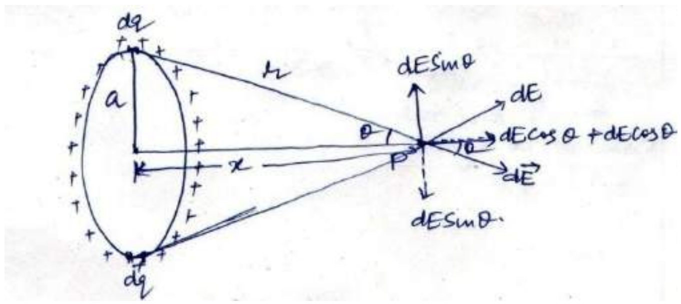
SECTION (C)

Set1,Q11
Set2,Q14
Set3,Q12

Obtaining an expression for Electric field intensity	2
Showing behavior at large distance	1



½

Net Electric Field at point P = $\int_{o}^{2\pi a} dEcos\theta$

dE = Electric field due to a small element having charge dq
$= \frac{1}{4\pi\varepsilon_o}\frac{dq}{r^2}$ ½

Let λ = Linear charge density
$= \frac{dq}{dl}$
$dq = \lambda dl$

Hence $E = \int_{o}^{2\pi a} \frac{1}{4\pi\varepsilon_o}.\frac{\lambda dl}{r^2} \times \frac{x}{r}$, where $\cos\theta = \frac{x}{r}$ ½

$= \frac{\lambda x}{4\pi\varepsilon_o r^3}(2\pi a)$

$= \frac{1}{4\pi\varepsilon_o}\frac{Qx}{(x^2+a^2)^{\frac{3}{2}}}$, where total charge $Q = \boldsymbol{\lambda}\times 2\pi a$ ½

At large distance i.e. x>>a

$E \simeq \frac{1}{4\pi\varepsilon_o}.\frac{Q}{x^2}$ ½
This is the Electric field due to a point charge at distance x. ½

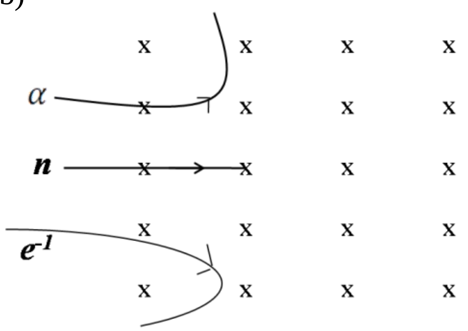
(**NOTE**: Award two marks for this question, if a student attempts this question but does not give the complete answer) 3

Set1,Q12
Set2,Q15
Set3,Q13

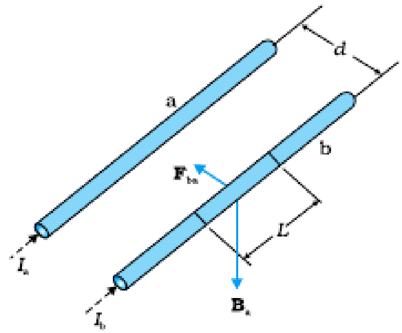
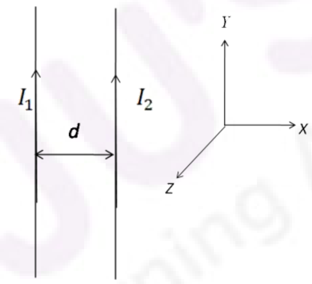
Three Characteristic features	1+1+1

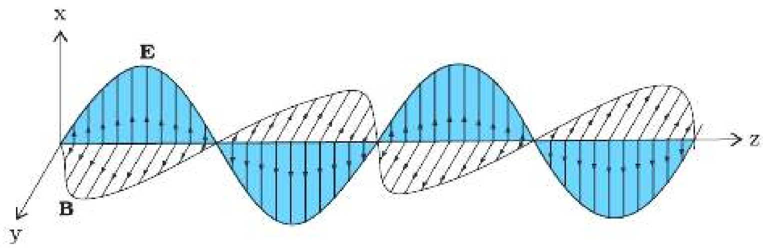
The three characteristic features which can’t be explained by wave theory are:

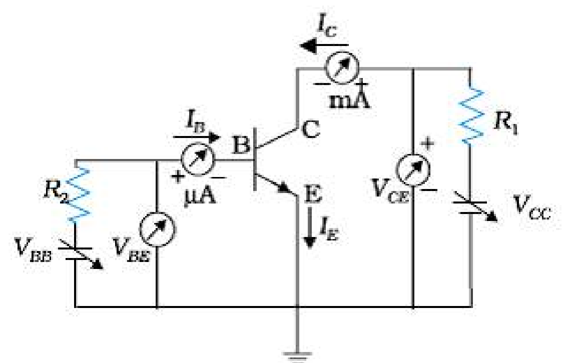
i. Kinetic energy of emitted electrons are found to be independent of intensity of incident light. 1

	ii. Below a certain frequency (threshold) there is no photo-emission. iii. Spontaneous emission of photo-electrons.	1 1	 3
Set1,Q13 Set2,Q16 Set3,Q11	a) Expression for the magnetic force — 1 b) Trace of paths — ½ + ½ + ½ Justification — ½ $\vec{F} = q(\vec{v} \times \vec{B})$ (Give Full credit of this part even if a student writes: $F = qvB \sin\theta$ and Force (F) acts perpendicular to the plane containing $\vec{v}$ and $\vec{B}$) b)  Justification: Direction of force experienced by the particle will be according to the Fleming's Left hand rule / (any other alternative correct rule.)	 1 ½ + ½+ ½ ½	 3
Set1,Q14 Set2,Q11 Set3,Q15	(i) Definition of mutual inductance — 1 (ii) Calculation of change of flux linkage — 2 (i) Magnetic flux, linked with the secondary coil due to the unit current flowing in the primary coil, $\phi_2 = MI_1$ [Alternatively Induced emf associated with the secondary coil, for a unit rate of change of current in the primary coil. $e_2 = -M \frac{dI_1}{dt}$] [Also accept the Definition of Mutual Induction, as per the Hindi translation of the question] [i.e. the phenomenon of production of induced emf in one coil due to change in current in neighbouring coil] (ii) Change of flux linkage	 1	

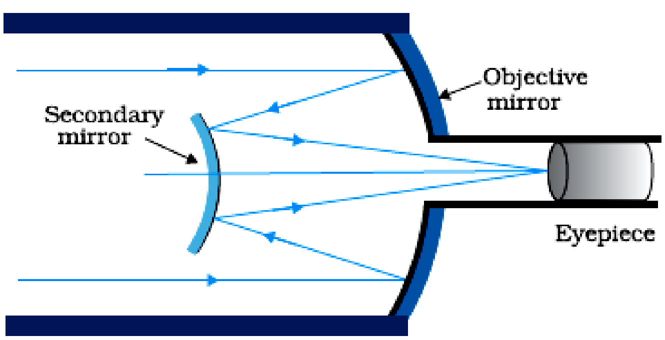
	$d\phi = M\,dI$ $= 1.5 \times (20\text{-}0)$W = 30 weber	1 ½ ½	 3
Set1,Q15 Set2,Q12 Set3,Q14	(i) Calculation of capacitance of each capacitor ½ + ½ (ii) Calculation of potential difference ½ + ½ (iii) Estimation of ratio of electrostatic energy 1 i) Let $C_X = C$ $C_Y = 4C$ (as it has a dielectric medium of $\varepsilon_r = 4$ For series combination of two capacitors $\frac{1}{C} = \frac{1}{C_X} + \frac{1}{C_Y}$ $\Rightarrow \frac{1}{4\mu F} = \frac{1}{C} + \frac{1}{4C}$ $\frac{1}{4\mu F} = \frac{5}{4C}$ $\Rightarrow$ C= $5\mu F$ Hence $C_X = 5\mu F$ $C_Y = 20\mu F$ ii) Total charge $Q = CV$ $= 4\mu\text{F} \times 15\text{ V} = 60\mu\text{C}$ $V_X = \frac{Q}{C_X} = \frac{60\ \mu C}{5\mu F} = 12\ V$ $V_Y = \frac{Q}{C_Y} = \frac{60\ \mu C}{20\mu F} = 3\ V$ iii) $\frac{E_X}{E_y} = \frac{\frac{Q^2}{2C_X}}{\frac{Q^2}{2C_Y}} = \frac{C_Y}{C_X} = \frac{20}{5} = 4 : 1$ (Also accept any other correct alternative method)	 ½ ½ ½ ½ 1	 3

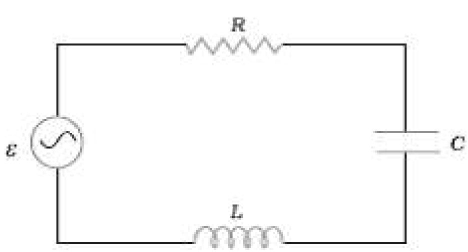
Set1,Q16 Set2,Q13 Set3,Q17	Diagram showing attractive force on other wire. 1 Obtaining an expression for force. 1 Definition of one ampere. 1  As shown in Figure, the direction of force on conductor b is attractive [Alternatively: $\vec{B}$ at a point on wire 2, is along $-\hat{k}$ $\therefore \vec{F}$, on wire 2, due to the $\vec{B}$, is along $-\hat{\imath}$, i.e. towards wire1. Hence the force is attractive.  Magnetic field, due to current in conductor a, $$B_1 = \frac{\mu_0 I_1}{2\pi d}$$ The magnitude of force on a length L of conductor b, $$F_2 = I_2 L B_1$$ $$F_2 = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$ One ampere is that steady current which, when maintained in each of the two very long, straight, parallel conductors, placed one meter apart in vacuum, would produce on each of these conductors a force equal to 2×10^{-7} newton per meter of their length.	½ ½ ½ ½ 1	3
Set1,Q17 Set2,Q20 Set3,Q18	Production of em waves 1 Drawing of sketch of linearly polarized em waves 1 Indication of directions of oscillating electric and magnetic fields ½ + ½ A charge oscillating with some frequency, produces an oscillating electric field in space, which in turn produces an oscillating magnetic		

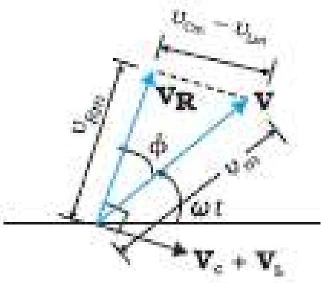
	field perpendicular to the electric field, this process goes on repeating , producing em waves in space perpendicular to both the fields.  Directions of $\vec{E}$ and $\vec{B}$ are perpendicular to each other and also perpendicular to direction of propagation of em waves. **OR** Maxwell's generalization of Ampere's Circuital law 1 Showing that current produced, within the plates of a capacitor is $i = \epsilon_0 \frac{d\phi_\epsilon}{dt}$ 2 Ampere's circuital law is given by as $\oint \vec{B}.\vec{dl} = \mu_0 i_c$ But for a circuit containing capacitor, during its charging / discharging the current within the plates of the capacitor varies, (producing displacement current i_d). Therefore, the above equation, as generalized by Maxwell, is given as $\oint \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0 i_d$ During the process of charging of capacitor, electric flux (ϕ_ϵ) between the plates of capacitor changes with time, which produces the current within the plates of capacitor. This current, being proportional to $\frac{d\phi_\epsilon}{dt}$, we have $$i = \epsilon_0 \frac{d\phi_\epsilon}{dt}$$	1 1 ½ + ½ 1 1 1	3
Set1,Q18 Set2,Q21 Set3,Q16	a) Explanation of any two factors justifying the need of modulation 1+ 1 b) Two advantages of FM over AM ½ + ½ a) A low frequency signal is modulated for the following purposes: (i) It reduces the wavelength of transmitted signal, and the minimum height of antenna for effective communication is $\lambda/4$. Therefore height of antenna becomes practically achievable.	1	

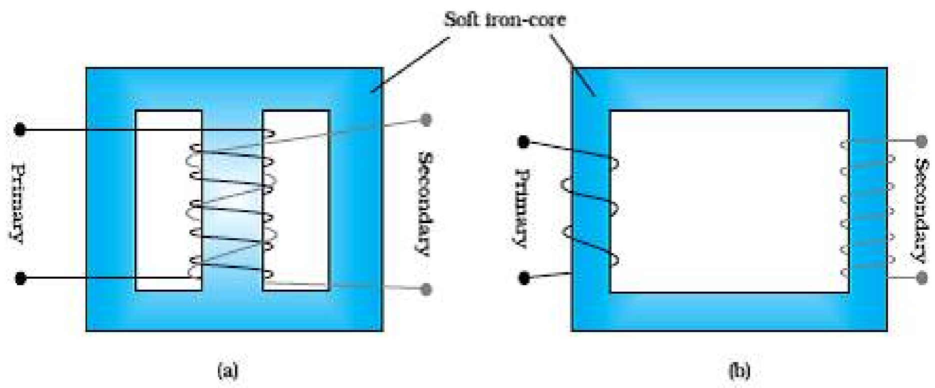
	(ii) Power radiated into the space by an antenna is inversely proportional to λ^2. Therefore, the power radiated into the space increases and signal can travel larger distance. (Give full credit of this part for any other correct answer) b) (i) High efficiency (ii) Less noise (iii) Maximum use of transmitted power (any two)	1 ½ + ½	3
Set1,Q19 Set2,Q22 Set3,Q20	(i) Function of three segments ½ + ½ + ½ (ii) Circuit diagram 1 Input and output characteristics ½ i) Emitter : Supplies the large number of majority charge carriers for the flow of current through the transistor. Base : Controls the movement of charge carriers coming from emitter region Collector: Collects a major portion of the majority carriers supplied by the emitter. (**NOTE:** Also accept the following explanation of these parts of the transistor as asked in Hindi translation) Emitter: Heavily doped and of moderate size. Base: Central region, thin and lightly doped. Collector: Moderately doped and large sized. ii)  Input characteristics are obtained by recording the values of base current I_B, for different values of V_{BE} at constant V_{CE} Output characteristics are obtained by recording the values of I_C for different values of V_{CE} at constant I_B	½ ½ ½ 1 ½	

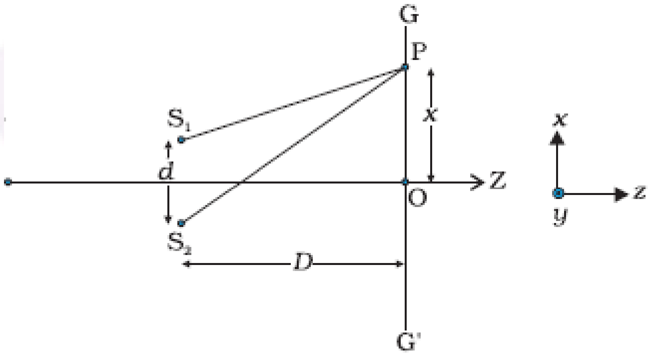
	[Alternatively Also accept input/output characteristic curves for this part of the question.]		3
Set1,Q20 Set2,Q17 Set3,Q19	(i) Calculation of distance of an object and location of image 2 (ii) Reason for virtual image, through convex mirror 1 a) Given R = -20 cm, and magnification m= -2 Focal length of the mirror $f = \frac{R}{2} = -10\ cm$ Magnification (m) = $-\frac{v}{u}$ $-2 = -\frac{v}{u}$ $\Rightarrow v = 2u$ Using mirror formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ ⇨ $-\frac{1}{10} = \frac{1}{2u} + \frac{1}{u}$ ⇨ u =-15 cm $\therefore v = 2 \times -15$ cm= -30 cm b) $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ Using sign convention, for convex mirror, we have f>0, u<0 From the formula $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$ $\because f$ is positive and u is negative, ⇨ v is always positive, hence image is always virtual.	½ ½ ½ ½ ½ ½	3
Set1,Q21 Set2,Q18 Set3,Q22	(i) Statement of Bohr's quantization condition ½ de- Broglie explanation of stationary orbits 1 (ii) Relation between $\lambda_1, \lambda_2, \lambda_3$ 1 ½ (i) Only those orbits are stable for which the angular momentum, of revolving electron, is an integral multiple of $\frac{h}{2\pi}$.		

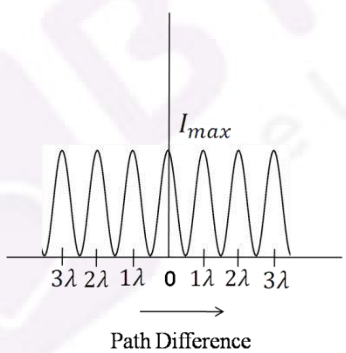
	[Alternatively $L = \frac{nh}{2\pi}$ i.e. angular momentum of orbiting electron is quantised.] According to de Broglie hypothesis Linear momentum $(p) = \frac{h}{\lambda}$ And for circular orbit $L = r_n p$ where 'r_n' is the radius of quantized orbits. $= \frac{rh}{\lambda}$ Also $L = \frac{nh}{2\pi}$ $\therefore \frac{rh}{\lambda} = \frac{nh}{2\pi}$ $\Longrightarrow 2\pi r_n = n\lambda$ $\therefore$ Circumference of permitted orbits are integral multiples of the wavelength λ $ii)\ E_C - E_B = \frac{hc}{\lambda_1}$ …….(i) $E_B - E_A = \frac{hc}{\lambda_2}$ ……..(ii) $E_C - E_A = \frac{hc}{\lambda_3}$ ……..(iii) Adding (i) & (ii) $E_C - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$………(iv) Using equation (iii) and (iv) $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \Rightarrow \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$	½ ½ ½ ½ ½ ½	3
Set1,Q22 Set2,Q19 Set3,Q21	Drawing of Schematic ray diagram — 2 Two advantages — ½ + ½ 	2	

	(i) Large gathering power **(ii)** Large magnifying power **(iii)** No chromatic aberration **(iv)** Spherical aberration is also removed **(v)** Easy mechanical support **(vi)** Large resolving power **(Any Two)**	½ +½	3
Set1,Q23 Set2,Q23 Set3,Q23	**SECTION (D)** Answers of part (i) ,(ii), (iii) 1+1+2 (i) Values displayed by Meeta: Inquisitive/ Keen Observer/ Scientific temperament/ (Any other value.) Values displayed by Father: Encouraging/ Supportive /(Any other value) (ii) Meeta's father explained that the traffic light is made up of tiny bulbs called light emitting diodes (LED) (Also accept other relevant answers) (iii)Light emitting diode These diodes (LED's) operate under forward bias, due to which the majority charge carriers are sent from these majority zones to minority zones. Hence recombination occur near the junction boundary, which releases energy in the form of photons of light.	1 1 ½ ½ 1	4
Set1,Q24 Set2,Q25 Set3,Q26	**SECTION (E)** (i) Obtaining expression for impedence & phase angle 1 ½ + 1 Condition of current being in phase with voltage ½ Naming of circuit condition ½ (ii) Calculation of P_1/P_2 1 ½ 		

		½	
	From Figure		
	$\vec{V} = \vec{V_L} + \vec{V_R} + \vec{V_C}$		
	where $\lvert\vec{V_R}\rvert = i_m R$		
	$\lvert\vec{V_L} + \vec{V_C}\rvert = V_{Cm} - V_{Lm}$		
	$= i_m(X_C - X_L)$		
	$\Rightarrow V_m^2 = V_{Rm}^2 + (V_{Cm} - V_{Lm})^2$	½	
	$l_m^2 Z^2 = l_m^2 R^2 + i_m^2 (X_C - X_L)^2$		
	$\Rightarrow \ Z=\sqrt{R^2 + (X_C - X_L)^2}$	½	
	From Figure		
	$\tan\phi = \frac{V_{Cm} - V_{Lm}}{V_{Rm}} = \frac{i_m(X_C - X_L)}{i_m R}$	½	
	$\phi = tan^{-1}(\frac{X_C - X_L}{R})$	½	
	Condition for current and voltage are in phase :		
	$V_L = V_C \quad or \quad X_L = X_C$	½	
	Circuit is called Resonant circuit.	½	
	ii) Power factor $P_1 = \frac{R}{Z} = \frac{R}{\sqrt{R^2+R^2}} = \frac{1}{\sqrt{2}}$	½	
	(as $X_L = R$)		
	Power factor when capacitor C of Reactance $X_C = X_L$ is put in series in the circuit		

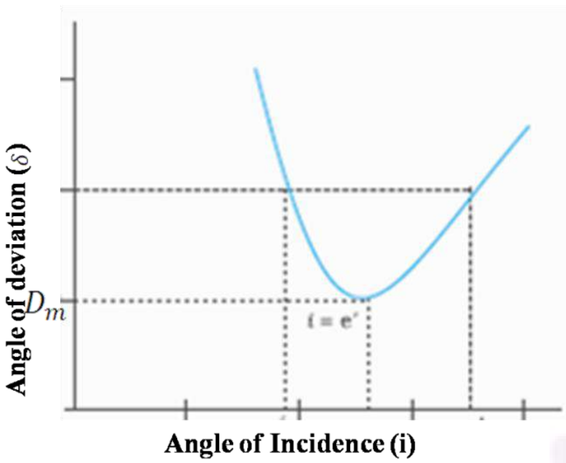
	$$P_2 = \frac{R}{Z} = \frac{R}{R} = 1$$ as $Z = R$ at resonance	½	
	$$\therefore \frac{P_1}{P_2} = \frac{\frac{1}{\sqrt{2}}}{1} = \frac{1}{\sqrt{2}}$$	½	5
	OR		
	(i) Function of transformer — ½ Working principle and diagram — ½ + ½ Various energy losses (two) — ½ + ½ (ii) Calculation of part (a) , (b), (c), (d) & (e) — 2½		
	(i) Conversion of ac of low voltage into ac of high voltage & vice versa	½	
	Mutual induction: When alternating voltage is applied to primary windings, emf is induced in the secondary windings.	½	
	 (Any one of the above diagram)	½	
	Energy losses: a. Leakage of magnetic flux b. Eddy currents c. Hysterisis loss d. Copper loss (Any two)	½ +½	
	ii) $N_p = 100$ Transformation ratio= 100 a) Number of turns in secondary coil		

	N_s = 100 x 100 = 10000 b) Input Power = Input voltage x current in primary 1100 = 220 x I_p $\Rightarrow I_p$ = 5A c) $\frac{V_s}{V_P} = \frac{N_s}{N_P}$ $\frac{V_s}{220} = 100$ $\Rightarrow V_s$ = 2.2 x 10^4 volts d) $\frac{I_P}{I_s} = \frac{N_S}{N_P}$ $\frac{5}{I_s} = 100$ $\Rightarrow I_s = \frac{5}{100}$ = 0.05 A e) Power in secondary = Power in Primary =1100 W	½ ½ ½ ½ ½	5
Set1,Q25 Set2,Q26 Set3,Q25	i) Deduce the conditions for a) constructive and b) destructive interference — 2 ½ Graph showing the variation of intensity — 1 ii) Three distinguishing features — 1 ½ **i)**  From figure Path difference = $(S_2P - S_1P)$ $(S_2P)^2 - (S_1P)^2 = [D^2 + \left(x + \frac{d}{2}\right)^2] - [D^2 + (x - \frac{d}{2})^2]$ $(S_2P + S_1P)\ (S_2P - S_1P) = 2xd$	½	

	$S_2P - S_1P = \frac{2xd}{S_2P+S_1P}$	½	
	For x, $d << D$ $S_2P + S_1P = 2D$ $\therefore\ S_2P - S_1P = \frac{2xd}{2D} = \frac{xd}{D}$	½	
	For constructive interference $S_2P - S_1P = n\boldsymbol{\lambda}$, n=0,1,2….. $\Rightarrow \frac{xd}{D} = n\boldsymbol{\lambda}$ $\Rightarrow \boldsymbol{x} = \frac{\boldsymbol{n\lambda D}}{\boldsymbol{d}}$	½	
	For destructive interference $S_2P - S_1P = (2n+1)\frac{\boldsymbol{\lambda}}{\mathbf{2}}$ n= 0, 1, 2 …. $\frac{xd}{D} = (2n+1)\frac{\boldsymbol{\lambda}}{\mathbf{2}}$ $\Rightarrow x = (2n+1)\frac{\lambda D}{2d}$	½	
		1	
	ii) (a) The Interference pattern has number of equally spaced bright and dark bands, while in the diffraction pattern the width of the central maximum is twice the width of other maxima.	½	
	(b) In Interference all bright fringes are of equal intensity, whereas in the diffraction pattern the intensity falls as order of maxima increases.	½	
	(c) In Interference pattern, maxima occurs at an angle $\frac{\boldsymbol{\lambda}}{\boldsymbol{a}}$, where a is the slit width, whereas in diffraction pattern, at the same angle, first minimum occurs. (Here 'a' is the size of the slit) (Any other distinguishing feature)	½	5

OR

i)	Plot showing the variation of the angle of deviation as a function of angle of incidence	1
	Derivation of expression of refractive index	1 ½
ii)	Definition of Dispersion and its cause	½ + ½
iii)	Calculation of minimum value of refractive index	1 ½



1

From figure $\delta = D_{m,}, i = e$ which implies $r_1 = r_2$

$2r = A$, or $r = {}^{A}/_{2}$ ½

Using $\delta = i + e - A$
$D_m = 2i - A$

$$i = \frac{A + D_m}{2}$$ ½

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin(\frac{A + D_m}{2})}{\sin {}^{A}/_{2}}$$ ½

(ii) The phenomenon of splitting of white light into its constituent colours. ½

Cause: Refractive index of the material is different for different colours
According to the equation, $\delta \ncong (\mu - 1)A,$ where A is the angle of prism, different colours will deviate through different amount. ½

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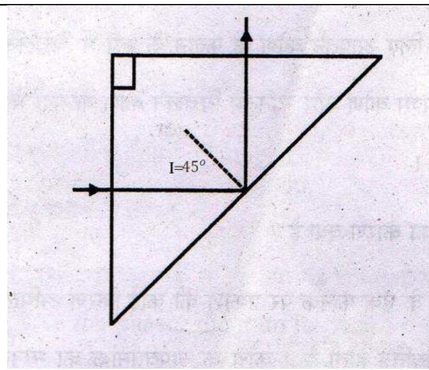
<td>

For total internal reflection,
$\angle i \geq \angle i_c$ (critical angle)

$\Rightarrow 45^0 \geq \angle i_c$, i.e. , $\angle i_c \leq 45^0$
$\sin i_c \leq sin\ 45^0$

$\leq \frac{1}{\sqrt{2}}$
$\frac{1}{sin\ i_c} \geq \sqrt{2}$
$\Rightarrow \mu \geq \sqrt{2}$

Hence, the minimum value of refractive index must be $\sqrt{2}$</td>
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½

½</td>
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<td>Set1,Q26
Set2,Q24
Set3,Q24</td>
<td>i) Definition of drift velocity — 1
ii) Derivation of expression of resistivity — 2
Factors affecting resistivity — 1
iii) Reason of using constantan and manganin — 1

i) Average velocity acquired by the electrons in the conductor in the presence of external electric field.
[Alternatively:
$v_d = \frac{-eE\tau}{m}$ where τ is the relaxation time.]

ii) $v_d = \frac{-eE\tau}{m}$
We have $E = -\frac{V}{\ell}$, where V is potential difference across the length 'ℓ'of the conductor
$v_d = \frac{eV\tau}{m\ell}$
Current flowing $I = neAv_d$
$I = neAv_d \frac{eV\tau}{m\ell} = \frac{ne^2AV\tau}{m\ell}$
$\frac{I}{V} = \frac{ne^2A\tau}{m\ell} = \frac{1}{R}$ -----------(i)</td>
<td>1

½
½

½</td>
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	Also, R = $\rho \frac{\ell}{A}$ -----------(ii) Comparing (i) and (ii) $$\rho = \frac{m}{ne^2\tau}$$ Resistivity of the material of a conductor depends on the relaxation time, i.e., temperature and the number density of electrons. iii) Because constantan and manganin show very weak dependence of resistivity on temperature	½ ½+ ½ 1	5
	OR i) Working Principle of potentiometer 2 ii) Calculation of potential gradient and balance length 3 i) When constant current flows through a conductor of uniform area of cross section, the potential difference, across a length l of the wire, is directly proportional to that length of the wire. [$V \propto l$ (Provided current and area are constant] ii) Current flowing in the potentiometer wire $$i = \frac{E}{R_{total}} = \frac{2.0}{15+10} = \frac{2}{25}\text{A}$$ ∴ Potential difference across the two ends of the wire $$V_{AB} = \frac{2}{25} \times 10V = \frac{20}{25} = 0.8\text{volt}$$ Hence potential gradient K=$\frac{V_{AB}}{l_{AB}} = \frac{0.8}{1.0} = 0.8\ ^{\text{V}}/_{\text{m}}$ Current flowing in the circuit containing experimental cell, $$= \frac{1.5}{1.2+0.3} = 1\text{A}$$ Hence, potential difference across length AO of the wire $$= 0.3 \times 1V = 0.3\text{V}$$ $\Rightarrow 0.3 = K \times l_{AO}$ $= 0.8 \times l_{AO}$ $\Rightarrow\ l_{AO} = \frac{0.3}{0.8} m = 0.375$ m $= 37.5$ cm	2 ½ ½ ½ ½ ½ ½	5