CURRENT ELECTRICITY

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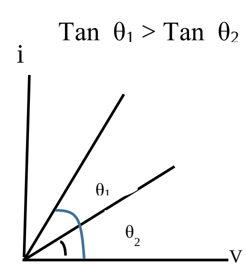
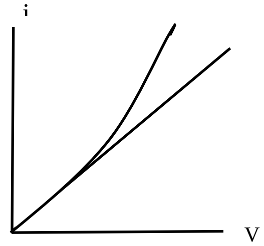
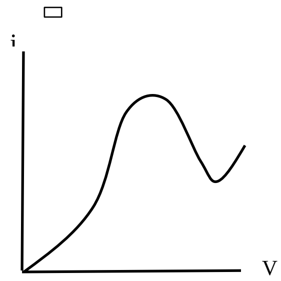
- Moving charges produce both electric and magnetic fields.
- The flow of electricity in solids is called conduction and due to electrons.
- The flow of electricity in liquids is known as electrolysis. It is due to flow of ions.
- The flow of electricity in gases is known as discharge of electricity through gases.
- The direction of flow of positive charge is taken as the direction of conventional flow of electricity (charge).
- Electric current:
- Consider a conductor in the form of a cylinder of radius R. Consider two thin discs having charges +Q and -Q distributed on them and made of dielectric material attached to the cylinder. Electric field is created and directed from +Q to -Q. Electrons are accelerated towards +Q to neutralize the charge. Hence a current is established for a short time.
- The rate of flow of charge across a conductor.
- $i = \frac{q}{t}$ unit. Coulomb. It is a scalar. D.F: I $I(t) = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t}$
- If i is not constant with time then $q = \int i \ dt = \int \frac{V}{R} \ dt = \int \frac{AV}{\rho l} \ dt$
- If n electrons pass through a cross section per second, then current $i = \frac{ne}{t}$
- 1 amp current is equal to passage of 6.25×10^{18} electrons per second.
- Current density (**J**):The current per unit area of cross section of the conductor.
- $J = \frac{i}{A}$ $i = \vec{j}.\vec{A}$. Unit. Am^{-2}. D.F:IL^{-2} It is a vector.
- Ohm's law: At constant temperature, p.d across a conductor is directly proportional to the current flowing through the conductor. It is valid over a range of temperatures. It is not valid at all temperatures.
- $V \propto i$ $V = iR$ where R is called resistance.
- $R = \frac{V}{i}$. Unit: Ω
- D.F: $R = \frac{V}{i} = \frac{W}{I^2 t} = \frac{ML^2T^{-2}}{i^2 T} = ML^2T^{-3}I^{-2}$
- Ohmic conductors: Conductors that obey ohm's law. Ex. Metals
- For ohmic conductors the graph between V and I is a straight line
- $\tan\theta = \frac{I}{V} = \frac{1}{R} = G$. For two wires at constant temperature if slope $\tan\theta_1 > \tan\theta_2$, then $R_1 < R_2$



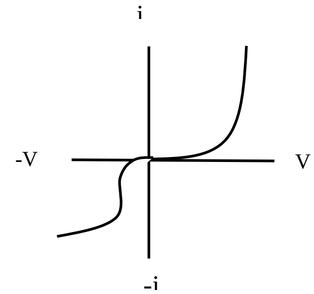
- Non-ohmic conductors: Conductors that do not obey ohm's law. Ex. Semiconductors, Thermistor,GaAs
- For non-ohmic conductors the graph between V and I is a curve.



Ohm's law for a good conductor

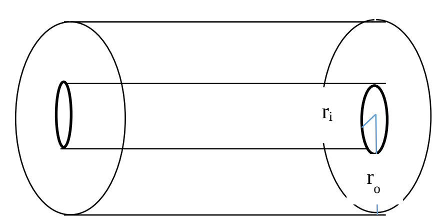


Varitation of current versus voltage for GaAs

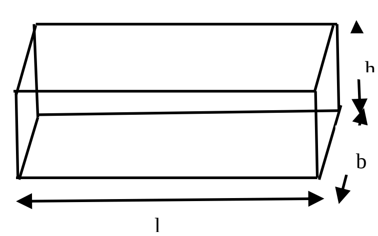


V-i graph for P-N diode

- Conductance: Reciprocal of resistance is called conductance.
- G = i/V. unit: Seimen or mho D.F: $M^{-1}L^{-2}T^{3}I^{2}$
- Resistivity or specific resistance: Resistance of unit length of conductor having unit area of cross section.
- $\rho = \frac{RA}{l} = \frac{E}{J}$. Unit: Ω-m $\left[\because V = El = IR = I\frac{\rho l}{A} = J\rho l\right]$
- D.F:$\rho = \frac{RA}{l} = \frac{ML^2T^{-3}I^{-2}L^2}{L} = ML^3T^{-3}I^{-2}$
- Conductivity or specific conductance: The reciprocal of resistivity is called conductivity.
- $\sigma = \frac{1}{\rho} = \frac{l}{RA} = \frac{J}{E}$. Unit : S-m^{-1}.
- D.F: $M^{-1}L^{-3}T^{3}I^{2}$
- Effect of stretching a wire: When a wire stretched its volume remains constant but length and radius will change.
- $R = \frac{\rho l}{A} = \frac{\rho l^2}{V}$. R ∝ l^2 since V is a constant.
- $R = \frac{\rho lA}{A^2} = \frac{\rho V^2}{\pi^2 r^4}$. $R \propto \frac{1}{A^2} \propto \frac{1}{r^4}$ since V is constant.
- Resistance of a hollow cylindrical tube of inner radius r_i and outer radius r_o is given by $R = \frac{\rho l}{\pi(r_o^2 - r_i^2)}$



- Ratio of maximum to minimum resistance of a block of conducting material of dimensions l×b×h(l>b>h) $\frac{R_{max}}{R_{min}} = \frac{l/bh}{h/lb} = \frac{l^2}{h^2}$
- When two identical wires made of materials having resistivities $\rho_1$andρ_2 are joined end to end, the effective resistivity is $\rho = \frac{\rho_1 + \rho_2}{2}$ and effective conductivity is $\sigma = \frac{2\sigma_1\sigma_2}{\sigma_1 + \sigma_2}$



- If two wires of resistivities ρ_1, ρ_2 having equal areas of cross sections and of same length are connected in parallel, then effective resistivity $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$ and effective conductivity $\sigma = \frac{\sigma_1 + \sigma_2}{2}$
- Drift velocity(v_d): The average velocity with which electrons move in an electric field. The order drift velocity is 10^{-4} m/s.
- Even though drift velocity is small (order of few mm/s) electric field is established throughout the circuit almost instantly (with speed of light) causing a local electron drift at every point. Establishment of current does not require an electron to reach the other end of conductor. However the current takes a little time to reach its steady state value.
- Each free electron accelerate in electric field and increases its drift speed. But it loses its speed due to collision with positive ion of metal. It starts accelerating again and gains drift speed only to lose it in collision. On the average electrons gain drift speed only.
- Though electron drift speed is small and the charge is also small, large currents are possible because the number density is large($10^{29}/m^3$)
- Drift velocity is superposed over large random velocities of electrons. Hence all the free electrons will not move in the same direction.
- In the absence of electric field, the paths of electrons are straight lines. In the presence of electric field they are curved.
- If n is the number of electrons per unit volume of the conductor, A is the area of the conductor, e is the charge of electrons and v_d is the drift velocity then current is I = neAv_d.

- Drift velocity $v_d = v_{av} - \frac{eE}{m}\tau$. Since velocities will have random directions v_{av}=0. $\therefore v_d = -\frac{eE}{m}\tau$.
- If λ is the mean free path and τ is the relaxation time (the average time between collisions) drift velocity $v_d = \frac{\lambda}{\tau} = -\frac{eE\tau}{m}$.
- $I = neAv_d = \frac{ne^2A\tau}{m}E$
- Current density: Electric current flowing through unit cross sectional area.
- J = i/A =nev_d=$\frac{ne^2\tau}{m}E$. It is a vector. $i = \vec{J}.\vec{A}$ or $i = \int \vec{J}.\overrightarrow{dS}$
- conductivity $\sigma = \frac{ne^2\tau}{m}$
- Mobility(μ): It is defined as the magnitude of drift velocity per unit electric field
- $\mu = \frac{v_d}{E} = \frac{e\tau E}{mE} = \frac{e\tau}{m}$

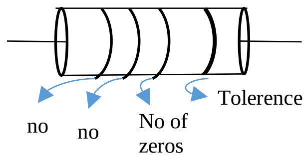
- Unit: m^2/Vs. D.F: $\mu = \frac{v_d}{E} = \frac{v_d}{V/d} = \frac{v_{d\,d}}{W/it} = \frac{LT^{-1}L\,IT}{ML^2T^{-2}} = M^{-1}IT^2$ Mobility is positive.
- Limitations of Ohm's law: For certain materials and devices used in electric circuits V is proportional to I does not hold. The following deviation occur
  a) V ceases to be proportional to I
  b) The relation between V and I depends on the sign of V. ex. diode
  c) The relation between V and I is not unique, i.e., there may be more than one value of V for the same current. Ex.GaAs

- Continuity equation: Charge leaving the volume envelope by the surface per unit time is equal to decrease of charge inside the volume per unit time.
- $\oint \vec{J}.\overrightarrow{ds} = -\frac{dq}{dt}$
- For direct current $\oint \vec{J}.\overrightarrow{ds} = 0 \quad \because \frac{dq}{dt} = 0 \quad q = const$
- We have $\vec{E} = \rho\vec{J} \quad J = \frac{I}{A} \qquad -\frac{dV}{dx} = \rho\frac{I}{A} \quad -dV = \rho\frac{I}{A}dx$
- $-\int_{V_1}^{V_2} dV = \rho\int\frac{I}{A}dx$ resistance of conductor $R = \frac{V_1 - V_2}{I} = \rho\int\frac{1}{A}dx$
- Wire wound resistors: They are made by winding the wires of an alloys like manganin, constantan, nichrome etc
- Carbon resistors: Resistors in the higher range are made mostly from carbon
- Resistivity of various materials

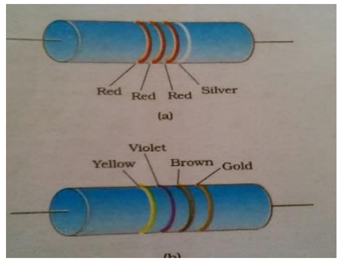
Material	Resistivity(ohm-m) at 0 °C	Temperature coeffα(0°C^{-1}) at 0°C
Silver	1.47×10^{-8}	0.0041
Copper	1.72×10^{-8}	0.0068
Aluminium	2.63×10^{-8}	0.0043
Tungsten	5.6×10^{-8}	0.0045
Nickel	86.84×10^{-8}	0.0060
Nichrome(Ni,Fe,Cr alloy)	100×10^{-8}	0.0004
Silicon	2300	-0.07
Germanium	0.46	-0.05
Fused quartz	1.47×10^{16}	
Carbon	3.5×10^{-5}	- 0.0005

- Colour code:

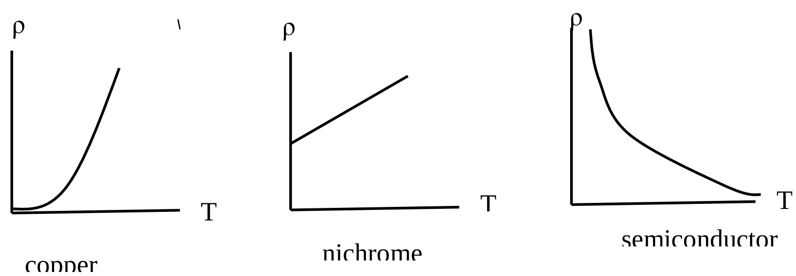
$\frac{B}{0}\frac{B}{1}\frac{R}{2}\frac{O}{3}\frac{Y}{4}\frac{G}{5}\frac{B}{6}\frac{V}{7}\frac{G}{8}\frac{W}{9}$ (Black Blue R O Y Great Britain Very Good Wife)



Carbon resistor



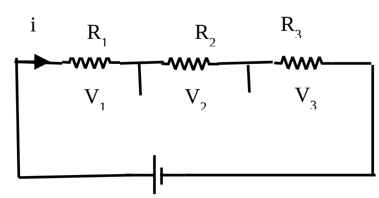
- In carbon resistor the first two bands are significant figures of resistance. The third band gives the decimal multiplier. The last band gives the tolerance. Tolerance – gold-5%,silver-10%, no colour-20%
- Effect of temperature on Resistivity and resistance: Resistivity of metals alloys increases with increase in temperature.
- Resistivity of semiconductors and electrolytes decreases with increase in temperature.
- Resistivity versus temperature in °C of various materials is shown in figure.



ρ-t graph

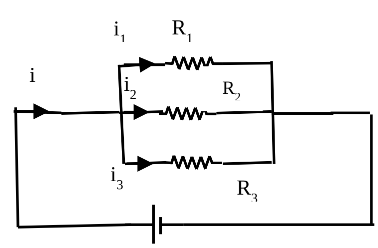
- $\rho = \rho_o[1+\alpha(T-T_o)]$ Where T is the absolute temperature (in K) and T_o is the reference temperature(in K).
- since R ∝ ρ $R = R_o[1+\alpha(T-T_o)]$
- If R_1 and R_2 are the resistances at temperatures $t_1$and t_2, then $\alpha = \frac{R_2 - R_1}{R_2 t_1 - R_1 t_2}$
- α is positive for metals and it is negative for carbon, India rubber, mica, thermistor etc.
- Tungsten has low resistivity and high melting point. It is used as filament of bulb.
- Nichrome is used as element of heating devices because it has high resistivity and high melting point.
- Fuse wire is made up of tin-lead alloy(63% tin+37% lead) and has low melting point and low resistivity.
- Thermistor is a heat sensitive non-ohmic device. It is a semiconductor.
- Thermistors can have both positive and negative temperature coefficients.
- Thermistors with negative α are used in the construction of thermometers to detect small temperatures. A Thermistor can measure a change in temperature of the order of 10^{-3} C.
- Thermistors are used to measure rate of energy flow in microwaves.

- Thermistors are used to protect the heater of a television tube.
- Thermistors are mostly prepared from metal oxides.
- Manganin is used in the construction of resistance boxes, Meter Bridge and potentiometer as it has negligible temperature coefficient.
- Joule's heating effect: When a p.d is applied between the ends of a resistor, work done by the electric field in time t is $W = Vit = i^2Rt$. This work is converted into thermal energy $H = i^2Rt = \frac{V^2t}{R} = Vit$
- Joule's effect is irreversible.
- Materials whose resistance falls to zero below certain temperature are called superconductors. This temperature is called critical temperature. Ex. Mercury below 4.2 K, lead below 8.2 K
- For superconductors resistivity falls suddenly to zero at critical temperature.
- Electric power and energy:
- Work W = Vq = Vit = i^2Rt
- Power: Rate of doing work.
- $P = \frac{W}{t} = Vi = i^2R$
- Kilowatt hour is the unit of electrical energy.1 KWH = 36×10^5 J
- Resistors in series:
- When resistors are connected in series current is same in each resistance but voltage is different
- Equivalent resistance $R_s = R_1 + R_2 + R_3 + \ldots$.
- If n resistors each having the same resistance are connected in series $R_s = nR$
- The ratio of the voltages across resistors is $V_1 : V_2 : V_3 = R_1 : R_2 : R_3$



Resistors in series

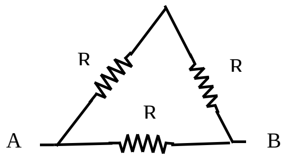
- Resistors in parallel: When resistors are connected in parallel voltage is same across each resistance but current is different.
- Equivalent resistance: $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots..$
- If n resistors each having the same resistance are connected in parallel then $R_p = \frac{r}{n}$
- $\frac{R_s}{R_p} = n^2$



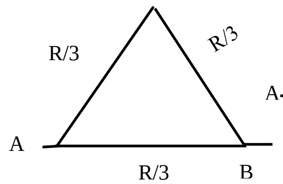
Resistors in parallel

- Ratio of currents through the resistors is $i_1 : i_2 : i_3 = \frac{1}{R_1} : \frac{1}{R_2} : \frac{1}{R_3}$
- Branch rule: When two resistors of resistances R_1 and R_2 are connected in parallel and a current i flows through them then the current in any one of them is given by $i_1 = \frac{R_2 i}{R_1 + R_2}$ and $i_2 = \frac{R_2 i}{R_1 + R_2}$

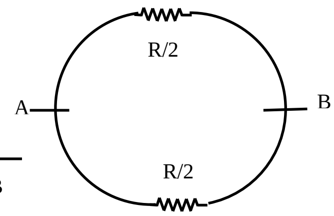
- If R_s and R_p are given then $R_1 = \frac{1}{2}\left[R_s + \sqrt{R_s^2 - 4R_sR_p}\right]$ and $R_2 = \frac{1}{2}\left[R_s - \sqrt{R_s^2 - 4R_sR_p}\right]$



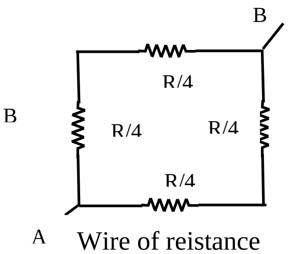
Three Resistors in the form of triangle



Wire of resistance R bent in the form of triangle

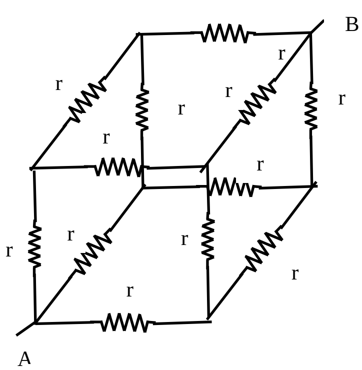


Wire of resistance R bent in the form of circle

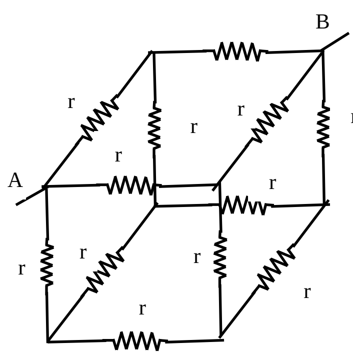


Wire of reistance R bent in the form of square

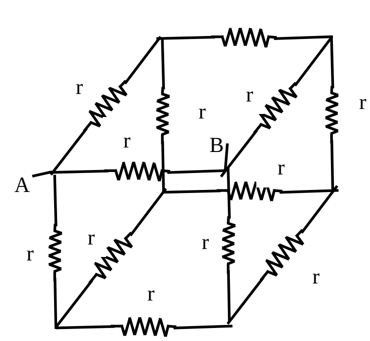
- If three identical resistors each of resistance R are connected in the form of a triangle, the equivalent resistance between the ends of a side is 2R/3.
- If an equilateral triangle is made of a uniform wire of resistance R, the equivalent resistance between the ends of a side is 2R/9.
- If a wire of resistance R is bent in the form of a circle, the effective resistance between the ends of a diameter is R/4.
- If a wire of resistance R is bent in the form of a square, the effective resistance between the ends of a diagonal is R/4.
- If four identical resistors each of resistance R are connected in the form of a square, the effective resistance between the ends of a diagonal is R.
- If we have n different conductors, then the number of combinations we can have using all at a time is 2^n. (if n>2)
- If we have n conductors of equal resistance, then the number of combinations we can have using all at a time is 2^{n-1} (if n>2)
- If n wires each of resistance R are connected to form a closed polygon, equivalent resistance across two adjacent corners is $R_{eq} = \left(\frac{n-1}{n}\right)R$
- A cylinder of radius r is filled completely with liquid then its resistance is R. Now the same liquid is taken in a cylinder of radius r/2. Then its resistance is 16 R.



R_{eq} across the body diagonal 5r/6



R_{eq} across the surface diagonal 3r/4

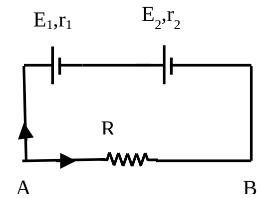


R_{eq} across the ends of a side 7r/12

- If 12 wires, each of resistance r, are connected to form a skeleton cube, then the equivalent resistance between the ends of the body diagonal of the cube is 5r/6.
- If 12 wires, each of resistance r, are connected to form a skeleton cube, then the equivalent resistance between the ends of a surface diagonal of the cube is 3r/4.
- If 12 wires, each of resistance r, are connected to form a skeleton cube, then the equivalent resistance between the ends of a side of the cube is 7r/12.
- If n wires each of resistance r are connected in the form of a closed polygon, the effective resistance between two adjacent corners is $R = \frac{(n-1)}{n} r$
- EMF: Work done by the cell in moving unit positive charge in the whole circuit including the cell once or open circuit voltage across the cell.
- Emf = work/charge
- Emf between the electrodes of a cell $= V_+ - (-V_-) = V_+ + V_-$.Here V+ is the potential on the positive electrode and V- is the potential on the negative electrode
- Potential difference: P.d is the work done in moving unit positive charge from one point to the other in a specified part of the circuit and is equal to the product or current and resistance.
- Internal resistance: The resistance offered by the electrolyte to the flow of current through the cell. It depends on the distance between the electrodes, area of the electrodes, nature, concentration and temperature.
- Lost voltage: The voltage dropped across the internal resistance is called lost voltage and is equal to ir.
- Relation between emf and terminal p.d: E = V +ir
- External work done by the cell $W_{ext} = Vit$
- Internal work done by the cell $W_{int} = i^2rt$
- Total work done by the cell $W = W_{ext} + W_{int} \quad Eit = Vit + i^2rt \quad \therefore E = V + ir$
- When the cell is charging V = E + i r
- Back emf: It is the emf developed in the cell against the emf of the cell due to ionic polarization.
- Open circuit: Resistance across the ends of the cell is infinity and current delivered by the cell is zero. For open circuit i=0 and V=E
- Short circuit: Resistance across the ends of the cell is zero and the cell delivers maximum current. For short circuit $i = \frac{E}{r}$ and V=0.
- Closed circuit: Cell delivers current to the external device. For closed circuit $i = \frac{E}{R+r}$.
- In case of closed circuit Power transferred to external resistance R is $P = i^2R = \frac{E^2R}{(R+r)^2}$
- Power transferred to the load by a cell is maximum when R = r. $P_{max} = \frac{E^2}{4r}$
- Grouping of cells:

- <u>Cells in series</u>
- If two cells of emf 's E_1 and E_2 and internal resistances r_1 and r_2 are connected in series then

$E_{eq} = E_1 + E_2$ and $r_{eq} = r_1 + r_2$

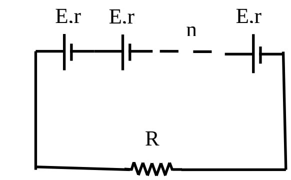


Cells in series

- If two cells of emf 's E_1 and E_2 and internal resistances r_1 and r_2 are connected with their negative terminals connected to each other in series then

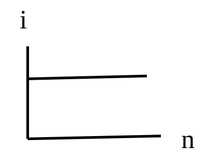
$E_{eq} = E_1 - E_2$ and $r_{eq} = r_1 + r_2$

- If n cells each of emf E and internal resistance r are connected in series $i = \frac{nE}{R + nr}$



n identical cells in series

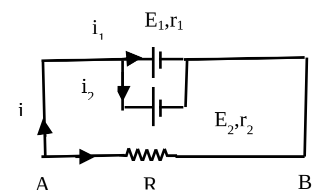
- If the cells are connected in series and the batteries are short circuited, then the current delivered is $i = \frac{E}{r}$. If a graph drawn between the number of cells (n) on x-axis and current (i) on y-axis is a straight line parallel to x- axis since current delivered is independent of the number of cells.



- If m cells are wrongly connected $E_{eq} = (n-2m)E$ and $i = \frac{(n-2m)E}{R + nr}$
- If the cells are not identical $i = \frac{\sum E_i}{R + \sum r_i}$
- <u>Cells in parallel</u>:
- If two cells of emf 's E_1 and E_2 and internal resistances r_1 and r_2 are connected in parallel

$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ and internal resistance $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

- $\{i = i_1 + i_2 = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2} = \frac{E_1}{r_1} + \frac{E_2}{r_2} - V(\frac{1}{r_1} + \frac{1}{r_2})$
- $\{V = \frac{E_1 r_2 - E_2 r_1}{r_1 + r_2} - i\frac{r_1 r_2}{r_1 + r_2} = E_{eq} - i r_{eq}$

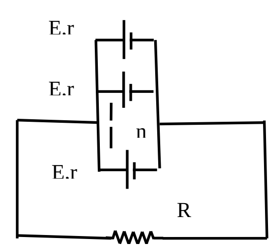


Cells in parallel

- If there are n cells of emf $E_1, E_2, \ldots\ldots. E_n$ and if internal resistances $r_1, r_2, \ldots\ldots r_n$ respectively connected in parallel, the combination is equivalent to a single cell of emf, E_{eq} and internal resistance r_{eq} then

$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \cdots \ldots \frac{1}{r_n}$ and

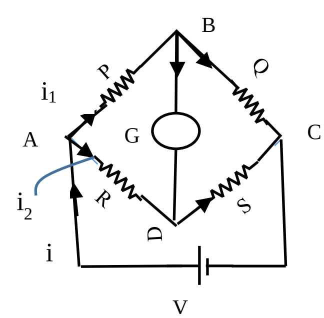
$\frac{E_{eq}}{r_{eq}} = \frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3} + \cdots \ldots \frac{E_n}{r_n}$



n identical cells in paralell

- If m identical cells are connected in parallel each of emf E and internal resistance r $i = \frac{E}{R+\frac{r}{m}}$
- Mixed grouping: If n cells are connected in series in a row and m such rows are connected $i = \frac{nE}{R+\frac{nr}{m}}$
- Maximum power transfer theorem: For maximum power output external resistance across the cell must be equal to internal resistance. In mixed grouping the condition for maximum power mR = nr.
- $i_{\max} = \frac{nE}{2R}$
- Kirchoff's rules:
- Current law or junction rule: The algebraic sum of all currents meeting at a junction is zero. Current arriving at the junction is taken as positive and the current leaving the junction is taken as negative. $\sum i = 0$. This law is based on conservation of charge.
- Voltage law or loop rule: In a closed mesh of a circuit the algebraic sum of emf's and p.d's is equal to zero. $\sum E = \sum iR$. While applying the law fall in potential is taken as negative and rise in potential is taken as positive. This law is based on conservation of energy.
- Wheatstone's bridge:

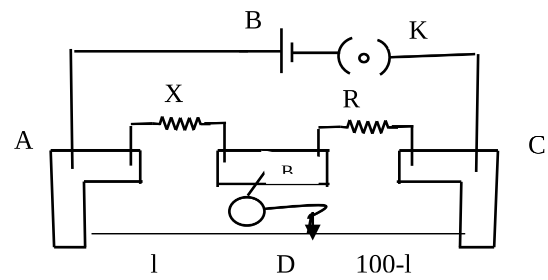
In Wheatstone's bridge the bridge is balanced if the p.d across the galvanometer is same or the current through the galvanometer is zero. Condition for the balance of the bridge $\frac{P}{Q} = \frac{R}{S}$



Wheatstone bridge

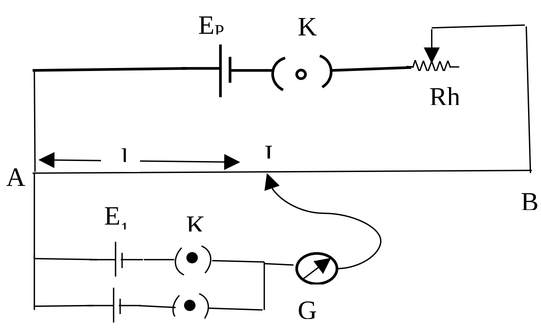
- Equivalent resistance of the bridge in the balanced condition $R = \frac{(P+Q)(R+S)}{P+Q+R+S}$
- The balance condition is independent of the applied voltage E. the balance will not change by changing the emf of the cell.
- The bridge is most sensitive if P=Q=R=S
- The condition for balance is not effected when positions of battery and Galvanometer are inter changed.
- Meter bridge: Manganin is used in the construction of meter bridge, as its temperature coefficient is negligible.

- In meter bridge the balancing condition does not change when the galvanometer and cell are interchanged.

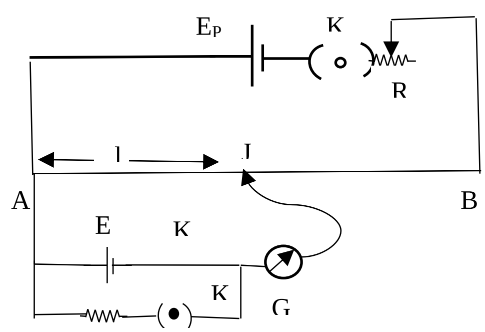


Meter bridge

- Unknown resistance $X = \frac{lR}{100-l}$.
- Specific resistance: $\rho = X\frac{\pi r^2}{l}$
- Draw backs of meter bridge: Low resistance cannot be measured due to contact resistance. We cannot accurately measure high resistance because the bridge is more sensitive when $\frac{R}{S} = \frac{l_1}{l_2} = 1$
- Potentiometer: It is based on the fact that the fall of potential across any portion of the wire is directly proportional to the length of that portion provided the wire is of uniform area of cross section and a constant current is flowing through it. $V \propto l$ or V = kl where k is the potential gradient.
- If Jockey is pressed to the left of the balancing point, current flows from secondary to primary circuit..
- If Jockey is pressed to the right of the balancing point, current flows from primary to secondary circuit..
- If Jockey is pressed at the balancing point, current flow between primary and secondary is zero..



Comparison of two cells



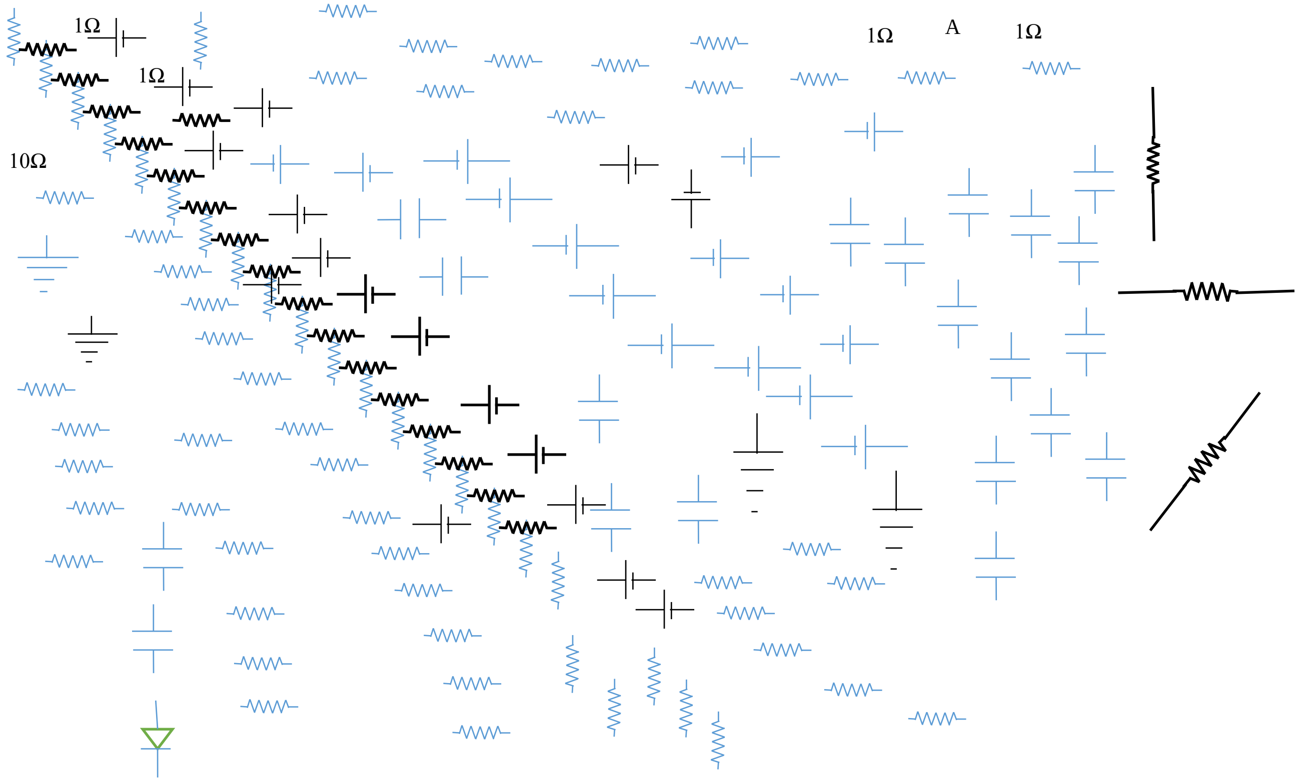
Internal resistance of a cell

- Potential gradient: Potential drop per unit length of the potentiometer wire is called potential gradient.
- Potential gradient $k = i\rho = \frac{iR}{L} = \frac{E}{R+R_S+r_o}\frac{R}{L}$ where ρ is the resistance per unit length, E is the emf of the cell in the primary circuit, R is resistance of the potentiometer wire, R_S is the series resistance in the primary circuit, r_o is the internal resistance of primary cell, L is the total length of potentiometer wire.
- Emf of the cell in the secondary circuit:
- If l is the balancing length of the wire $E_s = potential\ gradient \times balancing\ length = i\rho l$

- Potential difference across the potentiometer wire per unit length. $k = \frac{V}{l}$
- <u>Comparison of emf's of two cells</u>: $\frac{E_1}{E_2} = \frac{l_1}{l_2}$
- Sum and difference method: let l1 and l2 be the balancing lengths corresponding to two cells which are connected in secondary circuit first supporting each other and then opposing each other. Then $\frac{E_1+E_2}{E_1-E_2} = \frac{l_1}{l_2}$ or $\frac{E_1}{E_2} = \frac{l_1+l_2}{l_1-l_2}$
- <u>Determination of internal resistance of a cell</u>: $r = \frac{l_1-l_2}{l_2} R$ where l_1 is the balancing length of the wire without the external resistance and l_2 is the balancing length with the external resistance.
- Potentiometer is an ideal voltmeter.
- <u>Sensitivity of a potentiometer</u>: Sensitivity is inversely proportional to potential gradient. $S \propto \frac{L}{V} \propto \frac{L}{iR_P}$ where L is the length of potentiometer wire, R_P is resistance of wire and 'i' is current in the primary circuit.
- The sensitiveness of a potentiometer can be increased by decreasing its potential gradient along the potentiometer wire. Potential gradient can be decreased by increasing the length of the wire or by reducing the current.

- <u>Joule's heating effect</u>: When a p.d is applied between the ends of a resistor, work done by the electric field in time t is $W = Vit = i^2Rt$. This work is converted into thermal energy $H = i^2Rt = \frac{V^2t}{R} = Vit$
- Joule's effect is irreversible.
- Materials whose resistance falls to zero below certain temperature are called superconductors. This temperature is called critical temperature. Ex. Mercury below 4.2 K, lead below 8.2 K
- For superconductors resistivity falls suddenly to zero at critical temperature.
- <u>Electric power and energy</u>:
- Work W = Vq = Vit = i^2Rt
- <u>Power</u>: Rate of doing work.
- $P = \frac{W}{t} = Vi = i^2R$
- Kilowatt hour is the unit of electrical energy.1 KWH = 36×10^5 J
- Resistance of heater wire:
- If P is the power rating of a heater wire and V is the voltage rating of the heater wire, then the resistance of the heater wire is given by $R = \frac{V^2}{P}$.
- <u>Heaters in series</u>: As the current i is same, the power developed is proportional to the resistance $\frac{H_1}{H_2} = \frac{R_1}{R_2}$.Here H_1 and H_2 are the heats dissipated by the heater wires per second

- <u>Heaters in parallel</u>: When bulbs are connected in parallel, V is same, $H \propto \frac{1}{R}$ and $P_1H_1 = P_2H_2$. H_1 and H_2 are the heat dissipated in the wires per second.
- <u>Resistance of a bulb</u>:
- If P is the power rating of a bulb and V is the voltage rating of the bulb, then the resistance of the bulb is given by $R = \frac{V^2}{P}$.
- <u>Bulbs in series</u>: As the current i is same, the power developed is proportional to the resistance $\frac{P_1}{P_2} = \frac{R_1}{R_2}$.Here P_1 and P_2 are the powers consumed by the bulbs, not power ratings of the heater wires .
- <u>Bulbs in parallel</u>: When bulbs are connected in parallel, V is same, $P \propto \frac{1}{R}$ and $P_1R_1 = P_2R_2$


1Ω
1Ω
10Ω
1Ω
A
1Ω