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| **Qn** | **Answer** | **Marks** |
| 1. (a) | (i) This is the point from which all rays originally parallel and close to the principle axis appear to diverge after refraction by the lens | 1 |
| (ii) .. a pair of points such that when the object is placed at one, its image is formed at the other | 1 |
| (b) | A B  P  O I I΄ C  u v  v΄  f1 f2  X  Let A and B be the lenses  A ray OP passes through the middle undeviated and ray OX is refracted through the first lens A and would intersect OC at I΄. However, it is refracted further by B to meet OC at I. So, I is finally the image of O. Thus I΄ is the virtual object in lens B and in this case u = -v΄.  For the 1st lens A 1/v + 1/u = 1/f ……………………….(1)  For the 2nd lens B 1/v + 1/(-v) = 1/f …………………….(2)  Adding equations (1) and (2) we have  1/v + 1/u = 1/f1 + 1/f2  Since I is the image of O by refraction through both lenses  1/v + 1/u = 1/F  where F is the focal length of the combined lenses.  Hence | 1  ½ +½  ½  ½  ½  ½  1 |
| (c) | L1  L2  v  I1  I2  Real image  Virtual image  d  O  A converging lens, L1, is arranged to produce a focused real image I1, of an illuminated object O on a screen.  The distance L1I1, between the lens and the screen, is measured and noted.  The diverging lens L2, under investigation, is placed coaxially with L1 at a known distance d from L1.  The screen position is adjusted to get a focused real image I of the object again and the image distance L2I2 = v, between L2 and the screen is measured and noted.  The procedure is repeated for several different values of d.  Now, L1I1 – d = u, the object distance for L2. (where u is –ve)  A graph of 1/v against 1/u is plotted.  The intercept on either axis gives 1/f, where f is the focal length of L2. | 1  1  ½  ½  ½  ½  ½  ½  ½  ½ |
| (d) | (i)  *Award only if the symbols are defined*  Where f = focal length, n = refractive index  r1 and r2 are the radii of curvature of the lens’s surfaces | 1 |
| (ii) With L, the focal length of the combination is FL = 27.5 cm  With water the focal length of the combination is Fw = 24.6 cm  The focal length of the lens is f = 17 cm  Now, nw = 1.34, nL = refractive index of liquid L          ∴ *nL* = 1.42 | 1  1  1  1  1  1 |
| ***Total =20*** | | |
| 2.(a) | (i) This is the ratio of the velocity of light in vacuum to the velocity of light in the medium | 1 |
| (ii) Consider an object O below the surface of the medium of refractive index n. A ray OM from O perpendicular to the surface passes straight into the air along MS.  air  S T  *r*  M *r* N  glass  I  *i*  *i*  t  d  O  A ray ON, very close to OM, is refracted at  N away from the normal along NT so that to  an observer directly overhead the object O appears to be at I.  Now, nsin i = 1 x sin r  i.e n = sin r = MN/ IN = ON  sin i MN/ ON IN  Since the observer is directly above O, the rays ON and IN are very close to the normal OM. Hence ON is approximately equal to OM and IN = IM.  Thus n = OM  IM | 1  1  1  1  ½  ½ |
| (iii) Atravelling microscope is used (See diagram)  The traveling microscope M is focused on a mark made on a sheet of white paper and the reading on the scale, say x cm, is noted.  M  T  B  O  I  The sided glass slab is placed over the mark (preferably with its longest side vertical) and the microscope is adjusted until the mark is focused again. The reading on the scale, say y cm, is noted.  Some lycopodium particles are then sprinkled on top of the glass slab and the microscope is raised until they are focused. The reading, say z cm, on the scale is noted.  Then real depth of O = OB = (z-x) cm Apparent depth = IB = (z-y) cm | 1  1  1  1 |
| (b) | (i)  Deviation | 1 |
|  | Deviation  (ii)  Angle of incidence | 1 |
|  | (iii) The minimum deviation, say D, is read off from the graph.  Then the refractive index of the material, n, is given by | 1  1 |
| (c) | A  B  60o  50o  30o  θ  *r1*  *r2*  *r3*  *r4*    nA sin r1 = sin 30o  ∴ r1 = 19.3o  Now r2 = 60o – r1 = 40.7o  And nB sin r3 = nA sin r2  ∴ r3 = 37.4o  ∴ r4 = 50o – r3 = 50o – 37.4o = 12.6o  Now, sin θ = nB sin r4 = 1.62 sin 12.6o = 0.353  ∴ θ = 20.7o | 1  1  1  1  1  1 |
| ***Total = 20*** | | |
| 3. (a) | (i) With the incident ray fixed, when the refrlector is rotated, the reflected ray turns through twice the angle of rotation of the reflector. | 1 |
| (ii)  M2 M1  A  2θ  X  O  L  Lamp  S  θ  A beam of light from a fixed lamp, L, is directed on to the mirror, which is rigidly fixed to a system that rotates when current passes through it.  It is arranged such that when there is no current flowing in the system the beam strikes the mirror normally and it is reflected directly back and a spot of light is obtained at O on the scale, S (just above L)  When a current passes through the system, it rotates by an angle, say θ, the reflected beam rotates through 2θ, thus making the system more sensitive. | 2  1  1  1 |
| (b) | O  P  I  F  C  (i)  F = principal focus  C = centre of curvature  O  P  I  F  C  (ii) | 1  1 |
| (c) | O  P  I  F  C  F  X  D  B  A  h1  h1  h2  -v  -f  u  α  α  Y  A ray AB, parallel to the principal axis, is reflected along BX.  Another AP is reflected along PY at the same angle α.  The reflected rays appaer to come from D so that ID is the image of OA.  Object height = OA = PB = h1 and image height is h2.  Now ΔOAP is similar to ΔIDP  And ΔDIF is similar to ΔBPI  ALTERNATIVELY  Q  θ  θ  X  h  α γ β  N  O P I C  Consider a point object O on the principle axis of a convex mirror. A ray OX from O is reflected along XQ.  A ray OP, incident at P, is reflected back along PO and the point I where the two rays appear to emerge from is the virtual image of O.  The normal at X must be passing through the centre of curvature, C, of the mirror  From the geometry of the figure  θ = α + β……….……………..(1)  Also θ = γ - β……….………………(2)  Eq (1) and Eq (2) give α + β = γ – β  ∴ γ - α = 2β ……………………………….(3)  Now, γ, α and β are small angles  ∴ γ = tan γ, α = tan α and β = tan β    But the focal length, f = r/2 | 1  ½  ½  ½  ½  ½  ½  ½  ½ |
| (d) | (i) Let uo = original object distance  Then the original image distance, v1 = uo/2    ∴ uo = 3f ……………………….(1)  Since the second image is bigger, the object was moved closer to the mirror by 25 cm  So, object distance, u2 = uo – 25  And image distance,v2 = 3u2 = 3(uo - 25)    ∴ 4f = 3uo – 75  ∴ 4f = 3(3f) – 75  ∴ f = 15 cm | ½  1  ½  1  1  1 |
| (ii) Shift of the screen = v2 – v1  = 3(uo – 25) - ½ uo  = 3(3f – 25) - ½(3f)  = 3(45 – 25) - ½ x 45  = 37.5 cm | 1  1 |
| ***Total = 20*** | | |
| 4. (a) | (i) Current sensitivity of a galvanometer is the deflection per unit current | 1 |
| (ii) Magnetic moment of a coil is the torque exerted on the coil when it is placed in a field of unit induction with its plane parallel to the field. | 1 |
| (b) | A current flowing in a conductor produce a magnetic field around the conductor.  The two fields interact and this results in clustering of magnetic field lines of force on one side of the conductor. E.g.  Force  Now, the tendency of the lines of force is to straighten and spread out.  This is achieved by forcing the conductor away from the region of clustering. | ½  ½  ½  ½  1 |
| (c) | (i)  a  b  F1  F1  I  B  F2  F2  α  α  F1  F1  B  Consider one turn of the coil.  The forces F2 and F2 cancel out one another, but each of the forces F1 = BIa, where I is the current.  The torque on one turn of the coil is τ = F1bsin α  **∴** τ = BIab sin α = BIA sin α, where ab = A = area of the coil  For N turns, T = BIAN sin α  Thus, T is independent of the shape but of the area, etc | 1  1  1  1 |
| (ii)  T  α | 1 |
| (d) | B  Semiconductor  Connections for polarity test  I  A current, I, is passed through the semiconductor in a known direction.  A magnetic field, B, of known polarity is applied perpendicular to the current.  The polarity of the Hall voltage set up in a direction perpendicular to both the current and the magnetic field is tested.  The charge found in the direction of the force, as established by Fleming’s left hand rule, is the charge of the majority charge carriers | 1  1  1  1 |
| (e) | (i) Force per metre length, F = BI  Volume of conductor V = A x 1 = A  There are NV electrons in volume V | ½  ½  ½  1½ |
| (ii)      = 4.0 x 10-2 V | ½  ½  1  1 |
| ***Total = 20*** | | |
| 5. (a) | A  B  VAB  R  I  E  r  (i)  A source has internal resistance, r, and when the source is giving out a current I, the terminal p.d, VAB, is given by  VAB = E – Ir, where E is the emf  Now, when the current increases, the p.d Ir across the internal resistance increases.  Thus, the remainder, which is the terminal p.d, decreases. | 1  ½  1  ½ |
| (ii) A metal, for example, its lattice is an assembly of ions in a “sea” of mobile electrons.  As electrons drift they collide with the ions, which are already vibrating about their mean positions, thereby increasing the ion’s k.e.  Hence the conductor heats up.  Whatever the direction of the electrons’ drift, the collisions do occur. So the heating effect is independent of the direction of current | ½  ½  1 |
| (b) | (i)  A  P  B  S  R  Q  I1  I1  I2  I2  I  D  C  G  Suppose resistors P, Q, R and S are connected to form a Wheatstone bridge as shown.  At balance the galvanometer, G, passes no current  i.e. the p.d VBC = 0 V  So VAB = VAC …………………….(1)  VBD = VCD ……………………(2) | ½  1  1  ½  1 |
|  | (ii) The diameter, d, of the wire is measured and recorded.  Starting with a length *x* of the wire, a circuit as shown below is connected, in which R is a starndard resistance  R  *l*1 *l*2  Rx  G  *x*  If β is the resistivity of the wire, then the resistance of the length x of the wire is  The balance lengths *l*1 and *l*2 and found    The procedure is repeated for several values of x and the results are tabulated.  A graph of  against x is plotted and its slope, s, is found | ½  ½  1  ½  ½  ½  ½  ½  ½  ½  ½ |
| (c) | 1Ω  R  4V  4Ω  2V  4Ω  3V  2Ω  A  B  Loop I  Loop II  I1=0.2A  I2  (I1-I2)  Since VAB > 2V, the current I1 must be flowing against the 2V cell in that branch.  Now, VAB = 2.8 = 2 + 4I1  ∴ I1 =  = 0.2A  For loop I: 4I1 + 6(I1 – I2) = 3 – 2  ∴ 10 I1 - 6 I2 = 1  ∴ 10 x 0.2 - 6 I2 = 1  ∴ 6 I2 = 1  ∴ I2 =  A  For loop II: R I2 + 4 I1 + I2 = 4 – 2  ∴ R + 4 x 0.2 +  = 2  ∴ R + 4.8 + 1 = 1.2  ∴ R = 6.2 Ω | ½  1  1  ½  1  1 |
| ***Total = 20*** | | |
| 6. (a) | (i) The dielectric strength of a dielectric is the maximum potential gradient the dielectric can withstand without its insulation breaking down.  current  p.d  Time | 1 |
| (ii)  *Award only if the curves are identified and the time axis labelled* | 1  1 |
| (ii)  The potential difference decreases.  Electrostatic induction occurs in the metal slice, with positive charge residing next to the negative plate and negative charge next to the positive plate.  This arrangement reduces the p.d between the plates. | ½  1  ½ |
| (b) | V  *C*  Sensitive galvanometer  Vibrating-reed switch  Protective resistor  A  G  B  The first capacitor, of capacitance C1, is connected between points A and B and the circuit set up as shown.  The supply is switched on and the current I1, read from the galvanometer, is noted.  The procedure is repeated with the other capacitor, of capacitance C2, and the current I2 is noted.  Let Q1 be the charge passed through the galvanometer during each time of switching when C1 is connected between A and B.  Then the current, I1 = Q1f, where f is the switching frequency of the reed  i.e. I1 = C1Vf ………….(1)  Similarly I2 = C2Vf ………….(2) | 1  1  ½  ½  ½  ½  1 |
| (c) | Suppose that at a certain instant during charging when the p.d between the plates is V, the charging current is I and the charge on either plate is Q.  ⁺Q ⁻Q  V  I  Then the rate at which work is being done to charge the capacitor is the electrical power,      The total work done in accumulating the charge from zero to a quantity, say Qo, is  Now, Qo = CV  ∴ W = ½CV2 = energy stored in the capacitor  ALTERNATIVELY  Imagine a capacitor of capacitance C charged to a p.d V. Suppose that now the charge on its plates is to be increased from Q to Q + δQ, where δQ is small. Then a charge δQ must be transferred from the negative plate to the positive plate. This would increase the p.d by δV.  Since δQ is small, it follows that δV is also small compared to V.  Hence the p.d V may be regarded as constant.  Then the work done in transferring the charge δQ is  δW = V.δQ (from the definition of p.d). But V = Q/V  **∴** δW = QδQ  C  Therefore the total work done in raising the charge of the capacitor from zero to, say Qo is  This is the energy stored by a capacitor of capacitance C carrying a charge Qo.  Alternatively, Qo = CVo, where Vo is the p.d across the capacitor   * W = ½CVo2 = energy stored in the capacitor | 1  1    1  1  1 |
| 36V  40 µF  10µF  10 µF  30 µF  (d) | 36V  40µF  20 µF  30 µF    Energy stored ½CV2 = ½ x 30 x 10-6 x  = 1.84 x 10-3J | 1  1  2  1 |
| ***Total = 20*** | | |
| 7. (a) | (i) It is the piling of electrons on one side of a conductor, leaving a positive charge on the opposite side of it, due to presence of a charge nearby. | 1 |
| (ii) – The charging source is not affected.  - It makes it easy to concentrate a big charge on the reciepient at once. | 1  1 |
| (b) | When an electroscope is charged, the cap, rod and leaf all carry similar charge.  When a neutral conductor approaches the cap, electrostatic induction occurs in the conductor with the side nearest to the cap acquiring a charge opposite to that on the cap.  Neutral conductor  This arrangement reduces the charge on the electroscope.  So the divergence of the leaf decreases.  The nearer the body the greater the reduction in divergence | ½  1  ½  1  1 |
| (c) | (i) The force between two point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between the charges. | 1 |
| (ii) Suppose A is the point whose potential, VA, is required. Then imagine a small point charge q placed at point C, distance x from Q.  +Q ­A  z  δx  B  C  +q  x      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  δW = F(-δx)    The total work done in bringing q from infinity to point A is    The potential VA at point A is the work done per unit positive charge brought from infinity to A. | ½  ½  1  1  1  1 |
| (d) | (i) Force on Q1 = Q1 x Intensity due to Q2 and Q3 at the location of Q1.  = 2.7 x 106 NC-1 upwards  = 2.7 x 106 NC-1 towards the left  E2  E3  E    = 3.82 x 106 NC-1  ∴ Force on Q1 = EQ1 = 3.82 x 106x 4 x 10-6  = 15.3 N | ½  ½  1  1  1 |
|  | (ii) Work done = charge x potential at the centre  = Q x (V1 + V2 + V3)  = 2 x 10-6 x 9 x 109 x 40 x 10-6  = 1.02 J | 1  1  1 |
| ***Total = 20*** | | |