SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

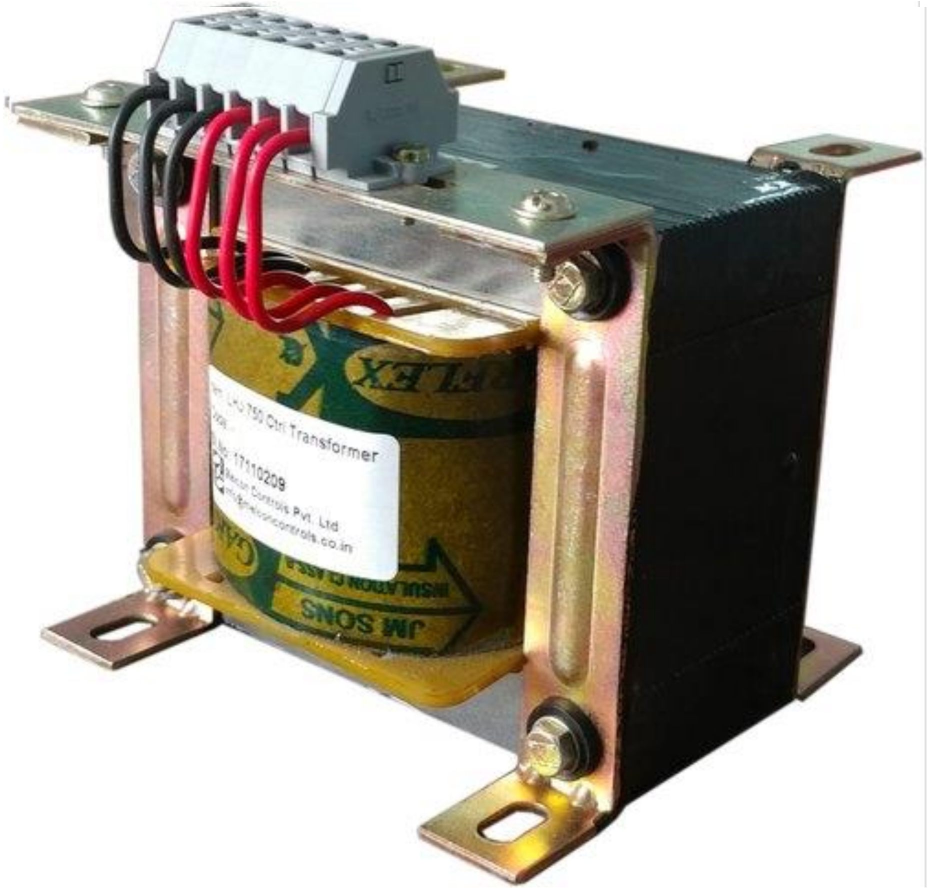
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE NAME : 23EEB201-THEORY OF DC MACHINES AND TRANSFORMER

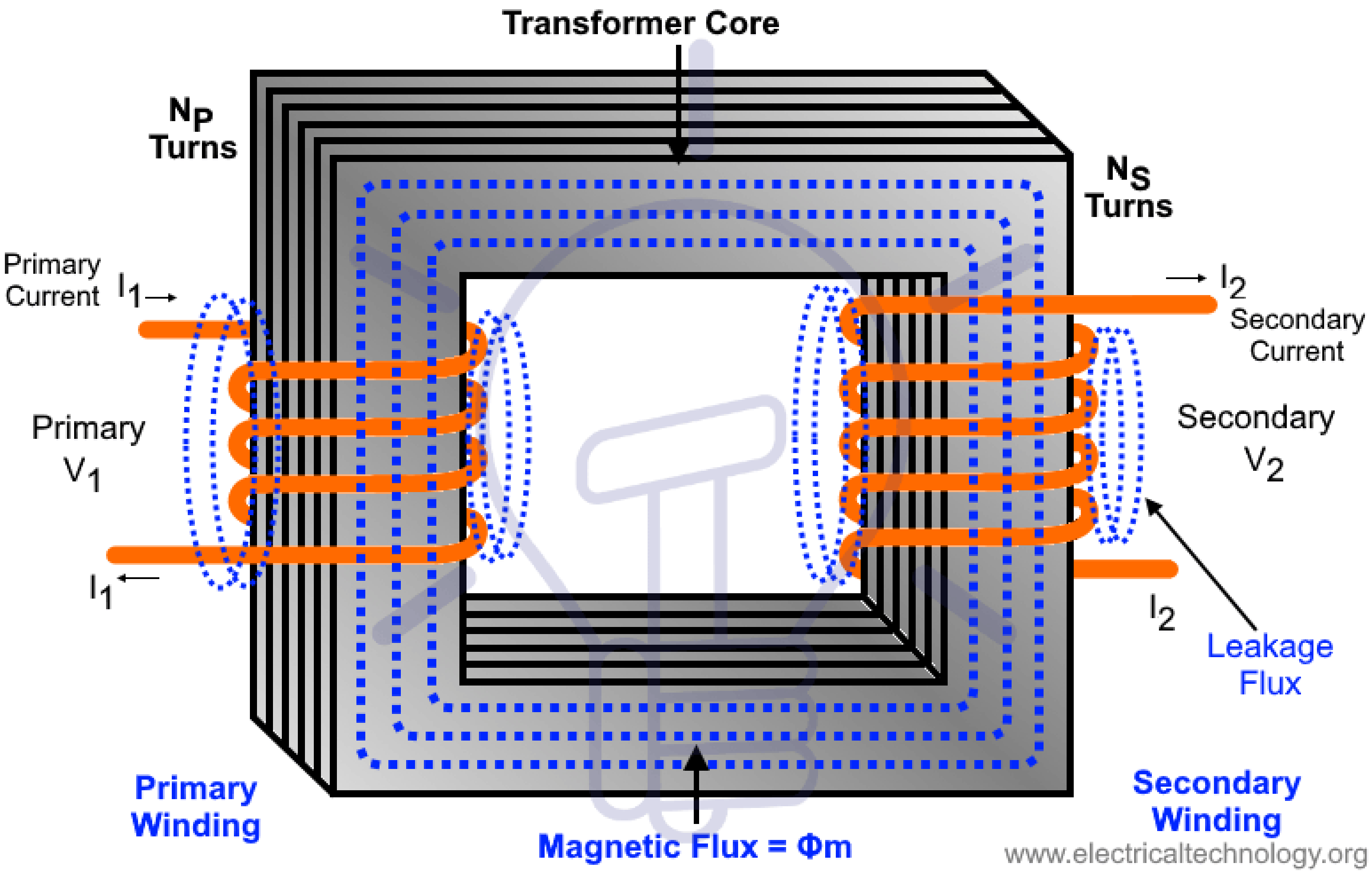
II YEAR /II SEMESTER

Unit 4:
Topic : Transformer

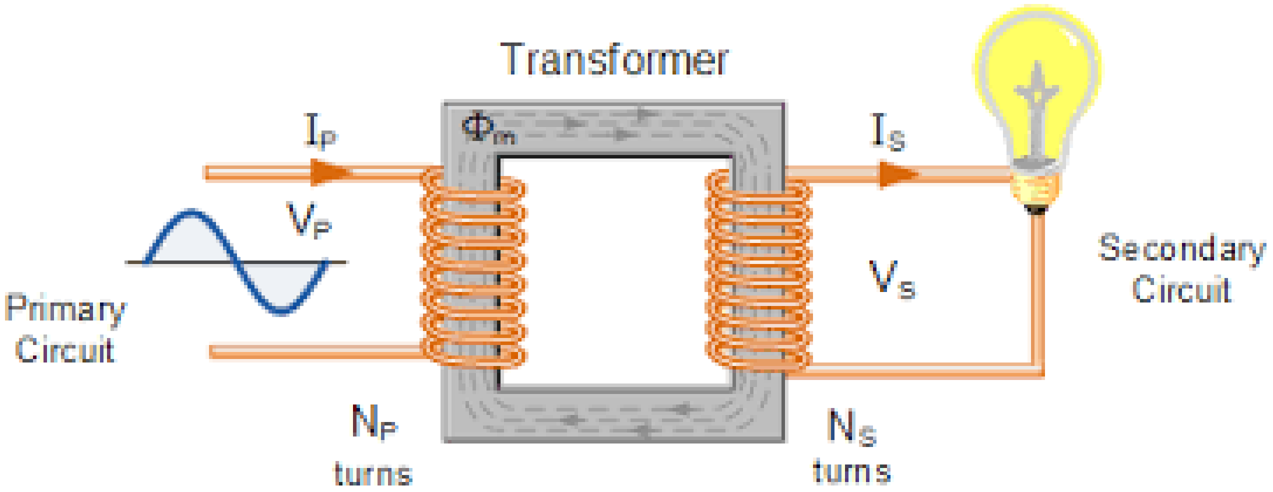
TRANSFORMER



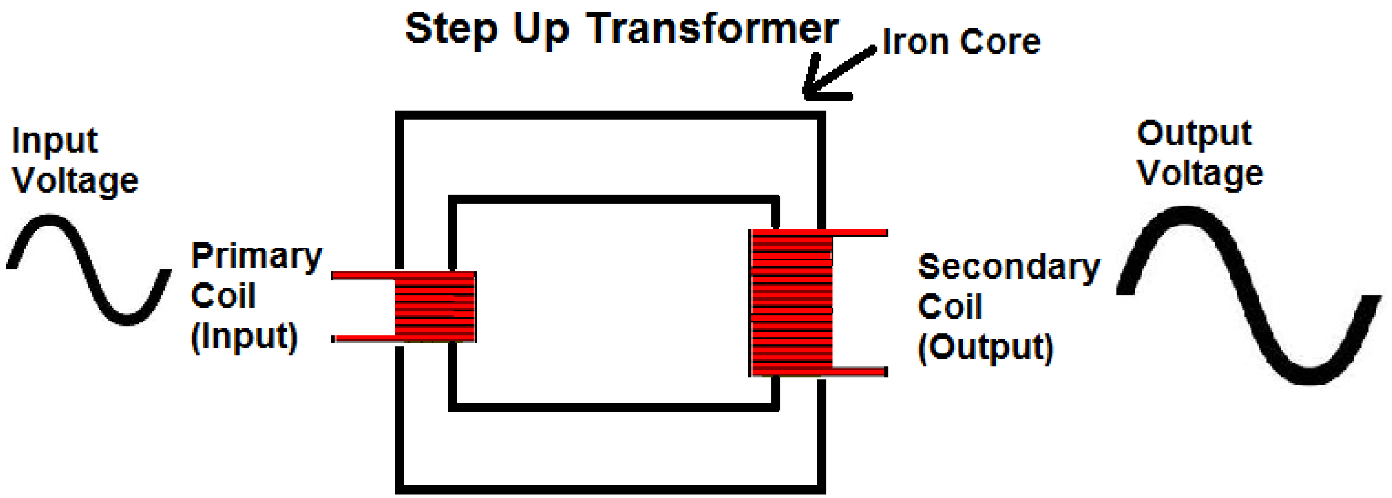
CONSTRUCTION OF TRANSFORMER

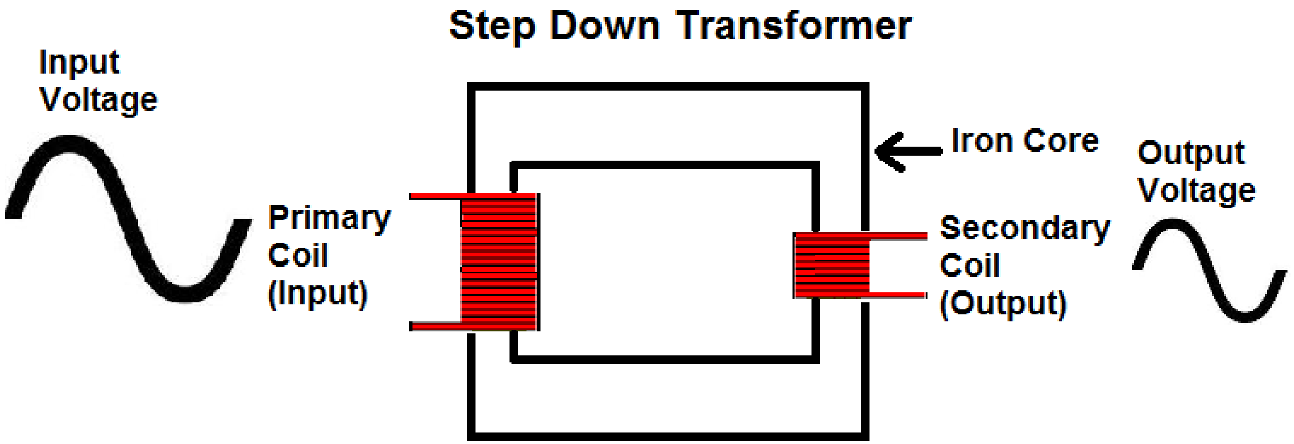


CONSTRUCTION OF TRANSFORMER



CONSTRUCTION OF STEP UP & STEP DOWN TRANSFORMER





EMF EQUATION OF A TRANSFORMER

If we assume sinusoidal AC voltage, then the magnetic flux can be given by,

$$\phi = \phi_{\mathrm{m}} \sin \omega t \cdots (1)$$

Now, according to principle of electromagnetic induction, the instantaneous value of EMF e_1 induced in the primary winding is given by,

$$e_1 = -N_1 \frac{d\phi}{dt}$$

$$\Rightarrow e_1 = -N_1 \frac{d}{dt}(\phi_{\mathrm{m}} \sin \omega t)$$

$$\Rightarrow e_1 = -N_1\, \omega\phi\, cos\, \omega t$$

$$\Rightarrow e_1 = -2\pi f N_1\, \phi_m\, cos\, \omega t$$

Where,

$$\omega = 2\pi f$$

$$\because -cos\, \omega t = \sin(\omega t - 90^\circ)$$

Therefore,

$$e_1 = 2\phi f N_1\, \phi_m \sin(\omega t - 90^\circ) \cdots (2)$$

Equation (2) may be written as,

$$e_1 = E_{m_1} \sin(\omega t - 90^\circ) \cdots (3)$$

Where, E_{m_1} is the maximum value of induced EMF e_1.

$$E_{\mathrm{m1}} = 2\pi f N_1 \phi_m$$

Now, for sinusoidal supply, the RMS value E_1 of the primary winding EMF is given by,

$$E_1 = \frac{E_{m1}}{\sqrt{2}} = \frac{2\pi f N_1 \phi_{\mathrm{m}}}{\sqrt{2}}$$

$$\therefore E_1 = 4.44\, f\phi_m N_1 \cdots (4)$$

Similarly, the RMS value E_2 of the secondary winding EMF is,

$$E_2 = 4.44\, f\phi_m N_2 \cdots (5)$$

In general,

$$E = 4.44\, f\phi_m N \cdots (6)$$

Equation (6) is known as EMF **equation of a transformer**.

For a given transformer, if we divide the EMF equation by the supply frequency, we get,

$$\frac{E}{f} = 4.44\,\phi_{\mathrm{m}} N = \text{Constant}$$

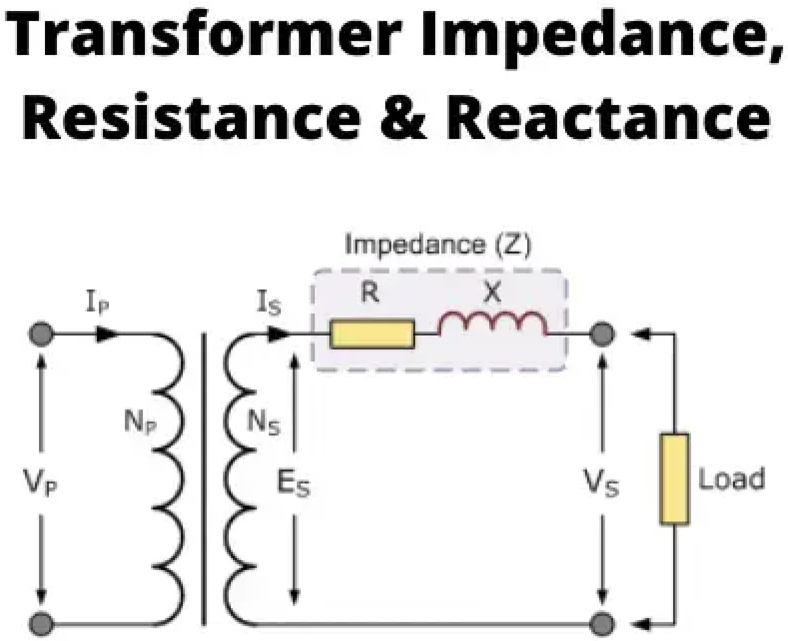
Which means the induced EMF per unit frequency is constant but it is not same on both primary and secondary side of the given transformer.

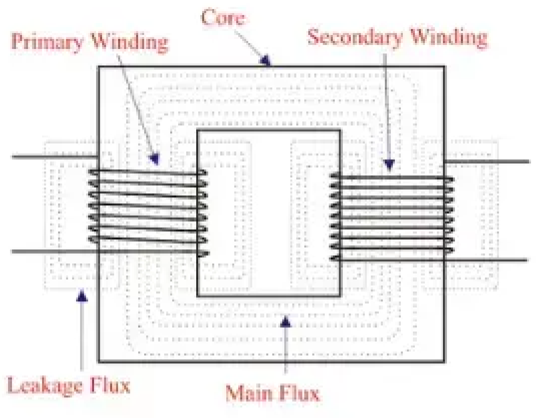
Also, from equations (4) and (5), we have,

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \text{ or } \frac{E_1}{N_1} = \frac{E_2}{N_2}$$

Hence, in a transformer, the induced EMF per turn in the primary winding is equal to the induced EMF per turn in the secondary winding.

EFFECT OF RESISTANCE AND LEAKAGE REACTANCE





Key learnings:

•**Leakage Reactance Definition**: Leakage reactance in a transformer is defined as the self-reactance caused by leakage flux that links either the primary or secondary winding but not both.

•**Transformer Impedance**: Impedance of a transformer is the combination of its resistance and leakage reactance, affecting voltage drops in windings.

•**Resistance in Windings**: The primary and secondary windings of a transformer, made of copper, possess inherent resistance.

•**Voltage Drops**: Voltage drops in transformer windings are due to their impedance, which includes resistance and leakage reactance.

•**Leakage Flux Path**: Leakage flux in a transformer passes through the winding insulation and transformer oil, leading to leakage reactance.

Leakage Reactance of Transformer

- In a transformer, not all the flux links both the primary and secondary windings. Some flux links with only one winding, called leakage flux.
- This leakage flux causes self-reactance in the affected winding.
- This self-reactance is also known as **leakage reactance**. When combined with the **transformer's resistance,** it forms impedance.
- This **impedance** causes voltage drops in both the primary and secondary windings.

Resistance of Transformer

The primary and secondary windings of a electrical power transformer are usually made of copper, which is a good conductor of current but not a superconductor. Superconductors are not practically available. Therefore, these windings have some resistance, known collectively as the **transformer's resistance**.

Impedance of Transformer

The both primary and secondary windings will have resistance and leakage reactance. These resistance and reactance will be in combination, is nothing but **impedance of transformer**. If R_1 and R_2 and X_1 and X_2 are primary and secondary resistance and leakage reactance of transformer respectively, then Z_1 and Z_2 impedance of primary and secondary windings are respectively,

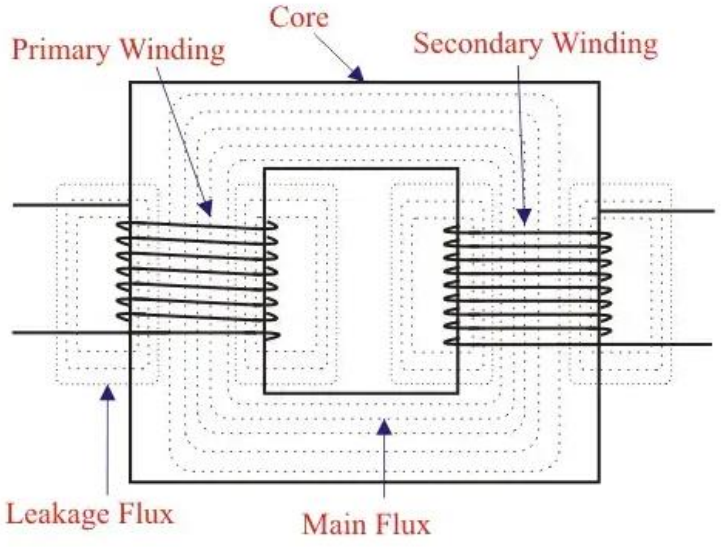
The Impedance of transformer plays a vital role during parallel operation of transformer.

$$Z_1 = R_1 + jX_1$$

$$Z_2 = R_2 + jX_2$$

Leakage Flux in Transformer

- In an ideal transformer, all the flux would link both the primary and secondary windings.
- However, in reality, not all flux links with both windings.
- Most flux passes through the core of transformer, but some flux links with only one winding.
- This is called leakage flux, which passes through the winding insulation and transformer oil instead of the core.
- Leakage flux causes **leakage reactance** in both primary and secondary windings, known as magnetic leakage.



Transformer Voltage Regulation

Transformer voltage regulation is the ratio or percentage value by which a transformers output terminal voltage varies either up or down from its no-load value as a result of variations in the connected load current

Voltage Regulation of single-phase transformers is the percentage (or per unit value) change in its secondary terminal voltage compared to its original no-load voltage under varying secondary load conditions.

In other words, regulation determines the variation in secondary terminal voltage which occurs inside the transformer as a result of variations in the transformers connected load thereby affecting its performance and efficiency if these losses are high and the secondary voltage becomes too low.

Transformer Voltage Regulation

- When there is no-load connected to the transformers secondary winding, that is its output terminals are open-circuited, there is no closed-loop condition, so there is no output load current (I_L = 0) and the transformer acts as one single winding of high self-inductance.
- Note that the no-load secondary voltage is a result of the fixed primary voltage and the turns ratio of the transformer.

- Loading the secondary winding with a simple load impedance causes a secondary current to flow, at any power factor, through the internal winding of the transformer.

- Thus voltage drops due to the windings internal resistance and its leakage reactance causes the output terminal voltage to change.

- A transformers voltage regulation change between its secondary terminal voltage from a no-load condition when I_L = 0, (open circuit) to a fully-loaded condition when $I_L = I_{MAX}$ (maximum current) for a constant primary voltage is given as:

Transformer Voltage Regulation

Transformer Voltage Regulation as a Fractional Change

$$\text{Regulation} = \frac{\text{Change in Actual Output Voltage}}{\text{The No-load Output Voltage}}$$

$$\therefore \text{Regulation} = \frac{V_{(\text{no-load})} - V_{(\text{full-load})}}{V_{(\text{no-load})}}$$

REFERENCES

1. Muthusubramanian R, Salivahanan S, “Basic Electrical and Electronics Engineering”, Tata McGraw Hill Publishers, (2009) - UNIT I – V
2. Bhattacharya. S.K, “Basic Electrical and Electronics Engineering”, Pearson Education , (2017) – UNIT I – IV
3. Mehta V K, Mehta Rohit, “Principles of Electrical Engineering and Electronics”, S.Chand & Company Ltd, (2010)- UNIT I and II
4. Mehta V K, Mehta Rohit, “Principles of Electronics”, S.Chand & Company Ltd, (2005)- UNIT IV and V

THANK YOU