Chapter = 13

CURRENT ELECTRICITY

CURRENT ELECTRICITY: "**The branch of physics which deals with the study of charges in motion through conductors is called current electricity. It is also called Electrodynamics**".

WHAT IS ELECTRIC CURRENT? GIVE ITS FORMULA, UNIT.

ELECTRIC CURRENT: "The time rate of flow of charges through any cross section of conductor is called electric current".

$I = \frac{\Delta Q}{\Delta t}$ And SI unit is ampere. It is scalar quantity.

Definition of "ampere": When one coulomb charge passes through any cross section of a conductor in one second, the current will be one ampere. 1 ampere= 1 Coulomb/ 1sec.

Charge carriers: Electric current is due to flow of charge particles, these charged particles are called charge carriers.

Charge carriers in metals: Negatively charged particle i.e electrons

Charge carriers in electrolyte: Positive and negative ions

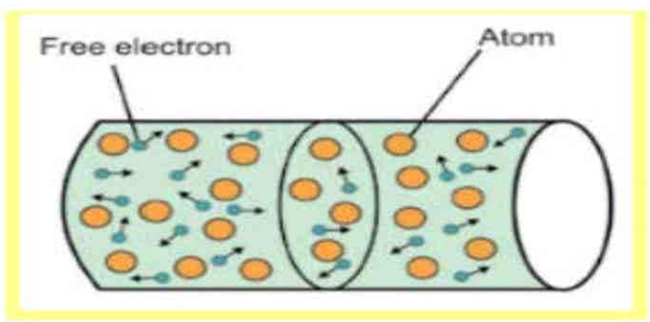
Charge carriers in gases: Electrons and ions

Charge carriers in semiconductor: Free electrons and holes

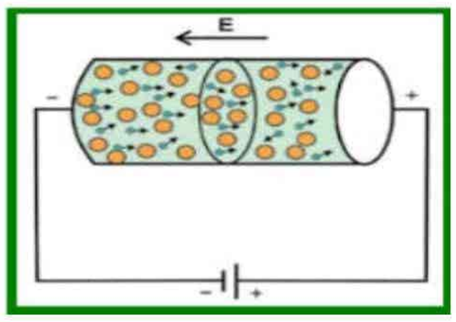
What is difference b/w electronic flow and conventional flow of electric current?

ELECTRONIC FLOW OF ELECTRIC CURRENT	CONVENTIONAL FLOW ELECTRIC CURRENT
The current which passes from a point of lower potential to high potential is called electronic flow of current	The current which passes from a higher potential to lower potential is called conventional flow of electric current
It is shown by the motion of negative particles	It is shown by motion of positive charges

Current through metals when no battery is connected: Current through the wire is zero in this case because free electrons passes through it from right to left is same as the rate at which pass from left to right.



Current through metals when battery is connected:



Drift Velocity:"Average constant velocity of free electrons inside the metallic conductors in opposite to electric field intensity is called drift velocity". Its value is 10^{-3} m/s.

Steady current: Steady current is maintained in wire when a constant potential difference is applied across it which produce necessary electric field along the wire.

WHAT ARE SOURCES OF CURRENT? DEFINE THEM.

Sources of current: A source which provides a constant potential difference across the conductor or ends of conductor is called source of current like generator, cell etc. OR A device which converts non electrical energy into electrical energy is called source of current. Some sources of current are as follows

- **Cell:** The device which convert chemical energy into electrical energy is called cell.
- **Electric generator:** The device which converts mechanical energy into electrical energy is called electric generator.
- **Thermocouple:** The device which converts heat energy into electrical energy is called thermocouple.
- **Solar cell:** The device which converts light energy into electrical energy is called solar cell.

EFECTS OF CURRENT

The presence of electric current is detected by various effects which are called effects of current namely

- **EXPLAIN HEATING EFFECT?**

The effect which is produced due to flow of current through metallic wire in which electrons collide with atoms of metals and give some their K.E to these atoms as result the kinetic energy of vibrations of atoms increased which generated heat is called heating effect $H=I^2Rt$, this effect is used in electric heater, kettles, toasters and in electrons iron.

- **EXPLAIN MAGNETIC EFFECT?**

An effect which is produce around the wire or coil when current flows through it is called magnetic effect and it is used in galvanometers, motors, fans, drill machines etc.

- **EXPLAIN CHEMICAL EFFECT?**

An effect that is produced by certain liquids like sulphuric acid solution conduct electricity due to some chemical reactions that placed within them is called chemical effect.

Chemical effect depend: It depends on a) nature of liquid b) quantity of electricity pass through it

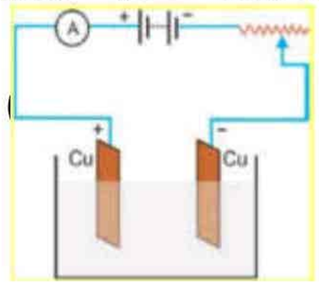
Electrolyte: The liquid which conduct electric current is called electrolyte.

Electrode: The material in the form of wire, rod or plate at which electric current enters or leave the electrolyte is called electrode.

Anode: The electrode connected with positive terminal of battery is called anode.

Cathode: The electrode connected with negative terminal of battery is called cathode

Voltammeter: The vessel containing two electrodes and liquid is called voltammeter.



Electroplating: A process in which a thin layer of an expensive metal is deposited on cheap metal is called electroplating.

STATE AND EXPLAIN OHM'S LAW.

Statement Of Ohm's Law: "Current flowing through a conductor is directly proportional to the potential difference across its ends provided physical state such as temperature remains same". V=IR,

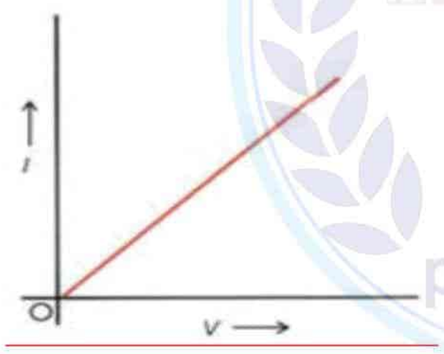
1/R is the constant in Ohm's law.

Resistance: The opposition to the flow of charge through conductor is called electrical resistance. R=V/I and unit is ohm.

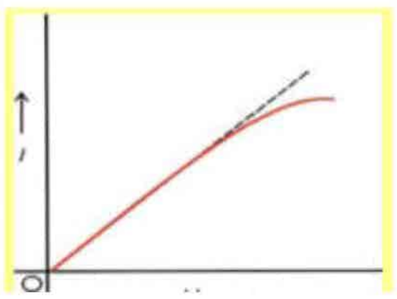
Ohm: If one ampere current is passed through a conductor by applying one volt potential difference, then resistance will be one ohm. 1ohm= 1volt/1 ampere

Factors upon resistance depends: Resistance of conductor depends upon nature, dimensions and physical state (temperature) of conductor.

Ohmic devices: The devices for which Ohm's law hold good and graph b/w V and I is straight line are called ohmic devices. For example metallic conductors silver gold etc.



Non ohmic devices: The devices for which Ohm's law not hold good and graph b/w V and I is not straight line are called non ohmic devices. For example filament of bulb, semiconductor diode.

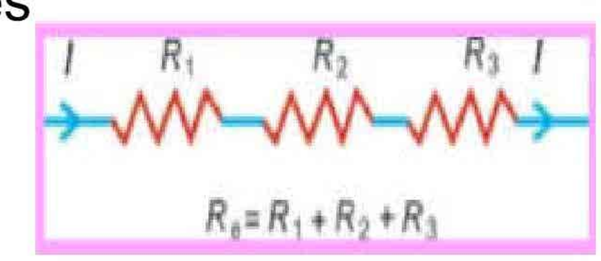


Graphical form of Ohm's law: Graphical form of Ohm law is Straight line.

EXPLAIN SERIES COMBINATION OF RESISTORS.

Definition: Such a combination in which resistors are connected end to end such that same current pass through it is called series combination of resistors. $Re=R_1+R_2+R_3+$…… They have following properties

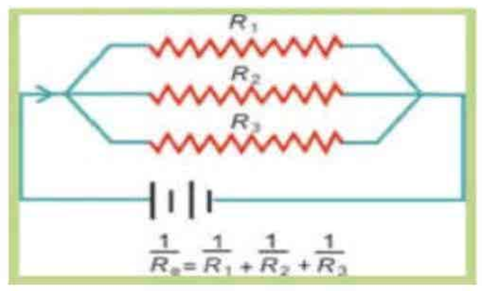
i. In series combination total resistance is **increased**
ii. Current is **same** through each R
iii. Voltage is **different** through each R



EXPLAIN PARALLEL COMBINATION OF RESISTORS

Such a combination in which resistors are connected side by side with their end connected together at common point to voltage source is called parallel combination of resistor. $1/R_e=1/R_1+1/R_2+1/R_3+$……They have following properties

i. In parallel combination, total resistance is **decreased**
ii. Voltage is **same** through each R
iii. Current is **different** through each R



Multiple Choice Questions

1	1 ohm is defined as	1 V/C	**V/A**	C/V	VA
2	The graphical representation of Ohm law is	Hyperbola	Ellipse	Parabola	**Straight line**
3	Ohm law is	**V=IR**	V=R/I	$V=I^2R$	I=VR
4	A source of 10V is applied across 5ohm wire, the current through wire will be	1A	**2A**	10A	15A
5	Current flow in gases due to	Electron only	**Electrons and ions**	Positive and negative ions	Electrons and holes
6	A student has five resistances each of value 1/5 ohm. The minimum resistance that can be obtained by combining them in parallel is	1/50 ohm	**1/25 ohm**	1/10 ohm	5 ohm

7	The proportionality constant between current and potential difference is	P	R	**1/R**	V
8	In liquid and gases current is due to motion of	Negative charges	Positive charges	Neutral charges	**Electrons and positive and negative ions**
9	In which of these heating effect used	Electric heater	Kettles	Electric iron	**All of these**
10	Three resistances 5000,500 and 50 ohms are connected in series across 550V mains, the current through them	1A	**100mA**	10mA	1Ma
11	The magnitude of drift velocity is order	**10^{-3} m/s**	10^{6} m/s	10^{-6} m/s	10^{7} m/s
12	A battery of 50V is attached to a series combination of 5,10,10ohm , the current in circuit is	**2A**	5A	10A	20A
13	The flow of charge through a uniform cross section wire in a unit time is called	**Current**	charge	Power	Ampere
14	Electrical analog of mass in electricity is	Capacitance	Inductance	**Charge**	Resistance
15	The smallest resistance obtained by connected 50 resistance each of ¼ ohm	200 ohm	**1/200 ohm**	50/4 ohm	4/50 ohm
16	The heat produced by the passage of	**I^2Rt**	IR^2t	I/TR	HIR

	current through a resistor H=?				
17	The potential difference between head and tail of electric eel is	400 V	500V	**600V**	700V
18	A current of 1 A ampere passes through a wire in in 1 min, charge flowing	**60C**	30C	1 c	0.016 C
19	The current which flow from higher potential to lower potential is called	Electronic current	**Conventional current**	Directional current	Either of these

Write a note on RESISTIVITY AND ITS DEPENDANCE UPON TEMPERATURE

Resistivity or specific resistance: The resistance of a meter cube of material is called resistivity or specific resistance.

Mathematically $R \propto L$ $R \propto \frac{1}{A}$ $R \propto \frac{L}{A}$ its unit is ohm m (Ωm).

$$R = \rho \frac{L}{A} \Rightarrow \rho = R\frac{A}{L}$$

Difference b/w Resistance and Resistivity

Resistance	Resistivity
The measure of opposition to flow charge	Resistance of one meter of cube of wire
Unit of resistance is ohm(Ω)	Unit of resistivity is ohm meter (Ωm)
Resistance depends upon nature, temperature and geometry of wire	Resistivity depends upon nature and temperature only

Conductance: The reciprocal of resistance is called conductance. Its formula is G=1/R and unit is mho or Siemen

Conductivity: The reciprocal of resistivity is called conductivity, its formula is σ=1/ϱ and its unit is mho m^{-1}.

Effect of temperature on resistance of conductor: The resistance of conductor increased as the temperature of conductor rises, K.E of atoms increases and they vibrate with greater amplitude so electrons find it more difficult to pass through them.

R_o = Resistance of material at 0^oC

R_t = Resistance of material at t^oC

$R_t - R_o \propto R_o$ $R_t - R_o \propto t$ $R_t - R_o \propto R_o t$

$R_t - R_o = \alpha R_o t$ $\alpha = \frac{R_t - R_o}{R_o t}$ α is temperature co - efficient of resistance

Temperature co-efficient of resistance: The fractional change in resistance per kelvin is called temperature co-efficient of resistance. Its formula is $\alpha = \frac{R_t - R_o}{R_o t}$ and unit is k^{-1}

Temperature co-efficient of resistivity: The fractional change in resistivity per kelvin is called temperature co-efficient of resistivity. Its formula is $\alpha = \frac{\rho_t - \rho_o}{\rho_o t}$ and unit is K^{-1}.

Positive and Negative temperature co-efficient of resistance α:

If resistance of conductor increase with increase of temperature then α is positive

If resistance of conductor decrease with increase of temperature then α is negative. Like Si, Ge etc

Explain COLOR CODE FOR CARBON RESISTOR

Carbon resistor: It consists of high grade ceramic rod or cone known as substrate on which thin resistive film of carbon is deposited.

Color code of carbon resistor: The numerical value of carbon resistors is indicated by a color code which consists of bands of different colors printed on body of the resistors.

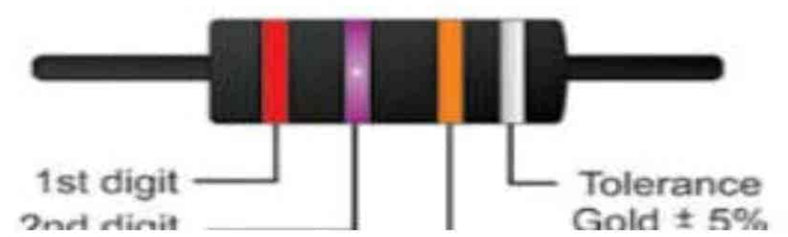
Bands in color code of resistor: There are four bands1st band: indicates 1st digit. 2nd band: indicates 2nd digit3rd band: indicates no of zeroes. 4th band: show tolerance

Tolerance: Possible variation from the marked value of resistance is called tolerance.

Tolerance of silver is ±10% and gold is ±5%. If there is no 4th band then tolerance will **±20%**

The color code

Color	Value	Color	Value
Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Gray	8
Yellow	4	White	9



What is RHEOSTAT? Give its uses.

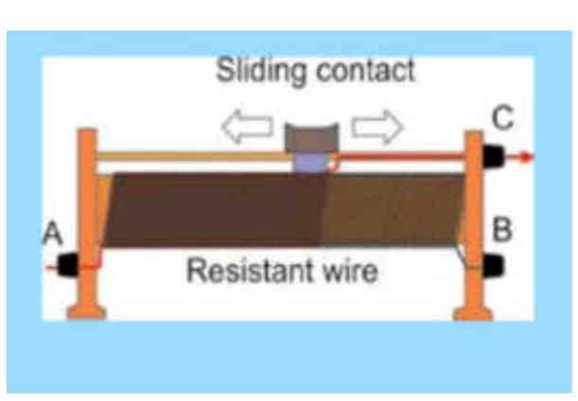
Rheostat: "A wire wound variable resistors which consist of bare mangnin wire over an insulating cylinder and its resistance can be changed is called Rheostat".

Uses of Rheostat: Rheostat can be used as

i. **Variable resistor**: A rheostat acts as variable resistor when terminal A and sliding terminal C are connected in circuit are used and this sliding terminal shifted increase or decrease the resistance. As shown in fig a

ii. **Potential divider:** A potential difference V is applied across the ends A and B of rheostat and R is the resistance of wire and r is the resistance b/w B and C then potential b/w the portion BC of wire AB will be

V_{BC}= V/R*r or V_{BC}=r/R*V this can be shown in fig b



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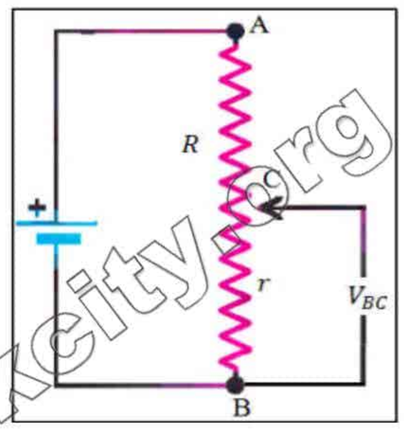

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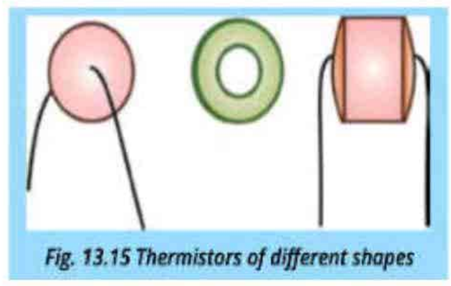


Fig. 13.15 Thermistors of different shapes

What is THERMISTOR? Write construction, advantage and uses.

Thermistor: A heat sensitive resistor is called thermistor. It is resistor whose resistance changes with temperature.

It has positive as well as negative temp. Co-efficient of resistance.

Construction: Thermistor are made from ceramics which are mixture of metallic oxides, manganese, nickel, cobalt, copper and iron etc. by heating them under high pressure.

Shapes of thermistor: They may be in the form of beads, rods or washers

Advantage of thermistor: Thermistor with high negative temperature co-efficient are very accurate for measuring low temperature especially near 10K.

Application/Use of thermistor: Thermistor are temperature sensors so they convert change in temperature into electrical voltage.

Multiple choice questions

1	If fourth band on a carbon resistor is of silver color then its tolerance is	±1%	±5%	**±10%**	±20%

2	A rheostat can be used as	Variable resistor	Potential divider	**Both A&B**	None of these
3	The substance having negative temperature co-efficient is	**Germanium**	Aluminum	Copper	Cobalt
4	Temperature co-efficient of resistivity of a material is measured in	Ohm-K	Ohm-m	Kelvin	**Per kelvin**
5	The color code for carbon resistor usually consist of	2 bands	**4 bands**	5 bands	7 bands
6	Resistivity is reciprocal of	Conductance	**Conductivity**	Induction	None of these
7	Tolerance for gold color is	±1%	**±5%**	±10%	±20%
8	The numerical value of violet color in color code represents	0	3	5	**7**
9	A wire of uniform area of cross section A and length L cut into two equal parts	Doubled	**Remain same**	Half	Increase three times

	the resistivity of each part is				
10	Siemen is the unit of	Resistance	**Conductance**	Resistivity	Conductivity
11	Resistivity of conductor increase with	Increase in Length	Increase in area	**Increase in its temperature**	Decrease in length
12	The substance having negative temperature co-efficient is	**Carbon**	Iron	Tungsten	Gold
13	Resistivity at a given temperature depends on	Area of cross section	Length	**Nature of material**	Both length and area
14	If the conductivity of a material is small then it is	Conductor	**A poor conductor**	A good conductor	An insulator
15	A thermistor is	A resistor	**Thermal sensitive resistor**	An adiabatic resistor	An isothermal resistor
16	Color code for green color is	2	3	4	**5**
17	Mho m^{-1} is the SI unit of	Conductivity	**Conductance**	Resistance	Capacitance
18	A rheostat can be used as	**Potential divider**	Conductance	Rectifier	Amplifier
19	The numerical value of	0	**3**	5	8

	orange color in color code carbon resistor is				
20	When conductivity of material is high then it is	An insulator	A semiconductor	**A good conductor**	A superconductor
21	A thermistor is a heat sensitive	Capacitor	Diode	**Resistor**	Inductor
	A wire of uniform area of cross section A and length L is cut into two equal parts, the resistance of each part becomes	Double	**Half**	4 times	One fourth
22	The color of strips on a carbon resistor from extreme left are yellow, black and red respectively its resistance will be	**4 killo ohm**	400 ohm	40 ohm	40 killo ohm
23	The numerical value of black color is	1	**0**	2	3
24	When	**Increases**	Decreases	Remains	Vanish

	temperature increases, the resistance of conductor			same	
25	The numerical value of orange color in color code carbon resistor is	0	**3**	5	8
26	If resistance is 500 ohm have fourth band of silver color then its upper maximum resistance will be	600 ohm	450 ohm	**550 ohm**	400 ohm
27	Specific resistance of material depends	Length	Area	**Temperature**	Both A&B
28	If there is no fourth band in carbon resistor then tolerance will be	±1%	±5%	±10%	**±20%**
29	A zero ohm resistor is indicated by a	**Single black color**	Single red color	Single blue color	Single green color
30	What is resistance of carbon	**100 ohm**	150 ohm	200 ohm	250 ohm

	resistor which bands brown, black and brown				
31	What is the color code for 52MΩ±5%?	**Green,red,blue** **Gold**	Green, blue, red Violet	Yellow,green, blue, yellow	Violet, red,green, gray
32	If resistor is indicated by single black color then value of resistance is	**Zero ohm**	One ohm	10 ohm	100 ohm
33	If the length of conductor is doubled and area of cross section is halved, its conductance becomes	Increase four times	**Decrease four times**	Becomes half	Remain same
34	Which is an example of wire wound variable resistor	Potentiometer	**Rheostat**	Thermistors	Wheatstone bridge
35	SI unit of conductance is	Ohm	**Siemen**	Per ohm	Per Kelvin
36	Substance having negative temperature coefficient	**Carbon**	Iron	Tungsten	Gold
37	Reciprocal of resistance is	**Conductance**	Conductivity	Resistivity	None
38	Color code	**Brown black**	Black black	Brown black	Brown black

	of 10 ohm resistance with 5% tolerance	**black gold**	brown gold	silver	black silver
39	Thermistor convert temperature into	**Electrical voltage**	heat	Sound	Light energy

What is ELECTRICAL POWER AND POWER DISSIPATION IN RESISTORS

Electrical power: The rate at which battery is supplying energy is called electrical power. Its unit watt.

Power dissipations in Resistors: If a circuit consisting of battery and Resistance R the work done in moving a charge through potential difference V in time Δt.

$$W = V * \Delta Q$$

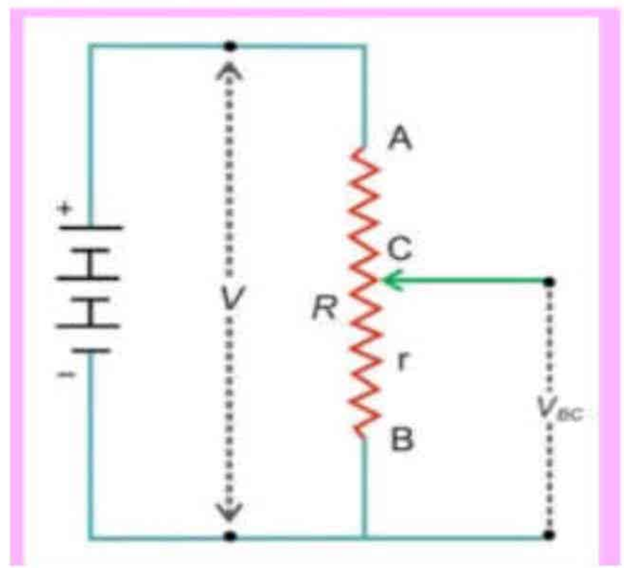
$$\text{Electrical power} = P = \frac{\Delta W}{\Delta t}$$

$$P = \frac{V * \Delta Q}{\Delta t} = V * \frac{\Delta Q}{\Delta t}$$

$$P = VI$$

$$P = (IR)I = I^2R \quad \text{or}$$

$$P = V(V/R) = V^2/R$$



Definition of watt :If one ampere current is passed through wire by applying one volt potential then power will be one watt

1 watt= 1 volt x 1ampere

Explain ELECTROMOTIVE FORCE AND POTENTIAL DIFFERENCE

EMF: "The energy supplied by the battery to a unit positive charge is called emf".

Consider a battery which is connected across resistance to maintain steady current then

E=Energy supplied/ charge= ΔW/ΔQ, SI unit of emf is J/C also known as volt.

Terminal potential difference: The potential difference across the terminals of cell or battery when current is drawn from it is called terminal potential difference.

Internal Resistance: "The resistance officered by electrolyte present b/w the electrodes of cell are called internal resistance denoted by r".

Expression b/w terminal potential difference and emf:

Consider a cell of emf E having internal resistance r connected as shown in fig and V is the terminal potential difference across the external resistance R. The current flowing through circuit is

$$I = \frac{E}{R+r} \Rightarrow E = IR + Ir \Rightarrow E = V_t + Ir$$

$V_t = E - Ir$ This is the relation for terminal potential difference

if internal resistance $r = 0$ then $V_t = E$ in special case

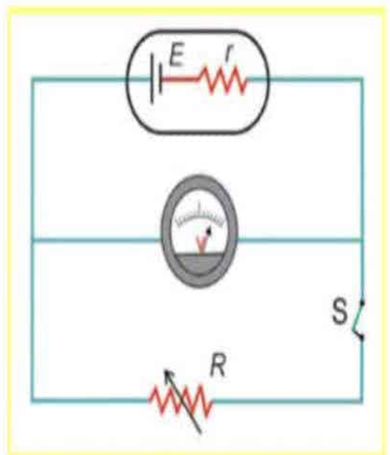


Fig. 13.19 The terminal potential difference V of a cell is E - I r

Difference b/w emf and potential difference

Emf	Potential difference
Emf is cause	Potential difference is effect
Emf is always present even no current passes through battery	Potential difference across the conductor is zero when no current pass through it

MAXIMUM POWER OUT PUT

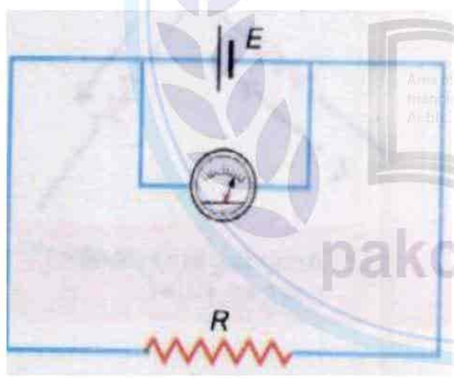
If current I flows through the resistance R, the charges flow from a point of higher potential to lower and loss of potential energy per second across R is VI. The loss of energy per second appear in the form of power delivered to R by current.

Power delivered to $R = Pout = VI = (IR)I = I^2R$

As we $I = \frac{E}{R+r}$

$$P = \left(\frac{E}{R+r}\right)^2 R$$

$$P = \frac{E^2 R}{(R+r)^2}$$



$$P = \frac{E^2 R}{(R-r)^2 + 4Rr}$$

as $(a+b)^2 = (a-b)^2 + 4ab$

if $r = R$ then maximum power out put relation

$$P_{max} = E^2/4r$$

KIRCHOFF RULES

State Kirchhoff first rule:

Statement :"Sum of all the currents meeting at a point in a circuit is zero".

$\sum I = 0$

Proof:

consider four wire carrying current I_1, I_2, I_3 and I_4

Current flowing towards point A which take as positive

is equal to current flowing away from the point A taken as

negative $I_1 + I_2 + (-I_3) + (-I_4) = 0$

$I_1 + I_2 = I_3 + I_4$, this law is accordance to law of conservation of charge

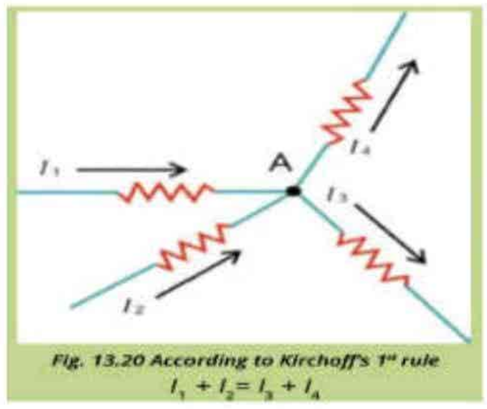


Fig. 13.20 According to Kirchoff's 1st rule
$I_1 + I_2 = I_3 + I_4$

State Kirchhoff 2nd rule:

Statement: "**Algebraic sum of voltage changes in closed circuit or loop is equal to zero ∑V=0**".

Explanation: Consider a circuit which consists of two cell of emf E1 and E2 and two resistors R1 and R2. The direction of current depends upon the cell of larger emf. If E1 is greater than E2 then current flow in anti clock wise direction.

First of all for finding potential changes following rules should be applied

i. Potential change is positive if source of emf is traversed from negative to positive terminal otherwise it negative
ii. Potential change is negative if resistor is traversed in the direction of current

Proof: As Kirchhoff 2nd rule is according to law of conservation of energy so across each terminal we find energy gain and lost and then adding to get the result

Energy gained across $E_1 = E_1 \Delta Q$ ----------(1

Energy lost across $E_2 = -E_2 \Delta Q$ ----------(2

Energy lost across $R_1 = -IR_1 \Delta Q$ ----------(3

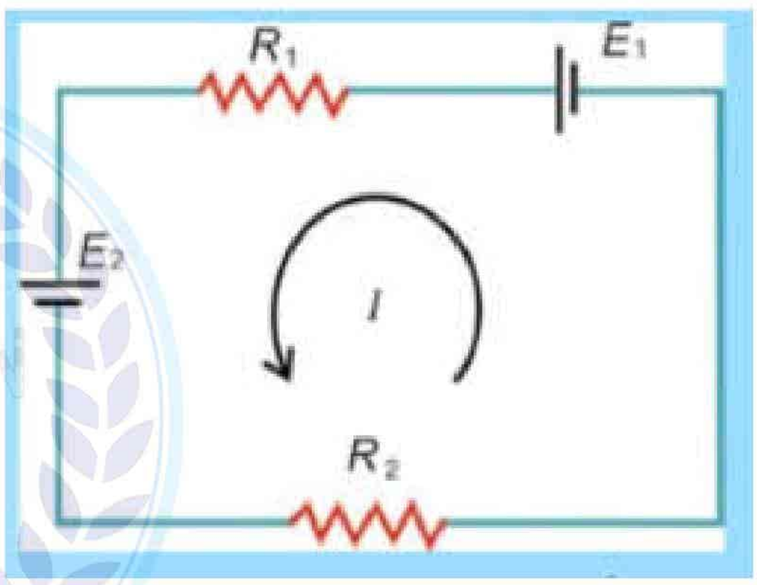
Energy lost across $R_2 = -IR_2 \Delta Q$ ----------(4

Adding all equations

$E_1 \Delta Q + (-E_2 \Delta Q) + (-IR_1 \Delta Q) + (-IR_2 \Delta Q) = 0$

$\Delta Q(E_1 - E_2 - IR_1 - IR_2) = 0$

$E_1 - E_2 - IR_1 - IR_2 = 0$ This is required Result



Multiple Choice Questions

1	Maximum power delivered by battery is	**$E^2/4r$**	$4r^2E$	Vit	V^2R
2	Kirchoff first rule is based on conservation o f	Energy	Voltage	**Charge**	Mass
3	SI unit of electric power is	**Watt**	Killo watt sec	Joule	KWh

4	The terminal potential difference of battery of short circuit of emf E is equal	2E	**E**	E/2	0
5	Electromotive force is closely related to	Electric intensity	Magnetic intensity	**Potential difference**	Inductance
6	The power output of a lamp is 6W. how much energy does the lamp gives out in 2 minutes	3J	12J	120J	**720J**
7	Power output is given by	$\frac{E2R}{(R+r)2}$	$\frac{E2R}{(R\quad r)2+4Rr}$	I^2R	**All of these**
8	100W bulb is operated by 200V, the current flowing through bulb is	**0.5A**	1A	2A	2.5A
9	SI unit of emf is	Newton	Pascal	**Volt**	Ampere
10	Kirchoff 2nd rule is accordance to law of conservation of	**Energy**	Mass	Charge	Momentum
11	Potential difference between head and tail of electric eel	**600V**	700 V	800 V	900 V
12	When current is drawn from cell, its terminal potential difference and emf is equal	**Different**	Same	Zero	Negative
13	For open circuit, terminal potential difference Vt is	**Vt=emf**	Vt=2emf	Vt=3emf	Vt=emf/2

Write PROCEDURE OF SOLUTION OF CIRCUIT PROBLEMS

Following steps should be taken to solve the circuit problem

- Draw the circuit diagram
- Choose the loop which contain at least one resistance

- Assume a loop current in each loop which may be clock wise or anti clock wise
- Write the loop equations for selected loops according to Kirchhoff voltage rule
- Solve these equations for unknown quantities.

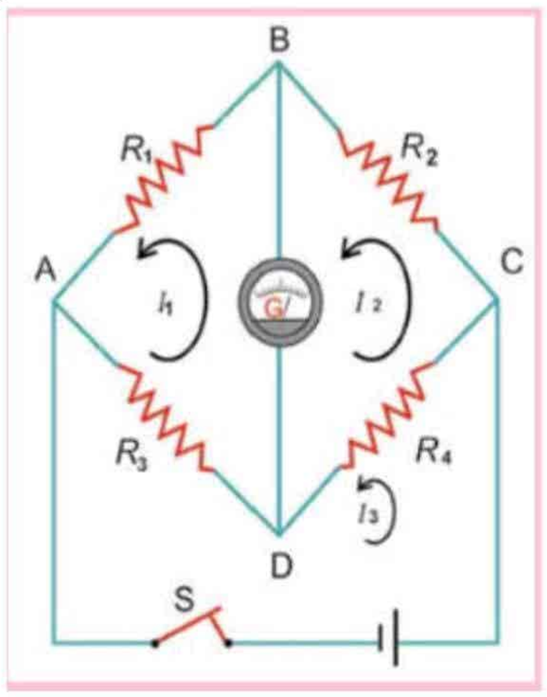
What is WHEAT STONE BRIDGE? Write its construction and working. Derive formula.

Definition: "An electrical circuit that is used to measure the value of unknown resistance is called Wheatstone bridge".

Construction: This circuit consists of four resistance R_1, R_2,R_3 and R_4 connected in such a way that form a loop ABCDA. A battery of emf E is connected b/w A and C and sensitive galvanometer is connected b/w B and D.

Working: If the key is closed a current will flow through galvanometer. We are to find the under which no current will flow through galvanometer even the key is closed.

Derivation: Using Kirchhoff voltage rule we consider two loop ABDA and BCDB and assume clock wise current I1 and I2 through the loop



Across the loop ABDA $-I_1R_1-(I_1-I_2)R_g-I_1R_3=0$ -------(1)

Across the loop BCDB $-I_2R_2-(I_2-I_1)R_g-I_2R_4=0$ -------(2)

under the balance condition $I_1-I_2=0$ so $I_1=I_2$

Eq (1) becomes $-I_1R_1-(0)R_g-I_1R_3=0 \Rightarrow -I_1R_1-I_1R_3=0$

$-I_1R_1=I_1R_3$ ----------(3)

Eq (2) becomes $-I_2R_2-(0)R_g-I_2R_4=0 \Rightarrow -I_2R_2-I_2R_4=0$

$-I_2R_2=I_2R_4$ ----------(4)

Dividing 3 and 4

$$\frac{-I_1R_1}{-I_2R_2}=\frac{I_1R_3}{I_2R_4} \Rightarrow$$

$$\frac{-I_1R_1}{-I_1R_2}=\frac{I_1R_3}{I_1R_4}$$

$$\Rightarrow \frac{R_1}{R_2}=\frac{R_3}{R_4}$$

$$R_4=\frac{R_2*R_3}{R_1} \qquad \Rightarrow X=\frac{R_2*R_3}{R_1}$$

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TID BITS/USEFUL INFORMATION

How electric eel save from danger?
When electric eel senses danger, it turns itself into a living battery, anyone who attacks this fish is likely to get a shock of **600V** and eel remains safe.
What is value of potential difference b/w head and tail of an electric eel: 600 volt
How inspectors can easily check the reliability of a concrete bridge made with carbon fiber?
Because the fiber conduct electricity, if sensors show that electrical resistance is increasing over time the fibers are separating because of cracks.
How zero ohm is indicated: A Zero ohm resistor is indicated by single black color band around the body of conductor
What measured by voltmeter across the terminals of cell: Emf of a cell on open circuit and Terminal potential difference on closed circuit

What is POTENTIOMETER? Explain its construction and working.

Definition: It is an electrical instrument which is used to measure and compare the potential difference b/w two points without drawing any current from the circuit is called potentiometer.

Principle: When a steady current flow through a wire then potential difference across any length of wire is directly proportional to its length Vαl.

Construction: A potentiometer consists of a resistor R in the form of wire on which terminal C can slide. As the sliding contact moves from A to B, the resistance b/w A and C changes from 0 to R.

Working as Potential divider: Let emf of cell is E, and current flowing through resistor R is $I=E/R$ ----(1)

If r is the resistance b/w A and C then potential drop b/w these points will be $V_{AC}=Ir$ putting the value of current

$V_{AC}=\frac{E}{R}r \quad =\frac{r}{R}E$

Potential drop can be changed by change the value of r.

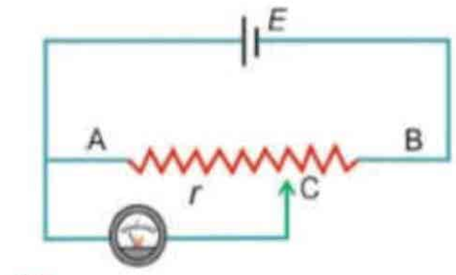
Measurement of unknown emf:

A potentiometer is used to measure the unknown emf of a cell by using

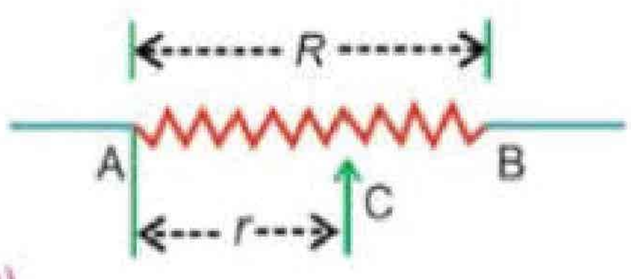
The relation

$$V_{AC} = \left(\frac{r}{R}\right)E$$

$$Ex = \left(\frac{r}{R}\right)E$$



(b)



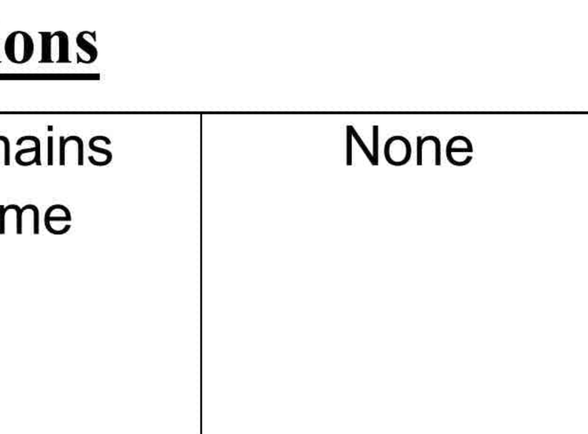
(a)

As resistance is directly proportional to length $R \propto L$ and $r \propto l$ so above equation can be written as

$$Ex = \left(\frac{l}{L}\right)E$$ as ($R = \rho L/A$ $r = \rho l/A$ ....$r/R = l/L$)

L is the length of total wire and l is length of wire b/w A and C.

Comparison of emf of cells: let l_1 and l_2 are balancing lengths for emf of two cells E_1 and E_2 respectively then



$$E_1 = E\frac{l_1}{L} \text{ and } E_2 = E\frac{l_2}{L}$$

Dividing both equations, we get

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

This shows that ratio of emfs is equal to ratio of balancing lengths

Uses of potentiometer: There are following uses of potentiometer

- ✓ To measure the emf of a cell
- ✓ To compare the emf of two cells and as potential divider
- ✓ To measure the internal resistance of cell

Why potentiometer is preferred instead of voltmeter?

Because it draws no current from the circuit and potential difference is measured accurately with this so it is used.

Multiple choice questions

1	If resistance is traversed in the direction of current, the change in potential	Positive	**Negative**	Remains same	None
2	The resistance of open circuit is	Zero	**Infinity**	100 ohm	None of these
3	In open circuit the current flowing through circuit will	Infinite	Finite	Maximum	**Zero**
4	The emf is always	Zero	**Present**	Absent	Maximum

	--- even no current is drawn through the battery or cell				
5	Which one is used to find the internal resistance of cell?	Ammeter	Voltmeter	Galvanometer	**Potentiometer**
6	Wheatstone bridge is used to find unknown	Voltage	Current	Potential	**Resistance**
7	The ratio of emfs in potentiometer is proportional	Ratio of balancing voltage	**Ratio of balancing lengths**	Ratio of balancing current	Ratio of unknown resistances
8	Potentiometer can be used as	Galvanometer	**Potential divider**	Ammeter	All of these

Exercise Short Questions

1.A potential difference is applied across the ends of a copper wire. What is the effect on the drift velocity of free electrons by i. increasing the potential difference ii. Decreasing the length and the temperature of the wire

i. Drift velocity of electron increases with increase in potential difference

ii. Drift velocity of electron also increases by decreasing the length and temperature of wire.

2.Do bends in a wire affect its electrical resistance? Explain**

The resistance of the conductor is described by the formula: $R = \rho \frac{L}{A}$, Where L is the length and A is the cross-section area of conductor. the electrical resistivity of the material which depends upon the nature of conductor. Hence the resistance of conductor depends upon the geometry and nature of conductor. Hence the bends in conducting wires don't affect its electrical resistance.

3. What are the resistances of the resistors given in the figure A and B. What is the tolerance of each?

Fig A	Fig B
Brown 1 (First Digit)	Yellow 4 (First Digit)
Green 5 (Second Digit)	White 9 (Second Digit)
Red 2 (Number of Zero)	Orange 3 (Number of Zero)

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Resistance = 1500 Tolerance = 5%

And therefore

T = Resistance = 49000

And Tolerance = T = 10%

Actual R= 1500±5%

Actual R=49000±10%

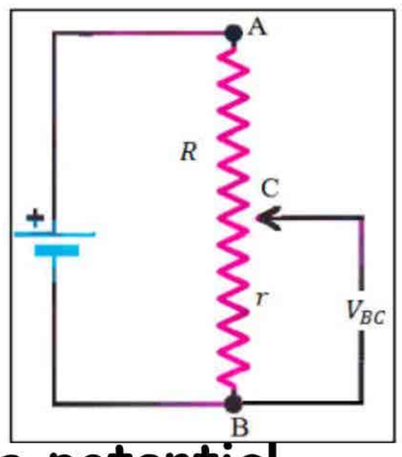
4. Why does the resistance of conductor rise with temperature?**

The resistance offered by a conductor to the flow of electric current is due to collisions which the free electrons encounter with atoms of the lattice. As the temperature of the conductor rises, the amplitude of vibration of atoms increases and hence the probability of their collision with free electrons also increases which result increase of resistance of conductor.

5.What are the difficulties in testing whether the filament of a lighted bulb obeys ohm's law?**

The main difficulty is the rise of temperature of filament with increase of in current. Because for obeying Ohm's law temperature must be remained constant and in filament temperature is changed so ohm's law is not applied on it.

6.Is the filament resistance lower or higher in a 500 W, 220 V bulb than in a 100 W, 220 V bulb?**



$$\text{1st case } R = \frac{V^2}{P} = \frac{(220)^2}{500} = 96.8\Omega$$

$$\text{2nd case } R = \frac{V^2}{P} = \frac{(220)^2}{100} = 484\,\Omega$$

so 100watt bulb has greater resistance

7. **Describe a circuit which will give a continuously varying potential.

A potentiometer can be used as potential divider to give a Continuously varying potential. It consists of resistor R in the Form of wire on which terminal C Can slide and battery is connected In which current I=E/R So V_{AC}=Ir Er/R .it varies from 0 to R

8. ** Explain why the terminal potential difference of a battery decreases when current drawn from itis increases.

The terminal potential difference of the battery of emf is described by the formula: $V_t = E - IR$ Where is the internal resistance of the battery and I is the current flowing through outer circuit. It is clear from equation that when I is large, the factor becomes large and becomes small. Hence terminal potential difference of a battery decreases when current drawn from it is increased.

9. **What is Wheatstone bridge? How can it be used to determine unknown resistance?

It is an electrical circuit which can be used to find the unknown resistance of a wire. By the following formula $\frac{R_1}{R_2} = \frac{R_3}{R_4}$, $X = \frac{R_2 * R_3}{R_1}$ X is unknown resistance.

Chapter = 13

Numerical problems

13.1: How many electrons pass through an electric bulb in one minute if the 300mA current is passing through it?

Given Data : charge on an electron $= e = 1.6*10^{-19}\,C$, time $= t = 1min = 60sec$, $I = 300m = 300*10^{-3}\,A$, $n = ?$

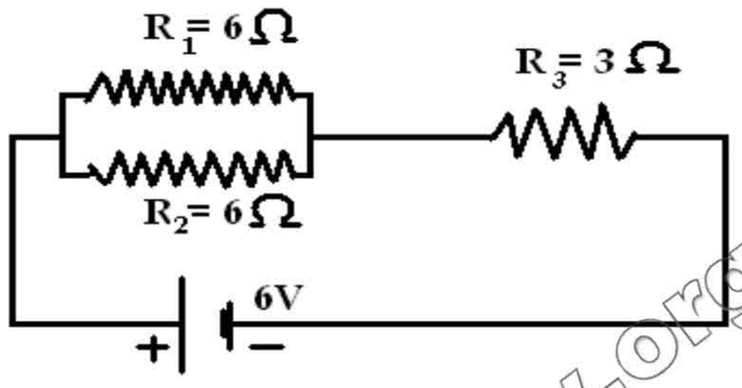
As we know that $I = \frac{Q}{t} = \frac{ne}{t} \Rightarrow n = \frac{I*t}{e} = \frac{300*10^{-3}*60}{1.6*10^{-19}} = 1.125*10^{20}\,electrons$

13.2: A charge of 90C passes through a wire in 1 hour and 15 minutes. What is the current in the wire?

Given data : Charge $= Q = 90C$, time $= t = 1\,hr\,15\,min = 3600\,sec + 900sec = 4500\,sec$, Current $= I = ?$

$I = \frac{Q}{t} = \frac{90}{4500} = 0.02A = 2*10-2 = 2*10^{-2}\,A$ also written as $I = 20mA$

13.3: Find the equivalent resistance of the circuit (Fig.P.13.3), total current drawn from the source and the current through each resistor.



Data : $R_1 = 6\Omega\Omega R_2 = 6\Omega\Omega R_3 = 3\Omega\Omega V = 6V$, $Re' = ?, I = ?, I_1, I_2, I_3 = ?$

Eq.Resistance for first two R $\frac{1}{Re} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow \frac{1}{Re} = \frac{1}{6} + \frac{1}{6} \Rightarrow \frac{1}{Re} = \frac{2}{6} \Rightarrow \frac{1}{Re} = \frac{1}{3} \Rightarrow Re = 3\Omega$

$Re' = Re + R_3 = 3 + 3 = 6\Omega$

Total Current $= I = \frac{V}{Re'} = \frac{6}{6} = 1$ ampere

$I_1 = \frac{V}{R_1} = \frac{3}{6} = 0.5A$, $I_2 = \frac{V}{R_2} = \frac{3}{6} = 0.5\,A$, $I_3 = \frac{V}{R_3} = \frac{3}{3} = 1\,A$

13.4: A rectangular bar of iron is 2.0cm by 2.0cm in cross section and 40cm long. Calculate its resistance if the resistivity of iron is $11\times10^{-8}\Omega m$.

Given Data : Length $= L = 40\,cm = 40/100 = 0.4\,m$, Area $= A = 2*2\,cm^2 = 4*10^{-4}\,m^2$, $\rho = 11*10^{-8}\Omega m$

Solution : $R = \frac{\rho L}{A} = \frac{11*10^{-8}*0.4}{4*10^{-4}} = 1.1*10^{-4}\,ohm$

13.5: The resistance of an iron wire at $0^\circ C$ is $1\times10^4\Omega$. What is the resistance at $500^\circ C$ the temperature coefficient of resistance of iron is $5.2\times10^{-3}K^{-1}$?

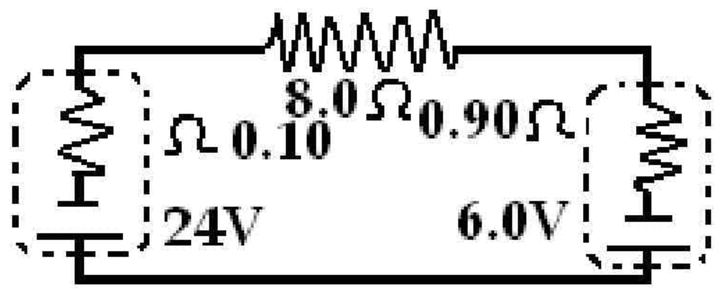
Given Data : $Ro = 1*10^4\,\Omega$, $t_1 = 0^o\,C = 273K$, $t_2 = 500^o\,C = 773K$, $t = t_2 - t_1 = 773 - 273 = 500K$,

$R_t = ?$ $\alpha = 5.2*10^{-3}\,K^{-1}$

As we know that $\alpha = \frac{R_t - R_o}{R_o t} \Rightarrow \alpha R_o t = R_t - R_o \Rightarrow \alpha R_o t + R_o = R_t \Rightarrow R_t = R_o(\alpha t + 1)$

$R_t = 1*10^4\,\Omega(5.2*10^{-3}*500 + 1) = 3.6*10^4\,ohm$

13.6 Calculate terminal potential difference of each of cells in circuit of Fig.



solution :

Given Date : $r_1 = 0.1\Omega, r_2 = 0.9\Omega, R = 8.0\Omega$

$R_e = r_1 + r_2 + R = 0.1 + 0.9 + 8 = 9\Omega$

Effective voltage in circuit $= v_{ef} = E_2 - E_1 = 6 - 2.4 = 3.6V$

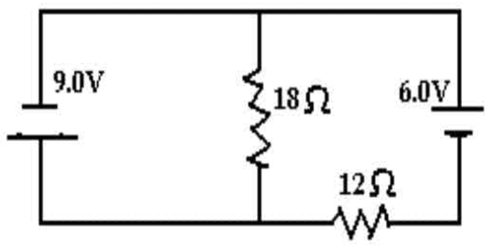
current through circuit $= I = V_{ef}/R_e = 3.6/9 = 0.4A$

from fig battery E_2 current flow through battery from - to + terminal

$V_{t1} = E_1 - Ir_1 = 2.4 - (0.4)(0.1) = 2.36V$

$V_{t2} = E_2 - (-I)r_2 = E_2 + Ir_2 = 6 + (0.4 * 0.9) = 6.36V$

13.7: Find the current, which flows in all the resistances of the circuit



Let I_1 & I_2 are the current flowing through loop in CW direction

first : Applying KVL on loop abcda

$-E_1 + (I_2 - I_1)R_1 = 0 \Rightarrow -9 + (I_1 - I_2)18 = 0$, taking 9 common

$2I_1 - 2I_2 = 1$ ----------(1)

second applying KVL on loop becfb

$-E_2 + I_2R_2 + (I_2 - I_1)R_1 = 0$

$-6 + 12I_2 + 18I_2 - 18I_1 = 0$, taking 6 common and solving

$-3I_1 + 5I_2 = 1$ ----------(2)

solving equation (1) and (2) simultaneo usly we get

$I_1 = 1.75$ A and $I_2 = 1.25$ A

Current th rough $R_1 = I_1 - I_2 = 1.75 - 1.25 = 0.5$ A

Current th rough $R_2 = I_2 = 1.25A$