SAMPLE QUESTION PAPER

BLUE PRINT

Time Allowed : 3 hours **Maximum Marks :** 70

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	4(4)	2(4)	1(3)	–	**9(16)**
2.	Current Electricity	2(5)	–	–		
3.	Magnetic Effects of Current and Magnetism	1(4)	–	1(3)	–	**7(17)**
4.	Electromagnetic Induction and Alternating Current	3(3)	1(2)	–	1(5)	
5.	Electromagnetic Waves	2(2)	1(2)	1(3)	–	**8(18)**
6.	Optics	1(1)	1(2)	1(3)	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	1(2)	–	–	**6(12)**
8.	Atoms and Nuclei	2(2)	1(2)	–	1(5)	
9.	Electronic Devices	–	2(4)	1(3)		**3(7)**
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

Subject Code : **042**

PHYSICS

Time allowed : 3 hours ***Maximum marks : 70***

(i) All questions are compulsory. There are 33 questions in all.

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.

(iii) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.

(iv) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

SECTION - A

All questions are compulsory. In case of internal choices, attempt any one of them.

1. If 10^9 electrons move out of a body to another body every second, then what will be the time required to get a total charge of 1 C on the other body?

OR

Write the expression for the torque $\vec{\tau}$ acting on a dipole of dipole moment $\vec{p}$ placed in an electric field $\vec{E}$.

2. What do you mean by *Q*-value of a nuclear reaction?

3. Is Ohm's law universally applicable for all conducting elements? If not, give examples of elements which do not obey Ohm's law.

4. When an ac source is connected across an inductor, show on a graph the nature of variation of the voltage and the current over one complete cycle.

OR

What is the value of impedance of a resonant series *LCR* circuit?

5. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. Calculate its radius in $n = 3$ orbit.

6. Four point charges each of charge $+q$ is placed on the circumference of a circle of diameter $2d$ in such a way that they form a square. What will be the potential at the centre?

7. What physical quantity is same for X-rays of wavelength 10^{-10} m, red light of wavelength 6800 Å and radio waves of wavelength 500 m?

OR

The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is $B_0 = 510$ nT. What is the amplitude of the electric field part of the wave?

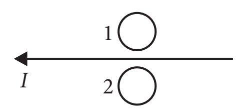
8. In Young's double slit experiment, what is the nature of the locus of a point P lying in a plane with a constant path difference between the two interfering waves?

9. The incident light has intensity I and the number of electrons emitted per second is N. Then the maximum kinetic energy of emitted electrons per second is K. If the intensity of the incident light is doubled, then what will be the number of electrons emitted per second and the maximum kinetic energy respectively?

OR

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

10. Predict the direction of induced current in metal rings 1 and 2 when current I in the wire is steadily decreasing ?



For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

11. **Assertion (A) :** If a conductor is given charge then no excess inner charge appears.

Reason (R) : Electric field inside conductor is zero.

12. **Assertion (A) :** A metallic surface is moved in and moved out in a magnetic field, then emf is induced in it.

Reason (R) : Eddy current will be produced in a metallic surface moving in and out of magnetic field.

13. **Assertion (A) :** Sharper is the curvature of spot on a charged body lesser will be the surface charge density at that point

Reason (R) : Electric field is non-zero inside a charged conductor.

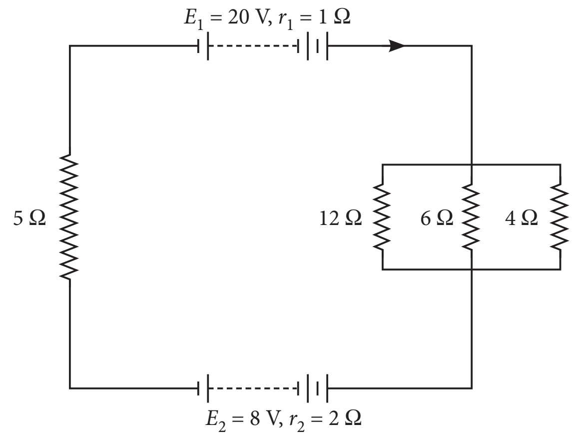
14. **Assertion (A) :** Environmental damage has increased the amount of ozone in the atmosphere.

Reason (R) : Increase of ozone increases the amount of ultraviolet radiation on earth.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. Group of cells is called a battery. In series grouping of cells their emf's are additive or subtractive while their internal resistances are always additive. Consider a case where, a 20 V battery of internal resistance 1 Ω is connected to three coils of 12 Ω, 6 Ω and 4 Ω in parallel, a resistor of 5 Ω and a reversed battery (e.m.f. = 8 V and internal resistance 2 Ω) as shown in figure.



(i) Calculate the total resistance of the circuit.

(a) 5 Ω (b) 10 Ω (c) 15 Ω (d) 20 Ω

(ii) Calculate the current in the circuit.

(a) 1.5 A (b) 0.5 A (c) 1.2 A (d) 1.0 A

(iii) The current in the coil of resistance 12 Ω is

(a) 0.2 A (b) 0.1 A (c) 0.5 A (d) 1.2 A

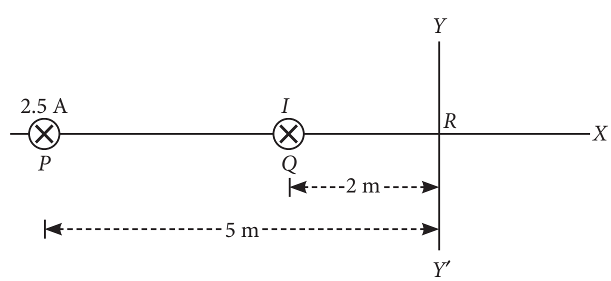
(iv) Find the potential difference across 20 V battery.

(a) 0.18 V (b) 1.88 V (c) 188 V (d) 18.8 V

(v) Find the potential difference across 8 V battery.

(a) 0.1 V (b) 10.4 V (c) 100 V (d) 1.88 V

16. Two long parallel wires carrying current 2.5 ampere and *I* ampere in the same direction (directed into the plane of the paper) are held at *P* and *Q* respectively, such that they are perpendicular to the plane of the paper. The points *P* and *Q* are located at a distance of 5 metres and 2 metres respectively from a collinear point *R* as shown in figure.



(i) Find the net magnetic field at point R.

(a) 10^{-7} (1 + I) (b) 10^{-7} (1 – I) (c) 10^{-7} (1 + 2I) (d) zero

(ii) What will be the direction of net magnetic field at point R.

(a) along positive *y*-axis (b) along positive *x*-axis
(c) along negative *y*-axis (d) along negative *x*-axis

(iii) An electron moving with a velocity of 4×10^5 m s^{-1} along the positive *X*-direction experiences a force of magnitude 3.2×10^{-20} N at the point *R*. Find the value of *I*.

(a) 0.4 A (b) 4 A (c) 5 A (d) 40 A

(iv) Find the positions at which a third long parallel wire carrying a current of magnitude 2.5 ampere directed into the paper may be placed, so that the magnetic induction at *R* is zero.

(a) 1 m from *R* on *RX* (b) 2 m from *R* on *PQ*
(c) 1 m from *R* on *RQ* (d) 2 m from *R* on *RX*

(v) Find the position at which a third long parallel wire carrying a current of magnitude 2.5 A which is directed out from the plane of the paper, may be placed, so that the magnetic induction at R is zero.

(a) 1 m from *R* on *RX* (b) 2 m from *R* on *RQ* (c) 1 m from *R* on *RQ* (d) 2 m from *R* on *RX*

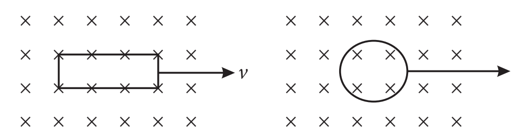
SECTION - C

All questions are compulsory. In case of internal choices, attempt anyone.

17. Obtain an expression for the magnetic energy in terms of the magnetic field B, area A and length l of the solenoid having n number of turns per unit length. Also, show that the magnetic energy per unit volume is given by $B^2/2\mu_0$.

OR

A rectangular loop and a circular loop are moving out of a uniform magnetic field region with a constant velocity $\vec{v}$ as shown in the figure. In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is normal to the loops.



18. Draw a labelled ray diagram of a compound microscope, showing the formation of image at the near point of the eye.

19. Given a uniform electric field $\vec{E} = 5\times10^3\,\hat{i}$ N/C. Find the flux of this field through a square of 10 cm on a side whose plane is parallel to the y-z plane. What would be the flux through the same square if the plane makes a 30° angle with the x-axis?

20. A semiconductor has equal electron and hole concentration of 6×10^8 m^3. On doping with certain impurity, electron concentration increases to $9 \times 10^{12}/\text{m}^3$.

(i) Identify the new semiconductor obtained after doping.

(ii) Calculate the new hole concentration.

21. You are given two nuclides ${}^7_3X$ and ${}^4_3Y$.

(i) Are they the isotopes of the same element?

(ii) Which one of the two is likely to be more stable? Give reason.

OR

Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions which you can draw regarding the nature of nuclear forces.

22. A proton and an α-particle are accelerated, using the same potential difference. How are the de Broglie wavelengths λ_p and λ_α related to each other?

23. Compare the conductivity of semiconductor at absolute zero temperature and at room temperature.

24. A radio can tune in to any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band?

25. Derive the expression for the torque acting on an electric dipole, when it is held in a uniform electric field. Identify the orientation of the dipole in the electric field, in which it attains a stable equilibrium.

OR

Define electric flux. Write its S.I. unit.

"Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is". Justify this statement with the help of a suitable example.

SECTION - D

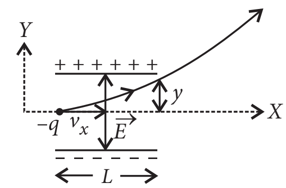
All questions are compulsory. In case of internal choices, attempt any one.

26. Show that average value of radiant flux density 'S' over a single period 'T' is given by $S = \frac{1}{2c\mu_0} E_0^2$.

OR

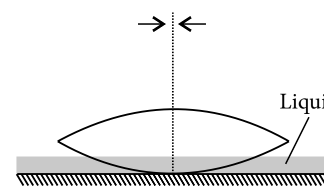
Show that the radiation pressure exerted by an EM wave of intensity I on a surface kept in vacuum is I/c.

27. A particle of mass m and charge $(-q)$ enters the region between the two charged plates initially moving along X-axis with speed v_x as shown in the given figure. The length of plate is L and an uniform electric field E is maintained between the plates. Show that the vertical deflection of the particle at the far edge of the plate is $\frac{qEL^2}{2mv_x^2}$.



28. The horizontal component, of the earth's magnetic field at a place is $\frac{1}{\sqrt{3}}$ times its vertical component. Find the value of the angle of dip at that place. What is the ratio of the horizontal component to the total magnetic field of the earth at that place?

29. An equiconvex lens with radii of curvature of magnitude R each, is put over a liquid layer poured on top of a plane mirror. A small needle, with its tip on the principal axis of the lens, is moved along the axis until its inverted real image coincides with the needle itself. The distance of the needle from the lens is measured to be a. On removing the liquid layer and repeating the experiment the distance is found to be b.

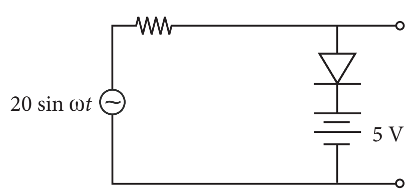


Given that two values of distances measured represent the focal length values in the two cases, obtain a formula for the refractive index of the liquid.

30. With the help of a suitable diagram, explain the formation of depletion region in a p-n junction. How does its width change when the junction is (i) forward biased, and (ii) reverse biased?

OR

Assuming the ideal diode, draw the output waveform for the circuit given in figure. Explain the waveform.



SECTION - E

All questions are compulsory. In case of internal choices, attempt any one.

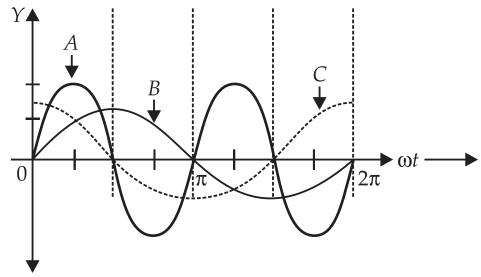
31. **(a)** In a series LCR circuit connected to an ac source of variable frequency and voltage $V = V_m \sin\omega t$, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and $R_2 (R_1 > R_2)$.

(b) Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced?

(c) Define Q-factor of the circuit and give its significance.

OR

A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph :



(a) Identify the device 'X'.

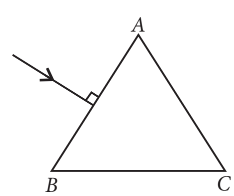
(b) Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer.

(c) How does its impedance vary with frequency of the ac source? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with ac voltage.

32. (a) A ray of light passing from air through an equilateral glass prism undergoes minimum deviation when the angle of incidence is $\frac{3}{4}$ of the angle of prism. Calculate the speed of light in the prism.

(b) The figure shows a ray of light falling normally on the face AB of an equilateral glass prism having refractive index $\frac{3}{2}$, placed in water of refractive index $\frac{4}{3}$. Will this ray suffer total internal reflection on striking the face AC? Justify your answer.



OR

(a) Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed ?

(b) A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (I) a medium of refractive index 1.65, (II) a medium of refractive index 1.33.

(i) Will it behave as a converging or a diverging lens in the two cases?

(ii) How will its focal length change in the two media?

33. (a) Using de Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.

(b) The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

OR

Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels.

SOLUTIONS

1. The charge given out in one second

$= 1.6 \times 10^{-19}$ C $\times 10^9 = 1.6 \times 10^{-10}$ C

Time required to accumulate a charge of 1 C,

$$= \frac{1\ \text{C}}{1.6\times10^{-10}\ \text{C s}^{-1}} = 6.25\times10^9\ \text{s}$$

$$= \frac{6.25\times10^9}{365\times24\times3600} = 198.18 \simeq 198\ \text{years}$$

OR

The torque $\vec{\tau}$ acting on a dipole of dipole moment $\vec{p}$ placed in an electric field $\vec{E}$ is given by

$\vec{\tau} = \vec{p}\times\vec{E}$

$\tau = pE\sin\theta$

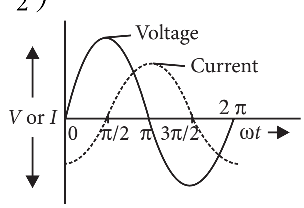
where θ = angle between dipole moment and electric field.

2. The difference between the rest masses of target nucleus, impinging particle and of product nuclei is called Q-value of nuclear reaction.

3. Ohm's law is not a fundamental law in nature. It is not universally followed. Semiconductor diodes, transistors, thermistors, vacuum tubes etc. do not follow Ohm's law.

4. $V = V_0 \sin\omega t$

$I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$



OR

Impedance of a resonant series LCR circuit,

$Z = \sqrt{R^2 + (X_L - X_C)^2} = R$ [$\because X_L = X_C$ at resonance]

5. Radius of n^{th} orbit, $r_n \propto n^2$

$\Rightarrow \frac{r_3}{r_1} = \frac{3^2}{1^2} = 9$ or $r_3 = 9r_1 = 9 \times 5.3 \times 10^{-11}$

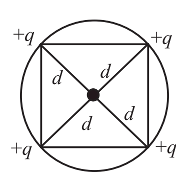
$= 47.7 \times 10^{-11}$ m $= 4.77 \times 10^{-10}$ m

6. Potential at centre due to all charges are

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{d}+\frac{q}{d}+\frac{q}{d}+\frac{q}{d}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{4q}{d} \text{ in S.I. units}$$

$$= \frac{4q}{d} \text{ in C.G.S units}$$



7. Though they all have different wavelengths and frequencies, but they have same speed *i.e.*, speed of light 3×10^8 m s^{-1} in vacuum.

OR

We know the relation, $\frac{E_0}{B_0} = c$

$E_0 = B_0 c = 510 \times 10^{-9} \times 3 \times 10^8$

Peak value of $E_0 = 1530 \times 10^{-1} = 153$ N C^{-1}

8. In Young's double slit experiment, the locus of a point P lying in a plane with a constant path difference between the two interfering waves is a hyperbola.

9. The maximum kinetic energy of emitted electrons is independent of intensity of incident light and the number of electrons emitted directly proportional to the intensity of incident light.

OR

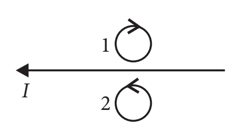
Given, slope of graph $= 4.12 \times 10^{-15}$ V s

slope $= \frac{h}{e}$

$4.12 \times 10^{-15} = \frac{h}{1.6 \times 10^{-19}}$

or $h = 6.592 \times 10^{-34}$ J s

10. When the current I in the wire is steadily decreasing, the direction of induced current in ring 1 will be clockwise and anticlockwise in ring 2 as shown in the figure.



11. (b) : When a conductor is charged the excess charge can reside only on the surface. The electric field inside conductor is zero.

12. (a)

13. (d) : Surface of a charged conductor is always an equipotential surface, whatever may be its shape. Hence σR = constant, at every point on the surface of charged conductor i.e. at the sharpest point ($R \to 0$) of the surface, charge density will be maximum. A uniformly charged conductor exerts no electrostatic force on a point charge located anywhere inside the conductor or electric field is zero.

14. (d) : Environmental damage has actually decreased the amount of ozone by making holes in the ozone layer because of which more UV radiation from sun enters our atmosphere.

15. Here, $E_1 = 20$ V; $r_1 = 1\ \Omega$; $E_2 = 8$ V and $r_2 = 2\ \Omega$

(i) (b) : Let I be the current in the circuit.

Total e.m.f. of the circuit, $E = E_1 - E_2 = 20 - 8 = 12$ V

Let R' be the resistance of the parallel combination of the coils of resistances 12 Ω, 6 Ω and 4 Ω. Then,

$$\frac{1}{R'} = \frac{1}{12} + \frac{1}{6} + \frac{1}{4} = \frac{1}{2} \text{ or } R' = 2\ \Omega$$

Therefore, total resistance of the circuit,

$R = R' + r_1 + r_2 + 5 = 2 + 1 + 2 + 5 = 10\ \Omega$

(ii) (c) : Here, $E_1 = 20$ V; $r_1 = 1\ \Omega$; $E_2 = 8$ V and $r_2 = 2\ \Omega$

Let I be the current in the circuit.

Total e.m.f. of the circuit,

$E = E_1 - E_2 = 20 - 8 = 12$ V

Hence, the current in the circuit,

$$I = \frac{E}{R} = \frac{12}{10} = 1.2 \text{ A}$$

(iii) (a) : The equivalent resistance of 6 Ω and 4 Ω

$$R_{eq} = \frac{6 \times 4}{6+4} = 2.4\ \Omega$$

∴ Current through 12 Ω is,

$$I_1 = \frac{2.4}{12+2.4} \times 1.2 = 0.2 \text{ A}$$

(iv) (d) : The terminal potential difference across 20 V battery,

$V_1 = E_1 - Ir_1 = 20 - 1.2 \times 1 = 18.8$ V

(v) (b) : Since the potential drop across internal resistance of 8 V battery aids its e.m.f., the terminal potential difference across 8 V battery.

$V_2 = E_2 + Ir_2 = 8 + 1.2 \times 2 = 10.4$ V

16. (i) (a) : Here, the distance of the wire at the point P from R, $r_1 = PR = 5$ m

Distance of the wire at the point Q from R,

$r_2 = QR = 2$ m

Current through the wire at the point P, $I_1 = 2.5$ A

Suppose that the current through the wire at the point Q is equal to I_2. If B_1 and B_2 are the corresponding magnetic fields, produced at the point R due to the wires at points P and Q respectively, then the net magnetic field at point R.

$$B = B_1 + B_2 = \frac{\mu_0}{4\pi} \cdot \frac{2I_1}{r_1} + \frac{\mu_0}{4\pi} \cdot \frac{2I_2}{r_2} = \frac{\mu_0}{4\pi} \times 2\left(\frac{I_1}{r_1} + \frac{I_2}{r_2}\right)$$

$$= 10^{-7} \times 2\left(\frac{2.5}{5} + \frac{I_2}{2}\right) = 10^{-7}(1 + I_2) \text{ or } B = 10^{-7}(1 + I)$$

(ii) (c) : The direction of the magnetic field B at the point R will be along the negative Y-axis. Therefore,

$$\vec{B} = 10^{-7}(1 + I_2)(-\hat{j}) = -10^{-7}(1 + I_2)\hat{j}$$

(iii) (b) : The velocity of the electron

$\vec{v} = 4 \times 10^5 \text{ m s}^{-1}$ (along X-axis)

$= 4 \times 10^5 \hat{i} (\text{m s}^{-1})$

Also, charge on the electron, $q = -e = -1.6 \times 10^{-19}$ C

Therefore, force on the electron,

$\vec{F} = q(\vec{v} \times \vec{B})$

$= (-1.6 \times 10^{-19}) [(4 \times 10^5 \hat{i}) \times (-10^{-7}(1 + I_2)\hat{j})]$

$= 6.4 \times 10^{-21} (1 + I_2)\hat{k}$

But $F = 3.2 \times 10^{-20}$ N

∴ $6.4 \times 10^{-21} (1 + I_2) = 3.2 \times 10^{-20}$

$$\text{or } 1 + I_2 = \frac{3.2 \times 10^{-20}}{6.4 \times 10^{-21}} = 5 \text{ or } I_2 = 4 \text{ A}$$

(iv) (a) : When the current 2.5 A is directed into the plane of paper. If r is the distance of this current wire from point R, then, we have

$$B_3 = \frac{\mu_0}{2\pi}\left(\frac{2.5}{r}\right)$$

Now, $B_1 + B_2 + B_3 = 0$

$$\therefore \frac{\mu_0}{2\pi}\left[\frac{2.5}{5} + \frac{4}{2} + \frac{2.5}{r}\right] = 0 \Rightarrow r = -1 \text{ m}$$

Thus, the third wire is located at 1 m from R on RX.

(v) (c) : When the current 2.5 A is directed out from the plane of the paper.

Here, $I_3 = -2.5$ A

$$\therefore \frac{\mu_0}{2\pi}\left[\frac{2.5}{5} + \frac{4}{2} - \frac{2.5}{r}\right] = 0 \Rightarrow r = 1 \text{ m}$$

Thus, the third wire is located at 1 m from R on RQ.

17. The magnetic energy is,

$$U_B = \frac{1}{2}LI^2 = \frac{1}{2}L\left(\frac{B}{\mu_0 n}\right)^2 \quad (\because B = \mu_0 nI, \text{ for a solenoid})$$

$$= \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B}{\mu_0 n}\right)^2 = \frac{1}{2\mu_0}B^2 Al$$

The magnetic energy per unit volume is,

$$u_B = \frac{U_B}{V} \quad \text{(where } V \text{ is volume that contains flux)}$$

$$= \frac{U_B}{Al} = \frac{B^2}{2\mu_0}$$

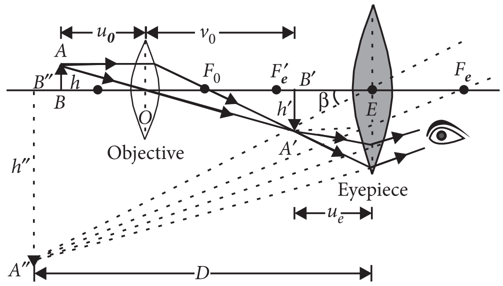
OR

Magnitude of induced emf is directly proportional to the rate of area moving out of the field, for a constant magnetic field,

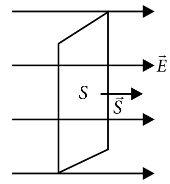
$$\varepsilon = -\frac{d\phi}{dt} = -B\frac{dA}{dt}$$

For the rectangular coil, the rate of area moving out of the field remains same while it is not so for the circular coil. Therefore, the induced emf for the rectangular coil remains constant.

18.



19. Here, $\vec{E} = 5\times10^3\,\hat{i}$ N/C



Side of square = a = 10 cm = 0.1 m
Area of square,
$S = a^2 = (0.1)^2 = 0.01$ m^2
Case I : Area vector is along x-axis,
$\vec{S} = 0.01\hat{i}$ m^2
Required flux, $\phi = \vec{E}\cdot\vec{S}$

$\Rightarrow\ \phi = (5\times10^3\,\hat{i})\cdot(0.01\hat{i}) \Rightarrow \phi = 50$ N m^2/C

Case II : Plane of the square makes a 30° angle with the x-axis.
Here, angle between area vector and the electric field is 60°.
So, required flux $\phi' = E\cdot S\cos\theta$
$= (5\times10^3)(10^{-2})\cos 60° = 25$ N m^2/C

20. (i) n-type

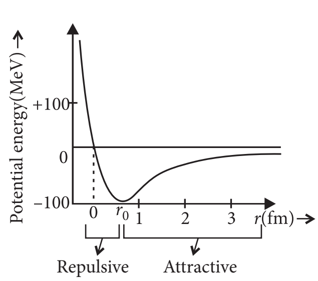
(ii) $n_e n_h = n_i^2$ or $n_h = \dfrac{n_i^2}{n_e} = \dfrac{(6\times10^8)^2}{9\times10^{12}} = 4\times10^4$ m^{-3}.

21. (i) Yes, they are the isotopes of the same element because they have same atomic number (Z = 3).

(ii) The isotope ${}^7_3X$ has 3 protons and 4 neutrons while the isotope ${}^4_3Y$ has 3 protons and 1 neutron. Due to the presence of a greater number of neutrons in ${}^7_3X$, the strong attractive nuclear force dominates over the electrostatic repulsion between the protons. So ${}^7_3X$ is more stable than ${}^4_3Y$.

OR

Plot of potential energy of a pair of nucleons as a function of their separation is given in the figure.



Conclusions : (i) The nuclear force is much stronger than the coulomb force acting between charges or the gravitational forces between masses.

(ii) The nuclear force between two nucleons falls rapidly to zero as their distance is more than a few fermies.

(iii) For a separation greater than r_0, the force is attractive and for separation less than r_0, the force is strongly repulsive.

22. We know that,

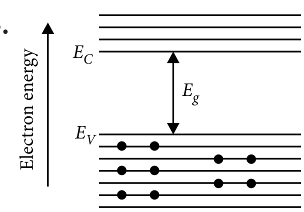
$$\lambda = \frac{h}{mv} \text{ and } qV = \frac{1}{2}mv^2$$

$$\therefore\ \lambda = \frac{h}{m\sqrt{2qV/m}} = \frac{h}{\sqrt{2mqV}}$$

$$\lambda \propto \frac{1}{\sqrt{mq}} \qquad \text{(for constant } V\text{)}$$

$$\therefore\ \frac{\lambda_p}{\lambda_\alpha} = \frac{\sqrt{m_\alpha q_\alpha}}{\sqrt{m_p q_p}} = \frac{\sqrt{4m_p\times 2e}}{\sqrt{m_p\times e}} = \sqrt{8}$$

23.



Energy band diagram of semiconductor at T = 0 K

At absolute zero temperature (0 K) conduction band of semiconductor is completely empty, *i.e.*, σ = 0. Hence the semiconductor behaves as an insulator. At room temperature, some valence electrons acquire enough thermal energy and jump to the conduction band where they are free to conduct electricity. Thus the semiconductor acquires a small conductivity at room temperature.

24. Maximum wavelength in the band is for lowest frequency

$$c = \upsilon_{min}\lambda_{max}$$

$$\lambda_{max} = \frac{c}{\upsilon_{min}} = \frac{3\times10^8}{7.5\times10^6} = 40 \text{ m}$$

Minimum wavelength in the band is for highest frequency

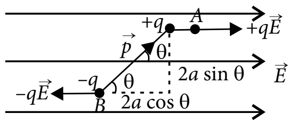
$$c = \upsilon_{max}\lambda_{min}$$

$$\lambda_{min} = \frac{c}{\upsilon_{max}} = \frac{3\times10^8}{12\times10^6} = 25 \text{ m}$$

So, the wavelength band for tuning is between 25 m to 40 m.

25. Torque on a dipole in uniform electric field:
When electric dipole is placed in a uniform electric field, its two charges experience equal and opposite

forces, which cancel each other and hence net force on an electric dipole in a uniform electric field is zero.



However these forces are not collinear, so they give rise to some torque on the dipole given by

Torque = Magnitude of either force

× Perpendicular distance between them

$\tau = Fr_{\perp} = qE.2a\sin\theta = q2a.E\sin\theta$

or $\tau = pE\sin\theta$

where θ is the angle between the directions of $\vec{p}$ and $\vec{E}$.

In vectorial form, $\vec{\tau} = \vec{p}\times\vec{E}$

(a) When θ = 0° or 180° then $\tau_{min} = 0$

(b) When θ = 90° then $\tau_{max} = pE$

Thus, torque on a dipole tends to align it in the direction of uniform electric field.

If the field is not uniform in that condition the net force on electric dipole is not zero.

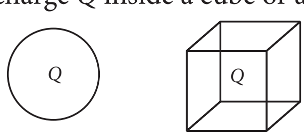
When θ = 0; τ = 0 and $\vec{p}$ and $\vec{E}$ are parallel and the dipole is in a position of stable equilibrium.

OR

Electric flux linked with a surface is the number of electric lines of force cutting through the surface normally.

It's SI unit is N m^2 C^{-1} or V m. On decreasing the radius of spherical surface to half there will be no effect on the electric flux.

Let us take a charge Q inside a cube or a sphere.



The flux through both the closed surfaces will be same.

i.e., $\phi_{net} = \dfrac{Q}{\varepsilon_0}$

26. Poynting vector is given by, $\vec{S} = \dfrac{\vec{E}\times\vec{B}}{\mu_0}$

Average value of magnitude of radiant flux density over one cycle is

$$S_{av} = \frac{1}{\mu_0}\left|\vec{E}_0\times\vec{B}_0\right|\left(\frac{1}{T}\right)\int_0^T\cos^2(kx-\omega t)dt$$

$[\because E = E_0\cos(kx-\omega t), B = B_0\cos(kx-\omega t)]$

$$= \frac{E_0B_0}{\mu_0}\left(\frac{1}{T}\right)(T/2) = \frac{E_0B_0}{2\mu_0}$$

$$\left[\because \int_0^T\cos^2(kx-\omega t)dt = T/2\right]$$

$$S_{av} = \frac{E_0(E_0/c)}{2\mu_0} = \left(\frac{1}{2c\mu_0}\right)E_0^2 \qquad \left(\because B_0 = \frac{E_0}{c}\right)$$

OR

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Force} = \frac{\text{Change in momentum}}{\text{Change in time}} = \frac{\Delta p}{\Delta t}$$

$$\therefore\ P = \frac{\Delta p/\Delta t}{A}\times\frac{c}{c}$$

$$P = \frac{1}{Ac\Delta t}c\Delta p = \frac{1}{Ac\Delta t}\times\Delta U \qquad (\because c\Delta p = U)$$

$$\text{Intensity, } I = \frac{\Delta U}{A\Delta t} = Pc$$

$\therefore\ P = I/c$

27. Let a particle of mass *m*, charge −*q* enter normally the region between two charged plates, each of length *L*, as shown in the figure. Uniform electric field $\vec{E}$ between the plates is along *Y*-axis and initial velocity of particle v_x is along *X*-axis.

Along *X*-axis, there is no force acting on charged particle and it moves with a constant velocity v_x and takes a time $t = \dfrac{L}{v_x}$ to reach the far edge of plate.

However, charged particle experiences a force *F* = *qE* towards positive charged plate along *Y*-axis. Thus, it is experiences an acceleration,

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

As a result, in time *t*, the particle will cover a distance *y* along *Y*-axis, where

$$y = \frac{1}{2}at^2 = \frac{1}{2}\frac{qE}{m}.\left(\frac{L}{v_x}\right)^2 = \frac{qEL^2}{2mv_x^2}$$

So, the vertical deflection of charged particle at the far edge of the plate is $\dfrac{qEL^2}{2mv_x^2}$.

28. Let the horizontal component of the earth's magnetic field be H_E and vertical component be Z_E

$$\therefore\ H_E = \frac{1}{\sqrt{3}}Z_E \qquad \text{(given)}$$

$$\therefore\ \tan\delta = \frac{Z_E}{H_E} = \frac{Z_E}{\frac{1}{\sqrt{3}}Z_E} = \sqrt{3} = \tan 60°$$

$\delta = 60°$

∴ The angle of dip is 60°.

Ratio of the horizontal component to the magnetic field is $\dfrac{H_E}{B_E} = \cos\delta = \cos 60° = \dfrac{1}{2} = 1:2$

29. Clearly, equivalent focal length of equiconvex lens and water lens $f = a$

Focal length of equiconvex lens, $f_1 = b$

Focal length f_2 of water lens is given by

$$\frac{1}{f_2} = \frac{1}{f} - \frac{1}{f_1} = \frac{1}{a} - \frac{1}{b} = \frac{b-a}{ab}$$

or $f_2 = \frac{ab}{b-a}$

The water lens formed between the plane mirror and the equiconvex lens is a planoconcave lens. For this lens,

$R_1 = -R$ and $R_2 = \infty$

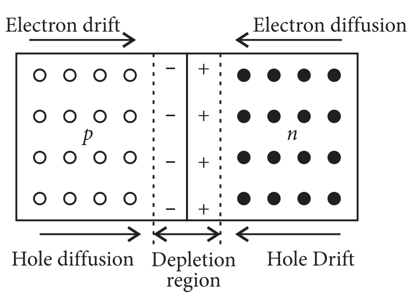
Using lens maker's formula,

$$\frac{1}{f_2} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

or $\frac{b-a}{ab} = (\mu - 1)\left[\frac{1}{-R} - \frac{1}{\infty}\right]$

or $\mu = 1 + \frac{(a-b)R}{ab}$

30.



When *p*-*n* junction is formed, then at the junction, free electrons from *n*-type diffuse over to *p*-type, and hole from *p*-type over to *n*-type. Due to this a layer of positive charge is built on *n*-side and a layer of negative charge is built on *p*-side of the *p*-*n* junction. This layer sufficiently grows up within a very short time of the junction being formed, preventing any further movement of charge carriers (electrons and holes) across the *p*-*n* junction.

This space - charge region, developed on either side of the junction is known as depletion region as the electrons and holes taking part in the initial movement across the junction deplete this region of its free charges.

Width of depletion region layer

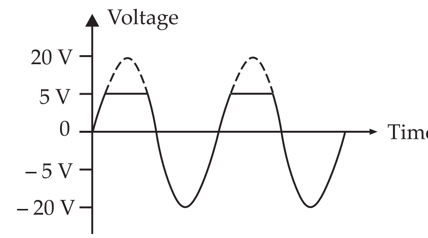
(i) decreases when the junction is forward biased and

(ii) increases when it is reverse biased.

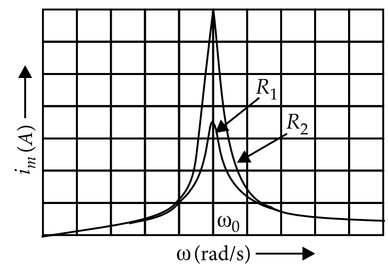
OR

For the voltage less than 5 V, the diode is reverse biased and circuit will act as open circuit.

When input voltage is greater than 5 V, diode is in conducting state.



31. (a) Figure shows the variation of i_m with ω in a *LCR* series circuit for two values of resistance R_1 and R_2 ($R_1 > R_2$),



(b) The condition for resonance in the *LCR* circuit is,

$$X_L = X_C \Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$

Thus, the current amplitude is maximum at the resonant frequency. Since $i_m = V_m / R$, at resonance the current amplitude for case R_2 is sharper to that for case R_1.

(c) Quality factor or simply the *Q*-factor of a resonant *LCR* circuit is defined as the ratio of voltage drop across the inductor and resistance at resonance.

$$Q = \frac{V_L}{V_R} = \frac{\omega L}{R}$$

Thus finally, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

The *Q* factor determines the sharpness at resonance as for higher value of *Q* factor the tuning of the circuit and its sensitivity to accept resonating frequency signals becomes much higher.

OR

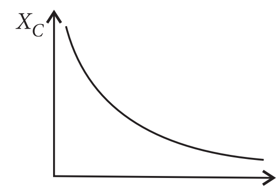
(a) Device *X* is a capacitor.

(b) $B \rightarrow$ Voltage (Because it is sine wave)

$C \rightarrow$ Current (Because current leads voltage by $\pi/2$)

$A \rightarrow$ Power (Average power over one cycle is zero)

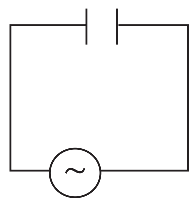
(c) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$



(d) $V = V_0 \sin\omega t$

$C = \frac{q}{V}$

$q = CV_0 \sin\omega t$

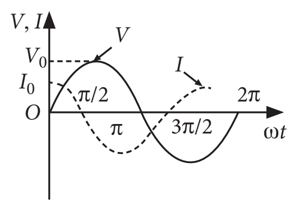


$$i = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin\omega t)$$

$$= \omega CV_0 \sin\omega t = \frac{V_0}{\frac{1}{\omega C}} \cos\omega t$$

$$i = \frac{V_0}{X_C} \sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{or} \quad i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

In pure capacitive circuit current leads voltage by $\frac{\pi}{2}$.

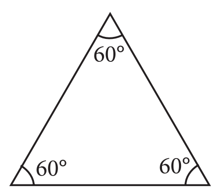


32. (a) For equilateral prism $A = 60°$

For minimum angle of deviation,

$i + e = A + \delta_m$

$2i = A + \delta_m$



$$\frac{2 \times 3A}{4} = A + \delta_m$$

$$\delta_m = \frac{3A}{2} - A = \frac{A}{2}$$

$$\because \ \mu = \frac{\sin\left(\frac{A + \frac{A}{2}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\Rightarrow \ \mu = \frac{\sin\left(\frac{3A}{4}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin 45°}{\sin 30°} = \frac{0.7071}{0.5} = 1.414$$

$\mu = 1.414$

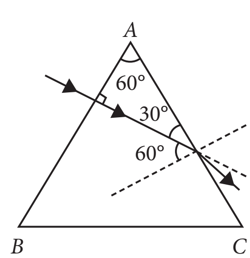
$$v = \frac{c}{\lambda} = \frac{3 \times 10^8}{1.414} = 2.1216 \times 10^8 \text{ m s}^{-1}$$

(b) Critical angle for the given pair of media

$$\theta_c = \sin^{-1}\left(\frac{\mu_w}{\mu_g}\right)$$

$$= \sin^{-1}\left(\frac{4/3}{3/2}\right) = \sin^{-1}\left(\frac{8}{9}\right)$$

$$\sin\theta_c = \frac{8}{9} = 0.89$$



Now, $\sin 60° = \frac{\sqrt{3}}{2} = 0.86$

On face AC, angle of incidence is less than that of critical angle, so there will be no total internal reflection.

OR

(a) $R = 20$ cm, $n_2 = 1.5$, $n_1 = 1$, $u = -100$ cm

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R} \quad \text{or} \quad \frac{1.5}{v} + \frac{1}{100} = \frac{1.5 - 1}{20}$$

$$\text{or} \quad \frac{1.5}{v} = \frac{0.5}{20} - \frac{1}{100} = \frac{1}{40} - \frac{1}{100} = \frac{3}{200}$$

$$\text{or} \quad v = \frac{200}{3} \times 1.5 = 100 \text{ cm}$$

So, a real image is formed on the other side, 100 cm away from the surface.

(b) Here, ${}^a\mu_g = 1.5$

Let f_{air} be the focal length of the lens in air,

Then,

$$\frac{1}{f_{air}} = ({}^a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\text{or} \quad \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f_{air}({}^a\mu_g - 1)} = \frac{1}{f_{air}(1.5 - 1)}$$

$$\text{or} \quad \left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{2}{f_{air}} \quad \text{... (i)}$$

(I) When lens is dipped in medium A

Here, ${}^a\mu_A = 1.65$

Let f_A be the focal length of the lens, when dipped in medium A. Then,

$$\frac{1}{f_A} = ({}^A\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{{}^a\mu_g}{{}^a\mu_A} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using the equation (i), we have

$$\frac{1}{f_A} = \left(\frac{1.5}{1.65} - 1\right) \times \frac{2}{f_{air}} = -\frac{1}{5.5 f_{air}}$$

or $f_A = -5.5 f_{air}$

As the sign of f_A is opposite to that of f_{air} the lens will behave as a diverging lens.

(II) When lens is dipped in medium B

Here, ${}^a\mu_B = 1.33$

Let f_B be the focal length of the lens, when dipped in medium B. Then,

$$\frac{1}{f_B} = ({}^B\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{{}^a\mu_g}{{}^a\mu_B} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Using the equation (i), we have

$$\frac{1}{f_B} = \left(\frac{1.5}{1.33} - 1\right) \times \frac{2}{f_{air}} = \frac{0.34}{1.33 f_{air}}$$

or $f_B = 3.91 f_{air}$

As the sign of f_B is same as that of f_{air}, the lens will behave as a converging lens.

33. (a) According to de Broglie, a stationary orbit is that which contains an integral number of de Broglie waves associated with the revolving electron.

For an electron revolving in n^{th} circular orbit of radius r_n,

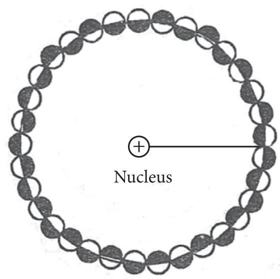
Total distance covered = Circumference of the orbit $= 2\pi r_n$

$\therefore$ For the permissible orbit, $2\pi r_n = n\lambda$

According to de-Broglie,

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

where v_n is speed of electron revolving in n^{th} orbit.



$$\therefore \quad 2\pi r_n = \frac{nh}{mv_n}$$

$$\text{or} \quad mv_n r_n = \frac{nh}{2\pi} = n\left(\frac{h}{2\pi}\right)$$

(b) For ground state, $n = 1$

$$E = \frac{-13.6}{n^2} = \frac{-13.6}{1^2} = -13.6 \text{ eV}$$

$\therefore$ K.E. $= -E = -(-13.6) = 13.6$ eV

$\therefore$ P.E. $= 2E$ $\therefore$ P.E. $= 2(-13.6) = -27.2$ eV

OR

(i) According to Bohr's postulates, in a hydrogen atom, as single electron revolves around a nucleus of charge $+e$. For an electron moving with a uniform speed in a circular orbit of a given radius, the centripetal force is provided by coulomb force of attraction between the electron and the nucleus. The gravitational attraction may be neglected as the mass of electron and proton is very small.

$$\text{So,} \quad \frac{mv^2}{r} = \frac{ke^2}{r^2} \qquad \left(\text{where, } k = \frac{1}{4\pi\varepsilon_0}\right)$$

$$\text{or} \quad mv^2 = \frac{ke^2}{r} \qquad \text{...(i)}$$

where, m = mass of electron

r = radius of electronic orbit

v = velocity of electron

Again, by Bohr's second postulates

$$mvr = \frac{nh}{2\pi}$$

where, $n = 1, 2, 3......$ or $v = \dfrac{nh}{2\pi mr}$

Putting the value of v in eq. (i)

$$m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{ke^2}{r} \Rightarrow r = \frac{n^2h^2}{4\pi^2 kme^2} \qquad \text{...(ii)}$$

Kinetic energy of electron,

$$E_k = \frac{1}{2}mv^2 = \frac{ke^2}{2r} \qquad \left(\because \frac{mv^2}{r} = \frac{ke^2}{r^2}\right)$$

Using eq. (ii) we get

$$E_k = \frac{ke^2}{2}\,\frac{4\pi^2 kme^2}{n^2h^2} = \frac{2\pi^2k^2me^4}{n^2h^2}$$

Potential energy of electron,

$$E_p = -\frac{k(e)\times(e)}{r} = -\frac{ke^2}{r}$$

Using eq. (ii), we get

$$E_p = -ke^2 \times \frac{4\pi^2 kme^2}{n^2h^2} = -\frac{4\pi^2k\,me^4}{n^2h^2}$$

Hence, total energy of the electron in the n^{th} orbit

$E = E_p + E_k$

$$= -\frac{4\pi^2k^2me^4}{n^2h^2} + \frac{2\pi^2k^2me^4}{n^2h^2}$$

$$= -\frac{2\pi^2k^2me^4}{n^2h^2} = -\frac{13.6}{n^2} \text{ eV}$$

When the electron in a hydrogen atom jumps from higher energy level to the lower energy level, the difference of energies of the two energy levels is emitted as a radiation of particular wavelength. It is called a spectral line.

(ii) In H-atom, when an electron jumps from the orbit n_i to orbit n_f, the wavelength of the emitted radiation is given by

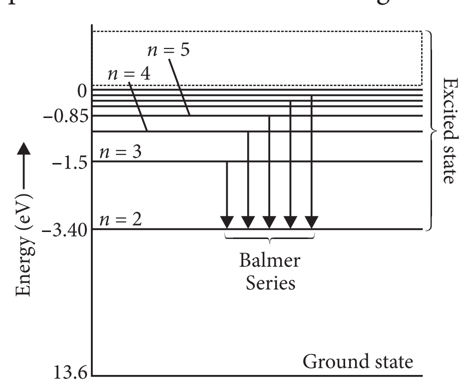
$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]; \quad R = 1.09 \times 10^7 \text{ m}^{-1}$$

For Balmar series, $n_f = 2$ and $n_i = 3, 4, 5, ...$

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_i^2}\right)$$

where, $n_i = 3, 4, 5, ...$

These spectral lines lie on the visible region.



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