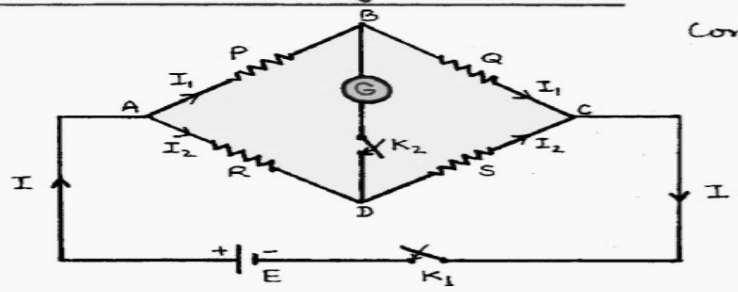
Chapter–3: Current Electricity

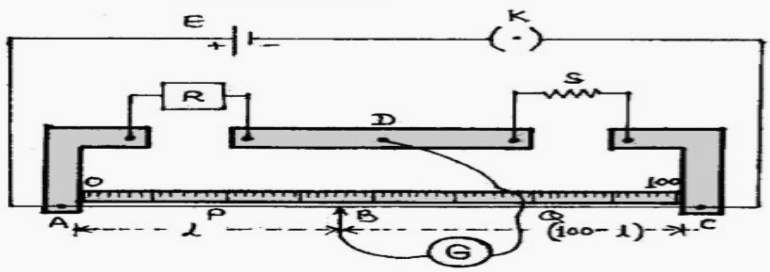
Wheatstone Bridge Principle



Condition for the balanced wheatstone bridge.

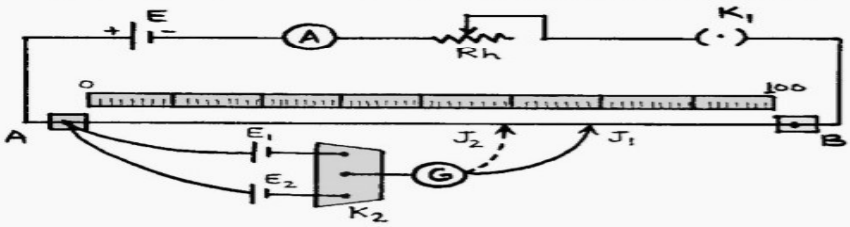
$$\frac{P}{Q} = \frac{R}{S}$$

Meter Bridge



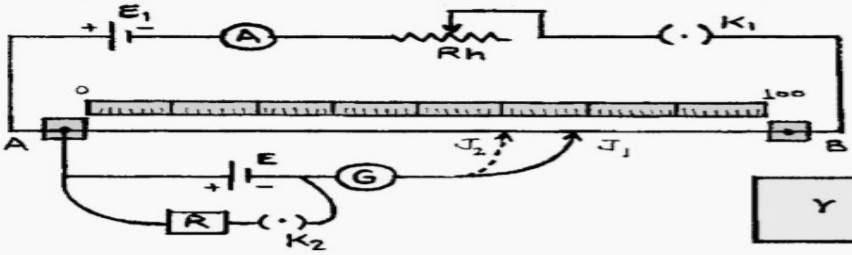
$$S = \left(\frac{100 - l}{l}\right) \times R$$

(i) Comparison of EMF's of two cells using potentiometer –



$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

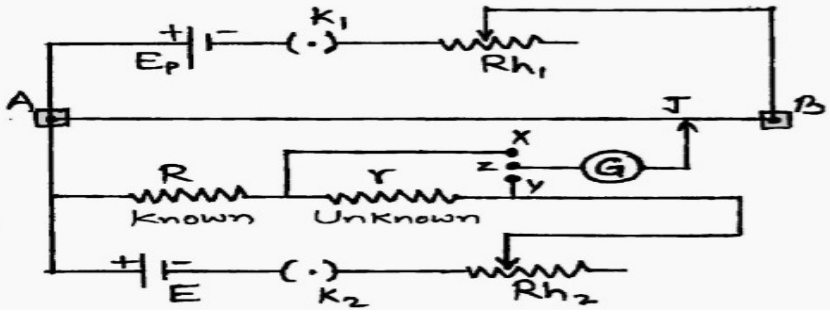
(ii) Determination of internal resistance of the cell



$$\frac{E}{V} = \frac{l_1}{l_2}$$

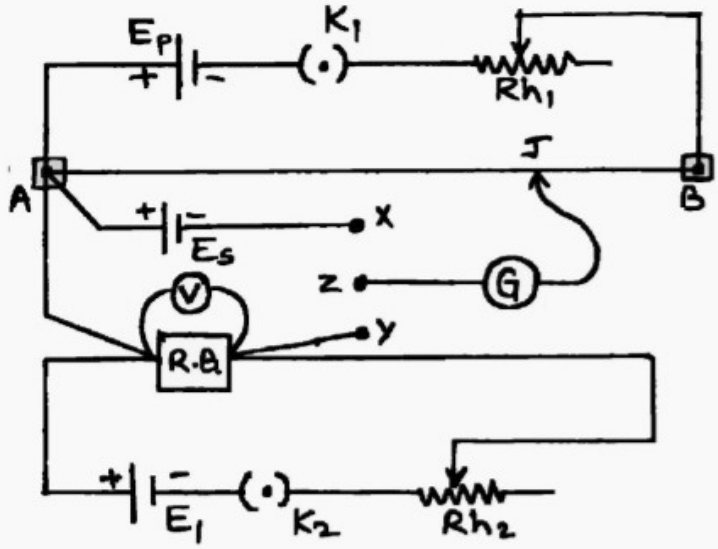
$$r = \left(\frac{l_1}{l_2} - 1\right) R$$

(iii) Determination of a small resistance by Potentiometer



$$r = \left(\frac{l_2 - l_1}{l_1}\right) R$$

(iv) Calibration of a voltmeter by Potentiometer

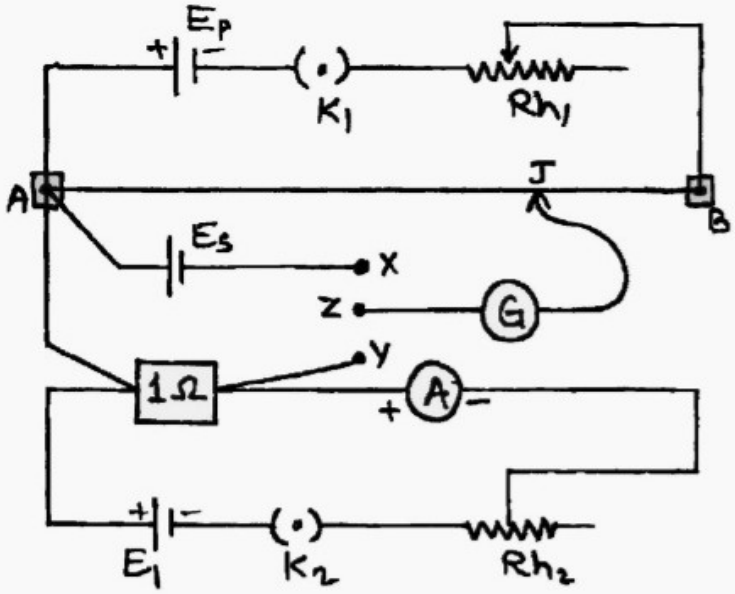


$$V' = \frac{E_s}{l_1} \times l_2$$

V = voltmeter reading

Error in Voltmeter reading $\Delta V = V - V'$

(v) Calibration of a ammeter by Potentiometer

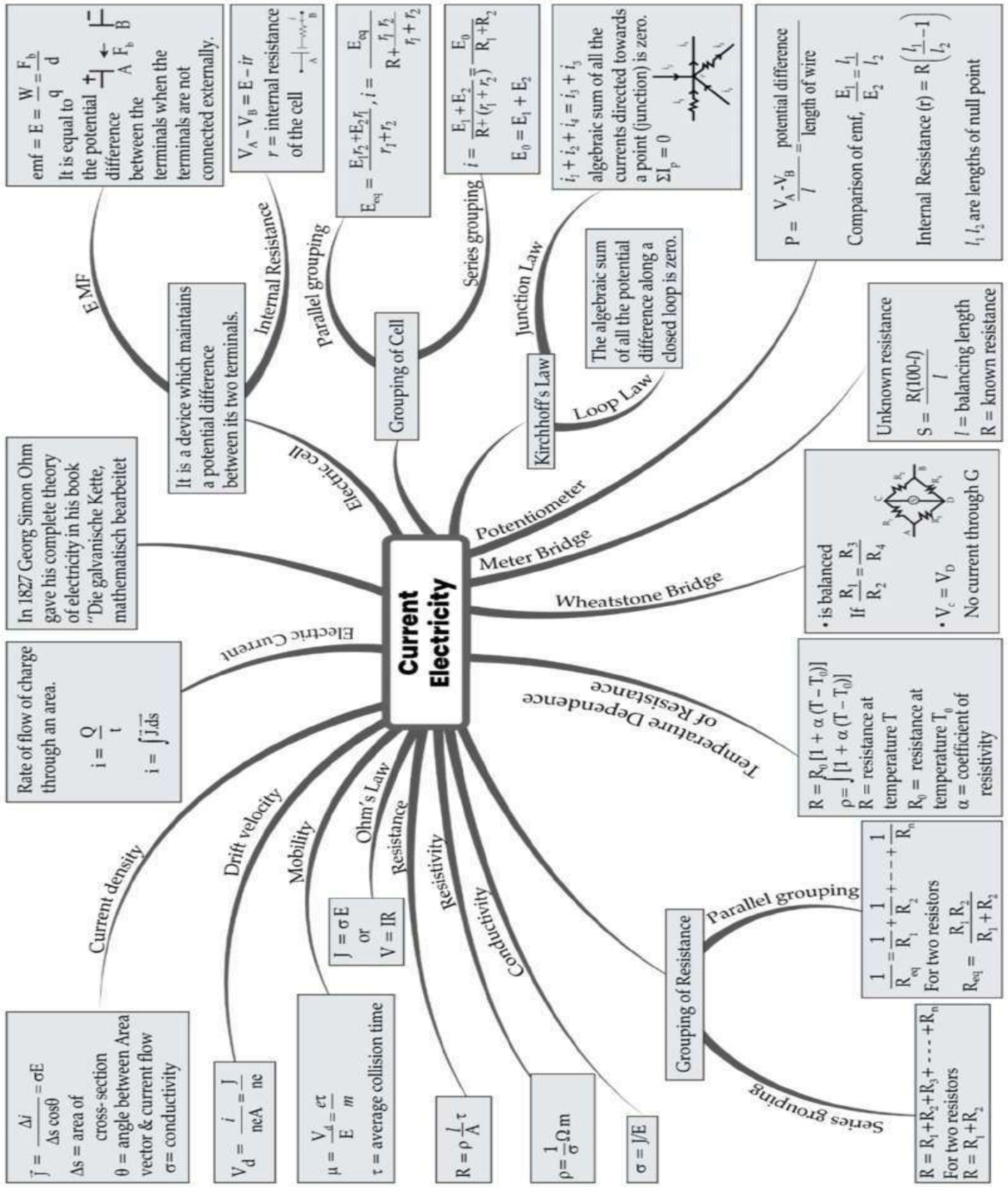


I = ammeter reading

$$I' = \frac{E_s}{l_1} \times l_2$$

Error in ammeter reading $\Delta I = I - I'$

Mind-Map


Current Electricity
Electric cell
It is a device which maintains a potential difference between its two terminals.
E.MF
emf = E = W/q = F_b/q
It is equal to the potential difference between the terminals when the terminals are not connected externally.
Internal Resistance
V_A – V_B = E – ir
r = internal resistance of the cell
Grouping of Cell
Parallel grouping
E_eq = (E_1r_2 + E_2r_1)/(r_1 + r_2), i = E_eq/(R + r_1r_2/(r_1 + r_2))
Series grouping
i = (E_1 + E_2)/(R + (r_1 + r_2)) = E_0/(R_1 + R_2)
E_0 = E_1 + E_2
Kirchhoff's Law
Junction Law
i_1 + i_2 + i_4 = i_3 + i_5
The algebraic sum of all the currents directed towards a point (junction) is zero.
ΣI_p = 0
Loop Law
The algebraic sum of all the potential difference along a closed loop is zero.
Potentiometer
P = (V_A - V_B)/l = potential difference / length of wire
Comparison of emf, E_1/E_2 = l_1/l_2
Internal Resistance (r) = R((l_1/l_2) – 1)
l_1, l_2 are lengths of null point
Meter Bridge
Unknown resistance
S = R(100-l)/l
l = balancing length
R = known resistance
Wheatstone Bridge
• is balanced
If R_1/R_2 = R_3/R_4
• V_c = V_D
No current through G
Temperature Dependence of Resistance
R = R_0[1 + α(T – T_0)]
ρ = ∫[1 + α(T – T_0)]
R = resistance at temperature T
R_0 = resistance at temperature T_0
α = coefficient of resistivity
Grouping of Resistance
Parallel grouping
1/R_eq = 1/R_1 + 1/R_2 + - - - + 1/R_n
For two resistors
R_eq = R_1R_2/(R_1 + R_2)
Series grouping
R = R_1 + R_2 + R_3 + - - - + R_n
For two resistors
R = R_1 + R_2
Electric Current
Rate of flow of charge through an area.
i = Q/t
i = ∫J.ds
In 1827 Georg Simon Ohm gave his complete theory of electricity in his book "Die galvanische Kette, mathematisch bearbeitet
Current density
J = Δi/Δs cosθ = σE
Δs = area of cross-section
θ = angle between Area vector & current flow
σ = conductivity
Drift velocity
V_d = i/neA = J/ne
Mobility
μ = V_d/E = eτ/m
τ = average collision time
Ohm's Law
J = σE or V = IR
Resistance
R = ρ l/A τ
Resistivity
ρ = 1/σ Ωm
Conductivity
σ = 1/E

FREQUENTLY ASKED QUESTIONS

Current Electricity

2 MARKS

1) Write the four measures that can be taken to increase the sensitivity of a galvanometer.

2) A galvanometer of resistance 120 Ω gives full scale deflection for a current of 5mA. How can it be converted into an ammeter of range O to 5A? Also determine the net resistance of the ammeter. (2021)

3) Two metallic wires of the same material have the same length but cross-sectional area is in the ratio 1:2 they are connected (i) in parallel. Compare the velocities of electrons in the two wires in both the cases (i) and (ii). (2021)

4) Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time.

5) A galvanometer coil has a resistance G. 1% of the total current goes through the coil and rest: through the shunt. What is the resistance of the shunt?

6) Show that $\vec{E} = \rho\vec{j}$ leads to Ohm's law. Write a condition in which the Ohm's law is not valid for a material. **(2025)**

7) n identical cells, each of e.m.f E and internal resistance r, are connected in series. Later on it was found out that two cells 'X' and 'Y' are connected in reverse polarities. Calculate the potential difference across the cell 'X'. **(2025)**

3 MARKS

8) Derive an expression for the torque on a magnetic dipole placed in a magnetic field and hence define magnetic moment.

9) Two heating elements of resistances R1 and R2 when operated at a constant supply of voltage, V, consume powers P1 and P2 respectively. Deduce the expressions for the power of their combination when they are, in turn, connected in (i) series and (ii) parallel across the same voltage supply.

10) a) A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus 1) R and 2) the current I.

b) It is found that when R = 4Ω, the current is 1A and when R is increased to 9Ω, the current reduces to 0.5A. Find the values of the emf E and internal resistance r. (2015)

11) Derive the expression for the current density of a conductor in terms of the conductivity and applied electric field. Explain, with reason how the mobility of electrons in a conductor changes when the potential difference applied is doubled, keeping the temperature of the conductor constant. (2017)

12) Two cells of emf E_1 and E_2 and internal resistance r_1 and r_2 respectively are connected in parallel. Obtain expressions for the equivalent.
a) Resistance and
b) emf of the combination (2018)

13) i) Define 'temperature coefficient of resistance' of a metal.
ii) Show the variation of resistivity of copper with rise in temperature.
iii) The resistance of a wire is 10 Ω at 27^0C. Find its resistance at -73^0C. The temperature coefficient of resistance of the material of the wire is $1.70 \times 10^{-4}\ ^0C^{-1}$. **(2024)**

14) A potential difference of 1.0 V is applied across a conductor of length 5.0 m and area of cross-section 1.0 mm^2. When current of 4.25 A is passed through the conductor, calculate i) The drift speed and ii) Relaxation time, of electrons. (Given number density of electrons in the conductor, $n= 8.5 \times 10^{28}\ m^{-3}$) **(2024)**

15) Two batteries of emf's 3V & 6V and internal resistance 0.2 Ω & 0.4 Ω are connected in parallel. This combination is connected to a 4 Ω resistor. Find:
(i) The equivalent emf of the combination
(ii) The equivalent internal resistance of the combination
(iii) The current drawn from the combination **(2025)**

16) (i) A conductor of length l is connected across an ideal cell of emf E. Keeping the cell connected, the length of the conductor is increased to 2 l by gradually stretching it. If R and R' are initial and final values of resistance and v_d and v_d' are initial and final values of drift velocity, find the relation between (i) R' and R (ii) v_d' and v_d
(ii) When electrons drift in a conductor from lower to higher potential, does it mean that all the 'free electrons' of the conductor are moving in the same direction? **(2025)**

5 MARKS

17) (a) State the two Kirchhoff's rules used in the analysis of electric circuits and explain them.
(b) Derive the equation of the balanced state in a Wheatstone bridge using Kirchhoff's laws. **(2022)**

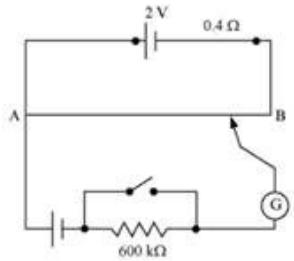
18) a) Draw a circuit diagram of a meter bridge used to determine the unknown resistance R of a given wire. Hence derive the expression for R in terms of the known resistances.
b) What does the term 'end error' in a meter bridge circuit mean and how is it corrected? How will the balancing point be affected, if the positions of the battery and galvanometer are interchanged in a meter bridge experiment? Give reason for your answer. **(2017)**

19) a) Define the term drift velocity.

b) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend?

c) Why alloys like constantan and manganin are used for making standard resistors?

20) Figure shows a potentiometer with a cell of 2.0 V and internal resistance 0.4**Ω** maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emf of 1.02 V (for very moderate currents up to a few mA) gives a balance point at 67.3 cm length of the wire. To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replace by a cell of unknown emf and the balance point found similarly, turns out to be at 82.3 cm length of the wire.



i) What is the value **E**?

ii) What purpose does the high resistance of 600 **KΩ** have?

iii) Is the balance point affected by this high resistance?

iv) Is the balance point affected by the internal resistance of the driver cell?

v) Would the method work in the above situation if the driver cell of the potentiometer had an emf of 1.0 V instead of 2.0 V?

vi) Would the circuit work well for determining an extremely small emf, say of the order of a few mV (such as the typical emf of a thermo-couple)? If not, how will you modify the Circuit?

21) Like resistors, cells can be combined together in an electrical circuit and can also be replaced by an equivalent cell.

a) Derive an expression to find the effective emf of two cells connected in parallel.

b) The potential difference across the terminals of a battery is 8.5 V, when a current of 5 A flows through it from the negative terminal to the positive terminal. When a current of 4 A flows through it in the opposite direction, the terminal potential difference of the battery is 10 V. Find the emf and the internal resistance of the battery.

Chap Gye Questions

1. If the temperature of a good conductor decreases, how does the relaxation time of electrons in the conductor change?

2. If potential difference V applied across a conductor is increases to 2V, how will the drift velocity of the electron change?

3. State one condition for maximum current to be drawn from the cell?

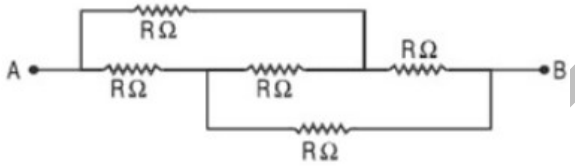
4. Draw the graph showing the variation of conductivity with temperature for a metallic conductor?

5. If a wire is stretched to double of its length. What will be its new resistivity and resistance?

6. Name any one material having a small value of temperature coefficient of resistance. Write one use of this material?

7. Why copper not used for making potentiometer wires?

8. Calculate the equivalent resistance between point A and B in the figure given below.



9. A silver wire has a resistance of 2.1Ω at 27.5 ^{0}C, and a resistance of 2.7 Ω at 100 ^{0}C. Determine the temperature coefficient of resistivity of silver.

10. Two electric bulbs A and B are marked 220V, 40w and 220V, 60w respectively. Which one has a higher resistance?

11. A carbon resistor has three strips of red colour and a gold strip. What is the value of resistor? What is its tolerance?

12. In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell?

13. A battery of emf E and internal resistance r sends a current I_1 and I_2, when connected to an external resistance of R_1 and R_2 respectively. Find the emf, and internal resistance of the battery?

14. A battery of emf 10 V and internal resistance 3Ω is connected resistor. If the current in the circuit is 0.5A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?

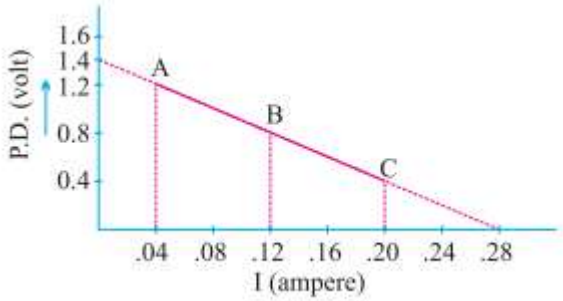
15. At room temperature (27.0 ^{0}C) the resistance of a heating element is 100 Ω. What is the temperature of the element if the resistance is found to be 117 Ω, given that the temperature coefficient of the material of the material of the resistor is $1.70 \times 10^{-4}\ ^0C^{-1}$?

16. A negligible small current is passed through a wire of length 15m and uniform cross section 6.0×10^{-7} m^2, and its resistance is measured to be 5.0 Ω. What is the resistivity of material at the temperature of the experiment?

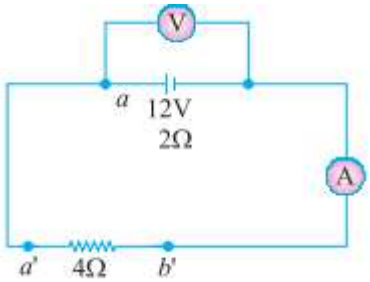
17. In a meter bridge, two unknown resistances R and S when connected in the two gaps, give a null point at 40cm from one end. What is the ratio of R and S?

18. A heater coil is rated 100W, 200V. It is cut into two identical parts. Both parts are connected together in parallel to the same source of 200V. Calculate the energy liberated per second in the new combination. **(200W)**

19. Potential difference across terminals of a cell are measured (in volt) against different current (in ampere) flowing through the cell. A graph was drawn which was a straight line ABC. Using the data given in the graph. Determine (i) the emf. (ii) The internal resistance of the cell. Ans. r = 5Ω emf = 1.4V



20. In the figure, an ammeter A and a resistor of resistance R = 4Ω have been connected to the terminals of the source to form a complete circuit. The emf of the source is 12V having an internal resistance of 2Ω. Calculate voltmeter and ammeter reading.



MCQ (Multiple-choice question)

1) Current carriers in electrolytes are

a) Volt b) positive ion

c) Watt d) Positive and Negative ion

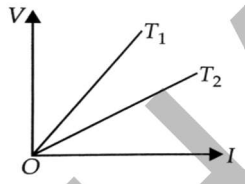
2) Graphs between I and V are plotted for a conductor at temperatures T_1 and T_2 as shown in figure:

a) $T_1 = T_2$

b) $T_1 > T_2$

c) $T_1 < T_2$

d) $T_1 \geq T_2$



3) If mobility of electron is μ_e and mobility of hole is μ_h, then

a) $\mu_e = \mu_h$ b) $\mu_e > \mu_h$

c). $\mu_e < \mu_h$ d) $\mu_e \leq \mu_h$

4) Which of the following relations is not correct?

a) $E = \frac{J}{\sigma}$

b) $J = \sigma E$

c) $E = \frac{J}{\rho}$

d) $\rho J = E$

5) Two cells, each of e.m.f. 'E' and internal resistance 'r' connected in series are connected to an external resistance R. The current in the circuit will be maximum if

a) R = 2r

b) R << 2r

c) R=r/2

d) R >> 2r

6) If the temperature of a conductor increases, its conductivity,

a) Increases

b) Decreases

c) Increases linearly

d) Decreases linearly.

7) The current flowing through a wire depends on time as $I = 3t^2 + 2t + 5$. The charge flowing through the cross-section of the wire in time t = 0 and t = 2s is

a) 5 C b)18 C

c) 20 C d) 22 C

8) The masses of three copper wires are in the ratio 5 : 3 : 1 and their length are in the ratio 1 : 3 : 5. The ratio of their electrical resistance is:

a) 1 : 3 : 5
b) 5 : 3 : 1
c) 1 : 15 : 125
d) 125 : 15 : 1

9) A set of n identical resistors, each of resistance R Ω when connected in series has effective resistance of X Ω and when resistors are connected in parallel the effective resistance is Y Ω. Find relation between R, X and Y

a) R = $\sqrt{XY}$
b) R = $\sqrt{X}$ Y
c) R =$X\sqrt{Y}$
d) $\sqrt{R}$ = XY

10) Copper and silicon are cooled from 300K to 60K, the specific conductivity:

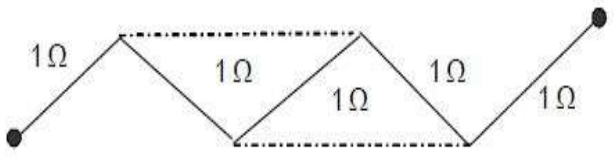
a) Increases in both
b) Decreases in both
c) Decreases in Cu but increases in Si.
d) Increases in Cu but decreases in Si.

11) Two copper wires A and B of same diameter have lengths 3cm and 5cm respectively. R_A and R_B are the resistance of A and B and ρ_A and ρ_B are the resistivity's respectively. Identify the correct statement.

a) $R_A > R_B$, $\rho_A > \rho_B$
b) $R_B > R_A$, $\rho_A > \rho_B$
c) $R_A > R_B$, $\rho_A < \rho_B$
d) $R_A < R_B$, $\rho_A = \rho_B$

12) A circuit consists of 5 identical conductors as shown in figure. The two similar conductors are added as indicated by dotted lines. The ratio of resistances before and after addition will be

a) 7/5
b) 3/5
c) 5/3
d) 6/5

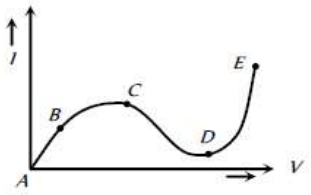


13) The conducting wire is marked with three color strips red, red and orange. The value of its resistance is

a) 22 Ω b) 220 Ω
c) 2200 Ω d) 22000 Ω

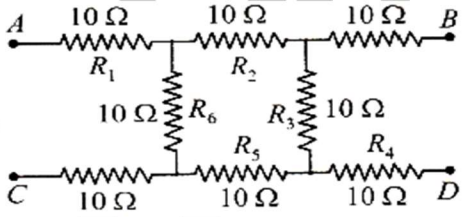
14) From the graph between current (I) and voltage (V) as shown in figure, identify the portion corresponding to negative resistance

a) AB
b) BC
c) CD
d) DE



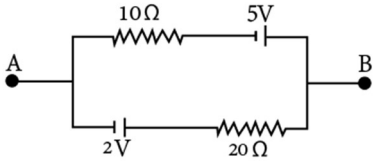
15) What will be the equivalent resistance between the points A and D?

a) 10 Ω
b) 20 Ω
c) 30 Ω
d) 40 Ω



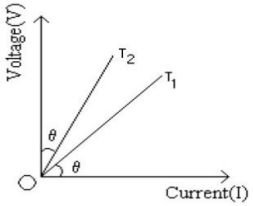
16) The current I in the given circuit is

a) 0.1 A
b) 0.2 A
c) 0.3 A
d) 0.4 A



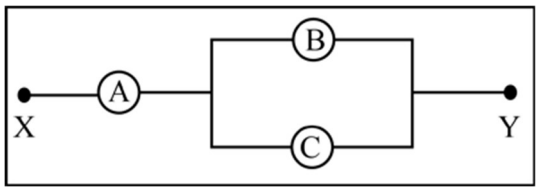
17) The V-I graphs for a conductor at temperature T_1 and T_2 are shown in figure. Here, $(T_2 – T_1)$ is proportional to

a) Cos 2θ
b) Cot 2θ
c) Sin 2θ
d) Tan 2θ



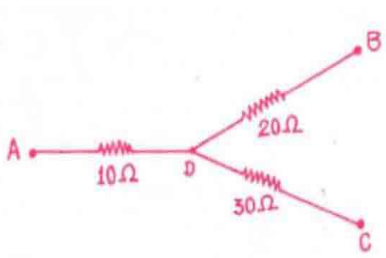
18) Three voltmeter A, B and C having resistance R, 1.5R and 3R respectively are used in circuit as shown. When a P.D. is applied between X and Y, the reading of the voltmeter are V_1, V_2 and V_3 respectively. Then

a) $V_1 > V_2 = V_3$
b) $V_1 > V_2 > V_3$
c) $V_1 < V_2 = V_3$
d) $V_1 = V_2 = V_3$



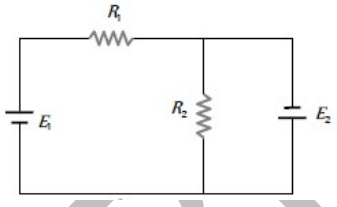
19) In the circuit given, the points A, B and C are 70 V, zero, 10 V respectively. Then

a) Current in the paths AD, DB and DC are in the ratio 3 : 2 : 1
b) Current in the paths AD, DB and DC are in the ratio 1 : 2 : 3
c) The point D will be at a potential of 20V
d) The point D will be at a potential of 60V



20) Two resistance R_1 and R_2 are joined, as shown in the figure, to two batteries of e.m.f E_1 and E_2 is short- circuited, the current through R_1 is

a) E_1/R_1
b) E_2/R_1
c) E_2/R_2
d) $E_1/(R_1 + R_2)$



21) A heater coil rated as (P, V) is cut into two equal parts. One of the parts is then connected to a battery of V volt. The power consumed by it will be

a) P b) P/2
c) P/4 d) 2P

22) The resistance of a wire of length L and radius r is R. Which one of the following would provide a wire of the same material of resistance R/2?

a) Using a wire of same radius and twice the length
b) Using a wire of same radius and half length
c) Using a wire of same length and twice the radius
d) Using a wire of same length and half the radius **(2025)**

23) Two conductors A and B of the same material have their lengths in the ratio 1:2 and radii in the ratio 2:3. If they are connected in parallel across a battery, the ratio V_A / V_B of the drift velocities of electrons in them will be-

a) 2 b) 1/2
c) 3/2 d) 8/9 **(2025)**

24) Two wires P and Q are made of the same material. The wire Q has twice the diameter and half the length as that of wire P. If the resistance of wire P is R, the resistance of the wire Q will be **(2025)**

a) R b) R/2
c) R/8 d) 2R

ASSERTION AND REASONS QUESTIONS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

Q.1 **Assertion (A):** An electric bulb becomes dim, when the electric heater in parallel circuit is switched on.
Reason (R): Dimness decreases after sometime.

Q.2 **Assertion (A):** Ohm's law is applicable for all conducting elements.
Reason (R): Ohm's law is a fundamental law.

Q.3 **Assertion (A):** Voltmeter is connected in parallel with the circuit.
Reason (R): Resistance of a voltmeter is very large.

Q.4 **Assertion (A):** A current continues to flow in superconducting coil even after switch is off.
Reason: Superconducting coils show Meissner effect.

Q.5 **Assertion (A):** A larger dry cell has higher emf.
Reason (R): The emf of a dry cell is proportional to its size.

Q.6 **Assertion (A):** In a simple battery circuit, the point of the lowest potential is positive terminal of the battery.
Reason (R): The current flows towards the point of the higher potential, as it does in such a circuit from the negative to the positive terminal.

Q.7 **Assertion (A):** When identical cells are connected in parallel to the external load, the effective e.m.f increases.
Reason (R): All the cells will be sending unequal current to the external load in the same direction.

Q.8 **Assertion (A):** An ammeter is always connected in series whereas a voltmeter is connected in parallel.
Reason (R): An ammeter is a low-resistance galvanometer while a voltmeter is high-resistance galvanometer

Q.9 **Assertion (A):** Each bulb in a frill of 20 bulbs in series when connected to supply voltage will emit more light than each bulb in frill of 19 bulbs in series when connected to same supply voltage.
Reason (R): Each bulb in a frill of 20 bulbs in series will get less voltage than that in frill of 19 bulbs.

Q.10 **Assertion (A):** Kirchhoff's voltage law indicates that electro static field is conservative.
Reason (R): Potential difference between two points in a circuit does not depends on path.

Q.11 **Assertion (A):** Current is a scalar quantity.
Reason (R): Electric current arises due to continuous flow of charged particles or ions.

Q.12 **Assertion (A):** The resistance of a copper wire varies directly as the length and diameter.
Reason (R): Because the resistance varies directly the area of cross-section.

Q.13 **Assertion (A):** Terminal potential difference of a cell is always less than its emf.
Reason (R): Potential drop on internal resistance of cell increases terminal potential difference.

Q.14 **Assertion (A):** When Wheatstone Bridge is balanced then current through cell depends on resistance of galvanometer.
Reason (R): At balanced condition current through galvanometer is non zero.

Q.15 **Assertion (A):** When cells are connected in parallel to the external load, the effective e.m.f increases.
Reason (R): Because effective internal resistance of cells decreases.

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