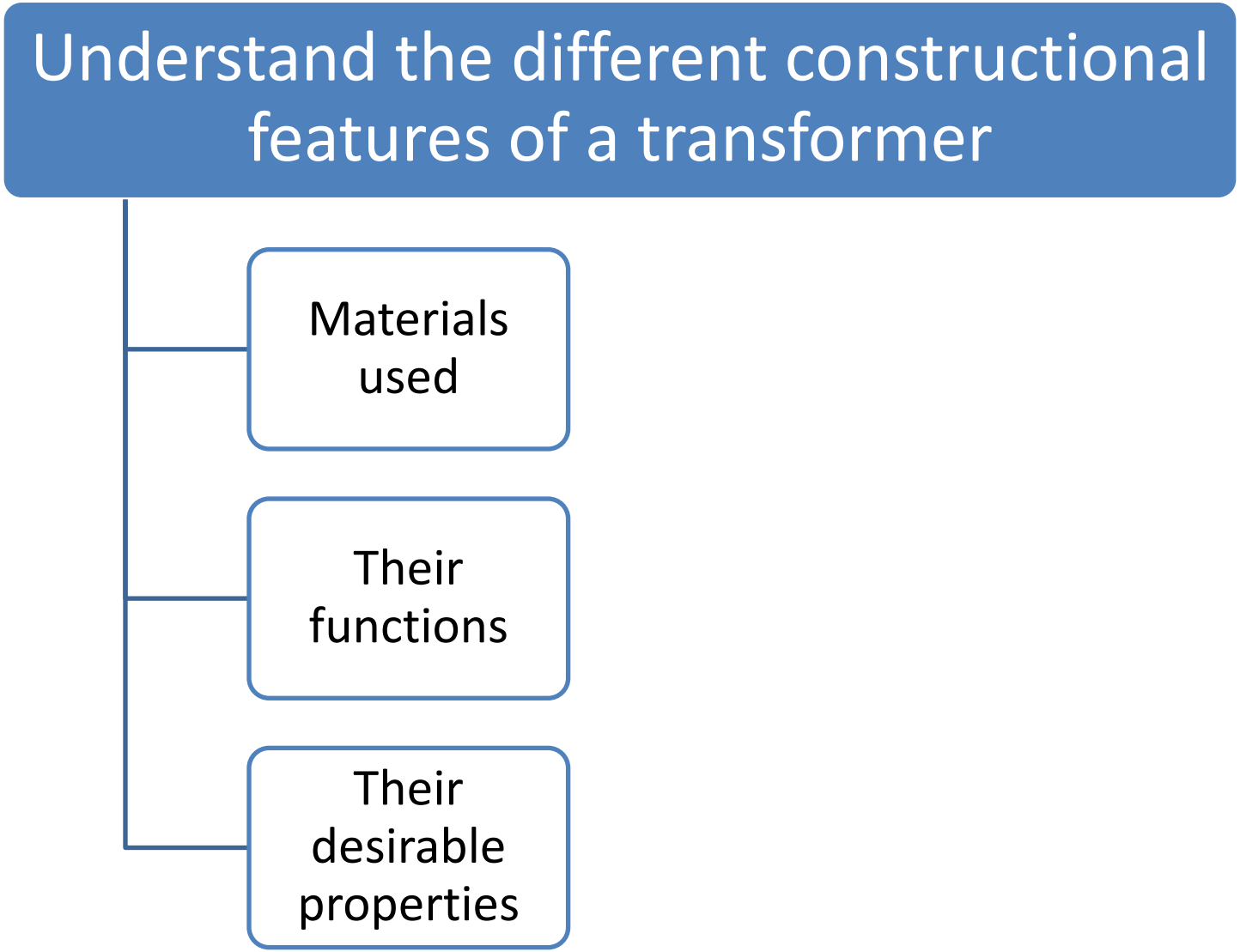
Transformers

Day 25

Construction

ILOs – Day 25

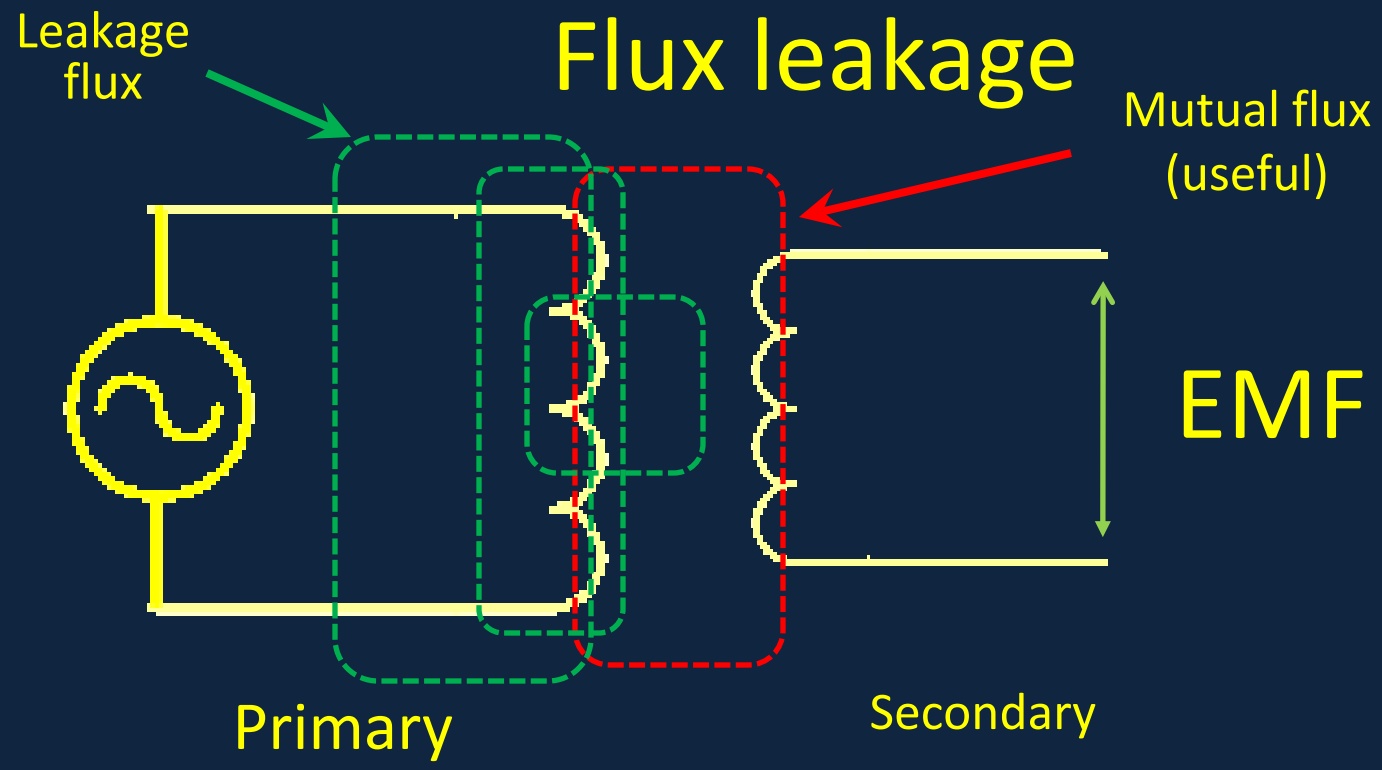

Understand the different constructional features of a transformer
Materials used
Their functions
Their desirable properties

Flux leakage

Q: What is an electrical insulator?

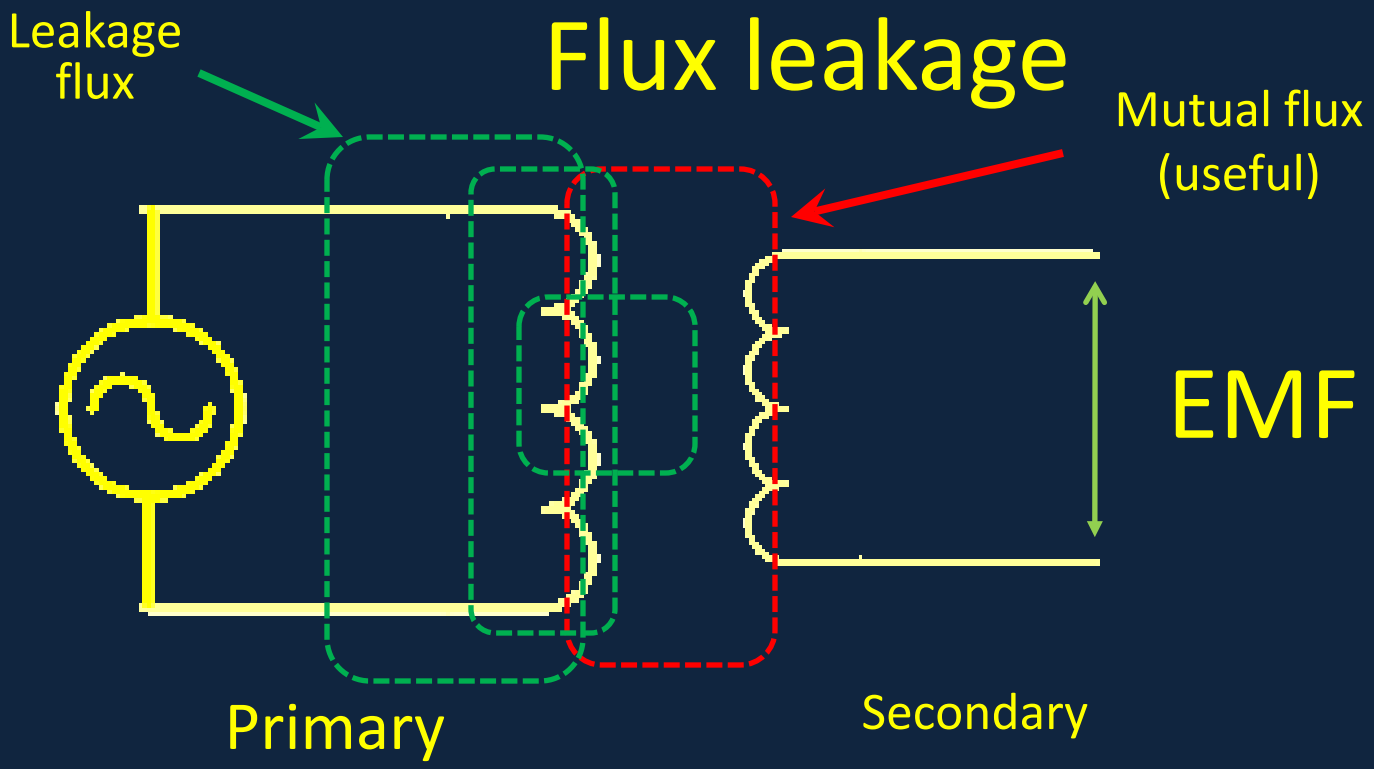
Q: What is a magnetic insulator?

Flux leakage



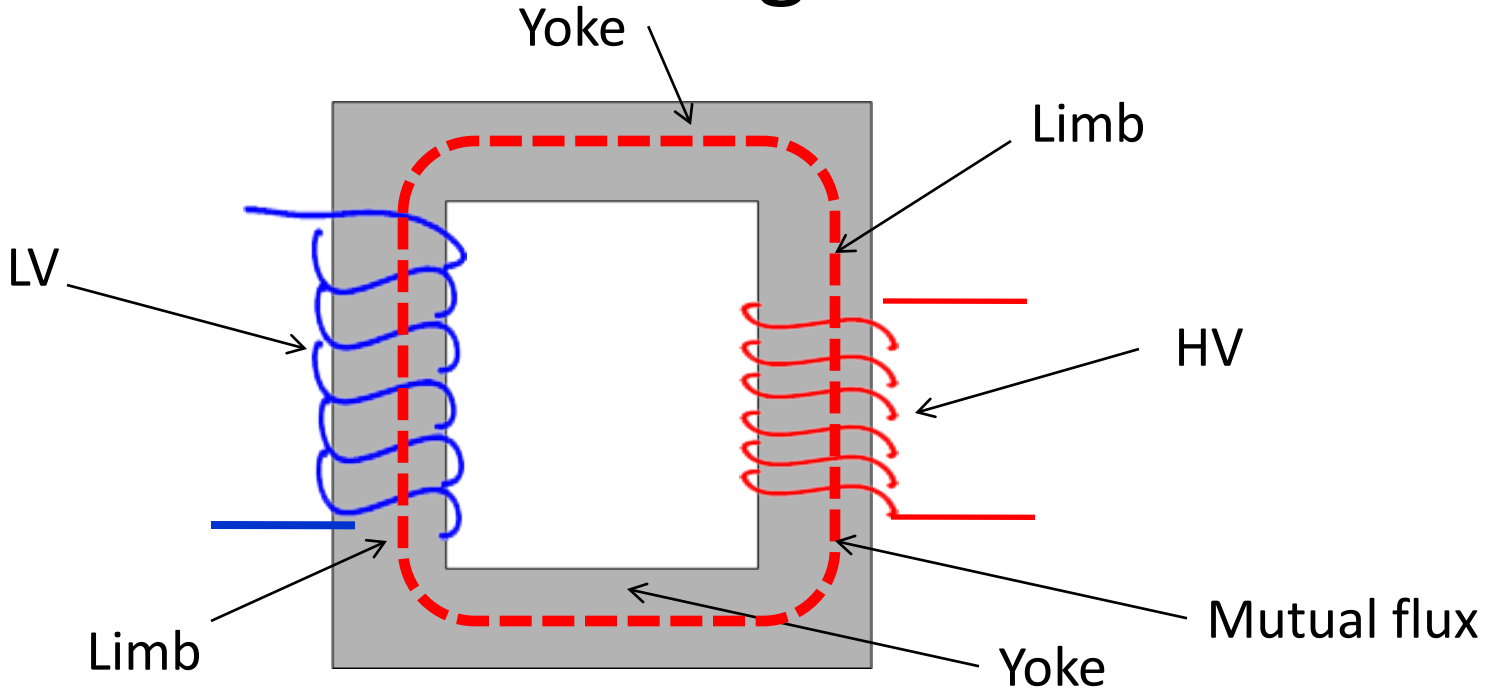
- Flux of P can go in any direction
- Only some part may link with S
- The flux linking with S is called mutual or useful flux
- Other flux that does not link S is called leakage flux

Flux leakage



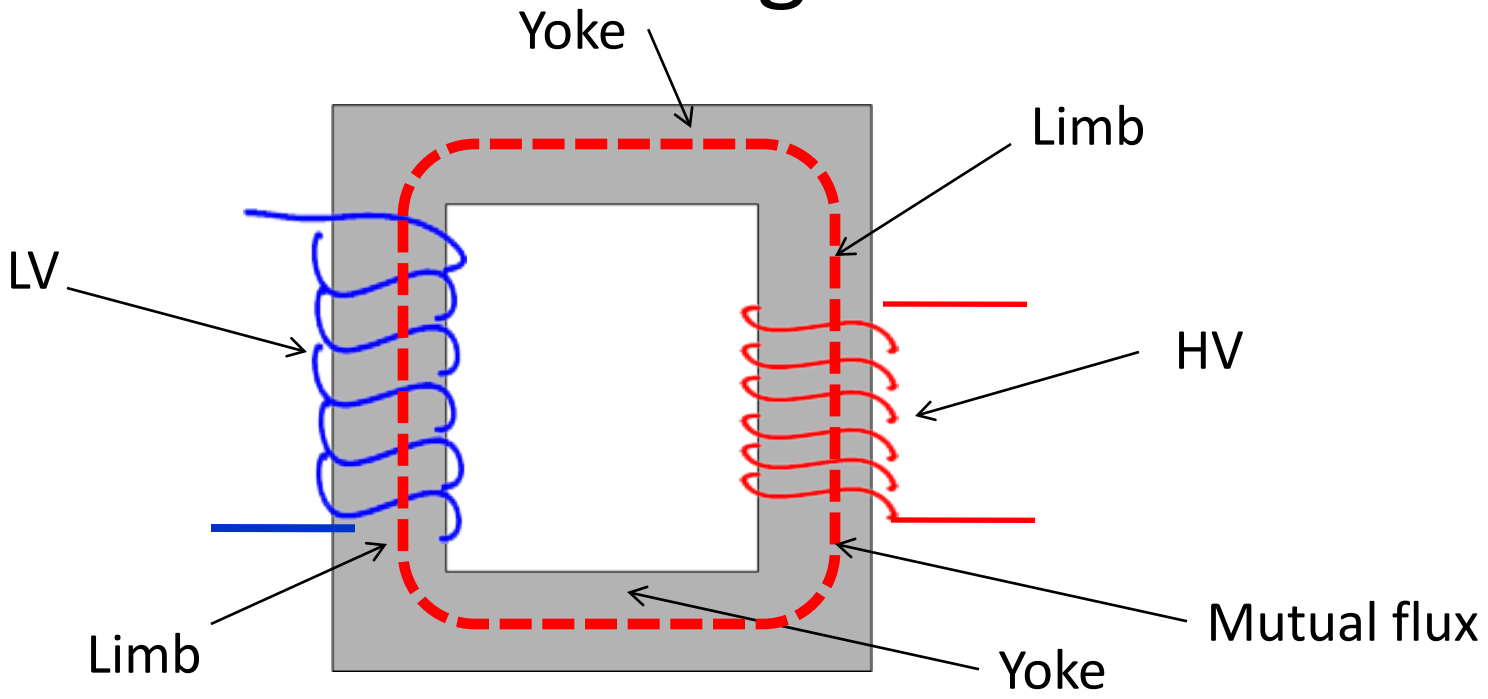
- Mutual flux is the flux that links both primary and secondary coils
- Mutual flux is the useful flux that takes part in energy transfer
- Leakage flux are those which link either only primary or only secondary, but not both together
- Leakage flux do not take part in energy transfer between primary and secondary, rather it causes unwanted losses

Reduce Flux leakage – use iron core



- Rectangular iron core is used
- To enhance the flux linkage between the two coils
- Core made of high permeability magnetic materials
- The two coils are wound on the core

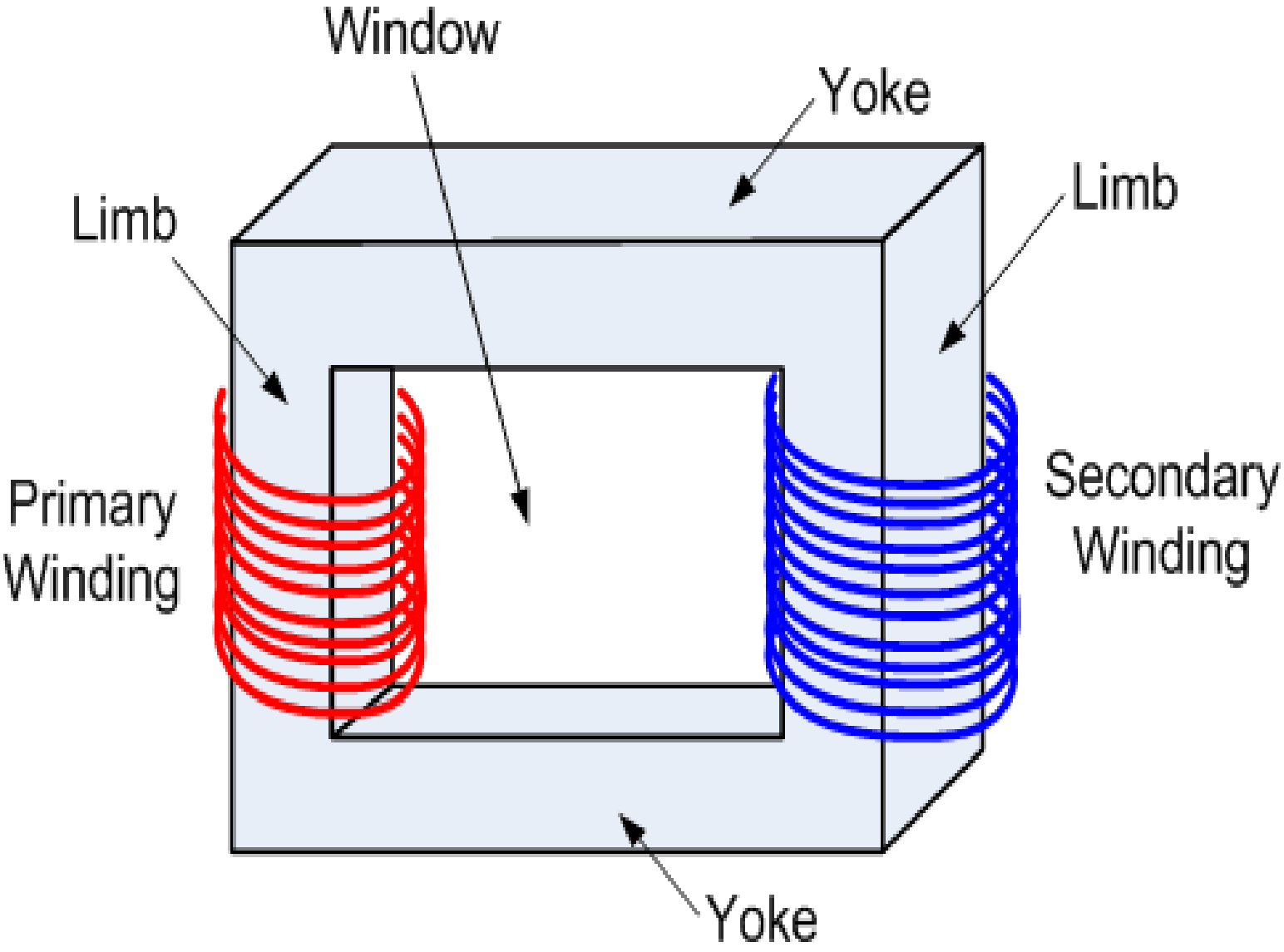
Reduce Flux leakage – use iron core



- Most flux lines tend to pass through the iron core due to its high permeability rather than through other paths (air)

- Thus, leakage flux is reduced

Reduce Flux leakage – use iron core

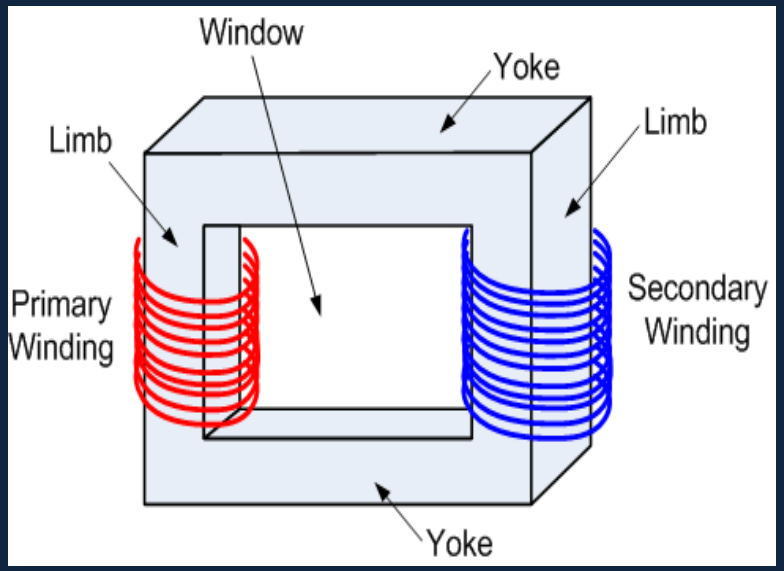


Construction of a transformer

- Magnetic parts
- Electrical parts
- Insulating parts
- Mechanical parts and accessories

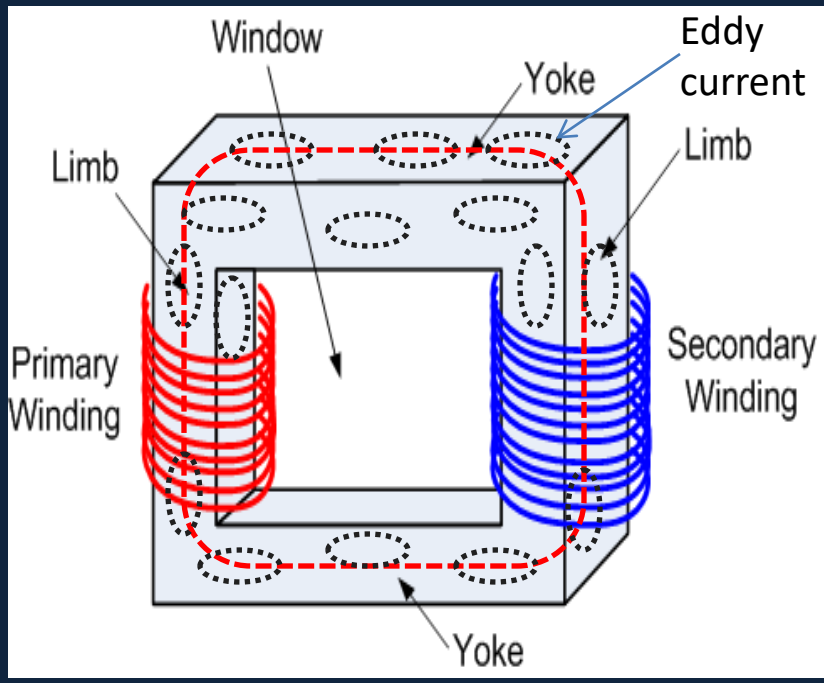
Magnetic parts

- Transformer core
  - Iron, (or steel) with some special treatment
  - Provide an easy path for the magnetic flux to flow through it
  - Provide mechanical support for holding the coils



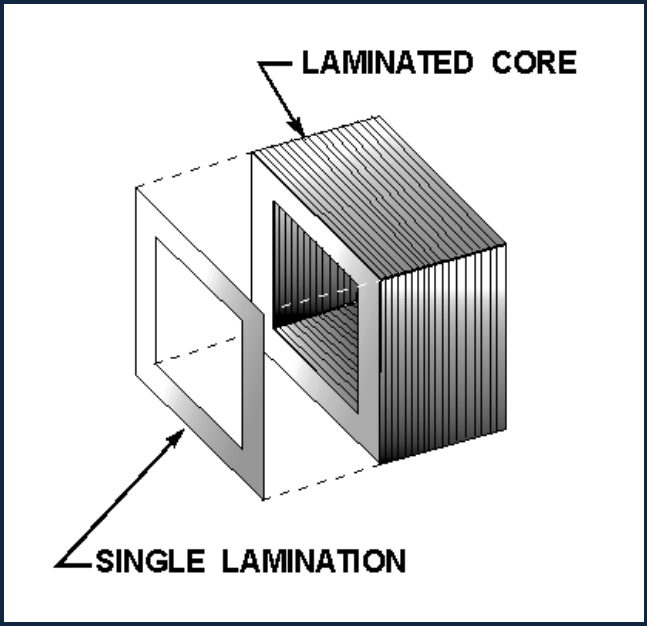
Transformer core – Eddy current

- The time varying flux will induce voltage inside the body of the core
- Flow of currents in small loops within the body of the core.
- Such currents are called eddy currents
- I^2R loss causing heating of the steel core body
- Called Eddy current loss



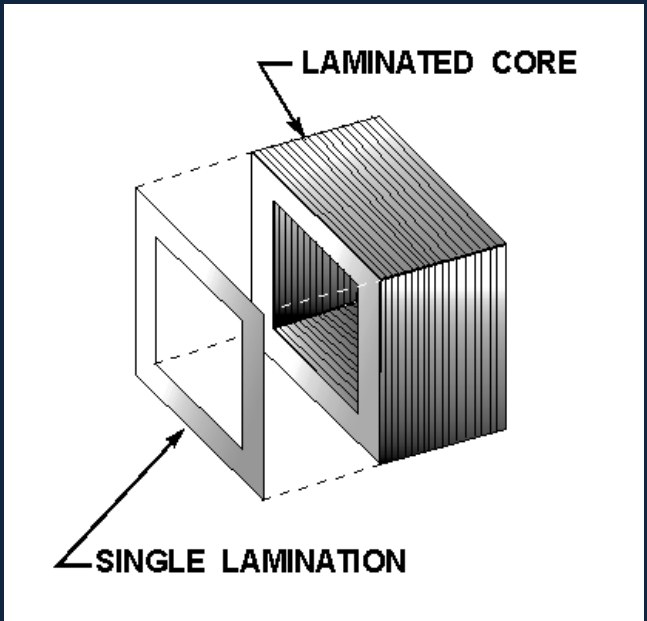
Eddy current loss

- To restrict the flow of eddy current through the body of the core
  - Core is made of **thin sheets** of steel **laminations**
  - **Insulated from each** other by varnish
  - The insulated laminations are stacked together tightly through bolts and clamping plates to form the core.



Eddy current loss

- Using laminations, insulated from each other, offers **very high resistance to the flow of eddy currents** through them
- Thus strength of the induced eddy current is reduced
- Thereby reducing the eddy current loss in the core to a large extent



Eddy current loss

- Expression for Eddy current loss

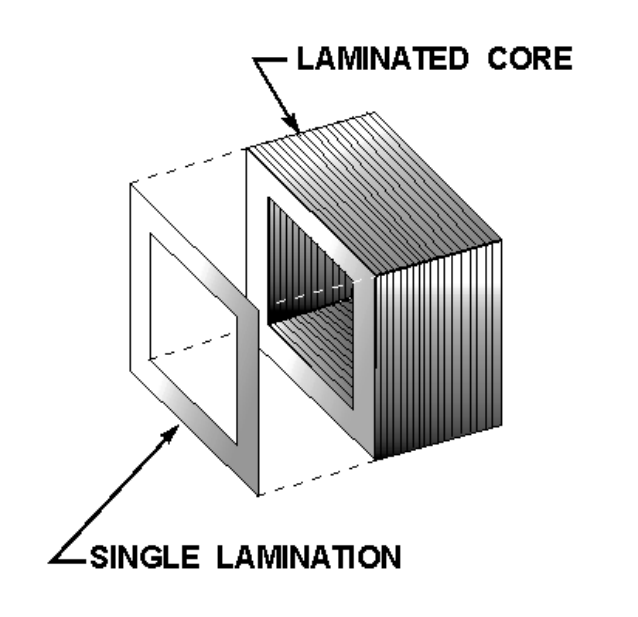
$$P_e = K_e f^2 t^2 B_m^2 \quad \text{W/m}^3$$

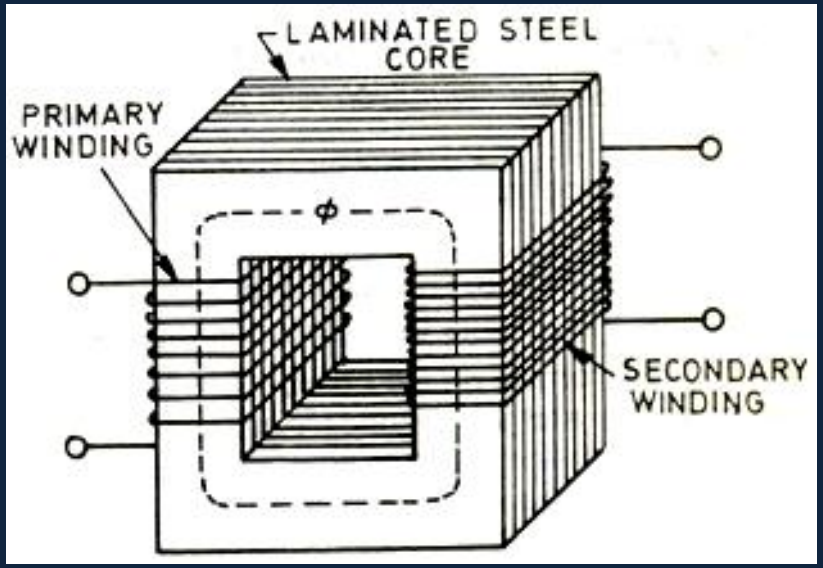
  - K_e is constant depending on the material properties including its resistivity
  - f is the supply frequency
  - t is the thickness of each lamination
  - B_m is he maximum value of flux density in the core

Eddy current loss

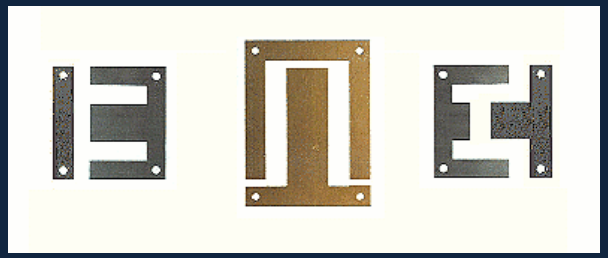
$$P_e = K_e f^2 t^2 B_m^2$$

- Thus by reducing the thickness (t) of laminations, Eddy current loss can be reduced.
- Lamination thickness 0.3 – 0.5 mm





Laminations



Hysteresis loss

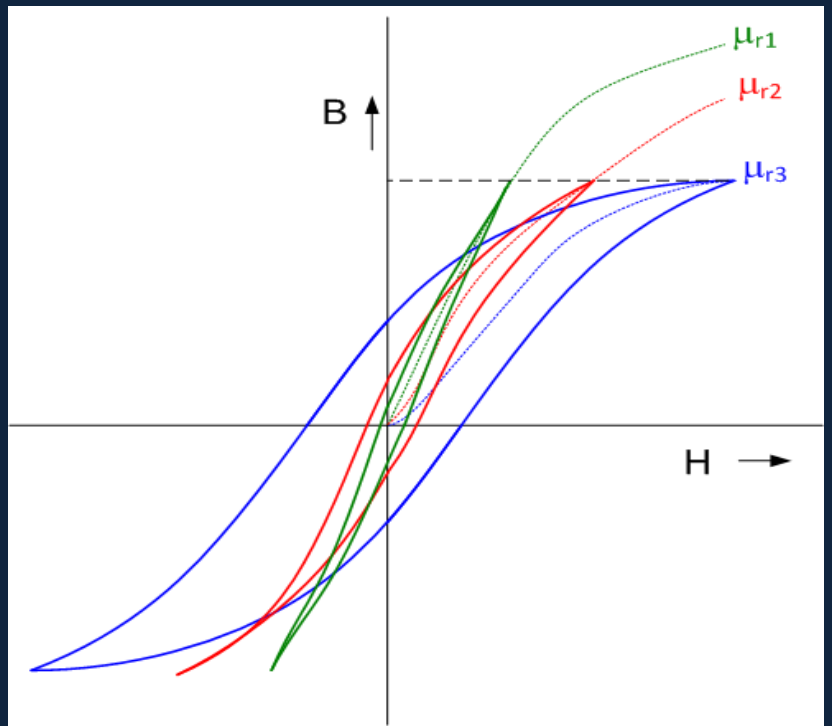
- Due to alternate magnetization
- Hysteresis loop area proportional to Hysteresis loss

$$P_h = K_h f B_m^{\ x} \quad \text{W/m}^3$$

  - K_h and x are constants depending on the material properties
  - f is the supply frequency
  - B_m is he maximum value of flux density in the core

Reducing Hysteresis loss - Adding silicon to steel

- Si-steel laminations (0.3% to 4.5% by weight)
  - Increases the permeability of steel
    - Reduces the Hysteresis loop area
    - Thus reduces Hysteresis loss



Reducing Hysteresis loss - Adding silicon to steel

- Additional advantages of adding Si
- It increases resistivity of steel
  - Reduces the Eddy current loss
- Increases mechanical strength
- Increases malleability of steel sheets
- Eliminates the ageing problem

Electrical grade steel

- HRS – Hot rolled steel
- CRGOS – Cold rolled grain oriented steel
- CRNOS – Cold rolled non oriented steel

Electrical parts – Cu or Al conductors

Insulating parts

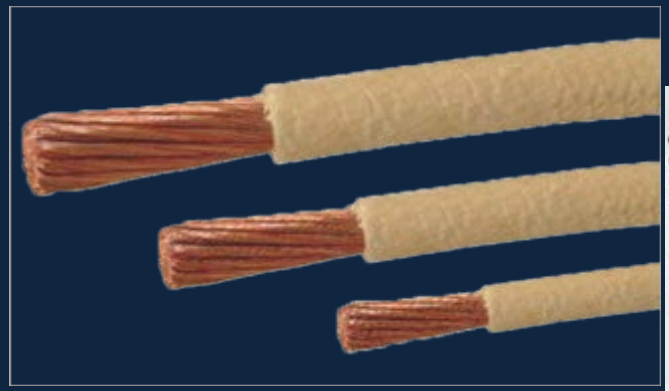
Major insulations in a transformer are:

- Between core and LV (Press board)
- Between LV and HV (impregnated press board, oil)
- Between top & bottom of winding and yoke (impregnated press board)
- Between HV and tank (impregnated paper, cotton, oil)
- Bushings (Porcelain)

Insulating parts

Major insulations

- Press board
- Oil
- Impregnated paper
- Cotton
- Porcelain



Insulating parts

Minor insulations in a transformer are:

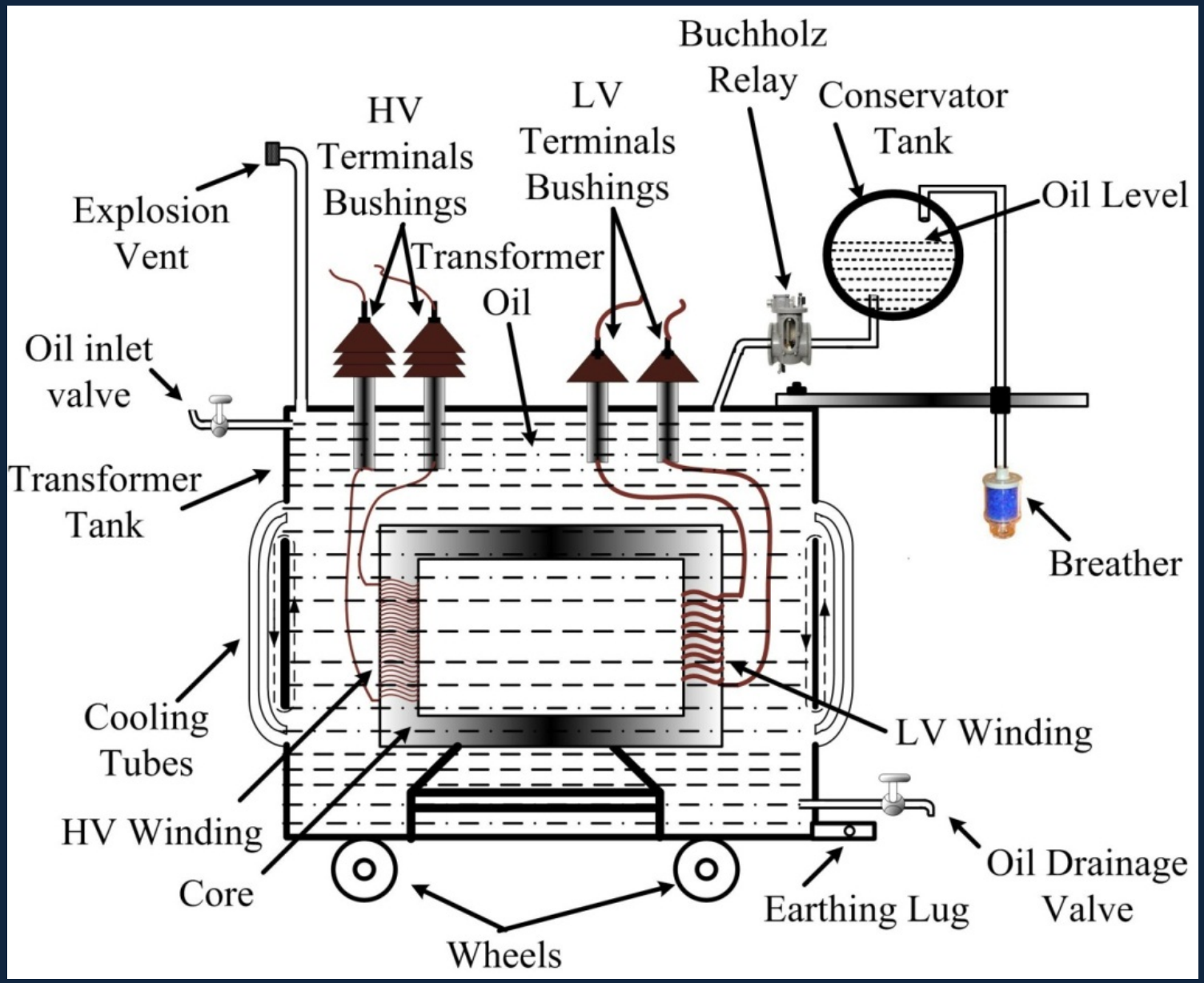
- Between conductors (enamel, varnish)
- Between turns (impregnated paper, cotton)
- Between layers (impregnated paper, cotton, pressboard)
- Between laminations (varnish)
- Between joints and connections (varnished tape)

Insulating parts

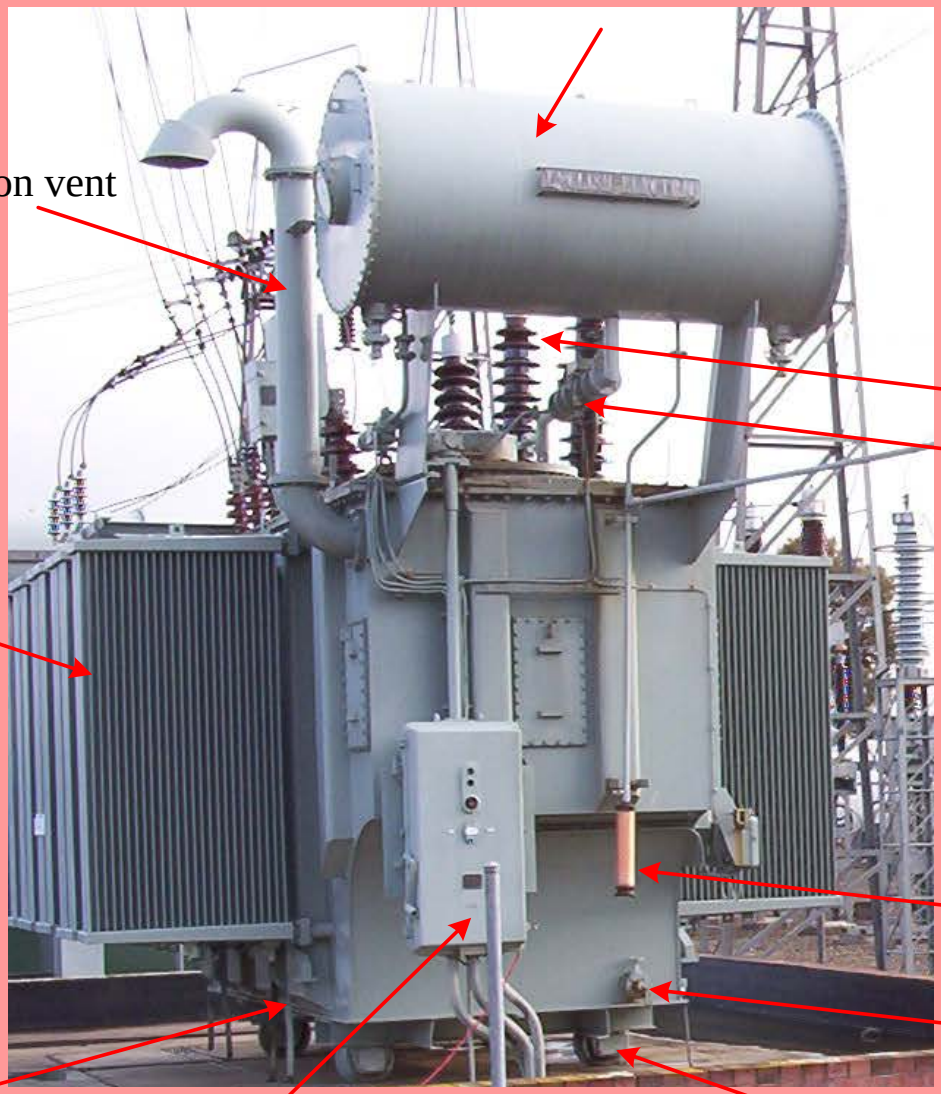
Minor insulations

- Enamel
- Varnish
- Impregnated paper
- Cotton
- Varnished tape

Mechanical parts and accessories



Mechanical parts and accessories



Mechanical parts and accessories