons (nearly) per square meter are incident on the Earth per second? Assume that the photons in the sunlight have an average wavelength of 550 nm.

4. In an experiment on photoelectric effect, the slope of the cut-off voltage versus frequency of incident light is found to be 4.12 x 10^{-15} Vs. Calculate the value of Planck's constant.

5. A 100 W sodium lamp radiates energy uniformly in all directions. The lamp is located at the center of a large sphere that absorbs all the sodium light which is incident on it. The wavelength of the sodium light is 589 nm. (a) What is the energy per photon associated with the sodium light (b) At what rate the photons delivered to the sphere ?

6. Light of frequency 7.21 x 10^{14} Hz is incident on a metal surface. Electrons with a maximum speed of 6.0 x 10^5 m/s are ejected from the surface. What is the threshold frequency for photoemission of electrons?

7. Light of wavelength 488 nm is produced by an argon laser which is used in the photoelectric effect. When light from this spectral line is incident on the cathode, the stopping (cut-off) potential of photoelectrons is 0.38 V. Find the work function of the material from which cathode is made.

8. Calculate the
(a) momentum,
(b) de Broglie wavelength of the electrons accelerated through a potential difference of 56 V.

9. What is the de Broglie wavelength of a nitrogen molecule in air at 300 K? Assume that the molecule is moving with the root-mean-square speed of molecules at this temperature.
(Atomic mass of nitrogen =14.0076 u)

10. (a) A monoenergetic electron beam with electron speed of 5.20 x 10^6 m s^{-1} is subject to a magnetic field of 1.30 x 10^{-4} T normal to the beam electron equals 1.76 x 10^{11} C kg^{-1}.
(b) Is the formula you employ in (a) valid for calculating radius of the path of
[**Note :** Exercises 12.24 (b) take you to relativistic mechanics which emphasise the point that the formulas you use in part (a) of the exercises are not valid at very high speeds or energies. See answers at the end to know what 'very high speed or energy' means.]

11. An electron gun with its anode at a potential of 100 V fires out electrons in a spherical bulb containing hydrogen gas at low pressure (-10^{-2} mm of Hg). A magnetic field of 2.38 x 10^{-4} T curves the path of the electrons in a circular orbit of radius 12.0 cm. (The path can be viewed because the gas ions in the path focus the beam by attracting electrons, and emitting light by electron capture; this method is known as the 'fine beam tube ' method .) Determine e/m from the data.

12. The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of the electron in this state?

13. The radius of the innermost electron orbit of a hydrogen atom is 5.3 x 10^{-11} m. What are the radii of the n = 2 and n = 3 orbits?

14. Choose the correct alternative from clues given at end of the each statement:
(a) the size of the atom in Thomson's model is......... the atomic size in Rutherford's model.(much greater than/no different from/ much less than.)
(b) In the ground state of .... electrons are in stable equilibrium, while in .... electrons always a net force. (Thomson's model/Rutherford's model.)
(c) A classical atom based on .... is doomed to collapse. (Thomson's model/Rutherford's model.)
(d) An atom has a nearly continuous mass distribution in a ...... but has a highly non-uniform mass distribution in .... (Thomson's model/Rutherford's model/both the model.)
(e)The positively charged part of the atom possesses most of the mass in .... (Rutherford's model/ both the models.

15. Answer the following questions, which help you understand the difference between Thomson's model and Rutherford's model better.
(a) Is the average angle of deflection of α-particles by a thin gold foil predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?
(b) Is the probability of backward scattering (i .e., scattering of α-particles at angles greater than 90º) predicted by Thomson's model much less, about the same, or much greater than that predicted by Rutherford's model?
(c) Keeping other factors fixed, it is found experimentally that for small thickness t, the number of α-particles scattered at moderate angles is proportional to t. What clue does this linear dependence on t provide?
(d) In which model is it completely wrong to ignore multiple scattering for the calculation of average angle of scattering of α-particles by a thin foil?

16. The gravitational attraction between electron and proton in a hydrogen atom is weaker than the coulomb attraction by a factor of about 10^{-40} . An alternative way of looking at this fact is to estimate the radius of the first Bohr orbit of a hydrogen atom if the electron and proton were bound by gravitational attraction. You will find the answer interesting.

17. Obtain an expression for the frequency of radiation emitted when a hydrogen atom de-excites from level n to level (n - 1). For large n, show that this frequency equals the classical frequency of revolution of the electron in the orbit.

ANSWERS

Exercise # 1

PART-I

A-1.	(C)	**A-2.**	(B)	**A-3.***	(BD)	**A-4.**	(A)	**A-5.**	(C)	**A-6.**	(B)	**A-7.**	(A)
A-8.	(C)	**A-9.**	(C)	**A-10.**	(C)	**A-11.**	(C)	**A-12.**	(A)	**B-1.**	(D)	**B-2.**	(D)
B-3.	(C)	**B-4.**	(A)	**B-5.**	(A)	**C-1.***	(AB)	**C-2.**	(A)	**C-3.**	(A)	**C-4.**	(C)
C-5.	(A)	**C-6.**	(D)	**C-7.***	(AD)	**C-8.***	(BD)	**C-9.**	(A)	**C-10.**	(A)	**D-1.**	(D)
D-2.	(D)	**D-3.**	(B)	**D-4.**	(A)	**D-5.**	(C)	**D-6.***	(ACD)	**D-7.**	(A)	**E-1.***	(CD)
E-2.	(A)	**E-3.***	(AC)	**E-4.**	(A)	**E-5.**	(A)	**E-6.**	(C)	**E-7.***	(AC)	**E-8.**	(C)

PART-II

1. (B) **2.** (A) **3.** (D) **4.** (D) **5.** (C) **6.** (C)

7. (A) P, R (B) Q, S (C) Q (D) Q, S **8.** (A) r, (B) s, (C) p (D) q

9. **(i)** false **(ii)** false **(iii)** True **(iv)** True **(v)** false **(vi)** True

10. **(i)** characteristic **(ii)** increased **(iii)** 0.27Å **(iv)** 3×10^8 **(v)** –1

Exercise # 2

PART-I

1.	(A)	**2.**	(D)	**3.**	(B)	**4.**	(B)	**5.**	(B)	**6.**	(A)	**7.**	(B)
8.	(B)	**9.***	(ABC)	**10.***	(ABC)	**11.***	(AD)	**12.***	(AC)	**13.**	(ACD)	**14.**	(BD)
15.	(AB)	**16.**	(ABC)	**17.**	(ACD)	**18.**	(AC)	**19.**	(ACD)				

PART-II

1. 4 **2.** x = 0 **3.** (i) n = 6, (ii) m = 6 **4.** 9 **5.** n = 1, 3

6. x = 6 **7.** n = 4 **8.** x = 4 **9.** n=5 **10.** (A) n = 2 (B) z = 6

11. 3.93 eV **12.** 1.84×10^{-6} amp **13.** 1.77×10^{19} **14.** 12.08 A°

15. 1.05×10^5 K **16.** 5×10^{15} Hz. **17.** He^+ 4, **18.** 0.55×10^{-6}% **19.** 20.4 eV

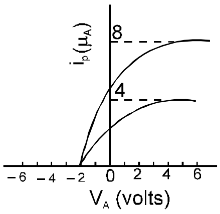
20. 15.9×10^3 V **21.** 985.6 pm, **22.** 154 pm

Exercise # 3

PART-I

1. (D) **2.** (a) n = 2; z = 4; G. S. E. - 217.6 eV ; (b) 6.25×10^{11}, Zero, 5.0 eV

3. (a) n = 12, z = 3 (b) 620/153 μm = 4.05 μm **4.** (B) **5.** (B)

6. 

7. 42 **8.** (A) **9.** (B) **10.** 0.55 eV

11.	(C)	**12.**	(A)	**13.**	$\sqrt{2}$	**14.**	(AC)	**15.**	n = 24.	**16.**	(B)	**17.**	(B)
18.	(A)	**19.**	(B)	**20.**	(C)	**21.**	(C)	**22.**	(A)	**23.**	(A)	**24.**	(B)
25.	(D)	**26.**	(A)	**27.**	3	**28.**	(D)	**29.**	(B)	**30.**	(C)	**31.**	(A)
32.	7	**33.**	7	**34.**	(A)	**35.**	1	**36.**	(AC)				

PART-II

1.	(3)	**2.**	(3)	**3.**	(1)	**4.**	(1)	**5.**	(2)	**6.**	(3)	**7.**	(1)
8.	(2)	**9.**	(1)	**10.**	(2)	**11.**	(2)	**12.**	(4)	**13.**	(3)	**14.**	(2)
15.	(1)	**16.**	(3)	**17.**	(3)	**18.**	(3)	**19.**	(2)	**20.**	(3)	**21.**	(3)
22.	(4)	**23.**	(3)	**24.**	(1)	**25.**	(3)	**26.**	(1)	**27.**	(4)	**28.**	(1)
29.	(4)	**30.**	(3)	**31.**	(4)	**32.**	(3)	**33.**	(4)	**34.**	(4)	**35.**	(4)

Exercise # 4

1. 1.5 eV = 24×10^{-19} J

2. (a) 3.14×10^{-19} J, 1.05×10^{-27} kg m/s (b) 3×10^{16} photons/s (c) 0.63 m/s

3. 4×10^{21} photons/ m^2 s **4.** 6.59×10^{-34} J s

5. (a) 3.38×10^{-19} J = 2.11 eV (b) 3.0×10^{20} photons/ s **6.** 4.73×10^{14} Hz

7. 2.16 eV = 3.46×10^{-19} J **8.** (A) 4.04×10^{-24} kg m s^{-1} (B) 0.164 nm

9. 0.028 nm **10.** (a) 22.7 cm (b) $R = \dfrac{m_0 \nu}{eB\sqrt{1-\nu^2/c^2}}$ **11.** 1.73×10^{11} C kg^{-1}

12. 13.6 eV; – 27.2 eV **13.** 2.12×10^{-10} m ; 4.77×10^{-10} m

14. (a) No different from (b) Thomson's model; rutherford's model (c) Rutherford's model

(d) Thomson's model; Ruitherford's model (e) Both the models **17.** $\dfrac{me^4}{32\pi^3\varepsilon_0^2(h/2\pi)^3n^3}$