SAMPLE QUESTION PAPER

SQP 4

BLUEPRINT

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

S. No.	Unit	Chapter	MCQs, A & R (1 mark)	SA-I (2 marks)	SA-II (3 marks)	Case Based (4 marks)	LA (5 marks)	Total	
1.	Unit-I	Electric Charges and Fields	1(1)	–	1(3)	–	–	4(10)	16
2.		Electrostatic Potential and Capacitance	1(1)	–	–	–	1(5)*		
3.	Unit-II	Current Electricity	1(1)	–	–	–	1(5)*	2(6)	
4.	Unit-III	Moving Charges and Magnetism	2(2)	–	1(3)	–	–	5(8)	17
5.		Magnetism and Matter	1(1)	1(2)	–	–	–		
6.	Unit-IV	Electromagnetic Induction	1(1)	–	–	–	–	5(9)	
7.		Alternating Current	2(2)	–	2(6)*	–	–		
8.	Unit-V	Electromagnetic Waves	1(1)	1(2)	–	1(4)*	–	3(7)	18
9.	Unit-VI	Ray Optics and Optical Instruments	–	–	–	–	–	5(11)	
10.		Wave Optics	2(2)	2(4)	–	–	1(5)*		
11.	Unit-VII	Dual Nature of Radiation and Matter	2(2)	–	1(3)*	–	–	3(5)	12
12.	Unit-VIII	Atoms	1(1)	–	1(3)	–	–	4(7)	
13.		Nuclei	1(1)	1(2)*	–	–	–		
14.	Unit-IX	Semiconductor Electronics : Materials, Devices and Simple Circuits	–	–	1(3)	1(4)*	–	2(7)	07
		Total	**16(16)**	**5(10)**	**7(21)**	**2(8)**	**3(15)**	**33(70)**	

*It is a choice based question.

Subject Code : **042**

SQP-4

PHYSICS

Time : 3 Hours ***Max. Marks : 70***

General Instructions :

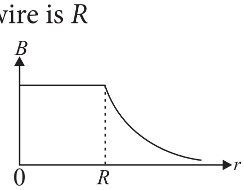
(1) There are 33 questions in all. All questions are compulsory.
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(3) All the sections are compulsory.
*(4) **Section A** contains sixteen questions, twelve MCQs and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.*
(5) There is no overall choice. However, an internal choice has been provided in one question in Section B, two questions in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
(6) Use of calculators is not allowed.
(7) You may use the following values of physical constants where ever necessary
i. $c = 3 \times 10^8$ m/s
ii. $m_e = 9.1 \times 10^{-31}$ kg
iii. $e = 1.6 \times 10^{-19}$ C
iv. $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}
v. $h = 6.63 \times 10^{-34}$ Js
vi. $\varepsilon_0 = 8.854 \times 10^{-12}$ C^{2}N^{-1}m^{-2}
vii. Avogadro's number = 6.023×10^{23} per gram mole

SECTION A

1. Which of the following statements is false for a perfect conductor?
(a) The surface of the conductor is an equipotential surface.
(b) The electric field just outside the surface of a conductor is perpendicular to the surface.
(c) The charge carried by a conductor is always uniformly distributed over the surface of the conductor.
(d) None of these

2. Point out the right statements about the validity of kirchhoff's junction rule.
(a) It is based on conservation of charge.
(b) Outgoing currents add up and are equal to incoming currents at a junction.
(c) Bending or reorienting the wire does not change the validity of kirchhoff's junction rule.
(d) All of above.

3. The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R

(a)


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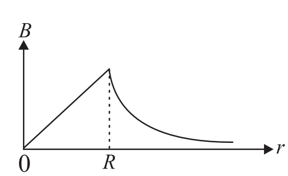

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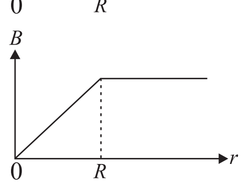

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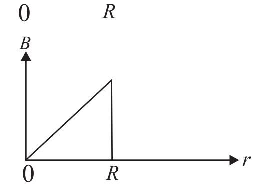
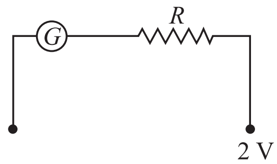
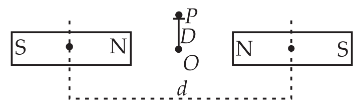


4. A voltmeter which can measure 2 V is constructed by using a galvanometer of resistance 12 Ω and that produces maximum deflection for the current of 2 mA, then the resistance R is



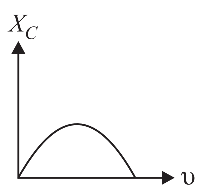
(a) 888 Ω (b) 988 Ω (c) 898 Ω (d) 999 Ω

5. Two identical bar magnets are fixed with their centres at a distance d apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance D from the centre O as shown in the figure. The force on the charge Q is



(a) zero
(b) directed along OP
(c) directed along PO
(d) directed perpendicular to the plane of paper.

6. Which of the following graphs represents the correct variation of capacitive reactance X_C with frequency υ ?

(a)


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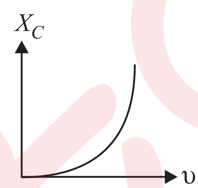

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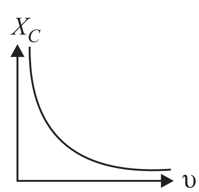

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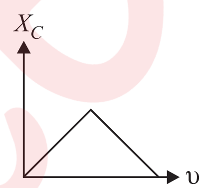
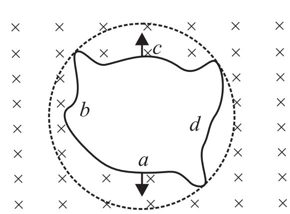


7. If a variable frequency ac source is connected to a capacitor then with decrease in frequency the displacement current will

(a) increase
(b) decrease
(c) remains constant
(d) first decrease then increase

8. A wire of irregular shape turning into a circular shape in a magnetic field which is directed into the paper. The direction of induced current is

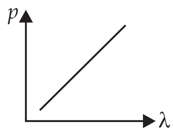


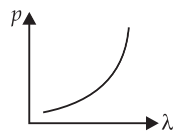
(a) along $abcda$
(b) along $adcba$
(c) into the plane of the paper
(d) out of the plane of the paper

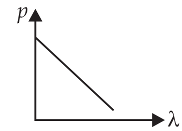
9. In a Young's double slit experiment an electron beam is used to obtain interference pattern. If the spread of electron is decreases then

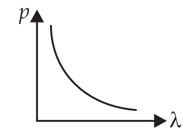
(a) distance between two consecutive fringes remains the same
(b) distance between two consecutive fringes decreases
(c) distance between two consecutive fringes increases
(d) none of these.

10. Which of the following figure represents the variation of particle momentum (p) and associated de Broglie wavelength (λ)?

(a) 

(b) 

(c) 

(d) 

11. The radius of n^{th} orbit r_n in terms of Bohr radius (a_0) for a hydrogen atom is given by the relation

(a) na_0 (b) $\sqrt{n}\,a_0$ (c) n^2a_0 (d) n^3a_0

12. The fission properties of $^{239}_{94}Pu$ are very similar to those of $^{235}_{92}U$. The average energy released per fission is 180 MeV. If all the atoms in 1 kg of pure $^{239}_{94}Pu$ undergo fission, then the total energy released in MeV is

(a) 4.53×10^{26} MeV (b) 2.21×10^{14} MeV (c) 1×10^{13} MeV (d) 6.33×10^{24} MeV

For Questions 13 to 16, two statements are given –one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below.

(a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.

(b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

(c) If Assertion is true but Reason is false.

(d) If both Assertion and Reason are false.

13. **Assertion (A) :** Step-down transformer increases the current.

Reason (R) : Transformer obeys the law of conservation of energy.

14. **Assertion (A) :** The tyres of aircrafts are slightly conducting.

Reason (R) : If a conductor is connected to ground, the extra charge induced on conductor will flow to ground.

15. **Assertion (A) :** Young's double slit experiment can be performed using a source of white light.

Reason (R) : The wavelength of red light is less than the wavelength of other colours in white light.

16. **Assertion (A) :** The threshold frequency of photoelectric effect supports the particle nature of light.

Reason (R) : If frequency of incident light is less than the threshold frequency, electrons are not emitted from metal surface.

SECTION B

17. Identify the electromagnetic waves whose wavelengths vary as

(a) 10^{-11} m $< \lambda < 10^{-14}$ m (b) 10^{-4} m $< \lambda < 10^{-6}$ m

Write one use of each.

18. What is the name given to the curves, the tangent to which at any point gives the direction of the magnetic field at that point? Can two such curves intersect each other? Justify your answer.

19. How is the size of a nucleus experimentally determined? Write the relation between the radius and mass number of the nucleus. Show that the density of nucleus is independent of its mass number.

OR

Energy of electron in first excited state in Hydrogen atom is –3.4 eV. Find K.E. and P.E. of electron in the ground state.

20. The radii of curvature of the faces of a double convex lens are 10 cm and 15 cm. If focal length of the lens is 12 cm, find the refractive index of the material of the lens.

21. (a) Is Huygens principle valid for longitudinal sound waves?

(b) Why is the diffraction of sound waves more evident in daily experience than that of light wave?

(c) If one of the slits in Young's double slit experiment is fully closed, the new pattern has _______ central maximum in angular size.

SECTION C

22. State Biot-Savart law, and write its mathematical expression.

Use this law to derive an expression for the magnetic field due to a circular coil carrying current at a point along its axis.

23. A circuit is set up by connecting L = 100 mH, C = 5 μF and R = 100 Ω in series. An alternating emf of $(150\sqrt{2})$ V, $\frac{500}{\pi}$ Hz is applied across this series combination. Calculate

(a) The impedance of the circuit.

(b) The peak value of the current flowing in the circuit.

(c) The power factor of this circuit.

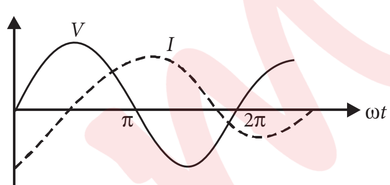
24. A series LCR circuit is made by taking R = 100 Ω, L = 2/π H, C = 100/π μF. The series combination is connected across an a.c. source of 220 V, 50 Hz. Calculate

(a) the impedance of the circuit,

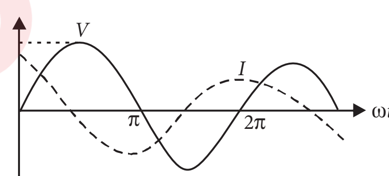
(b) the peak value of the current flowing in the circuit.

OR

For a series LCR circuit, connected to a sinusoidal ac voltage source, identify the graph that corresponds to $\omega > \frac{1}{\sqrt{LC}}$. Give reason.



Graph (a)



Graph (b)

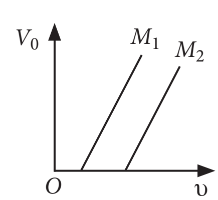
25. (a) Assuming an electron is confined to a 1 nm wide region, find the uncertainty in momentum using Heisenberg Uncertainty principle. You can assume the uncertainty in position Δx as 1 nm. Assuming $p \simeq \Delta p$, find the energy of the electron in electron volts.

OR

(i) (a) Define the terms, (i) threshold frequency and (ii) stopping potential in photoelectric effect.

(b) (i) Plot a graph of photocurrent versus anode potential for a radiation of frequency υ and intensities I_1 and I_2 ($I_1 < I_2$).

(ii) The variation of the stopping potential (V_0) with the frequency (υ) of the light incident on two different photosensitive surfaces M_1 and M_2 is shown in the figure.

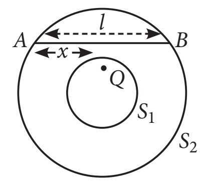


Identify the surface which has greater value of the work function.

26. In hydrogen atom, electron excites from ground state to higher energy state and its orbital velocity is reduced to $\left(\frac{1}{3}\right)^{\text{rd}}$ of its initial value. The radius of the orbit in the ground state is R. Find the radius of the orbit in that higher energy state.

27. Write the two processes that take place in the formation of a *p-n* junction. Explain with the help of a diagram, the formation of depletion region and barrier potential in a *p-n* junction.

28. In the figure shown, calculate the total flux of the electrostatic field through the spheres S_1 and S_2. The wire AB, shown here, has a linear charge density, λ, given by $\lambda = kx$ where x is the distance measured along the wire, from the end A.



SECTION D

Case Study Based Questions

29. Read the following paragraph and answer the questions that follow.

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is $p = \frac{U}{c}$. When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(i) The pressure exerted by an electromagnetic wave of intensity I (W m^{-2}) on a non-reflecting surface is (c is the velocity of light)

(a) Ic (b) Ic^2 (c) I/c (d) I/c^2

(ii) Light with an energy flux of 18 W/cm^2 falls on a non-reflecting surface at normal incidence. The pressure exerted on the surface is

(a) 2 N/m^2 (b) 2×10^{-4} N/m^2
(c) 6 N/m^2 (d) 6×10^{-4} N/m^2

(iii) Radiation of intensity 0.5 W m^{-2} are striking a metal plate. The pressure on the plate is

(a) 0.166×10^{-8} N m^{-2} (b) 0.212×10^{-8} N m^{-2}
(c) 0.132×10^{-8} N m^{-2} (d) 0.083×10^{-8} N m^{-2}

OR

A point source of electromagnetic radiation has an average power output of 1500 W. The maximum value of electric field at a distance of 3 m from this source (in V m^{-1}) is

(a) 500 (b) 100 (c) $\frac{500}{3}$ (d) $\frac{250}{3}$

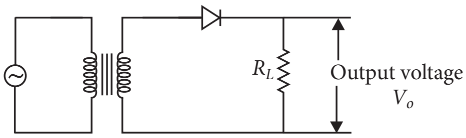
(iv) The radiation pressure of the visible light is of the order of

(a) 10^{-2} N m^2 (b) 10^{-4} N/m (c) 10^{-6} N/m^2 (d) 10^{-8} N

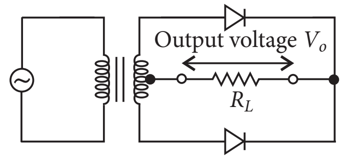
30. Read the following paragraph and answer the questions that follow.

Rectifiers

Rectifier is a device which is used for converting alternating current or voltage into direct current or voltage. Its working is based on the fact that the resistance of *p-n* junction becomes low when forward biased and becomes high when reverse biased. A half-wave rectifier uses only a single diode while a full wave rectifier uses two diodes as shown in figures (a) and (b).



(a) Half wave rectifier

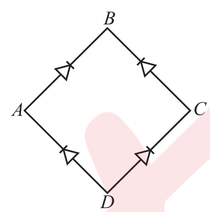


(b) Full wave rectifier

(i) If the rms value of sinusoidal input to a full wave rectifier is $\frac{V_0}{\sqrt{2}}$ then the rms value of the rectifier's output is

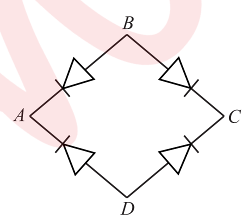
(a) $\frac{V_0}{\sqrt{2}}$ (b) $\frac{V_0^2}{\sqrt{2}}$ (c) $\frac{V_0^2}{2}$ (d) $\sqrt{2}\,V_0^2$

(ii) In the diagram, the input ac is across the terminals *A* and *C*. The output across *B* and *D* is



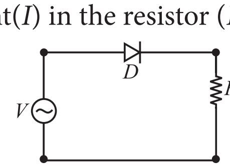
(a) same as the input (b) half wave rectified (c) zero (d) full wave rectified.

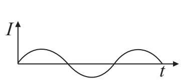
(iii) A bridge rectifier is shown in figure. Alternating input is given across *A* and *C*. If output is taken across *BD*, then it is

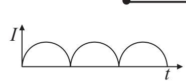


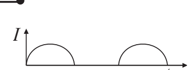
(a) zero (b) same as input (c) half wave rectified (d) full wave rectified.

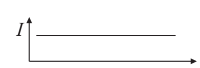
(iv) A *p-n* junction (*D*) shown in the figure can act as a rectifier. An alternating current source (*V*) is connected in the circuit. The current(*I*) in the resistor (*R*) can be shown by



(a) 

(b) 

(c) 

(d) 

OR

With an ac input from 50 Hz power line, the ripple frequency is

(a) 50 Hz in the dc output of half wave as well as full wave rectifier

(b) 100 Hz in the dc output of half wave as well as full wave rectifier

(c) 50 Hz in the dc output of half wave and 100 Hz in dc output of full wave rectifier

(d) 100 Hz in the dc output of half wave and 50 Hz in the dc output of full wave rectifier.

SECTION E

31. A parallel plate capacitor of capacitance 'C' is charged to 'V' volt by a battery. After some time the battery is disconnected and the distance between the plates is doubled. Now a slab of dielectric constant $1 < K < 2$ is introduced to fill the space between the plates. How will the following be affected?

(i) The electric field between the plates of the capacitor?

(ii) The energy stored in the capacitor.

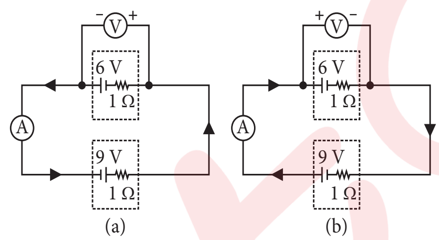
Justify your answer in each case.

OR

(a) An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

(b) The electric field inside a parallel plate capacitor is E. Find the amount of work done in moving a charge q over a closed rectangular loop *abcda*.

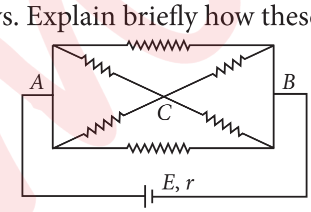
32. (a) In the two electric circuits shown in the figure, determine the readings of ideal ammeter (A) and the ideal voltmeter (V).



(b) Write a relation between current and drift velocity of electrons in a conductor. Use this relation to explain how the resistance of a conductor changes with the rise in temperature.

OR

(i) State the two Kirchhoff's laws. Explain briefly how these rules are justified.



(ii) The current is drawn from a cell of emf E and internal resistance r connected to the network of resistors each of resistance r as shown in the figure. Obtain the expression for (a) the current drawn from the cell and (b) the power consumed in the network.

33. (a) Use Huygen's geometrical construction to show how a plane wave-front at $t = 0$ propagates and produces a wave-front at a later time.

(b) Verify, using Huygen's principle, Snell's law of refraction of a plane wave propagating from a denser to a rarer medium.

(c) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency. Explain why.

OR

Draw a graph to show variation in the angle of deviation δ with the variation of angle of incidence i for a monochromatic ray of light passing through a prism of refracting angle A. Deduce the relation $\mu = \dfrac{\sin \dfrac{A + \delta_m}{2}}{\sin \dfrac{A}{2}}$.

Self Evaluation Sheet

*Once you complete **SQP-4**, check your answers with the given solutions and fill your marks in the marks obtained column according to the marking scheme. Performance Analysis Table given at the bottom will help you to check your readiness.*

Q.No.	Chapter	Marks Per Question	Marks Obtained
1	Electrostatic Potential and Capacitance	1	
2	Current Electricity	1	
3	Moving Charges and Magnetism	1	
4	Moving Charges and Magnetism	1	
5	Magnetism and Matter	1	
6	Alternating Current	1	
7	Electromagnetic Waves	1	
8	Electromagnetic Induction	1	
9	Wave Optics	1	
10	Dual Nature of Radiation and Matter	1	
11	Atoms	1	
12	Nuclei	1	
13	Alternating Current	1	
14	Electrostatic Potential and Capacitance	1	
15	Wave Optics	1	
16	Dual Nature of Radiation and Matter	1	
17	Electromagnetic Waves	2	
18	Moving Charges and Magnetism	2	
19	Nuclei / Atoms	2	
20	Ray Optics and Optical Instruments	2	
21	Wave Optics	2	
22	Moving Charges and Magnetism	3	
23	Alternating Current	3	
24	Alternating Current / Alternating Current	3	
25	Dual Nature of Radiation and Matter / Dual Nature of Radiation and Matter	3	
26	Atoms	3	
27	Semiconductor Electronics : Materials, Devices and Simple Circuits	3	
28	Electric Charges and Fields	3	
29	Electromagnetic Waves	1 + 1 + 1 + 1	
30	Semiconductor Electronics : Materials, Devices and Simple Circuits	1 + 1 + 1 + 1	
31	Electrostatic Potential and Capacitance / Electrostatic Potential and Capacitance	5	
32	Current Electricity / Current Electricity	5	
33	Wave Optics / Ray Optics and Optical Instruments	5	
	Total	**70**	....
		Percentage	..............%

Performance Analysis Table

If your marks is

> 90%	**TREMENDOUS!**	➢ *You are done! Keep on revising to maintain the position.*
81-90%	**EXCELLENT!**	➢ *You have to take only one more step to reach the top of the ladder. Practise more.*
71-80%	**VERY GOOD!**	➢ *A little bit of more effort is required to reach the 'Excellent' bench mark.*
61-70%	**GOOD!**	➢ *Revise thoroughly and strengthen your concepts.*
51-60%	**FAIR PERFORMANCE!**	➢ *Need to work hard to get through this stage.*
40-50%	**AVERAGE!**	➢ *Try hard to boost your average score.*

SQP 4 SOLUTIONS

1. **(d)** **2.** **(d)**

3. **(b) :** The magnetic field from the centre of wire of radius R is given by

$$B = \left(\frac{\mu_o I}{2R^2}\right) r \qquad (r < R)$$

$$\Rightarrow \quad B \propto r$$

and $B = \dfrac{\mu_o I}{2\pi r} \quad (r > R) \quad \Rightarrow \quad B \propto \dfrac{1}{r}$

From the above descriptions, we can say that the graph (b) is a correct representation.

4. **(b) :** $R = \dfrac{V}{I_g} - G$

Putting $V = 2$ V, $I_g = 2$ mA $= 2 \times 10^{-3}$ A, $G = 12\ \Omega$,

$$\therefore \quad R = \frac{2}{2 \times 10^{-3}} - 12 = 1000 - 12 = 988\ \Omega$$

5. **(a) :** Magnetic field due to bar magnets exerts force on moving charges only. Since the charge is at rest, zero force acts on it.

6. **(c) :** Capacitive reactance, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi \upsilon C}$

$$\Rightarrow \quad X_C \propto \frac{1}{\upsilon}$$

With increase in frequency, X_C decreases.
Hence, option (c) represents the correct graph.

7. **(b) :** Current through capacitor,

$$I = \frac{E}{X_C} = \frac{E}{\frac{1}{\omega C}} = \omega C E = 2\pi \upsilon\, CE \text{ or } \quad I \propto \upsilon.$$

$\therefore$ decrease in frequency υ of ac source decreases the conduction current. As displacement current is equal to conduction current, decrease in υ decreases displacement current in circuit.

8. **(b) :** When a wire of irregular shape turns into a circular loop, area of the loop tends to increase. Therefore, magnetic flux linked with the loop increases. According to Lenz's law, the direction of induced current must oppose the magnetic flux, for which induced current should flow along *adcba*.

9. **(c) :** Fringe width, $\beta = \dfrac{\lambda D}{d}$

Also, $\quad \lambda = \dfrac{h}{mv}$

Here h is planck's constant. This wavelength is inversely proportional to the velocity. Hence, the fringe width increases with decrease in electron speed.

10. **(d) :** de Broglie wavelength, $\lambda = \dfrac{h}{p}$

or $\quad \lambda \propto \dfrac{1}{p}$

Hence, curve (d) is the correct option.

11. **(c) :** The radius of n^{th} orbit

$$r_n = n^2 \frac{\hbar^2 4\pi\varepsilon_0}{me^2}$$

where $\dfrac{\hbar^2 4\pi\varepsilon_0}{me^2} = a_0$ (Bohr radius)

Hence, $r_n = n^2 a_0$.

12. **(a) :** Number of atoms in 1 kg of pure ^{239}Pu

$$= \frac{6.023 \times 10^{23}}{239} \times 1000 = 2.52 \times 10^{24}$$

As average energy released per fission is 180 MeV

$\therefore$ Total energy released

$= 2.52 \times 10^{24} \times 180$ MeV $= 4.53 \times 10^{26}$ MeV

13. **(b) :** If there is no loss of energy in transformer, then instantaneous output power is equal to instantaneous input power. From this we get $\dfrac{e_s}{e_p} = \dfrac{I_p}{I_s}$.

So in step up transformer voltage increases by decreasing the current. Similarly, step-down transformer decreases the voltage by increasing current. Therefore transformer simply transforms the voltage and current, obeying the law of conservation of energy.

14. **(b) :** During take off and landing, the friction between tyres and the run way may cause electrification of tyres. Due to conducting nature of tyre, the charge so collected is conducted to a ground and electrical sparking is avoided.

15. **(c) :** When source in Young's double slit experiment is of white light, the central fringe is white as all colours meet there in phase.

16. **(b) :** There is no emission of photoelectrons till the frequency of incident light is less than a minimum frequency, however intense light it may be. In photoelectric effect, it is a single particle collision. Intensity is $h\upsilon \times N$, where $h\upsilon$ is the individual energy of the photon and N is the total number of photon. In the wave theory, the intensity is proportional, not only to υ^2 but also to the square of amplitude. For the same frequency, increase in intensity only increase the number of photons (in the quantum theory of Einstein).

17. (a) The wavelength of Gamma rays lie between 10^{-11} m to 10^{-14} m.

These rays are used in radiotherapy to treat certain cancers and tumors.

(b) The wavelength of infrared waves lie between 10^{-4} m to 10^{-6} m. These waves are used in taking photographs during conditions of fog, smoke etc., as these waves are scattered less than visible rays.

18. Magnetic field lines. No, if they intersect at a point, it will show two magnetic fields with different directions at a point, which is never possible.

19. Nucleus was first discovered in 1911 by Lord Rutherford and his associates by experiments on scattering of α-particle by atoms. He found that the scattering result could be explained, if atoms consists of a small, central, massive and positive core surrounded by orbiting electron. The experiment results indicated that the size of the nucleus is of the order of 10^{-14} metres and it thus 10,000 times smaller than the size of atom.

Relation between the radius and mass number of the nucleus $R = R_0 A^{1/3}$

If m is the average mass of a nucleon and R is the nuclear radius, then mass of nucleus = mA, where A is the mass number of the element.

Volume of the nucleus, $V = \frac{4}{3}\pi R^3$

$$\therefore \quad V = \frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3 \Rightarrow V = \frac{4}{3}\pi R_0^3 A$$

Density of nuclear matter, $\rho = \frac{mA}{V}$

$$\Rightarrow \rho = \frac{mA}{\frac{4}{3}\pi R_0^3 A} \Rightarrow \rho = \frac{3m}{4\pi R_0^3}$$

This shows that the nuclear density is independent of A.

OR

Energy for $n = 2$, $\varepsilon_2 = -3.4$ eV.

It is total energy of second orbit or first excited state.

So, $E_n = -13.6\frac{Z^2}{n^2}$ for $n = 1$,

$$E_1 = \frac{-13.6\,(1)}{(1)} = -13.6 \text{ eV}$$

So, K.E = – T.E

K.E = 13.6 eV and PE = 2T.E ; PE = – 27.2 eV

20. Here, $R_1 = 10$ cm, $R_2 = -15$ cm, $f = 12$ cm, μ = ?

Using lens formula, we have

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

$$\frac{1}{12} = (\mu - 1)\left(\frac{1}{10} - \frac{1}{-15}\right) = (\mu - 1)\left(\frac{3+2}{30}\right) = (\mu - 1)\left(\frac{5}{30}\right)$$

$$\Rightarrow (\mu - 1) = \frac{1}{12} \times \frac{30}{5} \Rightarrow \mu - 1 = 0.5$$

$$\Rightarrow \mu = 1 + 0.5 \quad \therefore \quad \mu = 1.5$$

21. (a) Yes, Huygen's principle is valid for longitudinal as well as transverse waves and for all wave phenomena.

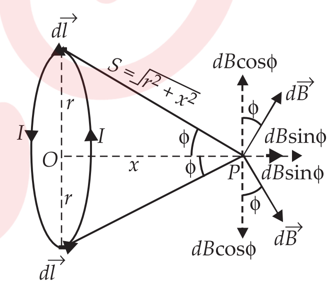
(b) The diffraction effect is more pronounce if the size of the aperture or the obstacle is of the order of wavelength of wave. As wavelength of light ($\simeq 10^{-6}$ m) is much smaller than size of object around us so diffraction of light is not easily seen but sound wave has large wavelength (15 mm < λ < 15 m), they get easily diffracted by objects around us.

(c) In Young's double slit experiment, if one slit is fully closed, the new pattern has larger central maximum in angular size.

22. Biot-Savart law states that magnitude of intensity of small magnetic field $d\vec{B}$ due to a current carrying element $d\vec{l}$ at any point P at distance r from it is given by

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

Magnetic field on the axis of circular coil :



Small magnetic field due to current element of circular coil of radius r at point P at distance x from its centre is

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin 90^\circ}{S^2} = \frac{\mu_0}{4\pi}\frac{Idl}{(r^2 + x^2)}$$

Component $dB\cos\phi$ due to current element at point P is cancelled by equal and opposite component $dB\cos\phi$ of another diametrically opposite current element, whereas the sine components $dB\sin\phi$ add up to give net magnetic field along the axis. So, net magnetic field at point P due to entire loop is $B = \oint dB\sin\phi = \int_0^{2\pi r}\frac{\mu_0}{4\pi}\frac{Idl}{(r^2 + x^2)}\cdot\frac{r}{(r^2 + x^2)^{1/2}}$

$$B = \frac{\mu_0 Ir}{4\pi(r^2 + x^2)^{3/2}}\int_0^{2\pi r} dl \text{ or } B = \frac{\mu_0 Ir}{4\pi(r^2 + x^2)^{3/2}}2\pi r$$

or $B = \frac{\mu_0 I r^2}{2(r^2 + x^2)^{3/2}}$ directed along the x-axis,

(i) towards the coil if current in it is in clockwise direction.

(ii) away from the coil if current in it is in anticlockwise direction.

23. Here, $L = 100$ mH, $C = 5$ μF,

$\varepsilon_{rms} = 150\sqrt{2}$ V, $\upsilon = \frac{500}{\pi}$ Hz , $R = 100\ \Omega$,

$X_L = \omega L = 2\pi\upsilon L$

$= 2\pi \times \frac{500}{\pi} \times 100 \times 10^{-3}\,\Omega = 100\,\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C} = \frac{1}{2\pi\left(\frac{500}{\pi}\right)\times 5 \times 10^{-6}}\,\Omega = 200\,\Omega$

(a) The impedance of the circuit is

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{100^2 + (100-200)^2}$

$= 100\sqrt{2}\,\Omega = 141.4\,\Omega$

(b) $I_{rms} = \frac{\varepsilon_{rms}}{Z} = \frac{150\sqrt{2}}{100\sqrt{2}}\,A = 1.5\,A$

$I_0 = I_{rms}\sqrt{2} = 2.12\,A$

(c) Power factor, $\cos\phi = \frac{R}{Z} = \frac{100}{100\sqrt{2}} = \frac{1}{\sqrt{2}}$

24. As per question, $R = 100\,\Omega$, $L = 2/\pi$ H

$C = \frac{100}{\pi}\,\mu F = \frac{100}{\pi} \times 10^{-6}\,F = \frac{1}{\pi} \times 10^{-4}\,F$

$V_{rms} = 220\,V$ and $\upsilon = 50$ Hz

(a) Inductive reactance, $X_L = \omega L = 2\pi\upsilon \times L$

$= 2\pi \times 50 \times \frac{2}{\pi} = 200\,\Omega$

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$

$= \frac{1}{2\pi \times 50 \times \left(\frac{10^{-4}}{\pi}\right)} = 100\,\Omega$

$\therefore$ Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(100)^2 + (200-100)^2} = 100\sqrt{2}\,\Omega$

(b) Peak value of current, $I_0 = \sqrt{2}\,I_{rms}$

$= \frac{\sqrt{2} \times V_{rms}}{Z} = \frac{\sqrt{2} \times 220}{100\sqrt{2}} = 2.2\,A$

OR

In series LCR circuit, when $\omega > \frac{1}{\sqrt{LC}}$

or $\omega^2 > \frac{1}{LC}$ > or $\omega L > \frac{1}{\omega C}$

or $X_L > X_C$ or $IX_L > IX_C$ or $V_L > V_C$

Then current I lags behind the applied voltage V. As in graph (a) current I lags behind applied voltage V, so graph (a) corresponds to $\omega > \frac{1}{\sqrt{LC}}$ in LCR circuit.

25. Given, $\Delta x = 1$ nm $= 1 \times 10^{-9}$m, $\Delta p = ?$

$\Delta x \Delta p = \hbar$

$\therefore \quad \Delta p = \frac{\hbar}{\Delta x} = \frac{h}{2\pi\Delta x} = \frac{6.62 \times 10^{-34}\,J\,s}{2 \times \left(\frac{22}{7}\right) \times 10^{-9}\,m} \quad \left(\because \hbar = \frac{h}{2\pi}\right)$

$= 1.05 \times 10^{-25}$ kg m s^{-1}

Energy of electron,

$E = \frac{p^2}{2m}$ (Taking $\Delta p \approx p$)

$= \frac{(1.05 \times 10^{-25})^2}{2 \times 9.1 \times 10^{-31}} = 0.06 \times 10^{-19}\,J$

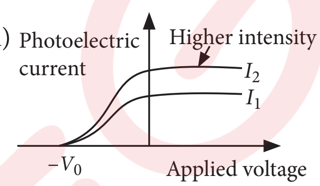
$= \frac{0.06 \times 10^{-19}}{1.6 \times 10^{-19}} = 0.0375\,eV = 3.75 \times 10^{-2}\,eV$

OR

(i) (a) (i) Threshold Frequency : The minimum frequency of incident light which is just capable of ejecting electrons from a metal is called the threshold frequency. It is denoted by υ_0.

(ii) Stopping Potential : The minimum retarding potential applied to anode of a photoelectric tube which is just capable of stopping photoelectric current is called the stopping potential. It is denoted by V_0 (or V_S).

(b) (i)



(ii) M_2 has greater value of work function, since it has higher value of threshold frequency.

26. As per question, $\frac{v_h}{v_g} = \frac{1}{3}$ ..(i)

where subscripts h and g denotes higher energy state and ground state.

Orbital velocity of electron in the nth orbit is

$v_n = \frac{e^2}{2\varepsilon_0 nh}$ or $v_n \propto \frac{1}{n}$

For ground state, $n = 1$, $\frac{v_h}{v_g} = \frac{1}{n}$ ...(ii)

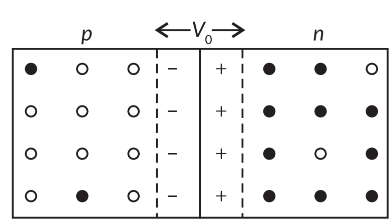
Equating eqns. (i) and (ii), we get $n = 3$

Radius of n^{th} orbit is $r_n = \frac{n^2 h^2 \varepsilon_0}{\pi e^2 m^2}$ or $r_n \propto n^2$

$\therefore \quad \frac{r_3}{r_1} = \frac{(3)^2}{(1)^2} = 9$

$r_3 = 9r_1 = 9R$ $(\because r_1 = R\text{(Given)})$

27. Two processes that take place in the formation of a p-n junction are diffusion and drift.



When p-n junction is formed, then at the junction free electrons from n-type diffuse over to p-type, thereby filling in the holes in p-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 (*i.e.,* electrons and holes) across the junction. Thus a potential difference V_0 of the order of 0.1 to 0.3 V is set up across the p-n junction called potential barrier or junction barrier. The thin region around the junction containing immobile positive and negative charges is known as depletion layer.

28. Electric flux linked with sphere S_1 is $\phi_1 = \dfrac{Q}{\varepsilon_0}$
Given that on charged wire AB,

Charge density $\dfrac{dq}{dx} = \lambda = kx.$
So, $dq = kx.dx$
Hence, the net charge on the wire AB is,

$$q = k\int_0^l x \cdot dx = k\left[\frac{x^2}{2}\right]_0^l = \frac{k}{2}[l^2 - 0] \text{ or } q = \frac{1}{2}kl^2$$

So, the electric flux linked with sphere S_2 is

$$\phi_2 = \frac{Q+q}{\epsilon_0} = \frac{Q + \frac{1}{2}kl^2}{\epsilon_0} \text{ or } \phi_2 = \frac{2Q + kl^2}{2\,\epsilon_0}$$

29. (i) (c) : Pressure exerted by an electromagnetic radiation, $P = \dfrac{I}{c}$

(ii) (d) : $P_{\text{rad}} = \dfrac{\text{Energy flux}}{\text{Speed of light}} = \dfrac{18 \text{ W/cm}^2}{3\times 10^8 \text{ m/s}}$

$$= \frac{18\times 10^4 \text{ W/m}^2}{3\times 10^8 \text{ m/s}} = 6\times 10^{-4} \text{ N/m}^2$$

(iii) (a) : $P = \dfrac{I}{c} = \dfrac{0.5}{3\times 10^8} = 0.166\times 10^{-8} \text{ N m}^{-2}$

OR

(b) : Intensity of EM wave is given by $I = \dfrac{P}{4\pi R^2}$

$$V_{av} = \frac{1}{2}\varepsilon_0 E_0^2 \times c$$

$$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2 \varepsilon_0 c}} = \sqrt{\frac{1500}{2\times 3.14(3)^2\times 8.85\times 10^{-12}\times 3\times 10^8}}$$

$$= \sqrt{10{,}000} = 100 \text{ V m}^{-1}$$

(v) (c) : The radiation pressure of visible light
$= 7 \times 10^{-6} \text{ N/m}^2$

30. (i) (a) : The rms value of the output voltage at the load resistance, $V_{\text{rms}} = \dfrac{V_0}{\sqrt{2}}.$

(ii) (d) : The output across B and D is zero.

(iii) (a)

(iv) (c) : The given circuit works as a half wave rectifier. In this circuit, we will get current through R when p-n junction is forward biased and no current when p-n junction is reverse biased. Thus the current (I) through resistor (R) will be shown in option (c).

OR

(c) : 50 Hz in the dc output of half wave and 100 Hz in the de output of rectifier.

31. (i) The electric field between the plates is

$$E = \frac{V}{d}$$

The distance between plates is doubled, $d = 2d$

$$\therefore\ E' = \frac{V'}{d'} = \left(\frac{V}{K}\right)\times\frac{1}{2d} = \frac{1}{2}\left(\frac{E}{K}\right)$$

Therefore, if the distance between the plates is double and dielectric ($1 < K < 2$) is inserted the electric field will reduce.
(ii) As the capacitance of the capacitor

$$C' = \frac{\varepsilon_0 KA}{d'} = \frac{\varepsilon_0 KA}{2d} = \frac{1}{2}C$$

Energy stored in the capacitor is $U = \dfrac{Q^2}{2C}$

New energy, $U' = \dfrac{Q^2}{2C'} = \dfrac{Q^2}{2(K/2)C} = 2\left(\dfrac{2Q^2}{2KC}\right) = \dfrac{2U}{K}$

Therefore, when the distance between the plates is doubled and dielectric ($1 < K < 2$) is inserted, so the energy stored in the capacitor increases.

OR

(a) Let P be a point at distance r from the sheet.
$W = q \cdot (V_P - V_\infty)$ ...(i)
Now, $V_P - V_\infty$

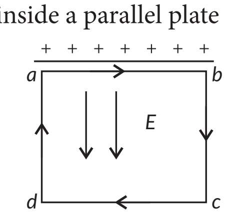
$$= -\int_\infty^r \vec{E}\cdot d\vec{r} = -\int_\infty^r E dr = -\int_\infty^r \left(\frac{\sigma}{2\varepsilon_0}\right)\cdot dr$$

(Field from an infinitely large plane sheet of charge q is uniform and is given by $\dfrac{\sigma}{2\varepsilon_0}$).

$$-\frac{\sigma}{2\varepsilon_0}\int_\infty^r dr = -\frac{\sigma}{2\varepsilon_0}\cdot[r]_\infty^r$$

$$-\frac{\sigma}{2\varepsilon_0}(r-\infty) = \infty \text{ or, } V_P - V_\infty = \infty$$

From eq. (i) $W = \infty$
(b) Electric field inside a parallel plate capacitor = E



Here, electric field is conservative. Work done by the conservative force in closed loop is zero.
So, required work done = 0.

32. (a) In first circuit :
Reading of ideal voltmeter = 6 V
Net potential difference = 9 + 6 = 15 V
Total resistance = 1 + 1 = 2 Ω

Current in ammeter $= \frac{V}{R} = \frac{15}{2} = 7.5$ A

In second circuit:
Reading of ideal voltmeter = 6 V
Net potential difference = 9 – 6 = 3 V
Total resistance = 1 + 1 = 2 Ω

Current in ammeter $= \frac{V}{R} = \frac{3}{2} = 1.5$ A

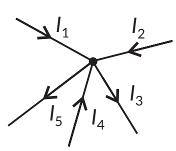
(b) Drift velocity $v_d = \frac{e\vec{E}}{m}\tau$, where E is electric field strength. And the relation between current and drift velocity is $I = neAv_d$.

$$\therefore \quad \frac{I}{A} = \frac{ne^2\tau}{m}E \Rightarrow J = \sigma E\,;\ \sigma = \frac{ne^2\tau}{m} = \frac{1}{\rho} \quad \text{or,} \quad \rho = \frac{m}{ne^2\tau}$$

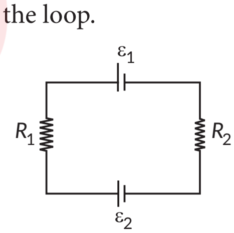
With rise of temperature, the rate of collision of electrons with ions of lattice increases, so relaxation time decreases. As a result resistivity of the material increases with the rise of temperature, hence the resistance.

OR

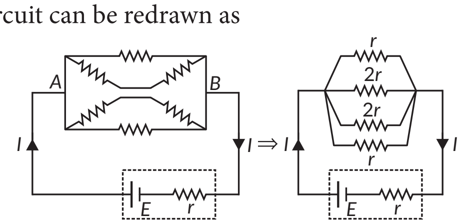
(i) Kirchhoff's first rule : The algebraic sum of all the current passing through a junction of an electric circuit is zero.



Here, I_1, I_2, I_3, I_4 and I_5 are current in different branches of a circuit which meet at a junction.
$I_1 + I_2 - I_3 + I_4 - I_5 = 0$
This rule is based on the principle of conservation of charge.
Kirchhoff's second rule : The algebraic sum of the applied emf's of an electrical circuit is equal to the algebraic sum of potential drops across the resistors of the loop.
Mathematically,
$\Sigma\varepsilon = \Sigma IR$
This is based on energy conservation principle.



Using this rule,
$\varepsilon_1 - \varepsilon_2 = IR_1 + IR_2$
(ii) Circuit can be redrawn as



For net resistance between point A and B.
Here, r, $2r$, $2r$ and r are in parallel.

So, $\frac{1}{R_{AB}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{2r} + \frac{1}{2r}\,;\ \frac{1}{R_{AB}} = \frac{3}{r}$ or, $R_{AB} = \frac{r}{3}$

Net resistance of the circuit,

$R = r + R_{AB} = r + \frac{r}{3} = \frac{4r}{3}$

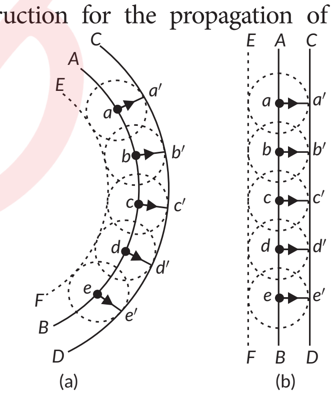
(a) Current drawn from the cell

$I = \frac{E}{R} = \frac{E}{(4r/3)} = \frac{3E}{4r}$

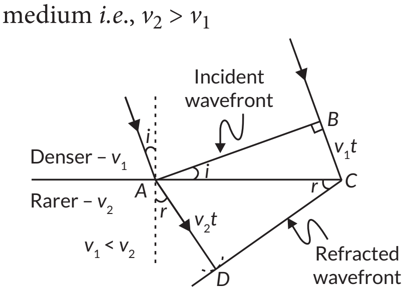
(b) Power consumed in network, $P = I^2R_{AB}$

$$\therefore \quad P = \left(\frac{3E}{4r}\right)^2 \frac{r}{3} = \frac{3E^2}{16r}$$

33. (a) Consider a spherical or plane wavefront moving towards right. Let AB be its position at any instant of time. The region on its left has received the wave while region on the right is undisturbed.
Huygens' geometrical construction for the propagation of (a) spherical, (b) plane wavefront.



According to Huygens' principle, each point on AB becomes a source of secondary disturbance, which takes with the same speed c. To find the new wavefront after time t, we draw spheres of radii ct, from each point on AB.
The forward envelope or the tangential surface CD of the secondary wavelets gives the new wavefront after time t.
The lines aa', bb', cc', etc., are perpendicular to both AB and CD. Along these lines, the energy flows from AB to CD. So these lines represent the rays. Rays are always normal to wavefronts.
(b) Given figure shows the refraction of a plane wavefront at a rarer medium *i.e.*, $v_2 > v_1$



Let the angles of incidence and refraction be i and r respectively.
From right ΔABC, we have,

$\sin \angle BAC = \sin i = \frac{BC}{AC}$

From right ΔADC, we have, $\sin \angle DCA = \sin r = \frac{AD}{AC}$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1t}{v_2t} \quad \text{or} \quad \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = {}^1\mu_2 \qquad \text{(a constant)}$$

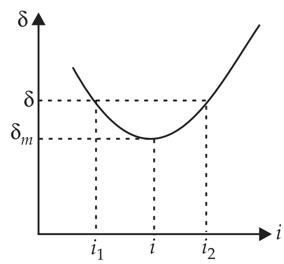
This verifies Snell's law of refraction. The constant ${}^1\mu_2$ is called the refractive index of the second medium with respect to first medium.

(c) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

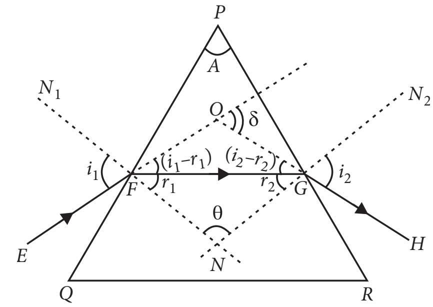
OR

Graph of deviation δ and angle of incidence *i*

If we determine experimentally, the angles of deviation corresponding to different angles of incidence and then plot *i* (on *X*-axis) and δ (on *Y*-axis), we get a curve as shown in figure above. Clearly if angle of incidence is gradually increased, from a small value, the angle of deviation first decreases, becomes minimum for a particular angle of incidence and the begins to increase. Obviously for one angle of deviation (δ), there are two angles of incidences i_1 and i_2, but for one and only one particular value of angle of incidence *i*, for which angle of emergence is equal to angle of incidence, the angle of deviation is the minimum. This minimum angle of deviation is represented by δ_m.



To deduce relation between μ and δ_m using a prism :



Let *PQR* be the principal section of the prism. The refracting angle of the prism is *A*.

A ray of monochromatic light *EF* is incident on face *PQ* at angle of incidence i_1. The refractive index of material of prism is μ. This ray enters from rarer to denser medium and so is deviated towards the normal *FN* and gets refracted along the direction *FG*. The angle of refraction for this face is r_1. The refracted ray *FG* becomes incident on face *PR* and is refracted away from the normal GN_2 and emerges in the direction *GH*. The angle of incidence on this face is r_2 (into prism) and angle of refraction (into air) is i_2. The incident ray *EF* and emergent ray *GH* when produced meet at *O*. The angle between these two rays is called angle of deviation 'δ'.

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