Unit V: Electromagnetic waves **04 Periods**

Chapter–8: Electromagnetic Waves

Basic idea of displacement current, Electromagnetic waves, their characteristics, their Transverse nature (qualitative ideas only).

Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

501. What is meant by displacement current ? **CBSE (AIC)-2010**

[**Ans**. **Displacement current** : A current which comes in to existence due to time varying electric field, is known as displacement current

$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

502. In which situation there is a displacement current but no conduction current ? **CBSE (AI)-2016**

[**Ans**. Between the plates of capacitor during charging/discharging or in the regions of time varying electric field

503. The charging current for a capacitor is 0.25 A. What is the displacement current across its plates ? **CBSE (F)-2016**

[**Ans**. same as the convection current, i,e, I_D = 0.25 A

504. Why is the quantity $\varepsilon_0 \frac{d\phi_E}{dt}$ is called displacement current ? **CBSE (AIC)-2001**

[**Ans**. Because the quantity $\varepsilon_0 \frac{d\phi_E}{dt}$ has the dimensions of current and this current exists in a region between the two plates of a capacitor when displacement of charges occurs there ,i,e, during charging or discharging of capacitor

505. How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery? Write the expression for displacement current in terms of the rate of change of electric flux. **CBSE (D)-2017**

[**Ans**. During charging, electric flux between the plates of capacitor keeps on changing; this results in the production of a displacement current between the plates

$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

506. Why does a galvanometer show a momentary deflection, at the time of charged or discharging a capacitor ? Write the necessary expression to explain this observation. **CBSE (AI)-2017,2016**

[**Ans**. During charging or discharging of the capacitor, displacement current between the plates is set up . Hence circuit becomes complete and galvanometer shows momentary deflection

$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

507. A capacitor has been charged by a d.c. source. What are the magnitudes of conduction and displacement currents, when it is fully charged ? **CBSE (D) -2013**

[**Ans**. when fully charged then both $I = I_D = 0$ and during charging $I = I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

508. What does the displacement current $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$ signify ? **CBSE (D)-2012**

[**Ans**. It signifies that the changing electric field can give rise to a magnetic field

509. When an ideal capacitor is charged by a d.c. battery, no current flows. However, when an a.c. source is used, the current flows continuously. How does one explain this, based on the concept of displacement current ? **CBSE (AI)-2017,(D)-2012**

[**Ans**. In case of d.c. there is no change in electric flux and hence there is no displacement current. Circuit remains incomplete and capacitor does not conduct and no current flows

In case of a.c. source changing voltage causes change in electric flux and so displacement current ($I_D = \varepsilon_0 \frac{d\phi_E}{dt}$) is set up between the plates of capacitor. It completes the circuit and current flows continuously.

510. A capacitor made of two parallel plates each of plate area A and separation d, is being charged by an external a.c. source. Show that the displacement current inside the capacitor is same as the current charging the capacitor.

[**Ans**. Let applied alternating voltage **CBSE (AI)-2013**

$V = V_0 \sin\omega t$

At any instant, the conduction current

$$I = \frac{dq}{dt} = \frac{d}{dt}(CV) = \frac{d}{dt}(CV_0 \sin\omega t) = CV_0 \frac{d}{dt}(\sin\omega t) = \omega CV_0 \cos\omega t = I_0 \cos\omega t$$

Displacement current,

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(E\,A) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0 A}A\right) = \frac{dq}{dt} = I = I_0 \cos\omega t$$

511. Write the expression for the generalized Ampere's circuital law. Through a suitable example, explain the significance of time dependent term. **CBSE (AI)-2015**

[**Ans**. **Generalized Ampere's circuital law** : $\oint \vec{B}.\vec{dl} = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$

Significance : Time dependent term i,e, $\varepsilon_0 \frac{d\phi_E}{dt}$ is the displacement current and it signifies that the changing electric field can give rise to a magnetic field

512. What are electromagnetic waves ? Are these waves transverse or longitudinal ? **CBSE (AIC)-2011,(AI)-2001**

[**Ans.** The waves produced by accelerated charged particles, in which there are sinusoidal variations of electric and magnetic field vectors at right angles to each other as well as at right angles to the direction of propagation of wave, are called electromagnetic waves

em waves are trans verse in nature

513. (i) How are electromagnetic waves produced ? Explain. **CBSE (F)-2017,(AI)-2016,2015**

(ii) What is the source of energy of these waves ?

[**Ans.(i) Production of em waves :** em waves are produced by accelerated/ oscillating charges

A charge oscillating with some frequency, produces an oscillating electric field in space, which produces an oscillating magnetic field perpendicular to the electric field, which in turn is a source of electric field, this process goes on repeating, producing em waves in space perpendicular to both fields.

(ii) Source of energy of em waves is the energy of accelerated/ oscillating charge

514. What oscillates in electromagnetic waves ? **CBSE (DC)-2010**

[**Ans.** Electric and magnetic vectors oscillates in an em wave

515. What is the phase relationship between oscillating electric and magnetic fields in an em wave ? **CBSE (AIC)-2010**

[**Ans.** They are in the same phase

516. What is the frequency of em waves produced by oscillating charge of frequency ? **CBSE (AI)-2015,2010**

[**Ans.** Frequency of em wave = frequency of oscillating charge = $\boldsymbol{\nu}$

517. When can a charge acts as a source of em wave ? **CBSE (D)-2013,2005,(AI)-2012,(AIC)-2004**

[**Ans.** when charge is either accelerated or oscillating

518. Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields.

[**Ans.** Speed of em waves is given by the ratio of the amplitudes of electric and magnetic field vectors. **CBSE (AI)-2017**

$$c = \frac{E_0}{B_0}$$

519. Write the expression for speed of electromagnetic waves in a medium of electrical permittivity ε and magnetic permeability μ.

[**Ans.** $\boldsymbol{c = \frac{1}{\sqrt{\mu\,\varepsilon}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}}}$ **CBSE (F)-2017**

520. What is meant by the transverse nature of electromagnetic waves ? **CBSE (AI)-2016,2015**

[**Ans.** Transverse nature means, $\vec{E}$ & $\vec{B}$ are $\perp$ to each other as well as $\perp$ to the direction of propagation of the wave

530. How are the directions of the electric and magnetic field vectors in an em wave are related to each other and to the direction of propagation of the em waves ? **CBSE (F)-2012**

[**Ans.** $\vec{E}$ & $\vec{B}$ are $\perp$ to each other as well as $\perp$ to the direction of propagation of the wave

531. In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the x-axis ?

[**Ans.** $\vec{E}$ along y-axis and $\vec{B}$ along z-axis **CBSE (AI)-2017**

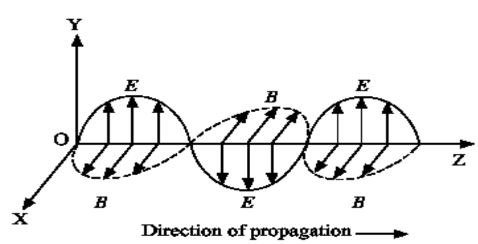
(Alternatively $\vec{E}$ along z-axis and $\vec{B}$ along y-axis

532. Write mathematical expression for electric and magnetic fields of an electromagnetic wave propagating along z-axis.

[**Ans.** $\overrightarrow{E_x} = E_0 \sin\,(Kz - \omega\,t)\,\hat{\imath}$ & $\overrightarrow{B_y} = B_0 \sin\,(Kz - \omega\,t)\,\hat{\jmath}$

533. Draw a sketch of linearly polarized em waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields. **CBSE (AI)-2016,2015,2010,(F)-2014,(D)-2009**

[**Ans.**



534.Write the expression for the energy density of an electromagnetic wave propagating in free space. **CBSE (AI)-2015**

[**Ans.** $u = u_E + u_B = \frac{1}{2}\,\varepsilon_0\,E^2 + \frac{B^2}{2\mu_0}$

535. State any four properties of electromagnetic waves. **CBSE (AI)-2016,2015**

[**Ans**. (i) do not require any material medium for their propagation
(ii) transverse in nature
(iii) do not get deflected by electric or magnetic fields
(iv) same speed in vacuum for all waves

536. Do the electromagnetic waves carry energy and momentum ? **CBSE (AI)-2017**

[**Ans**. **Yes**

537. How can we show that em waves carry momentum ? **CBSE (AI)-2016,2015**

[**Ans**. Electric charges present on a plane, normal to the direction of propagation of an em wave can be set and sustained in motion by the electric and magnetic fields of the electromagnetic wave. The charges thus acquire energy and momentum from the waves.
If the total energy transferred to a surface in time t is U, then the magnitude of the total momentum delivered to this surface (for complete absorption) is, $\mathrm{p} = \frac{\mathrm{U}}{c}$

538. Why is the amount of the momentum transferred by the EM waves incident on the surface so small ?

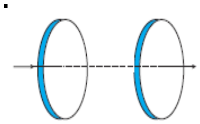
[**Ans**. momentum transferred by the em waves = energy/speed of light= $\mathrm{h}\nu/c = 10^{-22}$ **CBSE (D)-2014,(AI)-2009**
Which is very small

539. An em wave exerts pressure on the surface on which it is incident. Justify. **CBSE (F)-2012**

[**Ans**. em waves carry momentum $(\mathrm{p} = \frac{\mathrm{U}}{c})$ energy $(\mathrm{h}\nu)$ hence they exert a radiation pressure $P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$

540. Figure shows a capacitor made of two circular plates. The capacitor is being charged by an external source. The charging current is constant and equal to 0.15 A. **NCERT-2017**
(a) What is the displacement current across the plates.
(b) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

[**Ans**. (a) displacement current = charging current $= 0.15\ A$



(b) As $(I + I_D)$ is continuous so Kirchhoff's first rule (junction rule) valid at each plate of the capacitor

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541. Which physical quantity, if any, has the same value for the waves belonging to the different parts of the electromagnetic spectrum ? **CBSE (AI)-2012,(AIC)-2004**

[**Ans**. Velocity

542. Name the physical quantity which remains same for microwaves of wavelength 1mm and UV radiations of 1600 A^0 in vacuum.

[**Ans**. Velocity c= 3 X 10^8 m/s **CBSE (D)-2012**

543. What is the ratio of speed of infrared and ultraviolet rays in vacuum ? **CBSE (D)-2001**

[**Ans**. 1:1

544. Give the ratio of velocities of wavelengths 4000 A^0 and 8000 A^0 in vacuum ? **CBSE (AI)-2001**

[**Ans**. 1:1

545. Welders wear special goggles or face masks with glass windows to protect their eyes from electromagnetic radiations. Name the radiations & write the range of their frequency. **CBSE (D)-2014,(AI)-2013,(F)-2010**

[**Ans**. Ultraviolet radiations, from 10^{14} Hz to 10^{16} Hz]

546. Why are microwaves found useful for the radar systems in aircraft navigation ?**CBSE (D) -2016,2004,(F)-2013**

OR

State the reason why microwaves are best suited for long distance transmission of signals ? **CBSE (F)-2008**

[**Ans**. Due to short wavelength, microwaves have high penetrating power with respect to atmosphere and are not diffracted by the obstacle in the path of their propagation

547. Why is the thin ozone layer on the top of stratosphere is crucial for human survival ? Identify to which part of electromagnetic spectrum does this radiation belong and write one important application of the radiation.
CBSE (AI)-2016,2009,(AIC)-2015,(D)-2014

[**Ans**. Because ozone layer absorbs ultraviolet radiation coming from the sun and thus prevent these radiations from reaching the earth which causes Cancer
Identification : Ultraviolet radiations
Application : Water purification/ forensics

548. How are infrared rays produced ? Why are these referred to as " heat waves? Write their three important uses. Name the radiations which are next to these radiations in the electromagnetic spectrum having (a) shorter wavelength (b) longer wavelength. **CBSE (AI)-2016, (D)-2014,2011, (F) -2013,2010**

[**Ans. Production :** Infrared waves are produced by hot bodies due to the vibrations of their atoms/molecules.
Infrared rays are called heat waves because they produce heat when they fall on any object.
Uses : (i) in photography during fog (ii) treating muscular strain (iii) in remote controls of electronic devices
Radiations : (a) Visible light (b) Microwaves

549. What role does infra radiation play in (i) maintain the Earth's warmth, and (ii) Physical therapy ?**CBSE (AI) -2015**

[**Ans.** (i) Infrared radiations are absorbed by the earth's surface and radiated as longer wavelength infrared radiations. These radiations are trapped by green house gases such as CO_2 and maintain the Earth's warmth.

(ii) Infrared radiations are easily absorbed by the water molecules present in the body. After absorption, their thermal motion increases causes heating which is used as physical therapy

550. If the earth did not have atmosphere, would its average surface temperature be higher or lower than what it is now ? Explain.

[**Ans.** lower because of absence of green house gases **CBSE (D)-2014,(AI)-2009**

551. State clearly how a microwave oven works to heat up a food item containing water molecules? **CBSE (F) -2013**

[**Ans.** In a microwave oven, frequency of microwaves matches the resonant frequency of water molecules for heating (about 3 GHz), so that the energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water

552. Which segment of electromagnetic waves has highest frequency ? How are these waves produced ? Give one use of these waves. **CBSE (F)-2016**

[**Ans.** $\gamma - rays$,

Production : these are produced by Radioactive decay of the nucleus,

Use : used in medicine to destroy cancer cells

553. Which em waves lie near the high frequency end of visible part of em spectrum ? Give its one use. In what way This component of light has harmful effects on humans ? **CBSE (F)-2016**

[**Ans.** $Ultra\ violet\ rays$,
used in LASIK eye surgery, UV lamps to kill germs in water (water purification)
UV rays causes Skin Cancer/Sunburn/ harms eyes when exposed to direct UV rays

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554. Which of the following electromagnetic radiations has least frequency : **CBSE (AI)-2015**
UV radiations, X-rays, Microwaves

[**Ans.** Microwaves

555. Which of the following has the shortest wavelength : **CBSE (AI)-2010**
Microwaves, Ultraviolet rays, X-rays [**Ans.** X-rays

556. Arrange the following electromagnetic waves in order of increasing frequency : **CBSE (F)-2014,(D)-2009**
γ –rays, microwaves, infrared rays and Ultraviolet rays

[**Ans.** Microwaves, infrared rays, Ultraviolet rays, γ –rays

557. Arrange the following electromagnetic waves in order of decreasing frequency : **CBSE (F)-2014, (D)-2002**
x-rays, γ –rays, microwaves, UV rays and infrared rays

[**Ans.** γ –rays, x-rays, UV rays, infrared rays and Microwaves

558. Arrange the following em waves in order of their increasing wavelength : **CBSE (AI)-2015,(DC)-2001**
γ –rays, Microwaves, X-rays, U.V. rays and Radio waves

[**Ans.** γ –rays< X-rays ,UV rays < Microwaves < Radio waves

559. Arrange the following electromagnetic waves in decreasing order of wavelength : **CBSE (F)-2014**
γ –rays, infrared rays, x-rays and microwaves

[**Ans.** Microwaves, infrared rays, x-rays and γ –rays

560. Name the following constituent radiations of electromagnetic spectrum which- **CBSE (AI)-2016,2005**
(i) are used in satellite communication/in radar and geostationary satellite **CBSE (D) -2010, 2004**
(ii) are used for studying crystal structure of solids **CBSE (AI)-2007, (F)-2012,2005**
(iii) are similar to the radiations emitted during decay of radioactive nuclei **CBSE (AI)-2005, (AIC)-2005**
(iv) used for water purification/ are absorbed from sunlight by ozone layer **CBSE (AI)-2007, (F)-2005**
[**Ans**. (i) microwaves (ii) x- rays (iii) γ- rays (iv) UV rays
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561. Name the following constituent radiations of electromagnetic spectrum which- **CBSE (AI)-2016,2005**
(i) has its wavelength range between 390 nm to 770 nm **CBSE (AI)-2005, (AIC)-2005**
(ii) produce intense heating effect/ used in warfare to look through fog **CBSE (AI)-2007, (F)-2005**
(iii) are used for radar systems used in aircraft navigation **CBSE (D)-2015,(F)-2012,(AI)-2007**
[**Ans**. (i) visible light (ii) Infrared rays (iii) microwaves
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562. Name the following constituent radiations of electromagnetic spectrum which-
(i) are adjacent to the low frequency end of electromagnetic spectrum **CBSE (F)-2010**
(ii) produced by nuclear reactions/used to destroy cancer cells/treatment of cancer **CBSE (F)-2010**
(iii) produced by bombarding a metal target by high speed electrons. **CBSE (AI)-2016, (F)-2009**
(iv) maintains the earth's warmth/ used in remote sensing **CBSE (F) -2012 ,(AI) -2007**
[**Ans**. (i) microwaves (ii) γ- rays (iii) x- rays (iv) Infrared rays
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563. Which constituent radiations of electromagnetic spectrum is used - **CBSE (F)-2004**
(i) in Radar
(ii) in photographs of internal parts of human body/as a diagnostic tool in medicine **CBSE (D) -2015**
(iii) for taking photographs of sky, during night and fog conditions. **CBSE (D)-2004**
(iv) has the largest penetrating power **CBSE (D) -2010, 2004**
Give reason for your answer in each case.
[**Ans**. (i) microwaves because they go straight and are not absorbed by the atmosphere
(ii) x- rays because they can penetrate light elements (flesh)
(iii) Infrared rays, because they penetrate fog and are not absorbed by the atmosphere
(iv) $\boldsymbol{\gamma} - rays$ as they have the highest frequency and hence highest energy
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564. Electromagnetic waves with wavelengths- **CBSE (Sample Paper)-2009**
(i) λ_1 are used to treat muscular strain **CBSE (D) -2015**
(ii) λ_2 are used by a F.M. radio station for broadcasting
(iii) λ_3 are used to detect fractures in bones **CBSE (D) -2015**
(iv) λ_4 are absorbed by ozone layer of the atmosphere **CBSE (D) -2010, 2004**
Identify the name and part of electromagnetic spectrum to which these radiations belong. Arrange these wavelengths in order of magnitude.
[**Ans**. (i) Infrared rays (ii) radio waves (iii) x- rays (iv) UV rays, $\lambda_2 > \lambda_1 > \lambda_4 > \lambda_3$
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565. Identify the electromagnetic waves whose wavelength vary as and also write one use for each. **CBSE (AI)-2017**
(i) $10^{-12}\, m < \lambda < 10^{-8}\, m$ (ii) $10^{-3}\, m < \lambda < 10^{-1}\, m$
[**Ans**. (i) X-rays/ $\boldsymbol{\gamma} - rays$ used for medical purposes/ nuclear reactions (ii) Microwaves used for radar systems

566. Identify the electromagnetic waves whose wavelength vary as and also write one use for each. **CBSE (AI)-2017**
(i) $10^{-11}\, m < \lambda < 10^{-14}\, m$ (ii) $10^{-4}\, m < \lambda < 10^{-6}\, m$
[**Ans**. (i) X-rays/ $\boldsymbol{\gamma} - rays$ used for medical purposes/ nuclear reactions
(ii) Infrared/ visible used for muscular treatment/ vision

567. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$ **CBSE (D) -2016**

where ϕ_E is the electric flux produced during charging of the capacitor plates.

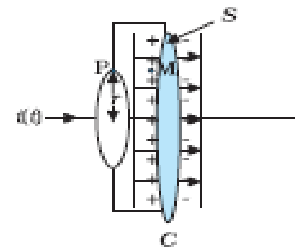
[**Ans**. Electric field between the plates of capacitor, $E = \frac{q}{\varepsilon_{0A}}$

⇨ electric flux, $\phi_E = E\,A = \frac{q}{\varepsilon_{0A}}\,A = \frac{q}{\varepsilon_0}$

⇨ $\frac{d\phi_E}{dt} = \frac{d}{dt}\left(\frac{q}{\varepsilon_0}\right) = \frac{1}{\varepsilon_0}\left(\frac{dq}{dt}\right)$

⇨ $\frac{dq}{dt} = \varepsilon_0 \frac{d\phi_E}{dt}$

⇨ $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$



568. Show that in the process of charging a capacitor, displacement current is always equal to conduction current.

[**Ans**. Displacement current between the plates of capacitor, during charging **CBSE (AIC) -2010**

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}(E\,A) = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_{0A}}A\right) = \frac{dq}{dt} = I$$

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569. Why does a galvanometer when connected in series with a capacitor show a momentary deflection, when it is Being charged or discharged ? How does this information lead to modify the Ampere's circuital law ? Hence write the generalized expression of Ampere's circuital law. **CBSE (F)-2015,(AI)-2014,2011**

[**Ans**. During charging or discharging of the capacitor, displacement current between the plates is set up . Hence circuit becomes complete and galvanometer shows momentary deflection

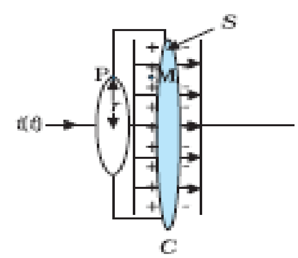
By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0 I$

Applying it to surface P, $\oint \vec{B}.\vec{dl} = \mu_0 I$

Applying it to surface S, $\oint \vec{B}.\vec{dl} = 0$

$\therefore \oint_p \vec{B}.\vec{dl} \neq \oint_s \vec{B}.\vec{dl}$.



This is in contradiction to Ampere's circuital law. Hence it needs modification.

In fact, during charging/ discharging of capacitor electric flux between the plates changes which produces current known as displacement current. Hence, there is a need to include displacement current.

Therefore, modified Ampere's circuital law is

$\oint \vec{B}.\vec{dl} = \mu_0 (I + I_D) = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$ Now for surface P, $\oint \vec{B}.\vec{dl} = (\mu_0 I + 0) = \mu_0 I$

For surface S, $\oint \vec{B}.\vec{dl} = (0 + I_D) = \mu_0 I_D = \mu_0 I$

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570. Write the generalized expression for Ampere's circuital law in terms of the conduction current and displacement current. Mention the situation when there is : **CBSE (F) -2013**

(i) only conduction current and no displacement current

(ii) only displacement current and no conduction current

[**Ans**. **Generalized Ampere's circuital law** : $\oint \vec{B}.\vec{dl} = \mu_0 (I + \varepsilon_0 \frac{d\phi_E}{dt})$

(i) In case of a steady current in conducting wire, electric field does not change with time, conduction current exists but displacement current is zero.

⇨ $\oint \vec{B}.\vec{dl} = \mu_0 I$

(ii) During charging of a capacitor displacement current flows in the space between the plates of capacitor but conduction current is zero.

⇨ $\oint \vec{B}.\vec{dl} = \mu_0\, \varepsilon_0 \frac{d\phi_E}{dt} = \mu_0 I_D = \mu_0 I$

571. A plane electromagnetic wave of frequency 25 MHz travels in free space along the *x*-direction. At a particular point in space and time, $\vec{E}$ = 6.3 $\hat{j}$ V/m. What is $\vec{B}$ at this point ? **NCERT- 2017**

[**Ans.** $\frac{E}{B} = c$ ⇨ $B = \frac{E}{c} = \frac{6.3}{3 X 10^8} = 2.1 \text{ X } 10^{-8}\ \hat{\boldsymbol{k}}$ Tesla]

572. In an electromagnetic wave the oscillating electric field having a frequency of 3 X 10^{10} H_Z and an amplitude of 30 V/m propagates in the positive x-direction. **CBSE (F)-2008**

(i) what is the wavelength of electromagnetic wave ?

(ii) write down the expression to represent the corresponding magnetic field.

[**Ans. (i)** $\lambda = \frac{c}{f} = \frac{3 X 10^8}{3 X 10^{10}} = 10^{-2}\ m$ **(ii)** $B_0 = \frac{E_0}{c} = \frac{30}{3 X 10^8} = 10^{-7}\ T$

$\omega = 2\pi f = 2\pi X 3 X 10^{10} = 6\pi X 10^{10}$ rad/s & $K = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 2\pi \text{ X } 10^2\ m^{-1}$

⇨ $B = B_0 \sin(\omega t - Kx) = 10^{-7} \sin(6\pi X 10^{10}\ t - 2\pi \text{ X } 10^2\ x)$]

573. In an electromagnetic wave propagating along x- direction, the magnetic field oscillates at a frequency of 3 X10^{10} H_Z and has an amplitude of 10^{-7} Tesla acting along the y-direction. **CBSE (F)-2008**

(i) what is the wavelength of electromagnetic wave ?

(ii) write the expression representing the corresponding oscillating electric field.

[**Ans. (i)** $\lambda = \frac{c}{f} = \frac{3 X 10^8}{3 X 10^{10}} = 10^{-2}\ m$ (ii) $\frac{E_0}{B_0} = c$ ⇨ $E_0 = B_0\ c = 10^{-7} \text{ X } 3 X 10^8 = 30\ V/m$

$\omega = 2\pi f = 2\pi X 3 X 10^{10} = 6\pi X 10^{10}$ rad/s & $K = \frac{2\pi}{\lambda} = \frac{2\pi}{10^{-2}} = 2\pi \text{ X } 10^2\ m^{-1}$

⇨ $E = E_0 \sin(\omega t - Kx)\ \hat{\boldsymbol{k}} = 30 \sin(6\pi\ X\ 10^{10}\ t - 2\pi \text{ X } 10^2\ x)\ \hat{\boldsymbol{k}}\ \ V/m$]

574. The oscillating magnetic field in a plane electromagnetic wave is given by **CBSE (D)-2008**

B_y = 8 X 10^{-6} sin (2 x 10^{11} t + 300 πx)] T

(i) calculate the wavelength of electromagnetic wave ?

(ii) write down the expression for the oscillating electric field.

[**Ans.** B_y = 8 X 10^{-6} sin (2 x 10^{11} t + 300 πx)] T Comparing with $B_y = B_0 \sin(\omega t + Kx)$

$B_0 = 8 X 10^{-6}$ T, ω = 2 x 10^{11} rad/s and $K = 300\,\pi$

(i) $K = \frac{2\pi}{\lambda}$ ⇨ $\frac{2\pi}{\lambda} = 300\,\pi$ ⇨ $\lambda = \frac{1}{150}\ m = \frac{100}{150}\ cm = \frac{2}{3}\ cm$

(ii) $\frac{E_0}{B_0} = c$ ⇨ $E_0 = B_0\ c = 8 X 10^{-6} \text{ X } 3 X 10^8 = 2400\ V/m$

⇨ $E_z = E_0 \sin(\omega t + Kx)\ \hat{\boldsymbol{k}} = 2400 \sin(2 X 10^{11}\ t + 300\,\pi\,x)\ \hat{\boldsymbol{k}}\ \ V/m$]

575. The oscillating electric field of an electromagnetic wave is given by **CBSE (D)-2008**

E_y = 30 sin(2 x 10^{11} t + 300πx)] V/m

(i) obtain the value of the wavelength of electromagnetic wave ?

(ii) write down the expression for the oscillating magnetic field.

[**Ans.** E_Y = 30 sin(2 x 10^{11} t + 300πx)] Comparing with $E_y = E_0 \sin(\omega t + Kx)$

E_0 = 30 V/m, ω = 2 x 10^{11} rad/s and $K = 300\,\pi$

(i) $K = \frac{2\pi}{\lambda}$ ⇨ $\frac{2\pi}{\lambda} = 300\,\pi$ ⇨ $\lambda = \frac{1}{150}\ m = \frac{100}{150}\ cm = \frac{2}{3}\ cm$

(ii) $\frac{E_0}{B_0} = c$ ⇨ $B_0 = \frac{E_0}{c} = \frac{30}{3 X 10^8} = 10^{-7}\ T$

⇨ $B_z = B_0 \sin(\omega t + Kx)\ \hat{\boldsymbol{k}} = 10^{-7} \sin(2 X 10^{11}\ t + 300\,\pi\,x)\ \hat{\boldsymbol{k}}\ \ T$]

576. In a plane em wave, the electric field oscillates sinusoidally at a frequency of 2.0 X 10^{10} H_Z and amplitude 48 V/m.

(i) what is the wavelength of the wave ? **NCERT- 2017,CBSE (AI)-2001,(AIC)-2002**

(ii) what is the amplitude of oscillating magnetic field ?

(iii) show that the average energy density of the $\vec{E}$ field equals the average energy density of the $\vec{B}$ field.

[**Ans.** (i) $\lambda = \frac{c}{f} = \frac{3 X 10^8}{2 X 10^{10}} = 1.5 X 10^{-2}\ m$ (ii) $\frac{E_0}{B_0} = c$ ⇨ $B_0 = \frac{E_0}{c} = \frac{48}{3 X 10^8} = 1.6 X 10^{-7}\ T$

(iii) $u_E = \frac{1}{2}\varepsilon_0\ E^2 = \frac{1}{2}\varepsilon_0\ (Bc)^2 = \frac{1}{2}\varepsilon_0\ B^2 (\frac{1}{\sqrt{\mu_0 \varepsilon_0}})^2 = \frac{B^2}{2\mu_0} = u_B$]

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Unit VI: Optics **27 Periods**

Chapter–9: Ray Optics and Optical Instruments

Ray Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and its applications, optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lensmaker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism.

Scattering of light - blue colour of sky and reddish appearance of the sun at sunrise and sunset.

Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

601. When a wave is propagating from a rarer to a denser medium, which characteristic of the wave does not change and why ?
[**Ans.** frequency, as frequency is a characteristic of the source of waves **CBSE (AI)-2015**

OR

When monochromatic light travels from one medium to another, its wavelength changes but its frequency remains same. Why ?
[**Ans.** frequency is a characteristic of the source of waves. That is why it remains the same. **CBSE (AI)-2011**
But wavelength is characteristic of medium. So wavelength and velocity both change.

602. When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency. Why ? **CBSE (AI)-2016,2010,(D)-2011**
[**Ans.** Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of incident light. Hence frequency remains unchanged.

603. When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave ? **CBSE (AI)-2016,2010**
[**Ans.** **No.** Energy carried out by a wave depends on the amplitude of the wave, not on the speed of wave propagation.

604. In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determine the intensity in the photon picture of light ? **CBSE (AI)-2016**
[**Ans.** In photon picture, intensity is determined by the number of photons incident normally on a unit area per unit time

605. When light comes from air to glass, the refracted ray is bent towards the normal. Why ? **CBSE (DC)-2004**
[**Ans.** $\mu = \frac{\sin i}{\sin r} = \frac{3}{2}$
⇨ $\sin r = \frac{2}{3}\sin i$ ⇨ $\sin r < \sin i$ ⇨ $r < i$ hence, refracted ray is bent towards the normal

606. For the same angle of incidence, the angle of refraction in to two media A and B are 25^0 and 35^0respectively. In which medium is the speed of light less ? **CBSE (AI)-2015,2012**
[**Ans. In medium A speed of light is less**
Reason : $\mu = \frac{\sin i}{\sin r} = \frac{c}{v}$ ⇨ $v = \frac{c\ X\ \sin r}{\sin i}$ ⇨ $v \propto \sin r$ [∵ angle of incidence is same
But $r_A < r_B$ ⇨ $v_A < v_B$

607. Define refractive index of a transparent medium. What is the minimum and maximum value of refractive index ?
[**Ans. Refractive index** : **CBSE (AIC)-2017,(AI)-2009**
Refractive index of a medium is defined as the ratio of velocity of light in vacuum to the velocity of light in that medium
i,e, $\mu = \frac{c}{v}$ Minimum value of refractive index is 1 for air and maximum is 2.42 for diamond

608. What is the ratio of the velocity of the wave in the two media of refractive indices μ_1 and μ_2 **CBSE (AI)-2015**
[**Ans.** $\frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$

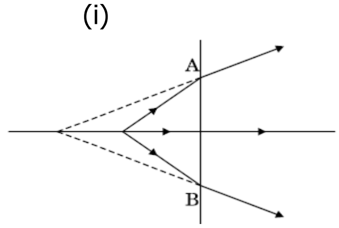
609. How does the refractive index of a transparent medium depend on wavelength of light used ? **CBSE (F)-2015**
[**Ans.** $\mu = a + \frac{b}{\lambda^2}$

610. When a glass slab is placed on an ink dot, ink dot appears to be raised. Why ? **BSE (AIC)-2010**
[**Ans.** due to refraction of light

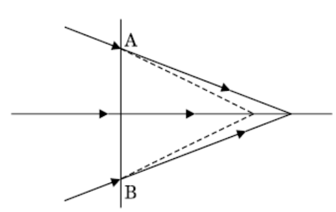
611. By how much would an ink dot appear to be raised, when covered by a glass plate of thickness $6.0\ cm$. Refractive index of glass is 1.5. **CBSE (AIC)-2010**
[**Ans.** $\Delta y = t\left(1 - \frac{1}{\mu}\right) = 6\left(1 - \frac{1}{1.5}\right) = 6\left(\frac{0.5}{1.5}\right) = 2.0\ cm$

612. The line AB in the ray diagram represents a lens. State whether the lens is convex or concave ? **CBSE (AI)-2015**

(i)



(ii)



[**Ans. (i) Convex lens,** **Reason** : refracted ray is bending towards the principal axis

613. What is total internal reflection of light ? **CBSE (AI)-2016,2001**

[**Ans. Total internal reflection** : When a ray of light travelling from denser to a rarer medium is incident on the interface at an angle greater than the critical angle, it is totally reflected back in to the denser medium. This phenomenon is called total internal reflection of light.

614. State the conditions for the phenomenon of total internal reflection to occur. **BSE (AI)-2016,(D)-2010**

[**Ans. Conditions for TIR** :

(i) light ray must travel from denser to a rarer medium

(ii) angle of incidence must be greater than the critical angle ($i > i_c$)

615. Name one phenomenon which is based on total internal reflection. **CBSE (AI)-2016**

[**Ans**. Mirage/ sparkling of diamond/ optical fibre/ totally reflecting prisms

616. Can total internal reflection occur when light goes from rarer to a denser medium ? **CBSE (D)-2007**

[**Ans. No**

617. Define critical angle.What is the relationbetween refractive index & critical angle for a given pair of optical media ?

[**Ans. Critical angle** : The angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90^0 is called critical angle. **CBSE (AI)-2009**

Relation : $\mu = \frac{1}{\sin i_c}$

618. When light travels from an optically denser medium to a rarer medium, why does the critical angle of incidence depend on the colour/wavelength of light ? **CBSE (AI)-2015,2009**

[**Ans.** $\mu = \frac{1}{\sin i_c}$ ⇨ $i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$

As $\mu = a + \frac{b}{\lambda^2}$. Hence critical angle would also be different for different colours/wavelengths of light

619. What is the critical angle for a material of refractive index $\sqrt{2}$? **CBSE (AI)-2010**

[**Ans.** $\sin i_c = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$ ⇨ $i_c = 45^0$ 620. Velocity of light in glass is $2 \text{ X } 10^8\ m/s$ and in air is $3 \text{ X } 10^8\ m/s$.

If the ray of light passes from glass to air, calculate the value of critical angle. **CBSE (F)-2015**

[**Ans.** $\mu = \frac{c}{v} = \frac{3\,X10^8}{2\,X10^8} = 1.5$

$\mu = \frac{1}{\sin i_c}$ ⇨ $i_c = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1}\left(\frac{1}{1.5}\right) == \sin^{-1}\left(\frac{2}{3}\right) = 41.8^0$

621 Calculate the speed of light in a medium whose critical angle is 30^0. **CBSE (AI)-2012,2010**

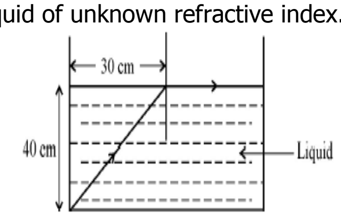
[**Ans.** $\mu = \frac{1}{\sin i_c} = \frac{1}{\sin 30} = \frac{1}{1/2} = 2$ Now, $\mu = \frac{c}{v}$ ⇨ $v = \frac{c}{\mu} = \frac{3\,X10^8}{2} = 1.5\,X10^8\ m/s$

622. In the following ray diagram, calculate the speed of light in the liquid of unknown refractive index. **CBSE (AIC)-2017**

[**Ans.** $\mu = \frac{c}{v} = \frac{1}{\sin i_c}$

⇨ $\frac{3 \text{ X } 10^8}{v} = \frac{1}{30/50}$

⇨ $v = \frac{30}{50} \text{ X } 3\,X10^8 = 1.8 \text{ X} 10^8\ m/s$

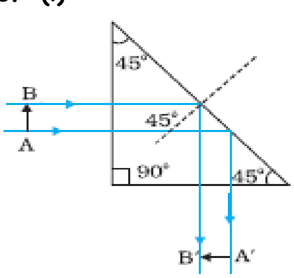


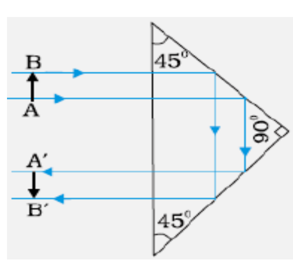
623. Draw a ray diagram to show how a right angled isosceles prism can be used to- **CBSE (AI)-2015,(DC)-2001**

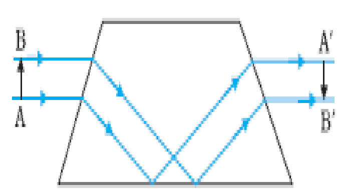
(i) deviate a light ray through (i) 90^0, (ii) deviate a light ray through 180^0/ to obtain the inverted image

(iii) to invert an image without the deviation of the rays ?

[**Ans. (i)** **(ii)** **(iii)**







624. Why does a diamond sparkle ? **CBSE (D)-2009,2002**

[Ans. The brilliance of diamond is due to total internal reflection of light

Refractive index of diamond is very large (2.42) so its critical angle is small (24.4^0). The faces of diamond are cut in such a manner that light entering diamond from any face suffers multiple total internal reflections and remains within the diamond but it comes out through only a few faces. Hence the diamond sparkles.

625. Find the relation between critical angle and refractive index. **CBSE (AI)-2016**

[Ans. By Snell's law, $\frac{\sin i}{\sin r} = \frac{1}{\mu}$

But when $i = i_c$, $r = 90^0$

⇨ $\frac{\sin i_c}{\sin 90} = \frac{1}{\mu}$ ⇨ $\mu = \frac{1}{\sin i_c}$

626. What is an optical fibre ? Name the phenomenon on which working of an optical fibre is based. Give any two uses of optical fibres. **CBSE (AI)-2016,(D)-2011**

[Ans. Optical fibre : An optical fibre is a fine strand of quality glass/quartz surrounded by a glass coating of slightly lower refractive index called cladding.

Phenomenon : Total internal reflection of light

Uses : (a) in transmission of optical signals

(b) as light pipe in medical examination of stomach etc.

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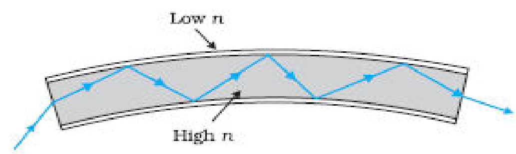
627. Draw a labelled diagram of an optical fibre. Explain how light propagates through the optical fiber.

[Ans. Phenomenon : Total internal reflection **CBSE (AI)-2016,(D)-2011**

Working :

When a signal in the form of light enters at one end of the fibre at suitable angle, it undergoes repeated total internal reflections and finally comes out at the other end.



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628 What is scattering light ? What is the condition for Rayleigh scattering to occur ? **CBSE (AIC)-2010**

[Ans. Scattering of light : This is the phenomenon in which light is deflected from its path due to its interaction with the particles of the medium through which it passes.

Condition : size of scatterer $a \ll \lambda$

629. Why cannot we see clearly through fog ? Name the phenomenon responsible for it. **CBSE (AI)-2016**

[Ans. Some light gets deviated/ scattered/ absorbed

Phenomenon- Scattering of light

630. Why does bluish colour predominate in the sky ? **CBSE (AI)-2015,2008,(D)-2010**

[Ans. due to most scattering of blue light

as blue light has the smallest wavelength and as per Rayleigh's law of scattering, intensity of scattered light $I \propto \frac{1}{\lambda^4}$

631. Why does Sun appears red at sunrise and sunset ? **CBSE (AI)-2016,(F)-2015**

[Ans. due to least scattering of red light

as red light has the longest wavelength and as per Rayleigh's law of scattering, intensity of scattered light $I \propto \frac{1}{\lambda^4}$

632. Clouds appear white. Why ? **CBSE (AIC)-2010**

[Ans. due to equal scattering of all colours of light

Large particles such as dust, raindrops, ice particle do not scatter light in accordance with Raleigh's law but scatters light of all colours almost equally

633 Give reasons for the following observations on the surface of the moon : **CBSE (AI)-2000**

(a) Sunrise and sunset are abrupt. (b) Sky appears dark (c) a rainbow is never formed.

[Ans. (a) Moon has no atmosphere. There is no scattering of light. Sunlight reaches the moon straight covering the short distance. Hence sunrise and sunset are abrupt.

(b) Moon has no atmosphere. There is nothing to scatter sunlight towards the moon. No skylight reaches moon surface. Hence sky appears black in the day time as it does at night.

(c) No water vapours are present at moon surface. No clouds are formed. There are no rains on the moon, so rainbow is never formed

634 Why is aperture of objective lens of a telescope is taken large ? **CBSE (AI)-2013**

[**Ans**. to increase the light gathering capacity and hence brightness of the image

635. State two main considerations taken into account while choosing the objective in optical telescopes with large diameters.

[**Ans**. (i) better light gathering power **CBSE (AI)-2015**

(ii) high resolving power

636. The objective of a telescope is of larger focal length and of larger aperture (as compared to eye piece). Why ?

[**Ans**. **(i)** Objective of larger focal length increases magnification ($m = -\frac{f_o}{f_e}$) **CBSE (AIC)-2013**

(ii) Objective of larger aperture has large light gathering capacity and hence increases the brightness of image/ have a high resolving power

637. Why is eye piece of a telescope is of short focal length, while objective of large focal length ? Explain.

[**Ans**. $m = -\frac{f_o}{f_e}$ **CBSE (F)-2013**

⇨ for large angular magnification, $f_o \gg f_e$

Hence, focal length of objective should be large, while focal length of eye piece should be small

638. State the condition under which a large magnification can be achieved in an astronomical telescope. **CBSE (F)-2017**

[**Ans**. $m = -\frac{f_o}{f_e}$

(i) By increasing f_o /decreasing f_e or $f_o \gg f_e$

(ii) Distance between two lenses $L > f_0 + f_e$

639. You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct an astronomical telescope ? Give reason. **CBSE (AI)-2017,(D)-2009**

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

[**Ans**. **Objective lens** : Lens L_1

& **Eye piece** : Lens L_3

Reason : $m = -\frac{f_o}{f_e}$

⇨ for higher magnification & brighter image, objective should have large aperture and large focal length & eye piece should have small aperture and small focal length

640. You are given three lenses of power $0.5\ D, 4\ D$ and $10\ D$ to design a telescope. Which lenses should you use as an objective and eyepiece of an astronomical telescope ? Justify your answer. **CBSE (AI)-2016**

[**Ans**. **Objective lens** : $0.5\ D$

& **Eye piece** : $10\ D$

Justification : $m = -\frac{f_o}{f_e}$

⇨ for higher magnification, objective should have large focal length & eye piece should have small focal length

641. Write two main limitations of refracting telescopes. Explain how these can be minimized in a reflecting telescope.

[**Ans**. **Limitations of refracting telescope**: **CBSE (F)-2016,2015,(AI)-2013**

(i) Suffers from spherical aberration . It can be corrected by using parabolic mirror objective

(ii) Suffers from chromatic aberration. It can be corrected by using mirror objective instead of spherical lens

(iii) Image is less bright/ small magnifying power/small resolving power

In reflecting telescope image is bright due to reflection and has high resolving power due to large aperture

642. Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope. **CBSE (F)-2017**

OR

State the advantages of reflecting telescope over refracting telescope. **CBSE (AI)-2016,2015,(D)-2016,2009**

[**Ans**. (i) No chromatic/spherical aberration as mirror is used as objective in reflecting telescope

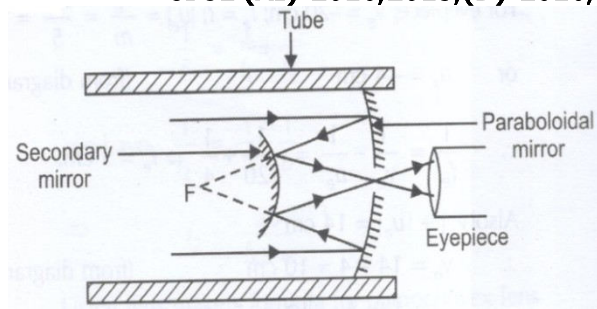
(ii) Brighter image/ high resolving power as mirror of large aperture is used as objective in reflecting telescope

643. (i) Draw a schematic diagram of a reflecting telescope. State the advantages of reflecting telescope over refracting telescope.
(ii) What is its magnifying power ? **CBSE (AI)-2016,2015,(D)-2016,2009**

[Ans. Advantages of reflecting telescope

(i) No chromatic aberration
(ii) No spherical aberration
(iii) Brighter image
(iv) large magnifying power
(v) High resolving power

$m = \frac{angle\ subtended\ at\ the\ eye\ by\ image}{angle\ subtended\ at\ the\ eye\ by\ object} = \frac{f_o}{f_e}$



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644. Does the magnifying power of a microscope depend on the colour of the light used ? Justify your answer.
[Ans. Yes Justification : $m \propto \frac{1}{f_o f_e}$ & focal length depends on colour/μ **CBSE (F)-2017**

645. Explain, why must both the objective and the eye piece of a compound microscope have short focal lengths ?
[Ans. $m = \frac{L}{f_o}$ X $\frac{D}{f_e}$ **CBSE (D)-2017,(D)-2009**
⇨ to increase magnifying power both the objective and the eye piece must have short focal lengths

646. Explain, why is the objective of a compound microscope be of short aperture ? **CBSE (AIC)-2014**
[Ans. to minimize spherical aberration and to collect all the reflected light from object to produce brighter image

647. Explain, While viewing through a compound microscope, why should our eyes be positioned not on the eye piece but a short distance away from it for best viewing ? **NCERT-2017**
[Ans. To collect complete light refracted by the objective and to increase field of view

648. You are given the following three lenses. Which two lenses will you use as an eyepiece and as an objective to construct a compound microscope ? Give reason. **CBSE (AI)-2017**

Lenses	Power (D)	Aperture (cm)
L_1	3	8
L_2	6	1
L_3	10	1

[Ans. Objective lens : Lens L_3 **Eye piece** : Lens L_2
Reason : Objective of a microscope should have small aperture and smallest focal length eye piece of a microscope should have small aperture and small focal length (but longer focal length than aperture)

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649. What is dispersion of light ? What is its cause ? **CBSE (D)-2016**
[Ans. Dispersion of light : When a ray of white light is incident on a glass prism, it splits into its seven constituent Colours. This phenomenon is called dispersion of light.
Cause of dispersion : Refractive index of material of prism is different for different colours of light. Hence from $\delta = (\mu - 1)A$, different colour will deviate through different angles

650. How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light ? Give reason.
[Ans. Decreases, Reason : $\delta = (\mu - 1)A$ & $\mu_{red} < \mu_{Violet}$ or $\lambda_{red} > \lambda_{Violet}$ **CBSE (AI)-2017**

651. Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism. Give reason
[Ans. $\delta = (\mu - 1)A$ & $\mu_{Violet} > \mu_{red}$ ⇨ $\delta_{Violet} > \delta_{red}$ **CBSE (D)-2010**
Hence, Violet colour is seen at the bottom of the spectrum when white light is dispersed by a prism

652. Out of blue and red light which is more deviate by prism ? Give reason. **CBSE (D)-2010**
[Ans. $\delta = (\mu - 1)A$ & $\mu_{blue} > \mu_{red}$ ⇨ $\delta_{blue} > \delta_{red}$ Hence, blue light deviates more than red light by a prism

653. For which colour the refractive index of prism material is maximum and minimum ? **CBSE (D)-2010**
[Ans. $\mu = a + \frac{b}{\lambda^2}$ & $\lambda_{Violet} < \lambda_{red}$ ⇨ $\mu_{Violet} > \mu_{red}$
Hence, refractive index of prism material is maximum for violet and minimum for red colour

654. How is the focal length of a spherical mirror affected, when the wavelength of light used is increased ?
[Ans. No change as focal length of a spherical mirror does not depend on wavelength **CBSE (AI)-2000**

655. How is the focal length of a spherical mirror is affected, when it is immersed in water/Glycerin ? **CBSE (F)-2010**
[Ans. No change as focal length of a spherical mirror does not depend on medium

657. How is the focal length of a spherical lens affected, when the wavelength of light used is increased ?
[Ans. Focal length of the lens increases **CBSE (AI)-2016,(F)-2010**
Reason : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$

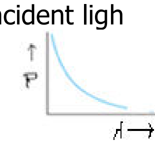
658. How does focal length of a convex lens change, if violet light is used instead of red light ?
[Ans. Focal length of the lens decreases **CBSE (F)-2012,(AI)-2010**
Reason : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$
As $\lambda_{Violet} < \lambda_{red}$ ⇨ $\mu_{Violet} > \mu_{red}$ ⇨ $f_{Violet} < f_{red}$

659. Explain with reason, how the power of a diverging lens changes when incident red light is replaced by violet light.
[Ans. Power of the lens will increases **CBSE (AIC)-2017**
Reason : $P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$
As $\lambda_{Violet} < \lambda_{red}$ ⇨ $\mu_{Violet} > \mu_{red}$ ⇨ $P_{Violet} > P_{red}$

660. What happens to the focal length of a convex lens when it is immersed in water ? Refractive index of the material of lens is greater than that of water . **CBSE (AI)-2016**
[Ans. Focal length will increase hence power will decrease
$P = \frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ As μ_1 increases f increases ($\mu_1\ for\ water > \mu_1\ for\ air$)

661. A lens of glass is immersed in water. What will be its effect on the power of lens ? **CBSE (AI)-2003**
[Ans. Power of the lens will decrease
$P = \frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ As μ_1 increases P decreases ($\mu_1\ for\ water > \mu_1\ for\ air$)

662. Draw a plot showing the variation of power of a lens with the wavelength of incident ligh **CBSE (D)-2008**
[Ans. Power of the lens decreases with increase in wavelength
Reason : $P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ & $\mu = a + \frac{b}{\lambda^2}$



663. A glass lens of refractive index 1.45 disappears when immersed in a liquid. What is the value of refractive index of the liquid ? **CBSE (D)-2010**
[Ans. The refractive index of the liquid should be equal to that of the lens, i,e, 1.45

664. What should be the value of the refractive index of the medium in which the lens should be placed so that it acts as a plane sheet of glass ? **CBSE (AI)-2015**

OR

Under what condition does a biconvex lens of glass having a certain refractive index acts as a plane glass sheet when immersed in a liquid ? **CBSE (D)-2012**
[Ans. The refractive index of the medium/liquid should be equal to that of the lens

665. Explain with reason, how the power of a diverging lens changes when it is kept in a medium of refractive index greater than that of the lens. **CBSE (AIC)-2017**
[Ans. Power will become positive, i,e, lens will behave as Converging lens.
Reason : $P = \frac{1}{f_m} = -\left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m > \mu_g$ ⇨ $P = \frac{1}{f_m} =$ +ve

666. A biconcave lens made of transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave a converging or diverging lens ? Give reason. **CBSE (D)-2015,(AI)-2014**
[Ans. Converging lens.
Reason : $\frac{1}{f_m} = -\left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$
As $\mu_m > \mu_g$ ⇨ $\frac{1}{f_m} =$ +ve ⇨ $f_m > 0$

667. A biconvex lens made of transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave a converging or diverging lens ? Give reason. **CBSE (AI)-2014**

[Ans. Diverging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m > \mu_g$ ⇨ $\frac{1}{f_m} = -\text{ve}$ ⇨ $f_m < 0$

668. A biconvex lens made of transparent material of refractive index 1.5 is immersed in water of refractive index 1.33. Will the lens behave a converging or diverging lens ? Give reason. **CBSE (AI)-2014**

[Ans. Converging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m < \mu_g$ ⇨ $\frac{1}{f_m} = +\text{ve}$ ⇨ $f_m > 0$

669. A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in **CBSE (AI)-2011**

(i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33

Will the lens behave a converging or diverging lens in the two cases ? Give reason.

[Ans. (i) Diverging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m > \mu_g$ ⇨ $\frac{1}{f_m} = -\text{ve}$ ⇨ $f_m < 0$

(ii) Converging lens.

Reason : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ As $\mu_m < \mu_g$ ⇨ $\frac{1}{f_m} = +\text{ve}$ ⇨ $f_m > 0$

670. A converging lens is kept coaxially in contact with a diverging lens, both the lenses being of equal focal length. What is the focal length of the combination ? **CBSE (AI)-2016,2010**

[Ans. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f} + \frac{1}{-f} = 0$

⇨ $F = \infty$ hence the combination will act as a plan e glass plate

671. Two thin lenses of power $+6\,D$ and $-2\,D$ are in contact. What is the focal length of this combination ?

[Ans. $P = P_1 + P_2 = +6 - 2 = +4\,D$ **CBSE (D)-2009**

⇨ $F = \frac{1}{P} = \frac{1}{4} = 0.25\ m = 25\ cm$

672. A convex lens of focal length $25\ cm$ is placed coaxially in contact with a concave lens of focal length $20\,cm$. Determine the power of the combination will the system be converging or diverging in nature ? **CBSE (AI)-2013**

[Ans. $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{25} + \frac{1}{-20} = \frac{4-5}{100} = -\frac{1}{100}$ ⇨ $F = -100\ cm = -1\ m$

⇨ $P = \frac{1}{F} = \frac{1}{-1} = -1$ hence the combination will be diverging in nature

673. The focal length of a convex lens made of glass($\mu = 1.5$) is 22 cm. What will be its new focal length when placed in a medium of refractive index 4/3 ? **CBSE (F)-2017,2016,(AI)-2015**

[Ans. $f_{medium} = \frac{({}_a\mu_g - 1)}{\left(\frac{{}_a\mu_g}{{}_a\mu_w} - 1\right)} \times f_{air} = \frac{(3/2-1)}{\left(\frac{3/2}{4/3} - 1\right)} \times 22 = 4 \times 22 = 88\ cm$

674. A double convex lens is made of a glass of refractive index 1.55, with both faces of the same radius of curvature. Find the radius of curvature required, if the focal length is 20 cm. **CBSE (AI)-2017,NCERT-2017**

[Ans. For biconvex lens, $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

⇨ $\frac{1}{20} = (1.55 - 1)\left(\frac{1}{R} + \frac{1}{R}\right)$ ⇨ $\frac{1}{20} = (0.55)\left(\frac{2}{R}\right)$ ⇨ $R = 2 \times 0.55 \times 20 = 22\ cm$

675. The focal length of an equiconvex lens is equal to the radius of curvature of either face. What is the refractive index of the material of the lens ? **CBSE (AI)-2015**

[Ans. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right) = (\mu - 1)\left(\frac{2}{R}\right)$

But $f = R_1 = R_2 = R$ ⇨ $\frac{1}{R} = (\mu - 1)\left(\frac{2}{R}\right)$ ⇨ $\frac{1}{2} = (\mu - 1)$ ⇨ $\mu = \frac{1}{2} + 1 = \frac{3}{2}$

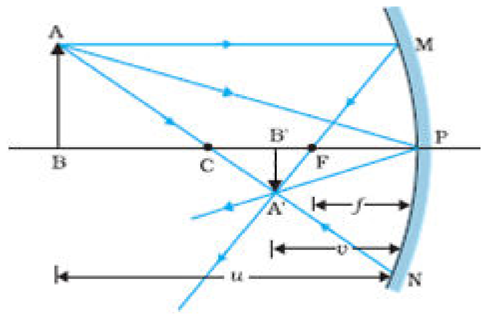
676. The radii of curvature of the faces of a double convex lens are $10\ cm$ and $15\ cm$. If the focal length of the lens is $12\ cm$, find the refractive index of the material of the lens ? **CBSE (D)-2010**

[Ans. $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ ⇨ $\frac{1}{12} = (\mu - 1)\left(\frac{1}{10} + \frac{1}{15}\right) = (\mu - 1)\left(\frac{3+2}{30}\right) = (\mu - 1)\left(\frac{1}{6}\right)$

⇨ $\mu - 1 = \frac{6}{12} = \frac{1}{2}$ ⇨ $\mu = 1 + \frac{1}{2} = \frac{3}{2}$

678. A concave mirror produces a real and magnified image of an object kept in front of it. Draw a ray diagram to show The image formation and use it to derive the mirror equation. **CBSE (AI)-2015**

[**Ans. Derivation of mirror formula:**



ΔABC and $\Delta A'B'C$ are similar

$\therefore \quad \frac{B'A'}{BA} = \frac{B'C}{CB} = \frac{PC-PB'}{PB-PC}$ -----------(1)

ΔABP and $\Delta A'B'P$ are also similar

$\therefore \quad \frac{B'A'}{BA} = \frac{PB'}{PB}$ ----------(2)

⇨ from equation (1) and (2)

$\frac{PC-PB'}{PB-PC} = \frac{PB'}{PB}$

⇨ $\frac{-2f-(-v)}{-u-(-2f)} = \frac{-v}{-u}$ ⇨ $\frac{v-2f}{2f-u} = \frac{v}{u}$ ⇨ $uv - 2uf = 2vf - uv$

⇨ $2uv = 2vf + 2uf$

Dividing by $2uvf$ on both sides we get, $\frac{2uv}{2uvf} = \frac{2vf}{2uvf} + \frac{2uf}{2uvf}$

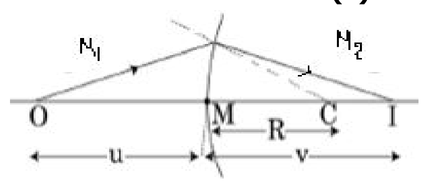
⇨ $\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$

===

679. A point object O on the principal axis of a spherical surface of radius R separating two media of refractive indices μ_1 and μ_2 forms an image 'I' as shown in the figure. **CBSE (F)-2017,(AI)-2015**

Prove that

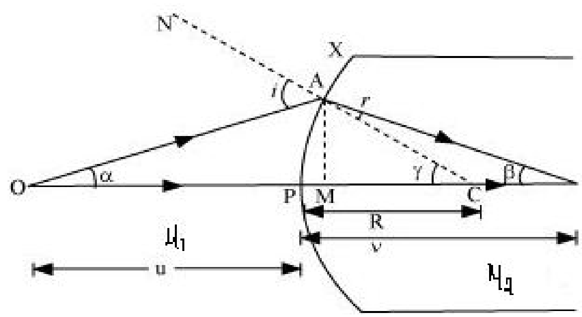
$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2-\mu_1)}{R}$$



[**Ans.** By Snell's law, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

For small angles, $\frac{i}{r} = \frac{\mu_2}{\mu_1}$

⇨ $\mu_1 i = \mu_2 r$ -----------(1)



In Δ OAC and Δ IAC,

$i = \alpha + \gamma$ & $\gamma = r + \beta$

⇨ from (1),

$\mu_1(\alpha + \gamma) = \mu_2(\gamma - \beta)$

⇨ $\mu_1\alpha + \mu_2\beta = (\mu_2 - \mu_1)\gamma$ ----------(2)

let the aperture of the surface is also very small then we have

$\alpha \approx \tan\alpha = \frac{AM}{MO} \approx \frac{AM}{PO}$

$\beta \approx \tan\beta = \frac{AM}{MI} \approx \frac{AM}{PI}$ & $\gamma \approx \tan\gamma = \frac{AM}{MC} \approx \frac{AM}{PC}$

⇨ from equation (2)

$\mu_1\left(\frac{AM}{PO}\right) + \mu_2\left(\frac{AM}{}\right) \quad (\mu_2-\mu_1)\left(\frac{AM}{}\right)$

⇨ $\frac{\mu_1}{-u} + \frac{\mu_2}{+v} = \frac{(\mu_2-\mu_1)}{+R}$

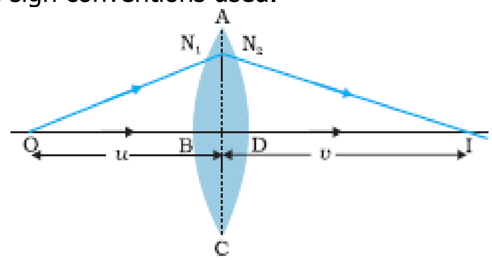
$\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2-\mu_1)}{R}}$ Or $\boxed{\frac{\mu}{v} - \frac{1}{u} = \frac{(\mu-1)}{R}}$

680. Derive expression for the lens maker's formula using necessary ray diagrams. **CBSE (AI)-2016,2014,2012,2011**

$$\frac{1}{f} = (\mu_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Also state the assumptions in deriving the above relation and the sign conventions used.

[**Ans.** For the refraction at the interface ABC,

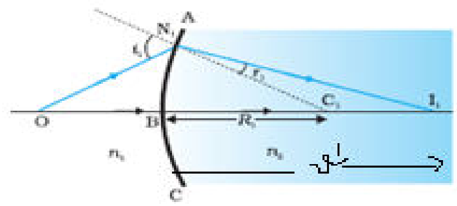


$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R_1} \qquad \text{---------(1)}$$

For the refraction at ADC, image I_1 will act as an imaginary object and if the lens is very thin, then

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = -\frac{(\mu_2 - \mu_1)}{R_2} \qquad \text{---------(2)}$$

on adding (1) & (2) we get

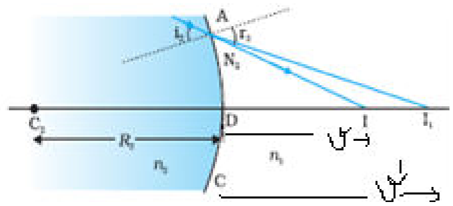


$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{(\mu_2 - \mu_1)}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = (\mu_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

But when $u = -\infty$ then $v = f$



$$\Rightarrow \frac{1}{f} - \frac{1}{-\infty} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\boxed{\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

Assumptions used :

(i) lens used is very thin.
(ii) Aperture of the lens is very small
(iii) Object is a point object placed at the principal axis.
(iv) All the rays are paraxial.

New Cartesian sign conventions used :

(i) All distances are measured from the optical centre of the lens
(ii) Distances measured in the direction of incident ray are positive
(iii) Distances measured in the opposite direction of incident ray are negative.

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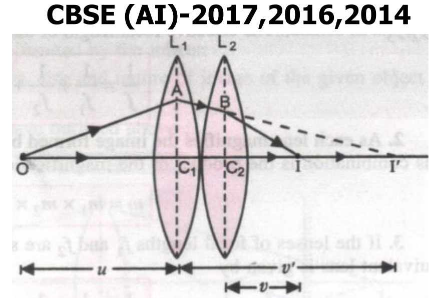
681. Two thin convex lenses L_1 and L_2 of focal lengths f_1 and f_2 respectively, are placed coaxially in contact. An object is placed at a point beyond the focus of lens L_1. Draw a ray diagram to show the image formation and hence derive the expression for the focal length of the combined system. **CBSE (AI)-2017,2016,2014**

[**Ans.** For the refraction by lens L_1 we have



$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \qquad \text{---------------(1)}$$

For the refraction by lens L_2, I' will act as an imaginary object,

$$\Rightarrow \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \qquad \text{--------------(2)}$$

On adding equation (1) and (2) we get

$$\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\Rightarrow \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \qquad \text{------------(3)}$$

Let F be the focal length of this lens combination then we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{F} \qquad \text{-------------(4)}$$

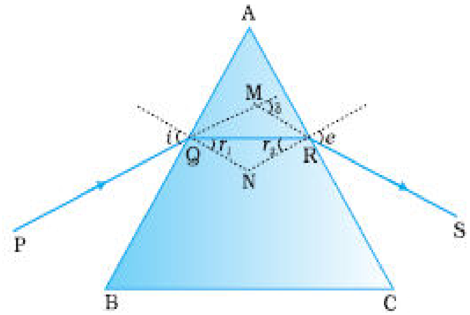
From (3) and (4),

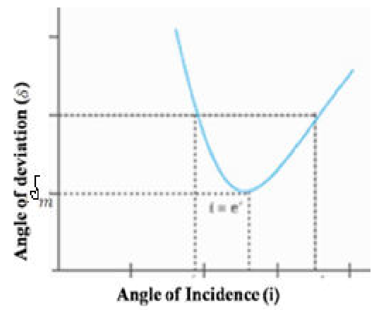
$$\boxed{\frac{1}{F} \quad \frac{1}{f} \quad \frac{1}{f}}$$

682**.** Draw a ray diagram to show the refraction of light through a glass prism. Hence derive the relation

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$$ **CBSE (F)-2017,(AI)-2016,(D)-2016**

[Ans. Refraction through a glass prism :





Let a light ray is incident on the principal section ABC of a glass prism as shown

In quadrilateral AQNR,

$\angle A + 90^0 + \angle QNR + 90^0 = 360^0$

⇨ $\angle A + \angle QNR = 180^0$ ----------(1)

In triangle QNR,

$r_1 + r_2 + \angle QNR = 180^0$ ----------(2)

From (1) and (2)

$r_1 + r_2 = A$ --------(3)

Now, total deviation

$\delta = (i - r_1) + (e - r_2) = (i + e) - (r_1 + r_2)$

⇨ $\delta = i + e - A$ ---------(4)

But when $\delta = \delta_m$, $i = e$ hence $r_1 = r_2$

⇨ from (3), $2r = A$ ⇨ $r = A/2$

From (4), $\delta_m = 2i - A$ ⇨ $i = (A + \delta_m)/2$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$

==

683. A ray of light incident on an equilateral glass prism propagates parallel to the base line of the prism inside it. Find the angle of incidence of this ray. Given refractive index of material of glass prism is $\sqrt{3}$. **CBSE (AI)-2016,2015**

[Ans. Given : $\mu_g = \sqrt{3}$, $A = 60^0$, i = ?

If the ray moves parallel to the base line, it means that, $r_1 = r_2 = r$

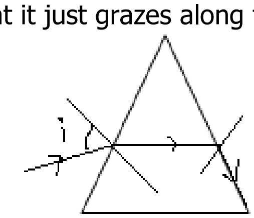
As $r_1 + r_2 = A$ ⇨ $2\,r = 60^0$ ⇨ $r = 30^0$

$\mu_g = \frac{\sin i}{\sin r}$ ⇨ $\sqrt{3} = \frac{\sin i}{\sin 30^0}$ ⇨ $\sin i = \sqrt{3} \times \sin 30^0 = \sqrt{3} \times 1/2 = \sqrt{3}/2$ ⇨ $i = 60^0$

==

684. Determine the value of the angle of incidence for a ray of light travelling from a medium of refractive index $\mu_1 = \sqrt{2}$ into the medium of refractive index $\mu_2 = 1$, so that it just grazes along the surface of separation. CBSE (F)-2017

[Ans. From Snell's law,



$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

⇨ $\frac{\sin i}{\sin 90} = \frac{1}{\sqrt{2}}$

⇨ $\sin i = \frac{1}{\sqrt{2}}$ ⇨ $i = 45^0$

==

685. A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is 3/4 th of the angle of prism. Calculate the speed of light in the prism. **CBSE (AI)-2017**

[Ans. Given : $A = 60^0$, & $i = \frac{3}{4}A$ ⇨ $i = \frac{3}{4} \text{ X } 60 = 45^0$

At minimum deviation, $r = A/2 = 60/2 = 30^0$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin 45}{\sin 30} = \frac{1/\sqrt{2}}{1/2} = \frac{2}{\sqrt{2}} = \sqrt{2}$

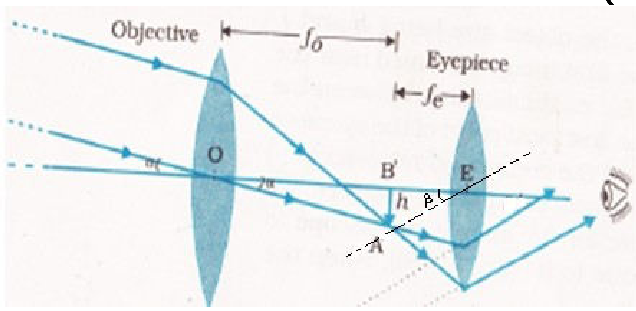
But, $\mu = \frac{c}{v}$ ⇨ $v = \frac{c}{\mu} = \frac{3 \text{ X } 10^8}{\sqrt{2}} = 2.1 \text{ X } 10^8\ m/s$

686. (i) Draw a labelled ray diagram to show the image formation by an astronomical telescope in normal adjustment.

(ii) Define magnifying power of an astronomical telescope in normal adjustment (i,e, when the final image is formed at infinity).

(iii) Derive the expression for its magnifying power in normal adjustment.

[Ans. **CBSE (AI)-2017,2016,(F)-2016,2009**



Magnifying power : It is defined as the ratio of the angle subtended at the eye by the final image to the angle subtended at the eye by the object, when both are at infinity

$$m = \frac{\beta}{\alpha} \approx \frac{\tan\beta}{\tan\alpha} = \frac{B'A'/EB'}{B'A'/OB'} = \frac{OB'}{EB'} = \frac{f_0}{-f_e}$$

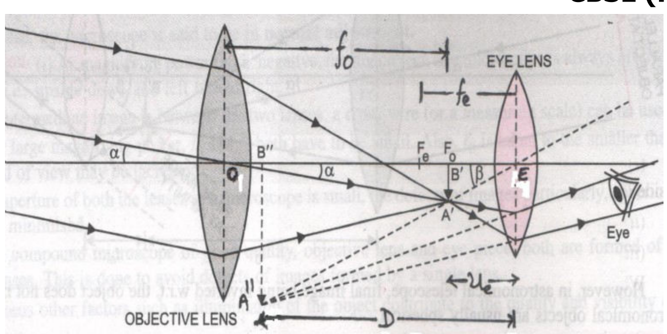
⇨ $m = -\frac{f_0}{f_e}$

==

687. (i) Draw a labelled ray diagram of an astronomical telescope when the final image is formed at least distance of distinct vision.

(ii) Define its magnifying power and deduce the expression for the magnifying power of telescope.

[Ans. **CBSE (F)-2015,2014,(AI)-2013**



Magnifying power : It is defined as the ratio of the angle subtended at the eye by the image at the least distance of the distinct vision to the angle subtended at the eye by the object at infinity, when seen directly

$$m = \frac{\beta}{\alpha} = \frac{\tan\beta}{\tan\alpha} = \frac{A'B'/EB'}{A'B'/OB'} = \frac{OB'}{EB'} = -\frac{f_0}{u_e} \quad \text{-------(1)}$$

But for eye lens,

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{-D} + \frac{1}{u_e}$$

⇨ $\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{f_e}\left(1 + \frac{f_e}{D}\right)$

⇨ from (1), $m = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$

688. Write the main considerations required in selecting the objective and eye piece lenses in order to have large magnifying power and high resolution of the telescope **CBSE (AI)-2014**

[Ans. $m = -\frac{f_o}{f_e}$ & $R.P. = \frac{D}{1.22\ \lambda}$

(i) to have large magnifying power $f_o \gg f_e$

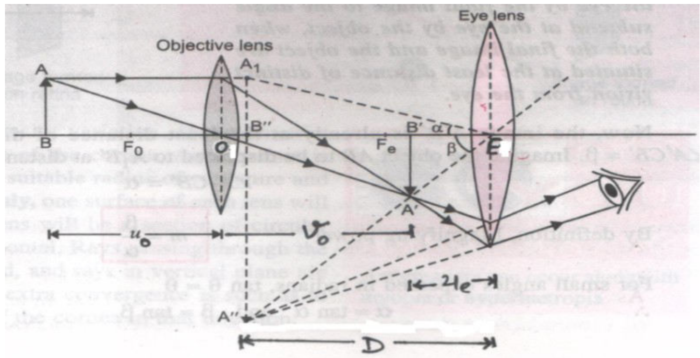
Hence, focal length of objective should be large, while focal length of eye piece should be small

(ii) to have high resolving power D should be large. Hence aperture of objective should be large

689. Draw a labelled ray diagram of a compound microscope when image is formed at least distance of distinct vision. Define its magnifying power and deduce the expression for the magnifying power of the microscope.

CBSE (AI)-2016,2010,(F)-2015,2013,(D)-2014

[Ans. ray diagram of a compound microscope when the final image is at least distance of distinct vision:



Magnifying power : It is defined as the ratio of the angle subtended at the eye by the image to the angle subtended at the eye by the object, when both lie at the least distance of distinct vision.

$$m = \frac{\beta}{\alpha} \approx \frac{\tan\beta}{\tan\alpha} = \frac{B'A'/EB'}{BA/EB} = \left(\frac{B'A'}{BA}\right)\left(\frac{EB}{EB'}\right) = \left(\frac{v_0}{-u_o}\right)\left(\frac{-D}{-u_e}\right)$$

⇨ $m = -\frac{v_0}{u_o}\left(\frac{D}{u_e}\right)$ ------------(1)

But for eye lens,

$$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{-D} + \frac{1}{u_e}$$

⇨ $\frac{1}{u_e} = \frac{1}{f_e} + \frac{1}{D} = \frac{1}{D}\left(1 + \frac{D}{f_e}\right)$

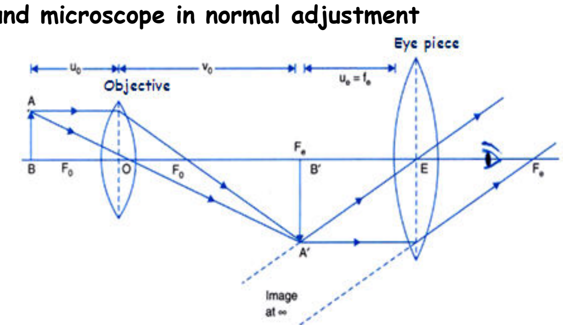
⇨ from (1), $m = \frac{v_0}{u_o}\left(1 + \frac{D}{f_e}\right) = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$

===

690. (i) Draw a labelled ray diagram for the formation of image by a compound microscope in normal adjustment.

(ii) Define magnifying power of a compound microscope in normal adjustment and derive an expression for it.

[Ans. ray diagram of a compound microscope in normal adjustment **CBSE (D)-2017,(AI)-2015**



[Ans. Magnifying power : Magnifying power of a compound microscope is defined as the angle subtended at the eye by the final image to the angle subtended (at the un aided eye) by the object

$m = m_0 \times m_e = \frac{v_0}{u_0} \times \frac{D}{f_e}$

When the object is very close to f_o, and the image formed is very close to eye lens, then

$u_o \simeq f_o$ and $v_o \simeq L$

$$m = -\frac{L}{f_o} \times \frac{D}{f_e}$$

691. Three rays (1,2,3) of different colours fall normally on one of the sides of an isosceles right angled prism as shown.The refractive index of prism for these rays is 1.39, 1.47 and 1.52 respectively. Find which of these rays get internally reflected and which get only refracted from AC. Trace the path of rays. Justify your answer.

[Ans. **For TIR**, $i > i_c$ **CBSE (F)-2016,(AI)-2011,(D)-2009**

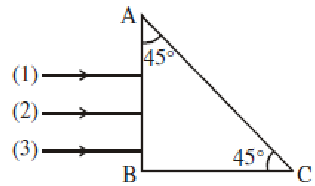
⇨ $\sin i > \sin i_c$

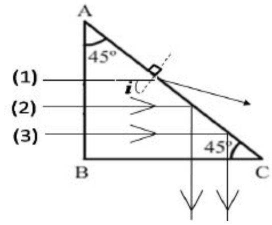
⇨ $\sin i > \frac{1}{\mu}$ $[\because \mu = \frac{1}{\sin i_c}]$

⇨ $\mu > \frac{1}{\sin i} = \frac{1}{\sin 45} = \frac{1}{1/\sqrt{2}} = \sqrt{2}$

⇨ $\mu > \sqrt{2} = 1.414$

Hence rays (2) & (3) will go TIR





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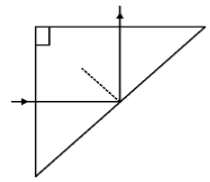
692. A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown. What must be The minimum value of refractive index of glass ? Give relevant calculations. **CBSE (D)-2016**

[Ans. For TIR, $i \geq i_c$

⇨ $\sin i \geq \sin i_c$

⇨ $\sin 45 \geq \frac{1}{\mu}$ ⇨ $\frac{1}{\sqrt{2}} \geq \frac{1}{\mu}$

⇨ $\sqrt{2} \leq \mu$ ⇨ $\mu \geq \sqrt{2}$



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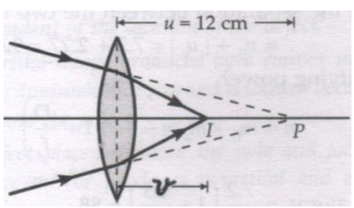
693. A beam of light converges at a point P. Now a lens is placed in the path of the convergent beam 12 cm from P. At what point does the beam converge if the lens is **CBSE (AI)-2015,NCERT-2017**

(i) a convex lens of focal length 20 cm,

(ii) a concave lens of focal length 16 cm ?

[Ans. u = + 12 cm, f = + 20 cm



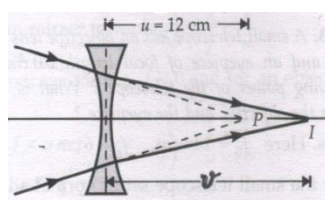
$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

⇨ $\frac{1}{20} = \frac{1}{v} - \frac{1}{12}$

⇨ $\frac{1}{v} = \frac{1}{20} + \frac{1}{12} = \frac{3+5}{60} = \frac{8}{60} = \frac{2}{15}$

⇨ $v = +7.5$ cm

u = + 12 cm, f = – 16 cm



$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

⇨ $\frac{1}{-16} = \frac{1}{v} - \frac{1}{12}$

⇨ $\frac{1}{v} = \frac{1}{12} - \frac{1}{16} = \frac{4-3}{48} = \frac{1}{48}$

⇨ $v = +48$ cm

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694. A ray of light incident on one of the faces of a glass prism of angle 'A' has angle of incidence 2A. The refracted ray in the prism strikes the opposite face which is silvered, the reflected ray from it retracing its path. Trace the ray diagram and find the relation between the refractive index of the material of the prism and the angle of the prism.

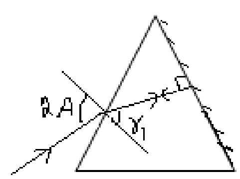
[Ans. We know **CBSE (AI)-2015**

$r_1 + r_2 = A$

But here, $r_2 = 0$

⇨ $r_1 = A$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin 2A}{\sin A} = \frac{2 \sin A \cos A}{\sin A} = 2\cos A$



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695. Using mirror formula, explain why does a convex mirror always produce a virtual image ? **CBSE (AI)-2016,2011**

[Ans. $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ ⇨ $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$ -------(1)

Hence from (1) v is always positive, hence image is always virtual

696. You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece.

[Ans. $m = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$ **CBSE (AI)-2015**

⇨ $-30 = -\frac{L}{1.25}\left(1 + \frac{25}{5}\right)$ ⇨ $-30 \text{ X } 1.25 = L \text{ X } 6$ ⇨ $L = 6.25\ cm$

697. (i) A small telescope has an objective lens of focal length 150 cm and eyepiece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment ? **CBSE (AI)-2015**

(ii) If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens ? **CBSE (AI)-2015**

[Ans. (i) $m = -\frac{f_0}{f_e} = -\frac{150}{5} = -30$

(ii) For objective lens, $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

⇨ $\frac{1}{1.5} = \frac{1}{v_o} - \frac{1}{-3000}$ ⇨ $\frac{1}{v_o} = \frac{1}{1.5} - \frac{1}{3000} = \frac{2000 - 1}{3000} = \frac{1999}{3000}$

⇨ $v_o = \frac{3000}{1999} \approx 1.5\ m$

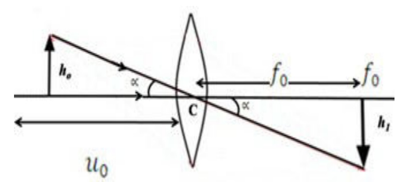
$h_2 = \frac{v_o}{u_o} \text{ X } h_1 = \frac{1.5}{3000} \text{ X } 100 = 0.05\ m$

698. (i) A giant refracting telescope has an objective lens of focal length 15 m. If an eye piece of focal length 1.0 cm is used, what is the angular magnification of the telescope ? **CBSE (D)-2015,(AI)-2011,NCERT-2017**

(ii) If this telescope is used to view the moon, what is the diameter of the image of the moon formed by the objective lens ? The diameter of the moon is $3.48 \times 10^6\ m$ and the radius of lunar orbit is $3.8 \text{ X } 10^8\ m$.

[Ans.(i) Angular magnification

$|m| = \frac{f_0}{f_e} = \frac{15}{1.0 \text{ X } 10^{-2}} = 1500$



(ii) Angle subtended by the moon

$\alpha = \frac{diameter\ of\ moon}{radius\ of\ lunar\ orbit} = \frac{3.48 \text{ X } 10^6}{3.8 \text{ X } 10^8} = \frac{3.48}{3.8} \text{ X } 10^{-2}$

Angle subtended by the image

$\alpha = \frac{diameter\ of\ image\ of\ moon}{f_0} = \frac{D}{f_o}$

⇨ $\frac{D}{f_o} = \frac{3.48}{3.8} \text{ X } 10^{-2}$ ⇨ $D = \frac{3.48}{3.8} \text{ X } 10^{-2} \text{ X } f_o = \frac{3.48}{3.8} \text{ X } 10^{-2} \text{ X } 15 = 13.73\ cm$

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699. Monochromatic light of wavelength 589 nm is incident from air on a water surface. If μ for water is 1.33, find the wavelength, frequency and speed of the refracted light. **CBSE (AI)-2017,NCERT-2017**

[Ans. $\lambda' = \frac{\lambda}{\mu} = \frac{589}{1.33} = 442.89\ nm$

$\nu = \frac{c}{\lambda} = \frac{3 \text{ X } 10^8}{589 \text{ X } 10^{-9}} = 5.09 \text{ X} 10^{12} \text{ Hz}$

Speed $v' = \frac{c}{\mu} = \frac{3 \text{ X } 10^8}{1.33} = 2.25 \text{ X} 10^8\ m/s$

699*. Calculate the distance of an object of height h from a concave mirror of radius of curvature $20\ cm$, so as to obtain a real image of magnification 2. Also find the location of the image. **CBSE (D)-2016**

[Ans. Given, $R = -20\ cm, f = \frac{R}{2} = \frac{-20}{2} = -10\ cm, m = -2, u = ?, v = ?$

$m = -\frac{v}{u}$ ⇨ $-2 = -\frac{v}{u}$ ⇨ $v = 2u$ --------(1)

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ ⇨ $\frac{1}{-10} = \frac{1}{u} + \frac{1}{u}$ ⇨ $u = -15\ cm$

From (1) $v = 2 \text{ X} - 15 = -30\ cm$

Chapter–10: Wave Optics

Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light, diffraction due to a single slit, width of central maximum, resolving power of microscope and astronomical telescope, polarisation, plane polarised light, Brewster's law, uses of plane polarised light and Polaroids.

601*. Define a wavefront. How is it different from a ray ? **CBSE (AI)-2017,2016,2015,2010,(D)-2013,2011**

[**Ans. Wavefront :** Continuous locus of all the particles of a medium vibrating in the same phase is called wavefront

Difference from a ray :

(i) A ray is always normal to the wavefront at each point.

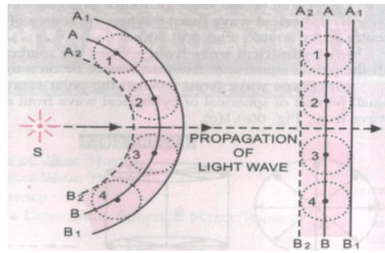
(ii) A ray gives the direction of propagation of light wave while the wavefront is the surface of constant phase

602*. State Huygen's principle. **CBSE (AI)-2016,2015,2010,2006,(D)-2013,2011,2008**

[**Ans. Huygen's Principle :**

(i) Each point on the wave front acts as a fresh source of new disturbance, called secondary wavelets, which spread out in all directions with the same velocity as that of the original wave

(ii) The forward envelope of these secondary wavelets drawn at any instant, gives the shape and position of new wave front at that instant

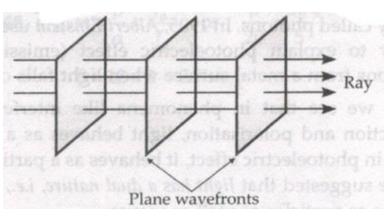


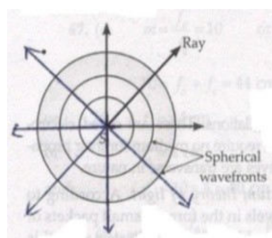
603*. (i) Sketch the wavefront that will emerge from a distance source of light like a star.
CBSE (F) -2010,(D)-2009,(AI)-2001,(AIC)-2004,2003

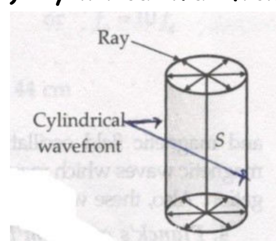
(ii) Sketch the shape of wavefront emerging/diverging from a point source of light and also mark the rays.
CBSE (F) -2009,2002,(D)-2009,2005, (AI)-2003,2001

(iii) Sketch the wavefront that will emerge from a linear source of light like a slit.
CBSE (D)-2009,(F)-2002,(AI)-2001

[**Ans. (i) Plane wavefront** **(ii) Spherical wavefront** **(iii) Cylindrical Wavefront**







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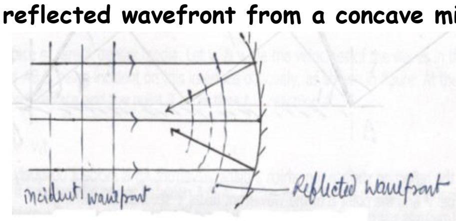
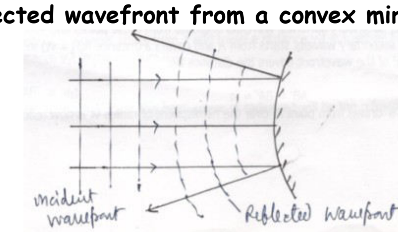
604*. Sketch the reflected wavefront emerging from a (i) concave mirror (ii) convex mirror, if plane wavefront is incident normally on it. **CBSE (AI)-2015,2006, (Sample Paper)-2011**

[**Ans. (i) reflected wavefront from a concave mirror** **(ii) reflected wavefront from a convex mirror**





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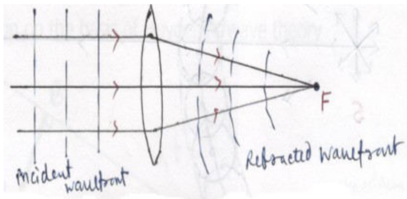
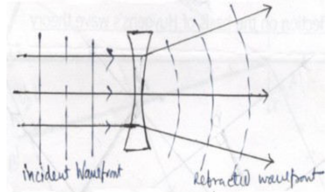
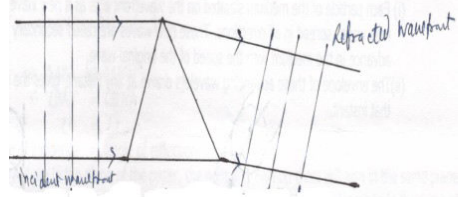
605*. Sketch the refracted wavefront emerging from a convex/concave lens/prism, if plane wavefront is incident normally on it.
CBSE (AI)-2016,2015,2006,2003,(AIC)-2004

[**Ans. (a) refracted wavefront from a convex/concave lens** **(b) refracted wavefront from a prism**







606*. What is interference of light ? Give one example of interference in daily life. **CBSE (AIC)-2012,(D)-2007**

[**Ans. Interference of light** : It the phenomenon of non-uniform distribution of resultant intensity when two light waves from two coherent sources superimpose on each other

Example in daily life : colours in bubbles of soap solution/ in thin oil films in white light

607*. What are coherent sources of light ? Why are coherent sources necessary to produce a sustained interference pattern? **CBSE (D)-2012,2007,(F)-2009**

[**Ans. Coherent sources** : Two sources producing light waves of same frequency and zero or constant initial phase difference are called coherent sources of light

Necessity : Coherent sources produce waves with constant phase difference, due to which positions of and minima does not change with time and a sustained interference pattern is obtained

608*. What are the essential conditions for two light sources to be coherent ? **CBSE (AIC)-2004**

[**Ans.** (i) Two sources must produce waves of same frequency/ wavelength, and

(ii) phase difference between the waves must be zero or constant

609*. What happens to the interference pattern if phase difference between two light sources varies continuously ? **CBSE (AI)-2012,2009**

[**Ans.** Positions of bright and dark fringes would change rapidly hence the interference pattern shall not be sustained

610*. Why cannot two independent monochromatic sources produce sustained interference pattern ? **CBSE (AI)-2015, (D)-2015**

[**Ans.** Two independent sources do not maintain constant phase difference, therefore the interference pattern will also change with time

611*. In Young's double slit experiment, the two slits are illuminated by two different lamps having same wavelength of light. Explain with reason, whether interference pattern will be observed on the screen or not **CBSE (AIC)-2017**

[**Ans.** Interference pattern will not be observed as two independent lamps are not coherent sources

612*. Does the appearance of bright and dark fringes in the interference pattern violate, in any way, law of conservation of energy ? Explain. **CBSE (AIC)-2015**

[**Ans. No** , Appearance of the bright and dark fringes is simply due to a redistribution of energy

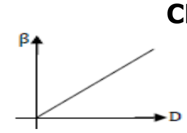
613*. Why does a soap bubble show beautiful colours when illuminated by white light ? Explain. **CBSE (AIC)-2004**

[**Ans. Due to Interference of light**

Reason : Light waves reflected from outer and inner surfaces of soap bubble interfere. For different wavelengths, conditions for constructive interference are satisfied at different positions. This is why beautiful colours are seen

614*. In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same. What information can one obtain from the slope of the curve ? **CBSE (AI)-2015**

[**Ans.** $\boldsymbol{\beta = \frac{D\lambda}{d}}$ ⇨ $\beta \propto D$



Slope $= \frac{\beta}{D} = \frac{\lambda}{d}$ ⇨ $\boldsymbol{\lambda} = (\text{Slope}) \times d$

615*. How would the angular separation of interference fringes in Young's double slit experiment change when the distance between the slits and screen is doubled/ halved ? **CBSE (AI)-2009**

[**Ans.** Angular separation ($\theta = \lambda/d$) remains unchanged as it does not depend on D

616*. In the Young's double slit experiment, how does the fringe width get affected if the entire experimental apparatus is immersed in water ? **CBSE (AI)-2011**

[**Ans.** fringe width will decrease, **Reason** : $\boldsymbol{\beta} = \frac{D\lambda}{d}$ & $\boldsymbol{\beta}_{water} = \frac{D\lambda/\mu_w}{d} = \frac{\beta}{\mu_w}$

617*. In the Young's double slit experiment, how does the fringe width get affected if the entire experimental apparatus is immersed in water (refractive index $4/3$) ? **CBSE (D)-2011,2008**

[**Ans.** $\boldsymbol{\beta}_{water} = \frac{\boldsymbol{\beta}}{\mu_w} = \frac{\boldsymbol{\beta}}{4/3} = \frac{3}{4}\boldsymbol{\beta}$, so fringe width decreases to 3/4 times

618*. Two identical coherent waves each of intensity I_0 are producing interference pattern. What are the values of resultant Intensity at a point of (i) constructive interference (ii) destructive interference pattern ? **CBSE (DC)-2004**

[**Ans.** **(i)** $\mathbf{I}_{max} = \left(\sqrt{\mathbf{I_1}} + \sqrt{\mathbf{I_2}}\right)^2 = \left(\sqrt{\mathbf{I_0}} + \sqrt{\mathbf{I_0}}\right)^2 = \left(2\sqrt{\mathbf{I_0}}\right)^2 = 4\,\mathbf{I_0}$

(ii) $\mathbf{I}_{min} = \left(\sqrt{\mathbf{I_1}} - \sqrt{\mathbf{I_2}}\right)^2 = \left(\sqrt{\mathbf{I_0}} - \sqrt{\mathbf{I_0}}\right)^2 = 0$

619*. What is diffraction of light ? State the essential condition for diffraction of light. **CBSE (F)-2016**

[**Ans. Diffraction** : The phenomenon of bending of light round the corners of small obstacles or apertures is called diffraction of light.

Essential condition : Size of slit/ aperture must be of the order of wavelength of light i,e, $a \approx \lambda$

620*. Why do secondary maxima get weaker in intensity with increasing the order ?Explain. **CBSE(AI)-2016,2014,2009**

OR

Explain how the intensity of diffraction pattern changes as the order (n) of the diffraction band varies. **CBSE(AIC)-2017**

[**Ans.** Intensity of diffraction pattern drops rapidly with order n because every higher order maxima gets intensity only from $\frac{1}{2n+1}$ part of the slit. The central maxima gets intensity from the whole slit $(n = 0)$

1st secondary maxima gets its intensity only from 1/3 of slit

2nd secondary maxima gets its intensity only from 1/5 of slit

and so on.

621*. Why do we not encounter diffraction effects of light in everyday observations ? **SE (AI)-2010,(F)-2009**

OR

Diffraction is common in sound but not common in light waves why ? **CBSE (D)-2002,(AI)-2000**

[**Ans.** This is because objects around us are much bigger in size as compared to the wavelength of visible light$(\simeq 10^{-6} m)$

622*. How would the width of central maximum in diffraction pattern due to a single slit be affected, when the width of the slit is doubled ? **CBSE (F) -2009**

[**Ans.** $y_0 = 2D\lambda/a$ ⇨ Width of central maximum will be halved

623*. How is the width of central maxima in diffraction pattern due to a single slit affected if the entire apparatus is immersed in water. Justify your answer. **CBSE (F)-2009**

[**Ans.** $y'_0 = 2D\lambda'/a = \frac{2D\lambda/\mu}{a} = \frac{y_0}{\mu}$

624*. If the width of the slit is made double to original width in diffraction at a single slit, how does it affect the size and ntensity of the central band ? **CBSE (F) -2016,2012, (AI)-2012,2008, (D)-2012**

[**Ans.** $y_0 = 2D\lambda/a$ & $I \propto a^2$

Hence y_0 will become half and the intensity becomes 4 times

625*. How would the diffraction pattern due to a single slit be affected when the width of the slit is decreased ?

[**Ans.** $\theta_n = n\lambda/a$ **CBSE (F) -2013**

On decreasing a, θ_n will increase hence, diffraction pattern is spread out

626*. How would the width of central maximum in diffraction pattern due to a single slit be affected, If the wavelength of the light used is increased ? **CBSE (F) -2009**

[**Ans.** $y_0 = 2D\lambda/a$ ⇨ Width of central maximum will be increased

627*. How does the angular separation between fringes in single slit diffraction experiment change when the distance of separation between the slit and screen is doubled ? **CBSE (AI) -2012**

[**Ans.** $\theta_n = n\lambda/a$, remains unchanged as it does not depend on D

628*. How would the diffraction pattern due to a single slit be affected when the monochromatic source of light is replaced by white light. **CBSE (F) -2013,2011, (AI)-2009**

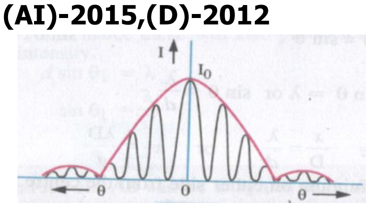
[**Ans.** (i) The diffraction pattern is coloured. As $\beta \propto \lambda$ so red fringe is wider than violet fringe

(ii) the central maxima is bright

(iii) more dispersion is obtained for higher order spectra, it causes an overlapping of different colours

629*. Show that the fringe pattern on the screen in Young's double slit experiment is actually a superposition of single slit diffraction from each slit. **CBSE (AI)-2015,(D)-2012**

[**Ans.** It is shown in figure, there is a broader diffraction peak in which there appear several fringes of smaller width due to double slit Interference pattern. In the limit of slit width 'a' becoming very small, the diffraction pattern become very flat and will observe the two slit interference pattern.

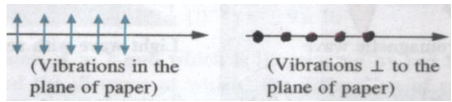


630*. What is polarization of light ? **CBSE (AI)-2013,2009,2008,(F)-2013,(D)-2010**

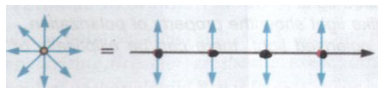
[**Ans. Polarization of light** : The phenomenon of restricting the vibrations of electric vectors in a plane perpendicular to the direction of propagation of light, is known as polarization of light

631. Define the term 'linearly polarised light' and 'unpolarised light'. **CBSE (AI)-2017,2013,2009,(F)-2013,(D)-2010**

[**Ans. Linearly Polarised light** : The light having vibrations of electric field vector in only one direction perpendicular to the direction of propagation of light is called plane or linearly polarised light



Unpolarised light : The light having vibrations of electric field vector in all possible directions perpendicular to the direction of propagation of light is called unpolarised light or ordinary light



632*. Which special characteristic of light is demonstrated only by the phenomenon of polarization ? **CBSE (AIC)-2004**

[**Ans.** Transverse nature of light

633*. Which type of waves show the property of polarization ? **CBSE (AIC)-2001**

[**Ans.** Transverse waves

634*. Name the phenomenon which proves transverse wave nature of **CBSE (Sample Paper)-2015**

[**Ans.** polarization

635*. Good quality sung-lasses made of polaroids are preferred over ordinary coloured glasses. Why ? Justify your answer.

CBSE (DC)-2015

[**Ans.** because they are more effective in reducing the glare due to reflections from horizontal surfaces/ provide better protection to our eyes / more effective in cutting off harmful UV rays of sun

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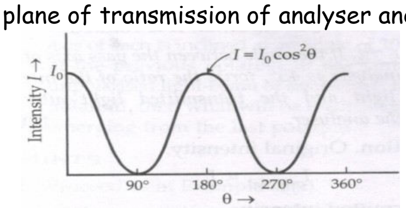
636*. (i) State law of Malus. **CBSE (AI)-2016**

(ii) Draw a graph showing the variation of intensity (I) of polarised light transmitted by an analyser with angle (θ) between polariser and analyser **CBSE (AI)-2017,2016**

[**Ans. Law of Malus** : When a beam of completely plane polarised light is incident on an analyser, intensity of transmitted light varies as the square of cosine of angle between plane of transmission of analyser and polariser

i,e, $I \propto cos^2\theta$

or $I = I_0 \ cos^2\theta$



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637*. Why does unpolarised light from a source show a variation in intensity when viewed through a Polaroid which is rotated ? **CBSE (AI)N-2016**

[**Ans.** By the law of Malus, $I = I_0 \ cos^2\theta$

Hence the transmitted intensity will show a variation as per $cos^2\theta$

638*. Does the intensity of polarised light emitted by a Polaroid depend on its orientation ? Explain briefly.

[**Ans. yes,** By Malus' law. transmitted intensity $I = I_0 \ cos^2\theta$ **CBSE (F)-2016**

639*. The vibrations in a beam of polarised light make an angle of 60^0 with the axis of the Polaroid sheet. What percentage of light is transmitted through the sheet ? **CBSE (F)-2016**

[**Ans.** $I = I_0 \ cos^2\theta = I_0 \ cos^2 60 = I_0 \ (1/2)^2 = \frac{I_0}{4}$ ⇨ $\frac{I}{I_0}$ X 100 = $\frac{1}{4}$ X 100 = 25%

640*. Unpolarised light of intensity I is passed through a Polaroid. What is intensity of light transmitted by the Polaroid ?

[**Ans.** $\frac{I}{2}$, as it will get polarised **CBSE (F)-2009**

641*. Unpolarized light is incident on a polaroid. How would the intensity of transmitted light change when the Polaroid is rotated ? **CBSE (AI)-2013**

[**Ans.** It will not change and remain $I_0/2$

642*. State Brewster's law. **CBSE (AI) -2016,(D)-2016,2002**

[**Ans. Brewster's law** : The refractive index of a refracting medium is numerically equal to the tangent of angle of polarization. i,e, $\mu = \tan i_\beta$

643*. What is Brewster's angle/Polarizing angle ? **CBSE (D)-2016,(F)-2013,(AIC)-2008**

[**Ans. Brewster's Angle** (i_β) : The angle of incidence of unpolarised light falling on a transparent surface, at which the reflected light is completely plane polarised light, is called Brewster's angle or polarizing angle i_β

644*. The value of Brewster angle for a transparent medium is different for light of different colours. Give reason

[**Ans.** We have $\mu = \tan i_\beta$ ⇨ $i_\beta = \tan^{-1}\mu$ **CBSE (D)-2016,(F)-2013**

Since μ is different for different colours, hence Brewster's angle (i_β) is different for different colours

645*. Show that the Brewster angle i_B for a given pair of transparent media, is related to the critical angle i_c through the relation, $i_c = sin^{-1}(\cot i_B)$. **CBSE (AIC)-2008**

[**Ans.** $\mu = \tan i_B = \frac{1}{\cot i_B}$ Also $\mu = \frac{1}{\sin i_c}$ ⇨ $\sin i_c = \cot i_B$ ⇨ $i_c = sin^{-1}(\cot i_B)$

646*. When unpolarised light passes from air to a transparent medium, under what condition does the reflected light get plane polarised ? **CBSE (D)-2011**

[**Ans.** when unpolrised light is incident at Brewster's angle

647*. What is the value of refractive index of a medium of polarizing angle 60^0 ? **CBSE (AI)-2016,(D)-2016,2002**

[**Ans.** $\mu = \tan i_\beta = \tan 60 = \sqrt{3}$

648*. What is the value of polarizing angle of a medium of refractive index $\sqrt{3}$? **CBSE (F)-2008**

[**Ans.** $\mu = \tan i_\beta$ ⇨ $\sqrt{3} = \tan i_\beta$ ⇨ $i_\beta = \tan^{-1}\sqrt{3} = 60^0$

649*. Unpolarised light is incident on a plane glass surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other ? **CBSE (AIC)-2010,NCERT-2017**

OR

Find the Brewster angle for air – glass interface, when the refractive index of glass = 1·5. **CBSE (AI)-2017**

[**Ans.** $\mu = \tan i_\beta$ ⇨ $i_\beta = \tan^{-1}\mu = \tan^{-1}1.5 = 56.3^0$

650*. A ray of light falls on a transparent slab of μ = 1.732, if reflected and refracted rays are mutually perpendicular, what is the angle of incidence ? **CBSE (D)-2009**

[**Ans.** $\mu = \tan i_\beta$ ⇨ $i_\beta = \tan^{-1}\mu = \tan^{-1}1.732 = 60^0$

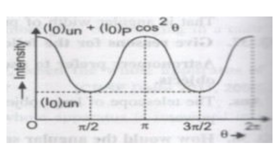
651*. The refractive index of a material is $\sqrt{3}$. What is the angle of refraction if the unpolarised light is incident on it at the polarizing angle of the medium ? **CBSE (D)-2002**

[**Ans.** $\mu = \tan i_\beta =$ ⇨ $i_\beta = \tan^{-1}\sqrt{3} = 60^0$ but $r + i_\beta = 90^0$ ⇨ $r = 90^0 - i_\beta = 90^0 - 60^0 = 30^0$

==

652*. A partially plane polarised beam of light passed through a Polaroid. Show graphically the variation of the transmitted light intensity with angle of rotation of Polaroid. **CBSE (F)-2014**

[**Ans.**



653*. If the angle between the pass axis of polarizer and analyser is 45^0, write the ratio of intensities of original light and the transmitted light after passing through the analyzer. **CBSE (D) -2009**

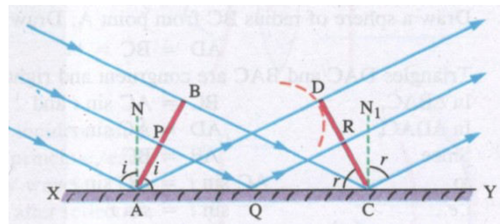
[**Ans.** $I_{original} = I_0$ & $I_{polariser} = I_1 = I_0 \overline{cos^2\theta} = \frac{I_0}{2}$

$I_{transmitted} = I_1 \, cos^2 45 = \frac{I_0}{2} (\frac{1}{\sqrt{2}})^2 = \frac{I_0}{4}$ ⇨ $\frac{I_{original}}{I_{transmitted}} = \frac{I_0}{I_0/4} = 4:1$

654*. Using Huygen's construction draw a figure showing the propagation of a plane wavefront reflecting at a plane surface. Show that the angle of incidence is equal to the angle of reflection. **CBSE (D)-2008,2003**

[**Ans**. <u>Explanation of reflection on the basis of Huygen's wave theory</u>

Let a plane wavefront AB is incident on a reflecting surface XY as shown. By the Huygens's principle, in the time disturbance reaches from B to C, secondary wavelets from A must have spread over a hemisphere of radius AD = BC = ct. Hence tangent CD be the reflected wavefront



In Δ ABC & Δ ADC,

AC = common

$\angle B = \angle D = 90^0$

AD = BC = c t

⇨ Δ ABC ≅ Δ ADC

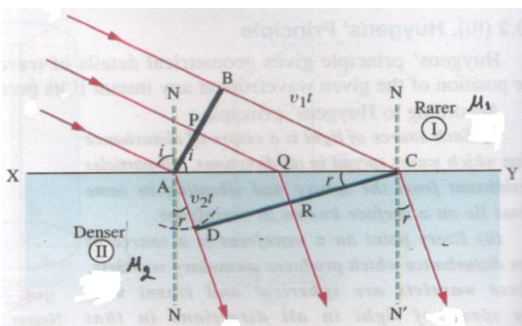
∴ $\angle i = \angle r$

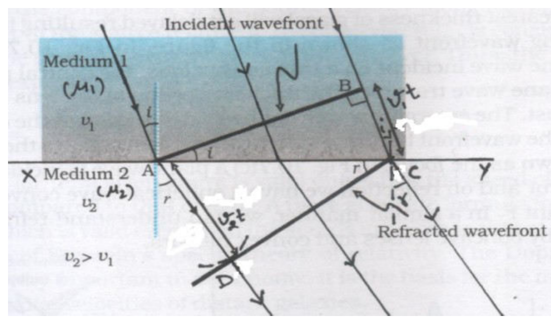
655*. Use Huygens' principle to verify the laws of refraction. **CBSE (AI)-2017**

OR

Derive Snell's law on the basis of Huygen's wave theory when light is travelling from a **rarer to a denser** medium/ **Denser to rarer** medium. **CBSE (AI)-2016,2015,2006,2002,(D)-2013,2011,2008,2005 (AIC)-2011**

[**Ans**. <u>Explanation of refraction on the basis of Huygen's wave theory</u>





Let a plane wavefront AB is incident on a refracting surface XY as shown. By the Huygens's principle, in the time $\left(t = \frac{BC}{v_1}\right)$ disturbance reaches from B to C, secondary wavelets from A must have spread over a hemisphere of radius $AD = v_2$t. Hence tangent CD be the refracted wavefront

Obviously, $\frac{\sin i}{\sin r} = \frac{BC/_{AC}}{AD/_{AC}} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2}$ = constant

This is Snell's law of refraction

56*. Two harmonic waves of monochromatic light **CBSE (AI)S -2016,(AIC)-2015,2014,(D)-2014**

$\boldsymbol{y_1 = a\cos\omega t}$ and $\boldsymbol{y_1 = a\cos(\omega t + \phi)}$

are superimposed on each other. Show that the maximum intensity in interference pattern is four times the intensity due to each slit. Hence write the condition for constructive and destructive interference in terms of the phase angle ϕ.

[**Ans**. $y_1 = a\cos\omega t$ & $y_1 = a\cos(\omega t + \phi)$

⇨ $Y = Y_1 + Y_2 = a\cos\omega t + a\cos(\omega t + \phi) = 2a\cos\left(\frac{\phi}{2}\right)\cos\left(\omega t + \frac{\phi}{2}\right)$

⇨ $A = 2a\cos\left(\frac{\phi}{2}\right)$ ⇨ Resultant intensity,

$I = 4\,a^2\cos^2\left(\frac{\phi}{2}\right) = 4\,I_0\cos^2\left(\frac{\phi}{2}\right)$ where $I_0 = a^2$ is the intensity of each monochromatic wave

Obviously, $I_{max} = 4\,I_0$ = 4 X intensity due to one slit

For constructive interference, $\cos^2\left(\frac{\phi}{2}\right) = 1$

⇨ $\frac{\phi}{2} = n\pi$ or $\phi = 2n\pi$ where n = 0,1,2,3,------- and $I_{max} = 4\,I_0$

For destructive interference, $\cos^2\left(\frac{\phi}{2}\right) = 0$

⇨ $\frac{\phi}{2} = (2n-1)\frac{\pi}{2}$ or $\phi = (2n-1)\pi$ where n = 1,2,3,------- and $I_{min} = 0$

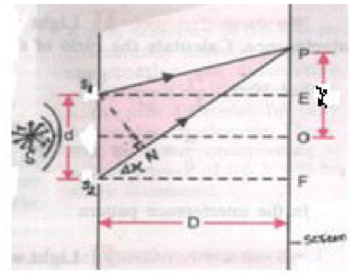
657*. Derive an expression for path difference in Young's double slit experiment and obtain the conditions for Constructive and destructive interference at a point on the screen. Hence find the expression for fringe width. Also draw a graph howing the variation of intensity in the interference pattern.

CBSE (AI)-2016,2015,2014,2012, (D)-2016,2012,2011, (F)-2015

[**Ans.** Let 'S ' be a monochromatic source of light of wavelength λ

The path difference

$\Delta x = S_2P - S_1P$



Now, $S_2P^2 - S_1P^2 = D^2 + \left(y + \frac{d}{2}\right)^2 - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right]$

⇨ $(S_2P - S_1P)(S_2P + S_1P) = D^2 + y^2 + 2y\frac{d}{2} - D^2 - y^2 + 2y\frac{d}{2} = 2yd$

⇨ $\Delta x = \frac{2yd}{(S_2P + S_1P)}$

If point P is very close to point O then

$S_2P \simeq S_1P \simeq D$

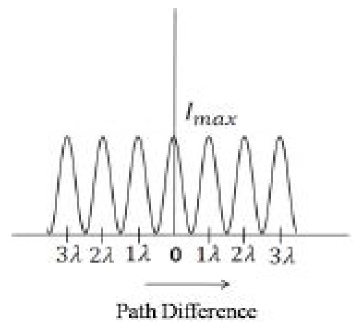
⇨ $\Delta x = \frac{2yd}{(D + D)} = \frac{2yd}{2D} = \frac{yd}{D}$

For constructive interference at P

$\Delta x = n\lambda$ where n = 0,1,2,3,------

⇨ $\frac{yd}{D} = n\lambda$

⇨ for n^{th} bright fringe, $\boldsymbol{y_n} = \frac{\boldsymbol{nD\lambda}}{\boldsymbol{d}}$



For destructive interference at P

$\Delta x = (2n-1)\lambda/2$ where n = 1,2,3,---------

⇨ $\frac{yd}{D} = (2n-1)\lambda/2$

⇨ for n^{th} dark fringe, $\boldsymbol{y_n} = \frac{\boldsymbol{(2n-1)D\lambda}}{\boldsymbol{2d}}$

Fringe width

Width of a dark fringe

$\beta = y_n - y_{n-1} = \frac{nD\lambda}{d} - \frac{(n-1)D\lambda}{d} = \frac{nD\lambda}{d} - \frac{nD\lambda}{d} + \frac{D\lambda}{d} = \frac{D\lambda}{d}$ ⇨ $\boxed{\beta = \frac{D\lambda}{d}}$

Width of a bright fringe

$\beta = y_n - y_{n-1} = \frac{(2n-1)D\lambda}{2d} - \frac{[2(n-1)-1]D\lambda}{d} = \frac{(2n-1)D\lambda}{2d} - \frac{(2n-3)D\lambda}{d}$

$\beta = \frac{(2n-1)D\lambda}{2d} - \frac{(2n-1)D\lambda}{d} + \frac{2D\lambda}{2d} = \frac{D\lambda}{d}$ ⇨ $\boxed{\beta = \frac{D\lambda}{d}}$

658*. (i) What is sustained interference pattern ? Write the necessary conditions to obtain sustained interference fringes.

[**Ans. Sustained interference pattern :** **CBSE (AI)-2015**

An interference pattern, in which the positions of maxima and minima on the screen does not change with time, is called sustained interference

Conditions : (i) Two sources must be coherent

(ii) Waves emitted by two sources should have same frequency and equal or nearly equal amplitude

(iii) Two sources should be quite narrow and the separation between them (d) should be small

(iv) Distance of screen (D) from the sources should be large

659*. (ii) What is the effect on interference fringes in a Young's double slit experiment when the monochromatic source of light is replaced by a source of white light ? Explain. **CBSE (F)-2012**

[**Ans.** The interference pattern consists of a central white fringe having on both sides a few coloured fringes and then a general illumination

Reason : Due to zero path difference, all the waves of different colour produce bright fringes at the centre which overlap and we get central white fringe.

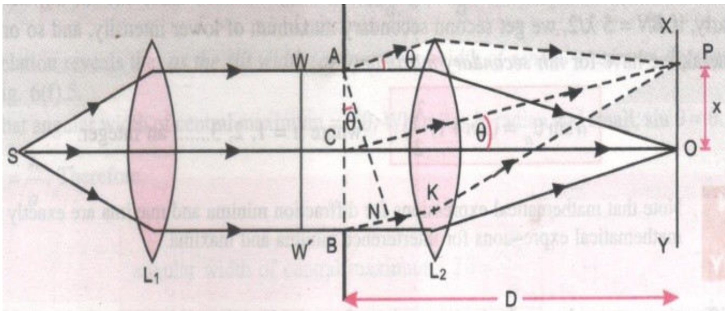
As, $\beta \propto D\lambda/d$, so closest fringe on either side of the central white fringe is violet and the farthest fringe is red. After a few fringes, the interference pattern is lost due to large overlapping of the fringes and uniform white illumination is seen on the screen.

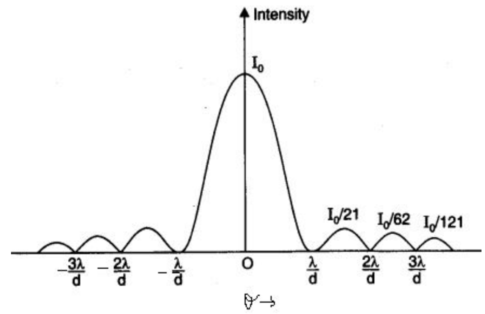
660*. When a parallel beam of monochromatic source of light of wavelength λ is incident on a single slit of width a, show how the diffraction pattern is formed at the screen by the interference of the wavelets from the slit.

(i) Show that, besides the central maximum at $\theta = 0$, secondary maxima are observed at $\theta_n = \left\{n + \frac{1}{2}\right\}\lambda/a$ & minima at $\theta_n = n\lambda/a$

(ii) Show that angular width of central maximum is twice the angular width of secondary maximum and hence find the relation for linear width of central maximum. **CBSE (F)-2017,2016,2013,2012,2011,(AI)-2016,2014,(D)-2012**

[**Ans.** When a parallel beam of monochromatic light is incident on a single slit, By the Huygen's principle, secondary wavelets from each point on the slit superpose on each other and diffraction pattern is obtained on the screen.





Central maximum : Wavelets from any two corresponding points of the two halves of the slit reach the central point in the same phase to produce maxima $(\theta = 0)$. The entire incident wavefront contributes to this central maxima

Positions of minima :

Path difference, $\Delta x = BN = AB\ \sin\theta = a\sin\theta$

Wavelets from upper half of the slit and the corresponding points in the lower half is received with path difference $\frac{\lambda}{2}$ at P. Thus destructive interference takes place and we get first minimum.

i,e, for first secondary minimum

$$a\sin\theta_1 = \frac{\lambda}{2} + \frac{\lambda}{2} = \lambda$$

⇨ for n^{th} secondary minimum ,

$$a\sin\theta_n = n\lambda \qquad \text{where } n = 1,2,3,\text{-------}$$

If θ is very small then for n^{th} secondary minima

$$\theta_n = n\lambda/a$$

Positions of secondary maxima :

Dividing the slit in to three equal parts, wavelets from two parts will meet with phase difference $\frac{\lambda}{2}$ each and produce destructive interference and the wavelets from third part will produce first secondary maximum

i,e, for first secondary maximum

$$a\sin\theta_1 = \frac{3\lambda}{2}$$

⇨ for n^{th} secondary maximum

$$a\sin\theta_n = \left\{n + \frac{1}{2}\right\}\lambda \qquad \text{where } n = 1,2,3,\text{-------}$$

If θ is very small then for n^{th} secondary maxima

$$\theta_n = \left\{n + \frac{1}{2}\right\}\lambda/a$$

Width of central maximum :

for the first minima, $\theta_1 = \lambda/a$

& for the second minima, $\theta_2 = 2\lambda/a$

⇨ linear width of first minimum $y_1 = D\ \theta_1 = D\lambda/a$

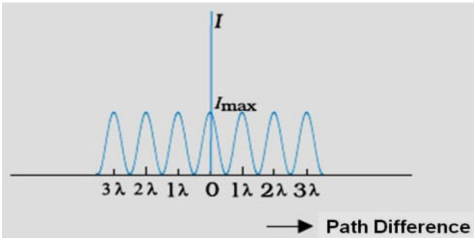
Angular width of central maximum $\theta_0 = \theta_1 - \theta_{-1} = \frac{\lambda}{a} - \left(-\frac{\lambda}{a}\right) = \frac{2\lambda}{a} = 2\theta_1$

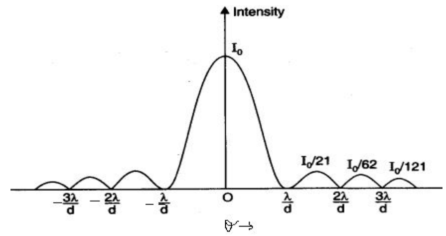
Angular width of secondary maxima $= \theta_2 - \theta_1 = \frac{2\lambda}{a} - \frac{\lambda}{a} = \frac{\lambda}{a} = \frac{1}{2}$ X Angular width of central maxima

⇨ linear width of central maxima $\boldsymbol{y_0} = D\,(2\theta_1) = \boldsymbol{2D\lambda/a}$ ⇨ $\boxed{y_0 = 2D\lambda/a}$

661*. Draw the intensity pattern for single slit diffraction and double slit interference. **CBSE (AI)-2017,2004**

[**Ans.** **Interference** **Diffraction**





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662*. State two differences between interference and diffraction patterns. **CBSE (AI)-2017,(D)-2017**

[**Ans.**

Interference	Diffraction
1. It is due to superposition of two waves from two coherent sources	1. It is due to superposition of secondary wavelets from different parts of the same wavefront
2. Width of fringes/ bands is equal	2. Width of fringes/bands is not equal
3. All maxima have same intensity	3. Maxima have different intensity and intensity decreases rapidly with the order of maxima

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663*. Explain with reason, how the resolving power of an astronomical telescope will change when - **CBSE (AI)-2002**

(i) frequency of the incident light on the objective lens is increased
(ii) the focal length of the objective lens is increased ?
(iii) aperture of the objective lens is halved
(iv) the wavelength of the incident light is increased ? Justify your answer in each case.

[**Ans.** R. P. of a Telescope $= \frac{D}{1.22\,\lambda} = \frac{D\,\nu}{1.22\,c}$

(i) R.P. increases as R.P. $\propto \nu$
(ii) R.P. does not change as it does not depend on focal length of the objective lens
(iii) R.P. is halved as R.P. $\propto D$
(iv) R.P. decreases as R.P. $\propto 1/\lambda$

664*. How does the resolving power of a microscope change when **CBSE (AI)-2015,2008,2005**

(i) the diameter/aperture of the objective lens is decreased,
(ii) the wavelength of the incident light is increased ?
(iii) refractive index of the medium between the object and the objective lens increases
(iv) the focal length of the objective lens is increased ? Justify your answer in each case.

[**Ans.** $\boldsymbol{R.P.} = \frac{2\,\mu\,sin\theta}{\lambda}$

(i) R.P. decreases because as D decreases, θ also decreases and R.P. $\propto sin\theta$
(ii) R.P. decreases as R.P. $\propto 1/\lambda$
(iii) R.P. increases as R.P. $\propto \mu$
(iv) R.P. does not change as it does not depend on focal length of the objective lens

665*. Why is no interference pattern is observed when two coherent sources are- **CBSE (AI)-2001**

(i) infinitely close to each other (ii) far apart from each other

[**Ans.** $\boldsymbol{\beta} = \frac{D\lambda}{d}$

(i) when sources are placed infinitely close to each other, $d \to 0$ ⇨ $\boldsymbol{\beta} \to \infty$
Even a single fringe may occupy the entire screen. Hence no interference pattern will be observed
(ii) when the distance d becomes too large, fringe width becomes too small to be detected. Hence no interference pattern will be observed

666*. Two slits are made $1\ mm$ apart and the screen is placed $1\ m$ away. What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern ? **CBSE (AI)-2016,2015**

[**Ans.** $\boldsymbol{\beta} = \frac{D\lambda}{d}$ & $\boldsymbol{y_0} = \frac{2D\lambda}{a}$

Given, $\boldsymbol{y_0} = 10\beta$ ⇨ $\frac{2D\lambda}{a} = 10\,\frac{D\lambda}{d}$ ⇨ $a = \frac{d}{5} = \frac{1}{5}mm = 0.5\ mm$

667*. (i) What is a Polaroid ? What does a polaroid consist **CBSE (AI)-2015,(DC)-2013,(AIC)-2001**

(ii) How does one demonstrate, using a suitable diagram, that unpolrised light when passed through a polaroid gets polarized ? **CBSE (D)-2014, (AI)-2012,2010**

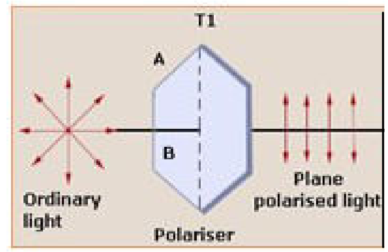
(iii) How will you use it to distinguish between unpolarised light and plane polarised light ? **CBSE (AI)-2015**

[**Ans. (i) Polaroid** : A Polaroid is a thin commercial sheet which makes use of the property of selective absorption to produce an intense beam of plane polarised light

A Polaroid consists of a long chain of molecules aligned in a particular direction

(ii) Plane Polarized light from Polaroid :

When an unpolarised light falls on it, the electric vectors oscillating along the direction of aligned molecules get absorbed and those oscillating in the direction perpendicular to the direction of alignment of molecules are passed through it. Hence the emergent light is plane polarised or linearly polarised



(iii) Distinction :

When unpolarised light is seen through a rotating Polaroid, intensity of transmitted light does not change, it remains $I_0/2$

When plane polarised light is seen through a rotating Polaroid, the intensity of transmitted light varies. It becomes twice maximum and twice zero in each rotation

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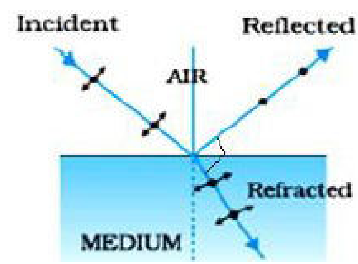
668*. When unpolarised light is incident on the boundary separating the two transparent media, explain, with the help of a suitable diagram, the conditions under which the reflected light gets polarised. Hence derive the relation of Brewster's angle in terms of the relative refractive index of the two media. **CBSE (AI)-2016,2014,2012,2008,(F)-2013,(D)-2014,2010**

[**Ans.** <u>**Polarization of light by reflection**</u>

When unpolarised light falls on a transparent surface, both the reflected and refracted light are found partially polarised. It is observed that, the degree of polarization of reflected light varies with angle of incidence. At Brewster's angle i_β, reflected light is completely plane polarised when the refracted and reflected rays make a right angle with each other.



i,e, when $i = i_\beta$, $i_\beta + r = 90$ ⇨ $r = 90 - i_\beta$

By Snell's law, $\mu = \frac{\sin i_\beta}{\sin r} = \frac{\sin i_\beta}{\sin(90 - i_\beta)} = \frac{\sin i_\beta}{\cos i_\beta} = \tan i_\beta$

⇨ $\boldsymbol{\mu = \tan i_\beta}$ This equation is called Brewster's law

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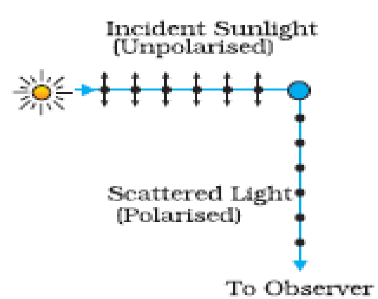
669*. Show, with the help of a suitable diagram, how unpolarized sunlight gets polarized due to scattering ? **CBSE (AI)-2017,2014,2013,(F)-2014**

[**Ans.** <u>**Polarization of sunlight due to scattering**</u>

Scattered light is found to be plane polarized perpendicular to the original direction.

Under the influence of electric field of incident wave, the electrons in the air molecules acquire components of motion in both the directions, parallel as well as perpendicular to the plane of paper (↥ as well as •). Charges accelerating parallel to ↥, do not radiates energy towards observer since their acceleration has no transverse component. Hence the radiation, scattered towards the observer gets linearly polarized.



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670*. The light from a clear blue portion of the sky shows a rise and fall in intensity when viewed through a polaroid which is rotated. Why ? **CBSE (AI)-2015**

[**Ans**. It is due to polarization of sunlight by scattering

Reason : When unpolarized sunlight falls on air molecules, it gets scattered and is found to be plane polarized ⊥ to the original direction hence shows rise & fall in intensity when viewed through a rotating polaroid.

671*. Unpolarised light is passed through a polaroid P_1. When this polarised beam passes through another polaroid P_2 and if the pass axis of P_2 makes angle θ with the pass axis of P_1, then write the expression for the polarised beam passing through P_2. **CBSE (AI)-2017**

[**Ans**. $I = \frac{I_0}{2} cos^2\theta$

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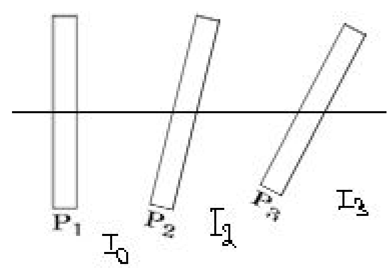
672*. Find an expression for intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids. In which position of the polaroid sheet will the transmitted intensity be maximum ? **CBSE (D)-2015,2010**

[**Ans**. Let $I_0 =$ Intensity of polarised light passing through $\mathbf{P_1}$

⇨ Intensity of light after passing through second polarizer $\mathbf{P_2}$

$I_2 = I_0\ cos^2\theta$ Now, Intensity of light after passing through third polarizer $\mathbf{P_3}$



$I_3 = I_2\ cos^2(90-\theta) = I_0\ cos^2\theta\ cos^2(90-\theta)$

⇨ $I_3 = I_0\ cos^2\theta\ sin^2\theta = \frac{I_0}{4}(\ 2\sin\theta\ \cos\theta)^2$

$$I_3 = \frac{I_0}{4}(\sin 2\theta)^2$$

⇨ Transmitted intensity will be –

(i) minimum when $\sin 2\theta = 0$ or $\theta = 0^0$ (ii) maximum when $\sin 2\theta = 1$ or $2\theta = 90^0$ or $\theta = 45^0$

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673*. A narrow beam of unpolarised light of intensity I_0 is incident on a Polaroid P_1. The light transmitted by it then incident on a second Polaroid P_2 with its pass axis making an angle of 60^0 with relative to the pass axis of P_1. Find the intensity of light transmitted by P_2. **CBSE (D)-2017**

[**Ans**. Intensity through P_1, $I_1 = I_0\ \overline{cos^2\theta} = \frac{I_0}{2}$ Intensity through P_2, $I_2 = I_1\ cos^2 60 = \frac{I_0}{2}\ (\frac{1}{2})^2 = \frac{I_0}{8}$

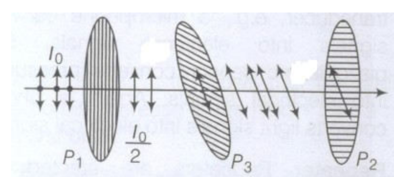
674*. Two Polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third Polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 60^0 with that of P_1. Determine the intensity of light transmitting through P_1, P_2 and P_3. **CBSE (AI) -2014**

[**Ans**. Intensity through P_1, $I_1 = I_0\ \overline{cos^2\theta} = \frac{I_0}{2}$

Intensity through P_3, $I_3 = I_1\ cos^2 60 = \frac{I_0}{2}\ (\frac{1}{2})^2 = \frac{I_0}{8}$

Intensity through P_2,

$I_2 = I_3\ cos^2(90-60) = \frac{I_0}{8}\ cos^2 30 = \frac{I_0}{8}\ (\frac{\sqrt{3}}{2})^2 = \frac{3I_0}{32}$



675*. Light waves from two coherent sources arrive at two points on a screen with path differences of 0 and $\lambda/2$. Find the ratio of intensities at these points. **CBSE (AIC)-2017**

[**Ans**. **(i)** $\Delta x = 0$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda = 0$ **(ii)** $\Delta x = \frac{\lambda}{2}$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$

⇨ $I_1 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2 0 = 4I_0$

& $I_2 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2\left(\frac{\pi}{2}\right) = 0$ ⇨ $\frac{I_1}{I_2} = \frac{4I_0}{0} = \infty$

676*. Find the intensity at a point on a screen in Young's double slit experiment where the interfering waves of equal intensity have a path difference of (i) λ /4, and (ii) λ /3. **CBSE (F)-2017**

[**Ans**. **(i)** $\Delta x = \frac{\lambda}{4}$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$ **(ii)** $\Delta x = \lambda/3$ ⇨ $\phi = \frac{2\pi}{\lambda} \times \lambda/3 = 2\pi/3$

$I_1 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2\left(\frac{\pi}{4}\right) = 4I_0\left(\frac{1}{\sqrt{2}}\right)^2 = 2I_0$ ⇨ $I_2 = 4I_0\ cos^2\left(\frac{\phi}{2}\right) = 4I_0\ cos^2(\pi/3) = 4I_0\ (1/2)^2 = I_0$

677*. In Young's double slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. Find out the intensity of light at a point where path difference is $\lambda/3$.

[Ans. (i) $\Delta x = \lambda$ ⇨ $\phi = \frac{2\pi}{\lambda} X \lambda = 2\pi$ **CBSE (D)-2015,2012,NCERT-2017**

⇨ $I_1 = 4I_0 \cos^2\left(\frac{\phi}{2}\right) = 4I_0 \cos^2(\pi) = 4I_0 (-1)^2 = 4I_0 = K$ (given)

(ii) $\Delta x = \lambda/3$ ⇨ $\phi = \frac{2\pi}{\lambda} X \lambda/3 = 2\pi/3$ ⇨ $I_2 = 4I_0 \cos^2\left(\frac{\phi}{2}\right) = 4I_0 \cos^2(\pi/3) = 4I_0 (1/2)^2 = I_0 = K/4$

678*. Two coherent sources have intensities in the ratio 25 : 16. Find the ratio of intensities of maxima to minima after interference of light occurs. **CBSE (DC)-2003**

[Ans. Given, $\frac{I_1}{I_2} = \frac{25}{16}$ ⇨ $\frac{{a_1}^2}{{a_2}^2} = \frac{25}{16}$ ⇨ $\frac{a_1}{a_2} = \frac{5}{4}$ $\frac{I_{max}}{I_{min}} = ?$

⇨ $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{\left(a_{1/a_2}+1\right)^2}{\left(a_{1/a_2}-1\right)^2} = \frac{\left(\frac{5}{4}+1\right)^2}{\left(\frac{5}{4}-1\right)^2} = 81 : 1$

679*. In Young's double slit experiment, two slits are $1\ mm$ apart and the screen is placed $1\ m$ away from the slits. Calculate the fringe width when light of wavelength $500\ nm$ is used. **CBSE (AI)E -2016**

[Ans. Given, $d = 1.mm = 1 X 10^{-3}m$, $D = 1\ m$, $\lambda = 500\ nm = 500\ X10^{-9}m, = ?$

fringe width, $\beta = \frac{D\lambda}{d} = \frac{1 X 500 X 10^{-9}}{1 X 10^{-3}} = 5X\ 10^{-4}\ m = 0.5\ mm$

680*.-A beam of light consisting of two wavelengths, $800\ nm$ and 600 nm, is used to obtain the interference fringes in a Young's double slit experiment on a screen is placed $1.4\ m$ away. If two slits are separated by $0.28\ mm$, Calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

[Ans. Given, $\lambda_1 = 800\ nm = 800\ X10^{-9}m$, $\lambda_2 = 600\ nm = 600\ X10^{-9}m$, $D = 1.4\ m$, **CBSE (AI)-2012**

$d = 0.28\ mm = 0.28\ X\ 10^{-3}m$, Least distance of coincide $y = ?$

condition for coincide is

$n\beta_1 = (n+1)\beta_2$ ⇨ $n \frac{D\lambda_1}{d} = (n+1)\frac{D\lambda_2}{d}$ ⇨ $n\ \lambda_1 = (n+1)\lambda_2$

⇨ $n\ X\ 800\ X\ 10^{-9} = (n+1)\ X\ 600\ X\ 10^{-9}$

⇨ $n\ X\ 8 = 6\ n + 6$ ⇨ $n = 3$ ⇨ Required least distance

$y = n\beta_1 = 3\frac{D\lambda_1}{d} = 3X\ \frac{1.4\ X\ 800\ X\ 10^{-9}}{0.28X\ 10^{-3}} = \frac{3\ X1.4\ X\ 8\ X\ 10^{-3}}{2.8} = 1.2\ X10^{-2}\ m$

681*. A slit of width $'a'$ is illuminated by red light of wavelength $6500\ A^0$. For what value of $'a'$ will -

(i) the first minimum fall at an angle of diffraction of 30^0 **CBSE (AI)-2009, (F)-2006**

(ii) the first maximum fall at an angle of diffraction of 30^0

[Ans. Given, $\lambda = 6500\ A^0 = 6500\ X10^{-10}m$

(i) $a \sin\theta_1 = \lambda$

⇨ $a = \frac{\lambda}{\sin\theta_1} = \frac{6500\ X10^{-10}}{\sin 30} = \frac{6500\ X10^{-10}}{1/2} = 2\ X\ 6500\ X10^{-10} = 1.3\ X\ 10^{-6}m$

(ii) $a \sin\theta_1 = 3\lambda/2$

⇨ $a = \frac{3\lambda}{2\sin\theta_1} = \frac{3\ X\ 6500\ X10^{-10}}{2\ X \sin 30} = \frac{3\ X\ 6500\ X10^{-10}}{2\ x1/2} = 3\ X\ 6500\ X10^{-10} = 1.95\ X\ 10^{-6}m$

682*.-The wavelengths of two Sodium light of $590\ nm$ and $596\ nm$ are used in turn to study the diffraction taking place at a single slit of aperture $2\ X\ 10^{-6}m$. The distance between the slit and the screen is $1.5\ m$. Calculate the separation between the positions of first maxima of the diffraction pattern observed in the two cases.

CBSE (AIC)-2017,(AI)-2014,(D)-2013,(DC)-2006

[Ans. Given, $\lambda_1 = 590\ nm = 500\ X10^{-9}m$, $\lambda_1 = 596\ nm = 596\ X10^{-9}m$, $D = 1.5\ m$, $a = 2\ X\ 10^{-6}m$, $y_2 - y_1 = ?$

⇨ ϕϕϕ

for first maxima, $y_1 = \frac{3D\lambda}{2a}$

⇨ $y\ \ -y = \frac{3D}{}(\lambda\ \ - \lambda\ ) = \frac{3\ X\ 1.5}{}(596\ X\ 10^{-9} - 590\ X\ 10^{-9}) = \frac{3X\ 1.5\ X6\ X10^{-3}}{} = \quad 10\quad m$

==

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

Chapter–11: Dual Nature of Radiation and Matter

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

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

701. What is Photoelectric effect ? **CBSE (AI)-2007,2004,(D)-2002**

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

702. Define the term Work function of a photoelectric surface. **CBSE (AI)-2007,2004,(D)-2002**

[**Ans. (i) Work function (W)** : The minimum energy required to by an electron to just eject out from the metallic surface is called work function of that surface

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

703. Define the term (i) cut off frequency & (ii) Threshold wavelength in photoelectric emission.
CBSE (F) -2016,2011,(D)-2004,(AI)-2002

[**Ans. (i) Cut off frequency (ν_0)** : The minimum frequency of incident radiation, **below which** photoelectric emission is **not** possible, is called cut off frequency or threshold frequency

(ii) Threshold Wavelength (λ_0): The maximum wavelength of incident radiation, **above which** photoelectric emission is **not** possible, is called threshold wavelength

704. Define the term 'intensity of radiation' in photon picture and write its S.I. unit. **CBSE (AI)-2016,2015**

[**Ans. Intensity of radiation** : Number of photons incident per unit area per second normal to the surface, is defined as the intensity of radiation. Its S.I. unit is Watt/ m^2

705. Define the term "stopping potential" or "Cut-off Potential" in relation to photoelectric effect.

[**Ans. Stopping potential or Cut-off Potential (V_0)** : **CBSE (AI) -2011,2008,2002, (D) -2005,2002**

The minimum negative potential of anode at which photoelectric current becomes zero is called stopping potential

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

[**Ans.** Photoelectric effect

707. What is the stopping potential applied to a photocell if the maximum kinetic energy of a photoelectron is 5 eV ?

[**Ans.** $V_0 = -5\,V$] **CBSE (AI) -2009, 2008, (D)-2001**

708. The stopping potential in an experiment is 1.5 V. What is the maximum K.E. of photoelectrons emitted ?

[**Ans.** $E_{k_{max}} = 1.5$ eV] **CBSE (AI)-2009**

709. Two metals A and B have work functions 4 eV and 10 eV respectively. Which metal has the highest threshold wavelength ? **CBSE (AI) -2004, (F)-2005**

[**Ans. Metal A** has highest threshold wavelength as W= $\frac{hc}{\lambda_0}$

710. Two metals X and Y, when illuminated with appropriate radiations emit photoelectrons. The work function of X is higher than that of Y. Which metal will have higher value of cut off frequency & why ? **CBSE (AIC)-2001**

[**Ans. Metal X** has the higher cut off frequency because $\nu_0 = W/h$ & $W_X > W_Y$

711. A photosensitive surface emits photoelectrons when red light falls on it. Will the surface emit photoelectrons when blue light is incident on it ? Give reason. **CBSE (F)-2017**

[**Ans. Yes,** **Reason :** $\boldsymbol{\nu_{Blue}} > \boldsymbol{\nu_{Red}}$ ⇨ $(h\boldsymbol{\nu})_{Blue} > (h\boldsymbol{\nu})_{Red}$

712. For a photosensitive surface, threshold wavelength is λ_0, Does photoemission occure, if the wavelength (λ) of the incident radiation is (i) more than λ_0 (ii) less than λ_0. Justify your answer. **CBSE (AI)-2010, (AIC)-2001**

[**Ans. (i) No (ii) yes** as for photoelectric emission $\frac{hc}{\lambda} \geq \frac{hc}{\lambda_0}$ hence $\lambda \leq \lambda_0$]

713. Electrons are emitted from a photosensitive surface when it is illuminated by green light but does not take place by yellow light. Will the electrons be emitted when the surface is illuminated by (i) red light, and (ii) blue light ?

[**Ans.(i) No (ii) yes** as λ_0 is for wavelength of green light] **CBSE (AI)-2012,2007, (D)-2005**

714. Red light however bright is it, cannot produce the emission of electrons from a clean zinc surface but even a weak Ultraviolet radiation can do so. Why ? **CBSE (AI)-2004, (AIC)-2003**

[**Ans.** The energy of photon of red light is less than work function of zinc surface and the energy of photon of Ultraviolet radiation is more than the work function of zinc surface

715. Work function of sodium is 2.3 eV. Does sodium show photoelectric emission for light of wavelength 6800 A^0 ?

[**Ans.** $E = \frac{hc}{\lambda} = \frac{6.6\,X 10^{-34}\,X 3\,X 10^{8}}{6800\,X\,10^{-10}\,X\,1.6\,X\,10^{-19}}\,eV = 1.8\,eV$ **CBSE (D)-2001**

⇨ $E <$ W, Hence photoelectric emission will **not** take place

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

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

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

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

718. Ultraviolet radiations of different frequencies ν_1 and ν_2 are incident on two photosensitive materials having work functions W_1 and $W_2 (W_1 > W_2)$ respectively. The kinetic energy of the emitted electrons is same in both the cases. Which one of the two radiations will be of higher frequency and why? **CBSE (AI)-2007**

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

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

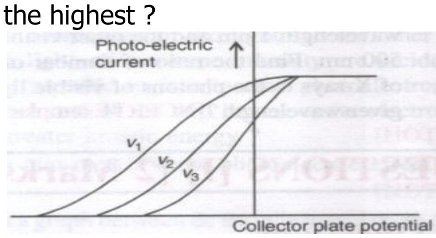
[Ans. $E_{K_{max}} = h\nu - W$ & $W = hf$

$$\Rightarrow \frac{\frac{1}{2} m v_1^2}{\frac{1}{2} m v_2^2} = \frac{h\nu_1 - W}{h\nu_2 - W} = \frac{h\,(2f) - hf}{h\,(5f) - hf} = \frac{hf}{4hf} = \frac{1}{4} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{1}{4} \Rightarrow v_1 : v_2 = 1 : 2$$

720. The graph below shows variation of photocurrent with collector plate potential for different frequencies of incident radiation.

(i) Which physical parameter is kept constant for the three curves ? **CBSE (F) -2009**

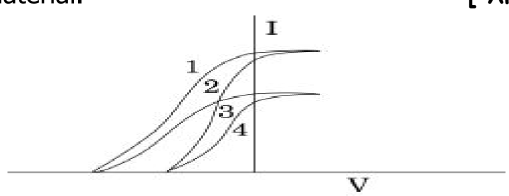
(ii) Which frequency (ν_1, ν_2 or ν_3) is the highest ? **[Ans**. (i) Intensity (ii) ν_1 is highest]



721. The given graph shows the variation of photoelectric current (I) with applied voltage (V) for two different materials and for two different intensities of the incident radiations. Identify the pair of curves that corresponds to

(i) different materials but same intensity of incident radiation **CBSE (AI)-2016,(D)-2013**

(ii) different intensities but same material. **[Ans**. (i) (1,2) and (3,4) (ii) (1,3) and (2,4)]



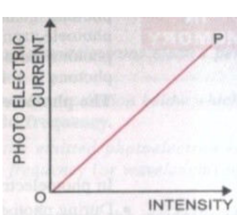
722. (i) Plot a graph showing the variation of photoelectric current with intensity of light.

(ii) Show the variation of photocurrent with collector plate potential for different intensity but same frequency of incident radiation

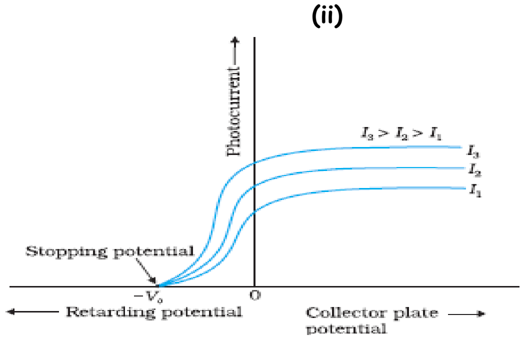
(iii) Show the variation of photocurrent with collector plate potential for different frequency but same intensity of incident radiation

[Ans. **CBSE (F) -2016,(D)-2014,(AI)-2010,(AIC)-2011**

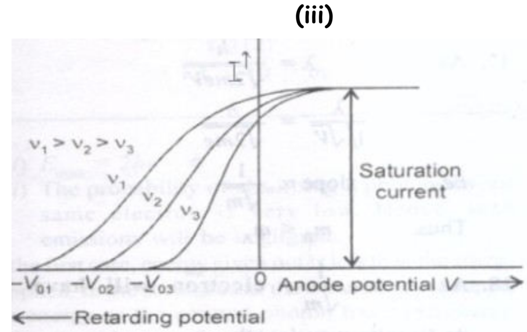
(i)



(ii)



(iii)



723. Two monochromatic beams, one red and other blue, have the same intensity. In which case- **CBSE (AI)-2015**
(i) the number of photons per unit area per second is larger,
(ii) the maximum kinetic energy of the photoelectrons is more ? Justify your answer.
[**Ans.** (i) number of photons per unit area per second is same because both red and blue light has the same intensity
(ii) blue light, because $E_{k_{max}} = \frac{hc}{\lambda} - W$ & $\lambda_{blue} < \lambda_{red}$

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

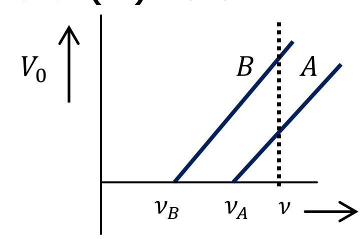
725. A beam of monochromatic radiation is incident on a photosensitive surface. Answer the following questions giving reasons :-
(i) Do the emitted photoelectrons have the same kinetic energy ? **CBSE (F)-2015**
(ii) Does the kinetic energy of the emitted electrons depend on the intensity of incident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

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

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

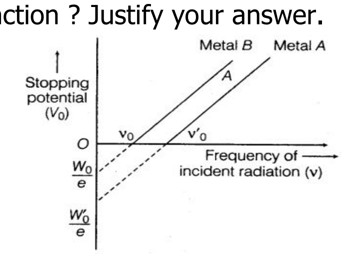
728. Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation. **CBSE (AI)-2017,(D)-2016**
[**Ans.** (i) Instantaneous emission of photoelectrons
(ii) Existence of threshold frequency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

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



[**Ans.** (i) V_0 is more for material B
Reason : $eV_0 = h(\nu - \nu_0)$ ⇨ $V_0 = \frac{h}{e}(\nu - \nu_0)$
V_0 is more for lower value of ν_0
(ii) No, slope = h/e, which is constant

730. The graph shows the variation of stopping potential with frequency of incident radiation for two photosensitive metals A and B. Which of the two has higher value of work function ? Justify your answer. **(AI) -2014**



[**Ans. Metal A has higher work function**
Justification : As $(\nu_0)_A > (\nu_0)_B$
⇨ $(h\nu_0)_A > (h\nu_0)_B$
⇨ $W_A > W_B$

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

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

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

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

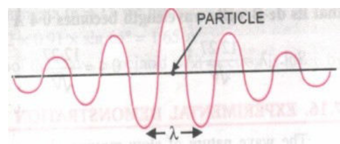
[**Ans**. Nature is symmetrical and that the two basic physical entities, matter and energy, must have symmetrical character So, if radiation shows dual nature, matter should also show it

733. Name the two quantities which determine the wavelength and frequency of de-Broglie wave associated with moving electron.

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

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

[**Ans**.



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

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

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

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

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

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

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

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

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

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

739. (i) Name an experiment which shows wave nature of electrons. **CBSE (F)-2011, (AIC)-2006,2004**

(ii) Which phenomenon was observed in this experiment using electron beam ?

(iii) Also name the important hypothesis that was confirmed by this experiment.

[**Ans**. **(i)** Davison- Germer experiment

(ii) Diffraction

(iii) de-Broglie hypothesis

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

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

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

OR

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

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

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

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

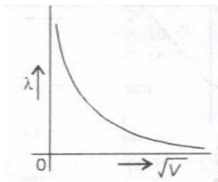
743. If the potential difference used to accelerate electrons is doubled, by what factor does the de-Broglie wavelength associated with the electron changed ? **CBSE (AI)-2013,2006,2004**

[**Ans**. becomes $\frac{1}{\sqrt{2}}$ times as $\lambda = \frac{\mathrm{h}}{\sqrt{2\,m\,\mathrm{qV}}}$ ⇨ $\lambda \propto \frac{1}{\sqrt{\mathrm{V}}}$

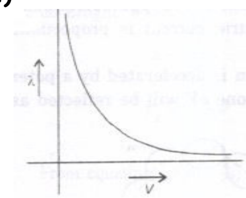
744. (i) Show on a graph the variation of the de-Broglie wavelength (λ) associated with an electron with the square root of accelerating potential V. **CBSE (F)-2012**

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

[**Ans**. **(i)**



(ii)



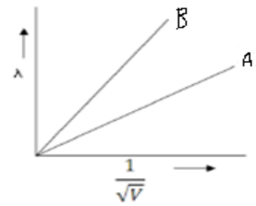
745. (i) Plot a graph showing variation of de-Broglie wavelength λ versus $\frac{1}{\sqrt{V}}$, where V is accelerating potential for two particles A and B carrying same charge but of masses m_1, $m_2 (m_1 > m_2)$.

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

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

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

⇨ slope $\propto \frac{1}{\sqrt{m}}$



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

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

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

[**Ans**. $E_K = 120$ eV ⇨ $V = 120$ Volts

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

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

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

⇨ $\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p}{m_\alpha}} \times \sqrt{\frac{q_p}{q_\alpha}} = \sqrt{\frac{m_p}{4m_p}} \times \sqrt{\frac{q_p}{2q_p}} = \frac{1}{2\sqrt{2}}$

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

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

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

Thus electron will have the greater de-Broglie wavelength

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

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

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

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

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

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

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

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

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

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

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

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

(iii) For a given photosensitive surface, there exists a certain minimum frequency of incident radiation, called threshold frequency (ν_0) below which no photoelectric emission takes place, whatever may be the intensity of incident radiation

(iv) The photoelectric emission is an instantaneous process

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

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

(ii) According to wave theory, if the intensity of incident radiation is sufficient photoelectron emission should take place, whatever may be the frequency. But, experimental observations shows that, if $\nu < \nu_0$, no emission of photo electrons takes place, whatever may be the intensity

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

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

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

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

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

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

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

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

⇨ $E_{K_{max}} = h\nu - W = h\nu - h\nu_0$ [$\because W = h\nu_0$]

⇨ $E_{K_{max}} = h(\nu - \nu_0)$ This is Einstein's photoelectric equation

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

(a) Existence of threshold frequency In the equation $E_{k_{max}} = h(\nu - \nu_0)$

If $\nu < \nu_0$, $E_{k_{max}}$ will be negative, which is not possible. Hence ν must be greater than ν_0.

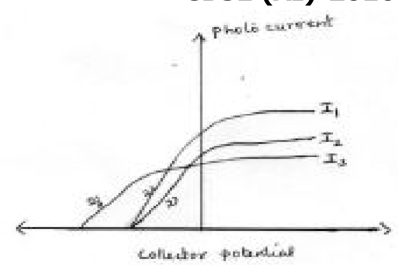
(b) The K.E. of photoelectrons is independent of intensity of incident light.

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

756. (i) Plot a graph showing the variation of photocurrent versus collector potential for three different intensities $I_1 > I_2 > I_3$, two of which (I_1 and I_2) have the same frequency ν and the third has frequency $\nu_1 > \nu$.

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

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



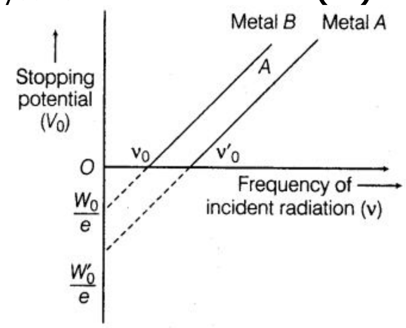
(ii) as per the Einstein's equation

$eV_0 = h(\nu - \nu_0)$ which concludes

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

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

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



[Ans. Metal A has higher threshold frequency

Justification : $eV_0 = h\nu - W$

⇨ $\frac{V_0}{e} = \left(\frac{h}{e}\right)\nu - \frac{W}{e}$

⇨ $\frac{W}{e}$ = Intercept on y-axis

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

⇨ $W_A > W_B$ ⇨ $(h\nu_0)_A > (h\nu_0)_B$

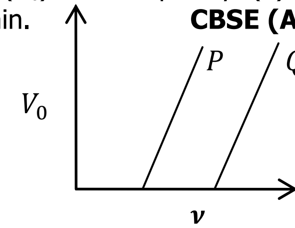
⇨ $(\nu_0)_A > (\nu_0)_B$

==

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

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

(ii) What does the slope of lines depict ?



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

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

⇨ $(h\nu_0)_Q > (h\nu_0)_P$

⇨ $W_Q > W_P$

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

Reason : $eV_0 = h\nu - W$

⇨ $\frac{V_0}{e} = \left(\frac{h}{e}\right)\nu - \frac{W}{e}$

On comparing with $y = mx + c$ ⇨ slope $= \left(\frac{h}{e}\right)$

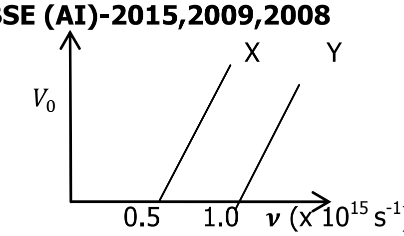
==

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

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

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

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



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

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

⇨ $\left(\frac{c}{\lambda_0}\right)_X < \left(\frac{c}{\lambda_0}\right)_Y$

⇨ $(\lambda_0)_X > (\lambda_0)_Y$

(ii) Metal X will emit electrons of larger kinetic energy

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

⇨ $(h\nu_0)_X < (h\nu_0)_Y$

⇨ $W_X < W_Y$

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

metal X will emit electrons of larger kinetic energy

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

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

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

⇨ $E_k = e\,V = \frac{1}{2}mv^2$

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

de-Broglie wavelength,

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

⇨ $\lambda = \frac{h}{\sqrt{2meV}} = \frac{6.6\,X\,10^{-34}}{\sqrt{2X\,9.1\,X\,10^{-31}X1.6\,X10^{-19}V}} = \frac{12.27\,X\,10^{-10}}{\sqrt{V}}$

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

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

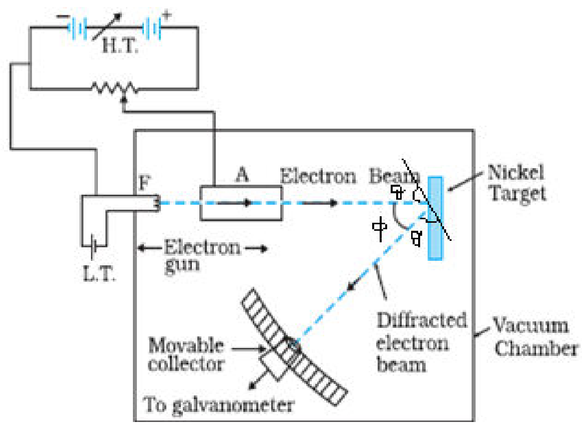
[**Ans. Davisson – Germer experiment** : It provides first experimental proof of concept of wave nature of electrons

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

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

Working:

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



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

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

From Bragg's diffraction condition,

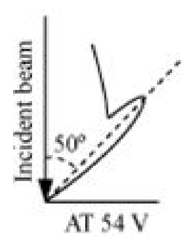
$2d\ \sin\theta = n\lambda$

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

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

Now the de-Broglie wavelength

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



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

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

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

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

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

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

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

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

OR

An electromagnetic wave of wavelength λ is incident on a photosensitive surface of negligible work function. If the photoelectrons emitted from this surface have the de-Broglie wavelength λ_1, Prove that, $\lambda=(\frac{2mc}{h})\lambda_1^2$ **CBSE (D)-2008**

[Ans. As, W is negligible

⇨ $E_{K_{max}} = \text{h}\nu - W = \text{h}\nu - 0 = \text{h}\nu = \frac{\text{h}c}{\lambda}$

Now de-Broglie wavelength,

$$\lambda_1 = \frac{\text{h}}{\sqrt{2\,m\,E_k}} = \frac{\text{h}}{\sqrt{2\,m\,\text{X}\,\frac{\text{h}c}{\lambda}}} = \sqrt{\frac{\text{h}\,\lambda}{2mc}} \quad ⇨ \lambda_1^2 = \frac{\text{h}\,\lambda}{2mc} \quad ⇨ \lambda=(\frac{2mc}{\text{h}})\,\lambda_1^2$$

764. A proton and an $\alpha-\text{particle}$are accelerated through the same potential difference. Which on of the two has
(i) greater de-Broglie wavelength, and **CBSE (AI)-2016,(D)-2014,2010,2009**
(ii) less kinetic energy ? Justify your answer.

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

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

(ii) $E_k = qV$ ⇨ $E_k \propto q$

As $q_{proton} < q_{\alpha-particle}$ ⇨ $E_{k_{proton}} < E_{k_{\alpha-particle}}$

765. A deuteron and an $\alpha-particle$ are accelerated with the same accelerating potential. Which one of the two has -
(i) greater value of de-Broglie wavelength associated with it, it, and **CBSE (AI)-2015,(D) -2014**
(ii) less kinetic energy ? Explain.

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

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

(ii) $E_k = qV$ ⇨ $E_k \propto q$

As $q_{deutron} < q_{\alpha-particle}$ ⇨ $E_{k_{deutron}} < E_{k_{\alpha-particle}}$

766. A proton and an $\alpha-particle$ have the same de-Broglie wavelength. Determine the ratio of-
(i) their accelerating potentials, and (ii) their speeds. **CBSE (D) -2015, (DC)-2009**

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

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

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

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

767. A proton and a deuteron are accelerated through the same accelerating potential. Which one of the two has –
(i) greater value of de-Broglie wavelength associated with it, it, and **CBSE (D)-2014**
(ii) less momentum ? Give reasons to justify your answer.

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

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

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

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

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

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

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

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

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

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

770. The work function for the following metals is given : **CBSE (F)-2016**

Na : 2.75 eV and Mo : 4.175 eV

(i) Which of these will not give photoelectron emission from a radiation of wavelength 3300 A^0 from a laser beam ?
(ii) What happens if the source of laser beam is brought closer ?

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

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

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

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

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

(ii) $eV_0 = E_{k_{max}} = 0.34$ eV ⇨ $V_0 = 0.34\ V$

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

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

[Ans. (i) (a) K.E. of fastest electron

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

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

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

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

⇨ $W = \frac{hc}{\lambda} - eV_0 = \frac{6.6 \text{ X } 10^{-34} \text{ X } 3 \text{ X } 10^{8}}{2271 \; X \; 10^{-10}} - 1.3 \text{ X } 1.6 \text{ X} 10^{-19} = 1.6 \text{ X } 10^{-19}$ (5.5– 1.3) J = 4.2 eV

Also, $W = \frac{hc}{\lambda_0}$ ⇨ $\lambda_0 = \frac{hc}{W} = \frac{6.6 \text{ X } 10^{-34} \text{ X } 3 \text{ X } 10^{8}}{1.6 \; X 4.2 \; X \; 10^{-19}} = 2.977 \text{ X } 10^{-7}\ m = 2977\ A^0$

As λ (= 6328 A^0) > λ_0(= 2977 A^0)

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

774. Calculate the- **NCERT-2017**

(a) momentum, and

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

[**Ans**. (a) $p = \sqrt{2\,m\,E_k} = \sqrt{2\,m\,eV} = \sqrt{2\ X\,9.1\ X\,10^{-31}\ X\,1.6\ X10^{-19} X\,56} = 4.04\ X\,10^{-24}\ Kg\ m/s$

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

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

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

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

(i) their momenta

(ii) the energy of photon, and

(iii) the kinetic energy of electron

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

(ii) energy of photon $= \frac{hc}{\lambda} = \frac{6.6\ X\,10^{-34}\ X3\ X\,10^{8}}{2.0\ X\,10^{-9}} = 9.945\ X10^{-17}$ J.

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

777. An electron and a proton each has de-Broglie wavelength of 1.6 nm. **CBSE (F)-2013**

(i) write the ratio of their linear momenta

(ii) compare the kinetic energy of the proton with that of the electron.

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

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

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

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

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

⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{2}{1}$ ⇨ $\lambda_2 = 2\,\lambda_1$

Hence, de-Broglie wavelength will become double

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

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

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

⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{4}{1}$ ⇨ $\lambda_2 = 4\,\lambda_1$

Hence, de-Broglie wavelength will become four times

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

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

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

⇨ $\frac{\lambda_2}{\lambda_1} = \frac{n_2}{n_1} = \frac{1}{4}$ ⇨ $\lambda_2 = \lambda_1/4$

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

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Unit VIII: Atoms and Nuclei **15 Periods**

Chapter–12: Atoms

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum.

Chapter–13: Nuclei

Composition and size of nucleus, Radioactivity, alpha, beta and gamma particles/rays and their properties; radioactive decay law.

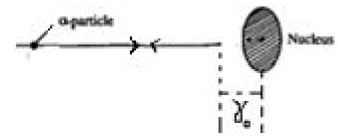
Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

801. Define the distance of closest approach. **CBSE (D)-2017**

[Ans. Distance of closest approach : The minimum distance up to which an α-particle can approach the nucleus just before retracing its path, is known as distance of closest approach

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K}$$

$= 2.5 \times 10^{-14}$ m



802. The K. E. of α –particle incident on gold foil is doubled. How does the distance of closest approach change?

[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K}$ ⇨ $r_0 \propto \frac{1}{E_K}$ **CBSE (D)-2017,(AI)-2015,2012**

hence, distance of closest approach will be halved when K.E. is doubled

803. In the Rutherford's scattering experiment the distance of closest approach for an α –particle is d_0. If α –particle is replaced by a proton, how much kinetic energy in comparison to α –particle will it require to have the same distance of closest approach d_0 ? **CBSE (F)-2009**

[Ans. $E_{K_\alpha} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{d_0}$ & $E_{K_p} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{d_0}$ ⇨ $E_{K_p} = \frac{1}{2}E_{K_\alpha}$

804. Determine the distance of closest approach when an alpha particle of kinetic energy 4.5 MeV strikes a nucleus of $Z = 80$, stops and reverses its direction. **CBSE (AI)-2015, 2012, (AIC)-2015**

[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K} = 9 \times 10^9 \times \frac{2 \times 80 \times (1.6 \times 10^{-19})^2}{4.5 \times 10^6 \times 1.6 \times 10^{-19}} = 5.12 \times 10^{-14}$ m

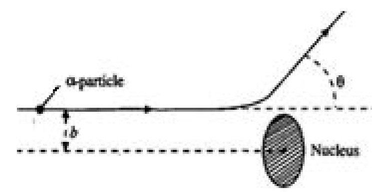
805. (i) What is Impact parameter ? **CBSE (AIC)-2015**

(ii) What is the significance of impact parameter ?

[Ans. (i) Impact parameter (b) :

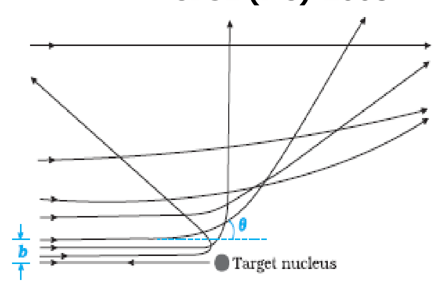
It is the perpendicular distance of the initial velocity vector of the α-particle from the

(ii) Significance : It gives an estimate of size of nucleus



806. The trajectories, traced by different α –particles, in Geiger-Marsden experiment were observed as shown in figure. (a) What names are given to the symbols 'b' and 'θ' shown here ? **CBSE (DC)-2008**

(b) What can we say about values of b for (i) $\theta = 0^0$ (ii) $\theta = \pi$ radians ?



[Ans. (a) symbol **'b'** represents **impact parameter**

& **'θ'** represents **scattering angle**

(b) $b = \frac{Ze^2 \cot\theta/2}{4\pi\varepsilon_0 (\frac{1}{2}m u^2)}$

(i) **when $\theta = 0^0$**, **b** is maximum & represent the **atomic size**

(ii) **When $\theta = \pi$ radians, b** is minimum & represent **nuclear size**

807. State Bohr's quantization condition for defining stationary orbits. **CBSE (D)-2016,(D)-2012,(F)-2010**

[Ans. Bohr's quantization condition : electrons can revolve only in those orbits in which their angular momentum is an integral multiple of $\frac{h}{2\pi}$

i, e, $m v r = n\frac{h}{2\pi}$ where $n = 1,2,3$,– – – – – – –

These orbits are called stationary orbits and electrons do not radiate energy while revolving in these orbits

908. State Bohr postulate of hydrogen atom that gives the relationship for the frequency of emitted photon in a transition. **OR** **CBSE (F)-2016**

State Bohr's postulate of hydrogen atom which successfully explains emission lines in the spectrum of hydrogen atom.

[Ans. Bohr's postulate of transition : **CBSE (AI)-2015, (D)-2013**

When an electron makes a transition from higher (E_2) to lower energy level (E_1), a photon is emitted which have the energy equal to the energy difference of two levels.

i, e, $h\nu = E_2 - E_1$ This equation is called Bohr's frequency condition

809. The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of electron in this state ? **CBSE (AI)-2014, 2011,(AIC)-2002**

[Ans. $E_K = +13.6\ eV$ & $P.E. = 2\ X\ (-13.6) = -27.2\ eV$

810. The total energy of an electron in the first excited state of hydrogen atom is $-3.4\ eV$. What is the kinetic and potential energy of the electron in this state ? **CBSE (DC)-2010,(D)-2001**

[Ans. $E_K = +3.4\ eV$ & $P.E. = 2\ X\ (-3.4) = -6.8\ eV$

811. Given the value of the ground state energy of hydrogen atom as −13.6 eV. Find out its kinetic and potential energy in the ground and second excited states. **CBSE (AI)-2015,2008**

[Ans. $\boldsymbol{E_n} = -\frac{\mathbf{13.6}}{\boldsymbol{n^2}}\text{eV}$

For ground state $n = 1$, ⇨ $E_1 = -13.6\ eV$ ⇨ $E_K = +13.6\ eV$ & $P.E. = 2\,X\,(-13.6) = -27.2\ eV$

For II excited state $n = 3$, ⇨ $E_3 = -\frac{\mathbf{13.6}}{\mathbf{3^2}} = -1.51\ eV$ ⇨ $E_K = +1.51\ eV$ & $P.E. = 2\,X\,(-1.51) = -3.02\ eV$

812. The value of ground state energy of hydrogen atom is −13.6 eV. **CBSE (AI)-2008, 2001, (F)-2009**

(i) what does the negative sign signify ?

(ii) How much energy is required to take an electron in this atom from the ground state to the first excited state ?

[Ans. (i) Negative sign shows that electron is bound with the nucleus by electrostatic force

(ii) $\boldsymbol{E_n} = -\frac{\mathbf{13.6}}{\boldsymbol{n^2}}\text{eV}$ & For ground state n =1 and for first excited state n =2

⇨ $\Delta E = E_2 - E_1 = -\frac{\mathbf{13.6}}{\mathbf{2^2}} - \left(-\frac{\mathbf{13.6}}{\mathbf{1^2}}\right) = -3.4 + 13.6 = 10.2\ \text{eV}$

813. In the ground state of hydrogen atom, its Bohr radius is given as 5.3 X $10^{-11}\ m$. The atom is excited such that the radius becomes 21.2X $10^{-11}\ m$. Find - **CBSE (AI)-2016**

(i) the value of principal quantum number and

(ii) the total energy of the atom in this excited state.

[Ans. (i) $\boldsymbol{r = n^2\ r_0}$ ⇨ $\boldsymbol{n^2 = \frac{r}{r_0}}$ ⇨ $\boldsymbol{n^2} = \frac{21.2\ X\ 10^{-11}}{5.3\ X\ 10^{-11}} = 4$ ⇨ $n = 2$

(ii) $\boldsymbol{E_n} = -\frac{\mathbf{13.6}}{\boldsymbol{n^2}}\text{e}$ ⇨ $\boldsymbol{E_2} = -\frac{\mathbf{13.6}}{\mathbf{2^2}}\text{eV} = -3.4\ \text{eV}$

814. Calculate the de-Broglie wavelength of the electron orbiting in the $n = 2$ state of hydrogen atom.

[Ans. $\boldsymbol{E_k} = \frac{\mathbf{13.6}}{\boldsymbol{n^2}}\text{eV} = \frac{\mathbf{13.6}}{\mathbf{2^2}}\text{eV} = \frac{\mathbf{13.6}}{\mathbf{4}}\text{eV} = 3.4\ \text{eV} = 3.4\ X\ 10^{-19}\text{J}$ **CBSE (AI)-2016**

de-Broglie wavelength, $\lambda = \frac{\text{h}}{\sqrt{2mE_k}} = \frac{6.6\ X\ 10^{-34}}{\sqrt{2X\ 9.1\ X\ 10^{-31}\ X3.4\ X\ 1.6\ X10^{-19}}} = 0.6\ X\ 10^{-10}\ m$

815. What is the longest wavelength of photon that can ionize a hydrogen atom in its ground state ? Specify the type of radiation. **CBSE (D)-2007**

[Ans. $\Delta E = \frac{hc}{\lambda}$ ⇨ $\lambda = \frac{hc}{\Delta E} = \frac{6.6\ X\ 10^{-34}\ X\ 3\ X\ 10^8}{13.6\ X\ 1.6\ X\ 10^{-19}} = 0.910\ X\ 10^{-10}\ m$, Ultraviolet region

816. Write the expression for Bohr's radius in hydrogen atom. **CBSE (D)-2010**

[Ans. $r_0 = \frac{\varepsilon_0 \text{h}^2}{\pi m e^2} = 0.53\ A^0$

817. In hydrogen atom, if the electron is replaced by a particle which is 200 times heavier but have the same charge, How would its radius change ? **CBSE (F)-2008**

[Ans. radius will be 1/200 times, **Reason :** $r = \frac{\varepsilon_0\, n^2\, \text{h}^2}{\pi\, m\, Ze^2}$ ⇨ $\boldsymbol{r \propto \frac{1}{m}}$

818. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom ?

[Ans. 4:1 as $\boldsymbol{r \propto n^2}$ **CBSE (D)-2010**

819.The radius of innermost electron orbit of a hydrogen atom is 5.3 X 10^{-11} m. What is the radius of orbit in the second excited state ? **CBSE (D)-2010**

[Ans. For II excited state $n = 3$ $\boldsymbol{r = n^2\ r_0} = \mathbf{3^2}$ **X** 5.3 X 10^{-11} = 47.7 X $10^{-11}\ m$

820. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom. **CBSE (D)-2017**

[Ans. $r_0 = 0.53\ A^0$ & For ground state $n = 1$

By the de-Broglie relation,

$2\pi r = n\,\lambda$ ⇨ $2\ X\ 3.14\ X\ 0.53\ X\ 10^{-10} = 1\ X\ \lambda$ ⇨ $\lambda = 3.32\ X\ 10^{-10}\ m = 3.32\ A^0$

821. Use Bohr model of hydrogen atom to calculate the speed of the electron in the first excited state.
[Ans. For first excited state, n = 2 **CBSE (AI)-2016**

$v_n = \frac{1}{137}\frac{c}{n}$ ⇨ $v_2 = \frac{1}{137} X \frac{3 X 10^8}{2} = 1.09 X 10^6$ m/s

822. Use Rydberg formula to determine the wavelength of H_α line. (Given : Rydberg's constant R =1.03 X 10^7 m^{-1})
[Ans. For H_α line, n_1=2 and n_2=3 **CBSE (AI)-2015, (D)-2012**

⇨ $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$ ⇨ $\lambda = \frac{36}{5R} = \frac{36}{5 X 1.03 X 10^7} = 6990 A^0$

823. When H_α line in the emission spectrum of hydrogen atom obtained ? Calculate the frequency of photon emitted during this transition. **CBSE (AI)-2016**
[Ans. for H_α line/first line in Balmer series transition is from $n = 3$ to $n = 2$

$\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

⇨ $\nu = \frac{c}{\lambda} = c X \frac{5R}{36} = \frac{3X10^8 X 5 X 1.09 X 10^7}{36} = 4.7 X 10^{14}$ Hz

824. Calculate the shortest wavelength of the spectral lines emitted in Balmer series. (Rydberg constant, $R = 10^7 m^{-1}$)
[Ans. $\frac{1}{\lambda_{min}} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = R\left[\frac{1}{4} - 0\right] = \frac{R}{4}$ ⇨ $\lambda_{min} = \frac{4}{R} = \frac{4}{10^7}$ m = 4000 A^0 **CBSE (AI)-2016**

825. Calculate the wavelength of radiation emitted when electron in a hydrogen atom jumps from $n = \infty$ to $n = 1$.
[Ans. $\frac{1}{\lambda} = R\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right] = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = R\,[1 - 0] = R$ **CBSE (AI)-2016**

⇨ $\lambda = \frac{1}{R} = \frac{1}{1.09 X 10^7} m = 912 A^0$

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826. (i) Write the relation between mass number and radius of a nucleus. **CBSE (F)-2012,(AI)-2011**
(ii) Show that nuclear density in a given nucleus is independent of mass number A. **CBSE (D)-2015,2013,2012**
[Ans. (i) $\boldsymbol{R} = R_0\, A^{1/3}$ where R_0 is constant

(ii) nuclear density $\rho = \frac{M}{V} = \frac{A}{\frac{4}{3}\pi r^3} = \frac{A}{\frac{4}{3}\pi(R_0 A^{1/3})^3} = \frac{3}{4\pi R_0^3}$

827. Compare the radii of two nuclei with mass numbers 1 and 27 respectively. **CBSE (AI)-2012,2010,(D)-2011**
[Ans. $\boldsymbol{R} \propto A^{1/3}$ ⇨ $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$

828. What is the nuclear radius of ^{125}Fe, if that of ^{27}Al is 3.6 Fermi ? **CBSE (AI)-2008**
[Ans. $\boldsymbol{R} \propto A^{1/3}$ ⇨ $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{125}{27}\right)^{1/3} = \frac{5}{3}$

⇨ $R_1 = R_2 X \frac{5}{3} = 3.6 X \frac{5}{3} = 6$ Fermi

829. Two nuclei have mass numbers in the ratio 1:2. What is the ratio of their nuclear densities ? **CBSE (D)-2009**
[Ans. 1:1 as nuclear density does not depend on mass number

830. What are nuclear forces ? State any two characteristic properties of nuclear forces.
CBSE (AIC)-2017,(AI)-2015,2012,2011,2008,2007
[Ans. Nuclear Forces ; Very short range strongest attractive forces, which firmly hold the nucleons together inside a nucleus, are called nuclear forces.

Properties: (i) very short range, strongest attractive forces.
(ii) charge independent.
(iii) non-central forces
(iv) do not obey inverse square law

831. Define the term mass defect. **CBSE (AIC)-2014,2001**
[Ans. Mass defect (Δm): The difference in mass of a nucleus and its constituents, is called the mass defect.

Δm = [Zm_p + (A – Z) m_n] $- M_N$

832. Define binding energy of a nucleus. **CBSE (AIC)-2002**

[Ans. Binding Energy (BE) : It is defined as the minimum energy required to separate its nucleons and place them at rest at infinite distance apart

It is the equivalent energy of mass defect, i,e, $BE = \Delta m \times c^2$

833. What is meant by the term binding energy per nucleon **CBSE (DC)-2010**

[Ans. Binding Energy per nucleon (E_{bn}) : It is the average energy per nucleon needed to separate a nucleus in to its individual nucleons

$$E_{bn} = \frac{E_b}{A} = \frac{\Delta m\, c^2}{A}$$

834. The binding energies of deuteron $({}_1^2\mathrm{H})$ and $\alpha - particle$ $({}_2^4\mathrm{He})$ are 1.25 and 7.2 MeV/ nucleon respectively. Which nucleus is more stable ? **CBSE (AIC)-2001**

[Ans. $\alpha - particle$ $({}_2^4\mathrm{He})$ is more stable as BE per nucleon of ${}_2^4\mathrm{He}$ is more than that of ${}_1^2\mathrm{H}$

835. Which out of two nuclei ${}_3^7X$ & ${}_3^4Y$ is more stable ? **CBSE (AI)-2004**

[Ans. Nucleus ${}_3^7X$ is more stable because n/p ratio for ${}_3^7X$ is more than that for ${}_3^4Y$

Reason : A nucleus is more stable if, it has -(a) high value of B.E./A (b) greater n/p ratio, or (c) even-even nucleus.

836. Why is mass of a nucleus is always less than the sum of the masses of its constituent, neutrons & protons ?**CBSE (AI)-2004**

[Ans. When nucleons approach each other to form a nucleus, they strongly attract each other. Hence their potential energy decreases and becomes negative. This decrease in P.E. results in the decrease in the mass of the nucleons

837. If the nucleons of a nucleus are separated far apart from each other, the sum of the masses of all these nucleons is larger than the mass of the nucleus. Why ? **CBSE (AIC)-2003**

[Ans. For the separation of nucleons to a distance far apart from each other, an energy equal to B.E. of the nucleus is given to these nucleons. From E = $\Delta m\ c^2$, thus mass difference comes

838. If the total number of neutrons & protons in a nuclear reaction is conserved, how is then the energy is absorbed or evolved in the reaction ? **CBSE (AI)-2015**

OR

In a nuclear reaction,

$${}_2^3\mathrm{He} + {}_2^3\mathrm{He} \longrightarrow {}_2^4\mathrm{He} + {}_1^1\mathrm{H} + 12.86 \text{ MeV}$$ **CBSE (D)-2013**

though the number of nucleons is conserved on both sides of the reaction, yet the energy is released. How ? Explain.

[Ans. Since certain mass disappears in the formation of a nucleus (mass defect), it appears in the form of energy E = Δmc^2. Thus the difference of B.E. of the two sides appear as energy released or absorbed in a nuclear reaction

839. A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks in to two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the energy released. **CBSE (D)-2016**

[Ans. Energy released = BE of two fragments − BE of nucleus

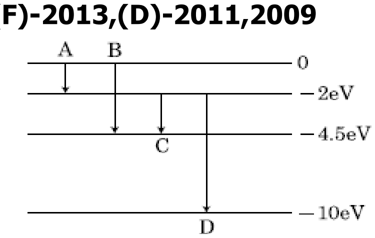
= 2 X 120 X 8.5 – 240 X 7.6 = 240 (8.5 – 7.6) = 240 X 0.9 = 216 MeV

840. Calculate the energy released in the fusion reaction : **CBSE (D)-2016**

$${}_1^2\mathrm{H} + {}_1^2\mathrm{H} \longrightarrow {}_2^3\mathrm{He} + n,$$ where BE of ${}_1^2\mathrm{H} = 2.23\ MeV$ and of ${}_2^3\mathrm{He} = 7.73\ MeV$

[Ans. Energy released = BE of ${}_2^3\mathrm{He} - BE$ of $({}_1^2\mathrm{H} + {}_1^2\mathrm{H}) = 7.73 - (2.23 + 2.23) = 3.73$ MeV

841. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of photon of wavelength 275 nm ? **[Ans.** B] **CBSE (F)-2013,(D)-2011,2009**



[Ans. $\lambda = 275$ nm = 275 X $10^{-9}\ m$

$$\Delta E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{2.75 \times 10^{-7} \times 1.6 \times 10^{-19}} = 4.5 \text{ eV}$$

For transition B

$\Delta E = 0 - (-4.5) = 4.5$ eV

842. Calculate the binding energy per nucleon of ${}_{20}^{40}Ca$ nucleus. **CBSE (AI)-2007,2004,2002,(D)-2002**

(Given, Mass of ${}_{20}^{40}Ca$ = 39.962589 u, Mass of proton= 1.007825 u, Mass of neutron =1.008665 u & 1u= 931 MeV/c^2)

[Ans. mass defect, Δm = [Zm_p + (A – Z) m_n] −M_N = [20(1.007825) + 20(1.008665)]−39.962589 =0.367211

⇨ B.E. = 0.367211 X 931 = 341.87 MeV ⇨ B.E. per nucleon = $\frac{341.87}{40}$ = 8.547 MeV

843. What is radioactivity ? **CBSE (AIC)-2001**

[**Ans. Radioactivity :** The phenomenon of spontaneous and continuous emission of radiations such as α or β and γ –rays from the nucleus of heavy elements is called radioactivity

844. When a radioactive radiation is placed in an electric or magnetic field it divides in to three parts. Why ? **CBSE (AIC)-2014**

[**Ans.** Radioactive decay occurs in series where daughter product give rise to grand daughter product and so on. Some of them emit α –particles while others emit β –particles. If after α- emission or β- emission, nucleus is left in the excited state it may emit γ –rays. Therefore radioactive sample give out α –particle, β –particles and γ –rays together

845. Why do α –particles have high ionising power ? **CBSE (F)-2010**

[**Ans.** Because of their large mass & large nuclear cross section α –particles have highest ionizing power

846. Which of the following radiations α-rays, β-rays, γ-rays **CBSE (AI)-2001**
(i) are similar to X-rays
(ii) are easily absorbed by the matter
(iii) travel with greatest speed
(iv) are similar in nature to cathode rays.

[**Ans.** (i) $\gamma - rays$ (ii) α-rays (iii) γ-rays (iv) β-rays

847. What is the difference between an electron and a $\beta - particle$? **CBSE (AIC)-2001**

[**Ans.** Both are essentially the same. In fact an electron of nuclear origin is called $\beta - particle$

848. A nucleus contains no electrons, yet it ejects them. How ? **CBSE (AIC)-2003**

[**Ans.** A neutron in a nucleus decays in to a proton and an antineutrino. It is this electron which is emitted as $\beta - particle$

$$n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$$

849. A nucleus undergoes $\boldsymbol{\beta}^{-} decay$. How does its (i) mass number (ii) atomic number change ? **CBSE (D)-2011**

[**Ans.** During $\boldsymbol{\beta}^{-} decay$ (i) mass number remains same (ii) atomic number increases by one

850. What is β-decay ? **CBSE (F)-2002**

[**Ans. $\boldsymbol{\beta - decay}$:** The process of spontaneous emission of β –particle from a radioactive nucleus is called β –decay

851. (i) Write the nuclear decay process of β-decay ${}_{15}^{32}P$ **CBSE (AI)-2010,2004,(D)-2004**
(ii) Write the β –decay of tritium in symbolic form. **CBSE (F) -2015,(AI)-2013**

[**Ans.** (i) ${}_{15}^{32}P \longrightarrow {}_{16}^{32}\mathrm{S} + {}_{-1}^{0}e + \overline{\nu}$

(ii) ${}_{1}^{3}\mathrm{H} \longrightarrow {}_{2}^{3}\mathrm{He} + {}_{-1}^{0}e + \overline{\nu}$

852. Write the basic nuclear process involved in the emission of (a) β^- decay and (b) β^+ decay in a symbolic form, by a radioactive nucleus. **CBSE (D)-2017,(AI)-2016,2013,(F)-2015,(AIC)-2015**

[**Ans.** (a) β^- decay, $n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$

(b) β^+ decay, $p \longrightarrow n + {}_{+1}^{0}e + \nu$

853. Why is the detection of neutrinos found very difficult ? **CBSE (AI)-2016,2013,(F)-2015,(AIC)-2015**

[**Ans.** Because neutrinos have no charge, almost no mass and their interaction with matter is very weak

854. Why the mass number of a nuclide undergoing β-decay does not change? **CBSE (DC)-2003**

OR

In both β-decay process, the mass number of the nucleus remains same, whereas the atomic number Z increases by one in β^-decay and decreases by one in β^+decay. Explain giving reason. **CBSE (F)-2014**

[**Ans.** In both β-decay process, the conversion of neutron to proton or proton to neutron inside the nuleus. These nucleons have nearly equal masses. Hence mass number does not change and

In $\boldsymbol{\beta}^-$ decay $n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$

or ${}_{Z}^{A}\mathrm{X} \longrightarrow {}_{Z+1}^{A}\mathrm{Y} + {}_{-1}^{0}e + \overline{\nu}$

In $\boldsymbol{\beta}^+$ decay $p \longrightarrow n + {}_{+1}^{0}e + \nu$

or ${}_{Z}^{A}\mathrm{X} \longrightarrow {}_{Z+1}^{A}\mathrm{Y} + {}_{+1}^{0}e + \nu$

855. Write the nuclear reactions for the following- **CBSE (DC)-2005**

(i) α-decay of $^{242}_{94}Pu$ (ii) β-decay of $^{32}_{15}P$ (iii) β^{+}decay of $^{11}_{6}\text{C}$ (iv) α-decay of $^{226}_{88}Ra$

[Ans. (i) $^{242}_{94}Pu \longrightarrow {}^{238}_{92}U + {}^{4}_{2}\text{He}$

(ii) $^{32}_{15}P \longrightarrow {}^{32}_{16}\text{S} + {}^{0}_{-1}e + \overline{\nu}$

(iii) $^{11}_{6}\text{C} \longrightarrow {}^{11}_{5}\text{C} + {}^{0}_{+1}e + \nu$

(iv) $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}\text{He}$

856. In the reactions given below, find the values of x, y & z and a, b & c. **CBSE (AI)-2016**

(a) $^{12}_{6}\text{C} \longrightarrow {}^{y}_{z}\text{B} + x + \nu$

(b) $^{12}_{6}\text{C} + {}^{12}_{6}\text{C} \longrightarrow {}^{20}_{a}\text{Ne} + {}^{c}_{b}\text{He}$

[**Ans**. (a) x = $^{0}_{+1}e$, y =5, z =11 (b) a=10, b=2, c= 4]

857. In the following nuclear reaction assign the value of Z and A. **[Ans**. (a) Z = 56, A = 89] **CBSE (AI)-2015**

$$n + {}^{235}_{92}U \longrightarrow {}^{144}_{Z}Ba + {}^{A}_{36}X + 3\,n$$

858. Identify the nature of the radioactive radiations emitted in each step of the decay process given below: **CBSE (AI)-2015**

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y \longrightarrow {}^{A-4}_{Z-1}W$$

[Ans. $^{A}_{Z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}Y \xrightarrow{\beta^-} {}^{A-4}_{Z-1}W$

859. Give the mass number and atomic number of elements on the right hand side of the decay process. **CBSE (D)-2004**

$$^{220}_{86}Ru \longrightarrow Po + \text{He}$$

[**Ans**. $^{220}_{86}Ru \longrightarrow {}^{216}_{84}Po + {}^{4}_{2}\text{He}$

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860. A radioactive nucleus 'A' undergoes series of decays shown in the following scheme : **CBSE (AI)-2015**

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\gamma} A_3$$

If mass number and atomiv number of A_3 are 176 and 69 respectively, find the mass number and atomic number of A

[**Ans**. $^{180}_{70}A \xrightarrow{\alpha} {}^{176}_{68}A_1 \xrightarrow{\beta} {}^{176}_{69}A_2 \xrightarrow{\gamma} {}^{176}_{69}A_3$

861. A radioactive nucleus 'A' undergoes a series of decays according to the following scheme- **CBSE (D)-2017,(D)-2009,(AIC)-2002**

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

If the mass number and atomic number of A are 180 & 72 respectively, What are these numbers for A_4?

[**Ans**. $^{180}_{72}A \xrightarrow{\alpha} {}^{176}_{70}A_1 \xrightarrow{\beta} {}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$

862. A radioactive isotope D decays according to the sequence - **CBSE (AI)-2002**

$$D \xrightarrow{{}^{1}_{0}n} D_1 \xrightarrow{\alpha} D_2$$

If the mass number & atomic number for D_2 are 176 & 71 respectively, find the mass number and atomic number of D

[**Ans**. $^{181}_{69}D \xrightarrow{{}^{1}_{0}n} {}^{180}_{69}D_1 \xrightarrow{\alpha} {}^{176}_{67}D_2$]

863. The sequence of stepwise decays of a radioactive nucleus is - **CBSE (D)-2010**

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2$$

If the atomic number and mass number of D_2 are 71 & 176 respectively, What are their corresponding values for D ?

[**Ans**. $^{180}_{72}D \xrightarrow{\alpha} {}^{176}_{70}D_1 \xrightarrow{\beta^-} {}^{176}_{71}D_2$

864. (a) Write two important limitations of Rutherford nuclear model of the atom. **CBSE (D)-2017,(AIC)-2015**
(b) How these were explained in Bohr's model of hydrogen atom ? **CBSE (AIC)-2015**

[Ans. (a) Limitations of Rutherford nuclear model of the atom :

(i) Electron moving in a circular orbit around the nucleus would get accelerated. Therefore it looses its energy and hence it would spiral into the nucleus

(ii) Due to continuously changing radii of orbits, electron will emit em waves of all frequencies. Hence atom should emit continuous spectrum

(b) Explanation according to Bohr's model of hydrogen atom :

(i) Electron in an atom can revolve in certain stable orbits without the emission of radiant energy, in which

$$m\,v\,r = n\frac{h}{2\pi} \qquad \text{Where } n = 1,2,3,\text{--------}$$

(ii) Energy is released/ absorbed only, when an electron jumps from one stable orbit to another stable orbit. This results in a discrete spectrum

865. How does de-Broglie explain the stationary orbits for revolution of electrons using Bohr's quantization condition ?

[Ans. de-Broglie's explanation of Stationary orbits **CBSE (D)-2016,(D)-2012,(F)-2010**

According to de- Broglie hypothesis,

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

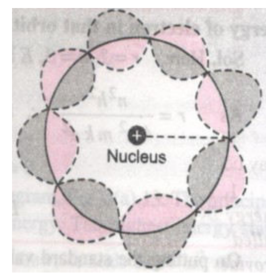
But for circular orbits,

$$L = m\,v\,r = r_n\,p$$ where r_n is the radius of quantized orbits

$$\Rightarrow \quad n\,\frac{h}{2\pi} = r_n\,\frac{h}{\lambda}$$ [$\because L = n\frac{h}{2\pi}$]

$$\Rightarrow \quad 2\,\pi\,r_n = n\,\lambda$$

⇨ Circumference of permitted orbits are integer multiples of wavelength λ



866. Derive the Bohr's quantization condition for angular momentum of the orbiting of electron in hydrogen atom, Using de-Broglie's hypothesis. **CBSE (AIC)-2017,(AI)-2016,2015,2011**

[Ans. de-Broglie wavelength

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

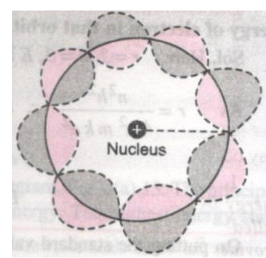
For electron moving in n^{th} orbit,

$$2\pi r = n\,\lambda$$

$$\Rightarrow \quad 2\pi r = n\frac{h}{mv}$$

$$\Rightarrow \quad m\,v\,r = n\,\frac{h}{2\pi}$$

This is Bohr's postulate of quantization of angular momentum



867. Use de-Broglie's hypothesis to write the relation for the n^{th} radius of Bohr orbit interms of Bohr's quantization condition of orbital angular momentum. **CBSE (F)-2016**

[Ans. de Broglie Wavelength associated with electron in its orbit

$$\lambda = \frac{h}{p} = \frac{h}{m\,v_n}$$

Only those waves survive which form standing waves. For electron moving in n^{th} circular orbit of radius r_n

$$2\pi r_n = n\,\lambda \qquad \text{where } n = 1,2,3,\text{-------------}$$

$$\Rightarrow \quad 2\pi r_n = n\frac{h}{m\,v_n}$$

$$\Rightarrow \quad r_n = n\frac{n\,h}{2\,\pi\,m\,v_n}$$

868. (i) Define Ionization energy. What is its value for hydrogen atom ? **CBSE (AI)-2016,2010**
(ii) How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge ?

[Ans. (i) **Ionization Energy** : It is the minimum energy required to just remove an electron from the atom

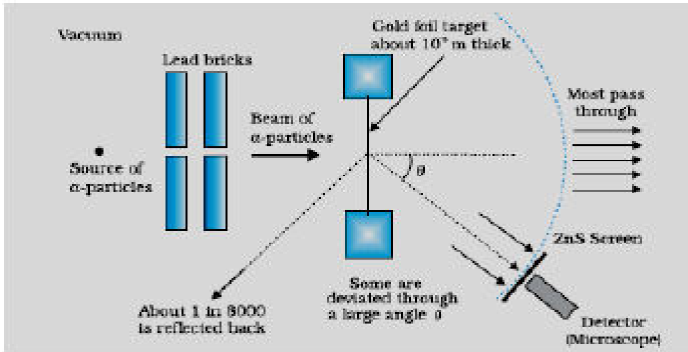
for H- atom ionization energy is $E_0 = \frac{m\,e^4}{8\,\varepsilon_0^2 h^2} = 13.6$ eV

(ii) As $E_0 \propto m$, hence ionization energy becomes 200 times

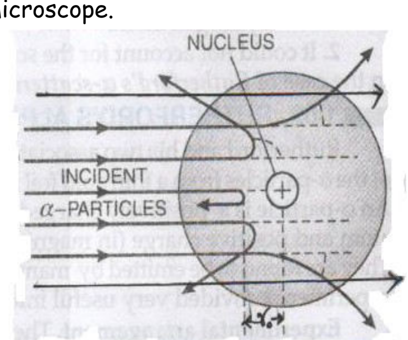
869. Draw a schematic arrangement of the Geiger – Marsden experiment for studying α –particle scattering by a thin foil of gold. Describe briefly, by drawing trajectories of the scattered α –particles, how this study can be used to estimate the size of the nucleus ? Draw a plot showing the number of particles scattered versus scattering angle θ.

CBSE (F)-2013,2010,2008,2003 (AI)-2009,(D)-2005

[Ans. <u>Geiger-Marsden experiment</u> (Rutherford's α–Particle scattering experiment) :



High energetic collimated beam of α–Particles is allowed to fall on a very thin gold foil as shown. The scattered α-particles are observed through a rotating detector consisting of ZnS screen and microscope.



<u>Observations and Conclusions</u> :

(i) most of the α–Particles passed un deflected through the foil.

It indicates that most of the space in an atom is empty.

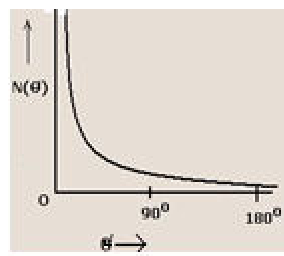
(ii) some α–Particles were deflected through small angles and only a few (1 in 8000) were deflected through large angles (> 90^0) to return back

It concludes that whole of the positive charge and almost whole mass is concentrated in a tiny central core known as nucleus.

(iii)The number of α–Particles at a scattering angle θ is

$$N(\theta) \propto \frac{1}{sin^4(\theta/2)}$$

It is due to the fact that, scattering of α-particles is in accordance with Coulomb's force.



Size of nucleus : It can be estimated by distance of closest approach

$$\frac{1}{2} m v^2 = \frac{1}{4\pi\varepsilon_0} \frac{(Ze)(2e)}{r_0}$$

$$\Rightarrow \quad r_0 = \frac{1}{4\pi\varepsilon_0} \frac{(2Ze^2)}{\frac{1}{2} m v^2} = 2.5 \times 10^{-14} \text{ m}$$]

==

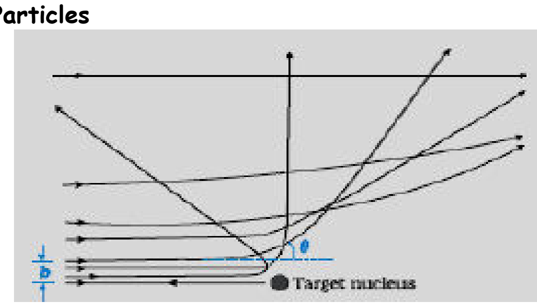
870. In Geiger- Marsden experiment, why is the most of the α–Particles go straight through the foil and only a small fraction gets scattered at large angles ?

CBSE (AIC)-2015

[Ans. for most of the α–Particles, impact parameter is large, hence they suffer very small repulsion due to nucleus and go straight (right) through the foil

871. In Geiger-Marsden experiment, draw the trajectories traced by α–Particles in the Coulomb's field of target.

[Ans. Trajectories traced by α–Particles **CBSE (AIC)-2015**



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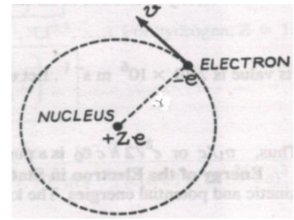
872. Using Bohr's postulates, derive the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence, derive the expression for the orbital velocity and orbital period of the electron moving in the n^{th} orbit of hydrogen atom. **CBSE (F)-2017,2014,2012,2011,(AI)-2015,2014,2013,(D)-2013**

[Ans. Bohr's theory of H-atom :



As the electrostatic force of attraction between electron and nucleus provides the necessary centripetal force

i,e, $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$

⇨ $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}$ ------------(1)

According to Bohr's quantum condition

$m\,v\,r = n\frac{h}{2\pi}$ -----------(2)

on squaring eqn (2) and dividing by eqn (1) we get

$$\frac{m^2v^2r^2}{m\,v^2} = \frac{n^2h^2/\,4\pi^2}{\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}}$$

⇨ $\boldsymbol{r = \frac{\varepsilon_0\, n^2\, h^2}{\pi\, m\, Ze^2}}$ ⇨ $\boldsymbol{r_n \propto n^2}$

For H-atom $Z = 1$ & for innermost orbit $n = 1$,

⇨ $r_0 = \frac{\varepsilon_0 h^2}{\pi\, m\, e^2}$ = 0.53 A^0. This is called **Bohr's orbit**

Energy of electron in stationary orbits

K.E. of electron, $E_K = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right)$ $\left[\because mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right]$

& P.E. $U = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

⇨ total energy of electron $E = E_K + U = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right) - \frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r} = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

⇨ $E_n = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{\frac{\varepsilon_0\, n^2\, h^2}{\pi\, m\, Z\, e^2}} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right)$

⇨ $E_n = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right) \times \frac{ch}{ch} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,c\,h^3}\left(\frac{ch}{n^2}\right) = -\boldsymbol{\frac{Z^2Rch}{n^2}}$

For H- atom $Z = 1$

⇨ $\boldsymbol{E_n = -\frac{Rch}{n^2} = -\frac{13.6}{n^2}}\,\mathrm{eV}$

Where, $R = \frac{m\,e^4}{8\varepsilon_0^2\,ch^3}$ = 1.097 X 10^7 m^{-1} and is called Rydberg's constant.

Orbital velocity & time period of electron in stationary orbits

dividing by eqn (1) by (2)

$$\frac{m\,v^2}{m\,v\,r} = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r} \times \frac{2\pi}{nh}$$

⇨ $v = \frac{Ze^2}{(2\,\varepsilon_0)n\,h} = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} \times \frac{c}{n} = \alpha\,\frac{c}{n} = \frac{1}{137}\frac{c}{n}$ ⇨ $\boldsymbol{v \propto \frac{1}{n}}$

where $\alpha = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} = \frac{1}{137}$ and is called fine structure constant

Orbital period of electron in H-atom :

$$T = \frac{2\pi r}{v} = \frac{2\pi(mvr)}{mv^2} = \frac{2\pi\left(\frac{nh}{2\pi}\right)}{m\left(\frac{e^2}{2\varepsilon_0 n\,h}\right)^2}$$

⇨ $T = \frac{4\varepsilon_0^2\,n^3h^3}{me^4}$

873. (a) Explain the origin of spectral series/ lines of hydrogen atom using Bohr's atomic model.
(b) Draw the energy level diagram showing how the line spectra corresponding to Lyman/Balmer series occur due to transition between energy levels in a hydrogen atom. **CBSE (AI)-2015,(D)-2013**

[Ans. (a) Spectral series of hydrogen atom :

According to Bohr's frequency condition, if an electron makes a transition from higher energy level E_2 to lower energy level E_1, then

$$\mathrm{h}\frac{c}{\lambda} = E_2 - E_1 = -\frac{Rch}{n_2{}^2} - \left[-\frac{Rch}{n_1{}^2}\right] = Rch\left[\frac{1}{n_1{}^2} - \frac{1}{n_2{}^2}\right]$$

⇨ $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1{}^2} - \frac{1}{n_2{}^2}\right]$ where $\bar{\nu}$ is called wave number

Where $\bar{\nu}$ is called wave number (number of waves per unit distance), & R is the Rydberg's constant ($R = 1.097 \times 10^7\ \mathrm{m}^{-1}$)

(i) <u>Lyman Series</u>

When an electron jumps from any higher energy level to the first level, we get Lyman series.
This series lies in ultraviolet region $(912 - 1215\ \mathrm{A}^0)$ and hence not visible. It is given by

$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 2,3,4,5,---------

(ii) <u>Balmer Series</u>

When an electron jumps from any higher energy level to the second level, we get Balmer series.
This series lies in visible region $(3646 - 6563\ \mathrm{A}^0)$ and is given by

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 3,4,5,6,---------

(iii) <u>Paschen Series</u>

When an electron jumps from any higher energy level to the third level, we get Paschen series.
This series lies in infrared region, $(8204 - 18752\ \mathrm{A}^0)$ hence not visible and is given by

$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 4,5,6,7,---------

(iv) <u>Brackett Series</u>

When an electron jumps from any higher energy level to the fourth level, we get Brackett series.
This series lies in infrared region, $(14576 - 40589\ \mathrm{A}^0)$ hence not visible & is given by

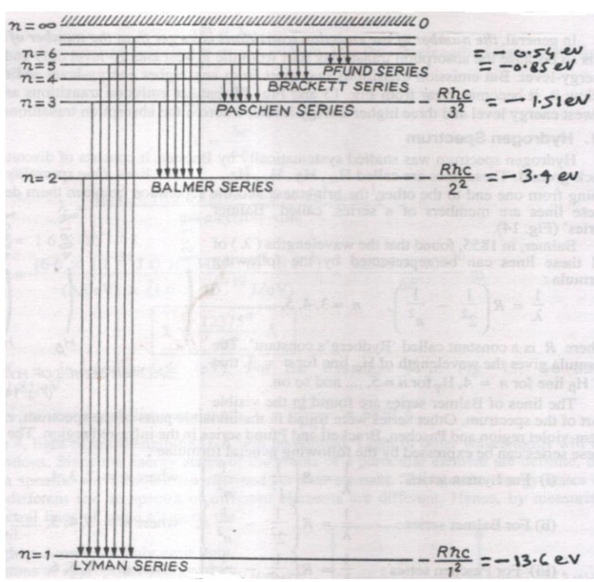
$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 5,6,7,8,--------

(v) <u>Pfund Series</u>

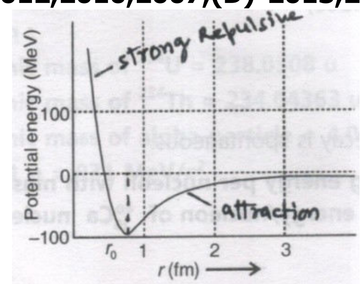
When an electron jumps from any higher energy level to the fifth level, we get Pfund series.
This series also lies in infrared region, $(22775 - 74536\ \mathrm{A}^0)$ hence not visible & is given by

$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2{}^2}\right]$ where n_2 = 6,7,8,9,--------

(b) Hydrogen spectrum :



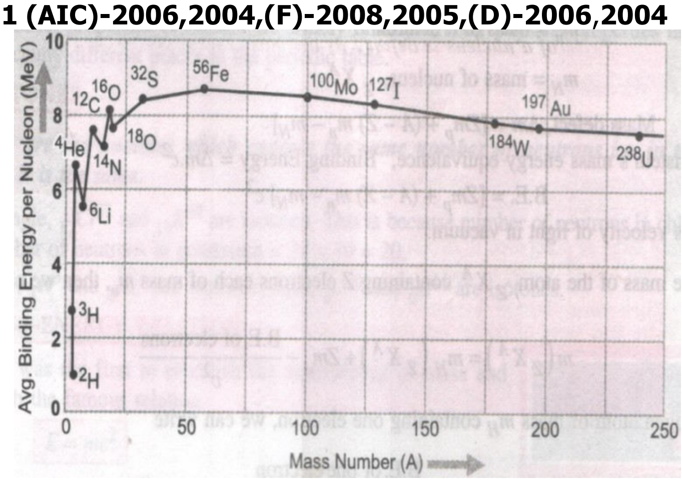
874. Draw a plot of potential energy of a pair of nucleons as a function of their separations.
(i) Write two important conclusions that can be drawn from the graph.
(ii) What is the significance of negative potential energy in the graph drawn ?
[**Ans. Graph :** **CBSE (AIC)-2017,(AI)-2015,2012,2010,2007,(D)-2013,2007**



(i) Conclusions :
(a) For $r < r_0$, P.E. increases rapidly with the decrease in r. This indicates strong repulsion between the nucleons
(b) For $r > r_0$, P.E. is negative which falls to zero for a separation more than a few Fermi. It indicates attractive force between the nucleons
(ii) Significance :
Negative potential energy shows that binding force between the nucleons is strong.

875. Draw a plot of binding energy per nucleon (B.E/A) as a function of mass number A.
(a) Write salient features of this curve.
(b) Write two important conclusions that can be drawn regarding the nature of nuclear force.
(c) Use this graph to explain the release of energy in both the processes of nuclear fission and fusion.
CBSE (AI)-2016,2013,2011,2009,2004,2001 (AIC)-2006,2004,(F)-2008,2005,(D)-2006,2004

[**Ans. Binding energy curve :**



(a) Salient features :
(i) BE per nucleon (E_{bn}) is practically constant (independent of A) for the nuclei of middle mass number (30 <A<170).
Maximum E_{bn} is about 8.75 MeV for $A = 56$, thus Fe^{56} is most stable.
For A = 238 E_{bn} drops to 7.6 MeV.
(ii) Average B.E. per nucleon is very small for both light nuclei ($A < 30$) and heavy nuclei($A > 170$), so these nuclei are less stable.

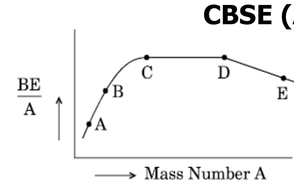
(b) Conclusions/Importance of BE curve :
(i) Nuclear force is attractive and sufficiently strong to produce BE of a few MeV per nucleon
(ii) Constancy of BE curve in the range 30 <A <170 is a due to the fact that nuclear force is short – ranged.
(c) Release of energy in fission & fusion :
(i) When a heavy nucleus undergoes nuclear fission, the BE per nucleon of product nuclei is more than that of the original nucleus. This means that the nucleons get more tightly bound. Hence, there is release of energy.
(ii) When two very light nuclei (A ≤10) undergoes nuclear fusion, the BE per nucleon of product nucleus becomes more than that of the original lighter nuclei. This means that the nucleons in the final nucleus get more tightly bound. Hence, there is release of energy.

876. What characteristic property of nuclear force explains the consistency of binding energy per nucleon (BE/A) in the range of mass number 'A' lying 30< A< 170 ? **CBSE (AI)-2015**
[**Ans.** Nuclear force is short ranged or saturated

877. Give the reason for the decrease of binding energy per nucleon for nuclei with high numbers.
[**Ans.** This is due to increase in Coulomb repulsive force between protons **CBSE (DC)-2006,(D)-2004**

878. The figure shows the plot of binding energy (BE) per nucleon as a function of mass number A. Point out, giving reasons, the two processes (in terms of A,B,C,D and E) , one of which can occur due to nuclear fission and the other due to nuclear fusion. **CBSE (AI)-2015**

[**Ans. (i) Nuclear fission of E in to D and C,**
as there is increase in binding energy per nucleon
(ii) Nuclear fusion of A and B in to C,
as there is an increase in binding energy per nucleon



879. State the law of radioactive decay.

(i) Derive the mathematical expression for law of radioactive decay for a sample of radioactive nucleus.

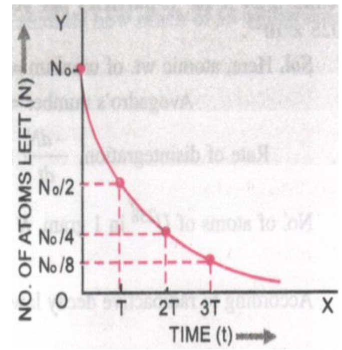
(ii) Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half-life T. **CBSE (AI) -2016, 2015, 2006, 2004, (D)-2014, 2011,2005, CBSE (F)-2013,2007**

[**Ans. Law of radioactive decay :** The rate of decay of a given radioactive sample is directly proportional to the total number of undecayed nuclei present in the sample

i,e, $-\frac{dN}{dt} \propto N$

⇨ $\frac{dN}{dt} = -\lambda N$

⇨ $\frac{dN}{N} = -\lambda\, dt$ -----------(1)



Where λ is constant of proportionality & is called decay constant

Let, when $t = 0$, $N = N_0$, Integrating (1) on both sides

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$$

$$[\log_e N]_{N_0}^{N} = -\lambda\, [t]_0^t$$

$$\log_e N - \log_e N_0 = -\lambda\,(t - 0)$$

$$\log_e \frac{N}{N_0} = -\lambda t$$

⇨ $\frac{N}{N_0} = e^{-\lambda t}$

⇨ $\mathbf{N = N_0\, e^{-\lambda t}}$

==

880. Define the terms half-life period & decay constant of a radioactive substance. Write their S.I. units. Establish the relation between them. **CBSE (AI)-2015,2006,2004,(F)-2007,(D)-2005,2001**

[**Ans. Half-life (T) :** It is defined as the time taken to decay one-half of the initial number of nuclei present in a radioactive sample

Its S.I. unit is second (s)

Decay constant (λ) : It is defined as the reciprocal of the time in which the number of nuclei left undecayed reduces to $\frac{1}{e}$ times of its initial value

Its S.I. unit is second (s^{-1})

Relation : We have, $N = N_0 e^{-\lambda t}$

But when $t = T, N = \frac{N_0}{2}$

⇨ $\frac{N_0}{2} = N_0 e^{-\lambda T}$

$\frac{1}{2} = e^{-\lambda T}$

⇨ $2 = e^{\lambda T}$

$\lambda T = \log_e 2$

$\lambda = \frac{\log_e 2}{T} = \frac{0.6931}{T}$

==

881. Define the term **mean life** of a radioactive nuclide. How is the mean life of a given radioactive nucleus related to the decay constant and Half-life ? **CBSE (AI) -2016, 2015, (F)-2014**

[**Ans. Average or Mean life (τ) :** mean life of a radioactive substance is defined as the sum of life time of all the nuclei divided by the number of all nuclei

i,e, Mean life (τ) = $\frac{sum\ of\ life\ time\ of\ all\ the\ nuclei}{total\ number\ of\ nuclei} = \frac{\int_0^{N_0} t\, dN}{N_0} = \frac{1}{\lambda}$

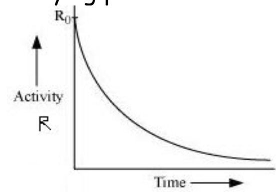
Relation : $\tau = \frac{1}{\lambda} = \frac{T}{0.6931} = \mathbf{1.44\ T}$

882. Define activity of a radioactive substance and write its S.I. unit. Plot a graph showing variation of activity of a given radioactive sample with time **CBSE (F)-2016,(AI)-2015,2009,(D)-2010,2005,(F)-2008**

[Ans. **Activity** $(\boldsymbol{R})$: It is defined as the number of radioactive nuclei decaying per second at any time

i,e, $R = -\frac{dN}{dt}$

S.I. unit of Activity is Becquerel (Bq)



883. Show that the decay rate 'R' of a sample of a radioactive nuclide is related to the number of radioactive nuclei 'N' at the same instant by the expression $R = \lambda N$ & $\frac{dR}{dt} \propto \frac{1}{T^2}$ **CBSE (AIC)-2010**

[Ans. $R = -\frac{dN}{dt} = -\frac{d}{dt}\left(\mathrm{N}_0 e^{-\lambda t}\right) = -\mathrm{N}_0\ \left(-\lambda\, e^{-\lambda t}\right) = \lambda\left(\mathrm{N}_0\, e^{-\lambda t}\right) = \lambda\, N$ ⇨ $R = \lambda\, N$

Now, $R = \lambda\, N$

⇨ $\frac{dR}{dt} = \frac{d}{dt}(\lambda\, N) = \lambda \frac{d\,N}{dt} = \lambda\,(R) = \lambda\,(\lambda\,\mathrm{N}) = \lambda^2 \mathrm{N} = \left[\frac{\log_e 2}{T}\right]^2 \mathrm{N}$

⇨ $\frac{dR}{dt} \propto \frac{1}{T^2}$

884. A radioactive sample having N nuclei has activity R. Write down an expression for its half-life in terms of R and N

[Ans. Activity $R = \lambda\, N$ ⇨ $\lambda = \frac{R}{N}$ **CBSE (AIC)-2011**

Half-life, $T = \frac{0.6931}{\lambda} = \frac{0.6931\, N}{R}$

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885. What is nuclear fission and fusion ? Give one representative equation of each. **CBSE (AIC)-2005**

[Ans. __Nuclear fission :__ When a heavy nucleus is bombarded with slow neutrons it splits in to two or more light nuclei and a very large amount of energy is released. This phenomenon is called nuclear fission

$${}^{235}_{92}U + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{236}_{92}U \longrightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}\mathrm{n} + Q$$

Nuclear reactor and atom bomb are based on nuclear fission

Nuclear fusion : When two light nuclei are combined to form a heavy nucleus, a tremendous amount of energy is released. This phenomenon is called nuclear fission

$${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + 3.27\ \mathrm{MeV}$$

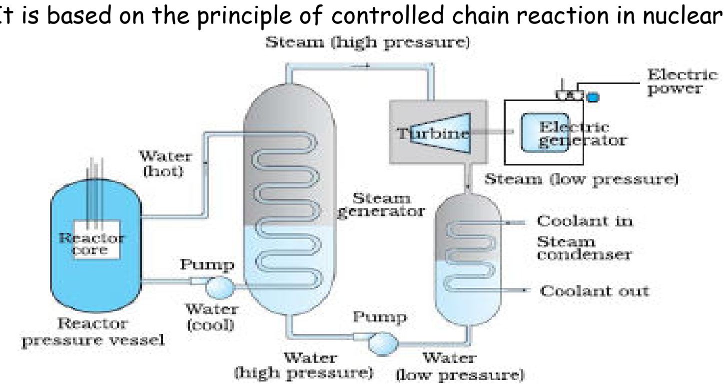
Source of energy in Sun is nuclear fusion. Hydrogen bomb is based on nuclear fusion

==

886. What is nuclear reactor ? Draw a labelled diagram of a nuclear reactor. Write its principle and explain its working.

[Ans. __Nuclear Reactor__ : It is device used to convert nuclear energy it to electric energy.

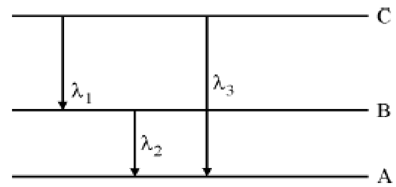
Principle : It is based on the principle of controlled chain reaction in nuclear fission.



Working : In a nuclear reactor, ${}^{235}_{92}U$ is used as a fuel, cadmium rods are used as control rods and graphite or heavy water as moderator. The entire set up is shielded with a heavy thick lead sheets and then with a thick concrete walls. The energy obtained from fission is used to heat up the water to produce steam. This steam is then used to rotate the turbines to produce electricity

887. Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below.

CBSE (D)-2016



[Ans. $E_c - E_B = \frac{hc}{\lambda_1}$ ------(1)

$E_B - E_A = \frac{hc}{\lambda_2}$ ------(2)

$E_c - E_A = \frac{hc}{\lambda_3}$ ------(3)

Adding (1) and (2)

$E_c - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$

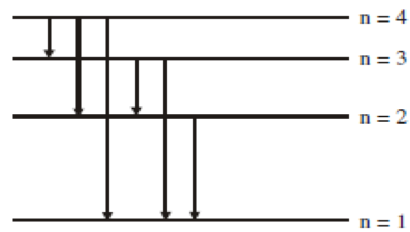
⇨ $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$ ⇨ $\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

===

888 . The figure shows energy level diagram of hydrogen atom. **CBSE (AIC)-2015**

(i) Find out the transition which results in the emission of a photon of wavelength $496\ nm$

(ii) Which transition corresponds to the emission of radiation of maximum wavelength ? Justify your answer.



[Ans. (*i*) $\lambda = 496$ nm $= 496 \times 10^{-9}\ m$

$$\Delta E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.96 \times 10^{-7} \times 1.6 \times 10^{-19}} \text{ eV} \cong 2.5 \text{ eV}$$

For hydrogen atom, $E_n = -\frac{13.6}{n^2}$eV

⇨ $E_1 = -13.6$, $E_2 = -3.4$, $E_3 = -1.51$, $E_4 = -0.85$ eV

$E_4 - E_2 \cong 2.5$ eV hence transition n= 4 to n=1 will give radiation of wavelength 496 nm

(ii) $\Delta E = \frac{hc}{\lambda}$ ⇨ $\lambda \propto \frac{1}{\Delta E}$ for transition n= 4 to n=3 ΔE is minimum hence λ will be maximum

889. A hydrogen atom initially in its ground state absorbs a photon and is in the excited state with energy 12.5 eV. Calculate the longest wavelength of the radiation emitted and identify the series to which it belongs .
(Rydberg constant, $R = 1.1 \times 10^7 m^{-1}$) **CBSE (AI)-2016**

[Ans. $\Delta E = -13.6 + 12.5 = -1.1$ eV

$E_n = -\frac{13.6}{n^2}$eV ⇨ $-1.1 = -\frac{13.6}{n^2}$ ⇨ n = 3

⇨ $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$ ⇨ $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.1 \times 10^7} = 6563\ A^0$ It belongs to Balmer series

890 . Using Rydberg's formula, calculate the longest wavelengths belonging to Lyman and Balmer series. In which region f hydrogen spectrum do these transmission lie ? (Given, $R = 1.1 \times 10^7 m^{-1}$) **CBSE (F)-2015**

[Ans. $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For Lyman series, $\frac{1}{\lambda_{max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$

⇨ $\lambda_{max} = \frac{4}{3R} = \frac{4}{3 \times 1.1 \times 10^7} = 1210\ A^0$. It lies in Ultraviolet region

For Balmer series $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

⇨ $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.1 \times 10^7} = 6563\ A^0$. It lies in visible region

891. The ground state energy of hydrogen atom is −13.6 eV. **CBSE (AI)-2008**

(i) what is the kinetic energy of an electron in the 2nd excited state ?

(ii) If the electron jumps to the ground state from 2nd excited state, calculate the wavelength of the spectral line emitted.

[Ans. (i) $E_{kn} = \frac{13.6}{n^2}$ eV & $U_n = -2 \times \frac{13.6}{n^2}$ eV

For ground state n =1 and for second excited state n = 3,

$E_{k3} = \frac{13.6}{3^2} = \frac{13.6}{9} = 1.51$ eV & $U_3 = -2 \times \frac{13.6}{3^2} = -\frac{27.2}{9} = 3.02$ eV

(ii) $\Delta E = E_3 - E_1 = -\frac{13.6}{3^2} - \left(-\frac{13.6}{1^2}\right) = -1.51 + 13.6 = 12.09$ eV $= 12.09 \times 1.6 \times 10^{-19}$ J

⇨ $\frac{hc}{\lambda} = \Delta E$ ⇨ $\lambda = \frac{hc}{\Delta E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{12.09 \times 1.6 \times 10^{-19}} = 1.02 \times 10^{-7}$ m

892. Two different radioactive elements with half lives T_1 and T_2 have N_1 and N_2 undecayed atoms respectively present at a given instant. Derive an expression for the ratio of their activities at this instant in terms of N_1 & N_2

[Ans. $R = -\frac{dN}{dt} = -\frac{d}{dt}\left(N_0 e^{-\lambda t}\right) = -N_0\ \left(-\lambda\, e^{-\lambda t}\right) = \lambda\left(N_0\, e^{-\lambda t}\right) = \lambda\, N$ **CBSE (DC)-2012**

⇨ $R = \lambda\, N$ ⇨ $R_1 = \lambda_1 N_1 = \frac{\mathbf{0.6931}}{\boldsymbol{T_1}} N_1$ & $R_2 = \lambda_2 N_2 = \frac{\mathbf{0.6931}}{\boldsymbol{T_2}} N_2$

⇨ $\frac{R_1}{R_2} = \frac{N_1}{N_2} \times \frac{T_2}{T_1}$

893. Half life of $^{238}_{92}U$ against $\alpha - decay$ is 4.5 X 10^9 years. Calculate the activity of 1 g sample of $^{238}_{92}U$.
(Given Avogadro's number = 6 X 10^{26} atoms/ Kmol) **CBSE (AI) E-2016,(F)-2006, (D)-2005**

[Ans. Half-life T = 4.5 X 10^9years $= 4.5\ X\ 10^9\ X\ 365\ X\ 24\ X\ 60\ X\ 60$ s = 1.42 X 10^{17}s

Number of atoms present in 1 g sample of $^{238}_{92}U$, $N = \frac{6\ X\ 10^{23}}{238}$

Activity, $R = \lambda N = \frac{0.6931}{T}\ X\ N = \frac{0.6931}{1.42\ X\ 10^{17}}\ X \frac{6\ X\ 10^{23}}{238}$ = 1.23 X $10^4\ Bq$

894. A radioactive sample contains 2.2 mg of pure $^{11}_{6}C$ which has half-life period of 1224 seconds. Calculate :
(i) the number of atoms present initially. **CBSE (AI)-2005**
(ii) the activity when 5 μg of the sample will be left.

[Ans. Given $T = 1224$ s

(i) Number of atoms present initially in 2.2 mg of $^{11}_{6}C$

$N_0 = \frac{6\ X\ 10^{23}\ X\ 2.2\ X\ 10^{-3}}{11}$ = 1.2 X 10^{20}

(ii) Number of atoms present in 5 μg of $^{11}_{6}C$

$N = \frac{6\ X\ 10^{23}\ X\ 5\ X\ 10^{-6}}{11}$ = 2.74 X 10^{17}

$R = \lambda N = \frac{0.6931}{T}\ X\ N = \frac{0.6931}{1224}$ X 2.74 X 10^{17} = 1.55 X 10^{14} Bq

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895. The half life of a certain radioactive material against α –decay is 100 days. After how much time, will the Undecayed fraction of the material be 6.25 % ? **CBSE (AI)-2015**

[Ans. Given : $T = 100$ days & $\frac{N}{N_0} = 6.25\ \% = \frac{6.25}{100} = \frac{1}{16}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{16} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 4$

⇨ $t = n\,T$ = 4 X 100 = 400 days

896. The half life of radioactive substance is 20s. calculate- **CBSE (F)-2009**
(i) The decay constant, and
(ii) time taken for the sample to decay 7/8th of the initial value.

[Ans. Given $T = 20$ s & $\frac{N}{N_0} = 1 - \frac{7}{8} = \frac{1}{8}$

(i) $\lambda = \frac{0.6931}{T} = \frac{0.6931}{20} = 0.0346\ s^{-1}$

(ii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{8} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 3$

⇨ $t = n\,T$ = 3 X 20 = 60 s

897. The activity of a radioactive element drops to $\frac{1}{16}$th of its initial value in 32 Years. Find the mean life of the sample.

[Ans. Given, $\frac{R}{R_0} = \frac{1}{16}$ & $t = 32$ years **CBSE (AIC)-2010**

$\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{16} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 4$ & $T = \frac{t}{n} = \frac{32}{4}$ = 8 years

⇨ τ = 1.44 T = 1.44 x 8 = 11.52 yrs

898. Calculate the energy release in MeV in the deuterium-tritium fusion reaction

CBSE (D)-2015,2010, (AI)-2009,(DC)-2008,2003

$${}_1^2\text{H} + {}_1^3\text{H} \longrightarrow {}_2^4\text{He} + {}_0^1\text{n}$$

Given $m({}_1^2\text{H})$ = 2.014102 u, $m({}_1^3\text{H})$ = 3.016049 u, $m({}_2^4\text{He})$ = 4.002603 u, m_n = 1.008665 u & 1u = 931.5 MeV/c^2

[**Ans**. $\Delta m = [m({}_1^2\text{H}) + m({}_1^3\text{H}) - \{ m({}_2^4\text{He}) + m_n\}]$= [2.014102 + 3.016049 –{ 4.002603 +1.008665 }]

⇨ $\Delta m = 0.018883\ u$ ⇨ Q = 0.018883 X 931.5 = 17.59 MeV

899. Calculate the energy released if, U^{238} , emits an α-particle. **CBSE (AI)-2007**

OR

Calculate the energy released in MeV in the following nuclear reaction. **CBSE (AI)-2008,(D)-2007**

$${}_{92}^{238}\text{U} \longrightarrow {}_{90}^{234}\text{Th} + {}_2^4\text{He} + Q$$

[**Ans**. 4.25

[Given, mass of ${}_{92}^{238}\text{U}$ = 238.05079 u, mass of ${}_{90}^{234}\text{Th}$ = 234.043630 u, mass of ${}_2^4\text{He}$ =4.002600 u & 1u = 931.5 MeV/c^2]

[**Ans**. $\Delta m = [m({}_{92}^{238}\text{U}) - \{m({}_{90}^{234}\text{Th}) + m({}_2^4\text{He})\}]$= [238.05079 –{234.043630+ 4.002600}]

⇨ $\Delta m = 0.0456\ u$ ⇨ Q = 0.0456 X 931.5 = 4.25 MeV

899a. A neutron is absorbed by a ${}_3^6\text{Li}$ nucleus with the subsequent emission of an alpha particle. Write the corresponding nuclear reaction. Calculate the energy released in this nuclear reaction. **CBSE (AI)-2006,(D)-2005**

OR

Calculate the energy released in the following nuclear reaction **CBSE (AI)-2006,2002,(D)-2005,2003**

$${}_3^6\text{Li} + {}_0^1\text{n} \longrightarrow {}_2^4\text{He} + {}_1^3\text{H} + Q$$

[**Ans**. 4.78 MeV]

[mass of ${}_0^1\text{n}$ = 1.008665 u, mass of ${}_3^6\text{Li}$ = 6.015126 u, mass of ${}_2^4\text{He}$= 4.002603 u, mass of ${}_1^3\text{H}$ = 3.016049 u]

[**Ans**. $\Delta m = [m({}_3^6\text{Li}) + m({}_0^1\text{n}) - \{m({}_2^4\text{He}) + ({}_1^3\text{H})\}]$= [6.015126 + 1.008665 – {4.002603 + 3.016049}]

⇨ Δm = 0.005138 u

⇨ Q = 0.005138 X 931 = 4.78 MeV

899b. (i) Write symbolically the nuclear β^+ decay process of ${}_6^{11}\text{C}$. Is the decayed product X an isotope or isobar of ${}_6^{11}\text{C}$?
(ii) Given tha mass value of $m({}_6^{11}\text{C})$ = 11.011434 u and $m(X)$ = 11.00935 u. Estimate the Q value in this process.

[**Ans**. (i) ${}_6^{11}\text{C} \longrightarrow {}_5^{11}\text{C} + {}_{+1}^{0}e + \nu$, X is an isobar **CBSE (AI)-2015**

(ii) $\Delta m = [m({}_6^{11}\text{C}) - m(X)]$ = [11.011434– 11.00935] = 0.002129 u

⇨ Q = 0.002129 X 931.5 = 1.98 MeV

899c. A nucleus ${}_{10}^{23}\text{Ne}$, β-decays to give the nucleus of ${}_{11}^{23}\text{Na}$. Write down the β-decay equation. Calculate the kinetic energy of electron emitted. (Rest mass of electron may be ignored.) **CBSE (D)-2008,(AI)-2004**

(Given, $m({}_{10}^{23}\text{Ne}) = 22.994466\ u$ & $m({}_{11}^{23}\text{Na}) = 22.989770\ u$)

[**Ans**. ${}_{10}^{23}\text{Ne} \longrightarrow {}_{11}^{23}\text{Na} + {}_{-1}^{0}e + \overline{\nu}$

⇨ $\Delta m = [m({}_{10}^{23}\text{Ne}) - \{m({}_{11}^{23}\text{Na})] = [22.994466 - 22.989770\,] =$ 0.004696 u

⇨ Energy released or the K.E. of emitted electron Q = Δm X c^2 = 0.004696 X 931.5 = 4.374 MeV

899d. When a deuteron of mass $2.0141\,u$ and negligible kinetic energy is absorbed by a Lithium (${}_3^6\text{Li}$) nucleus of mass $6.0155\,u$, the compound nucleus disintegrates spontaneously in to two alpha particles each of mass $4.0026\,u$. Calculate the energy in Joules carried by each alpha particle. $(1\,u = 1.66\,X\,10^{-27}\,\text{Kg})$ **CBSE (AI)-2004**

[**Ans**. ${}_3^6\text{Li} + {}_1^2\text{H} \longrightarrow {}_2^4\text{He} + {}_2^4\text{He} + Q$

⇨ $\Delta m = [m({}_3^6\text{Li}) + m({}_1^2\text{H}) - 2\,X\,m({}_2^4\text{He})]$ = [6.0155 + 2.0141 – $4\,X$ 4.0026] = 8.0296 –8.0052

⇨ $\Delta m = 0.0244\ u$ = 0.0244 X $1.66\,X\,10^{-27}$ Kg

⇨ Q = Δm X c^2 = 0.0244 X $1.66\,X\,10^{-27}$X $(3\,X\,10^8)^2$ = 3.645 X 10^{-12} J

Hence energy carried by each alpha particle = 3.645 X 10^{-12}/2 = 1.8225 X 10^{-12} J

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Unit IX: Electronic Devices **12 Periods**

Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits

Energy bands in conductors, semiconductors and insulators (qualitative ideas only)

Semiconductor diode - I-V characteristics in forward and reverse bias, diode as a rectifier;

Special purpose p-n junction diodes: LED, photodiode, solar cell and Zener diode and their characteristics, zener diode as a voltage regulator.

901. Give the ratio of the number of holes and number of conduction electrons in an intrinsic semiconductor.
[Ans. $n_h / n_e = 1$ **CBSE (F)-2003**

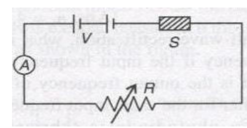
902. What is meant by the term doping of an intrinsic semiconductor ? How does it affect the conductivity of a semiconductor ?
[Ans. Doping : **CBSE (AIC)-2001**
Deliberate adding of desired impurity to a semiconductor to increase its conductivity is called doping.
Conductivity of a semiconductor increases due to doping

903. How does the energy gap of an intrinsic semiconductor vary, when doped with a trivalent impurity/ pentavalent impurity?
[Ans. Decreases **CBSE (AI)-2002,(D)-2002**

904. How does the forbidden energy gap of an intrinsic semiconductor vary with increase in temperature?
[Ans. no effect **CBSE (AI)-2002,(D)-2002**

905. Name the two factors on which electrical conductivity of a pure semiconductor at a given temperature depends.
[Ans. (i) The width of the forbidden band **CBSE (AIC)-2005**
(ii) Intrinsic charge carrier concentration

906. The diagram shows a piece of pure semiconductor 'S' in series with variable resistor R and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant when semiconductor 'S' is heated ? Give one reason. **CBSE (DC)-2005**
[Ans. Increase the value of R
Reason : on heating, conductivity of the semiconductor increases



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907. Give reason, why, a p-type semiconductor crystal is electrically neutral, although $n_h >> n_e$
[Ans. because impurity atoms added to the semiconductor are electrically neutral **CBSE (F)-2013,(D)-2008**

908. An n-type semiconductor has a large number of electrons but still it is electrically neutral. Explain the reason.
[Ans. because impurity atoms added to the semiconductor are electrically neutral] **CBSE (AI)-2008**

909. Is the ratio of the number of holes and number of electrons in a p-type semiconductor more than, less than or equal to 1 ?
[Ans. $n_h / n_e > 1$ **CBSE (AIC)-2003**

910. Why is the conductivity of n-type semiconductor greater than that of the p-type semiconductor even when both of these have same level of doping ? **CBSE (AIC)-2005**
[Ans. because mobility of electrons is higher than that of holes

911. How does the conductivity of a semiconductor change with the rise in its temperature ? **CBSE (DC)-2010**
[Ans. Conductivity of a semiconductor increases exponentially with the temperature

912. Why does the conductivity of a semiconductor increase with the rise in its temperature ? **CBSE (DC)-2005**
[Ans. $\sigma = e\,[\,n_e\mu_e + n_h\mu_h\,]$
On increasing the temperature μ_e & μ_h decreases (due to increase in the collision frequency). But n_e & n_h increases (as $n \propto e^{-\frac{E_g}{KT}}$). Since n_e & n_h is so large that decrease of μ_e & μ_h does not affect too much. So overall conductivity of the semiconductor increases

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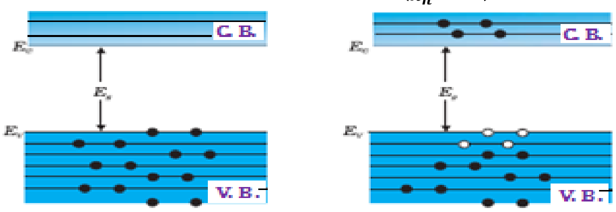
913. What are energy bands ? How are these formed ? **CBSE (AI)-2016,2008,2006,(D)-2010,2006,2005,(F)-2003**
[Ans. Energy bands : A group of large number of closely spaced energy levels spread in a very short energy range, is called an energy band
Formation of energy bands :
Due to interaction of electrons in outermost orbits of atoms in a crystal, different energy levels with continuous energy variation splits and energy bands are formed.

914. What is a valance band & conduction band ?
[Ans. **Valence Band :** The highest energy band filled with valence electrons is called the valence band
Conduction Band : The lowest unfilled allowed energy band above the valence band is called conduction band

915. Define forbidden energy gap ?
[Ans. Forbidden energy gap (E_g) : The energy gap between the valence band and the conduction band in which no allowed energy levels can exists is called the energy band gap (E_g)

916. Draw the energy band diagram of an intrinsic semiconductor. **CBSE (AIC)-2006,2005,2003**

[Ans. Energy band diagrams of an intrinsic semiconductor $\left(\frac{n_e}{n_h} = 1\right)$



(a) at T = 0 K **(b) at T > 0 K**

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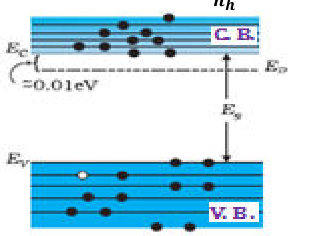
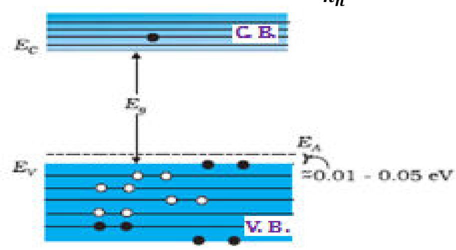
917. Draw the energy band diagram of $n - type$ & $p - type$ semiconductor.

[Ans. **CBSE (AI)-2012,2006,2005,2003,2001,(D)-2005,2004,2002**

n-type semiconductor ($\frac{n_e}{n_h}$ >1)



p-type semiconductor ($\frac{n_e}{n_h}$ <1)



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918. Distinguish between intrinsic and extrinsic semiconductors. **CBSE (F)-2017,(D)-2015,2008**

[Ans.

Intrinsic Semiconductor	Extrinsic Semiconductor
1. It is a pure semiconductor.	1. It is a semiconductor with added impurity.
2. $n_e = n_h$	2. $n_e \neq n_h$
3. Low conductivity at room temperature	3. High conductivity at room temperature
4. Its electrical conductivity depends on temperature only.	4. Its electrical conductivity depends on temperature and the amount of doping.

919. Distinguish between intrinsic and a p-type semiconductor. **CBSE (F)-2013**

[Ans.

n-type semiconductor	p-type semiconductor
1. It is obtained by adding controlled amount of pentavalent impurity to a pure semiconductor.	1. It is obtained by adding controlled amount of trivalent impurity to a pure semiconductor.
2. $n_e \gg n_h$	2. $n_h \gg n_e$
3. Its electrical conductivity is due to free electrons.	3. Its electrical conductivity is due to holes.

==

920. Name the two important processes that occur during the formation of a p-n junction. **CBSE (AI)-2016,(D)-2017**

[Ans. (i) Diffusion (ii) drift

921. What happens when a forward bias is applied to a p-n junction ? **CBSE (AI)-2015**

[Ans. p-n junction conducts current when a forward bias is applied to it

922. Name any semiconductor device which operates under the reverse bias in the breakdown region. **CBSE (AI)-2013**

[Ans. Zener diode

923. Name the p-n junction diode, which emits spontaneous radiation when forward biased. **CBSE (DC)-2004**

[Ans. Light Emitting Diode (LED)

924. Why is the current under reverse bias almost independent of the applied potential up to a critical voltage ? **CBSE (AI)-2013**

[Ans. As the number of minority charge carriers is very small, so the current is almost independent of the applied voltage up to reverse breakdown voltage

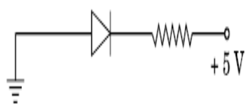
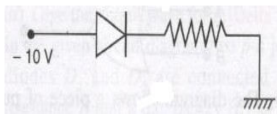
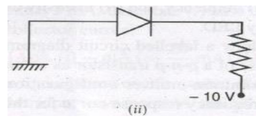
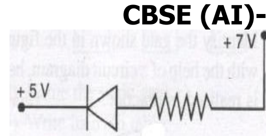
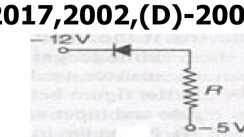
925. Why does the reverse current shows a sudden increase at the critical voltage ? **CBSE (AI)-2013**

[**Ans.** At the critical voltage, i,e, reverse breakdown voltage, the applied voltage is large enough to break covalent bonds producing more minority charge carriers which conduct causing a sudden increment in the current

926. Explain how the width of depletion region in a p-n junction diode change, when the junction is- (i) forward biased (ii) reverse biased. **CBSE (AI)-2011, 2002,(D)-2010,2003**

[**Ans.** (i) decreases (ii) increases

927. In the following circuit diagram, is the junction diode forward biased or reverse biased ? **CBSE (AI)-2017,2002,(D)-2005**

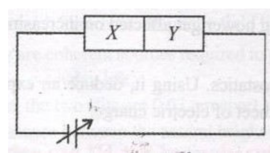
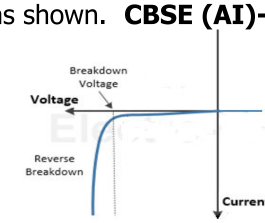
[**Ans.** (i) reverse bias (ii) reverse bias (iii) Forward bias (iv) forward bias (v) forward bias

928. Two semiconductor materials X and Y shown in given figure are made by doping germanium crystal with Indium and Arsenic respectively. The two are joined end to end and connected to a battery as shown. **CBSE (AI)-2007**

(i) Will the junction be forward biased or reverse biased ?

(ii) sketch V-I graph for this arrangement.

[**Ans. (i) Reverse bias**

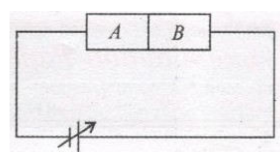
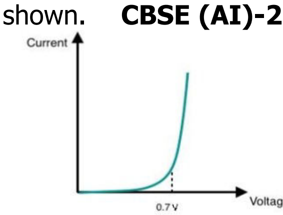



929. Two semiconductor materials A and B shown in given figure are made by doping germanium crystal with Arsenic and Indium respectively. The two are joined end to end and connected to a battery as shown. **CBSE (AI)-2007**

(i) Will the junction be forward biased or reverse biased ?

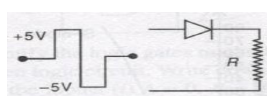
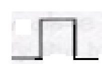
(ii) sketch V-I graph for this arrangement.

[**Ans. (i) Forward bias**

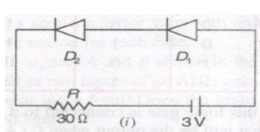
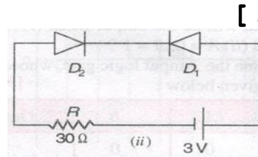



930. Draw and explain the output wave forms across the load resistor R, if the input waveform is as shown in the figure.

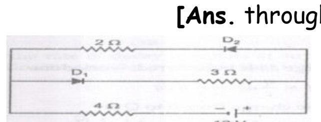
[**Ans.** **CBSE (D)-2006**

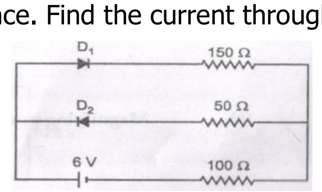
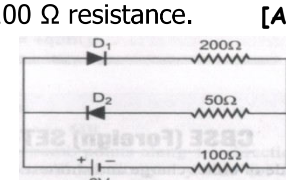
931. Determine the currents through the resistance R of the circuits (i) and (ii), when similar diodes D_1 and D_2 are connected as shown. **[Ans. (i)** $0.1\,A$ **(ii) zero** **CBSE (DC)-2002**

932. The circuit shown in the figure has two oppositely connected ideal diodes connected in parallel. Find the current flowing through each diode in the circuit. **[Ans.** through D_1, I=0, through D_2, I = 2A] **CBSE (F)-2013**



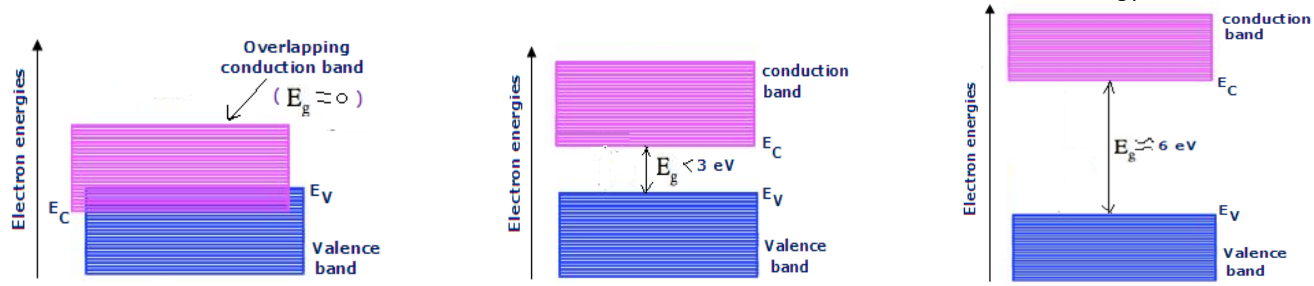
933. The circuit shown in the figure consists of two diodes each with a forward resistance of 50 Ω and infinite backward resistance. Find the current through 100 Ω resistance. **[Ans.** 6/300 A, 6/350 A] **CBSE (F)-2013**

934. Distinguish between a conductor, an insulator and a semiconductor on the basis of energy band diagrams.

CBSE (AI)-2016,2008,2006,(D)-2010,2006,2005,(F)-2003

[Ans. **Distinction between Conductors (metals), insulators and semiconductors on the basis of Energy bands**



(a) Conductors(Metals) (b) Semiconductors (c) Insulators

1. **Conductors (Metals) :**

In conductors either conduction and valence band partly overlap each other or the conduction band is partially filled. Forbidden energy gap does not exists ($E_g \approx 0$). This makes a large number of free electrons available for electrical conduction. So the metals have high conductivity.

2. **Semiconductors :**

In semiconductors, conduction band is empty and valance band is totally filled. E_g is quite small (< 3 eV). At $0\ K$, electrons are not able to cross this energy gap and semiconductor behaves as an insulator. But at room temperature, some electrons are able to jump to conduction band and semiconductor acquires small conductivity

3. **Insulators**

In insulators, conduction band is empty and valance band is totally filled. E_g is very large ($\approx$ 6 eV). It is not possible to give such large amount of energy to electrons by any means. Hence conduction band remains total empty and the crystal remains as insulator

935. What is p-n junction ? Explain briefly, with the help of suitable diagram, how a p-n junction is formed. Define the term Potential barrier and depletion region.

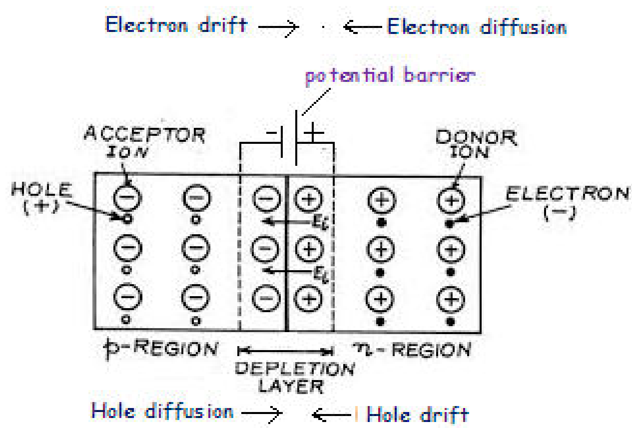
CBSE (D)-2017,2014,2010,2006,(AI)-2016,2015,2012,2009,2003,(F)-2015,2009,2006

[Ans. p-n junction : When a semiconductor crystal is so prepared that, it's one half is p-type and other is n-type, then the contact surface dividing the two halves, is called p-n junction

Formation of p-n junction : potential barrier & depletion region

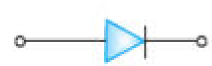
Diffusion and drift are the two important processes involved during the formation of a p-n junction

Due to different concentration gradient of the charge carriers on two sides of the junction, electrons from $n - side$ starts moving towards $p - side$ and holes start moving from $p - side$ to $n - side$. This process is called $\boldsymbol{Diffusion}$.



Due to diffusion, positive space charge region is created on the $n - side$ of the junction and negative space charge region is created on the $p - side$ of the junction. Hence an electric field called Junction field is set up from $n - side$ to $p - side$ which forces the minority charge carriers to cross the junction. This process is called **Drift.**

The potential difference developed across the p-n junction due to diffusion of majority charge carriers, which prevents the further movement of majority charge carriers through it, is called potential barrier. For Si, V_B = 0.7 V and for Ge, V_B =0.3 V

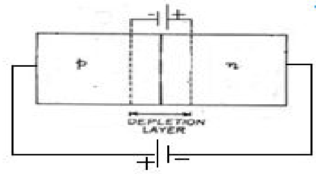


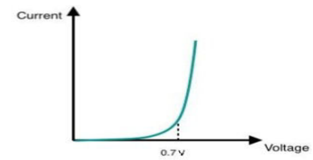
The small space charge region on either side of the p-n junction, which becomes depleted from mobile charge carriers is known as depletion region (10^{-6}m)

936. What is meant by forward and reverse biasing of a p-n junction ? Draw the circuit diagram of a forward and reverse biasing of a p-n junction. **CBSE (AIC)-2010**

[Ans. (i) Forward biasing :

When the positive terminal of external battery is connected to p-side and negative terminal to the n-side, then the p-n junction is said to be forward biased





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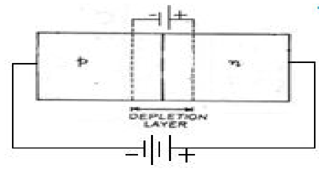
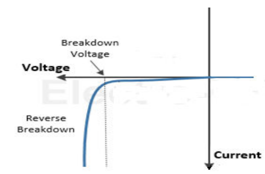
(ii) Reverse biasing :

When the positive terminal of external battery is connected to n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased





937. Describe briefly: (i) 'minority carrier injection' in forward bias (ii) 'Breakdown voltage' in reverse bias. **CBSE (AI)-2015**

[Ans. (i) Minority carrier injection in forward bias :

During forward bias, electrons from n-side cross the junction and reach p-side. (where they are minority carries). Similarly, holes from p-side cross the junction and reach the n-side (where they are minority carries). This process is known as minority carrier injection

(ii) Breakdown voltage in reverse bias : At very high reverse voltage, the current suddenly increases and becomes independent of applied voltage. This critical voltage is called breakdown voltage

938. Define the terms 'depletion region' and 'potential barrier' in a p-n junction. Explain how the width of depletion region in a p-n junction diode change, when the junction is- (i) forward biased (ii) reverse biased. **CBSE (AI)-2016,2011,2010,2002**

[Ans. Depletion region : The small space charge region on either side of the p-n junction which becomes depleted from mobile charge carriers. is known as depletion region

Potential barrier : The potential difference developed across the p-n junction due to diffusion of majority charge carriers, which prevents the further movement of these charge carriers through it, is called potential barrier

(i) Width of depletion region decreases in forward bias

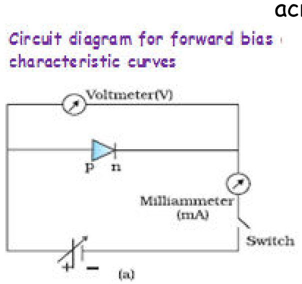
Reason : In the forward bias, external battery pushes the majority charge carriers towards the junction.

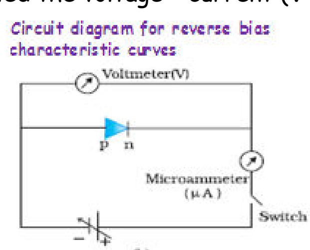
(ii) Width of depletion region increases in reverse bias

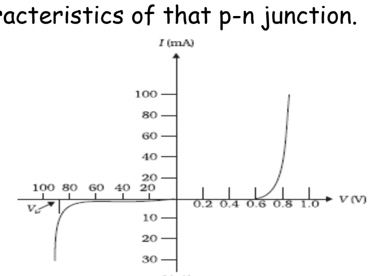
Reason : In the reverse bias, external battery attracts the majority charge carriers away from the junction.

939. Draw the circuit diagram for studying the V-I characteristics of a p-n junction diode in (i) forward bias and (ii) reverse bias. Draw the typical V-I characteristics of a silicon diode. **SE (AI)-2015,2014,2013,2010,2009,(D)-2014**

[Ans. V-I characteristics : A graph showing the variation of current through a p-n junction with the voltage applied across it, is called the voltage – current (V-I) characteristics of that p-n junction.







For different values of voltages, the value of the current is noted. A graph between *V* and **I** is obtained as in fig. This V-I graph shows that -

(i) At a certain forward bias voltage, current increases rapidly showing the linear variation. This voltage is known as knee voltage or threshold voltage or cut-in voltage.

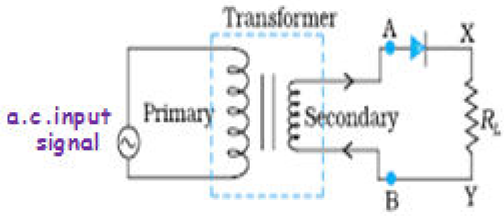
(ii) The ratio of change in forward voltage to the change in forward current is called dynamic resistance (r_d)

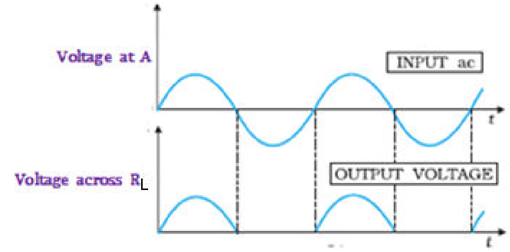
i,e, $r_d = \frac{\Delta V}{\Delta I}$ Ω

(iii) Under reverse bias, the current is very small (~μA) and remains almost constant. However, when reverse bias voltage reaches a high value, reverse current suddenly increases. This voltage is called Zener breakdown voltage.

940. Explain with the help of a circuit diagram, the working of p-n junction diode as half wave rectifier.

[Ans. Half wave rectifier : **CBSE (AI)-2014,2006,(D)-2009**





During the positive half cycle of ac input signal, the diode is forward biased and it conducts. Hence, there is current in the load resistance R_L and we get an output voltage.

During the negative half cycle of ac input signal, diode is reverse-biased and it does not conduct. Hence, there is no current in the load resistance and there is no output.

Thus, we get the output only for half cycle of a.c. input signal.

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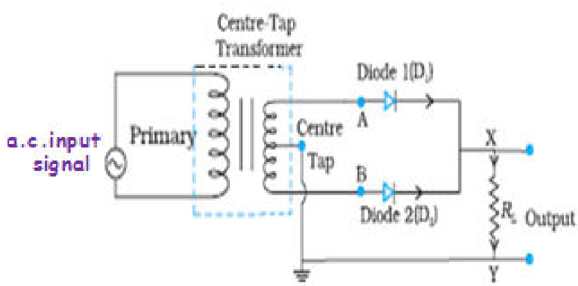
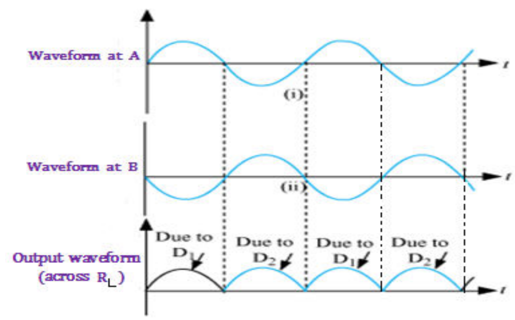
941. Draw a labelled circuit diagram of a junction diode as a full wave rectifier. Explain its underlying principle and working. Depict the input and output wave forms. **CBSE (AI)-2017,2015,2011,2006,(D)-2012,2009,(F)-2009,2005**

[Ans. Full wave rectifier





During the positive half cycle of a.c. input signal, diode D_1 gets forward biased and conducts while D_2 being reverse biased does not conducts. Hence, there is a current in R_L due to diode D_1 and we get an output voltage.

During the negative half cycle of ac input signal, diode D_1 gets reverse biased and does not conduct while D_2 being forward biased conducts. Hence, now there is a current in R_L due to diode D_2 and again we get an output voltage.

Thus, we get output voltage for complete cycle of a.c. input signal in the same direction

942. Which characteristic property makes the junction diode suitable for rectification ? **CBSE (AI)-2015**

[Ans. A p-n junction diode allows current to pass only when it is forward biased

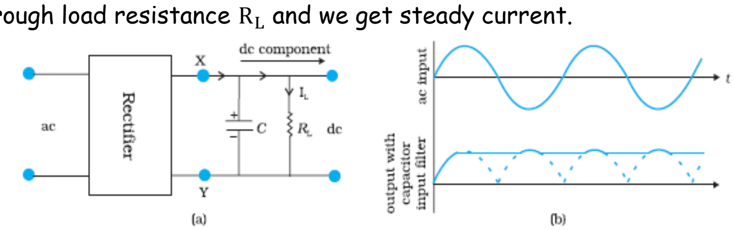
943. Frequency of an a.c. input signal is $50\ \text{Hz}$. What is the output frequency of a - **CBSE (AIC)-2010**

(i) Half wave rectifier (ii) Full wave rectifier

[Ans. (i) $50\ \text{Hz}$ **(ii)** $100\ \text{Hz}$

947. Describe briefly the role of a capacitor in filtering. **CBSE (AI)-2015**

[Ans. A capacitor connected across the output terminals of a rectifier offers a low resistance path for a.c. and blocks dc. So all dc will pass through load resistance R_L and we get steady current.



948. How are the V-I characteristics of a p-n junction diode made use of in rectification ? **CBSE (D)-2014**

[Ans. It is obvious from V-I characteristics that diode allows the current to pass only when it is forward biased. So, when an alternating voltage is applied across a junction diode, the current will flow only in that part of the cycle when diode is forward biased. This property is used to rectify the alternating voltages

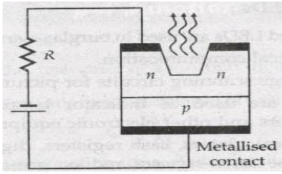
949. What is a light emitting diode ? How is a light emitting diode fabricated ? Draw a circuit diagram showing the biasing of a LED. Explain briefly the process of emission of light by a light emitting diode (LED).

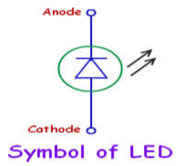
CBSE (D)-2016,2004,(AI)-2015, 2010,(F)-2008,(DC)-2005

[Ans. Light Emitting Diode (LED) : It is a special heavily doped p-n junction diode, which emits spontaneous light, when forward biased. It converts electrical energy in to light energy.

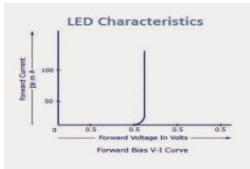
LED is fabricated by- (i) heavily doped p-n junction made from a semiconductor like GaAs having $E_g \approx 1.8$ eV.

(ii) Providing a transparent cover so that light can come out





Symbol of LED



Working : When p-n junction is forward biased, electrons and holes moves across the junction from n to p and p to n-side respectively. As a result, the concentration of minority carriers increases rapidly at the junction. These excess minority carriers on either side of the junction, recombine with majority carriers and energy is released in the form of photons ($h\nu = E_g$)

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981. Give two advantages of using LEDs over conventional incandescent lamps. **CBSE (AI)-2015,2007,2004**

[Ans. low operational voltage/less power consumption/Long life/ fast on-off switching capability/no warm-up time required

982. Mention two uses of LEDs. **CBSE (AIC)-2010,2004**

[Ans. in remote controls/in electronic watches & calculators /in burglar alarm systems/ in optical communication

983. Which semiconductors are preferred to make LEDs and why ? **CBSE (AI)-2015,2010**

[Ans. GaAs and GaAsP

Reason: these materials have energy gap $E_g \geq 1.8$ eV which is suitable to produce visible light of desired wavelengths

984. What criterion is kept in mind while choosing the semiconductor material for a LED ? **CBSE (D)-2013,2007**

[Ans. semiconductor used must have an energy band gap of 1.8 eV

985. The band gap of the semiconductor used for fabrication of visible LED's must at least be 1.8 eV. Why ? **CBSE (SP)-2015**

[Ans. The photon energy of visible light photons varies about 1.8 eV to 3 eV. Hence for visible LED's the semiconductor used must have a band gap of at least 1.8 eV

986. State the factor which controls (i) wavelength/frequency of light (ii) intensity of light emitted by LED. **CBSE (F)-2008**

[Ans. (i) nature of material of diode/band gap (ii) forward biasing of LED

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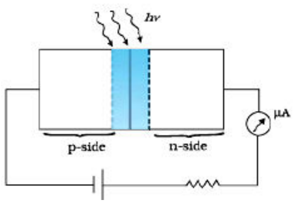
987. What is Photodiode ? How is photodiode fabricated ? Describe the working of photodiode by drawing the circuit diagram. Also draw the characteristics of a photodiode for different illumination intensities.

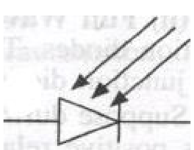
CBSE (AI)-2016,2015,2005,(D)-2015,2012,2005,(F)-2014,2010,2005

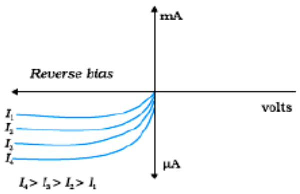
[Ans. Photodiode : It is a reverse biased p-n junction diode, in which current carriers are generated by photons through photoconduction by light

Fabrication of Photodiode : It is a special reverse biased p-n junction diode fabricated with a transparent window to allow the light of suitable frequency ($h\nu > E_g$) to fall on the junction of diode



Biasing of a photodiode


Symbol of a photodiode



Characteristics of a photodiode

Working : (i) when light of energy ($h\nu > E_g$) falls on photodiode, electron-holes pairs are generated in the depletion region due to absorption of photons

(ii) due to electric field at the junction, electrons and holes are separated before they recombine

(iii) electrons are collected on n-side and holes are collected at p-side, giving rise to an emf and current flows in the load. Photocurrent is proportional to the incident light intensity

988. Give any two uses of photodiode. **CBSE (DC)-2010**

[Ans. in detection of optical signals / in light operated switches/ in electronic counters

989. A photodiode is operated under reverse bias although in the forward bias the current is known to be more than the current in the reverse bias. Explain giving reason. **CBSE (D)-2015,2012,2005,(F)-2010,2005,(AI)-2005**

[Ans. The fractional change, due to photo effects, in the reverse bias current, is much more than the fractional change in the forward bias current. Hence, photodiode is used in reverse bias.

Explanation : Let us consider n-type semiconductor ($n \gg p$).

When illuminated with light, both type of carriers increase equally in number.

⇨ $n' = n + \Delta n$ & $p' = p + \Delta p$

Now as $n \gg p$ & $\Delta n = \Delta p$, ⇨ $\frac{\Delta n}{n} \ll \frac{\Delta p}{p}$

990. Write briefly how a photodiode can be used as a photo detector to detect optical signals. **CBSE (D)-2013**

[Ans. It is easier to observe change in the current, with change in the light intensity, when reverse bias is applied. Hence photodiode can be used as a photo detector to detect optical signals

991. A photodiode is fabricated from a semiconductor with a band gap of 2.8eV.Can it detect a wavelength of 6000nm? Justify. **CBSE (AI)-2005,(D)-2005,(F)-2005**

[Ans. $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 10^{-9}} = \mathbf{0.207\ eV}$

As $E < E_g$, photodiode **cannot** detect the radiation of wavelength 6000 nm

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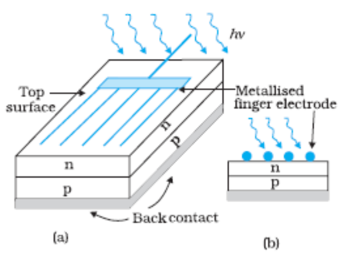
992. What is a Solar Cell ? How a solar cell is fabricated ? State the working principle of a solar cell. Mention three Basic processes involved in the generation of emf. **CBSE (F)-2016,(AI)-2015,2008**

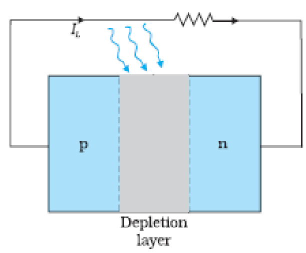
[Ans. Solar Cell : It is a p-n junction diode, which converts light energy in to electrical energy.

Principle : It is based on the principle of **photovoltaic effect**

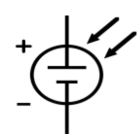
Fabrication : A simple p-n junction solar cell consists of a very thin p-Si wafer. On one side of this wafer, a thin layer of n-Si is grown by diffusion process and on the other side there is a metal coating which acts as back contact. On the top of n-Si layer, metallic grid is deposited, which acts as a front contact.



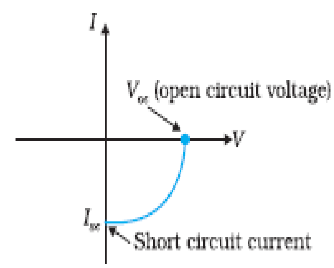
Solar cell



Circuit diagram



Symbol



characteristic curve

Working : Generation of emf by a solar cell, when light falls on, it is due to the following three basic processes:

(i) generation of electron hole pairs due to incident light (with $h\nu > E_g$) close to the junction

(ii) separation of electrons and holes due to electric field of the depletion region

(iii) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photo voltage.

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993. Write any two uses of solar cells. **CBSE (AIC)-2010**

[Ans. (i) to power electronic devices in satellites and space vehicles

(ii) in power supply for watches, calculators

(iii) in charging solar batteries

994. Why are Si and GaAs preferred materials for solar cells ? **CBSE (F)-2016, (AI)-2008**

[Ans. Solar radiation has maximum intensity of photons of energy = 1.5 eV. Hence, semiconducting materials Si and GaAs, with $E_g \approx$ 1.5 eV, are preferred materials for solar cell

995. Write two important criteria required for the selection of a material for solar cell fabrication. **CBSE (AI)-2015**

[Ans. (i) Band energy gap E_g must be of range 1.0 to 1.8 eV (ii) strong electrical conductivity

(iii) high optical absorption ($\approx 10^4 cm^{-1}$) (iv) availability and low cost of the raw material

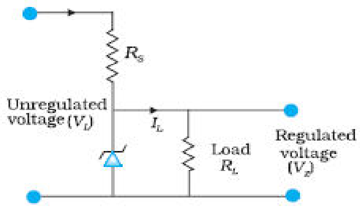
996. What is Zener diode ? How is a Zener diode fabricated ? What causes the setting up of high electric field even for small reverse bias voltage across the diode ? With the help of a circuit diagram explain the use of a Zener diode as a voltage stabilizer. **CBSE (AI)-2015,2009,2008,2004,(F)-2007,2001**

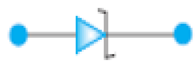
[Ans. Zener Diode: It is a heavily doped p-n junction diode specially designed to operate in the reverse breakdown region Continuously

Principle : At reverse breakdown voltage, the voltage across Zener diode remains constant for a large change in reverse current.

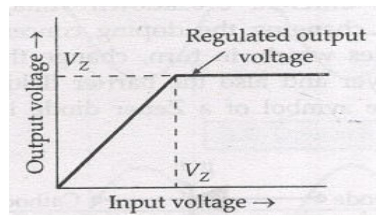
Fabrication : Zener diode fabricated by heavily doping both p and n- side of the junction. Heavy doping makes the depletion region very thin. This makes the electric field of the junction extremely high (≈5 X 10^6 V/m), even for a small reverse voltage (≈ 5V). This in turn helps the Zener diode to act as voltage regulator

Zener diode as a Voltage stabilizer :





Symbol of Zener diode



Working :

If input voltage increases/ decreases, current through Zener diode will also increase/ decreases. It increases/ decreases voltage drop across Rs without any change in voltage across R_L as potential across Zener diode does not change in breakdown region giving the regulated output voltage

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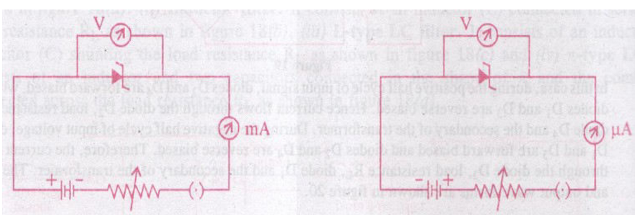
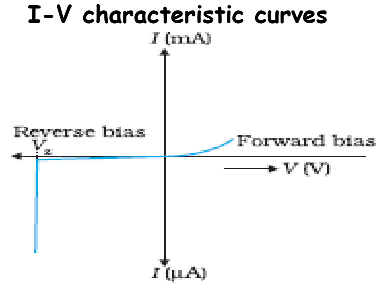
997. Draw the circuit diagram to study the characteristic curves of a Zener diode and draw its typical I-V characteristics. **CBSE (F)-2012,2010**

[Ans. Circuit diagram to draw characteristic curves :



(a) Forward Biased (b) Reverse Biased

I-V characteristic curves



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997a. Write two important considerations used while fabricating a Zener diode. **CBSE (AI)-2015,2012**

[Ans. (i) heavily doping of both p and n-sides of the junction (ii) Proper breakdown voltage under reverse biasing

997b. Why Zener diode is called a special purpose diode ?

[Ans. Because operates in reverse breakdown region and acts as a voltage regulator

997c. Why is Zener diode fabricated by heavily doping both p and n- side of the junction ? **CBSE (F)-2014**

OR

How is a Zener diode fabricated ? What causes the setting up of high electric field even for small reverse bias voltage across the diode ? **CBSE (AI)-2015**

[Ans. Zener diode fabricated by heavily doping both p and n- side of the junction. Heavy doping makes the depletion region very thin. This makes the electric field of the junction extremely high (≈5 X 10^6 V/m), even for a small reverse voltage (≈5V). This in turn helps the Zener diode to act as voltage regulator

998. Zener diodes have higher dopant densities as compared to ordinary p-n junction diodes. How does it affect the- (i) width of depletion layer (ii) junction field ? **CBSE (Sample Paper)-2010**

[Ans.(i) width of depletion layer decreases (ii) junction field increases

999. How the reverse current suddenly increases at the breakdown voltage ? Explain. **CBSE (F)-2012,2010**

[Ans. At V = V_Z, electric field is high enough (10^6 V/m) to pull valence electrons from the host atoms on the p-side which are accelerated to n-side. These electrons account for high current observed at the breakdown. The emission of electrons from the host atoms due to the high electric field is known as internal field emission or field ionization. The breakdown of diode due to internal field emission is called Zener breakdown