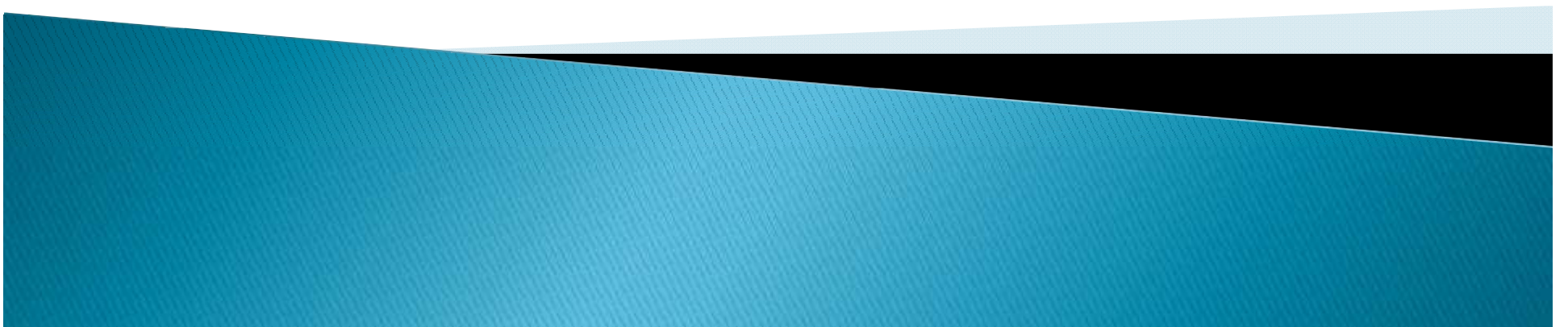
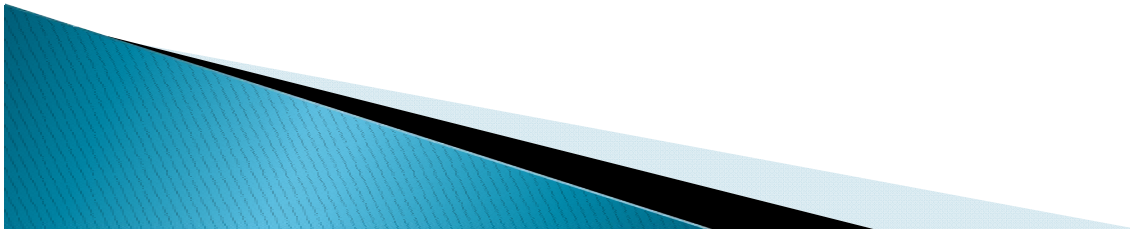


# Power Systems Analysis




# References

- **Elements of power system analysis**  
( **William Stevenson** )
- **Power system analysis**  
( **Hadi Sadaat** )



# Introduction

- ▶ An overhead line comprises mainly of i ) conductor, ii ) supports , iii ) insulators and pole fittings . The function of overhead lines is to transmit electrical energy , and the important characteristics which the line conductors must have are :
    - a) High electrical conductivity .
    - b) High tensile strength .
    - c) Low density .
    - d) Low cost .
  
  - ▶ The metals which posses the above properties are copper , aluminum and steel , which are used either alone or in combination .
- 

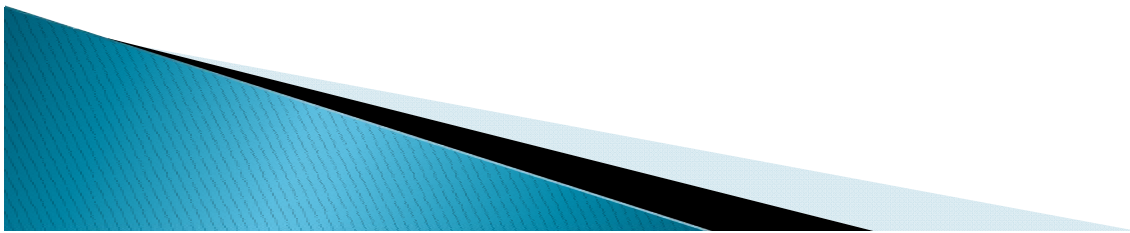
# *Types of conductors*

## Copper

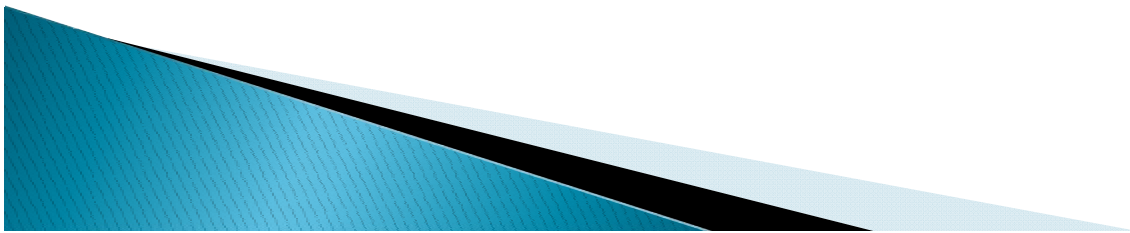
- ▶ The most common conductor used for transmission is copper , because it is twice as strong as soft drawn copper

The merits of this metal as a line conductor are :

- i ) It has a best conductivity in comparison to other metals .



- ii ) It has higher current density , so for the given current rating , lesser cross-sectional area of conductor is required and hence it provides lesser cross-sectional area to wind loads .
- iii ) The metal is quite homogeneous .
- iv ) It has low specific resistance .
- v ) It is durable and has a higher scrap value .



# Aluminum

▶ Next to copper aluminum is the conductor used in order of performance as far as the conductivity is concerned .Its merits and demerits are :

i ) It is cheaper than copper .

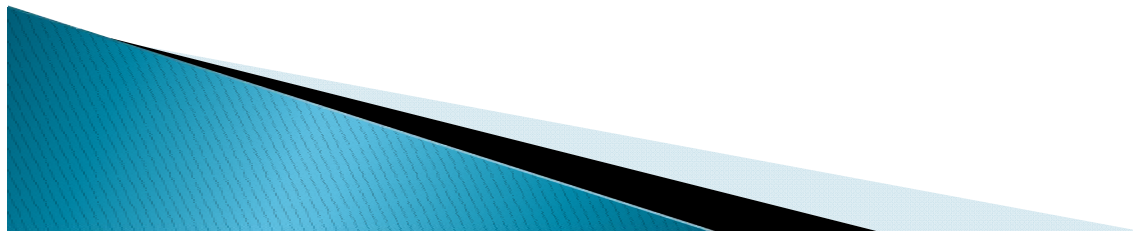
ii ) It is lighter in weight .

iii ) It is second in conductivity ( among the metals used for transmission ) . Commercial hard-drawn aluminum wire at standard temperature has approximately 60.6 per cent conductivity in comparison to standard annealed copper wire .

iv ) For same ohmic resistance , its diameter is about 1.27 times that of copper .

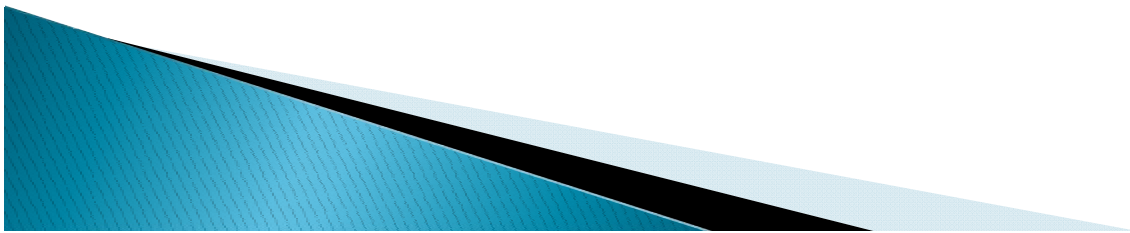


- v ) At higher voltages it causes less corona loss .
- vi ) Since the diameter of the conductor is more , so it is subject to greater wind pressure due to which greater is the swing of the conductor and greater is the sag .
- vii ) Since the conductors are liable to swing, so it requires larger cross arms .
- viii ) As the melting point of the conductor is low , so the short circuit etc. will damage it .
- ix ) Joining of aluminum is much more difficult than that of any other material .



# Steel

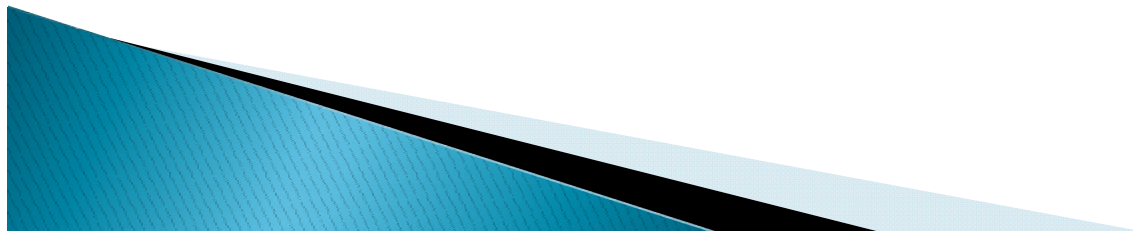
- ▶ No doubt it has got the greatest tensile strength , but it is least used for transmission of electrical energy as it has got high resistance. It has the following properties :
  - i ) It is lowest in conductivity .
  - ii ) It has high internal reactance .
  - iii ) It is much subjected to eddy current and hysteresis loss.
  - iv ) In a damp atmosphere it is rusted .
  
- ▶ Hence its use is limited .



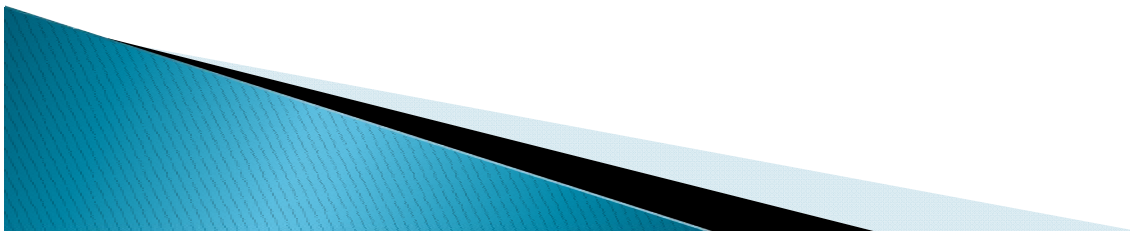


# Aluminum conductor with steel reinforced ( A.C.S.R )


- ▶ An aluminum conductor having a central core of galvanized steel wires is used for high voltage transmission purposes.
- ▶ This is done to increase the tensile strength of aluminum conductor. The galvanized steel core is covered by one or more strands of aluminum wires.
- ▶ The steel conductors used are galvanized in order to prevent rusting.



- ▶ Thus the steel reinforced aluminum conductor has less sag and longer span than the copper conductor line since it has high tensile strength .
- ▶ The aluminum steel conductor has a larger diameter than any other type of conductor of same resistance .
- ▶ For all calculation purposes , it is assumed that the current is passing only in the aluminum section .



# *Line supports*

- ▶ **The line supports are poles and the chief requirements for such supports are :**
    - i ) They must be mechanically strong with factor of safety of 2.5 to 3 .
    - ii ) They must be light in weight without the loss of strength .
    - iii ) They must have least number of parts .
    - iv ) They must be cheap .
    - v ) Their maintenance cost should be minimum .
    - vii ) They must have longer life .
    - viii ) They must be of pleasing shape .
- 

- ▶ The different types of poles which can be used as line supports are :

- Wooden poles .
- Steel tubular poles
- Reinforced concrete poles .
- Steel towers .

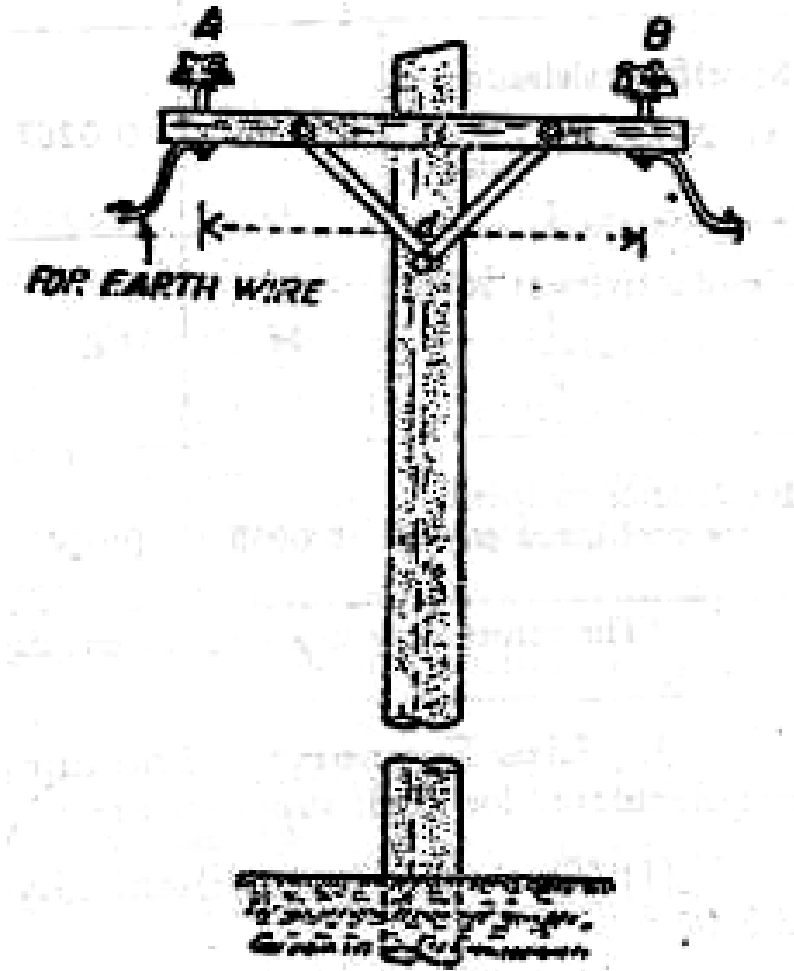
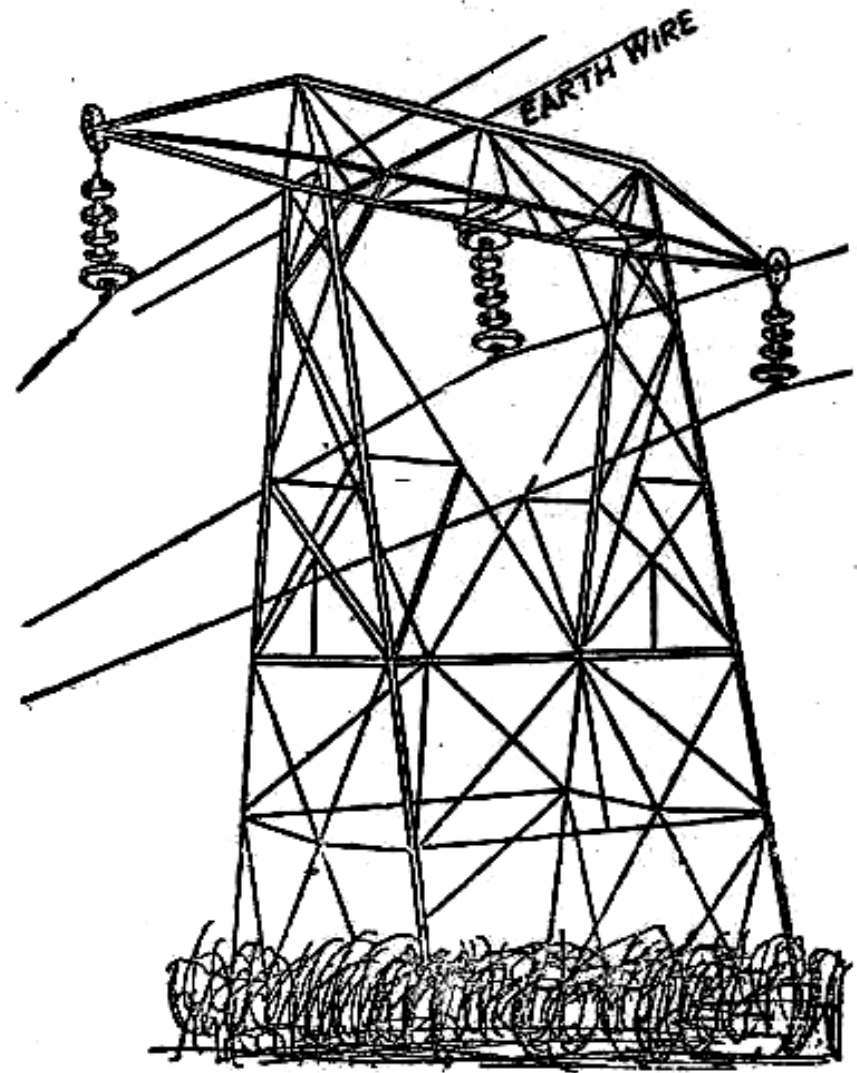


Fig.(1):Single phase single-circuit

# Spacing between the conductors

- ▶ The most suitable spacing between the conductors can be arrived at by mathematical calculations.
- ▶ It can only be obtained by empirical formulae which have been obtained from practical considerations.



**Fig.(7): Three-phase single circuit horizontal disposition of conductor and steel towers**

- ▶ Generally the following formulae are used for obtaining spacing between the conductors :

$$spacing = 0.01 V_{kv} + 1.24 \frac{d}{\omega} \sqrt{D} \quad \text{feet}$$

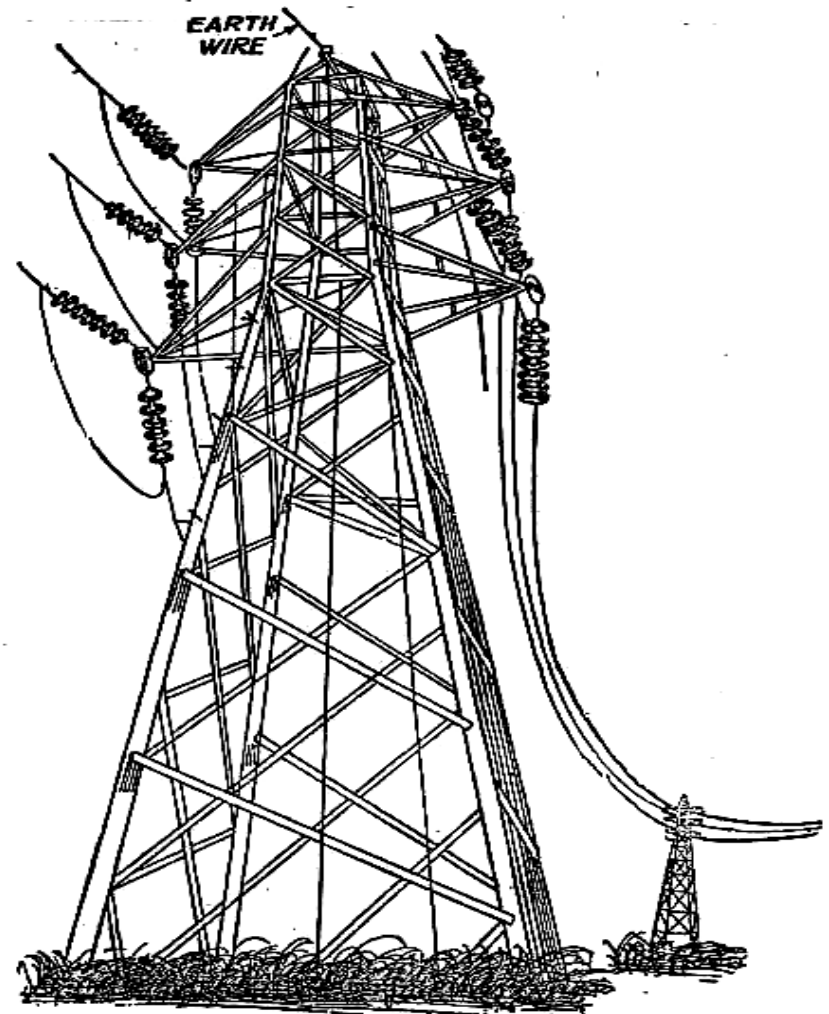
- ▶ Where,

$V_{kv}$  : is voltage in kilovolts .

$d$  : is diameter of conductor  
in inches .

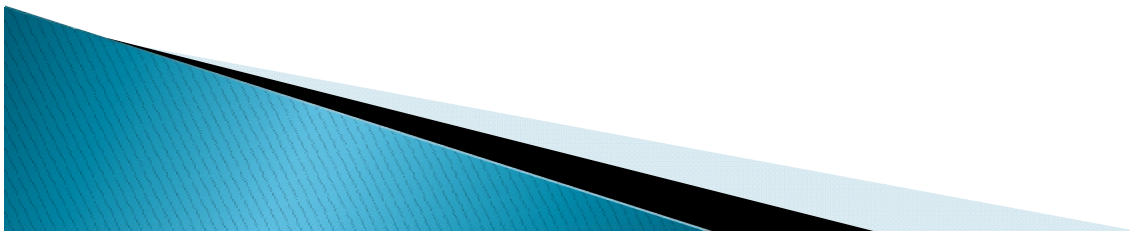
$w$  : is weight of conductor  
in lb. per foot run .

$D$  : is sag in feet .



# Series impedance of T.L .

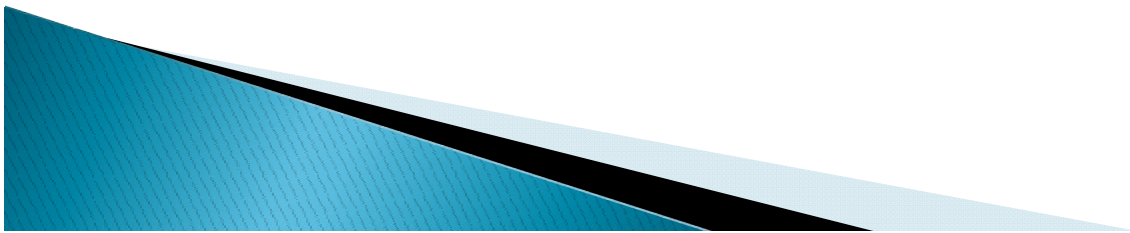
- ▶ It has four parameters : resistance, inductance, capacitance and conductance.
- ▶ Conductance is between the conductors and between conductors and the ground through the insulators as a leakage current.
- ▶ The resistance and inductance are uniformly distributed along the line.



# Types of conductors .

1. **Copper conductor .**
2. **Aluminum conductor .**
3. **Aluminum conductor, steel reinforced**

**Aluminum conductors have replaced copper because of the much lower cost and lighter weight.**

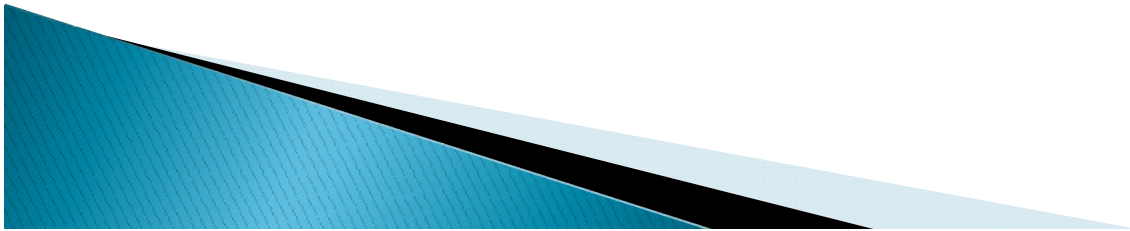




# Resistance

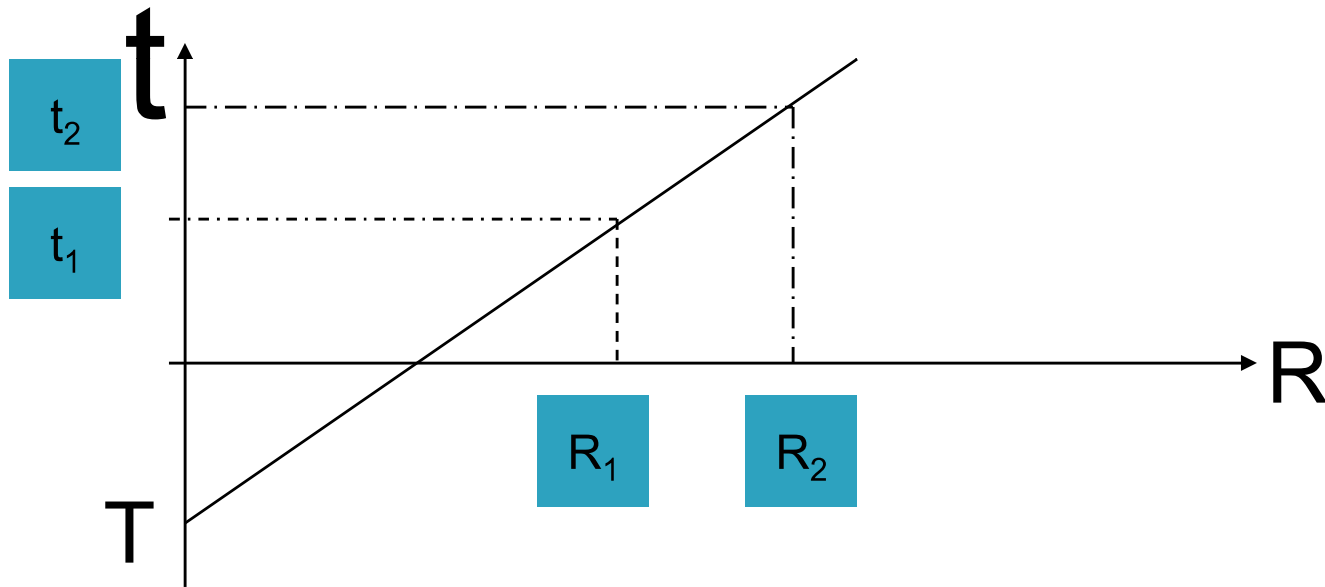
- ▶ Resistance causes power loss in the T.L.
- ▶ For uniform resistance ,

$$R = \rho L / a$$



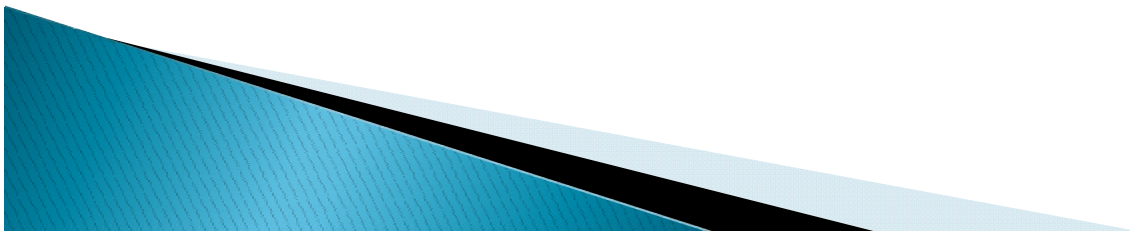
# Relation between resistance and temperature rise .

$$(R_2/R_1) = (T + t_2)/(T + t_1)$$



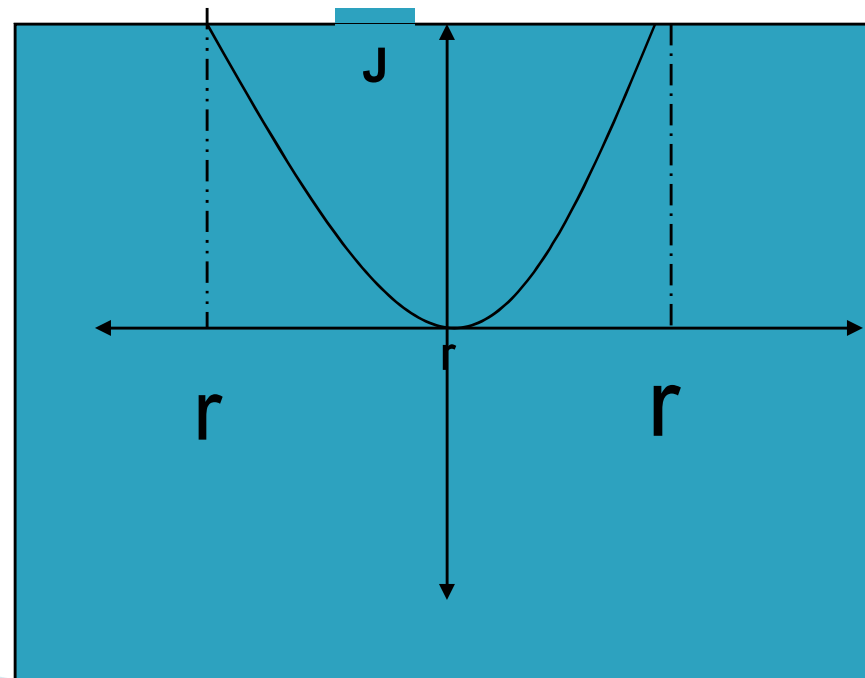
# The influence of skin effect on resistance

Uniform distribution of current throughout the cross-section of a conductor exists only for D.C. In A.C, as increased of frequency, the non-uniformly of distribution of current becomes more appearance. This case is called skin effect.



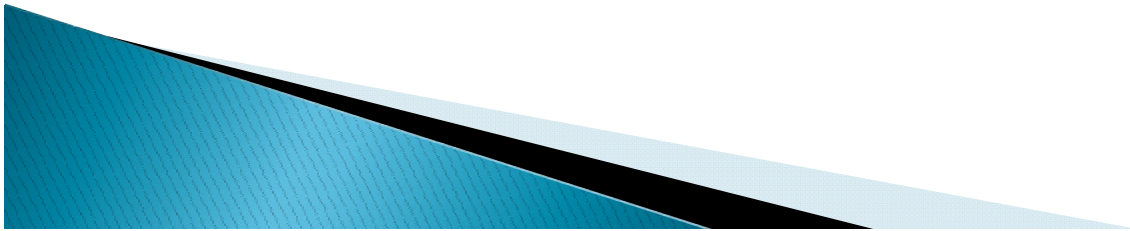
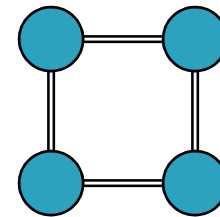
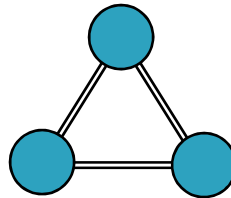
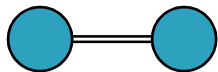
The alternating flux induces higher voltages acting on the interior filaments than are induced on filaments near the surface of the conductor .

$$L_a \succ L_b$$
$$X_a \succ X_b$$
$$Z_a \succ Z_b$$
$$I_a \prec I_b$$



# Bundled conductors

- The trend toward ever higher voltages for T.L has stimulated interest in the use of two or more conductors per phase.
- Such a line said to be composed of " bundled " conductors.



- Usually the spacing of conductors of a phase is about ( 10 ) times the diameter of one conductor , that is about ( 8 to 20 in ).
- The advantages of bundling are reduced reactance because of increased self SGM and reduce voltage drop and voltage gradient which result in reduced radio interference

