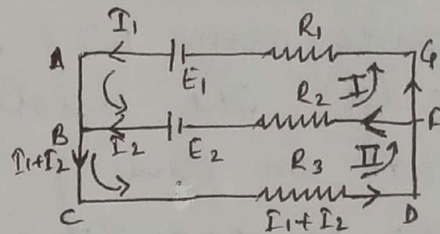
kirchhoff's 2nd Law or kirchhoff's Voltage law :-

In any closed path (mesh) of a circuit, the sum of the products of the current and the resistance in each part of the mesh is equal to the algebric sum of the emf's in that mesh, that is

$$\Sigma(IR) = \Sigma E$$

In appeying this law, when we mone in the direction of current then the product of the current and the corresponding resistance is taken as +ve (Positive) and Emf is taken as positive (+ve) when we mone from -ve to +ve electrode of the cell through the electroyle.



Applying kirchhoff's 2nd Law to Mesh 1 or closed path ABFGA

$$I_1R_1 - I_2R_2 = E_1 - E_2$$

IIly for Mesh 2 or closed path (BCDFB)

$$I_1R_2 + (I_1 + I_2)R_3 = E_2$$

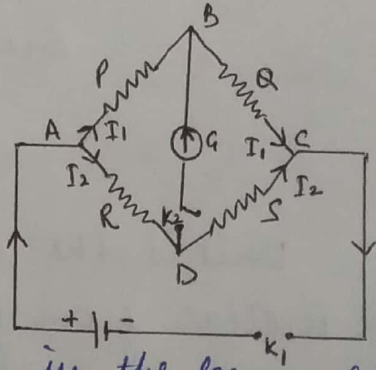
From these eqns., we can determine the values of currents in different Parts of circuit

⇒ This law is based on "Conservation of Energy".

Applications :- (1) They can be used to analyse any electrical circuit.
(2) Computation of current and voltage of complex circuits

Application of kirchhoff's Law :-

Wheat Stone Bridge :- Wheatstone devised a bridge arrangement of four resistances, by which resistance of a given conductor can be determined. This arrangement is called "Wheatstone bridge."



In fig. four resistances P, Q, R, S are connected in the form of four arms of a Parallelogram ABCD.

Between B and D, a sensitive galvanometer is connected and b/w A & C, a cell is connected. k_1 is battery key and k_2 is galvanometer key. By pressing the key k_1, a current I is allowed to flow from the cell. The current distribution is in accordance with kirchhoff's Ist law.

The arms P & Q are called "ratio arms", arm AD 'known arm' and arm CD "unknown arm". When the bridge is balanced then on interchanging the positions of the galvanometer and the cell there is no effect on the balance of the bridge.

Hence the arms BD & AC are called "conjugate arms" of the bridge. The resistances P, Q, R and S are so adjusted that on pressing the key k_2 there will be no deflection in the galvanometer G.

This is called the balanced condition of the bridge. At balanced condition, there is no current in the diagonal BD, and the pts. B & D will be at same potential. Applying kirchoff's second law for the closed mesh ABDA, we have

$$I_1P - I_2R = 0 \quad \text{or} \quad I_1P = I_2R \qquad \text{—(I)}$$

Similarly, for the closed mesh BCDB, we have

$$I_1Q - I_2S = 0 \quad \text{or} \quad I_1Q = I_2S \qquad \text{—(II)}$$

Dividing eq (I) by eq (II), we have

$$\frac{I_1P}{I_1Q} = \frac{I_2R}{I_2S} \quad \text{or} \quad \boxed{\frac{P}{Q} = \frac{R}{S}}^{*}$$

This is the condition of Balanced Bridge.

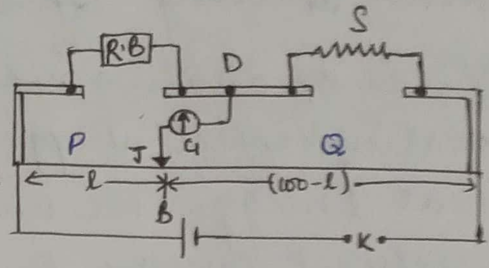
It is clear from this formula that if the ratio of the resistance P and Q, and the resistance R are known, then the unknown resistance S can be calculated.

The sensitivity of bridge depends upon value of the resistances. The bridge is most sensitive when all the four resistances are of same order.

Slide Wire Bridge:-

A slide wire bridge is also known as meter bridge. It is constructed on the principle based on balanced Wheatstone Bridge and is used to find the resistance of an unknown conductor.

AC is 1m long uniform wire. RB is known resistance and S is unknown resistance. A cell is connected across 1m long wire and Galvanometer is connected b/w Jockey and midpt. of R & S. To find out unknown resistance we touch jockey from A to C. When the jockey is moved along the wire there is one point where the galvanometer will show no current or in other words needle of galvanometer will show zero deflection. Then this meter bridge is said to be balanced.



Slide wire bridge

$AB = l$ cm $\quad P = r \cdot l$

$BC = (100-l)$ cm $\quad Q = r \cdot (100-l)$

r = resistance per unit length of wire

At balanced condition

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

$$\frac{rl}{r(100-l)} = \frac{R}{S} \Rightarrow \boxed{S = \frac{(100-l)}{l} \times R}$$

The value of 'S' is calculated for different values of R and the mean value gives the value of the unknown resistance.

HEATING EFFECTS OF CURRENT

Meaning of Heating Effect :- When an electric current passes through a conductor (like a high resistance wire) the conductor becomes hot after some time and produces heat. This is called Heating effect of electric current.

Causes of Heating effect of Electric current :-
Heating effect happens due to conversion of electric energy into heat energy. We know that battery or cell is a source of electrical energy. Due to chemical reaction in this battery or cell, Potential difference is generated which causes electrons to flow through circuit. This circuit has resistors which resists flow of current. Work is to be done to overcome this resistance. While doing work, this energy is dissipated in resistor as Heat Energy.

Electric Power :- Power is defined as rate of doing work.

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \Rightarrow P = \frac{W}{T}$$

⇒ It is measured in Joules/sec.

Electric power is defined as rate at which electric energy is consumed in a electrical circuit

$$\text{Power} = VI$$

Joule's law :- When a current I passes through a resistor of Resistance R having potential difference V between the ends, the work done by the electric field on the free e^- in time 't' is

$$W = V \cdot q = VIt$$

$$\Rightarrow V \cdot \frac{V}{R} \cdot t = \frac{V^2}{R} t$$

$$\Rightarrow (IR)It = I^2Rt$$

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This appears as thermal energy of the resistor because of the collision of e^- with the lattice.
This thermal energy is generally called Heat and is denoted by 'H'.

$$\boxed{H = I^2Rt = \frac{V^2}{R}t = VIt}$$

This heating effects were first studied by James Prescott Joule and hence three laws obtained directly from the relation $H = I^2Rt$ are known as Joule's laws of Heating

Formula for Power

we have seen $P = \frac{W}{t}$

we know that $V = \frac{W}{q}$

so $W = Vq$

$$P = \frac{Vq}{t} \Rightarrow V\left(\frac{q}{t}\right)$$

$\boxed{P = VI}$ Power = voltage × current

S.I unit of Power is watt

1 watt = 1 volt × 1 Ampere.

Different formulas

we know that

$$\boxed{P = VI}$$

Putting $V = IR$, we get

$$\boxed{P = I^2R}$$

Similarly putting $I = \frac{V}{R}$, we get

$$\boxed{P = \frac{V^2}{R}}$$

Commercial Unit of electric Power is kilo watt i. - ( )

Electric Energy → The work done by a source to maintain a current in an electric circuit is known as electric energy

$$\boxed{E = W = VIt = I^2Rt = \frac{V^2}{R}t}$$

S.I unit of electric Energy is Joule.

$$1J = (1V)(1A)(1s)$$

Electric energy can also be written as product of electric Power and time

$$E = P \times t$$

Commercial unit or board of trade unit (B.O.T.U) of electric energy is kilowatt hour (kWh). This is commonly called "unit".

$$1 \text{ unit of Electricity} = 1 \text{ kWh}$$

$$\text{and } 1 \text{ kWh} = \underline{\underline{3.6 \times 10^6 J}}$$