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12

HALF-YEARLY EXAMINATION – JANUARY 2025

PART – III

இயற்பியல் / PHYSICS

(English Version)

Time Allowed : 3.00 Hours] [Maximum Marks : 70

Instructions : (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

PART – I

Note : (i) Answer **all** the questions. **15x1=15**

(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer.

1. Two identical conducting balls having positive charges q_1 and q_2 are separated by a centre to centre distance r. If they are made to touch each other and then separated to the same distance, the force between them will be :

   (a) less than before (b) same as before
   (c) more than before (d) zero

2. In an ac circuit voltage and current are given by V = 50 sin 50t Volt and i = 100 sin $(50t) + \frac{\pi}{3}$ A. The power dissipated in the circuit will be:

   (a) 2.5 kW (b) 1.25 kW (c) 5 kW (d) 500 W

3. The nucleus is approximately spherical in shape. Then the volume of nucleus having mass number A varies as :

   (a) A (b) $A^{4/3}$ (c) $A^{1/3}$ (d) $A^{5/3}$

4. The wavelength λ_e of an electron and λ_p of a photon of same energy E are related by

   (a) $\lambda_p \propto \lambda_e$ (b) $\lambda_p \propto \sqrt{\lambda_e}$ (c)) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (d) $\lambda_p \propto \lambda_e^2$

5. The resistance of a uniform wire of length l and cross-sectional area A, is R. The resistance of wire of the same material having length $2l$ and cross-sectional area 2A is :

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

6. Two polaroid's P_1 and P_2 are placed with their optic axes perpendicular to each other. If an un-polarized light of intensity I_0 is incident on the first polaroid P_1 then the intensity of transmitted light through the second polaroid P_2 will be :

(a) $\frac{I_0}{2}$ (b) $\frac{I_0}{4}$ (c) 0 (d) $\frac{I_0}{8}$

7. A parallel plate capacitor stores a charge Q at a voltage V. Suppose the area of the parallel plate capacitor and the distance between the plates are each doubled then which is the quantity that will change?

(a) capacitance (b) Charge(c) Voltage (d) Energy density

8. The value of Bohr magneton μ_B is :

(a) 9.27×10^{-24} Am (b) 9.27×10^{24} Am^{-1}

(c) 9.27×10^{24} Am^{-2} (d) 9.27×10^{-24} Am^2

9. The variation of frequency of carrier wave with respect to the amplitude of the modulating signal is called :

(a) amplitude modulation (b) phase modulation

(c) frequency modulation (d) pulse width modulation

10. A system consists of N_0 nucleus at t = 0. The number of nuclei remaining after half of half-life (that is, at time $t = \frac{1}{2} T_{1/2}$)

(a) $\frac{N_0}{2}$ (b) $\frac{N_0}{\sqrt{2}}$ (c) $\frac{N_0}{4}$ (d) $\frac{N_0}{8}$

11. When the current changes from 2 A to – 2 A in 0.05 s, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is:

(a) 0.2 H (b) 0.4 H (c) 0.8 H (d) 0.1 H

12. The average energy density of an electromagnetic wave is:

(a) $\frac{1}{2}\varepsilon_0 E$ (b) $\frac{1}{2}\varepsilon_0 E^2$ (c) $\frac{1}{4}\varepsilon_0 E^2$ (d) $\frac{1}{4}\varepsilon_0 E$

13. The threshold wavelength for a metal surface whose photoelectric work function is 3.313 eV is :

(a) 4125 Å (b) 37350 Å (c) 6000 Å (d) 2062.5 Å

14. The dopant to be added with a pure Germanium Crystal to form n type semiconductor is:

(a) Boron (b) Phosphorus (c) Aluminium (d) Indium

15. If a beam of un-polarized light is incident on a reflecting glass surface at an angle of 57.5^0, then the angle between the reflected and refracted beam will be :

(a) 45^0 (b) 60^0 (c) 90^0 (d) 30^0

PART – II

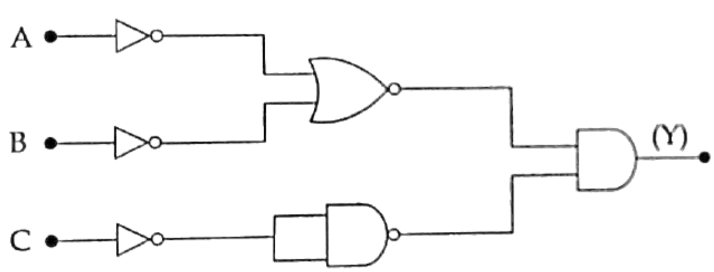
Note : Answer **any six** questions. Question No. **24** is **compulsory.** 6x2=12

16. Define skip distance.
17. Calculate the cut-off wavelength and cut-off frequency of X-rays from an X-ray tube of accelerating potential 20,000 V.
18. State Lenz's law.
19. Potential in a given region is given as a function of distance x, V=5(x^2+x) Volt. Find the electric field when x = 1 cm.
20. What is Photovoltaic cell?
21. What are paraxial rays and marginal rays?
22. What are the constituent particles of Neutron and Proton?
23. What are the uses of X-rays?
24. If an electric field of magnitude 570 NC^{-1}. Is applied in the copper wire, find the acceleration experienced by the electron.

PART – III

Note : Answer **any six** questions. Question No. **33** is **compulsory.** 6x3=18

25. Half lives of two radioactive elements A and B are 20 minutes and 40 minutes respectively. Initially the samples have equal number of nuclei. Calculate the ratio of decayed number of A and B nuclei after 80 minutes.
26. State Kirchhoff's Current and Voltage laws.
27. An 500 μH, $\frac{80}{\pi^2}$ pF capacitor and a 628 Ω resistor are connected to form a series RLC circuit. Calculate the resonant frequency and Q-factor of this circuit at resonance.
28. Obtain Gauss's law of electrostatics from Coulomb's inverse square law.
29. Compare the properties of dia, para and ferromagnetic materials.
30. Fibre optic communication is gaining popularity among various transmission media. Justify.
31. What are the characteristics of photons?
32. Write the output (Y) Boolean expression for the following circuit with inputs A, B and C.



33. What is total internal reflection? Give the condition for the total internal reflection takes place.

PART – IV

Note : **Answer all the questions.** **5x5=25**

34. (a) Explain the construction and working of transformer and define its efficiency.

(OR)

(b) Derive the equation for the angle of deviation produced by a prism and thus obtain the expression for refractive index of material of the prism.

35. (a) Obtain the condition for bridge balance in Wheatstone's bridge.

(OR)

(b) (i) State Ampere's Circuital Law.

(ii) Find the magnetic induction due to a long straight conductor using Ampere's Circuital Law.

36. (a) Derive an expression for the radius of the orbit of electron in an atom using Bohr atom model.

(OR)

(b) (i) Write down any six properties of electromagnetic wave.

(ii) Compute the speed of electromagnetic wave in a medium if the amplitudes of electric and magnetic fields in it are 3×10^4 NC^{-1} and 2×10^{-4} T respectively.

37. (a) Obtain Lens Maker's Formula, from that derive Lens equation.

(OR)

(b) Describe the function of transistor as an amplifier with the neat circuit diagram. Sketch the input and output waveform.

38. (a) (i) Obtain Einstein's Photoelectric equation with necessary explanation.

(ii) What will happen to the stopping potential in the following cases when;

(A) Work function of the metal is increased.

(B) Intensity of incident ray is increased.

(OR)

(b) Explain in detail the effect of introducing a dielectric medium between the plates of a parallel plate capacitor, when the capacitor is disconnected from the battery.

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HIGHER SECONDARY SECOND YEAR HALF-YEARLY EXAMINATION – JANUARY 2025

PHYSICS ANSWER KEY

Note:

1. Answers written with **Blue** or **Black ink** only to be evaluated.
2. Choose the most suitable answer in Part A, from the given alternatives and write the **option code** and the **corresponding answer.**
3. For answers in Part-II, Part-III and Part-IV like reasoning, explanation, narration, description and listing of points, students may write in their own words but without changing the concepts and without skipping any point.
4. In numerical problems, if formula is not written, marks should be given for the remaining correct steps.
5. In graphical representation, physical variables for X-axis and Y-axis should be marked.

PART – I

Answer all the questions. 15x1=15

Q. No.	OPTION	Answer	Q. No.	OPTION	Answer
1	(c)	more than before	9	(c)	frequency modulation
2	(b)	1.25 kW	10	(b)	$\frac{N_0}{\sqrt{2}}$
3	(a)	A	11	(d)	0.1 H
4	(d)	$\lambda_p \propto \lambda_e^2$	12	(b)	$\frac{1}{2}\varepsilon_0 E^2$
5	(a)	R	13	(b)	37350 Å
6	(c)	0	14	(b)	Phosphorus
7	(d)	Energy density	15	(c)	90^0
8	(d)	9.27×10^{-24} Am^2			

PART – II

Answer **any six** questions. Question number **24 is compulsory.** 6x2=12

16	**Skip distance:** The shortest **distance between the transmitter and the point of reception** of the sky wave along the surface is called as the skip distance.	2

17	The cut-off wavelength of the characteristic x-rays is $\lambda_0 = \frac{12400}{V}$ Å $= \frac{12400}{20000}$ Å ; = 0.62 Å The corresponding frequency is $\nu_0 = \frac{c}{\lambda_0}$; $= \frac{3 x 10^8}{0.62 x 10^{-10}}$; ν_0= 4.84 x 10^{18} Hz	2
18	**Lenz's law.** Lenz's law states that the direction of the **induced current** is such that is **always opposes** the cause responsible for its production.	2
19	E = $\frac{dv}{dx}$; = $\frac{d}{dx}$ (5x^2 + 5x) ; = 10x + 5 ; x = 1 ; E = 10 +5 =15 Vcm^{-1}	2
20	**Photo voltaic cell:** Here sensitive element made of semiconductor is used which **generates voltage proportional to the intensity of light** or other radiations.	2
21	**Paraxial rays:** The **rays travelling very close to the principal axis and make small angle** with it are called paraxial rays. **Marginal rays:** **The rays travelling far away from the principal axis and fall on the mirror far away from the pole** are called as marginal rays.	2
22	Protons and neutrons are made up of quarks which are now considered as elementary particles. According to quark model, (1) Proton is made up of two up quarks $\left(+\frac{2}{3}e\right)$ and one down quark $\left(-\frac{1}{3}e\right)$ (2) Neutron is made up of one up quark $\left(+\frac{2}{3}e\right)$ and two down quarks $\left(-\frac{1}{3}e\right)$	2
23	**Uses of X- Ray :** (i) Studying structures of **inner atomic electron shell** and crystal structures. (ii) Detecting **fracture, diseased organs, formation of bones** and stones, observing the progress of healing bones (iii) **Detect faults, cracks, flaws and holes** in a finished metal product	2
24	a = $\frac{Ee}{m}$; = $\frac{570 \text{ x } 1.6 \text{ x } 10^{-19}}{9.1 \text{ x } 10^{-31}}$; a= 100.29 x 10^{12} ms^{-2}	2

PART – II

Answer **any six** questions. Question number **33 is compulsory.** 6x3=18

25	Decayed part of A atom : $\frac{15}{16}$ or 93.75 % Decayed part of B atom : $\frac{3}{4}$ or 75 % Ratio between A and B atom $\frac{N_A}{N_B} = \frac{5}{4}$ or $N_A = N_B = 5 : 4$ $N_A = N_B$ = 1.25% **(OR)** $N = N_0 \left(\frac{1}{2}\right)^n$ For A : $n_A = \frac{80}{20}$; n_A =4 ; $N_A = N_0 \left(\frac{1}{2}\right)^4$; $N_A = \frac{N_0}{16}$ **Number of A Nuclei decayed** $N_A = N_0 - \frac{N_0}{16}$; $N_A = \frac{15N_0}{16}$ For B : $n_B = \frac{80}{40}$; n_B =2 ; $N_B = N_0 \left(\frac{1}{2}\right)^2$; $N_B = \frac{N_0}{4}$ **Number of B Nuclei decayed** $N_B = N_0 - \frac{N_0}{4}$; $N_B = \frac{3N_0}{4}$ $\frac{N_A}{N_B} = \frac{15N_0}{16} \text{ x } \frac{4}{3N_0}$; $\frac{N_A}{N_B} = \frac{5}{4}$ (or) $\frac{N_A}{N_B} = 5 : 4$	3
26	**Kirchhoff's first law (current rule or junction rule)** It states that the **algebraic sum of currents at any junction** in a circuit **is zero**. ($\sum I = 0$). It is a statement of conservation of electric charge. **Kirchhoff's second law (voltage rule or loop rule)** It states that in a closed circuit the **algebraic sum of the products** of the **current and resistance of each part of the circuit is equal** to the **total emf** included in the circuit ($\sum IR = \sum \xi$). It is a statement of conservation of energy for an isolated system.	3
27	$f = \frac{1}{2\pi\sqrt{LC}}$; $= \frac{1}{2\pi\sqrt{500 \text{ x } 10^{-6} \text{x} \frac{80}{\pi L} \text{x} 10^{-12}}}$ $= \frac{1}{2\sqrt{40000 \text{ x } 10^{-10}}}$; $= \frac{10000 \text{ x } 10^3}{4}$; f = 2500kHz Q factor = $\frac{\omega_r L}{R}$; $\frac{2 \text{ x } 3.14 \text{ x } 2500 \text{ x } 10^3 \text{ x } 500 \text{ x} 10^{-6}}{628}$ Q factor = 12.5	3

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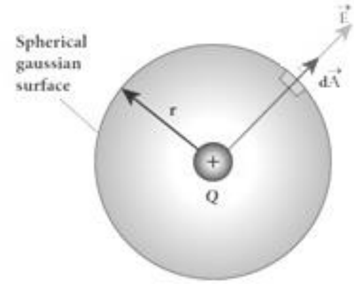
<u>**Gauss law from Coulomb's law:**</u>

Consider a charged particle of charge '+q'

Draw a Gaussian spherical surface of radius 'r' around this charge.



Due to symmetry, the electric field $\vec{E}$ at all the points on the spherical surface have same magnitude and radically outward in direction.

If a test charge 'q_0' is placed on the Gaussian surface, by Coulomb law the force acting it is, $|\vec{F}| = \frac{1}{4\pi\varepsilon_0}\frac{Qq_0}{r^2}$

By definition, the electric field, $|\vec{F}| = \frac{|\vec{F}|}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ .... (1)

Since the area element is along the electric field, we have $\theta = 0^0$.

Hence the electric flux through the Gaussian surface is,

$\Phi_E = \oint \vec{E}.\overrightarrow{dA}$; $= \oint E\, dA \cos 0^0$; $= E \oint dA$

Here $\oint dA = 4\pi r^2$ → area of Gaussian sphere. put in equation (1)

$\Phi_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \times 4\pi r^2$; $\therefore \Phi_E = \frac{Q}{\varepsilon_0}$ .This is known as Gauss law.

Result:

The total electric flux through the closed surface depends only on the charges enclosed by the surface and independent of charges outside the surface. The **total electric flux is independent of the location of charges** inside the closed surface and shape on the closed surface.

Gauss law is another form of Coulomb law and also applicable to charges in motion.

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<u>**Properties of Diamagnetic materials:**</u>

Magnetic susceptibility is negative. Relative permeability is slightly less than one. The magnetic field lines are excluded by diamagnetic materials when placed in a magnetic field. **Susceptibility is nearly temperature independent.**

<u>**Properties of Paramagnetic materials:**</u>

Magnetic susceptibility is **small positive value**. Relative permeability is greater than one. The magnetic field lines are attracted in to paramagnetic materials when placed in a magnetic field. **Susceptibility is inversely proportional to temperature.**

<u>**Properties of Ferromagnetic materials:**</u>

Magnetic susceptibility is **positive and large,** Relative permeability is very, very greater than one, the magnetic field lines are strongly attracted in to the ferromagnetic materials when placed in a magnetic field. **Susceptibility is inversely proportional to temperature.**

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30	**Fiber optic communication:** The method of **transmitting information from one place to another in terms of light pulses through an optical fiber** is called fiber optic communication. It is in the process of replacing wire transmission in communication systems. **Light has very high frequency** (400THz –790 THz) than microwave radio systems. The fibers are **made up of silica glass or silicon dioxide which is highly abundant on Earth**. Now it has been replaced with materials such as chalcogenide glasses, **fluoroaluminate crystalline materials** because they provide larger infrared wavelength and better transmission capability. As fibers are **not electrically conductive**, it is preferred in places where multiple channels are to be laid and isolation is required from electrical and electromagnetic interference. **Applications:** Optical fiber system has a number of applications namely, international communication, **inter-city communication, data links, plant and traffic control and defense applications.** **Merits:** Fiber cables are **very thin and weigh lesser than copper cables**. This system has much larger band width. This means that its **information carrying capacity is larger**. Fiber optic system is immune to electrical interferences. Fiber optic cables are cheaper than copper cables. **Demerits:** Fiber optic cables are more fragile when compared to copper wires. It is an expensive technology. **Importance:** Fiber optic cables provide the fastest transmission rate compared to any other form of transmission. It can **provide data speed of 1 GBps for homes and business.** **Multimode fibers operate at the speed of 10 MBps**. Recent developments in optical communication provide the **data speed at the rate of 25 GBps**	3
31	**Characteristics of photons:** 1) Each **photon will have energy** given by $E = h\nu = \frac{hc}{\lambda}$ 2) The energy of a photon is determined by the frequency of the radiation and not by its intensity. The photons travel with the velocity of light and its momentum is given by, $p = \frac{h}{\lambda} = \frac{hc}{\lambda}$ 3) Photons are electrically neutral, and hence they are not deflected **knee electric and magnetic fields**. When photon interacts with matter, the total energy, total linear momentum and angular momentum are conserved.	3

32	Output of A and B = $\overline{\overline{A}+\overline{B}}$ or $\overline{\overline{AB}}$ or AB Output of C = C Output of circuit Y = ABC	3
33	**Total internal reflection:** **If the angle of incidence in the denser medium is greater than the critical angle, there is no refraction possible in the rarer medium.** The entire light is **reflected back in to the denser medium** itself; this phenomenon is called total internal reflection. **Conditions to achieve total internal reflection:** Light must travel from **denser to rarer medium** Angle of incidence must be **greater than critical angle** ($i > i_C$)	3

PART – IV

Answer **all** the questions. 5x5=25

34 (a)

Transformer:

It is a stationary device used to transform electrical power from one circuit to another without changing its frequency. It is done with either increasing or decreasing the applied alternating voltage with corresponding decrease or increase of current in the circuit.

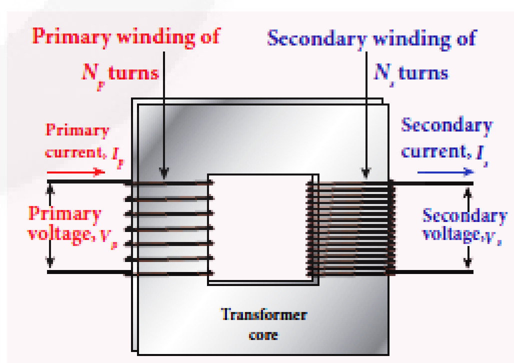
If the transformer **converts an alternating current with low voltage in to an alternating current with high voltage,** it is called **step-up transformer**. If the transformer converts an alternating current with high voltage in to an alternating current with low voltage, it is called step-down transformer.

Principle:

Mutual induction between two coils.

Construction:

It consists of **two coils of high mutual inductance wound over the same transformer core made up of silicone steel**. To avoid eddy current loss, the core is generally laminated. The alternating voltage is applied across primary coil (P), and the output is taken across secondary coil (S)



The assembled core and coils are kept in a container which is filled with suitable medium for better insulation and cooling purpose.

Working:

The **alternating voltage given to the primary coil**, set up an **alternating magnetic flux in the laminated core**. As the result of **flux change**, emf is induced in both primary and secondary coils.

(5 marks)

The emf induced in the primary coil 'ϵ_P' is almost equal and opposite to the applied voltage 'VP' and is given by,

$$V_P = \epsilon_P = -N_P \frac{d\phi_B}{dt} \text{ --------- } (1)$$

The frequency of alternating magnetic flux is same as the frequency of applied voltage. Therefore **induced in secondary will also have same frequency as that of applied voltage,** The emf induced in the secondary coil 'ϵ_S' is, $V_S = \epsilon_S = -N_S \frac{d\phi_B}{dt}$ --------- (2)

Dividing equating (1) by (2), $\frac{V_S}{V_P} = \frac{N_S}{N_P}$ --------- (3)

Where, K → Transformation ratio

For an **ideal transformer, Input Power = Output Power**

$$V_P i_P = V_S i_S \;; \quad \frac{V_S}{V_P} = \frac{i_P}{i_S} \text{ --------- } (4)$$

From equation (3) and (4), we have

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{i_P}{i_S} = K \text{ --------- } (5)$$

(i) If $K > 1$ (or) $N_S > N_P$, then $V_S > V_P$ and $i_S < i_P$

This is **step up transformer** in which **voltage increased** and the corresponding **current is decreased**.

(ii) If $K < 1$ (or) $N_S < N_P$, then $V_S < V_P$ and $i_S > i_P$

This is **step down transformer** in which **voltage decreased** and the corresponding **current is increased**.

Efficiency of a transformer:

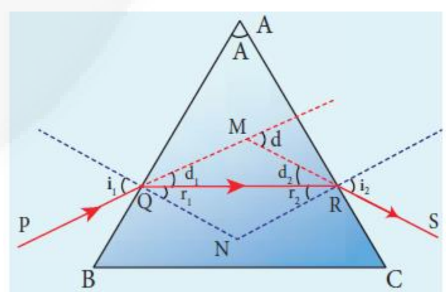
The efficiency (η) of a transformer is defined as the ratio of the useful output power to the input power.

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} \times 100\%$$

34 (b)

Angle of deviation (d) :

Let 'ABC' be the section of triangular prism.



Here face 'BC' is grounded and it is called base of the prism. The other two faces **'AB' and 'AC' are polished which are called refracting faces.** The angle between two refraction faces is called angle of the prism 'A' 5

Here, 'PQ' be incident ray, 'QR' be refracted ray and 'RS' be emergent ray. The angle between incident ray and emergent ray is called angle of deviation (d). Let QN and RN be the normal drawn at the points Q and R

The incident and emergent ray meet at a point M

From figure, $\angle MQR = d_1 = i_1 - r_1$ and $\angle MRQ = d_2 = i_2 - r_2$

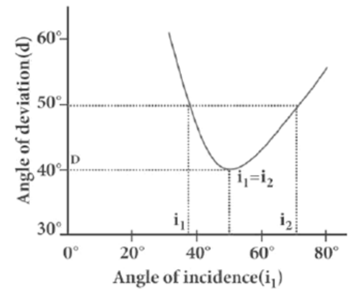
Then total angle of deviation, $d = d_1 + d_2$

$d = (i_1 - r_1) + (i_2 - r_2)\,;\; d = (i_1 + i_2) + (r_1 + r_2)$ ....(1)

In the quadrilateral AQNR, $\angle Q = \angle R = 90^0$

Hence A + $\angle QNR = 180^0$ (or) A = $180^0 - \angle QNR$ .... (2)
In ΔQNR, $r_1 + r_2 + \angle QNR = 180^0$;
$r_1 + r_2 = 180^0 - \angle QNR$---------(3)
From equation (2) and (3) A = $r_1 + r_2$ .... (4)
Put equation (4) in equation (1),
$d = (i_1 + i_2) - A$ ....(5)

Thus **the angle of deviation depends** on,



(1) The angle of incidence (i_1)
(2) The angle of the prism (A)
(3) The material of the prism (n)
(4) The wavelength of the light (λ)

<u>Angle of minimum deviation (D):</u>

A graph is plotted between the angle of incidence along x-axis and angle of deviation along y-axis. From the graph, as angle of incidence increases, the angle of deviation decreases, reaches a minimum value and then continues to increase.

The **minimum value of angled of deviation** is called angle of minimum deviation (D).

At minimum deviation, (1) $i_1 + i_2$ (2) $r_1 + r_2$
(3) Refracted ray 'QR' is parallel to the base 'BC' of the prism.

Refractive index of the material of the prism (n):

At angle of minimum deviation, $i_1 = i_2 = i$; $r_1 = r_2 = r$
i_1 and r_1 values substitute in equation (4) and (5)

A = $r + r = 2r$ (or) $r = \frac{A}{2}$ .... (6)

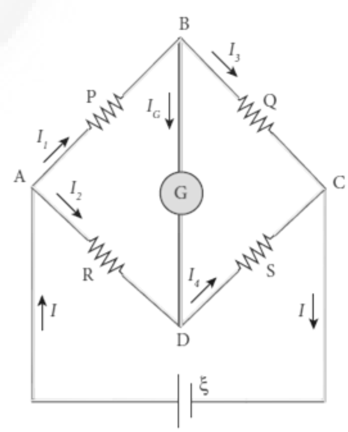
and D = $(i + i) - A = 2i - A$ (or) $2i = A + D$

$i = \frac{A+D}{2}$ .... (7); Then by Snell's law, n = $\frac{\sin i}{\sin r}$; n = $\frac{\sin\left[\frac{A+D}{2}\right]}{\sin\left[\frac{A}{2}\right]}$ ....(8

35 (a)

<u>Wheatstone's bridge:</u>

An important application of **Kirchhoff's laws is the Wheatstone's bridge.** It is **used** to compare resistances and also helps in **determining the unknown resistance in the electrical network**. The bridge consists of four resistances P, Q, R, S connected as shown. A galvanometer 'G' is connected between B and D. A battery 'ξ' is connected between A and C. Let I_1, I_2, I_3, I_4 currents through various branches and $\mathbf{I_G}$ be the **current through the galvanometer**.



5

Applying Kirchhoff's current law at B and D,

$I_1 - I_G - I_3 = 0$ − − − − (1)
$I_2 + I_G - I_4 = 0$ − − − − (2)

Applying Kirchhoff's voltage law ABDA and ABCDA,

$I_1 P + I_G G - I_2 R = 0$ ----- (3)

$I_1P + I_3Q - I_2R - I_4S = 0$ ----- (4)

At balanced condition, the potential at B and D are same, and hence the **galvanometer** shows **zero deflection**. So $\mathbf{I_G = 0}$

Put this in equation (1), (2) and (3)

$I_1 - I_3 = 0$ (or) $I_1 = I_3$ ----- (5)

$I_2 - I_4 = 0$ (or) $I_2 = I_4$ ----- (6)

$I_1P - I_2R = 0$ (or) $I_1P = I_2R$ ----- (7)

Put equation (5) and (6) in (4)

$I_1P + I_1Q - I_2R - I_2S = 0$;

$I_1 (P + Q) - I_2 (R + S) = 0$

$\therefore I_1 (P+Q) = I_2 (R + S)$ ----- (8)

Divide equation (8) by (7)

$$\frac{I_1(P+Q)}{I_1P} = \frac{I_2(R+S)}{I_2R} \; ; \quad \frac{(P+Q)}{P} = \frac{(R+S)}{R}$$

$$1 + \frac{Q}{P} = 1 + \frac{S}{R} \; ;$$

$$\frac{Q}{P} = \frac{S}{R} \text{ (or) } \mathbf{\frac{P}{Q} = \frac{R}{S}} \text{ ....(9)}$$

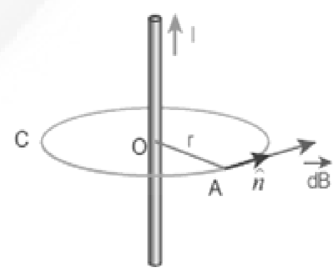
35 (b)

(i) <u>Ampere's circuital law.</u>

It state that the **line integral of magnetic field over a closed loop** is μ_0 times **net current enclosed by the loop.** $\oint \vec{\mathbf{B}}.\vec{\mathbf{dl}} = \boldsymbol{\mu_0 I_0}$

<u>(ii) Magnetic field due to current carrying straight wire using Ampere's law:</u>

Consider a straight conductor of infinite length carrying current 'I' Imagine an Amperian circular loop at a distance 'r' from the centre of the conductor. From Ampere's circuital law, $\oint \vec{B}.\vec{dl} = \mu_0 I$



Here $\vec{dl}$ is the line element along the tangent to the Amperian loop. So, the angle between $\vec{B}$ and $\vec{dl}$ is zero (θ = 0°). Thus, $\oint \vec{B}.\vec{dl} = \mu_0 I$

Due to symmetry, the magnitude of the magnetic field is uniform over the Amperian loop and hence, $B \oint dl = \mu_0 I$

For circular loop, $\oint dl = 2\pi r$ $\quad B (2\pi r) = \mu_0 I$

$$B = \frac{\mu_0 I}{2\pi r}\hat{n}, \text{ In vector notation, } \vec{B} = \frac{\mu_0 I}{2\pi r}\hat{n}$$

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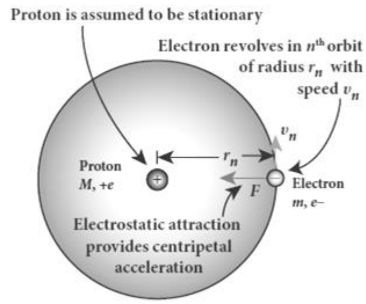
36 (a)

Radius of n[th] orbit:

Consider an atom which contains the nucleus at rest which is made up of protons and neutrons. Let an electron revolving around the state nucleus



Atomic number = Z,

Total charge of n[th] nucleus = + e;

Charge of an electron = − e,

Mass of the electron = m

From Coulomb's law, the force of attraction between the nucleus and the electron is

$$\vec{F}_{Coulomb} = \frac{1}{4\pi\epsilon_0}\frac{(+Ze)(-e)}{r_n^2}\hat{r} \; ; \; \vec{F}_{Coulomb} = -\frac{1}{4\pi\epsilon_0}\frac{Ze_2}{r_n^2}\hat{r}$$

This force provides necessary centripetal force given by.

$$\vec{F}_{Centripetal} = -\frac{mv_n^2}{r_n}\hat{r} \; ;$$

At equilibrium, $\vec{F}_{Coulomb} = \vec{F}_{Centripetal}$

$$-\frac{1}{4\pi\epsilon_0}\frac{Ze_2}{r_n^2}\hat{r} = -\frac{mv_n^2}{r_n}\hat{r} \; ; \frac{1}{4\pi\epsilon_0}\frac{Ze_2}{r_n^2} = \frac{mv_n^2}{r_n} \quad \text{............... (1)}$$

$$r_n = \frac{(4\pi\epsilon_0)\, m\, v_n^2\, r_n^2}{Z\,e^2} \; ; r_n = \frac{(4\pi\epsilon_0)\, m^2\, v_n^2\, r_n^2}{Z\,e^2 m} \; ; r_n = \frac{(4\pi\epsilon_0)\,[m\, v_n r_n]^2}{Z\,e^2 m}$$

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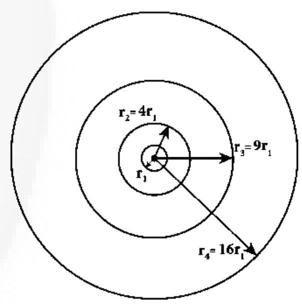
From Bohr's Postulate, $l_n = mv_n r_n = n\frac{h}{2\pi} = n\hbar$



$$\text{Hence, } r_n = \frac{(4\pi\epsilon_0)\,[l_n]^2}{Ze^2 m} \; ; r_n = \frac{(4\pi\epsilon_0)\left[\frac{nh}{2\pi}\right]^2}{Z\,e^2 m}$$

$$r_n = \frac{(4\pi\epsilon_0)\, n^2 h^2}{Z\,e^2 m \; x \; 4\pi^2} \; ; r_n = \left[\frac{h^2\epsilon_0}{\pi\, m\, e^2}\right]\frac{n^2}{Z} \text{............... (2)}$$

$r_n = a_0\frac{n^2}{Z}$ .... (3) Where, $a_0 \rightarrow \frac{h^2\epsilon_0}{\pi\, m\, e^2}$ = **0.529**Å **→Bohr Radius**

For hydrogen, (Z = 1), So radius of n^{th} orbit, $r_n = a_0 n^2$............... (4)

For first orbit, n = 1, (ground level) $r_1 = a_0$ = 0.529Å

For second orbit, n = 2, (first excited level)

$r_2 = 4a_0$ = 4 x 0.529Å = 2.116 Å

For third orbit, n = 3, (second excited level)

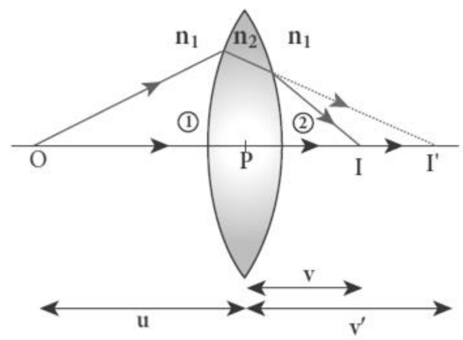
$r_3 = 9a_0$ = 9 x 0.529Å = 4.761 Å

Thus, **radius of the orbit,** $\boldsymbol{r_n \propto n^2}$

36 (b)	**(i) Properties of electromagnetic waves:** 1) Electromagnetic waves are **produced by any accelerated charge.** 2) They **do not require any medium** for propagation. So **electromagnetic waves are non-mechanical wave**. 3) They are **transverse in nature**, (i.e) the oscillating electric field vector, oscillation magnetic field vector and direction of propagation are mutually perpendicular to each other. 4) They **travel with speed of light in vacuum or free space** and it is given by, $C = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3x10^8 ms^{-1}$ 5) In a medium with permittivity 'ε' and permeability 'μ', the speed of electromagnetic wave is less than speed in free space or vacuum. (i.e.) $(v < c)$ Hence**, refractive index of the medium** is, $\mu = \frac{C}{v} = \frac{1/\sqrt{\varepsilon_0\mu_0}}{1/\sqrt{\varepsilon\mu}}$ $\therefore n = \sqrt{\varepsilon_r \mu_r}$ where ε_r is the relative permittivity of the medium (also known as dielectric constant) and μ_r is the relative permeability of the medium. 6) They are **not deflected by electric or magnetic field.** 7) They **show interference, diffraction and polarization**. 8) Like other waves, electromagnetic waves also **carry energy, linear momentum and angular momentum.** 9) If the electromagnetic wave incident on a material surface is **completely absorbed, then the energy delivered** is 'U' and the **momentum imparted on the surface** is $p = \frac{U}{C}$, 10) If the incident electromagnetic wave of energy 'U' is **totally reflected from the surface, then the momentum delivered to the surface** is $\Delta p = \frac{U}{c} - \left(-\frac{U}{c}\right) = 2\frac{U}{c}$ (ii) **Speed of the electromagnetic wave in a medium is** $v = \frac{E}{B}$ $v = \frac{3 \times 10^4}{2 \times 10^{-4}}$; v = 1.5 x 10⁸ ms⁻¹	5

37(a) **Lens maker's formula:**

A thin lens of refractive index n_2 is placed in a medium of refractive index n_1. Let R_1 and R_2 be radii of curvature of two spherical surfaces ① and ② respectively Let P be pole of the lens and O be the Point object.



Here I' be the image to be formed due the refraction at the surface ① and I be the final image obtained due the refraction at the surface ②

We know that, equation for single spherical surface

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

For refracting surface ①, the light goes from n_1 to n_2, Hence

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \quad .... (1)$$

For refracting surface ②, the light goes from n_2 to n_1, Hence

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R_2} \quad .... (2)$$

Adding equation (1) and (2), we get,

$$\frac{n_2}{v'} - \frac{n_1}{u} + \frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_2 - n_1}{R_1} + \frac{n_1 - n_2}{R_2}$$

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} - \frac{1}{u} = \frac{(n_2 - n_1)}{n_1}\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad ....(3)$$

If the object is at infinity, the image is formed at the focus of the lens. Thus, $u = \infty, v = f$

Then equation becomes, $\frac{1}{f} - \frac{1}{\infty} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad ....(4)$$

Here first medium is air and hence $n_1 = 1$ and let the refractive index of second medium be $n_2 = n$.

Therefore $\frac{1}{f} = (n - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$..............(5)

The above equation is called **lens maker's formula.**

By comparing equation (3) and (4) $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

This equation is known as **lens equation**.

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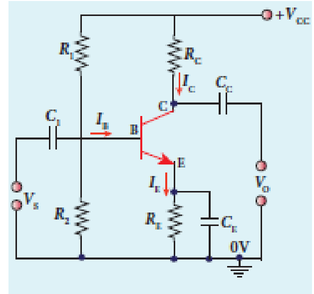
37 (b)

Transistor as an amplifier:



Amplification is the process of increasing the signal strength (increase in the amplitude). If a large amplification is required, multistage amplifier is used. Here, the amplification of an electrical signal is explained with a single stage transistor amplifier.

Single stage indicates that the circuit consists of one transistor with the allied components. An NPN transistor is connected in the common emitter configuration. A load resistance, R_C is connected in series with the collector circuit to measure the output voltage.

The capacitor C_1 allows only the ac signal to pass through. The emitter bypass capacitor CE provides a low reactance path to the amplified ac signal.

The coupling capacitor CC is used to couple one stage of the amplifier with the next stage while constructing multistage amplifiers. V_S is the sinusoidal input signal source applied across the base-emitter. The output is taken across the collector-emitter. $I_c = \beta I_B$

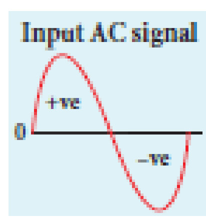
Applying Kirchhoff's voltage law in the output loop, the collector-emitter voltage is $V_{CE} = V_{CC} - I_C R_C$

Working of the amplifier:

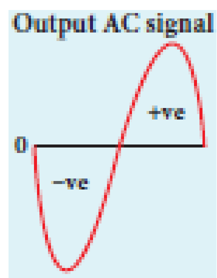
(1) **During the positive half cycle:**

Input signal (Vs) increases the forward voltage across the emitter-base. As a result, the base current (I_B) increases. Consequently, the collector current (I_C) increases β times. This **increases the voltage drop across R_C which in turn decreases the collector-emitter voltage (V_{CE}). Therefore, the input signal in the positive direction produces an amplified signal in the negative direction at the output. Hence, the output signal is reversed by 180^0.** 5

(2) **During the negative half cycle:**



Input signal (Vs) decreases the forward voltage across the emitter-base. As a result, base current (IB) decreases and in turn increases the collector current (I_C). The increase in collector current (I_C) decreases the potential drop across RC and increases the collector-emitter voltage (V_{CE}).

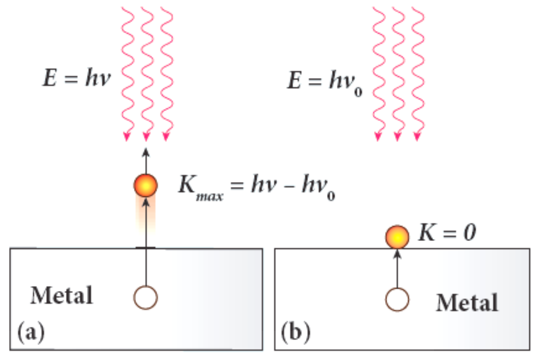


Thus, the input signal in the negative direction produces an amplified signal in the positive direction at the output. Therefore, **180^0 phase reversal is observed during the negative half cycle of the input signal**

38 (a)

(i) Einstein's explanation of photoelectric equation:

When a photon of energy 'hv' is incident on a metal surface, it is completely absorbed by a single electron and the electron is ejected.



In this process, the energy of incident photon is utilized in two ways.

(1) Part of the photon energy is used for the ejection of the electrons from the metal surface and it is called work function (ϕ_0)

(2) Remaining energy as the kinetic energy (K) of the ejected electron.

From the law of conservation of energy, $hv = \phi_0 + K$ (or)

$hv = \phi_0 + \frac{1}{2}mv^2$ .... (1)

Where m → mass of the electron and v → velocity

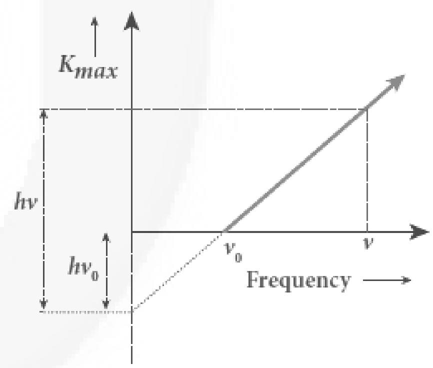
At threshold frequency, the kinetic energy of ejected electrons will be zero. (i.e.) when $v = v_0$ then K = 0 Thus equation (1) becomes

$hv_0 = \phi_0$ ....(2)

Put equation (2) in (1) $hv = hv_0 + \frac{1}{2}mv^2$........... (3)

The equation (3) is known as Einstein's photoelectric equation.

If the electron does not lose energy by internal collisions, then it is emitted with maximum kinetic energy K_{max}.



Then $hv = hv_0 + \left[\frac{1}{2}mv^2\right]_{max}$

(or) $\frac{1}{2}mv^2_{max} = hv - hv_0$ (or)

$K_{max} = hv - \phi_0$.................... (4)

A graph between maximum kinetic energy K_{max} of the photoelectron and frequency v of the incident light is a straight line.

(ii) (A) Work function increases stopping potential **increases**

(B) Intensity of incident radiation increases stopping potential **does not change**

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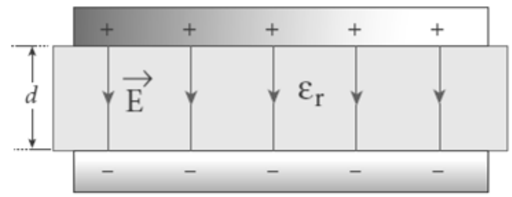
38 (b)

Effect of dielectrics when the capacitor is disconnected from the battery:

Consider a parallel plate capacitor. Area of each plates = A,



Distance between the plates = d,
Voltage of battery = V_0
Total charge on the capacitor= Q_0.
So the capacitance of capacitor without dielectric, $C_0 = \frac{Q_0}{V_0}$.

The battery is then disconnected from the capacitor and the dielectric is **inserted between the plates. This decreases the electric field.**

Electric field without dielectric = E_0, Electric field with dielectric = E,

Relative permittivity or dielectric constant = ε_r

$\therefore \quad E = \frac{E_0}{\varepsilon_r}$. Since $\varepsilon_r > 1$, we have $E < E_0$

Hence electrostatic potential between the plates is reduced and at the same time the charge Q_0 remains constant.

$$V = Ed\ ;\ = \frac{E_0}{\varepsilon_r} d\ ;\ = \frac{V_0}{\varepsilon_r}$$

Then **the capacitance of a capacitor with dielectric**,

$$C = \frac{Q_0}{V}\ ;\ = \frac{Q_0}{\left[\frac{V_0}{\varepsilon_r}\right]}\ ;\ = \varepsilon_r \frac{Q_0}{V_0}\ ;\ \varepsilon_r C_0$$

Since $\varepsilon_r > 1$, we have $C > C_0$.

Thus **insertion of dielectric slab increases the capacitance.**

We have, $C_0 = \frac{\varepsilon_0 A}{d}$; $C = \frac{\varepsilon_r \varepsilon_0 A}{d}$; $\mathbf{C = \frac{\varepsilon A}{d}}$

Where, $\varepsilon_r \varepsilon_0 = \boldsymbol{\varepsilon} \rightarrow$ permittivity of the dielectric medium.

The **energy stored in the capacitor without dielectric**,

$U_0 = \frac{1}{2}\frac{Q_0{}^2}{C_0}$; after the dielectric is inserted,

$$U = \frac{1}{2}\frac{Q_0{}^2}{C}\ ;\ = \frac{1}{2}\frac{Q_0{}^2}{\varepsilon_r C_0}\ ;= \frac{U_0}{\varepsilon_r}$$

Since $\varepsilon_r > 1$, we have $U < U_0$

There is a **decrease in energy** because, when the **dielectric is inserted,** the capacitors spend some energy to pulling the dielectric slab inside

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