18 Electrons & Photons

COMPREHENSIVE REVIEW

1. Cathode Rays & Positive Rays

A) Properties of cathode rays

i) They travel in straight lines.

ii) They are emitted perpendicular to the cathode.

iii) They produce heat on striking against the targets.

iv) They can cause emission of X-rays by striking against the high atomic weight targets.

v) They exert mechanical pressure on the targets on which they are incident.

vi) They can cause chemical changes.

vii) They can ionise the gases.

viii) They can cause fluorescence.

ix) They can peneterate through the thin metal foils.

x) They are deflected by the magnetic fields.

xi) They are deflected by the electric field.

xii) They consist of negatively charged particles called electrons.

xiii) Their charge to mass (e/m) ratio is an universal constant equal to 1.76×10^{11} C/kg.

xiv) They travel with very high speed upto 90% the speed of the light.

B) Positive rays

i) The ionised gas atoms (positively charged) moving towards the cathode are called **positive rays**.

ii) Positive rays were first observed in a discharge tube by Goldstein in 1886.

iii) The e/m of the positive rays is much smaller as compared to the cathode rays and is not a universal constant.

iv) A charged particle fired through electric field experiences a force given by : $\vec{F}_e = q_0\vec{E}$

where q_0 is the charge on the particle and $\vec{E}$ is the electric field.

v) The magnitude of $\vec{F}_e$ is independent of the velocity of the particle.

vi) The direction of $\vec{F}_e$ depends on the sign of q_0 and direction of $\vec{E}$.

vii) The charged particle follows a straight line path when its velocity $\vec{\upsilon}$ is parallel or anti-parallel to $\vec{E}$.

viii) The charged particle follows a parabolic path when the angle between $\vec{\upsilon}$ and $\vec{E}$ is other than 0^0 or 180^0.

ix) If m be the mass of the particle, then its acceleration is given by :

$$\vec{a} = \frac{q_0\vec{E}}{m}$$

x) If the electric field is applied through a distance ℓ, then distance covered by the particle parallel to $\vec{E}$ is given by :

$$y = \frac{1}{2}at^2 \quad \text{or} \quad y = \frac{1}{2}\frac{q_0E}{m}\frac{\ell^2}{\upsilon^2}$$

xi) If a charged particle carrying charge q_0 is fired through a magnetic field $\vec{B}$, then the magnetic force on charged particle is :

$$\vec{F}_m = q_0\vec{\upsilon} \times \vec{B}$$

where $\vec{\upsilon}$ is the velocity of the particle.

a) If $\vec{\upsilon} \perp \vec{B}$, the particle describes a circle in a plane perpendicular to $\vec{B}$.

b) In the above case the centripetal force on the charged particle is given by :

$$F_m = q_0\upsilon B$$

c) The magnitude of momentum, the speed as well as kinetic energy of the charged particle does not change while moving through a magnetic field.

d) The acceleration of the charged particle moving perpendicular to the magnetic field is given by :

$$a = \frac{q_0 \upsilon B}{m}$$

e) The deflection of the particle due to magnetic field, is given by :

$$z = \frac{1}{2}at^2 = \frac{1}{2}\frac{q_0 \upsilon B}{m}\frac{\ell^2}{\upsilon^2}$$

2. Thomson's parabola method

Suppose electric field is $\vec{E} = \hat{j}E$ and magnetic field is $\vec{B} = \hat{j}B$.

They are existing in the same space and a test charge q_0 is fired through them with velocity $\vec{\upsilon} = \hat{i}\upsilon$. Let ℓ = distance over which the charged particle moves in the electric and magnetic fields. Then deflections of the charged particle due to electric and magnetic fields are given by :

$$y = \frac{1}{2}\frac{q_0 E}{m}\frac{\ell^2}{\upsilon^2} \quad \text{... (i)}$$

And $$z = \frac{1}{2}\frac{q_0 B}{m}\frac{\ell}{\upsilon} \quad \text{... (ii)}$$

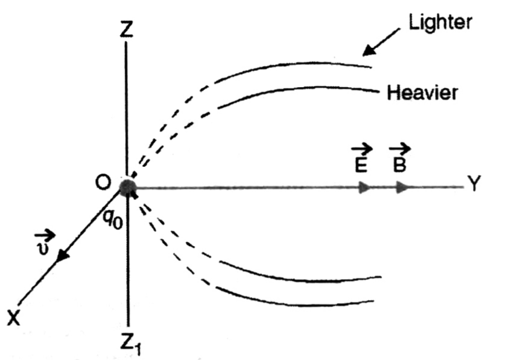

Fig. 2.1

If the charged particles have different velocities, then, they strike the screen placed parallel to the YZ plane on a parabolic track as shown in the figure.

The equation of the parabola is obtained by eliminating υ from equations (i) & (ii) as follows :

$$z^2 = \left(\frac{\ell^2 E^2}{2B}\right)\frac{q_0}{m}y$$

It can be written as :

$$z^2 = \frac{k}{m}y$$

where $k = \frac{\ell^2 E^2}{2B}q_0$ = a constant for the given experimental set up.

The parabolic curves so obtained have the following properties.

a) All the particles with same e/m strike on the same parabola.

b) The particles with higher velocity have less values of y and z (because $y \propto \frac{1}{\upsilon^2}$ and $z \propto \frac{1}{\upsilon}$). Hence they strike nearer to the origin.

c) Only particles with infinite velocity can strike the origin. This is not possible. So, the parabolic tracks donot touch the origin.

d) Knowing y and z, the value of $\frac{q_0}{m}$ can be determined from the parabola.

e) Since $z \propto \frac{q_0}{m}$, therefore, the particles with larger value of $\frac{q_0}{m}$ strike on outer parabola.

f) In general q_0 is same for all particles therefore, lighter particles strike on the outer parabola.

g) Parabola can be obtained on both sides of Y-axis by reversing the magnetic field.

h) More than one parabola is obtained corresponding to different isotopes. This, in fact lead to the discovery of the existence of isotopes.

i) Relative intensities of the different parabolae represents the abundance of different isotopes.

i) The apparatus used for the study of positive rays by Thomson's parabola method is called Thomson's mass spectrograph because it gives, what is commonly known as mass spectrum. (Different lines corresponding to different isotopes).

ii) Resolving power of Thomson's mass spectrograph is low because the particles with different velocities are spread along the parabola.

iii) In Thomson's parabola method $\vec{E} \parallel \vec{B}$.

iv) Dr. F.W. Aston, improved upon the Thomson parabola method and made all ions corresponding to one isotope strike at one point. This increased the resolving power of the mass spectrograph.

v) In Aston's mass spectrograph $\vec{E} \perp \vec{B}$.

vi) In the Aston's mass spectrograph, the positive rays are first subjected to electro-static field which makes the ions disperse. Then, they are subjected to a magnetic field perpendicular to the electric field, which focuses the ions at a point.

vii) If a charged particle is subjected simultaneous to mutually perpendicular electric field such that electric and magnetic forces are oppositely directed, then for no deflection of the beam of charged particles, we have

$$Bq_0\upsilon = q_0E$$

Hence,

$$\upsilon = \frac{E}{B}$$

This can be used as **velocity selector**.

Only particles with velocity $\frac{E}{B}$ will go undeviated.

viii) In Bainbridge mass spectrograph particles of same velocity are selected by using a velocity selector and then they are subjected to a uniform magnetic field perpendicular to the velocity of the particles. The particles corresponding to different isotopes follow different circular paths as shown in the figure.

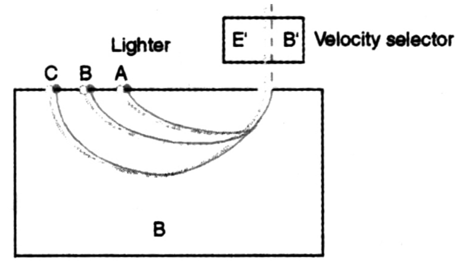

Fig 2.2

a) If r be the radius of the circular path, then

$$\frac{m\upsilon^2}{r} = q_0\upsilon B \quad \text{or} \quad \frac{q_0}{m} = \frac{\upsilon}{rB}$$

If electric and magnetic fields in the velocity selector be E' and B', then :

$$\upsilon = \frac{E'}{B'}$$

Hence, $\frac{q_0}{m} = \frac{E'}{rBB'}$

b) This shows that :

$$\frac{q_0}{m} \propto \frac{1}{r}$$

That is, lighter particles have smaller radius for the circular path.

3. Thomson's method for determining e/m of charged particles.

i) The charged particle is fired through crossed electric $(\vec{E})$ and magnetic $(\vec{B})$ fields.

ii) Both $\vec{E}$ and $\vec{B}$ are also perpendicular to the velocity $(\vec{\upsilon})$ of the particle.

Thus $\vec{E} \perp \vec{\upsilon} \perp \vec{B}$

iii) First electric field is applied. The acceleration produced by the electric field is given by :

$$q_E = \frac{eE}{m}$$

iv) The deflection of the electron in the electric field alone is given by :

$$y = \frac{1}{2}\frac{eE}{m}\frac{\ell^2}{\upsilon^2} \quad \text{... (i)}$$

where ℓ = distance through which electric field is applied.

This gives, $\frac{e}{m} = \frac{2y\upsilon^2}{E\ell^2}$

v) Then the magnetic field is applied and adjusted so that the beam of charged particles goes undeviated. In such a case.

$$eE = e\upsilon B$$

Hence $\upsilon = \frac{E}{B}$

vi) Substituting in (i), we find :

$$y = \frac{1}{2}\frac{eE}{m}\frac{\ell^2}{(E/B)^2} \quad \text{or} \quad \frac{e}{m} = \frac{2yE}{B^2\ell^2}$$

Here, it is assumed that all the particles enter the electric and magnetic fields with the same velocity.

4. In the Millikan's oil drop experiment

The charge on the drop is given by,

$$q = \frac{6\pi\eta}{E}\left[\frac{9\eta\upsilon_0}{2(\rho-\sigma)g}\right]^{\frac{1}{2}}(\upsilon_0 + \upsilon)$$

where η is co-efficient of viscosity of air, E is the electric field, υ_0 is the terminal velocity of the drop in the absence of electric field, υ is the upward velocity of the drop in the presence of electric field, ρ is the density of oil, σ is the density of air.

5. Importance of the Millikan's experiment

i) It establishes the quantisation of charge.

ii) It helped in determining the mass of the electron, the specific charge being known from the Thomson's experiment.

6. Sparking potential

Ordinarily the gases are bad conductors of electricity. When a high potential difference is applied across a discharge tube and the pressure of the gas is lowered, current begins to flow through the gas with a cracking noise. The potential at which it happens is called sparking potential.

a) The sparking potential depends on the following factors :

i) Nature of gas

ii) Pressure of gas

iii) Size of electrodes

iv) Distance between the electrodes.

b) The sparking potential is less for pointed electrode under the similar conditions.

c) The sparking potential is proportional to the product of pressure p and spark length ℓ of the gas.

That is $V \propto p\ell$. It is called **Paschen'slaw**.

7. Photoelectric Effect

a) The ejection of electrons from certain metallic surfaces on absorption of light is called photoelectric effect.

b) Photoelectric effect was discovered by Hallwach.

c) Photoelectric effect was investigated by Lenard and he proposed the laws of photoelectric effect as follows.

i) There is no time lag between the absorption of photon and ejection of electron.

ii) The rate of emission of electrons is proportional to the intensity of the incident light.

iii) Kinetic energy or velocity of electrons depends on the frequency of the incident light and not on the intensity of light.

iv) Higher the frequency of the incident radiations greater is the velocity of photoelectrons.

v) No photoelectric emission occurs if the frequency of the incident radiations is below a certain minimum frequency called threshold frequency.

vi) Threshold frequency depends on the nature of the substance from which photoelectric emission takes place.

vii) Threshold frequency (f_0) is the frequency of incident radiations below which no photoelectric emission occurs from the given photosensitive substance.

viii) Threshold wavelength (λ_0) is the wavelength of the incident radiations above which no photoelectric emission takes place from the given photosensitive substance.

ix) The minimum energy required to just eject the photoelectron from the photosensitive metal is called work function (ω_0).

It is related to f_0 and λ_0 as follows :

$$\omega_0 = hf_0 = \frac{hc}{\lambda_0}$$

where, c = speed of light

h = Planck's contant

8. Einstein's photoelectric equation

Suppose, the frequency of incident photon is f and work function of the photoelectric metal is ω_0. Let the maximum velocity of the ejected electron be υ_m and mass of the electron be m. Then according to the Einstein's photoelectric equation.

$$hf = \omega_0 + \frac{1}{2}m\upsilon_m^2$$

a) The Einstein's photoelectric equation is in accordance with the law of conservation of energy. That is, energy of the incident photon (hf) = Energy spent in taking the electron just out of the photosensitive surface (ω_0) + kinetic energy of the photoelectron.

b) Since $\omega_0 = hf_0 = \frac{hc}{\lambda_0}$.

Hence Einstein's photoelectric equation may be written as :

$$hf = hf_0 + \frac{1}{2}m\upsilon_m^2$$

Or $$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}m\upsilon_m^2$$

c) The photoelectrons are ejected with velocities ranging from 0 to υ_m.

d) The work function is the minimum amount of energy spent in taking the photo electron out of the metallic surface. In general, the energy spent in doing so may be more than ω_0 and hence the velocity (or kinetic energy) of the photoelectron decreases in accordance with the law of conservation of energy.

e) If the collector of the photocell is given –VE potential, the photoelectron moving towards it are retarded. The –VE potential of the collector, which just stops the photoelectron with maximum velocity from reaching the collector is called stopping potential. It is denoted by V_0.

In such a case $\frac{1}{2}m\upsilon_m^2 = eV_0$.

Hence Einstein's photoelectric equation may be written as :

$$hf = \omega_0 + eV_0$$

f) The pliotoelectric emission is instantaneous. That is, the photoelectron is ejected as soon as the photon is absorbed.

g) Einstein was awarded Nobel prize for his photoelectric equation.

h) Einstein has proposed his theory of photo-electric effect in 1905.

i) Einstein's photoelectric equation was experimentally verified by R.A. Millikan.

i) From the quotation,

$$hf = \omega_0 + K_m$$

where K_m is the maximum kinetic energy, we can write,

$$K_m = hf - \omega_0 = hf - hf_0$$

Hence the graph between f and K_m is a straight line as shown below

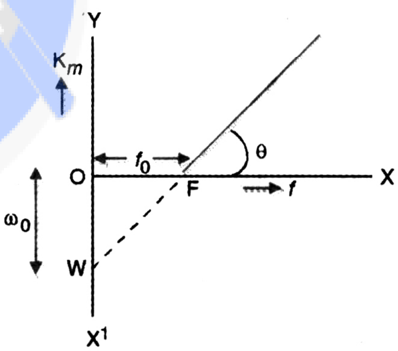

Fig. 8.1

ii) The slope of the graph gives the value of Planck's constant. That is :

$$h = \tan\theta$$

iii) The intercept on the K_m axis gives the work function. That is :

$$OW = \omega_0$$

iv) The graph intersects with the f-axis and the point of intersection represents the threshold frequency (f_0). That is :

$$OF = f_0$$

v) The above conclusions were experimentally verified by Millikan.

vi) Graphical relation between the photoelectric current (i) and potential (V) of the collector is shown ahead.

vii) From the graph we conclude that the saturation photoelectric current (i) depends on intensity (I) of the incident light. That is :

$$i \propto I$$

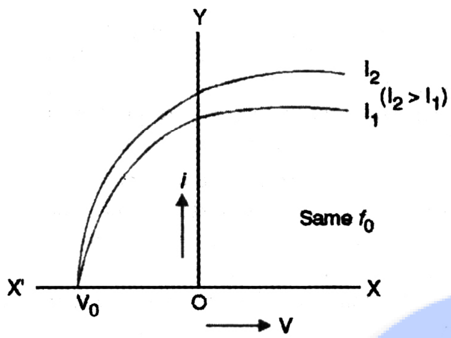

Fig. 8.2

viii) The stopping potential is independent of the intensity of the incident light.

ix) The stopping potential depends on the frequency of the incident light as shown below.

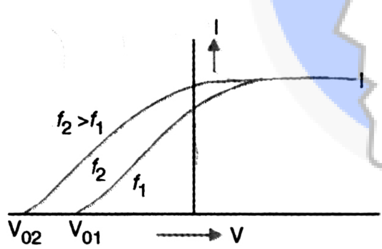

Fig. 8.3

x) The value of stopping potential increases with the frequency of the incident radiations.

9. Wave theory of light

Fails to explain the photoelectric effect.

a) According to the wave theory of light, the energy carried by light flows continuously and is proportional to the intensity of light. Thus, larger intensity of light should eject photoelectrons with higher velocity. This is contrary to the experimental observations.

b) The wave theory also suggests that light of any frequency should cause photoelectric emission. That is, there should be no threshold frequency. This is also contrary to the experimental observations.

c) Photoelectric effect confirms the particle or quantum nature of light.

d) Photoelectric effect assumes that the photoelectron is bound and a certain amount of energy is required to free it.

i) Photoelectric effect occurs, when the energy of the incident photon is of the order of work function. That is : $hf \approx \omega_0$

ii) The electron ejected in photoelectric effect completely absorbs the incident photon.

iii) All of the incident photons donot cause photoelectric emission.

10. Quantum theory of light

Max Planck proposed the Quantum theory of light. According to this theory, the energy of each packet or quantum of light (also called photon) is given by :

$$E = hf = \frac{hc}{\lambda}$$

i) The rest mass (m_0) of the photon is zero.

ii) The energy of the photon is completely kinetic.

iii) Momentum of the photon is :

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

iv) Mass of the moving photon is :

$$m = \frac{hf}{c^2} = \frac{h}{c\lambda}$$

11. Compton effect

Scattering of high energy e.m radiations with a change in wavelength is called **Compton effect**.

i) The change in wavelength due to compton effect is called **Compton shift** ($\Delta\lambda$). It is given by :

$$\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\phi)$$

where ϕ is the angle between the incident light and the scattered light, h = Planck's constant and c = speed of light.

ii) When $\phi = 0$, $\Delta\lambda = 0$.

iii) When $\phi = 90^0$, $\Delta\lambda = \frac{h}{m_0 c}$.

It is called compton wavelength and is equal to 0.24 nm. That is :

$$\frac{h}{m_0 c} = 0.24 \text{ nm}$$

iv) When $\phi = 180^0$, $\Delta\lambda = \frac{2h}{m_0 c} = 0.48$ nm.

v) Compton effect also confirms the particle nature of light.

vi) In compton effect the incident photon is scattered and not absorbed by the electron as is the case in photoelectric effect.

vii) The wavelength of the scattered photon is more than the incident photon. That is :

$$\lambda_s \geq \lambda_i$$

viii) The compton effect simply modifies the wavelength of light. It happens due to the collision of the photon with electron.

ix) The energy lost by the photon is carried by the recoiled electron as kinetic energy.

x) Compton effect assumes that the recoiling electron is free. This is possible when the energy of the incident photon is very very large as compared to that of the electron. Due to this reason, the compton effect is observed with X-rays and γ-rays, whose photons have very high energy.

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MULTIPLE CHOICE QUESTIONS

CATHODE RAYS AND POSITIVE RAYS

1. The mass of electron is M, its charge is *e* and it is accelerated from rest through a potential V. The kinetic energy of the electron will be :
   a) V b) eV
   c) MeV d) none of the above
2. In the above question the velocity acquired by the electron will be :
   a) V b) eV
   c) MeV d) none of the above
3. In question 1, the energy acquired by the particle is electron volt will be :
   a) V b) eV
   c) MeV d) none of the above
4. In the J. J. Thomson method for the determination of e/m, what is the angle between the magnetic. and electric fields to which the electrons are subjected ?
   a) 0° b) 45°
   c) 90° d) 180°
5. In which of the following case the specific charge is **NOT** constant ?
   a) α-rays b) Cathode rays
   c) Canal rays d) β-rays
6. The specific charge of electron is (s). What will be the order of specific charge of the heaviest isotope of hydrogen ?
   a) 4000 (s) b) s / 4000
   c) 6000 (s) d) s / 6000
7. The specific charge of proton is x. What is the specific charge of deutron ?
   a) x b) 2 x
   c) $\frac{x}{2}$ d) none of the above
8. What is the nature of path of an electron when it moves in a transverse electric field ?
   a) Straight line b) Ellipse
   c) Parabola d) Circle
9. In the Thomson's experiment for the analysis of positive rays from a discharge tube containing neon gas two parabolas are obtained. Why ?
   a) Due to impurities in the neon gas
   b) Different energy of the isotopes of neon
   c) Different velocity of the isotopes of neon
   d) Different masses of the isotopes of neon
10. What is the ratio of specific charge of the electron and nucleus of hydrogen atom ?
    a) 1 b) 2
    c) 4 d) none of the above
11. What do we determine with mass spectrograph ?
    a) Wavelength b) Charge
    c) Mass d) Specific charge
12. If S_1 be the specific charge of cathode rays and S_2 be that of positive rays then which of the following is true ?
    a) $S_1 = S_2$ b) $S_1 > S_2$
    c) $S_1 < S_2$ d) It cannot be predicted
13. Cathode rays enter a magnetic field making oblique angle with the lines of magnetic induction. What will be the nature of the path followed ?
    a) Parabola b) Helix
    c) Circle d) Straight line
14. If an electron has an initial velocity perpendicular to direction of magnetic field, the path of the electron is :
    a) a straight line b) a parabola
    c) a circle d) an ellipse
15. An electron and a proton are injected into a uniform magnetic field perpendicular to it with the same momentum. What is the nature of their trajectories ?
    a) Radius of curvature is less for electron
    b) Radius of curvature is more for electron
    c) Radius of curvature is same for both
    d) Both move along straight lines
16. What is the nature of the parabolic trajectory of the +VE ions in the J. J. Thomson experiment ?
    a) Does not pass through the origin
    b) May pass through the origin
    c) Have equal intercepts on both the axes
    d) Have constant intercept on one of the axes
17. The e/m is not constant for :
    a) cathode rays b) positive rays
    c) α-rays d) β-rays

18. In the discharge tube the +VE ions with same e/m have a velocity distribution because :
    a) they are emitted with different velocities
    b) they are produced at different site but accelerated through the same potential
    c) they are produced at different site and accelerated through different potentials
    d) some reason other than those mentioned above
19. What is the order of pressure of the gas in the cathode ray tube ?
    a) 1 atmospheric b) 1 mm of Hg
    c) 1 μm of Hg d) 1 nm of Hg
20. In cyclotron the potential difference of A.C. source is V and frequency is f Then what is the increase in energy of particle of charge q in one revolution ?
    a) qV joule b) 2 qV joule
    c) $\frac{qV}{2}$ joule d) f qV joule
21. A beam of electrons passes through crossed electric and magnetic fields $E = 7.2 \times 10^6\ NC^{-1}$ and $B = 2.4$ T. If the beam goes undeviated, what is the velocity of electrons ?
    a) $7.2 \times 2.4 \times 10^6\ ms^{-1}$
    b) $3.0 \times 10^6\ ms^{-1}$
    c) $2.0 \times 10^6\ ms^{-1}$
    d) none of the above
22. A beam of α-particles passes undeflected through crossed electric and magnetic fields with $E = 6.6 \times 10^6$ N/C and B = 1.2 tesla.
    Their speed in m/s will be :
    a) 1.8×10^6 b) 5.5×10^6
    c) 7.8×10^6 d) 1.1×10^6
23. What is the use of magnetic field in the cyclotron?
    a) Increases the speed of particle only
    b) Changes the direction of particle only
    c) Changes the direction of particle and increases the speed as well
    d) Neither changes the direction nor increases the speed
24. What is the use of cyclotron ?
    a) To accelerate charged particles to any high speed
    b) To accelerate charged particles to moderate speeds
    c) To produce charged particles
    d) To produce neutral particles
25. In cyclotron the resonance condition is that the frequency of revolution of charged particle :
    a) is equal to the frequency of A.C. voltage source
    b) is equal to the frequency of applied magnetic field
    c) is equal to the frequency of rotation of earth
    d) frequency of A.C. source and frequency of magnetic field are equal
26. Which of the following can not be accelerated by a cyclotron ?
    a) α-particle b) proton
    c) ion d) neutron
27. The cyclotron was deviced by :
    a) E. Lawrence b) Lorentz
    c) Oersted d) Maxwell
28. A cathode ray tube has a potential difference of 100 V between the cathode and anode. The speed acquired by the electron in going from cathode to anode will be nearest to :
    a) 600 m/s b) 6000 m/s
    c) 600 km/s d) 6000 km/s
29. In a cathode ray tube the distance between the cathode & anode is 40 cm. A potential difference of 91 kV is applied across them. With what minimum velocity will the electron strike the cathode, assuming that no collision occurs on the way ?
    a) 1.79×10^8 m/s
    b) 1.79×10^7 m/s
    c) 1.79×10^6 m/s
    d) 1.79×10^5 m/s
30. A charged oil drop is at rest in an electric field 500 V/m. If the mass of the drop be 0.8×10^{-12} g, then what is the number of electrons removed from the drop ?
    a) 1 b) 10
    c) 100 d) 1000
31. A beam of electrons passess through mutually perpendicular electric field 30 kV/m and magnetic field 3 mT. If the beam goes undeviated, then what is the speed of the electrons ?
    a) 10^5 m/s b) 10^6 m/s
    c) 10^7 m/s d) 10^8 m/s

32. What will be the momentum of α-particle moving in a circular path of radius 5 cm perpendicular to a magnetic field of 0.1 T ?

a) 1.6×10^{-6} kg m/s b) 1.6×10^{-18} kg m/s

c) 1.6×10^{-20} kg m/s d) 1.6×10^{-21} kg m/s

33. A beam of charged particles is moving with a speed of 2×10^7 m/s. It passes through an electric field perpendicularly through a distance of 10 cm. The electric field is 4 kV/m. What is q/m of the particles ? The deflection of the beam is 2 mm.

a) 10^{10} C/kg b) 2×10^{10} C/kg

c) 4×10^{10} C/kg d) 8×10^{10} C/kg

34. An electron enters the electric field 2 kV/m perpendicular to it with a speed 10^7 m/s. What will be the displacement of the electron parallel to electric field after 1 ns ?

a) 0.09 mm b) 0.18 mm

c) 0.09 μm d) 0.18 μm

35. In the Thomson's experiment, the equation of the parabola for the singly ionised Ne^{20} is $x = 10 y^2$. What will be the equation of parabola for Ne^{22} ?

a) $y^2 = \frac{x}{22}$ b) $y^2 = \frac{x}{11}$

c) $y^2 = \frac{x}{20}$ d) $y^2 = \frac{x}{10}$

36. The average atomic mass of neon is 20.2. If the given sample of neon contains Ne^{20} and Ne^{22} only, then the ratio of the two isotopes is :

a) $\frac{1}{3}$ b) $\frac{1}{9}$

c) $\frac{3}{1}$ d) $\frac{9}{1}$

37. An electron with energy, 1 keV enters a uniform magnetic field of 3 mT. What is the radius of the circular path followed by the particle ?

a) 36 mm b) 18 mm

c) 9 mm d) 4.5 mm

38. What voltage is needed to balance an oil drop carrying 5 electrons when placed between the plates of a capacitor 5 mm apart ? The mass of the drop is 3.2×10^{-16} kg.

a) 2 V b) 10 V

c) 20 V d) 100 V

PHOTOELECTRIC EFFECT

39. The photoelectric effect is a phenomenon which can be used to convert :

a) electric energy into mechanical energy

b) light energy into electric energy

c) photon into electron

d) light energy into mechanical energy

40. Increase in the frequency of the incident radiations increases the :

a) rate of emission of photoelectrons

b) work function

c) kinetic energy of photoelectrons

d) threshold frequency

41. Threshold wavelength depends upon :

a) frequency of radiation

b) velocity of electrons

c) work function

d) none of the above

42. The frequency and intensity of the incident beam of light falling on the surface of photoelectric material is increased by a factor of two. This will :

a) increase the maximum kinetic energy of the photoelectrons as well as photoelectric current by a factor of two

b) increase the maximum kinetic energy of photoelectrons and would increase the photoelectric current by a factor of two

c) increase the maximum kinetic energy of photoelectrons by a factor of two and will have no effect on photoelectric current

d) increase the photoelectric current by a factor of two but will have no effect on kinetic energy of emitted electrons.

43. The magnitude of saturated photoelectric current depends upon :

a) frequency of radiations

b) intensity of radiations

c) work function

d) stopping potential

44. Which of the following makes use of photoelectric effect ?

a) Television receiver

b) Television camera

c) Cathode Ray oscillograph

d) Radar

45. The study of photoelectric effect is useful in understanding :
a) quantization of energy
b) quantization of charge
c) conservation of charge
d) conservation of kinetic energy

46. The graph between, which of the following two factors for photoelectric effect, is a straight line ?
a) Intensity of radiation and photoelectric current
b) Potential of anode and photoelectric current
c) Threshold frequency and velocity of photo-electrons
d) Intensity of radiations and stopping potential

47. Which of the following characteristics of photo-electric effect supports the particle nature of radiations ?
a) Threshold frequency
b) Dependence of the velocity of photoelectron on frequency
c) Independence of velocity of photoelectrons of intensity of radiations
d) Instantaneous photoelectric emission

48. What is E in the Einstein's photoelectric equation : $E = h\nu - \omega_0$, where ν is the frequency of incident radiations and ω_0 is the work function :
a) Kinetic energy of every photoelectron
b) Mean kinetic energy of photoelectrons
c) Minimum kinetic energy of photoelectrons
d) Maximum kinetic energy of photoelectrons

49. A photoelectron is accelerated through 3.2 V. The energy gained by it is :
a) 3.2 eV b) 3.2 J
c) 3.2×10^{-19} eV d) 3.2×10^{-19} J

50. In photoelectric effect, the current :
a) increases with increase of frequency of incident photon
b) decreases with increase of frequency of incident photon
c) does not depend on the frequency of photon but depends only on intensity of incident light
d) depends both on intensity and frequency of incident beam

51. Why does the photoelectric effect reveal the particle nature of radiations ?
a) Energy of the emitted electrons depends on the intensity of radiations
b) Energy of the emitted electrons depends on the frequency of radiations
c) Radiations eject electrons
d) Radiations are absorbed by the electrons

52. How does the photoelectric current vary with the intensity of the incident light ?
a) Decreases with increase in intensity
b) Decreases with the decrease in intensity
c) Independent of the intensity
d) Decreases with intensity below the threshold frequency and increases above it.

53. Which of the following support the quantum nature of the e/m radiations ?
I) Photoelectric effect
II) Compton effect
III) Doppler's effect
IV) Field effect
a) I and II b) II and III
c) III and IV d) IV and I

54. A photo sensitive metal is not emitting photo-electrons when irradiated. It will do so when threshold is crossed. To cross the threshold we need to increase :
a) intensity b) frequency
c) wavelength d) none of the above

55. The minimum energy required to remove an electron is called :
a) Stopping potential b) Binding energy
c) Work function d) None of these

56. What determines the work function of a metal ?
a) Frequency of the incident light
b) Energy required to ionise the atom
c) Energy required to eject the electron from the orbit
d) None of the above

57. Which electrons are emitted in the photoelectric effect ?
a) Electrons in the inner orbits of the atom
b) Electrons in the miter most orbit of the atom
c) Electrons from within the nucleus
d) Electrons freely roaming about in the interatomic space

58. The photoelectric effect supports a theory of light proposed by :
a) Newton b) Huygen
c) Einstein d) None of the above

59. Which of the following achieves conversion of electromagentic wave energy into electrical energy ?
a) Coolidge tube b) Cathode ray tube
c) Thermocouple d) Photocell

60. What does in the photoelectric effect support quantum nature of light ?
a) Threshold frequency
b) Distribution of kinetic energy among the electrons
c) Instantaneous emission of electrons
d) Quantisation of electric charge on the electrons

61. The photoelectric effect is described as the ejection of electrons from the surface of a metal when :
a) it is heated to a high temperature
b) electrons of suitable velocity impinge on it
c) light of suitable wavelength falls on it
d) it is placed in a strong magnetic field

62. A source of light is placed at a distance of 1 m from a photo cell and the cut off potential is V_0. If the source of light is placed at a distance of 50 cm, the cut off potential will be :
a) V_0 b) $2\ V_0$
c) $4\ V_0$ d) $16\ V_0$

63. A photosensitive plate is illuminated by green light and photoelectrons are emitted with maximum kinetic energy equal to 4 eV. If the intensity of the radiations is reduced to one fourth of its original value, then the maximum kinetic energy of the photo electrons will be :
a) 0.1 eV b) 1 eV
c) 4 eV d) 16 eV

64. In photoelectric effect, the photoelectric current :
a) does not depend on photo frequency, but only on intensity of incident beam
b) depends both on intensity and frequency of incident beam
c) increases when frequency of incident photons increases
d) decreases when frequency of incident photon increases

65. Photoelectric effect can be explained by assuming that light :
a) is a form of transverse waves
b) is a form of longitudinal waves
c) can be polarised
d) consists of quanta of energy

66. In photoelectric effect when photons of energy hv fall on a photosensitive surface (work function hv_0) electrons are emitted from the metallic surface with a kinetic energy. It is possible to say that :
a) all ejected electrons have same kinetic energy equal to $hv - hv_0$
b) the ejected electrons have a distribution of kinetic energy from zero to $(hv - hv_0)$
c) the most energetic electrons have kinetic energy equal to hv_0
d) all ejected electrons have kinetic energy hv_0

67. A metallic surface has a threshold wavelength 5200 Å. This surface is irradiated by mono-chromatic light of wavelength 4500 Å. Which of the following statement is true ?
a) The electrons are emitted from the surface having energy between 0 and infinity
b) The electrons are emitted from the surface having energy between 0 and certain finite maximum value
c) The electrons are emitted from the surface, all having certain finite energy
d) No electron is emitted from the surface

68. A photo cell is illuminated by a small bright source placed 1 m away. When the same source of light is placed 2 m away. Which of the following is true about the electrons emitted by the photo cathode ?
a) Each carry one quarter of their previous energy
b) Each carry one quarter of their previous momenta
c) Are half as numerous
d) Are one quarter as numerous

69. Photoelectric effect supports the quantum nature of light because :
a) there is minimum frequency of light below which no photoelectrons are emitted

b) the maximum kinetic energy of photoelectrons depends only on the frequency of light and not on intensity

c) even when a metal surface is faintly illuminated, the photo-electrons leave the surface immediately

d) electric charge of the photoelectrons is quantised

70. A metal surface is illuminated by a light of given intensity and frequency to cause photoemission. If the intensity of illumination is reduced to one fourth of its original value, then the maximum kinetic energy of the emitted photoelectrons would become :

a) unchanged

b) $\frac{1}{16}$ th of original value

c) twice the original value

d) four times the original value

71. Einstein photoelectric equation states that,

$$\frac{1}{2}m\upsilon^2 = h\nu - h\upsilon_0$$

In this equation υ refers to :

a) velocity of all ejected electrons

b) mean velocity of emitted electrons

c) minimum velocity of emitted electrons

d) maximum velocity of emitted electrons

72. The maximum energy of the electrons released in photocell is independent of :

a) frequency of incident light

b) intensity of incident light

c) nature of cathode surface

d) none of these

73. Blue light can cause photoelectric ermssion from a metal, but yellow light cannot. If red light is incident on the metal, then :

a) photoelectric current will increase

b) rate of emission of photoelectrons will decrease

c) no photoelectric emission will occur

d) energy of the photoelectrons will increase

74. If the distance of 100 watt lamp is increased from a photo cell, the saturated current 'i' in the photocell varies with distance 'd' as :

a) $i \propto d^2$ b) $i \propto d$

c) $i \propto \frac{1}{d}$ d) $i \propto \frac{1}{d^2}$

75. A source of light is placed at a distance x from a photocell and the cut off potential is V. If the distance of the same source from the photocell is doubled, then cut off potential will be :

a) $\frac{V}{4}$ b) $\frac{V}{2}$

c) V d) 2 V

76. The saturation current I of a photocell varies with distance from the source (d) as :

a) $I \propto d$ b) $I \propto d^2$

c) $I \propto \frac{1}{d}$ d) $I \propto \frac{1}{d^2}$

77. A photo-sensitive material would emit electrons if excited by photons beyond a threshold. To cross the threshold you would increase :

a) intensity of light

b) wavelength of light

c) frequency of light

d) the voltage applied to light source

78. Light of frequency 1.5 times the threshold frequency is incident on photo-sensitive material. If the frequency is halved and intensity is doubled, the photocurrent becomes :

a) quadrupled b) doubled

c) halved d) zero

79. The threshold frequency of potassium is 3×10^{14} Hz. The work function is :

a) 1.0×10^{-19} J b) 2.0×10^{-19} J

c) 4.0×10^{-19} J d) 0.5×10^{-19} J

80. What determines the maximum velocity of the electron emitted from the photosensitive plate ?

a) Frequency of incident radiations alone

b) Work function of the metallic surface alone

c) Both the frequency of incident radiations and work function of the metallic surface

d) None of the above

81. Which of the following statements is not correct for saturation current in a photoelectric cell ?

a) All the electrons emitted from the photo-sensitive plate reach the collector

b) The potential difference between the emitter and collector should be equal to the stopping potential

c) Collector is +VE w.r.t. emitter

d) It is the maximum current that can be set up in the photoelectric cell

82. The work function of a metal is 3.3×10^{-19} J. The maximum wavelength of the photons required to eject electron from the metal is :

a) 200 nm b) 300 nm
c) 400 nm d) 600 nm

83. The threshold wavelength of a metal surface is 600 nm. The wavelength of the incident light is 450 nm. The maximum kinetic energy of the incident photons will be nearest to :

a) 0.3 eV b) 0.6 eV
c) 0.9 eV d) 1.2 eV

84. A photo sensitive metal is incident with radiations of wavelength 400 nm and then with radiations of wavelength 800 nm. What will be the difference in the maximum energy of the photoelectrons ?

a) 0.5 eV b) 1.0 eV
c) 1.5 eV d) 2 eV

85. The energy of the incident photon is 20 eV and the work function of the photosensitive metal is 10 eV. What is the stopping potential ?

a) 5 V b) 10 V
c) 15 V d) 30 V

86. The light photons of energy 1.5 eV & 2.5 eV are incident on a metallic surface of work function 0.5 eV. What is the ratio of the maximum kinetic energy of the photoelectrons ?

a) $\frac{1}{4}$ b) $\frac{1}{2}$
c) 2 d) 4

87. The work function of metal-I and metal-II are 5 eV and 2.5 eV respectively. If the threshold wavelength of metal-I be 6000 Å. then that for metal-II will be :

a) 3000 Å b) 9000 Å
c) 12000 Å d) 15000 Å

88. If the threshold frequency be 2×10^{14} Hz. what is the work function ?

a) 1.6×10^{-19} J b) 3.2×10^{-19} J
c) 6.6×10^{-20} J d) 13.2×10^{-20} J

89. Light of wavelength 4000 Å is incident on a metal of work function 3.2×10^{-19} J. What is the maximum kinetic energy of the emitted electron ?

a) 0.75×10^{-19} J b) 1.1×10^{-19} J
c) 1.75×10^{-19} J d) 2.2×10^{-19} J

90. In an experiment photoelectrons are emitted when light of wavelength 4000 Å is incident on it. They can be stopped by a retarding potential of 2 V. If the wavelength of the incident light be 3000 Å, the stopping potential will be :

a) 1 V b) 1.5 V
c) 2 V d) 3 V

91. A photon of 6 eV is incident on a metal surface and the emitted electron is stopped by a retarding potential of –5 eV. What is the work function of the metal ?

a) 1 eV b) 2.5 eV
c) 3 eV d) 11 eV

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92. Photons of energy 5 eV are incident on a metal surface. The stopping potential was found to be 3.5 V. The work function of the metal is :

a) 1.5 eV b) 3.5 eV
c) 5 eV d) 8.5 eV

93. Photoelectric current in photodiode reaches a saturation value because :

a) The kinetic energy of electrons has an upper limit

b) The number of electrons emitted depends upon the intensity of incident light

c) The voltage of the power supply in the circuit is fixed

d) The work function of the metal fixed

94. Energy of photon whose frequency is 10^{12} MHz. will be :

a) 4.14×10^3 keV b) 4.14×10^2 eV
c) 4.14×10^3 MeV d) 4.14×10^3 eV

95. An electron is projected with a velocity of 1.6×10^5 ms^{-1} at right angles to the magnetic field of 0.013×10^{-4} T. The radius of circle described by the electron will be :

a) 0.7 m b) 0.5 m
c) 0.3 m d) 0.2 m

96. If 3 kg of mass is converted into energy. Energy released is :

a) 9×10^8 J b) 9×10^{16} J

c) 27×10^8 J d) 27×10^{16} J

97. An electron beam is moving between two parallel plates having electric field 1.125×10^{-6} N/m. A magnetic field 3×10^{-10} T is also applied so that beam of electrons do not deflect. The velocity of the electron is :

a) 4225 m/s b) 3750 m/s

c) 2750 m/s d) 3200 m/s

98. The electron in a hydrogen atoms circles around the proton in 1.5941×10^{-18} seconds. The equivalent current due to motion of the electron is :

a) 127.37 mA b) 122.49 mA

c) 100.37 mA d) 94.037 mA

99. Charge on an electron is :

a) 1.6×10^{-16} C b) 1.6×10^{-17} C

c) 1.6×10^{-18} C d) 1.6×10^{-19} C

100. The maximum velocity of the photoelectrons ejected by light of wavelength λ from a metal surface of wave function ϕ is :

a) $\left[\frac{2(hc-\lambda\phi)}{m\lambda}\right]^{1/2}$ b) $\left[\frac{2hc-\lambda\phi}{m\lambda}\right]^{1/2}$

c) $\left[\frac{2(hc-\phi)}{m\lambda}\right]$ d) $\left[\frac{hc+\lambda\phi}{m\lambda}\right]^{1/2}$

101. In an experiment to measure the charge on an electron, the electrons travelling at a speed of 1.825×10^7 m/s are subjected to a deflecting electric field 3.2×10^4 V/m. The intensity of magnetic field applied so that the beam is undeflected is :

a) 1.7×10^{-3} Wb/m^2 b) 7.1×10^{-3} Wb/m^2

c) 1.7×10^3 Wb/m^2 d) 7.1×10^3 Wb/m^2

102. Photons of energies 1 eV and 2.5 eV are incident on metal surface having work function 0.5 eV, the ratio of maximum velocities is :

a) 1 : 2 b) 2 : 1

c) 1 : 4 c) 1 : 1

103. Stopping potential in case of photoelectric emission depends upon :

a) Frequency of incident light

b) intensity of incident light

c) both 'A' and 'B'

d) neither 'A' nor 'B'

104. Potential difference between 2 plates is 500 V and they are 2 cm apart. If B = 2×10^{-2} tesla, then, velocity of an electron is :

a) 125 km/s b) 1250 km/s

c) 1.25 km/s d) 12.5 km/s

105. An electron of mass 'm' and charge e performs circular motion in magnetic. Field of 'B', then, frequency of evolution is :

a) $\frac{eB}{2\pi m}$ b) $\frac{2\pi m}{eB}$

c) $\frac{2\pi}{emB}$ d) $\frac{em}{2\pi B}$

106. An electron enters in a magnetic held of induction 2 mT with velocity of 1.8×10^7 m/s. The radius of circular path is :

a) 5.1 cm b) 5.1 mm

c) 5 km d) 2.1 cm

107. Speed of an electron passing undeviated through a region of cross electric and magnetic fields of magnitude 4×10^5 V/m and 0.02 Wb/m^2 respectively in meter per second is :

a) 2×10^6 b) 8×10^7

c) 8×10^6 d) 2×10^7

108. The orbital frequency of an electron in the hydrogen atom is proportional to :

a) n^3 b) n^{-3}

c) n^{-1} d) n^0

109. The de-Broglie wavelength of an electron in the ground state of hydrogen atom is :

a) πr^2 b) $2\pi r$

c) πr d) $\sqrt{2}\,\pi r$

110. Calcium plate has maximum possible radiation of wavelength 1 of 400 nm to eject electrons. Its work function is :

a) 2.3 eV b) 3.1 eV

c) 4.5 eV d) 1.8 eV

111. Two particles of same charge are accelerated to same potential difference and they enter perpendicular to uniform magnetic field and moves in circular paths of radii r_1 and r_2. Ratio of their masses is :

a) $r_1 : r_2$ b) $r_2^2 : r_1^2$

c) $r_2 : r_1$ d) $r_1^2 : r_2^2$

112. If the wavelength λ of photon decreases then momentum and energy of photon :

a) both increases

b) both decreases

c) momentum increases and energy decreases

d) momentum decreases and energy increase

113. The de-Broglie wavelength in I[st] Bohr's orbit is :

a) πr b) $2\pi r$

c) $3\pi r$ d) $\frac{\pi r}{2}$

114. In Millikan's experiment, an oil drop having charge q, mass m, gets accelerated by applying a potential difference V in between two plates separated by a distance 'd' . The acceleration is :

a) qVd b) $q\frac{d}{V}$

c) $\frac{qm}{Vd}$ d) $\frac{qV}{md}$

115. The de-Broglie wavelength λ associated with charged particle of charge q mass m and potential difference V is :

a) $\frac{h}{\sqrt{2mqV}}$ b) $\frac{h^2}{\sqrt{2mqV}}$

c) $\frac{h}{\sqrt{mqV}}$ d) $\frac{h}{\sqrt{2qV}}$

116. If a charged particle of charge q mass m moves in a circular path in a magnetic field of induction B, under a potential of V volts then radius of circular path is :

a) $\sqrt{\frac{2mV}{q}}$ b) $\frac{B}{1}\sqrt{\frac{2mV}{q}}$

c) $\frac{1}{B}\sqrt{\frac{2mV}{q}}$ d) $\frac{1}{B^2}\sqrt{\frac{2mV}{q}}$

117. In photoelectric effect, stopping potential for a light of frequency n_1 is V_1. If light is replaced by another having a frequency n_2 then its stopping potential will be :

a) $V_1 - \frac{h}{e}(n_2 - n_1)$ b) $V_1 + \frac{h}{e}(n_2 + n_1)$

c) $V_1 + \frac{h}{e}(n_2 - 2n_1)$ d) $V_1 + \frac{h}{e}(n_2 - n_1)$

118. Light of wavelength λ_A & λ_B falls on two identical metal plates A and B respectively. The maximum kinetic energy of photoelectrons is K_A and K_B respectively, then which one of the following relations is true ($\lambda_A = 2\lambda_B$) :

a) $K_A < \frac{K_B}{2}$ b) $2K_A = K_B$

c) $K_A = 2K_B$ d) $K_A > 2K_B$

119. When monochromatic light of wavelength 'λ' is incident on a metallic surface, the stopping potential for photoelectric current is '$3V_0$'. When same surface is illuminated with light of wavelength '2λ', the stopping potential is 'V_0'. The threshold wavelength for this surface when photoelectric effect takes place is :

a) λ b) 2λ

c) 3λ d) 4λ

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REVISION OUESTIONS
from Competitive Exams

1. Photoelectric work function of a metal is 1 eV. Light of wavelength = 3000 Å falls on it. The photoelectrons come out with velocity :
   a) 10 metre per second
   b) 10^3 metre per second
   c) 10^4 metre per second
   d) 10^6 metre per second

2. The cathode of a photoelectric cell is changed such that the work function changes from W_1 to W_2 ($W_2 > W_1$). If the current before and after change are I_1 & I_2, all other conditions remaining unchanged, then (assuming $h\nu > W_2$) :
   a) $I_1 = I_2$ b) $I_1 < I_2$
   c) $I_1 > I_2$ d) $I_1 < I_2 < 2 I_1$

3. When light of wavelength 300 nm (nanometer) falls on a photoelectric emitter, photoelectrons are liberated. For another emitter, however, light of 600 nm wavelength is sufficient for creating photoemission. What is the ratio of the work functions of the two emitters ?
   a) 1 : 2 b) 2 : 1
   c) 4 : 1 d) 1 : 4

4. Threshold frequency for photoelectric effect on sodium corresponds to a wavelength 5000 Å. Its work function is :
   a) 15 J b) 16×10^{-14} J
   c) 4×10^{-19} J d) 4×10^{-18} J

5. Number of ejected photoelectron increases with increase :
   a) in intensity of light
   b) in wavelength of light
   c) in frequency of light
   d) never

6. A photoelectric cell converts :
   a) electrical energy to light energy
   b) light energy to light energy
   c) light energy to electrical energy
   d) light energy to elastic energy

7. In the experiment for determination of e/m of electrons by the Thomson method, electric and magnetic fields are :
   a) parallel and both are perpendicular to the motion of the electron
   b) both mutually parallel and also parallel to the motion of the electron
   c) both mutually perpendicular and also perpendicular to the motion of the electron
   d) both mutually perpendicular and have no relation with the motion of the electron

8. If we consider electrons and photons of the same wavelength, then they will have the same :
   a) velocity b) angular momentum
   c) energy d) momentum

9. K.E. of emitted cathode rays is dependent on :
   a) Only voltage b) Work function only
   c) Both (a) and (b)
   d) It does not depend upon any physical quantity

10. The kinetic energy of an electron which is accelerated through a potential of 100 volts is :
    a) 1.602×10^{-17} joules
    b) 418.6 calories
    c) 1.16×10^4 K
    d) 6.626×10^{-34} watt-second

11. Which of the following statements is correct ?
    a) The current in a photocell increases with increasing frequency of light
    b) The photo current is proportional to applied voltage
    c) The photocurrent increases with increasing intensity of light
    d) The stopping potential increases with increasing intensity of incident light

12. The specific charge of an electron is :
    a) 1.6×10^{-19} coulomb
    b) 4.8×10^{-10} stat coulomb
    c) 1.76×10^{11} coulomb/kg
    d) 1.76×10^{-11} coulomb/kg

13. Light of wavelength 5000 Å falls on a sensitive plate with photoelectric work function of 1.9 eV. The kinetic energy of the photoelectron emitted will be :
    a) 0.58 eV b) 2.48 eV
    c) 1.24 eV d) 1.16 eV

14. In a photo-emissive cell, with exciting wavelength λ, the fastest electron has speed υ. If the exciting wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be :

a) $\upsilon\left(\frac{3}{4}\right)^{1/2}$ b) $\upsilon\left(\frac{4}{3}\right)^{1/2}$

c) less than $\upsilon\left(\frac{4}{3}\right)^{1/2}$

d) greater than $\upsilon\left(\frac{4}{3}\right)^{1/2}$

15. An electron of charge 'E' is liberated from a hot filament and attracted by an anode of potential 'V' volts positive with respect to the filament. The speed of the electron when it strikes the anode is :

a) 1 EV^2 b) mEV

c) $\sqrt{\frac{2E}{mV}}$ d) $\sqrt{\frac{2EE}{m}}$

16. An electron starts from rest in an electric field and acquires a speed u in reaching a point A. The potential difference between the starting point and the point A is V_A :

a) $u \propto V_A^2$ b) $u \propto V_A$

c) $u \propto \sqrt{V_A}$ d) $u \propto V_A^{2/3}$

17. The kinetic energy of an electron, which is accelerated in the potential differene of 100 V, is :

a) 1.6×10^{-17} J b) 1.6×10^{4} J

c) 416.6 cal d) 6.636 cal

18. Which of the following is not dependent on the intensity of incident radiation in a photoelectric experiment ?

a) Work function of the surface

b) Amount of photoelectric current

c) Stopping potential will be reduced

d) Maximum K.E. of photoelectron

19. When a proton is accelerated through 1 V, then its kinetic energy will be :

a) 1840 eV b) 13^{-6} eV

c) 1 eV d) 0.54 eV

20. As the intensity of incident light increases :

a) photoelectric current increases

b) photoelectric current decreases

c) kinetic energy of emitted photo electrons increases

d) kinetic energy of emitted photo electrons decreases

21. The photoelectric work function for a metal surface is 4.125 eV. The cut-off wavelength for this surface is :

a) 4125 Å b) 2062.5 Å

c) 3000 Å d) 6000 Å

22. The resistance of a discharge tube is :

a) zero b) ohmic

c) non-ohmic d) both 'A' and 'B'

23. Energy required to remove an electron from an aluminium surface is 4.2 eV. If light of wavelength 2000 Å falls on the surface, the velocity of fastest electron ejected from the surface is :

a) 2.5×10^{28} m/s b) 2.5×10^{23} m/s

c) 6.7×10^{28} m/s d) none of these

24. Maximum velocity of photoelectron emitted is 4.8 m/s. If e/m ratio of electron is 1.76×10^{11} C kg^{-1}, then stopping potential is given by :

a) 5×10^{-10} joule b) 3×10^{-7} joule

c) 7×10^{-10} joule d) 2.5×10^{2} joule

25. In Millikan's oil drop experiment; a drop of charge Q and radius r is kept constant between two plates of potential difference of 800 volt. Then charge on other drop of radius 3 r which is kept constant with a potential difference of 3200 volt is :

a) $\frac{Q}{2}$ b) 2 Q

c) 4 Q d) $\frac{Q}{4}$

26. Who indirectly determined the mass of the electron by measuring the charge of the electron ?

a) Rutherford b) Millikan

c) Einstein d) Thomson

27. Einstein's work on the photoelectric effect provided support for the equation :

a) $E = mc^2$ b) $E = hv$

c) $E = -\frac{Rhc}{n^2}$ d) $K.E. = \frac{1}{2}m\upsilon^2$

28. Photoelectric emission occurs only when the incident light has more than a certain minimum :

a) power b) wavelength

c) intensity d) frequency

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

a) 1 : 4 b) 1 : 2

c) 1 : 1 d) 1 : 5

30. In photoelectric emission process from a metal of work function 1.8 eV, the kinetic energy of most energetic electrons is 0.5 eV. The corresponding stopping potential is :

a) 1.8 eV b) 1.3 V

c) 0.5 V d) 2.3 V

31. A silver sphere of radius 1 em 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 $A \times 10^z$ (where $1 < A < 10$). The value of Z is :

32. The work functions 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 :

33. For photoelectric emission from certain metal the cutoff frequency 2 υ impinges on the metal plate, the maximum possible velocity of the emitted electron will be (m is the electron mass) :

a) $\sqrt{\frac{2h\upsilon}{m}}$ b) $2\sqrt{\frac{h\upsilon}{m}}$

c) $\sqrt{\frac{h\upsilon}{(2m)}}$ d) $\sqrt{\frac{h\upsilon}{m}}$

34. When the energy of the incident radiation is increased by 20%, the kinetic energy of the photoelectrons emitted from a metal surface increased from 0.5 eV to 0.8 eV. The work function of the metal is :

a) 1.5 eV b) 0.65 eV

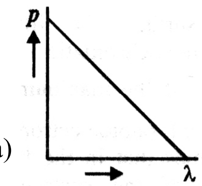
c) 1.0 eV d) 1.3 eV

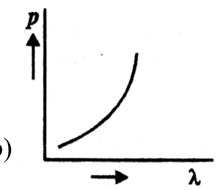
35. A metal surface is illuminated by light of two different wavelengths 248 mm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2, respectively. If the ratio $u_1 : u_2 = 2 : 1$ and hc = 1240 eV nm, the work function of the metal is nearly :

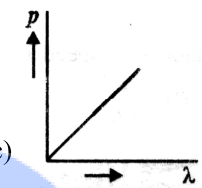
a) 3.7 eV b) 3.2 eV

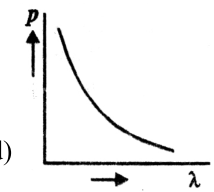
c) 2.8 eV d) 2.5 eV

36. Which of the following figures respresent the variation of particle momentum and the associated de-Broglie wavelength ?

a) 

b) 

c) 

d) 

37. A certain metallic surface is illuminated with monochromatic light of wavelength, λ. The stopping potential for photo-electric current for this light is $3V_0$. If the same surface is illuminated with light of wavelength 2λ, the stopping potential is V_0. The threshold wavelength for this surface for photo electric effect is :

a) $\frac{\pi}{4}$ b) $\frac{\pi}{6}$

c) 6 λ d) 4 λ

38. Match List-I (Fundamental Experiment) with List-II (its conclusion) and select thecorrect option from the choices given below the list :

List-I		List-II
P. Franck-Hertz	i)	Particle nature of light Experiment
Q. Photo-electric experiment of atom	ii)	Disrete energy levels
R. Davison-Germer	iii)	Wave nature of Experimet electron
	iv)	Structure of atom

a) P – (ii), Q – (i), R – (iii)

b) P – (iv), Q – (iii), R – (ii)

c) P – (i), Q – (iv), R – (iii)

d) P – (ii), Q – (iv), R – (iii)

39. A photoelectric surface is illuminated successively by monochromatic tight of wavelength λ and $\frac{\lambda}{2}$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the surface of the material is :
[h = Planck's constant, c = speed of tight]

a) $\frac{2hc}{\lambda}$ b) $\frac{hc}{3\lambda}$

c) $\frac{hc}{2\lambda}$ d) $\frac{hc}{\lambda}$

40. Light of wavelength 500 nm is incident on a metal with work function 2.28 eV. The de Broglie wavelength of the emitted electron is :

a) $\geq 2.8 \times 10^{-9}$ m b) $\leq 2.8 \times 10^{-12}$ m

c) $< 2.8 \times 10^{-10}$ m d) $< 2.8 \times 10^{-9}$ m

● ● ●

Brain Teasers

1. If the specific charge of proton (e/m_p) is 9.6×10^7 coulomb per kilogram, then for an alpha particle (e/m_α) will be :
a) 2.4×10^7 C/kg
b) 4.8×10^7 C/kg
c) 19.2×10^7 C/kg
d) 38.4×10^7 C/kg

2. An electron (charge *e*) at rest is accelerated in a uniform electric field of strength E. It covers a distance *x*, the kinetic energy gained by the electron will be :

a) Eex b) $\frac{Ex}{e}$

c) $\frac{Ee}{x}$ d) Ex

3. In the Thomson's experiment to determine e/m of electron, the same high tension is used to accelerate the electrons as to deflect them in the region of crossed electric and magnetic fields. If the voltage of the high tension is made 4 times by what factor should the magnetic field be increased so that the electron goes undeflected ?
a) 4 b) 2
c) 1 d) 0.5

4. An electron and a proton are fired through uniform magnetic fields perpendicular to it with the same kinetic energy. What is the nature of trajectory?
a) Electron trajectory is more curved than the proton trajectory
b) Electron trajectory is less curved than the proton trajectory
c) Both trajectories are equally curved
d) Both particles move along straight line path

5. An electron and a proton are injected into a uniform electric field at right angle to the field with the same kinetic energy. What is the nature of their trajectories ?
a) Electron trajectory is more curved than the proton trajectory
b) Electron trajectory is less curved than the proton trajectory
c) Both trajectories are equally curved
d) Both trajectories are straight lines

6. A charged particle is moving with velocity $\vec{\upsilon}$ through a magnetic field $\vec{B}$ and electric field $\vec{E}$. In which of the following cases the direction of velocity may not change ?

1) $\vec{E} \parallel \vec{B}$ 2) $\vec{E} \perp \vec{B}$

3) $\vec{E} \parallel \vec{B} \parallel \vec{\upsilon}$ 4) $\vec{E} \perp \vec{B} \perp \vec{\upsilon}$

a) 1 and 2 b) 3 and 4
c) 1 and 3 d) 2 and 4

7. The specific charge of a proton is 9.6×10^7 C/kg. That for α-particle will be :
a) 2.4×10^7 C/kg b) 4.8×10^7 C/kg
c) 19.2×10^7 C/kg d) 38.4×10^7 C/kg

8. Two ions of same charge and kinetic energy but having different masses m_1 and m_2 are projected into the same magnetic field. If r_1 and r_2 be the radii of the circular paths followed by the ions, then $\frac{r_1}{r_2} =$

a) $\frac{m_1}{m_2}$ b) $\frac{m_2}{m_1}$

c) $\left(\frac{m_1}{m_2}\right)^{\frac{1}{2}}$ d) $\left(\frac{m_2}{m_1}\right)^{\frac{1}{2}}$

9. The stopping potential for a certain photosensitive metal is V_0 when the frequency of incident radiation is v_0. When the frequency of the incident radiations is doubled, what will be the stopping potential ?
a) V_0 b) 2 V_0
c) 4 V_0 d) none of the above

10. The slope of the kinetic energy versus frequency graph for photoelectric effect is equal to :
a) h b) he
c) $\frac{h}{e}$ d) e

11. Radiations of wavelength 450 nm are incident on a photosensitive surface and photo electrons are emitted. When light of 500 nm is incident, no photoelectrons are emitted whatever the intensity of radiations. If λ_0 be the threshold wavelength, then :
a) $\lambda_0 \le 500$ nm b) $\lambda_0 \ge 500$ nm
c) $\lambda_0 \le 450$ nm d) $\lambda_0 = 475$ nm

12. Threshold wavelength for a metal having work function ω_0 is λ. What is the threshold wavelength for the metal having work function 2 ω_0 ?
a) 4 λ b) 2 λ
c) $\frac{\lambda}{2}$ d) $\frac{\lambda}{4}$

13. The maximum energy of the photoelectrons emitted in a photocell is 5 eV. For no photo-electron to reach the anode, the potential difference of the anode w.r.t. the photo sensitive plate should be :
a) zero b) + 2V
c) + 5V d) none of the above

14. Photoelectrons are being obtained by irradiating zinc by a radiation of 3100 Å. In order to increase the kinetic energy of ejected photoelectron :
a) the intensity of radiation should be increased
b) the wavelength of radiation should be increased
c) the wavelength of radiation should be decreased
d) both wavelength and intensity of radiation should be increased

15. The threshold wavelength for photoelectric emission from a material is 5200 Å. Photo-electrons will be emitted when this material is illuminated with monochromatic radiation from a :
a) 50 watt infra red lamp
b) 1 watt infra red lamp
c) 50 watt red light lamp
d) 1 watt ultraviolet lamp

16. Given that for photoelectric effect ν = frequency of the incident radiations, ω_0 = work functi on of the metallic surface, V = potential difference between the emitter and collector of the photocell. What determines the maximum velocity of the electron reaching the collector ?
a) ν alone b) ω_0 alone
c) V alone d) ν, ω_0 and V

17. Radiations of frequency ν are incident on a photo sensitive metal. The maximum kinetic energy of the photo electrons is E. When the frequency of the incident radiations is doubled, what is the maximum kinetic energy of the photoelectrons ?
a) 2 E b) 4 E
c) E + hv d) E – hv

18. The slope of the stopping potential versus frequency graph for photoelectric effect is equal to :

a) h b) he

c) $\frac{h}{e}$ d) e

19. The threshold frequency for a photosensitive metal is ν_0. When photons of frequency 2 ν_0 are incident on a phot ensitive plate, the cut off potential is V_0. What will be the cut off potential, when light of frequency 5 ν_0 is incident on it ?

a) V_0 b) 2 V_0

c) 4 V_0 d) 5 V_0

20. What is the stopping potential for photoelectrons ejected from a metal of work function 1.2 eV when the incident light consists of photons of energy 1.8 eV ?

a) 0.6 eV b) 1.2 eV

c) 1.8 eV d) 2.4 eV

21. What is the energy of an X-ray photon of wavelength 0.0001 nm ?

a) 6.6×10^{-22} J b) 6.6×10^{-27} J

c) 6.6×10^{-34} J d) one of the above

22. An electron having kinetic energy E possesses wavelength λ. What will be its wavelength when the velocity becomes 4 times of the initial velocity ?

a) $\frac{\lambda}{4}$ b) $\frac{\lambda}{2}$

c) 2 λ d) 4 λ

23. An electron enters a magnetic field of induction 2 mT with a velocity of 1.8×10^7 m/s. The radius of the circular path is :

a) 5.1 mm b) 5.1 cm

c) 5.1 m d) 5.1 km

24. An electron and a proton are accelerated through a potential V. If p_e and p_p be their momenta, then $\frac{p_p}{p_e}$ is approximately equal to :

a) 21 b) 43

c) 55 d) 81

25. If p_x be momentum of 10^5 eV X-ray photon and p_e be the momentum of an electron accelerated through 10^5 V, then $\frac{p_e}{p_x} \cong$

a) 3 b) 2

c) 1 d) 0.5

26. In the Millikan's oil drop experiment the oil drop is subjected to a horizontal electric field 2 NC^{-1} and the drop moves with constant velocity making angle 45^0 with the horizontal. If the weight of the drop be W, then the electric charge in coulomb on the drop is :

a) 2 W b) W

c) $\frac{W}{2}$ d) $\frac{W}{4}$

27. A beam of a-particles pas es through crossed electric and magnetic fields $E = 7.2 \times 10^6$ NC^{-1} and B = 2.4 T. If the beam goes undeviated, what is the velocity of α-particles ?

a) $7.2 \times 2.4 \times 10^6$ m s^{-1}

b) 3×10^6 m s^{-1}

c) 2.0×10^6 m s^{-1}

d) none of the above

28. Electrons are fired with a velocity 2.55×10^7 m s^{-1} at right angle to the magnetic field of 1.5×10^{-2} T. The specific charge of the electrons is 1.7×10^{11} C/kg. What is the radiu of the circular path of the electron ?

a) 1 m b) 1 cm

c) 1 mm d) 0.1 mm

29. In Millikan oil drop experiment, a charged drop of mass 1.8×10^{-14} kg is stationary between its plates. The distance between its plate, is 0.90 cm and potential difference is 2.0 kilo-volt. The number of electrons on the drop is :

a) 500 b) 50

c) 5 d) 0

30. A proton and an α-particle having same momentum are fired through a magnetic field. If r_1 and r_2 respectively, be the radii of their circular paths, then $\frac{r_1}{r_2} =$

a) 2 b) $\frac{1}{2}$

c) $\sqrt{2}$ d) $\frac{1}{\sqrt{2}}$

31. A proton and an α-particle having same kinetic energy are fired through a magnetic field. If r_1 and r_2 respectively, be the radii of their circular path., then $\frac{r_1}{r_2} =$

a) 1 b) 2

c) $\sqrt{2}$ d) none of the above

32. A charged oil drop is held stationary in an electric field. The pace containing the drop is exposed to a radioactive source and the drops moves with different terminal velocities υ, 2υ, 3υ, 4υ etc. What does it uggest ?

a) Charge is conserved

b) The drop carries –VE charge

c) The drop carrie +VE charge

d) The charge is quantised

33. The mass of proton is about 1840 times the mass of electron. An electron and a proton are fired perpendicular to the same magnetic field with the same kinetic energy. The ratio of the radius of curvature of the trajectory of proton to electron will be about :

a) 18 b) 36

c) 43 d) 60

34. The work function for a photoelectric material is 3.3 eV. The threshold frequency will be equal to :

a) 8×10^{14} Hz b) 8×10^{10} Hz

c) 4×10^{14} Hz d) 5×10^{20} Hz

35. A photosensitive plate is irradiated from a distance of 1 m. The photoelectric current is 0.1 A. If the source of radiations is brought nearer to a distance of 50 cm, the photoelectric current will be :

a) 0.1 A b) 0.2 A

c) 0.4 A d) 0.8 A

36. Light of two different frequencies whose photons have energies 1 eV and 2.5 eV respectively successively illuminate a metal of work function 0.5 eV. The ratio of maximum peeds of the emitted electrons will be :

a) 1 : 5 b) 1 : 4

c) 1 : 2 d) 1 : 1

37. The photoelectric threshold of a metal is ν_0. When light of frequency 5 ν_0 is incident. the maximum kinetic energy of the photoelectrons will be :

a) $h\nu_0$ b) $2\ h\nu_0$

c) $3\ h\nu_0$ d) $4\ h\nu_0$

38. The threshold frequency for a certain metal is ν_0. When light of frequency $\nu = 2\ \nu_0$ is incident on it, the maximum velocity of photoelectrons is 4×10^6 m/s. If the frequency of incident radiation is increased to 5 ν_0, then the maximum velocity of photoelectrons in mls will be :

a) $\left(\frac{4}{5}\right) \times 10^6$ b) 2×10^6

c) 8×10^6 d) 2×10^7

39. When a certain metallic surface is illuminated with monochromatic light of wavelength λ, the stopping potential for photoelectric current is 3 V_0. When the same surface is illuminated with light of wavelength 2 λ the stopping potential is V_0. The threshold wavelength for this surface for photo-electric effect is :

a) 6 λ b) 4 λ

c) $\frac{\lambda}{4}$ d) 8 λ

40. Threshold frequency for a photoelectrically active metal is 4.0×10^{14} hertz. If Planck's constant h is 6.62×10^{-34} Js, then work function is :

a) 1.6 erg

b) 1.66 joule

c) 1.66 eV

d) 1.06 MeV

41. Monochromatic light incident on a metal surface emits electrons with kinetic energy from 0 to 2.6 eV. What is the least energy of the incident photon if the tightly bound electron needs 4.2 eV to be removed ?

a) 1.6 eV

b) between 1.6 and 6.8 eV

c) 6.8 eV

d) more than 6.8 eV

42. Ultraviolet radiation of 6.2 eV falls on an aluminium surface (work function 4.2 eV). The kinetic energy in joule of the fastest electron emitted is approximately :

a) 3×10^{-21} b) 3×10^{-19}

c) 4×10^{-17} d) 3×10^{-15}

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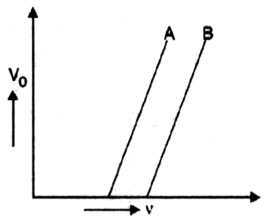
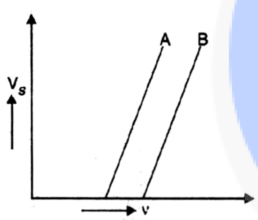
GRAPHICAL BANK

43. The stopping potential as a function of frequency of incident radiation is plotted for two different photoelectric surfaces A and B. The graphs shows that the work function of A is :



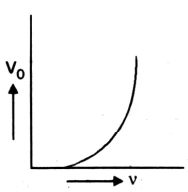
a) greater than that of B
b) smaller than that of B
c) same as that of B
d) such that no comparison can be done from given graphs

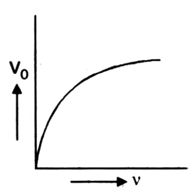
44. Fig. shows ν versus V_0 graph for photoelectric emission from two metals A and B. Here ν is the frequency of the incident radiations and V_0 is the stopping potential. Which of the following statements for the two metals is correct ?

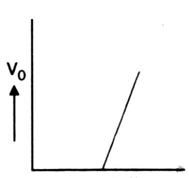


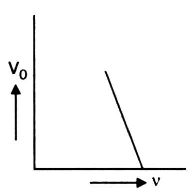
a) Work function for A is greater than that for B
b) Work function for A is less than that for B
c) The threshold frequency is same for both the metals
d) The threshold frequency is less for the metal B

45. Which of the following is the graph between the frequency (ν) of the incident radiations and the stopping potential ?

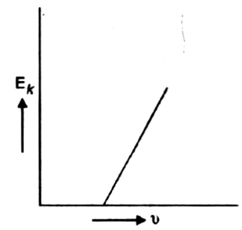
a) 

b) 

c) 

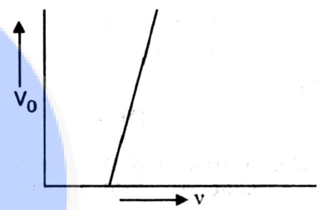
d) 

46. The maximum kinetic energy of emitted photo-electrons against frequency ν of incident radiation is plotted as shown in fig. The slope of the graph is equal to :



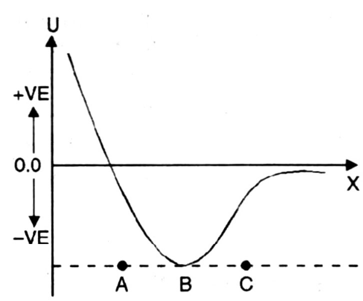
a) charge on electron
b) work function of emitter
c) Planck's constant
d) Ratio of Planck's constant and charge on electrons

47. In photoelectric effect the slope of straight line graph between stopping potential (V_0) and frequency of incident light (ν) gives :



a) charge on electrons
b) work function of emitter
c) Planck's constant
d) ratio of Planck's constant to charge on electron

48. The potential energy U between two molecules as a function of the distance X between them has been shown in the adjoining figure. The two molecules are :



a) attracted when X lies between A and B and are repelled when X lies between B and C
b) attracted when X lies between B and C and are repelled when lies between A and B
c) attracted when they reach B
d) repelled when they reach B

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Answer Key

MH Text Book Based MCQ's

01. (a)	19. (c)	37. (a)	55. (c)	73. (c)	91. (d)	109. (b)
02. (d)	20. (b)	38. (c)	56. (d)	74. (d)	92. (a)	110. (b)
03. (a)	21. (b)	39. (b)	57. (d)	75. (c)	93. (b)	111. (d)
04. (c)	22. (b)	40. (c)	58. (c)	76. (d)	94. (d)	112. (a)
05. (c)	23. (b)	41. (c)	59. (d)	77. (c)	95. (a)	113. (b)
06. (d)	24. (b)	42. (b)	60. (a)	78. (d)	96. (d)	114. (d)
07. (c)	25. (a)	43. (b)	61. (c)	79. (b)	97. (b)	115. (a)
08. (c)	26. (d)	44. (b)	62. (a)	80. (c)	98. (c)	116. (c)
09. (d)	27. (a)	45. (a)	63. (c)	81. (b)	99. (d)	117. (d)
10. (d)	28. (d)	46. (a)	64. (a)	82. (d)	100. (a)	118. (a)
11. (c,d)	29. (a)	47. (a)	65. (d)	83. (b)	101. (a)	119. (d)
12. (b)	30. (c)	48. (d)	66. (b)	84. (c)	102. (a)	
13. (b)	31. (c)	49. (a)	67. (b)	85. (b)	103. (a)	
14. (b)	32. (d)	50. (c)	68. (d)	86. (b)	104. (b)	
15. (c)	33. (c)	51. (b)	69. (a,b,c)	87. (c)	105. (a)	
16. (a)	34. (b)	52. (b)	70. (a)	88. (d)	106. (a)	
17. (b)	35. (b)	53. (a)	71. (d)	89. (c)	107. (d)	
18. (c)	36. (d)	54. (b)	72. (b)	90. (d)	108. (b)	

REVISION QUESTIONS from Competitive Exams.

01. (d)	07. (c)	13. (a)	19. (b)	25. (d)	31. (-)	37. (d)
02. (a)	08. (d)	14. (d)	20. (a)	26. (b)	32. (-)	38. (a)
03. (b)	09. (c)	15. (d)	21. (c)	27. (b)	33. (a)	39. (c)
04. (c)	10. (a)	16. (c)	22. (c)	28. (d)	34. (a)	40. (a)
05. (a)	11. (c)	17. (a)	23. (b)	29. (b)	35. (a)	
06. (c)	12. (c)	18. (a)	24. (c)	30. (c)	36. (d)	

BRAIN TEASERS

01. (b)	08. (c)	15. (d)	22. (a)	29. (c)	36. (c)	43. (b)
02. (a)	09. (d)	16. (d)	23. (b)	30. (a)	37. (d)	44. (b)
03. (b)	10. (a)	17. (c)	24. (b)	31. (a)	38. (c)	45. (c)
04. (a)	11. (b)	18. (c)	25. (a)	32. (d)	39. (b)	46. (c)
05. (c)	12. (c)	19. (c)	26. (c)	33. (c)	40. (c)	47. (d)
06. (b)	13. (d)	20. (a)	27. (b)	34. (a)	41. (c)	48. (b)
07. (b)	14. (c)	21. (d)	28. (b)	35. (c)	42. (b)	

Hints and Explanations

1-3. Here $eV = \frac{1}{2} M\upsilon^2$. And $\upsilon = [2 e V/M]^{1/2}$.

Energy in joules is eV.

4. Electric force should be opposite to the magnetic force. This is possible when the angle between $\vec{E}$ and $\vec{B}$ is 90°.
5. Canal rays consist of ions of the gas contained in the discharge tube.
6. Heaviest isotope of hydrogen is ${}_1H^3$ with mass about 6000 times that of electron.
7. Mass of deutron is twice that of proton.
8. $\vec{F}_m = q_0 \vec{\upsilon} \times \vec{B}$. Here $\vec{\upsilon} \perp \vec{B}$.
9. The curvature of the path of ion depends on the mass.
10. Mass of hydrogen is 1840 times that of electron but charge has same magnitude in both the cases.
11. Spectrograph measures e/m of ions.
12. Charge is same in both cases but mass is more for the positive rays.
13. When the charged particle enters the magnetic field making angle other than 90° with it, the path is a helix.
14. It is similar to the throwing of stone horizontally from the top of a tower.
15. Here $\frac{m\upsilon^2}{r} = e\upsilon B$. Hence $r = m\upsilon/eB$. It is same for both.
16. Cannot pass through the origin because for doing so infinite accelerating potential is required.
17. Positive rays may consist of ions of different elements.
18. The ions are produced during collisions in the discharge tube.
19. The pressure is very very low in CRO.
20. In cyclotron, the charge crosses the electric field twice.
21. $\upsilon = E/B = 7 \cdot 2 \times 10^6 / 2 \cdot 4 = 3 \times 10^6 \text{ m s}^{-1}$
22. $\upsilon = E/B = 6 \cdot 6 \times 10^6 / 1 \cdot 2$.
23. $\vec{F}_m = q_0 \vec{\upsilon} \times \vec{B}$. It acts as a centripetal force.
24. At very high speed mass begins to vary with speed to a large extent.
25. This makes the charged particle enter the electric field so that it always gains energy.
26. The cyclotron can accelerate only the charged particles.
27. The cyclotron was first installed by E. Lawrence.
28. $\upsilon = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1 \cdot 6 \times 10^{-19}}{9 \cdot 1 \times 10^{-31}} \times 100}$

$$= 6000 \text{ km/s}$$

29. Here $\upsilon = \sqrt{\frac{2eV}{m}}$
30. $n \times 1 \cdot 6 \times 10^{-19} \times E = mg$

$$\Rightarrow \quad n = \frac{mg}{1 \cdot 6 \times 10^{-19} \times E}$$

31. $\upsilon = \frac{E}{B} = \frac{30 \times 1000}{3 \times 10^{-3}} = 10^7 \text{ m/s}$
32. $\frac{m\upsilon^2}{r} = q\upsilon B \quad \Rightarrow p = m\upsilon = q r B$

$$= 2 \times 1.6 \times 10^{-19} \times \frac{5}{100} \times 0.1$$

$$= 1.6 \times 10^{-21} \text{ kg m/s.}$$

33. $$\frac{e}{m} = \frac{2y\upsilon^2}{El^2} = \frac{2 \times 2 \times 10^{-3} \times (2 \times 10^7)^2}{4000 \times (0.1)^2}$$

$$= 4 \times 10^{10}$$

34. $a = \frac{q_0 E}{m}$ and $y = \frac{1}{2} at^2$

$$= \frac{1}{2} \times \frac{1.6 \times 10^{-19} \times 2000}{9.1 \times 10^{-31}} \times (10^{-9})^2$$

35. The standard equation for parabola is :

$$y^2 = \frac{k}{m} x$$

Here $y^2 = \frac{x}{10} = \frac{k}{m} x = \frac{k}{20} x$

This gives $k = 2$.

Hence equation for Ne^{22} is $y^2 = \frac{2}{22} x = \frac{x}{11}$

36. $$A = \frac{n_1 A_1 + n_2 A_2}{n_1 + n_2}$$

or $20.2 = \frac{n_1 \times 20 + n_2 \times 22}{n_1 + n_2}$

Solving, we find : $\frac{n_1}{n_2} = \frac{9}{1}$.

37. $$r = \frac{\sqrt{2mK}}{qV}$$

$$= \frac{(2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 1000)^{1/2}}{1.6 \times 10^{-19} \times 3 \times 10^{-3}}$$

38. $mg = qE = q\frac{V}{d}$

$$\Rightarrow V = \frac{mgd}{q} = \frac{3.2 \times 10^{-16} \times 10 \times 5 \times 10^{-3}}{5 \times 1.6 \times 10^{-19}} = 20 \text{ V}$$

39-49. Knowledge based questions.

50. It is the statement of a fact.

51. Frequency is always an integral number.

52. Decrease in intensity means decrease in the number of photons incident per second.

53. Both photoelectric effect and compton effect support quantum theory of light.

54. Current ∝ Intensity. Kinetic energy increases with frequency.

55. Work function is the minimum energy required to just remove the electron from lattice/atom.

56. It is the energy required to free the electron from the metallic surface against coulomb attraction.

57. Free electrons are ejected in photoelectric effect.

58. Einstein explained photoelectric effect on the basis of quantum theory.

59. Photocell produces electric current with the help of light.

60. Frequency has integral values.

61. It is the definition of photoelectric effect.

62. The cut off potential is independent of the intensity of light.

63. Maximum kinetic energy is independent of intensity.

64. Larger intensity means more incident photons which ejects larger number electrons.

65. Photoelectric effect, in fact, confirms the quantum nature of light.

66. $h\nu_0$ is the minimum energy used to eject the electron. More energy of the electron can be lost due to collision etc.

67. Work function is the minimum amount of energy lost to get the electron ejected. More energy can also be lost due to collision etc.

68. Intensity of light varies inversely as the square of the distance.

69. This shows that, there is a minimum amount of energy required to eject the electron. Also, according to quantum theory (*i*) max. KE depends only on frequency and is independent of intensity,. (*ii*) photoelectric emission is instantaneous.

70. The kinetic energy of the photoelectrons does not depend on the intensity of the incident light.

71. It is the maximum kinetic energy, when minimum amount of energy is used to take the electron out.

72. $E_k = h\nu - h\nu_0$.

73. Threshold wave length is less than that of yellow light. So, the red light cannot cause photoelectric emission.

74. The saturation current ∝ intensity ∝ $(1/d^2)$.

75. V depends on frequency and not on the intensity of radiations.

76. Saturation current depends on the intensity of radiations.

77. $h\nu = h\nu_0 + E_k$. Here $\nu > \nu_0$.

78. When frequency is halved it becomes $0.75\,\nu_0$. No emission of light takes place.

79. $\omega = h\nu = 6.6 \times 10^{-34} \times 3 \times 10^{14} = 2 \times 10^{-19}$ J.

80. $h\nu = \omega_0 + \frac{1}{2} m\upsilon_m^2$. Here υ_m depends on ω_0 and ν.

81. For saturation current the potential of the emitter is +VE. For cut off potential, the emitter is at – VE potential.

82. $$\lambda_0 = \frac{hc}{\omega_0} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3.3 \times 10^{-19}}$$

$$= 600 \text{ nm.}$$

83. $$\text{K.E.} = \frac{hc\,[\lambda_0 - \lambda]}{\lambda\lambda_0}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8} [600 - 450] \times 10^{-9}}{660 \times 450 \times 10^{-18}}$$

$= 0.625$ eV.

84. $K_1 = \frac{hc}{\lambda_1} - \omega_0$

$K_2 = \frac{hc}{\lambda_2} - \omega_0$

$$K_1 - K_2 = hc\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right] = hc\,\frac{\lambda_2 - \lambda_1}{\lambda_2 \lambda_1}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}[800 - 400] \times 10^{-9}}{400 \times 800 \times 10^{-18}}$$

$$= \frac{2.475 \times 10^{-19}}{\text{J}} \cong 1.5 \text{ eV}$$

85. $V_0 = \frac{(20-10)\text{ eV}}{e} = \frac{10 \times e}{e} = 10$ V

86. $\frac{K_1}{K_2} = \frac{hV_1 - \omega_0}{hV_2 - \omega_0} = \frac{1.5 - 0.5}{2.5 - 0.5} = \frac{1}{2}$

87. $\lambda_{01} = \frac{hc}{\omega_{01}}$ and $\lambda_{02} = \frac{hc}{\omega_{02}}$

Hence $\frac{\lambda_{02}}{\lambda_{01}} = \frac{\omega_{01}}{\omega_{02}}$

or $\lambda_{02} = \frac{\omega_{01}}{\omega_{02}} \times \lambda_{01} = \frac{5}{2.5} \times 6000$ Å

$= 12000$ Å

88. $\omega_0 = h\nu_0 = 6.6 \times 10^{-34} \times 2 \times 10^{14}$

$= 13.2 \times 10^{-20}$ J

89. $K = \frac{hc}{\lambda} - \omega_0 = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4000 \times 10^{-10}} - 3.2 \times 10^{-19}$

$= 1.75 \times 10^{-19}$J.

90. $\frac{hc}{\lambda_1} - \omega_0 = eV_1$

$\frac{hc}{\lambda_2} - \omega_0 = eV_2$

Hence $e(V_2 - V_1) = hc\left[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right]$

$$= hc\left[\frac{\lambda_1 - \lambda_2}{\lambda_1 \lambda_2}\right]$$

This gives $V_2 = 3$ V.

91. $\omega_0 = h\nu - eV_0 = 6$ eV$-(-5$eV$) = 11$ eV.

92. $V_0 = \frac{E - \omega_0}{e}$

Or 3.5 eV $= 5$ eV ω_0

Hence $\omega_0 = 1.5$ eV

93. Knowledge based question.

94. $E = h\nu = 6.63 \times 10^{-34} \times 10^{18}$ J

$$\Rightarrow E = \frac{6.63 \times 10^{-16}}{1.6 \times 10^{-19}} \text{ eV} = 4.14 \times 10^{3} \text{ eV.}$$

95. As $\frac{m\upsilon^2}{r} = e\upsilon B$

$r = \frac{m\upsilon}{eB}$

$$r = \frac{9.1 \times 10^{-31} \times 1.6 \times 10^{5}}{16 \times 10^{-19} \times 0.013 \times 10^{-4}}$$

$r = 0.7$ m

96. We know that

$E = mc^2$

$E = 3 \times (3 \times 10^8)^2$

$E = 27 \times 10^{16}$ J

97. The speed of the wave, $\upsilon = \frac{E}{B}$

or $\upsilon = \frac{1.125 \times 10^{-6}}{3 \times 10^{-10}}$

or $\upsilon = 3.75 \times 10^{3}$ m/s

or $\upsilon = 3750$ m/s

98. Current, $I = \frac{q}{t}$

or $I = \frac{e}{T} = \frac{1.6 \times 10^{-19}}{1.5941 \times 10^{-18}}$

or $I = 100.37 \times 10^{-3}$ A

or $I = 100.37$ mA

99. The actual value of charge lies on an electron is -1.6×10^{-19}C.

100. The energy of photon $h\nu$, work function of metal ϕ and K.E. of ejected electron are related to each other according to principle of conservation of energy :

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

Since $\nu = \frac{c}{\lambda}$

$\therefore \frac{hc}{\lambda} - \phi = \frac{1}{2}mV^2$

or $V^2 = \frac{2(hc - \lambda\phi)}{m\lambda}$

or $V = \left[\frac{2(hc - \lambda\phi)}{m\lambda}\right]^{1/2}$

101. We know that

$\upsilon = \frac{E}{B}$

$\therefore\ B = \frac{E}{\upsilon} = \frac{3.2 \times 10^4}{1.825 \times 10^7} = 1.753 \times 10^{-3}\ \text{Wb/m}^2$

$\cong 1.7 \times 10^{-3}\ \text{Wb/m}^2$.

102. $\frac{1}{2} m\upsilon^2 = E - W \Rightarrow \upsilon \propto \sqrt{E - W}$

So, $\frac{\upsilon_1}{\upsilon_2} = \sqrt{\frac{1 - 0.5}{2.5 - 0.5}} = \frac{1}{2}$

103. Stopping potential depends on frequency f is independent of intensity of light.

104. $V = \frac{E}{B} = \frac{V_P/d}{B} = \frac{V_P}{dB} = \frac{500}{2 \times 10^{-2} \times 2 \times 10^{-2}}$

$\Rightarrow\ V = 125 \times 10^4\ \text{m/s} = 1250\ \text{km/s}$

105. $\frac{e}{m} = \frac{V}{rB} = \frac{r\omega}{rB} = \frac{\omega}{B} = \frac{2\pi f}{B}$

$\therefore\ f = \frac{eB}{2\pi m}$

106. $\boxed{r = \frac{m\upsilon}{qB}}$

107. $\boxed{\upsilon = \frac{E}{B}}$

108. Time period of electron, T $= \frac{4\varepsilon_0^2 n^3 h^3}{mZ^2 e^4}$

$\therefore\ T \propto n^3$

$\therefore\ \frac{1}{\text{frequency}\ (f)} \propto n^3$

or $f \propto n^{-3}$

109. We know that, $\lambda = \frac{h}{m\upsilon}$

$\lambda = \frac{hr}{mvr} = \frac{hr}{\frac{nh}{2\pi}}$ $\left(\because \frac{nh}{2\pi} = m\upsilon r\right)$

or $n\lambda = 2\pi r$

Here $n = 1$

$\therefore\ \lambda = 2\pi r$

110. The work function is given by

$W_0 = h\nu_0 = \frac{hc}{\lambda_0}$

$W_0 = \frac{12420}{\lambda_0}$ eV (λ is in angstrom)

$W_0 = \frac{12420}{4000} = 3.1$ eV

111. The radius of charged particle in uniform magnetic field is

$r = \frac{m\upsilon}{q\text{B}} = \frac{m}{q\text{B}}\sqrt{\frac{2qV}{m}}$

$r = \sqrt{\frac{2mV}{q}}$

$\therefore\ r \propto \sqrt{m}$

or $m \propto r^2$

$\therefore\ \frac{m_1}{m_2} = \frac{r_1^2}{r_2^2}$

112. We know that, energy of photon is

$E = h\nu = \frac{hc}{\lambda}$

$\therefore\ E \propto \frac{1}{\lambda}$

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

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

$\therefore\ p = \frac{1}{\lambda}$

As the wavelength of photon decreases then energy and momentum of photon both increase.

113. As $\lambda = \frac{h}{m\upsilon}$

$\lambda = \frac{hr}{m\upsilon r} = \frac{hr}{\frac{nh}{2\pi}}$ $\left(\because \frac{nh}{2\pi} = m\upsilon r\right)$

or $n\lambda = 2\pi r$

Here $n = 1\ \therefore\ \lambda = 2\pi r$

114. The acceleration is,

$a = \frac{F}{m} = \frac{qE}{m}$

We know that, $E = \frac{V}{d}$

$\therefore\ a = \frac{qV}{md}$

115. The de-Broglie wavelength is given by

$\lambda = \frac{h}{m\upsilon}$

For charged particle of charge q, mass m and potential difference V the de-Broglie wavelength is $\lambda = \frac{h}{\sqrt{2mqV}}$ $\left(\because p = \sqrt{2mE} = \sqrt{2mqV}\right)$

116. The radius of charged particle in uniform magnetic field is

$r = \frac{m\upsilon}{qB} = \frac{n}{qB}\sqrt{\frac{2qV}{m}}$

or $r = \frac{1}{B}\sqrt{\frac{2mV}{q}}$.

117. We know that

$W_0 = h\nu_1 - eV_1$

$= h\nu_2 - eV_2$

$$eV_2 = h(\nu_2 - \nu_1) + eV_1$$

or $$V_2 = V_1 + \frac{h}{e}(\nu_2 - \nu_1)$$

$$V_2 = V_1 + \frac{h}{e}(n_2 - n_1)$$

118. We know that

$$\frac{1}{2}m\upsilon^2 = h\nu - W_0$$

$$\frac{1}{2}m\upsilon^2 = \frac{hc}{\lambda} - W_0$$

For metal plate A, $K_A = \frac{hc}{\lambda_A} - W_0$

$$K_A = \frac{hc}{2\lambda_B} - W_0$$

...(*i*) ($\because \lambda_A = 2\lambda_B$)

For metal plate B, $K_B = \frac{hc}{\lambda_B} - W_0$ ...(*ii*)

From eqn. (1) and eqn. (ii), we get

$$K_A < \frac{K_B}{2}$$

119. $V_s = \frac{(\text{K.E.})_{max}}{e}$

$$(\text{K.E.})_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

$$3V_0 = \frac{hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)}{e} \text{ and } V_0 = \frac{hc\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right)}{e}$$

From eqns. (*i*) and (*ii*)

$$\lambda_0 = 4\lambda$$

REVISION QUESTIONS from Competitive Exams.

1. $hc/\lambda = \omega + \frac{1}{2}m\upsilon^2$. Here $\omega = 1\ eV$

$= 1\cdot6 \times 10^{-19}$ J. $\lambda = 3000$ Å $= 3000 \times 10^{-10}$m,

$c = 3 \times 10^8$ m s^{-1}, $h = 6\cdot6 \times 10^{-34}$ Js,

$m = 9\cdot1 \times 10^{-31}$ kg. Hence $\upsilon \cong 10^6$ m s^{-1}.

2. The work function has no effect on current so long it has $h\nu > W$. The photoelectric current is proportional to the intensity of light. Since, there is no change in the intensity of light, therefore $I_1 = I_2$.

3. Work function $= hc/\lambda_0$ where λ_0 is threshold wavelength. Hence $\omega_1/\omega_2 = \lambda_2/\lambda_1 = 2/1$.

4. $\omega_0 = hc/\lambda_0 = \frac{6\cdot625 \times 10^{-34} \times 3 \times 10^8}{5000 \times 10^{-10}}$ J

$\cong 4 \times 10^{-19}$ J.

5. Photoelectric current is proportional to the intensity of light.

6. In photoelectric effect, the light is absorbed and electrons are emitted.

7. The electric force on the electron should be opposite to the magnetic force.

8. $\lambda = h/p$.

9. Higher the voltage, higher is the KE. And higher the work function smaller is the KE.

10. $U_k = eV = 1\cdot6 \times 10^{-19} \times 100$

$= 1\cdot6 \times 10^{-17}$ J

11. Each photon ejects one electron. Therefore greater intensity of light produces larger photo current.

12. Specific charge is the ratio of charge to mass of the particle.

13. $\frac{hc}{\lambda} = \omega_0 + E_k$.

14. $\frac{hc}{\lambda_1} = \omega_0 + \frac{1}{2}m\upsilon_1^2$ And $\frac{hc}{\lambda_2} = \omega_0 + \frac{1}{2}m\upsilon_2^2$

15. $\frac{1}{2}m\upsilon^2 = EV$. Hence $\upsilon = \sqrt{\frac{2EV}{m}}$

16. $K = \frac{1}{2}mu^2 = eV_A$

17. $k = eV = 1\cdot6 \times 10^{-19} \times 100 = 1\cdot6 \times 10^{-17}$ J

18. Knowledge based question.

19. The eV is the energy gained by a proton when accelerated through 1V.

20. Knowledge based question.

21. Use $\omega = h\frac{c}{\lambda}$. Also 1 eV $= 1\cdot6 \times 10^{-19}$C

22. Knowledge based question.

23. $\frac{hc}{\lambda} = \omega_0 + \frac{1}{2}m\upsilon^2$.

24. Here we have, $eV_0 = \frac{1}{2}m\upsilon^2$

Hence $V_0 = \frac{1}{2}\left(\frac{m}{e}\right)\upsilon^2$

$$= \frac{1}{2} \times \left(\frac{1}{1\cdot76 \times 10^{11}}\right) \times (4\cdot8)^2$$

$$= 7 \times 10^{-10}\text{ J}$$

25. Here

$$Q \times \left(\frac{V}{l}\right) = \frac{4\pi}{3} r^3 \rho g.$$

Or $$Q' \times \left(\frac{V'}{l}\right) = \frac{4\pi}{3}(3r)^3 \rho g$$

Hence $$\frac{QV}{Q'V'} = \frac{1}{27}$$

This gives $$Q' = \frac{QV \times 27}{V'} = \frac{Q \times 800}{3200} = \frac{Q}{4}$$

26. Knowledge based question.

27. The photoelectric effect was explained by Einstein on the basis of particle nature of light.

28. The photoelectric emission is only possible when the light frequency of the incident light is greater than certain minimum frequency.

29. We know that, $E = \frac{1}{2}m\upsilon^2 + \phi$

$K.E_1 = E_1 - \phi = 1 - 0{\cdot}5 = 0{\cdot}5$ eV

$K.E_2 = E_2 - \phi = 2{\cdot}5 - 0{\cdot}5 = 2$ eV

$$\frac{K.E_1}{K.E_2} = \frac{1}{4} \Rightarrow \frac{\frac{1}{2}m\upsilon_1^2}{\frac{1}{2}m\upsilon_2^2} = \frac{1}{4}$$

$$\Rightarrow \frac{\upsilon_1}{\upsilon_2} = \frac{1}{2}$$

30. We know that $\frac{1}{2}m\upsilon^2 = eV_0 = 0{\cdot}5$ eV

$$V_0 = 0{\cdot}5 \text{ V}$$

31. Energy of incident radiation is

$$E = h\nu = \frac{hc}{\lambda} = \frac{1240\ eV}{200\ nm}\text{ nm}$$

$$E = 6{\cdot}2\ eV$$

Also, from Einstein's photoelectric equation

$$E = \phi_0 + K.E$$

$$6{\cdot}2\ eV = 4{\cdot}7\ eV + eV_s$$

$$V_s = 1{\cdot}5\text{ V}$$

Photo electrons will stop when potential on the surface is $1{\cdot}5$ V

$$\therefore\quad 1{\cdot}5 = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$$

or $$1{\cdot}5 = \frac{1}{4\pi\epsilon_0}\frac{ne}{R}$$

$$\therefore\quad n = \frac{1{\cdot}5 \times 4\pi\epsilon_0 R}{e}$$

Subsitute the value, we will get

$$\lambda = 1{\cdot}04 \times 10^7$$

$$\lambda = 1{\cdot}04 \times 10^7$$

$$\therefore\quad Z = 7$$

32. The photoelectric equation is

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

or $$eV_s = h\nu - \phi_0$$

$$\therefore\quad V_s = \frac{h\nu}{e} - \frac{\phi_0}{e} \qquad ...(i)$$

So, the graph between V_s versus is a straight line

Also, we know that

$$y = mx + c \qquad ...(ii)$$

(for straight line)

Comparing (*i*) and (*ii*), we have

Slope of V_s versus $\nu = \frac{h}{e}$

This is same for both the metals

$\therefore$ ratio of slopes $= \frac{h/e}{h/e} = 1$

33. Use Einstein's photoelectric equation *i.e.*,

$$\frac{1}{2}m\nu_{max}^2 = h(2\nu) - h\nu$$

or $$\frac{1}{2}m\nu_{max}^2 = h\nu$$

or $$\nu_{max}^2 = \frac{2h\nu}{m}$$

or $$\nu_{max} = \sqrt{\frac{2h\nu}{m}}$$

34. We know that,

$$E = \phi + 0{\cdot}5\ eV \qquad ...(1)$$

$$E + \frac{20}{100}E = \phi_0 + 0{\cdot}8\ eV \qquad ...(2)$$

$$\therefore\quad \frac{20}{100}E = 0{\cdot}3\ eV$$

$$\Rightarrow\quad E = 1{\cdot}5\ eV$$

$\therefore$ From eqn. (1)

$$\phi = \mathbf{1{\cdot}0\ eV}$$

35. We know that

$$K = \frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$$

For $\lambda = 248$ nm, $v = u_1$

$$\therefore\quad K_1 = \frac{1}{2}mu_1^2 = \frac{hc}{248} - \phi \qquad ...(i)$$

For $\lambda = 310\ nm$, $v = u_2$

$$\therefore\quad K_2 = \frac{1}{2}mu_2^2 = \frac{hc}{310} - \phi \qquad ...(ii)$$

Dividing equation (*i*) by (*ii*), we get

$$\frac{u_1^2}{u_2^2} = \frac{\frac{hc}{248} - \phi}{\frac{hc}{310} - \phi} = \frac{\frac{1240}{248} - \phi}{\frac{1240}{310} - \phi}$$

$$\frac{2^2}{1^2} = \frac{5 - \phi}{4 - \phi} \Rightarrow 16 - 4\phi = 5 - \phi$$

$$\Rightarrow\quad \phi = 3{\cdot}67\ eV = 3{\cdot}7\ eV$$

36. $\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$

This represents a rectangular hyperbola.

37. Use Einstein's photoelectric equation

$$eV_s = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

or, $$V_s = \frac{hc}{e}\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

Now, $$3V_0 = \frac{hc}{e}\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right] \quad ...(i)$$

and $$V_0 = \frac{hc}{e}\left[\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right] \quad ...(ii)$$

on dividing, Eqn. (*i*) by (*ii*), we get

$$3 = \frac{\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]}{\left[\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right]}$$

or, $$3\left[\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right] = \left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

or, $$\frac{3}{2\lambda} - \frac{3}{\lambda_0} = \frac{1}{\lambda} - \frac{1}{\lambda_0}$$

or, $$\frac{2}{\lambda_0} = \frac{1}{2\lambda} \Rightarrow \lambda_0 = 4\lambda.$$

38. Franck Hertyz-Experiment—Discrete energy levels of atom

Photoelectric experiment—Particle nature of light

Davisor–Germer experiment—Wave nature of electron.

39. $\frac{1}{2}mv^2 = h\nu - \phi_0$

or, $$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi_0$$

1st Case : $$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi_0 \quad ...(i)$$

2nd Case : $$\frac{3}{2}mv^2 = \frac{hc}{\lambda/2} - \phi_0$$

$$\Rightarrow \quad \frac{3}{2}mv^2 = \frac{2hc}{\lambda} - \phi_0 \quad ...(ii)$$

By solving eqns. (*i*) and (*ii*), we get,

$$\phi_0 = \frac{hc}{2\lambda}.$$

40. From Einstein's photoelectric equation,

$$\frac{1}{2}mv^2 = h\nu - h\nu_0$$

$$\frac{1}{2}mv^2 = h\nu - \phi_0$$

$$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi_0$$

$$E = \frac{hc}{\lambda} - \phi_0 \left(\because \frac{1}{2}mv^2 = E\right)$$

$$\therefore \quad E = \frac{6\cdot6\times10^{-34}\times3\times10^{8}}{500\times10^{-9}\times1\cdot6\times10^{-19}} - 2\cdot28 \text{ eV}$$

$$= \frac{198}{80} - 2\cdot28\ eV$$

$$E = 2\cdot48 - 2\cdot28 = 0\cdot20\ eV$$

∴ de-Broglie wavelength of electron is

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

$$\lambda = \frac{6\cdot6\times10^{-34}}{\sqrt{2\times9\cdot1\times10^{-31}\times0\cdot20}} \approx 28 \text{ A}^\circ$$

So $\lambda \geq 2\cdot8\times10^{-9}$ m.

Hints and Explanations

1. Charge is doubled but mass becomes 4 times.
2. F = eE and $K = W = Fx = eEx$. Note that initially the particle was at rest. Therefore $\vec{x} \parallel \vec{E}$.
3. In the crossed electric field υ = E/B when accelerating potential is made 4 times. υ becomes double. Also, electric field becomes 4 times. Hence $B' = E'/\upsilon' = 4E/2\upsilon$. $2E/\upsilon = 2B$.
4. Here $\frac{m\upsilon^2}{r} = eB\upsilon$

   Hence $r = \frac{\sqrt{2m}\left(\frac{1}{2}m\,\upsilon^2\right)^{1/2}}{eB}$. That is r is greater for proton. K.E. is same for both, hence $r \propto \sqrt{m}$.
5. The path will be parabola given by :
   $$y = \frac{1}{2}\frac{eE}{m\upsilon^2}x^2 = \frac{1}{4}\frac{eE}{(KE)}x^2$$
   Since K.E. is same for both particles, hence both trajectories are equally curved.
6. $\vec{F}_m = q\vec{\upsilon} \times \vec{B}$ and $F_e = q\vec{E}$.
7. Specific charge (α) = $\frac{2e}{4m} = \frac{1}{2} \times$ specific charge (p)
8. $Bq\upsilon = m\upsilon^2/r$. Hence $r = \frac{m\upsilon}{Bq}$
   $$= \frac{1}{Bq} \times \left[\frac{1}{2}m\upsilon^2 \times 2m\right]^{\frac{1}{2}} = \frac{\sqrt{2mK.E.}}{Bq}$$
   Hence $r \propto \sqrt{m}$
9. $h\nu = \omega_0 + e\,V_0$ and $2h\nu = \omega_0 + eV_0'$.

   Hence $V_0' = V_0 + h\nu/e$.
10. $h\nu = h\nu_0 + E_k$. Hence $E_k = h\nu - h\nu_0$. Comparing with $y = mx + c$, we find $m = h$.
11. Emission occurs for $\lambda < \lambda_0$.
12. $\omega_0 = hc/\lambda_0$. Hence $\lambda_0 = hc/\omega_0$.
13. It should be -5V.
14. $\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + E_k$.

    To increase E_k, λ should be decreased.
15. The wavelength of the incident light should be less than 5200 Å.
16. $h\nu = \omega_0 + \frac{1}{2}m\,\upsilon_m^2$. The final velocity with which the electron reaches the collector depends on initial velocity υ_m and the accelerating/retarding potential V.
17. $h\nu = \omega_0 + E$. And $h(2\nu) = \omega_0 + E'$. Solve to find E'.
18. $h\nu = h\nu_0 + eV$. Hence $V = \frac{h}{e}\nu - \frac{h}{e}\nu_0$.

    Comparing with $y = mx + c$, we find $m = h/e$.
19. Kinetic energy in the second case is 4 times of that in the first case.
20. Max. K.E. of the photo electrons = $(1\cdot 8 - 1\cdot 2)$ eV $= 0\cdot 6$ eV.
21. $E = hc/\lambda$
22. $\lambda = h/\sqrt{2\,m \times KE} = h/m\upsilon$
23. $\frac{M\upsilon^2}{r} = q\,\upsilon B$. Therefore $r = M\upsilon/qB$

    $= 9\cdot 1 \times 10^{-31} \times 1\cdot 8 \times 10^7/1\cdot 6 \times 10^{-19} \times 2 \times 10^{-3}$

    $= 0\cdot 051$ m $= 5\cdot 1$ cm.
24. Energy acquired by the proton is same as that acquired by electron. That is :
    $$\frac{1}{2}M_e\upsilon_2^2 = \frac{1}{2}M_p\upsilon_p^2$$
    Therefore, $\frac{p_p^2}{p_e^2} = \frac{M_p^2\upsilon_p^2}{M_e^2\upsilon_e^2} = \frac{M_p}{M_e}$

    And hence $\frac{p_p}{p_e} = \left[\frac{M_p}{M_e}\right]^{\frac{1}{2}} = [1840]^{1/2} \cong 43$.
25. For photon, $p_x = h/\lambda = \frac{h\nu}{c} = \frac{E_x}{c}$

    For electron, $\lambda = \frac{12\cdot 27}{\sqrt{V}} \times 10^{-10}$ m and $p_e = \frac{h}{\lambda}$

    Hence $\frac{p_e}{p_x} = \frac{h\sqrt{V}}{12\cdot 27 \times 10^{-10}} \times \frac{C}{E_x} \cong 3\cdot 2$.
26. $W = mg = 6\pi\eta r\upsilon_1$, $qE = 6\pi\eta r\upsilon_2$.

    Here $\upsilon_1 = \upsilon_2$. Hence $q = W/E$.
27. In case of α-particles : $B\,(2e)\,\upsilon = (2e)\,E$.

    Hence $\upsilon = E/B = 7\cdot 2 \times 10^6/2\cdot 4 = 3 \times 10^6\,ms^{-1}$.
28. $r = \upsilon/(e/m)$

    $B = 2\cdot 55 \times 10^7/(1\cdot 7 \times 10^{11})(1\cdot 5 \times 10^{-2}) = 0\cdot 01$ m.
29. Here qE = mg. Hence $E = (2 \times 10^3/0\cdot 009)$ Vm^{-1}. This gives $q \cong 5e$.
30. $Bq\upsilon = m\upsilon^2/r$. Hence $r = m\upsilon/Bq$.
31. $r = \frac{\sqrt{2m\,KE}}{Bq}$
32. $q = \frac{6\pi\eta r}{E}[\upsilon_0 + \upsilon]$

    Here $\upsilon_0 + \upsilon$ = V, 2V, 3V, 4V, ... nV etc.

or $q = n\left[\frac{6\pi\eta r}{E}V\right]$ where $n = 1, 2, 3$.........

33. $r = \frac{m\upsilon}{eB} = \frac{\sqrt{2m\,(1/2\,m\upsilon^2)}}{eB} = \frac{\sqrt{2mK}}{eB}$ *i.e.*, $r \propto \sqrt{m}$

34. $h\nu_0 = 3 \cdot 3\, eV_0 = 3 \cdot 3 \times 1 \cdot 6 \times 10^{-19}$.

Hence $\nu_0 = 8 \times 10^{14}$ Hz.

35. Photoelectric current is proportional to intensity of light.

36. $\frac{1}{2}m\upsilon_1^2 = 1 - 0 \cdot 5 = 0 \cdot 5$ eV and

$\frac{1}{2}m\upsilon_2^2 = 2 \cdot 5 - 0 \cdot 5 = 2 \cdot 0$

Hence $\upsilon_1/\upsilon_2 = \sqrt{0 \cdot 5/2 \cdot 0} = 1 : 2$.

37. $h\,(5\nu_0) = h\nu_0 + E_k$.

38. $hv = h\nu_0 + \frac{1}{2}m\upsilon^2$.

$\therefore\ \frac{1}{2}mv_1^2 = h\nu_0$ and $\frac{1}{2}m\upsilon_2^2 = 4\,h\nu_0$.

Hence $\upsilon_2 = 2\upsilon_1$.

39. $\frac{hc}{\lambda} = \omega_0 + eV$

Here $\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + e\,(3V_0)$ and $\frac{hc}{2\lambda} = \frac{hc}{\lambda_0} + e\,(V_0)$.

This gives $\lambda_0 = 4\,\lambda$.

40. $\omega = h\nu_0 = 6 \cdot 62 \times 10^{-34} \times 4 \cdot 4 \times 10^{14}$

$= 2 \cdot 648 \times 10^{-19}$ J

$\cong 1 \cdot 66$ eV. Note that *i.e.*, $V = 1 \cdot 6 \times 10^{-19}$ J.

41. Here $\omega_0 = 4 \cdot 2$ eV, $E_k = 2 \cdot 6$ eV.
Hence $E = \omega_0 + E_k = 6 \cdot 8$ eV.

42. $E_k = 6 \cdot 2 - 4 \cdot 2 = 2$ eV

$= 2 \times 1 \cdot 6 \times 10^{-19}$ J $= 3 \cdot 2 \times 10^{-19}$ J.

43. The intersect of the graph with ν-axis gives threshold frequency $\omega = h\nu_0$.

44. $\omega_0 = h\nu_0$. For $\nu = \nu_0$, we have $V_0 = 0$.

45. $hv = h\nu_0 + eV_0$. That is $V_0 = \frac{hv}{e} - \frac{h\nu_0}{e}$.

46. $hv = \omega_0 + E_k$. Therefore $E_k = hv - \omega_0$.
Comparing with $y = mx + c_1$ we find $m = h$.

47. $hv = h\nu_0 + eV_0$. Hence $V_0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$

Compare with $y = mx + c$.

48. B is equilibrium position.