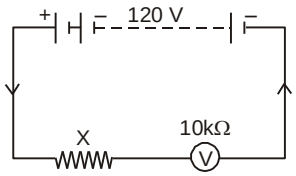
# High Level Problems (HLP)

## SUBJECTIVE QUESTIONS

**1.** A galvanometer having 30 divisions has current sensitivity of 20 μA/div. It has a resistance of 25 ohm. How will you convert it to an ammeter measuring upto 1 ampere? How will you now convert this ammeter into a voltmeter reading upto 1 volt? **[REE 1987]**

**2.** A D.C. supply of 120 volt is connected to a large resistance X. A volt meter of resistance 10 kΩ, placed in series in the circuit reads 4 volts. What is the value of X? What do you think is the purpose in using a voltmeter, instead of an ammeter, to determine the large resistance X?



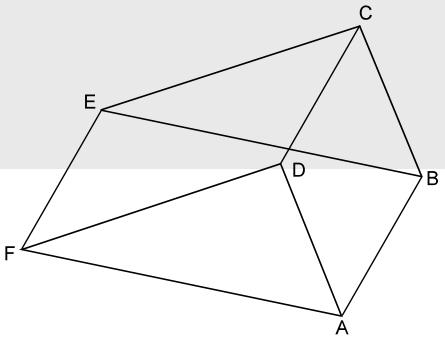

**3.** A person decides to use his bath tub water to generate electric power to run a 40 watt bulb. The bath tub is located at a height of 10 m from the ground and it holds 200 liters of water. If we install a water driven wheel generator on the ground, at what rate should the water drain from the bath tub to light bulb? How long can we keep the bulb on, if the bath tub was full initially? The efficiency of generator is 90 %. ($g=10 m/s^{-2}$) **[REE 1990]**

**4.** A cell of emf 3.4 volt and internal resistance 3Ω connected to an ammeter having resistance 2 Ω and to an external resistance of 100 Ω. When a voltmeter is connected across the 100 Ω resistance the ammeter reading is 0.04 ampere. Find the voltage read by the voltmeter and its resistance. Had the voltmeter been an ideal one, what would have been its reading? **[REE 1990]**

**5.** When a cell is connected in a circuit, a current $I_1$ flows in the circuit. When one more identical cell is connected in series with the first one, a current $I_2$ is found to flow in the circuit. When same cell is connected in parallel with the first one, the current is found to be $I_3$. Show that $3I_2I_3 = 2I_1(I_2 + I_3)$.

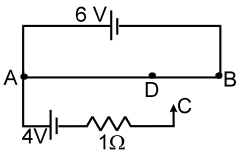
**6.** A battery is made by joining m rows of identical cells in parallel. Each row consists of n cells joined in series. This battery sends a maximum current I in a given external resistor. Now the cells are so arranged that instead of m rows, n rows are joined in parallel and each row consists of m cells joined in series. Find the current through the same external resistor (Total number of cells which is equal to nm is connected)

**7.** In the circuit shown in figure, all wires have equal resistance r. Calculate equivalent resistance between A and B?



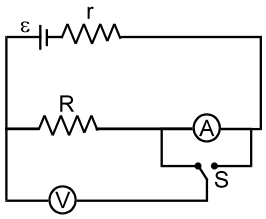

**8.** A galvanometer having a coil resistance of 100 ohms gives a full scale deflection when a current of one milli-ampere is passed through it. What is the value of resistance which can convert this galvanometer into ammeter giving a full scale deflection for a current of 10 amperes? A resistance of the required value is available but it will get burnt if the energy dissipated in it is greater than one watt. Can it be used for the above described conversion of the galvanometer? When this modified galvanometer is connected across the terminals of battery, it shows a current 4 amp. The current drops to 1 amp., when the resistance of 1.5 ohm is connected in series with modified galvanometer. Find the emf and internal resistance of battery. **[JEE 1972]**

**9.** A 6 volt battery of negligible internal resistance is connected across a uniform wire AB of length 100 cm. The positive terminal of another battery of emf 4V and internal resistance 1Ω is joined to the point A as shown in figure. Take the potential at B to be zero.



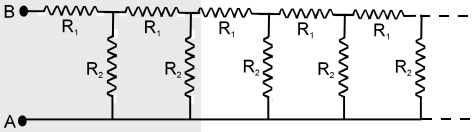

(a) What are the potentials at the points A and C?
(b) At which point D of the wire AB, the potential is equal to the potential at C.
(c) If the point C and D are connected by a wire, what will be the current through it?
(d) If the 4V battery is replaced by 7.5 V battery, what would be the answers of parts (a) and (b)?

**10.** The emf ε and the internal resistance r of the battery shown in figure are 4.3 V and 1.0 Ω respectively. The external resistance R is 50 Ω. The resistances of the ammeter and voltmeter are 2.0 Ω and 200 Ω respectively.

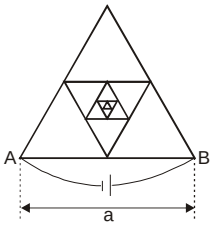



(a) Find the readings of the two meters.
(b) The switch is thrown to the other side.
What will be the readings of the two meters now?

**11.** Consider an infinite ladder network shown in fig. A voltage is applied between points A and B. If the voltage is halved after each section, find the ratio $R_1/R_2$. Suggest a method to terminate it after a few sections without introducing much error in attenuation. **[REE 1998]**



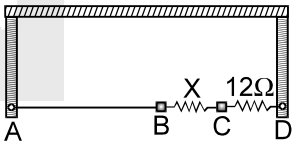

**12.** Determine the resistance $R_{AB}$ between points A and B of the frame made of thin homogeneous wire (as shown in figure), assuming that the number of successively embedded equilateral triangles (with sides decreasing by half) tends to infinity. Side AB is equal to a, and the resistance of unit length of the wire is ρ.




**13.** A nichrome wire of uniform cross-sectional area is bent to form a rectangular loop ABCD. Another nichrome wire of the same cross-section is connected to form the diagonal AC. Find out the ratio of the resistances across BD and AC if AB = 0.4 m and BC = 0.3 m. **[REE 2000]**

**14.** An electric heater has heating coils A and B, when coil A is switched on, the water boils in 10 minute, and when coil B is switched on the water boils in 20 minute. Calculate the time taken by water, to boil if the coils connected in **[REE 2000]**
(a) Series and (b) Parallel all switched on.

**15.** A thin uniform wire AB of length 1 m, an unknown resistance X and a resistance of 12 Ω are connected by thick conducting strips, as shown in the figure. A battery and a galvanometer (with a sliding jockey connected to it) are also available. Connections are to be made to measure the unknown resistance X using the principle of Wheatstone bridge. Answer the following question.




(a) Are there positive and negative terminals on the galvanometer?
(b) Copy the figure in your answer book and show the battery and the galvanometer (with jockey) connected at appropriate points. **[IIT-JEE (Main) 2002; (1+2+2)/60]**
(c) After appropriate connections are made, it is found that no deflection takes place in the galvanometer when the sliding jockey touches the wire at a distance of 60 cm from A. Obtain the value of the resistance X.

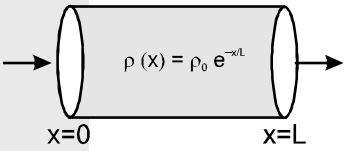
**16.** In a potentiometer circuit, two wires of same material of resistivity $\rho$, one of radius of cross-section ' a ' and other of radius of cross-section ' 2 a ' are joined in series. They are of length $\ell$ and 2 $\ell$ respectively. This combination acts as the potentiometer wire of length 3 $\ell$. The emf of the cell in the primary circuit is $\varepsilon$ and internal resistance is $\frac{\rho\ell}{2\pi a^2}$. This cell is connected to the potentiometer wire by a conducting wire of negligible resistance with positive terminal of the cell connected to one end (call it A) of longer wire. The negative terminal of the cell is connected to one end of the smaller wire. The remaining ends of the two wires are joined together. Find:

(i) The maximum voltage which can be balanced on the potentiometer wire.

(ii) The length, measured from point A, where cell of emf $\frac{\varepsilon}{2}$ will balance.

(iii) If positive terminal of cell of emf $\frac{\varepsilon}{2}$ and internal resistance $\frac{\rho\ell}{2\pi a^2}$ is connected to point A and other terminal is joined to the junction of the two wires, then find the current through this cell.

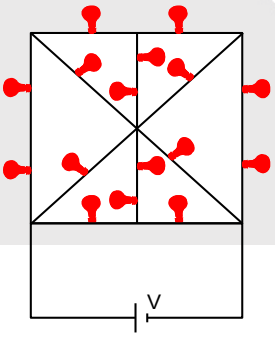
**17.** A rod of length L and cross-section area A lies along the x-axis between x = 0 and x = L. The material obeys Ohm's law and its resistivity varies along the rod according to, $\rho(x) = \rho_0 e^{-x/L}$
The end of the rod at x = 0 is at a potential $V_0$ and it is zero at x = L



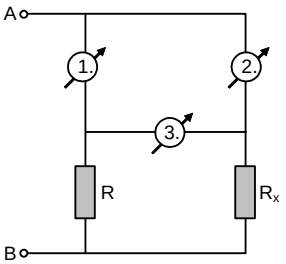

(a) Find the total resistance of the rod and the current in the wire.
(b) Find the electric potential V(x) in the rod as a function of x.

**18.** A galvanometer having 50 divisions provided with a variable shunt S is used to measure the current when connected in series with a resistance of 90 Ω and a battery of internal resistance 10 Ω. It is observed that when the shunt resistances are 10 Ω & 50 Ω respectively, the deflection are respectively 9 and 30 divisions. What is the resistance of the galvanometer? Further, if the full scale deflection of the galvanometer movement require 200 mA, find the emf of the cell.

**19.** Standard rating of each bulb is P, V. If total power consumption by combination is $\frac{3XP}{5}$ then calculate 'X'.



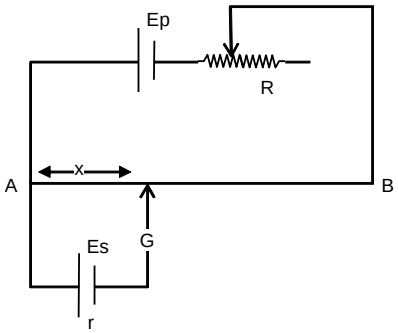

**20.** In the circuit shown the three ammeters (marked as 1, 2, 3) are identical, each have a resistance $R_0 = 2\Omega$. Between points A and B there is a constant potential difference of 19V. The first and second ammeter read $I_1 = 2.5A$ and $I_2 = 1.5A$ respectively.



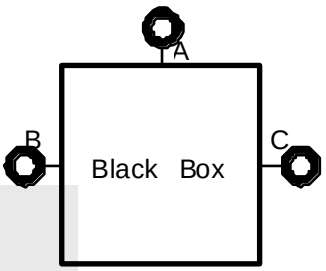

(a) What is the reading of third ammeter?
(b) Calculate value of resistance R.
(c) Investigate what happens to current $I_3$ if the value of $R_x$ is changed.Show approximately graphical variation of $I_3$ vs $R_x$.

**Note : Reading of ammeter implies current through branch of ammeter.**

**21.** Consider a potentiometer circuit, Primary cell is ideal. The length of potentiometer wire is 1m and the resistance per unit length of potentiometer wire varies with length as $\lambda = 2x\Omega/m$. Where x is distance from end A. Resistance fo Rheostat varies with time as $R = t^2\Omega$. Null deflection point for secondary cell is obatained at $x = \frac{1}{2}$ m and at t =1 sec. If emf of secondary cell is $\frac{1}{\gamma}$ times of emf of primary cell, find $\gamma$.




**22.** This question is about a closed electrical black box with three terminals A, B, and C as shown. It is known that the electrical elements connecting the points A, B, C inside the box are resistances (if any) in delta formation. A student is provided a variable power supply, an ammeter and a voltmeter. Schematic symbols for these elements are given in part (a). She is allowed to connect these elements externally between only two of the terminals (AB or BC or CA) at a time to form a suitable circuit. **[Olympiad 2016]**




(a) Draw a suitable circuit using the above elements to measure voltage across the terminals A and B and the current drawn from power supply as per Ohm's law.

(b) She obtains the following readings in volt and milliampere for the three possible connections to the black box.

| AB | | BC | | AC | |
|---|---|---|---|---|---|
| V (V) | I (mA) | V (V) | I (mA) | V (V) | I (mA) |
| 0.53 | 0.54 | 0.83 | 0.17 | 0.85 | 0.15 |
| 0.77 | 0.77 | 1.65 | 0.35 | 1.70 | 0.30 |
| 1.02 | 1.01 | 2.47 | 0.53 | 2.55 | 0.45 |
| 1.49 | 1.51 | 3.29 | 0.71 | 3.4 | 0.60 |
| 1.98 | 2.02 | 4.11 | 0.89 | 4.25 | 0.75 |
| 2.49 | 2.51 | 4.94 | 1.06 | 5.10 | 0.90 |

In each case plot V (on Y-axis)-I (on X-axis) on the graph papers provided. Preferably use a pencil to plot. Calculate the values of resistances from the plots. Show your calculations below for each plot clearly indicating graph number.

(c) From your calculations above draw the arrangement of resistances inside the box indicating their values.

# HLP Answers

**1.** $S = \frac{15\times10^{-3}}{1-0.6\times10^{-3}} \approx 0.015\ \Omega$ in parallel ; R = 0.985 $\Omega$ in series.

**2.** 290 k$\Omega$, Due to very small value of current, Ammeter has not been used. The ammeter reading would have been very small. Note that this is unusual use of a voltmeter. It is meant only for the measurement of high resistance.

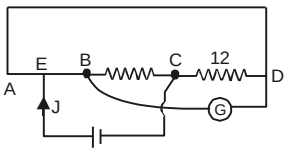
**3.** 4/9 kg/sec; 450 sec **4.** $400\Omega, \frac{16}{5}$ = 3.2 V, $\frac{68}{21}$ = 3.238 V

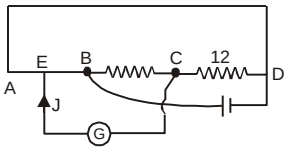
**6.** $\frac{2mn\ I}{m^2+n^2}$ **7.** $\frac{3r}{5}$ **8.** $S = \frac{0.1}{10-10^{-3}} \cong 0.01\ \Omega$, yes, E = 2V, r = 0.5 – 0.01 = 0.49 $\Omega$.

**9.** (a) 6 V, 2 V (b) AD = $\frac{200}{3}$ = 66.7 cm (c) zero (d) 6 V, – 1.5 V, no such point D exists. D

**10.** (a) 0.1 A, 4.0 V (b) $\frac{1083.6\times200}{10652\times252}$ = 0.08 A, $4.3-\frac{1083.6}{10652}$ = 4.2 V

**11.** $\frac{1}{2}$ **12.** $R_{AB}=\frac{a\rho\ (\sqrt{7}-1)}{3}$ **13.** $\frac{R_{BD}}{R_{AC}}=\frac{59}{35}$ **14.** (a) $t_s$ = 30 min. (b) $t_p=\frac{20}{3}$ min.

**15.** (a) No (b) 

or 

(c) 8 Ω

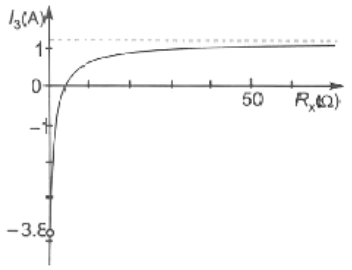
**16.** (i) $v_0=\frac{3\varepsilon}{4}$ (ii) $\frac{5\ell}{2}$ (iii) $\frac{\varepsilon}{7R}$, where $R=\frac{\rho\ell}{A}$ and $A=2\pi a^2$

**17.** (a) $R=\rho_o\frac{L}{A}\left(\frac{e-1}{e}\right)$, $i=\frac{V_0}{R}$, (b) $V(x)=\frac{V_o(e^{-x/L}-e^{-1})}{1-e^{-1}}$

**18.** $R_g=\frac{700}{3}\Omega$, E = 96 volt. **19.** 2

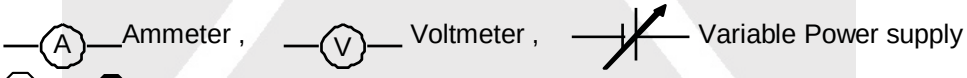
**20.** (a) 1A, (b) 4Ω

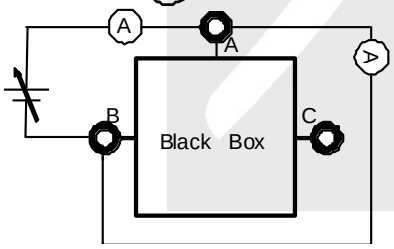
$$I_3=\frac{V(R_x-R)}{(2R_0+3R)R_x+R_0(R_0+2R)}$$



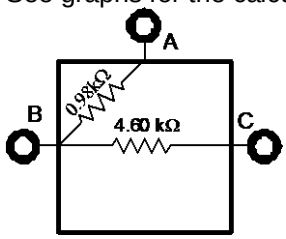

The graph of the function is a hyperbola. Its special points are: at $R_x$ = 0 $I_3$= –3.8 A ; at $R_x$ ; = 4$I_3$ = 0; at $R_x$ = 32Ω $I_3$ = 1A ; If $R_x\to\infty$, $I_3$ tends to 19/16 = 1.1875A.

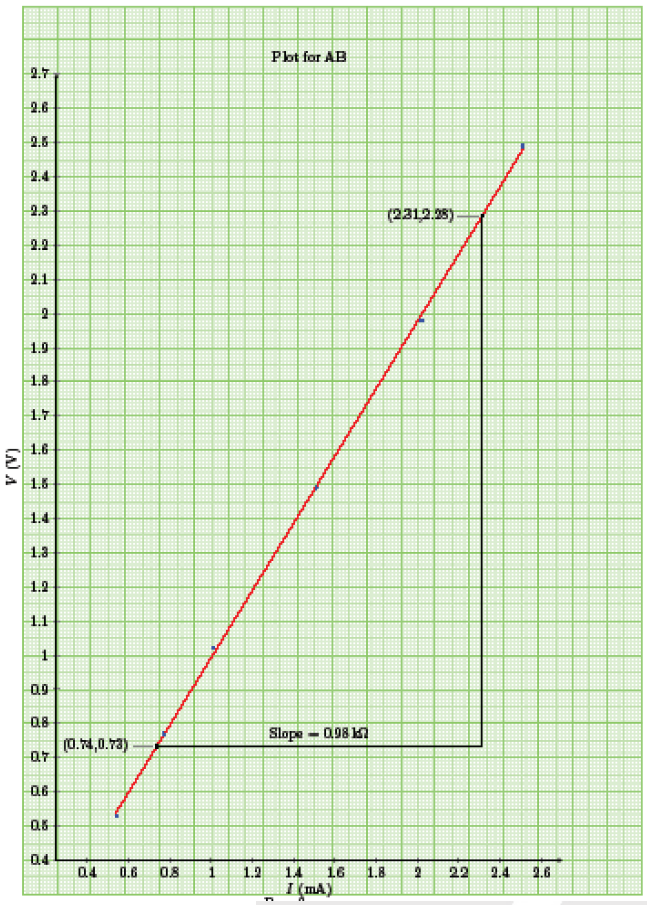
**21.** 8

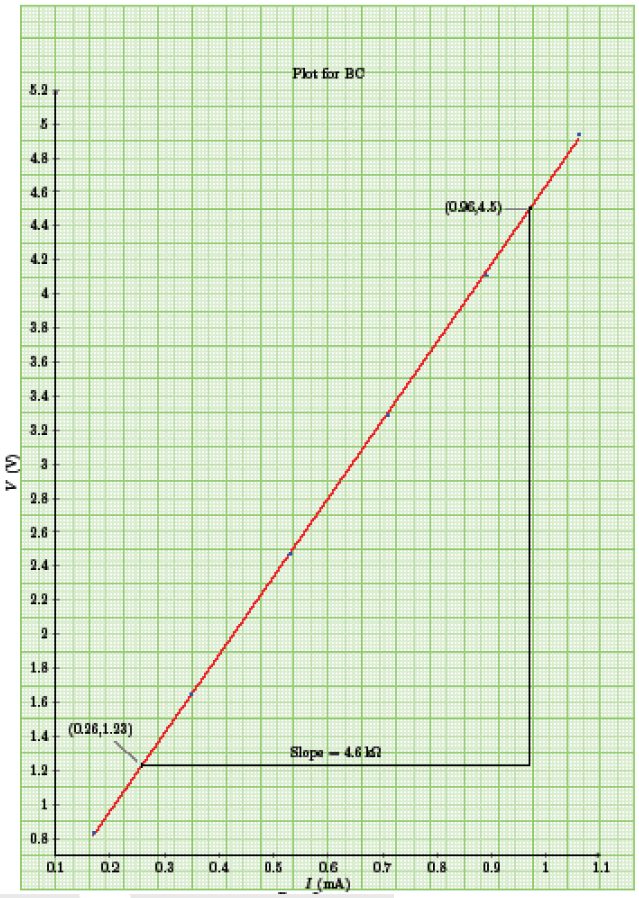
**22.** (a) 

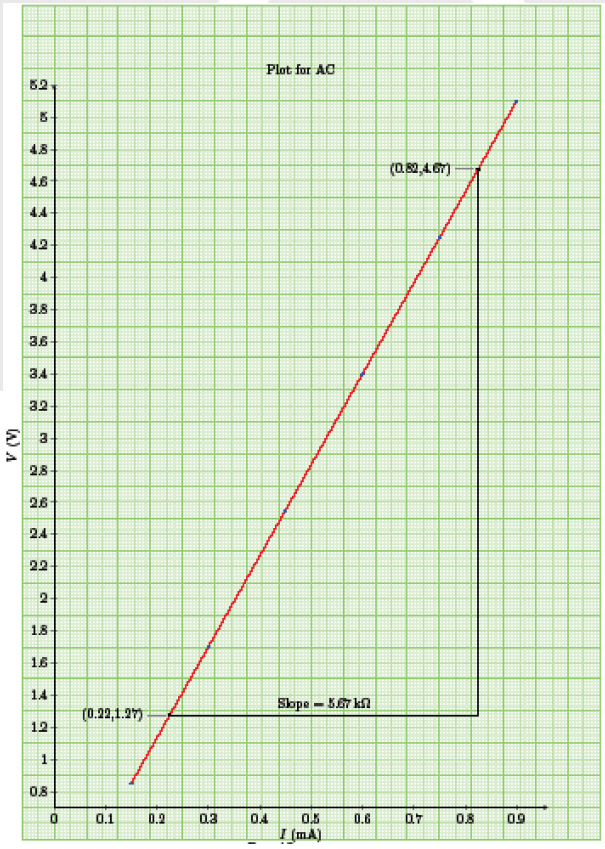




(b) See graphs for the calculations of slopes. $R_{AB}$ = 0.98 kΩ, $R_{BC}$ = 4.60 kΩ, $R_{CA}$ = 5.67 kΩ

(c) 


Plot for AB
V (V)
I (mA)
(2.31,2.28)
(0.74,0.73)
Slope = 0.98 kΩ


Plot for BC
V (V)
I (mA)
(0.96,4.5)
(0.26,1.23)
Slope = 4.6 kΩ


Plot for AC
V (V)
I (mA)
(0.82,4.67)
(0.22,1.27)
Slope = 5.67 kΩ