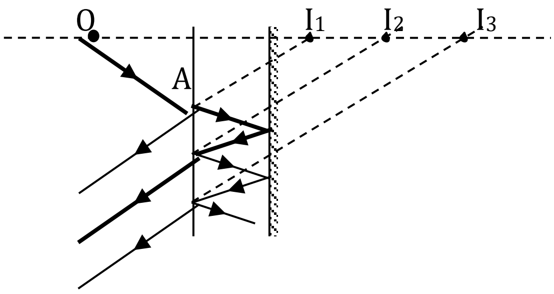
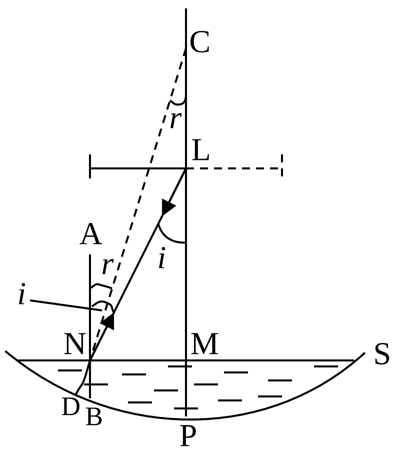
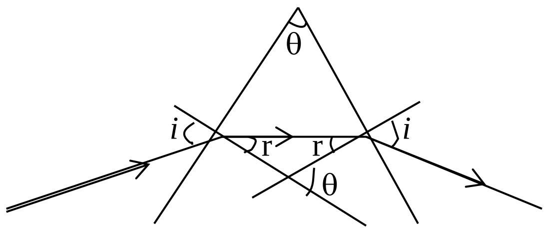
Qn	Answer	Mark
1 (a)	(i) Absolute refractive index of a medium is the ratio of the speed of light in vacuum to the speed light in the medium.	1
	(ii) 	1
	When an incident ray **OA** meets the front surface of the mirror, a small fraction of it is reflected there, giving rise to a faint image $\mathbf{I_1}$.	1
	The main ray is refracted and then reflected on the back surface and as it emerges it is refracted to give rise to the main image $\mathbf{I_2}$.	1
	At each emergence a small fraction of the ray is internally reflected and this results in a series of faint images in a line.	1
(b)	– A concave mirror, S, is placed on a bench. – A pin is held above the mirror and a position along the principal axis is found where it coincides with its own image.	1
	The height of the pin from the pole of the mirror is measure and noted. It is equal to the radius of curvature of the mirror.	½
		
	– A little of the liquid is placed on a concave mirror and a position L is located by the no-parallax method where the image of a pin held over the mirror coincides in position with the pin itself.	1
	The distance LP, between the pin and the mirror is measured.	½

	In this case the rays are reflected back along the incident path and must therefore be striking the mirror normally. A ray LN close to the axis LP is refracted at N along ND in the liquid, strikes the mirror normally at D, and is reflected back along DNL. Thus if DN is produced it passes through the centre of curvature C. Let ANB be the normal to the liquid surface at N. Then $\angle ANL = \angle NLM = i$ (angle of incidence) and $\angle BND = \angle ANC = \angle NCM = r$ (angle of refraction) The refractive index, $n = \frac{\sin i}{\sin r} = \frac{NM/LN}{NM/CN} = \frac{CN}{LN}$ Since LN is a ray very close to the principle axis CP, LN is approximately = LM and CN = CM so that $n = \frac{CM}{LM}$ But if the depth MP of the liquid is very small compared with LM and CM, CM = CP and LM = LP approximately. Hence, approximately, $n = \frac{CP}{LP}$, where CP is the radius of curvature.	½ ½ 1 ½ ½
(c)	(i) $h\left(1-\frac{1}{n}\right)$	1
	(ii) The observed displacement is the sum of the displacements due to the two media. i.e $h_l\left(1-\frac{1}{n_l}\right) + h_w\left(1-\frac{1}{n_w}\right) = d$ $\therefore\ h_l - \frac{h_l}{n_l} + h_w - \frac{h_w}{n_w} = d$ $\therefore\ \frac{h_l}{n_l} = h_l + h_w - \frac{h_w}{n_w} - d$ $\therefore\ \frac{8}{n_l} = 8 + 15 - 6 - \frac{15}{1.33} = 23 - 17.3 = 5.7$ $\therefore\ n_l = \frac{8}{5.7} = \mathbf{1.40}$	1 ½ ½ 1
(d)	(i) The ray must pass symmetrically through the prism	1

(ii)



1

At minimum deviation the ray passes symmetrically

$\therefore$ $i - r + i - r = \gamma$ ………………..(1) 1

and $r + r = \theta$

$\therefore$ $r = \frac{1}{2}\theta$ ½

Substituting for r in equation (1)

$2i = \theta + \gamma$

$\therefore$ $i = \frac{1}{2}(\theta + \gamma)$ ½

$\therefore$ $n = \frac{\sin i}{\sin r} = \frac{\sin \frac{1}{2}(\theta + \gamma)}{\frac{1}{2}\theta}$ 1

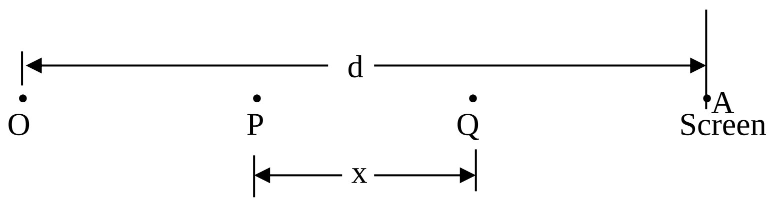
Total = 20

2(a)

(i) This is a pair of points such that if the object is placed at one, the image is formed at the other. 1

(ii) This is an image formed by actual intersection of incident rays 1

(ii)



O and A are conjugate points with respect to the lens.

So OP = QA and OQ = PA. ½

Now, OP = d - ½ (d - x) = ½ (d - x) ½

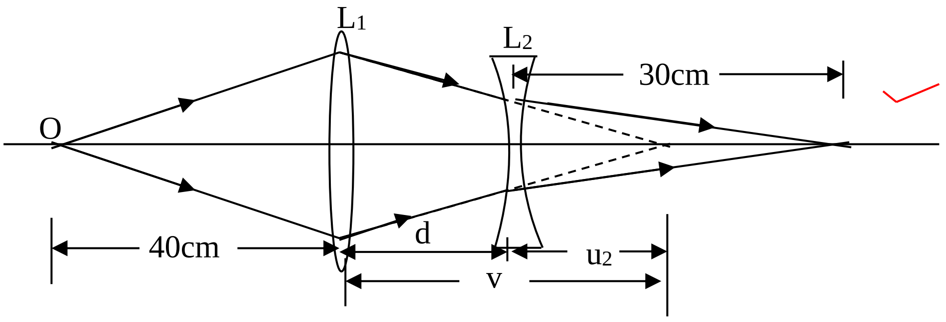
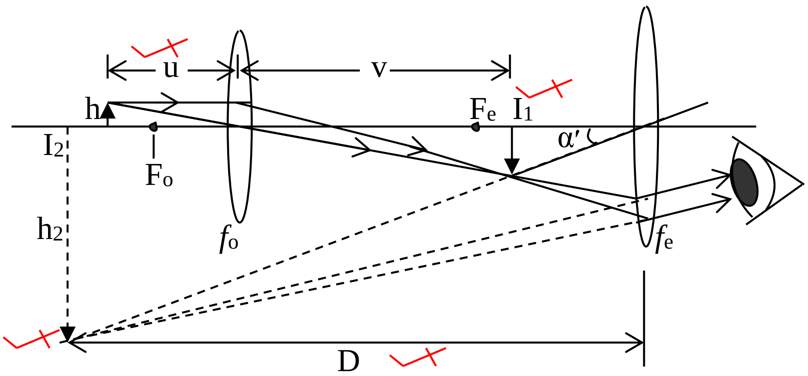
and PA = x + QA = x + ½(d - x) = ½(d + x)

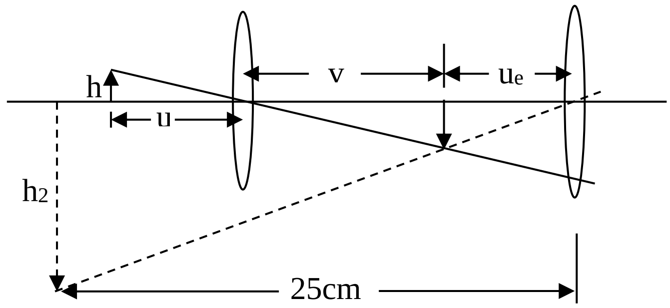
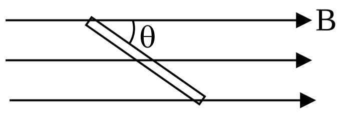
Using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, we have

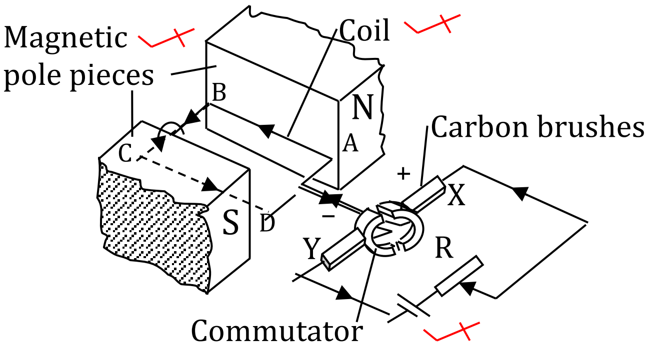
$$\frac{2}{d + x} + \frac{2}{d - x} = \frac{1}{f}$$ 1

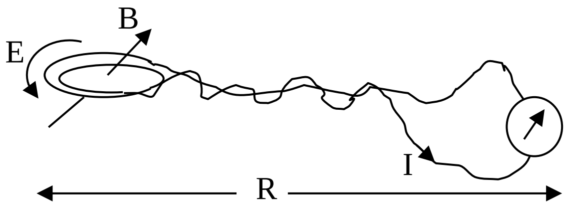
$$\therefore \quad \frac{4d}{d^2 - x^2} = \frac{1}{f}$$

1

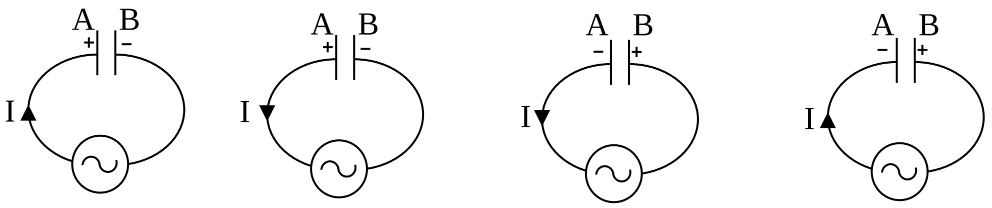
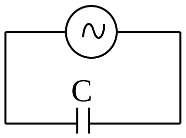
	So $\quad f = \dfrac{d^2 - x^2}{4d}$	
(b)	(i)  Using $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ for L_1 , we have $\quad \frac{1}{v}+\frac{1}{40}=\frac{1}{20}$ $\therefore \quad \frac{1}{v}=\frac{1}{20}-\frac{1}{40}=\frac{1}{40} \quad \Rightarrow \; v = 40$ cm For L_2 $\quad \frac{1}{u_2}+\frac{1}{30}=\frac{1}{-10}$ $\therefore \quad \frac{1}{u_2}=\frac{1}{-10}-\frac{1}{30}=\frac{-4}{30} \quad \Rightarrow \; u_2 = -7.5$ cm Now, the separation, d = v - $\lvert u_2\rvert$ = 40 – 7.5 = **32.5 cm**	1 1 ½ 1 ½ 1
	(ii) Let the new object distance (virtual) from L_2 be u_3 Then, $\frac{1}{u_3}+\frac{1}{-30}=\frac{1}{-10}$ $\therefore \quad \frac{1}{u_3}=\frac{1}{-10}+\frac{1}{30}=\frac{-2}{30} \quad \Rightarrow \; u_3 = -15$ cm $\therefore$ the separation, d′ = v - $\lvert u_3\rvert$ = 40 – 15 = **35 cm**	1 1 1
(c)	(i) 	1 1

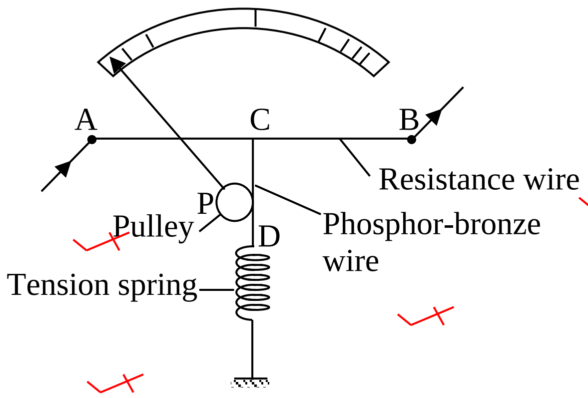
	F_o is the principal focus of the objective while F_e is that of the eyepiece. D = least distance of distinct vision	
	(ii)  Using $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ for the objective $\therefore \quad \frac{1}{v}=\frac{1}{2.2}-\frac{1}{2.5}$ $\therefore \quad v = \frac{2.2x2.5}{2.5-2.2} = 18.3$ cm Also $\frac{1}{u_e}=\frac{1}{f_e}-\frac{1}{v} = \frac{1}{5}+\frac{1}{25}=\frac{6}{25}$ $\therefore \quad u_e = \frac{25}{6} = 4.2$ cm Now $h_2 = m_1.m_2.h = \frac{v}{u}.\frac{25}{u_e}h = \frac{18.3}{2.5}x\frac{25}{4.2}$ = **87.4 mm**	 1 1 1 1 1
	Total = 20	
3.(a)	(i) This is the direction in which a north pole would move if freely placed there.	1
	(ii) 1. The induced emf is in such a direction as to oppose the flux change causing it. 2. The magnitude of the induced emf is directly proportional to the rate of change of flux linkage.	1 1
	(iii)  The flux linkage, φ = NAB sinθ The induced emf, E = $\frac{d\varphi}{dt}$ = ωNAB cosθ	 1 1

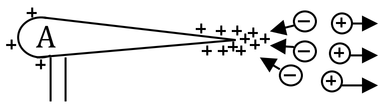
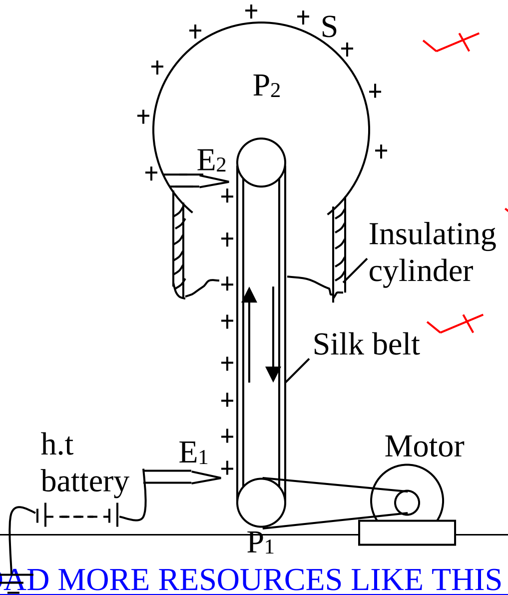
		$= 2\pi fNAB \cos\theta$, where f = 50 Hz $= 2\pi \times 50 \times 100 \times (0.1 \times 0.1) \times 0.8 \cos 60^o$ = **40 V**	 1 1
(b)	(i)  - The supply is connected to the coil by means of carbon brushed which engage with the commutator as shown. - When the d.c supply is connected as shown, current flows through the coil in the direction ABCD. - Using Fleming's left hand rule it can be established that side AB is forced upwards while side CD downwards. So the coil rotates in the anticlockwise direction. - The brushes X and Y remain stationary as the commutator rotates with the coil and when the coil plane is perpendicular to the field, the brushes are in the empty gaps of the commutator. - However, momentum maintains the rotation until the commutator halves interchange connections to the brushes to maintain the same direction of rotation of the coil.		1 ½ ½ ½ ½ 1 ½ ½
	(ii) A motor is run by passing a current through its coil which is placed in a magnetic field. As the motor runs, its coil sweeps across the magnetic field and by virtue of this, an emf is induced in the coil. According to Lenz's law, the induced emf opposes the applied voltage and the rotation of the coil. Hence it is referred to as a back emf.		1 1 1
(c)	(i) The emf created by the armature = back emf = V – Ir = 240 – 20 x 1 = **220 V**		1 1
	(ii) Power supplied to the armature = IV = 20 x 240 = **4800 W**		1
	(iii) Mechanical power by the motor = power spent on the back emf		

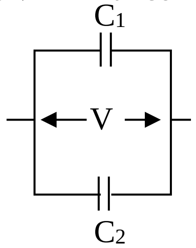
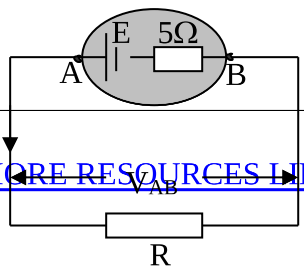
	$= IE_b = 20 \times 220 = \mathbf{4400\ W}$	1
	(iv) Efficiency of the motor $= \frac{IE_b}{IV} \times 100\% = \frac{4400}{4800} \times 100\% = \mathbf{91.7\%}$	1
	Total = 20	
4.(a)	(i) This is the coming into existence of an emf due to fluctuation of current in the coil itself.	1
	(ii) This is a current that circulates in a lump of conductor which is rotated in a magnetic field, or which is placed in a changing magnetic field.	1
(b)	(i) Features of a ballistic galvanometer: A heavier coil – so that its period of oscillation is long as to have all the charge to pass through the coil before it moves appreciably An insulating former – so that the oscillation of the coil has as little damping as possible. No shunt – so that all the charge actually flows through the coil No short-circuited turns – since there is no effort for achieving critical damping	1 1 1 1
	(ii) Consider a closed circuit in which the total resistance is R, placed in a magnetic field such that at an instant t the total flux linking the coil is Φ.  At any instant, the emf induced in the circuit is $E = -\frac{d\Phi}{dt}$ $\therefore$ Currrent, $I = \frac{E}{R} = -\frac{1}{R}\frac{d\Phi}{dt}$ But the current, I = rate of flow of charge $= \frac{dQ}{dt}$ $\therefore \frac{dQ}{dt} = -\frac{1}{R}\frac{d\Phi}{dt}$	1 ½ ½ ½

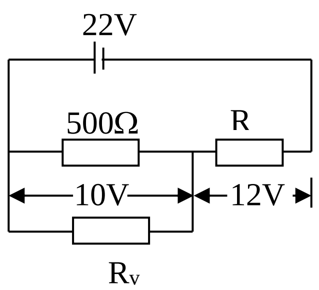
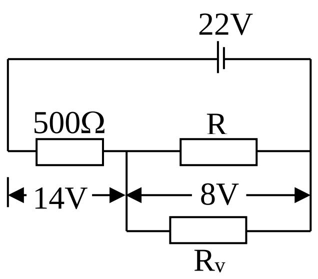
	If the flux changes from, say Φ_1 to Φ_2, the total charge that circulates in the circuit is $$Q = \int_0^Q dQ = -\frac{1}{R}\int_{\Phi_1}^{\Phi_2} d\Phi$$ $$\therefore \quad Q = \frac{\Phi_1 - \Phi_2}{R} = \frac{\text{Change in flux linkage}}{\text{Total resistance in circuit}}$$ Thus, the charge circulated is proportional to the flux-linkage change, and is independent of the time taken.	1 ½
(c)	A capacitor of known capacitance, C, is charged to a p.d, V, and then discharged through the ballistic galvanometer and the first throw, θ, is noted. Then the charge, Q = CV. The procedure is repeated for several values of V and a graph of Q against θ is plotted. Its slope gives the constant, k, of the galvanometer.	2 ½ 1 ½
(d)	Charge on the capacitor, $Q_1 = CV = k\theta_1$, where θ_1 = 24 divisions $$\therefore k = \frac{CV}{\theta_1} = \frac{10\times10^{-6}\times5}{24} \text{ C div}^{-1}$$ Initial flux-linkage, $\Phi_1 = NAB = NA\mu nI$, where I = current in the solenoid N= number of turns in the coil = 20 A = area of the coil = $\frac{1}{4}\pi d^2$ n = number of turns per metre of the solenoid = 10^3 Final flux-linkage, $\Phi_2 = -NAB = -NA\mu nI$ $\Delta\Phi = \Phi_1 - \Phi_2 = 2NA\mu nI$ Now, charge circulated, $$Q_2 = \frac{\Delta\Phi}{R} = \frac{2NA\mu nI}{R}$$ $$\therefore \quad \frac{2N\pi d^2\mu nI}{4R} = k\theta_2 = \frac{CV}{\theta_1}\theta_2$$ $$\therefore \quad I = \frac{2RCV\theta_2}{\pi Nd^2\mu n\theta_1} = \frac{2 \times 12 \times 10 \times 10^{-6} \times 5 \times 10}{\pi \times 20 \times 16 \times 10^{-4} \times 4\pi \times 10^{-7} \times 24}$$ $= \mathbf{3.96\ A}$	1 ½ ½ 1 1 1 1
	Total = 20	

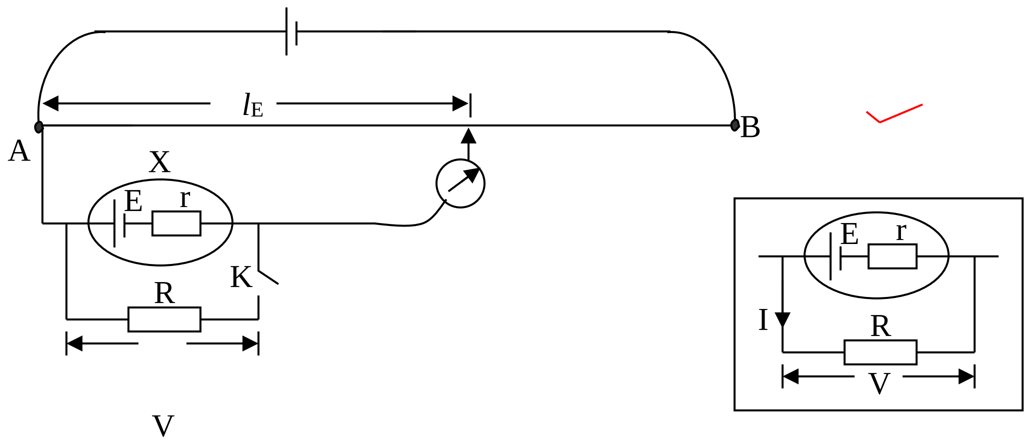
5.(a)	(i) - It is easier and cheaper to generate. - It is easily stepped up or down (using transformers) - Can be subdivided with not much power loss using chokes. - It facilitates transmission with not much power loss.	Any 2
	(ii) In one cycle of the alternating current four processes are performed. Let A and B be the capacitor plates as shown below.  (i) (ii) (iii) (iv) Let us start with a quarter of the cycle when A is charging positively (fig(i)). The current is flowing clockwise until the capacitor is fully charged. In the next quarter the plates are discharging. So the current reverses but the polarity of the capacitor remains until it is fully discharged (fig (ii)). In the next quarter, B is now charging positively while A negatively. So the current remains flowing anticlockwise until the capacitor is fully charged. In the last quarter the plates are discharging. So the current reverses and flows in that direction until the capacitor is fully discharged and the cycle repeats. This way an alternating current flows in the circuit.	1 ½ ½ 1 1
(b)	(i) $V = V_o \sin \omega t$  The instantaneous p.d across the capacitor is $V = V_o \sin \omega t$. So, the charge $Q = CV = CV_o \sin \omega t$. The current flowing at the instant is the rate at which charge is accumulating on or leaving the capacitor. i.e $I = \frac{dQ}{dt} = \frac{d(CV_o \sin \omega t)}{dt} = \omega CV_o \cos \omega t$ ……………(1) Equation (1) can also be written as $I = I_o \cos \omega t$ ……………..(2) where I_o is the peak current. i.e $I_o = \omega CV_o$	½ 1 1 ½

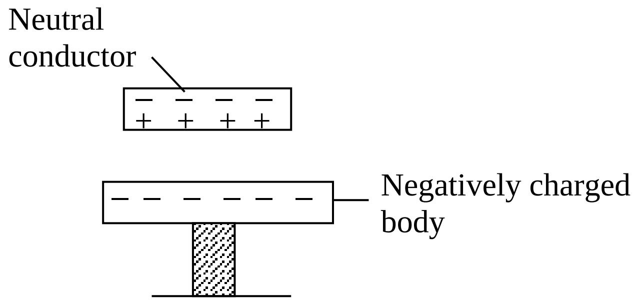
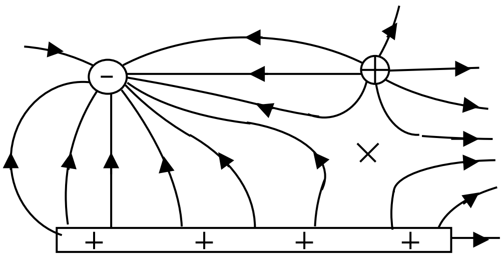
	Thus $\frac{V_o}{I_o} = \frac{1}{\omega C}$ But $\frac{V_o}{I_o} = \frac{V_{r.m.s}}{I_{r.m.s}} = \frac{1}{\omega C} = \frac{1}{2\pi fC}$ So, the reactance, $X_C = \mathbf{\frac{1}{2\pi fC}}$	1
(c)		½ ½ ½ ½
	It consists of a fine resistance wire AB. Another fine wire CD, whose one end is fixed to the mid-point, C, of AB wraps round a pulley P and has its other end fixed to a tension spring. The spring keeps CD taut. The current to be measured is led through AB, which heats up. So AB expands and sags, the sag is taken up by CD, which is held taut by the tension spring. The expansion stops when the resistance wire is losing heat at the same rate as it is developed in it by the current. Due to the wrapping of CD round the pulley, the pulley rotates and turns the pointer clockwise, which is attached to it. The rate at which heat is generated in AB is proportional to the square of the current. So the scale is non-linear.	½ ½ 1 ½ 1 ½
(d)	Total resistance, R = 0.2 x 2000 = 400 Ω Let I be the output current Then the power lost = $I^2R = \frac{6}{100} \times 60 \times 10^3$ $\therefore$ I = $\sqrt{\frac{0.06 \times 60000}{400}}$ = 3.0 A	½ 1

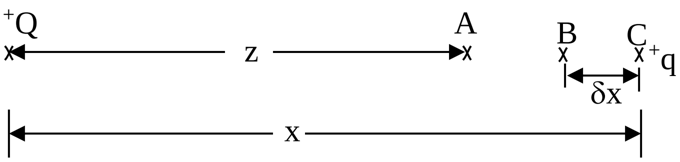
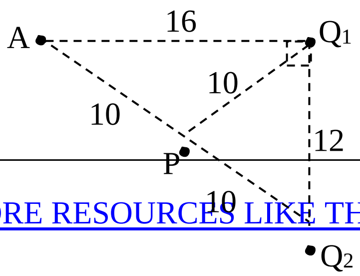
	Let V be the output voltage Then IV = 60000 ∴ $V = \frac{60000}{3} = \mathbf{20,000\ V}$	½ 1 1
	Total = 20	
6.(a)	(i) The dielectric constant, ε_r, is the ratio of the capacitance with the dielectric in between the plates to the capacitance when the space between the plates is vacuum.	1
	(ii) An equipotential is any surface or volume over which the potential is constant.	1
(b)	(i) - Equipotentials meet the electric lines of force at right angles. - Equipotentials never cross each other	1 1
	(ii)  Suppose a pointed conductor A is charged positively. Most of the charge concentrates at the tip, creating an intense electric field there. This ionises the air there. The negative ions are attracted to the tip and are neutralised while the positive ions are repelled. The net result is that positive charge is being sprayed from the tip into the air.	1 ½ ½ ½ ½
(c)		½ ½ ½

	A Van de Graaf generator consists of a hollow metal sphere S supported on an insulating cylinder several metres high. E_1 and E_2 are electrodes in form of sharply pointed combs. *Action:* - E_1 is given a potential of about 10,000 volts, positive with respect to the earth, by a battery. - The high electric field at the points of E_1 ionises the air there, positive charges being repelled to the belt. - The belt, driven by a motor over pulleys P_1 and P_2, carries the charges up into the sphere. - The positive charge induces a negative charge on the points of E_2 and a positive charge on the sphere. - The high electric field at the points of E_2 ionises the air there, and negative charge is repelled to the belt thereby discharging it before it passes over the pulley P_2. Thus, the sphere gradually charges up positively to millions of volts with respect to the earth.	½ ½ ½ 1 ½ 1 ½
(d)	(i) Charge stored = C_1V_1, where C_1 = 600 μF and V_1 = 150 V This remains so all through Let V = final common voltage across the combination.  Then $V(C_1 + C_2) = C_1V_1$ $\therefore \quad V = \frac{C_1V_1}{C_1 + C_2}$ $= \frac{600 \times 150}{600 + 900} = 60$ V Energy = $\frac{1}{2}CV^2$ $= \frac{1}{2} \times 900 \times 10^{-6} \times 60^2 = \mathbf{1.62\ J}$	½ 1 ½ 1 1
	(ii) The new capacitance of C_1 becomes $C_1' = 1.5 \times 600 = 900$ μF The new common p.d becomes $V' = \frac{C_1V_1}{C_1' + C_2} = \frac{600 \times 150}{900 + 900} = \mathbf{50\ V}$	1 2
		Total = 20
7.(a)		

	The output power, $P_o = I^2R = \frac{RE^2}{(R+5)^2}$	1
	For fixed values of E and internal resistance the maximum power output P_{max} is obtained when	
	$\frac{dP_o}{dR} = 0$	½
	i.e when $\frac{RE^2}{(R+5)^2} - \frac{2RE^2}{(R+5)^3} = 0$	½
	i.e when R = 5Ω	1
(b)	 	
	(i) Let R_v = resistance of the voltmeter	
	Then $\frac{500R_v}{(500+R_v)R} = \frac{10}{12}$ ………………………... (1)	1
	and $\frac{RR_v}{(R+R_v)500} = \frac{8}{14}$ ……………………..…. (2)	1
	From (1) $600R_v = 500R + RR_v$	
	$\therefore\ 600\frac{R_v}{R} = 500 + R_v$ ……………………..……. (3)	1
	From (2) $7RR_v = 2000R + 2000R_v$	
	$\therefore\ 7R_v = 2000 + 2000\frac{R_v}{R}$ ………………..…. (4)	1
	Eq(3) x 20: $12000 + \frac{R_v}{R} = 10000 + 20R_v$ ……..…. (5)	
	Eq(4) x 6: $42R_v = 12000 + 12000\frac{R_v}{R}$ …….(6)	
	Eq(5) + Eq(6): $42R_v = 22000 + 20R_v$	1

	∴ $22R_v = 22000 \Rightarrow R_v = \mathbf{1000\ \Omega}$ (ii) From (1) $R = \dfrac{12 \text{x} 500R_v}{10(500 + R_v)} = \dfrac{12\text{x}500\text{x}1000}{10(500+1000)} = \mathbf{400\ \Omega}$	1 1
(c)	 The circuit is connected as shown in which X is the cell of emf, E, and internal resistance, r, required. With switch K open, a balance length l_E, is found for the emf E. Then K is closed and another balance length, l, for the terminal p.d, V, is found. In this case a circuit like the one in the inset on the right is completed. Now, $\dfrac{V}{E} = \dfrac{R}{R+r}$ But $\dfrac{V}{E} = \dfrac{l}{l_E}$ ∴ $\dfrac{l}{l_E} = \dfrac{R}{R+r} \Rightarrow \mathbf{r = R\left(\dfrac{l_E}{l} - 1\right)}$	1 1 1 ½ 1 ½
(d)	(i) $V_{AB} = \dfrac{10}{12} \text{x}\ 3 = 2.5\ \text{V}$ $V_{ef} = \dfrac{80}{100} \text{x}\ 2.5 = 2.0\ \text{V}$ Considering cell Y, the p.d across the internal resistance is $2.2 - V_{ef}$ If I is the current flowing in the resistors, then $1.0 \text{ x } I = 2.2 - 2.0 = 0.2$ ∴ $I = \mathbf{0.2\ A}$	½ ½ 1 1

	(ii) $0.2R_1 = \frac{45}{100} \times 2.5$ $\therefore R_1 = \frac{0.45 \times 2.5}{0.2} = \mathbf{5.625\ \Omega}$ $0.2(R_1 + R_2) = 2.0$ $\therefore R_2 = \frac{2.0}{0.2} - R_1 = 10 - 5.625 = \mathbf{4.375\ \Omega}$	1 1
	Total = 20	
8.(a)	(i)  When the two bodies are close together, electrostatic induction occurs in the conductor as shown. Since unlike charges are near each other, attraction between the two bodies occurs.	1 1 1
	(ii)  *Pattern* *Direction* *Neutral point*	3
(b)		1

	The conductor, A, is supported on an insulator and given a charge. Proof planes of the same area, but shaped to fit the various respective parts of the conductor, are prepared. A proof plane (on an insulating handle) at a time is placed on the part it fits, charged by induction and then transferred to the inside of a hollow can connected to the cap of a neutral electroscope (without making contact with the can), each time noting the divergence of the leaf. It is observed that proof planes from sharper parts cause greater divergence. This implies that ***surface density*** (charge per unit area) increases with curvature.	½ ½ 1 1 ½ ½
(c)	Suppose A is the point whose potential, V_A, is required. Then imagine a small point charge q placed at point C, distance x from Q.  The force acting on q is F $= \frac{Qq}{4\pi\varepsilon x^2}$ Suppose q is now moved a small distance δx to B, δx being so small that the field due to Q is not affected. Over this small distance, the force F may be regarded as constant. So the work done by the external agent over δx against the force of the field is $\delta W = F(-\delta x)$ $\therefore \quad \delta W = \frac{Qq(-\delta x)}{4\pi\varepsilon x^2}$ The total work done in bringing q from infinity to point A is $W = \frac{-Qq}{4\pi\varepsilon}\int_{\infty}^{z}\frac{1}{x^2}dx = \frac{-Qq}{4\pi\varepsilon}\left[\frac{-1}{x}\right]_{\infty}^{z} = \frac{Qq}{4\pi\varepsilon z}$ The potential V_A at point A is the work done per unit positive charge brought from infinity to A. Hence $V_A = \frac{W}{q} = \mathbf{\frac{Q}{4\pi\varepsilon z}}$	½ ½ 1 1 1 1
(d)	 	

	$V_A = \frac{1}{4\pi\pi}\left(\frac{Q_1}{r_1}+\frac{Q_2}{r_2}\right) = 9 \text{ x } 10^9\left(\frac{4}{16}+\frac{6}{20}\right)\frac{\text{x}10^{-6}}{\text{x}10^{-2}} = 4.95 \text{ x } 10^5 \text{ V}$	1
	$V_P = 9 \text{ x } 10^9\left(\frac{4}{10}+\frac{6}{10}\right)\frac{\text{x}10^{-6}}{\text{x}10^{-2}} = 9.0 \text{ x } 10^5 \text{ V}$	1
	Work done, $W = Q(V_P + V_A)$	
	$= 2 \text{ x } 10^{-6}(9 - 4.95) \text{ x } 10^5$	1
	$=$ **$8.1 \text{ x } 10^{-1}$ J**	1
	Total = 20	