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	2(5)	2(4)	–	1(5)	**6(16)**
2.	Current Electricity	–	1(2)	–	–	
3.	Magnetic Effects of Current and Magnetism	1(1)	1(2)	2(6)	–	**7(17)**
4.	Electromagnetic Induction and Alternating Current	2(5)	–	1(3)		
5.	Electromagnetic Waves	1(1)	–	1(3)	–	**9(18)**
6.	Optics	4(4)	1(2)	1(3)	1(5)	
7.	Dual Nature of Radiation and Matter	2(2)	1(2)	–	–	**6(12)**
8.	Atoms and Nuclei	1(1)	1(2)	–	1(5)	
9.	Electronic Devices	3(3)	2(4)	–	–	**5(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.

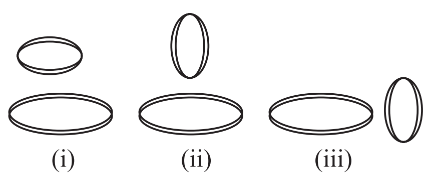
(iii) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section 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. Two circular coils can be arranged in any of three situations as shown in the figure. In which of the following situations, the mutual inductance will be maximum?



OR

Depict a graph which shows variation of induced e.m.f. with the rate of change of current flowing through a given coil.

2. What do you call the angle between magnetic meridian and geographical meridian?

3. How can we shield an object from the influence of a strong electrostatic field?

OR

Two identical conducting balls *A* and *B* have charges $-Q$ and $+3Q$ respectively. They are brought in contact with each other and then separated by a distance *d* apart. Find the nature of the Coulomb force between them.

4. Two identical light waves, propagating in the same direction, have a phase difference δ. After they superpose find the relation between the intensity of the resulting wave and the phase difference.

5. The nuclear radius of $^{27}_{13}\text{Al}$ is 3.6 fermi. Find the nuclear radius of $^{64}_{29}\text{Cu}$.

OR

Four nuclei of an element undergo fusion to form a heavier nucleus, with release of energy. Which of the two — the parent or the daughter nucleus — would have higher binding energy per nucleon?

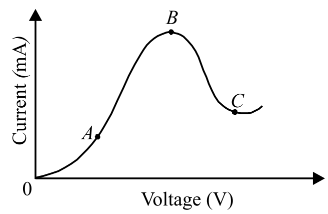
6. State the criteria for the phenomenon of total internal reflection of light to take place.

7. Calculate the de-Broglie wavelength of the electrons accelerated through a potential difference of 10 kV.

OR

In an experiment of 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.

8. The graph shown in the figure represents a plot of current versus voltage for a given semiconductor. Identify the region, if any, over which the semiconductor has a negative resistance.



9. State one use of photodiode.

10. Red, blue, green and violet colour lights are one by one made to incident on a photocathode. It is observed that only one colour light produces photoelectrons. Identify that light.

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) :** Electron has higher mobility than hole in a semiconductor.
Reason (R) : Mass of electron is less than the mass of hole.

12. **Assertion (A) :** X-ray astronomy is possible only from satellites orbiting the earth.
Reason (R) : Efficiency of X-rays telescope is large as compared to any other telescope.

13. **Assertion (A) :** Critical angle of light passing from glass to air is minimum for violet colour.
Reason (R) : The wavelength of blue light is greater than the light of other colours.

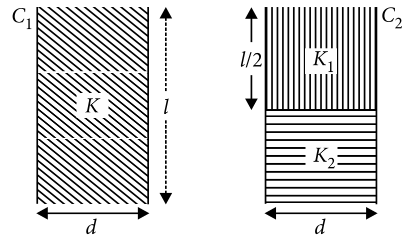
14. **Assertion (A) :** For best contrast between maxima and minima in the interference pattern of Young's double slit experiment, the intensity of light emerging out of the two slits should be equal.
Reason (R) : The intensity of interference pattern is proportional to square of amplitude.

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. Effect of dielectric on capacity : A parallel plate capacitor consists of two parallel metallic plates separated by a small distance. If a dielectric medium of dielectric constant K is filled completely between the plates then, capacitance increases by K times. Now, consider

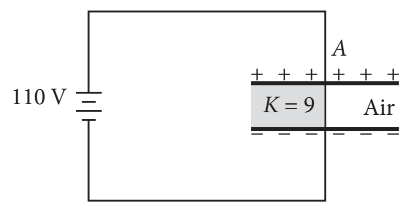
Two parallel plate capacitors A and B have the same separation $d = 8.85 \times 10^{-4}$ m between the plates. The plate area of A and B are 0.04 m^2 and 0.02 m^2 respectively. A slab of dielectric constant (relative permittivity $K = 9$) has dimensions, such that it can exactly fill the space between the plates of capacitor B.



(i) A dielectric can be made a conductor by

(a) compression (b) heating (c) doping (d) freezing

(ii) The dielectric slab is placed inside A as shown in figure. A is then charged to a potential difference of 110 V. Calculate the capacitance of A.

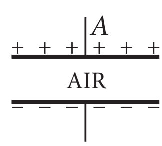


(a) 2×10^{-9} F (b) 3×10^{-6} F (c) 2.5×10^{-9} F (d) 3.6×10^{-6} F

(iii) Find the energy stored in capacitor A when a potential of 110 V is applied across it.

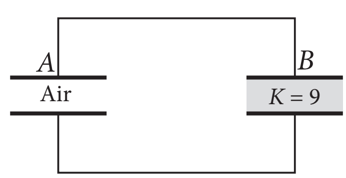
(a) 2.2×10^{-5} J (b) 3.2×10^{-5} J (c) 1.2×10^{-5} J (d) 4.2×10^{-5} J

(iv) If the battery is disconnected and the dielectric slab is removed from A then find the work done by the external agency in removing the slab from A.



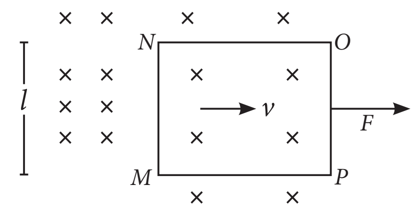
(a) 6.3×10^{-4} J (b) 6.2×10^{-5} J (c) 4.84×10^{-5} J (d) 4.84×10^{-4} J

(v) The same dielectric slab is now placed inside B, filling it completely. The two capacitors A and B are then connected as shown in figure. Calculate the energy stored in the system.



(a) 1.1×10^{-5} J (b) 2.6×10^{-5} J (c) 3.1×10^{-5} J (d) 2×10^{-5} J

16. An emf induced by the motion of the conductor across the magnetic field is called motional electromotive force. It is given as, $\varepsilon = -Bvl$. This equation is true as long as the velocity, field and length are mutually perpendicular. The minus sign associated with the Lenz's law. As shown in figure, a rectangular loop $MNOP$ is pulled out of a magnetic field with a uniform velocity v by applying an external force F. The length MN is equal to l and the total resistance of the loop is R.



(i) Find the current in the loop.

(a) $\frac{vBl}{R}$ (b) $\frac{vBR}{l}$ (c) $\frac{vRl}{B}$ (d) $\frac{R}{vBl}$

(ii) Find the magnetic force on the loop.

(a) $\frac{B^2l^2v^2}{R}$ (b) $\frac{B^2l^2v}{R}$ (c) $\frac{Bl^2v^2}{R}$ (d) $\frac{B^2l^2v^2}{2R}$

(iii) Find the external force F needed to maintain constant velocity.

(a) $\frac{B^2l^2v}{R}$ (b) $\frac{B^2l^2v^2}{R}$ (c) $\frac{B^2l^2v^2}{2R}$ (d) $\frac{Bl^2v^2}{R}$

(iv) The power delivered by the external force is

(a) $\frac{B^2l^2v^2}{R}$ (b) $\frac{B^2l^2v}{R}$ (c) $\frac{Bl^2v^2}{R}$ (d) $\frac{B^2l^2v^2}{2R}$

(v) The thermal power developed in the loop is

(a) $\frac{B^2l^2v^2}{R}$ (b) $\frac{Bl^2v^2}{R}$ (c) $\frac{Blv}{R}$ (d) $\frac{B^2l^2v^2}{2R}$

SECTION - C

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

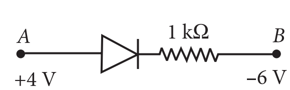
17. Calculate the energy in fusion reaction : ${}_1^2\text{H} + {}_1^2\text{H} \rightarrow {}_2^3\text{He} + n$, where B.E. of ${}_1^2\text{H}$ = 2.23 MeV and of ${}_2^3\text{He}$ = 7.73 MeV.

18. Explain how electron mobility changes for a good conductor, when (a) the temperature of the conductor is decreased at constant potential difference and (b) applied potential difference is doubled at constant temperature.

OR

Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1 mm. Conductor B is a hollow tube of outer diameter 2 mm and inner diameter 1 mm. Find the ratio of resistance R_A to R_B.

19. Consider the junction diode as ideal. Find the value of current flowing through AB is



OR

The current in the forward bias is known to be more (~mA) than the current in the reverse bias (~ μA). What is the reason, then, to operate the photodiode in reverse bias?

20. Consider two conducting spheres of radii R_1 and R_2 with $R_1 > R_2$. If the two are at the same potential, the larger sphere has more charge than the smaller sphere. State whether the charge density of the smaller sphere is more or less than that of the larger one.

21. The intensity at the central maxima in Young's double slit experimental set-up is I_0. Show that the intensity at a point where the path difference is $\lambda/3$ is $I_0/4$.

OR

Two independent monochromatic sources of light cannot produce a sustained interference pattern. Give reason.

22. The magnetic force depends on $\vec{v}$ which depends on the inertial frame of reference. Does then the magnetic force differ from inertial frame to frame? Is it reasonable that the net acceleration has a different value in different frames of reference?

23. A hemisphere is uniformly charged positively. Give the direction of electric field at a point on the diameter, and away from the centre.

24. A proton and an α-particle have the same de-Broglie wavelength. Determine the ratio of
(i) their accelerating potentials (ii) their speeds.

25. In a semiconductor, $\frac{2}{3}$rd of the total current is carried by electrons and remaining $\frac{1}{3}$rd by the holes. If at this temperature, the drift velocity of electrons is 3 times that of holes, what will be the ratio of number density of electrons to that of holes?

SECTION - D

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

26. Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily.

27. When the oscillating electric and magnetic fields are along the x-and y-direction respectively, then
(i) Point out the direction of propagation of electromagnetic wave.
(ii) Express the velocity of propagation in terms of the amplitudes of the oscillating electric and magnetic fields.

OR

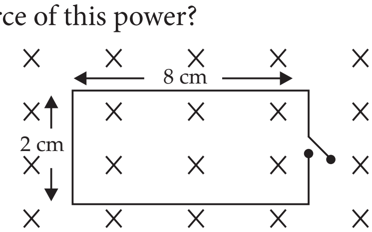
(a) How do you show that the e.m. wave carries energy and momentum?
(b) Which *e.m.* waves lie near the high frequency end of visible part of *e.m.* spectrum? Give its one use. In what way this component of light has harmful effects on humans?

28. Distinguish between Biot Savart's law and Ampere's circuital law.

29. Two inductors of self-inductances L_1 and L_2 are connected in parallel. The inductors are so far apart that their mutual inductance is negligible. Derive the equivalent inductance of the combination.

OR

Suppose the loop with a small cut as shown in figure is stationary but the current feeding the electromagnet that produces the magnetic field is gradually reduced so that field decreases from its initial value of 0.3 T at the rate of 0.02 T s^{-1}. If the cut is joined and the loop has a resistance of 1.6 Ω, how much power is dissipated by the loop as heat? What is the source of this power?



30. **(a)** The earth's magnetic field varies from point to point in space. Does it also change with time? If so, on what time scale does it change appreciably?

(b) The earth's core is known to contain iron. Yet geologists do not regard this as a source of the earth's magnetism. Why?

SECTION - E

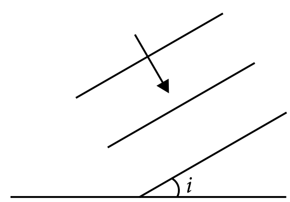
All questions are compulsory. In case of internal choices, attempt any one.

31. **(a)** Write three characteristic features to distinguish between the interference fringes in Young's double slit experiment and the diffraction pattern obtained due to a narrow single slit.

(b) A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is a distance of 2.5 mm away from the centre. Find the width of the slit.

OR

A plane wavefront propagating in a medium of refractive index 'μ_1' is incident on a plane surface making the angle of incidence i as shown in the figure. It enters into a medium of refraction of refractive index 'μ_2' ($\mu_2 > \mu_1$). Use Huygens' construction of secondary wavelets to trace the propagation of the refracted wavefront. Hence verify Snell's law of refraction.



32. Derive an expression for the potential energy of an electric dipole in a uniform electric field. Explain conditions for stable and unstable equilibrium.

OR

A small sphere of radius r_1 and charge q_1 is enclosed by a spherical shell of radius r_2 and charge q_2. Show that if q_1 is positive, charge will necessary flow from the sphere to the shell (when the two are connected by a wire) no matter what the charge q_2 on the shell is.

33. Using postulates of Bohr's theory of hydrogen atom, show that

(a) the radii of orbits increase as n^2, and

(b) the total energy of the electron increase as $1/n^2$, where n is the principal quantum number of the atom.

OR

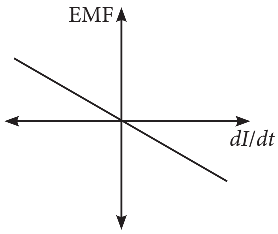
(a) Write Rydberg's formula for wavelengths of the spectral lines of hydrogen spectrum. Mention to which series in the emission spectrum of hydrogen, H_α line belongs.

(b) Using Rydberg formula, calculate the longest wavelength belonging to Lyman and Balmer series of hydrogen spectrum. In which region these transitions lie?

SOLUTIONS

1. The mutual inductance will be maximum in the first situation.

OR



2. Angle between magnetic meridian and geographical meridian is known as angle of declination or magnetic declination.

3 As we found that electric field inside the cavity of conductor is zero, even on charging the conductor, so the object can be shielded from the strong electrostatic fields in its environment, by covering it with a metallic cover.

OR

Final charge on each ball

$$= \frac{q_A + q_B}{2} = \frac{-Q + 3Q}{2} = +Q$$

As both the balls have same nature of charges, hence nature of the Coulomb force is repulsive.

4. Here $A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\delta$

$\because\ a_1 = a_2 = a$

$\therefore\ A^2 = 2a^2(1+\cos\delta) = 2a^2\left(1 + 2\cos^2\frac{\delta}{2} - 1\right)$

or $A^2 \propto \cos^2\frac{\delta}{2}$

Now $I \propto A^2$, $\therefore\ I \propto A^2 \propto \cos^2\frac{\delta}{2}$, $\quad \therefore\ I \propto \cos^2\frac{\delta}{2}$

5. $R = R_0 A^{\frac{1}{3}} \Rightarrow \frac{R_{\text{Al}}}{R_{\text{Cu}}} = \left(\frac{A_{\text{Al}}}{A_{\text{Cu}}}\right)^{\frac{1}{3}}$

$\Rightarrow\ R_{\text{Cu}} = R_{\text{Al}}\left(\frac{A_{\text{cu}}}{A_{\text{Al}}}\right)^{\frac{1}{3}} = 3.6\left(\frac{64}{27}\right)^{\frac{1}{3}} = 4.8 \text{ fermi}$

OR

In nuclear fusion, daughter nucleus would have higher binding energy per nucleon.

6. Essential conditions for total internal reflection:

(i) Light should travel from a denser medium to a rarer medium.

(ii) Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.

7. $\lambda = \frac{12.27\text{Å}}{\sqrt{V}} = \frac{12.27\text{Å}}{\sqrt{10^4}} = 0.1227\ \text{Å}$

OR

$\frac{h}{e} = 4.12\times10^{-15}$ or $h = 4.12 \times 10^{-15}e$

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

or $h = 6.6 \times 10^{-34}$ J s

8. Region *BC* of the graph has a negative slope, hence in region *BC* semiconductor has a negative resistance.

9. Photo diodes are used to detect optical signals.

10. The energy of incident light is

$E = h\upsilon$

where *h* is the Planck's constant and υ is the frequency of incident light.

As $\upsilon_{\text{violet}} > \upsilon_{\text{blue}} > \upsilon_{\text{green}} > \upsilon_{\text{red}}$

$\therefore\ E_{\text{violet}} > E_{\text{blue}} > E_{\text{green}} > E_{\text{red}}$

Since the incident energy is maximum for violet colour, therefore violet light produces photoelectrons.

11. (b) : Electrons move in conduction bands which are mostly empty so they encounter lesser resistance than holes moving in dense valence bands.

12. (c) : The earth's atmosphere is transparent to visible light and radio waves, but absorbs X-rays. Therefore X-rays telescope cannot be used on earth surface.

13. (c) : According to Snell's law the critical angle is given by, $\sin C = \frac{1}{\mu}$

where μ is refractive index of medium. Since μ decreases with increase in λ, hence *C* is minimum for the violet colour which has smallest wavelength.

14. (b) : When intensity of light emerging from two slits is equal, the intensity at minima,

$$I_{\text{min}} = \left(\sqrt{I_a} - \sqrt{I_b}\right)^2 = 0, \text{ or absolute dark.}$$

15. (i) (b)

(ii) (a) : Here, area of the plates of capacitor *A*,

$A_1 = 0.04\ \text{m}^2$

Area of the plates of capacitor *B*,

$A_2 = 0.02\ \text{m}^2$

Separation between the plates of the two capacitors,
$d_1 = d_2 = 8.85 \times 10^{-4}$ m

Since the dielectric slab can exactly fill the space between the plates of capacitor B, Thus, area of dielectric slab , $A_2 = 0.02\ \text{m}^2$;

and dielectric constant of the dielectric slab, $K = 9$

When the dielectric slab is introduced between the plates of capacitor A, then half of the space between the two plates gets filled with slab and the other half has air.

Let C' and C'' be the capacitances of the two parts of the capacitor A. The area of the plates of capacitor C' is A_2, while that of C'' is equal to $A_1 - A_2$. As already said, the capacitor A can be looked as a parallel combination of C' and C'' and its capacitance is given by

$$C_1 = C' + C'' = \frac{\varepsilon_0 K A_2}{d} + \frac{\varepsilon_0 (A_1 - A_2)}{d}$$

Since $A_1 = 2A_2$, it follows that

$$C_1 = \frac{\varepsilon_0 K A_2}{d} + \frac{\varepsilon_0 A_2}{d} = \frac{\varepsilon_0 A_2}{d}(K+1)$$

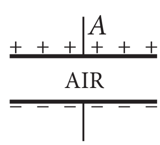
$$= \frac{8.85 \times 10^{-12} \times 0.02(9+1)}{8.85 \times 10^{-4}} = 2 \times 10^{-9}\ \text{F}$$

(iii) (c) : The energy stored in the capacitor A on applying a potential difference of 110 V,

$$U_1 = \frac{1}{2} C_1 V^2 = \frac{1}{2} \times 2 \times 10^{-9} \times (110)^2$$

$= 1.21 \times 10^{-5}$ J

(iv) (c) : As shown in figure, when the battery is disconnected and the dielectric slab is removed, the capacitor A becomes completely an air capacitor and its capacitance becomes



$$C_1' = \frac{\varepsilon_0 A_1}{d} = \frac{8.85 \times 10^{-12} \times 0.04}{8.85 \times 10^{-4}} = 4 \times 10^{-10}\ \text{F}$$

Let V' be the value of potential difference across the capacitor A on removing the dielectric slab. Since the charge on the capacitor remains same, we have

$C_1' V' = C_1 V$

$$\text{or } V' = \frac{C_1 V}{C_1'} = \frac{2 \times 10^{-9} \times 110}{4 \times 10^{-10}} = 550\ \text{V}$$

Therefore, electrostatic energy stored in the capacitor on removing the dielectric slab

$$U_2 = \frac{1}{2} C_1' V'^2 = \frac{1}{2} \times 4 \times 10^{-10} \times (550)^2$$

$= 6.05 \times 10^{-5}$ J

The energy of the capacitor increases at the expense of the work done by the external agency in removing the slab.

Therefore, work done by the external agency

$W = U_2 - U_1 = 6.05 \times 10^{-5} - 1.21 \times 10^{-5}$

$= 4.84 \times 10^{-5}$ J

(v) (a) : The capacitance of the capacitor B, when dielectric slab is placed between its plates,

$$C_2 = \frac{\varepsilon_0 K A_2}{d} = \frac{8.85 \times 10^{-12} \times 9 \times 0.02}{8.85 \times 10^{-4}}$$

$= 1.8 \times 10^{-9}$ F

When the charged capacitor A (without slab) is connected to the capacitor B, the capacitance of the parallel combination becomes

$C = C_1' + C_2 = 4 \times 10^{-10} + 1.8 \times 10^{-9}$

$= 2.2 \times 10^{-9}$ F

Charge on the parallel combination of the capacitors,

$q = C_1' V' = 4 \times 10^{-10} \times 550$ C

Therefore, energy stored in the combination,

$$U = \frac{1}{2}\frac{q^2}{C} = \frac{(4 \times 10^{-10} \times 550)^2}{2 \times 2.2 \times 10^{-9}} = 1.1 \times 10^{-5}\ \text{J}$$

16. (i) (a) : The emf induced in the loop is due to the motion of the wire MN. The emf is $\varepsilon = vBl$ with the positive end at N and the negative end at M. The current is $i = \frac{\varepsilon}{R} = \frac{vBl}{R}$ in the clockwise direction.

(ii) (b) : The magnetic force on the wire MN is $\vec{F}_1 = i\vec{l} \times \vec{B}$. The magnitude is $F_1 = ilB = \frac{vB^2l^2}{R}$ and is opposite to the velocity. The force on the parts of the wire NO and PM lying in the field cancel each other. The resultant magnetic force on the loop is, therefore,

$$F_1 = \frac{B^2 l^2 v}{R} \text{ opposite to the velocity.}$$

(iii) (a) : To move the loop at a constant velocity, the resultant force on it should be zero. Thus, one should pull the loop with a force $F = F_1 = \frac{vB^2l^2}{R}$

(iv) (d) : The power delivered by the external force is

$$P = F_1 \cdot v = \frac{B^2 l^2 v^2}{R}$$

(v) (a) : Thermal power, developed is,

$$P = i^2 R = \left(\frac{vBl}{R}\right) \cdot R = \frac{B^2 l^2 v^2}{R}$$

17. Fusion reaction,

$${}^2_1\text{H} + {}^2_1\text{H} \longrightarrow {}^3_2\text{He} + n$$

Energy released = final $B.E.$ – initial $B.E.$

= 7.73 – (2.23 + 2.23) = 3.27 MeV.

18. Electron mobility in a conductor is given by,

$$\mu = \frac{v_d}{E} = \frac{\frac{eE}{m}\tau}{E} = \frac{e\tau}{m} \qquad \left(\because\ v_d = \frac{eE}{m}\tau\right)$$

(a) When the temperature of the conductor decreases, the relaxation time, τ of the electrons increases, so mobility μ increases.

(b) Mobility μ is independent of applied potential difference.

OR

For a solid wire of resistance R_A,

$l_1 = l, \rho_1 = \rho, D_1 = 1$ mm

$$A_1 = \frac{\pi D_1^2}{4} = \frac{\pi(1)^2}{4}\text{ mm}^2\ ;\ R_A = \frac{\rho_1 l_1}{A_1} = \frac{\rho l}{\pi(1)^2/4} = \frac{4\rho l}{\pi}$$

For hollow tube of resistance R_B, $l_2 = l$, $\rho_2 = \rho$,

$$A_2 = \pi\frac{(D_2^2 - D_1^2)}{4} = \frac{\pi(2^2-1^2)}{4} = \frac{3\pi}{4}\text{ mm}^2$$

$$R_B = \frac{\rho_2 l_2}{A_2} = \frac{\rho l}{(3\pi/4)} = \frac{4\rho l}{3\pi}$$

$$\therefore\ \frac{R_A}{R_B} = 3:1$$

19. Here, the *p-n* junction diode is forward biased, hence it offers zero resistance.

$$\therefore\ I_{AB} = \frac{V_A - V_B}{R_{AB}} = \frac{4\text{ V} - (-6\text{ V})}{1\text{ k}\Omega} = \frac{10}{1000}\text{ A} = 10^{-2}\text{ A}$$

OR

Consider the case of an *n*-type semiconductor. The majority carrier density (n) is considerably larger than the minority hole density p (*i.e.*, $n >> p$).

On illumination, let the excess electrons and holes generated be Δn and Δp, respectively :

$$n' = n + \Delta n\ ;\ p' = p + \Delta p$$

Here n' and p' are the electron and hole concentrations at any particular illumination and n and p are carrier concentration when there is no illumination. Remember $\Delta n = \Delta p$ and $n >> p$. Hence, the fractional change in the majority carriers (*i.e.*, $\Delta n/n$) would be much less than that in the minority carriers (*i.e.*, $\Delta p/p$). In general, we can state that the fractional change due to the photo-effects on the minority carrier dominated reverse bias current is more easily measurable than the fractional change in the forward bias current. Hence, photodiodes are preferably used in the reverse bias condition for measuring light intensity.

20. $C_1 = 4\pi\varepsilon_0 R_1$, $C_2 = 4\pi\varepsilon_0 R_2$

Given $V_1 = V_2$ or $\frac{Q_1}{C_1} = \frac{Q_2}{C_2}$

or $$\frac{Q_1}{4\pi\varepsilon_0 R_1} = \frac{Q_2}{4\pi\varepsilon_0 R_2} \Rightarrow \frac{Q_1}{Q_2} = \frac{R_1}{R_2} \qquad \text{... (i)}$$

Now, $\sigma_1 = \frac{Q_1}{4\pi R_1^2}$ and $\sigma_2 = \frac{Q_2}{4\pi R_2^2}$

$$\therefore\ \frac{\sigma_1}{\sigma_2} = \frac{Q_1}{Q_2}\times\left(\frac{R_2}{R_1}\right)^2 = \left(\frac{R_1}{R_2}\right)\times\left(\frac{R_2}{R_1}\right)^2 = \frac{R_2}{R_1}$$

$\because\ R_1 > R_2$,

$\therefore\ \sigma_1 < \sigma_2$ *i.e.*, charge density of smaller sphere is more than that of the larger one.

21. Fringe width $(\beta) = \frac{\lambda D}{d}$

$$y = \frac{\beta}{3} = \frac{\lambda D}{3d}$$

Path difference $(\Delta p) = \frac{yd}{D} \Rightarrow \Delta p = \frac{\lambda D}{3d}\cdot\frac{d}{D} = \frac{\lambda}{3}$

$$\Delta\phi = \frac{2\pi}{\lambda}\cdot\Delta p = \frac{2\pi}{\lambda}\cdot\frac{\lambda}{3} = \frac{2\pi}{3}$$

Intensity at point $P = I_0\cos^2\Delta\phi$

$$= I_0\left[\cos\frac{2\pi}{3}\right]^2 = I_0\left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$$

OR

Two independent monochromatic sources cannot produce sustained interference pattern because the phase difference between the light waves from two independent sources keeps on changing continuously.

22. Magnetic force is given by,

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

Here, $\vec{F}_m$ depends on the inertial frame of reference. Hence magnetic force is frame dependent. Net acceleration arising from this force is however frame independent for inertial frames.

23. When the point is on the diameter and away from the centre of hemisphere which is charged uniformly and positively, the component of electric field intensity parallel to the diameter cancel out. So the electric field is perpendicular to the diameter.

24. de-Broglie wavelength of a particle of mass m and charge q accelerating through a potential V is given by

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}} \qquad \text{...(i)}$$

(i) Here, $m_p = m, q_p = e, m_\alpha = 4m_p = 4m, q_\alpha = 2q_p = 2e$

From eqn. (i),

$$\therefore\ \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha V_\alpha}{m_p q_p V_p}}$$

$$1 = \sqrt{\frac{4m \times 2e \times V_\alpha}{m \times e \times V_p}} \qquad (\because \lambda_p = \lambda_\alpha)$$

$$\therefore \quad \frac{V_p}{V_\alpha} = \frac{8}{1}; V_p : V_\alpha = 8 : 1$$

(ii) Again from eqn. (i),

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

$$\therefore \quad \frac{\lambda_p}{\lambda_\alpha} = \frac{m_\alpha v_\alpha}{m_p v_p}; 1 = \frac{4mv_\alpha}{mv_p} \text{ or } \frac{v_p}{v_\alpha} = \frac{4}{1}$$

$$v_p : v_\alpha = 4 : 1$$

25. If I is the total current, then

Current carried by electrons is $I_e = \frac{2}{3}I$

and that carried by holes is $I_h = \frac{1}{3}I$

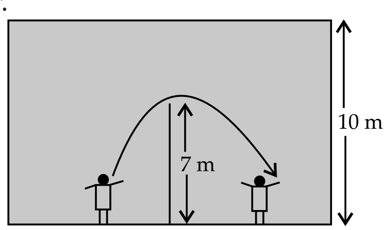
But $I_e = n_e eAv_e$ and $I_h = n_h eAv_h$

$$\therefore \quad \frac{I_e}{I_h} = \frac{n_e eAv_e}{n_h eAv_h} = \frac{n_e v_e}{n_h v_h} \text{ or } \frac{n_e}{n_h} = \frac{I_e}{I_h}\frac{v_h}{v_e}$$

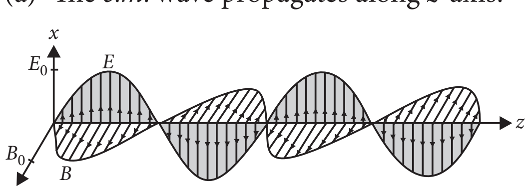
Here, $I_e = \frac{2}{3}I, I_h = \frac{1}{3}I, v_e = 3v_h$

$$\therefore \quad \frac{n_e}{n_h} = \frac{\left(\frac{2}{3}I\right)}{\left(\frac{1}{3}I\right)}\left(\frac{v_h}{3v_h}\right) = \left(\frac{2}{1}\right)\left(\frac{1}{3}\right) = \frac{2}{3}$$

26. We know for diffraction to take place, size of the obstacle/aperture should be of the order of wavelength. Wavelength of sound waves is of the order of few meters that is why sound waves can bend through the aperture in partition wall but wavelength of light waves is of the order of micrometer, hence light waves can not bend through same big aperture. That is why the two students can hear each other but cannot see each other.



27. (a) The *e.m.* wave propagates along z-axis.



(b) The speed of em-waves in vacuum determined by the electric (E_0) and magnetic fields (B_0) is, $c = \frac{E_0}{B_0}$

OR

(a) Electromagnetic waves or photons transport energy and momentum. When an electromagnetic wave interacts with a small particle, it can exchange energy and momentum with the particle. The force exerted on the particle is equal to the momentum transferred per unit time. Optical tweezers use this force to provide a non-invasive technique for manipulating microscopic-sized particles with light.

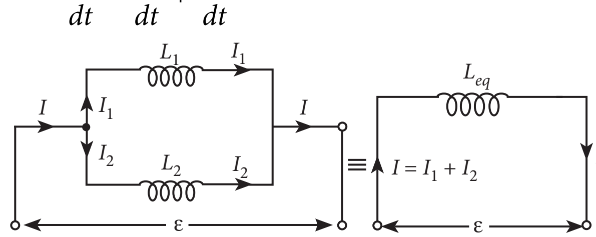
(b) Ultraviolet rays lie near the high-frequency end of visible part of *e.m.* spectrum. These rays are used to preserve food stuff. The harmful effect from exposure to ultraviolet (UV) radiation can be life threatening, and include premature aging of the skin, suppression of the immune systems, damage to the eyes and skin cancer.

28.

	Biot Savart's law	Ampere's circuital law
1.	This law is based on the principle of magnetism.	This law is based on the principle of electromagnetism.
2.	This law is valid for asymmetrical and symmetrical current distributions.	This law is valid for symmetrical current distributions.
3.	This law is the differential form of magnetic induction *i.e.*, $\lvert d\vec{B}\rvert = \frac{\mu_0 Idl\sin\theta}{4\pi r^2}$	This law is the integral form of $\vec{B}$, *i.e.*, $\oint \vec{B}\cdot d\vec{l} = \mu_0 I$

29. Inductances in parallel : For the parallel combination, the total current I divides up through the two coils as $I = I_1 + I_2$.

$$\therefore \quad \frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt}$$



For parallel combination, induced emf across the combination is equal to the induced emf across each inductance. Thus

$$\varepsilon = -L_1\frac{dI_1}{dt} \text{ or } \frac{\varepsilon}{L_1} = -\frac{dI_1}{dt}$$

$$\varepsilon = -L_2 \frac{dI_2}{dt} \text{ or } \frac{\varepsilon}{L_2} = -\frac{dI_2}{dt}$$

This is because the mutual inductance M is negligible. If L_{eq} is the equivalent inductance of the parallel combination, then

$$\varepsilon = -L_{eq} \cdot \frac{dI}{dt} = -L_{eq}\left[\frac{dI_1}{dt} + \frac{dI_2}{dt}\right]$$

(negative sign shows the opposition of change in flux by inductors)

$$\text{or} \quad \frac{\varepsilon}{L_{eq}} = \left[\frac{\varepsilon}{L_1} + \frac{\varepsilon}{L_2}\right] \text{ or } \frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$$

$$\text{or} \quad L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$$

OR

Here area is constant but the magnetic field is reducing at a constant rate.

$$\frac{dB}{dt} = -(0.02)\text{ T s}^{-1}$$

Area of the loop, $A = l \times b$

$= 8 \times 2 \text{ cm}^2$

$= 16 \text{ cm}^2 = 16 \times 10^{-4} \text{ m}^2$

Induced emf in the loop

$$\varepsilon = -\frac{d\phi}{dt} = -A\frac{dB}{dt}$$

$\varepsilon = -16 \times 10^{-4} [-0.02] = 32 \times 10^{-6}$ Volt

Induced current in the closed loop

$$I = \varepsilon/R = \frac{32 \times 10^{-6}}{1.6} = 20 \text{ µA}$$

Power loss as heat $P = I^2R$

$P = (20 \times 10^{-6})^2 \times 1.6 = 6.4 \times 10^{-10}$ W

Source of the power is work done in changing magnetic field.

30. **(a)** Yes, earth's field undergoes a change with time. For example, daily changes, annual changes, secular changes with period of the order of 960 years and irregular changes like magnetic storms. Time scale for appreciable change is roughly a few hundred years.

(b) The earth's core does contain iron but in the molten form only. This is not ferromagnetic and hence it cannot be treated as a source of earth's magnetism.

31. **(a)** Difference between interference and diffraction:

experiment to observe diffraction pattern

	Interference	**Diffraction**
1.	Interference is caused by superposition two waves starting from two coherent sources.	Diffraction is caused by superposition of a number of waves starting from the slit.
2.	All bright and dark fringes are of equal width.	Width of central bright fringe is double of all other maxima.
3.	All bright fringes are of same intensity.	Intensity of bright fringes decreases sharply as we move away from central bright fringe.
4.	Dark Fringes are perfectly dark.	Dark fringes are not perfectly dark.

(b) Given $\lambda = 500$ nm $= 5 \times 10^{-7}$ m; $D = 1$ m

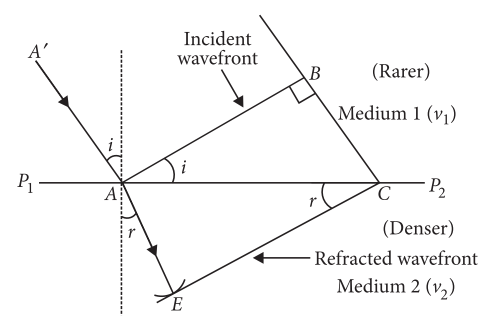
If a is width of slit, then for first minimum,

$$\sin\theta_1 = \frac{\lambda}{a}; \text{ For small } \theta_1, \sin\theta_1 = \frac{y_1}{D}$$

$$\therefore \frac{y_1}{D} = \frac{\lambda}{a} \Rightarrow a = \frac{\lambda D}{y_1} = \frac{5 \times 10^{-7} \times 1}{2.5 \times 10^{-3}} = 2 \times 10^{-4} \text{ m}$$

OR

Snell's law of refraction : Let P_1P_2 represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and medium 2 respectively. We assume a plane wavefront AB propagating in the direction $A'A$ incident on the interface at an angle i. Let t be the time taken by the wavefront to travel the distance BC.

$\therefore \quad BC = v_1 t \qquad$ [$\because$ distance = speed × time]

In order to determine the shape of the refracted wavefront, we draw a sphere of radius v_2t from the point A in the second medium (the speed of the wave in second medium is v_2).

Let CE represents a tangent plane drawn from the point C. Then

$AE = v_2 t$

$\therefore$ *CE* would represent the refracted wavefront.

In ΔABC and ΔAEC, we have

$$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC} \quad \text{and} \quad \sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$$

where *i* and *r* are the angles of incident and refraction respectively.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \cdot \frac{AC}{v_2 t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

If *c* represents the speed of light in vacuum, then

$$\mu_1 = \frac{c}{v_1} \text{ and } \mu_2 = \frac{c}{v_2}$$

$$\Rightarrow \quad v_1 = \frac{c}{\mu_1} \text{ and } v_2 = \frac{c}{\mu_2}$$

where μ_1 and μ_2 are the refractive indices of medium 1 and medium 2.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{c/\mu_1}{c/\mu_2} \Rightarrow \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$$

This is the Snell's law of refraction.

32. Since net force on electric dipole in uniform electric field is zero, so no work is done in moving the electric dipole in uniform electric field, however some work is done in rotating the dipole against the torque acting on it. So, small work done in rotating the dipole by an angle $d\theta$ in uniform electric field *E* is

$$dW = \tau \, d\theta = pE \sin\theta \, d\theta$$

Hence, net work done in rotating the dipole from angle θ_i to θ_f in uniform electric field is

$$W = \int_{\theta_i}^{\theta_f} pE \sin\theta \, d\theta = pE\,[-\cos\theta]_{\theta_i}^{\theta_f}$$

or $W = pE\,[-\cos\theta_f + \cos\theta_i] = pE\,[\cos\theta_i - \cos\theta_f]$

If initially, the dipole is placed at an angle $\theta_i = 90°$ to the direction of electric field, and is then rotated to the angle $\theta_f = \theta$, then net work done is

$$W = pE\,[\cos 90° - \cos\theta]$$

or $W = -\,pE\cos\theta$

This gives the work done in rotating the dipole through an angle θ in uniform electric field, which gets stored in it in the form of potential energy *i.e.*,

$$U = -\,pE\cos\theta$$

This gives potential energy stored in electric dipole of moment *p* when placed in uniform electric field at an angle θ with its direction.

(i) When $\theta = 0°$, then $U_{min} = -pE$

So, potential energy of an electric dipole is minimum, when it is placed with its dipole moment *p* parallel to the direction of electric field *E* and so it is called its most stable equilibrium position.

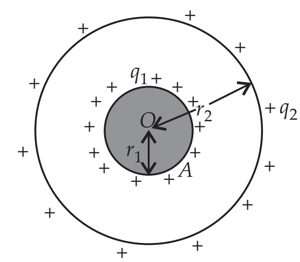
(ii) When $\theta = 180°$, then $U_{max} = +\,pE$

So, potential energy of an electric dipole is maximum, when it is placed with its dipole moment *p* anti parallel to the direction of electric field *E* and so it is called its most unstable equilibrium position.

OR

The potential on inner small sphere is

$$V_A = V_{AA} + V_{AB}$$



$$\text{or} \quad V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$$

whereas the potential on the outer shell *B* is

$$V_B = V_{BA} + V_{BB} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$$

$$\text{So,} \quad V_A - V_B = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} - \frac{q_1}{r_2}\right] = \frac{q_1}{4\pi\varepsilon_0}\left[\frac{r_2 - r_1}{r_1 r_2}\right]$$

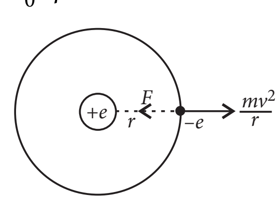
As $r_2 > r_1$, so $V_A > V_B$ *i.e.* inner sphere *A* is at higher potential than outer conducting shell *B*, for any value of charge q_1. So, when inner sphere *A* is connected to outer shell *B*, then charge will flow from inner sphere *A* to outer shell *B*, until electric potentials on them is same i.e.

$V_A - V_B = 0$ or $q_1 = 0$ [As $r_1 \neq r_2$]

So, charge q_1 given to sphere *A* will flow on the shell *B*, no matter what the charge on the shell *B* is.

33. (a) Radius of n^{th} orbit of hydrogen atom : In *H*-atom, an electron having charge $-e$ revolves around the nucleus of charge $+e$ in a circular orbit of radius *r*, such that necessary centripetal force is provided by the electrostatic force of attraction between the electron and nucleus.

$$i.e., \quad \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e.e}{r^2} \text{ or } mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \qquad ...(i)$$



From Bohr's quantization condition

$$mvr = \frac{nh}{2\pi} \quad \text{or} \quad v = \frac{nh}{2\pi mr} \qquad \text{...(ii)}$$

Using equation (ii) in (i), we get

$$m \cdot \left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \quad \text{or} \quad \frac{m \cdot n^2h^2}{4\pi^2m^2r^2} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$\text{or} \quad r = \frac{n^2h^2\varepsilon_0}{\pi me^2} \qquad \text{...(iii)}$$

where $n = 1, 2, 3, ...$ is principal quantum number. Equation (iii), gives the radius of n^{th} orbit of H-atom. So the radii of the orbits increase proportionally with n^2 *i.e.*, $[r \propto n^2]$. Radius of first orbit of H-atom is called Bohr radius a_0 and is given by

$$a_0 = \frac{h^2\varepsilon_0}{\pi me^2} \quad \text{for } n = 1 \text{ or } a_0 = 0.529 \text{ Å}$$

So, radius of n^{th} orbit of H-atom then becomes

$r = n^2 \times 0.529$ Å

(b) 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)

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

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

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

Potential energy of electron,

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

Using eq. (ii), we get

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

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.

OR

(a) Rydberg's formula for wavelengths of the spectral lines of the hydrogen atom spectrum is given by,

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right],$$

where R = Rydberg's constant = 1.0973×10^7 m^{-1}

The emission spectrum of hydrogen, H_α line (656.3 nm) lies in Balmer series.

(b) For longest wavelength of Lyman series $n_i = 2$

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3R}{4}$$

$$\lambda_{max} = \frac{4}{3R} = \frac{4}{3 \times 1.097 \times 10^7} = 1.215 \times 10^{-7} \text{ m}$$

$\lambda_{max} = 1215$ Å

The lines of the Lyman series are found in ultraviolet region.

For longest wavelength of Balmer series $n_i = 3$

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5}{36}R$$

$$\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.097 \times 10^7} = 6.563 \times 10^{-7} \text{ m} = 6563 \text{ Å}$$

Balmer series lie in the visible region of electromagnetic spectrum.

☺☺☺