

# **BEEE Unit-3 Notes**

## **Magnetic Circuits & Single Phase Transformer**

**Premium Printable Notes for RGPV Students**

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### **UNIT-3 TOPICS COVERED**

#### **Magnetic Circuits**

- Magnetic Flux
  - Magnetomotive Force
  - Reluctance
  - Magnetization Characteristics
  - Self Inductance
  - Mutual Inductance
  - Energy in Magnetic Systems
  - Coils Connected in Series
  - AC Excitation in Magnetic Circuits
  - Magnetic Field due to Current Carrying Conductor
  - Force on Current Carrying Conductor
  - Electromagnetic Induction
  - Induced EMF
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#### **Single Phase Transformer**

- Construction
  - Working Principle
  - EMF Equation
  - Equivalent Circuit
  - Phasor Diagram
  - Voltage Regulation
  - Transformer Losses
  - Efficiency
  - Open Circuit Test
  - Short Circuit Test
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# 1. MAGNETIC CIRCUITS

## Definition

A magnetic circuit is a closed path followed by magnetic flux.

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## Magnetic Flux

### Definition

Total magnetic field lines passing through a surface.

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## Symbol

$\Phi$  (Phi)

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## Unit

Weber (Wb)

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## Magnetomotive Force (MMF)

### Definition

Force responsible for establishing magnetic flux.

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## Formula

$$\text{MMF} = NI$$

Where:

- N = Number of turns
- I = Current

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## Unit

Ampere Turns (AT)

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## Reluctance

### Definition

Opposition offered to magnetic flux.

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## Formula

$$\mathfrak{R} = l / \mu A$$

Where:

- $l$  = Length
  - $\mu$  = Permeability
  - $A$  = Area
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## Unit

AT/Wb

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## Comparison with Electric Circuit

Electric Circuit	Magnetic Circuit
Current	Magnetic Flux
EMF	MMF
Resistance	Reluctance

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## 2. MAGNETIZATION CHARACTERISTICS OF FERROMAGNETIC MATERIALS

### Definition

Relationship between magnetic flux density and magnetizing force.

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### Characteristics

- High permeability
  - Hysteresis effect
  - Saturation occurs
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### Examples

- Iron
  - Nickel
  - Cobalt
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### Applications

- Transformers
  - Motors
  - Generators
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## 3. SELF INDUCTANCE

### Definition

Property by which changing current induces emf in same coil.

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### Formula

$$e = -L(di/dt)$$

Where:

- L = Self inductance
  - $di/dt$  = Rate of change of current
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## Unit

Henry (H)

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## Applications

- Chokes
  - Transformers
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## 4. MUTUAL INDUCTANCE

### Definition

Property by which changing current in one coil induces emf in another coil.

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### Formula

$$e = -M(di/dt)$$

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### Applications

- Transformers
  - Coupled circuits
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## 5. ENERGY IN LINEAR MAGNETIC SYSTEM

### Formula

$$W = 1/2 LI^2$$

Where:

- W = Energy
  - L = Inductance
  - I = Current
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### Applications

- Magnetic energy storage
  - Inductors
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## 6. COILS CONNECTED IN SERIES

### Series Aiding

Magnetic fluxes support each other.

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### Equivalent Inductance

$$L = L1 + L2 + 2M$$

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### Series Opposing

Fluxes oppose each other.

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### Formula

$$L = L1 + L2 - 2M$$

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## 7. AC EXCITATION IN MAGNETIC CIRCUITS

### Definition

Magnetic circuit supplied with alternating current.

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### Characteristics

- Alternating flux produced
  - Hysteresis loss occurs
  - Eddy current loss occurs
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### Applications

- Transformers
  - AC machines
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## 8. MAGNETIC FIELD PRODUCED BY CURRENT CARRYING CONDUCTOR

### Definition

Current carrying conductor produces magnetic field around it.

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### Fleming's Right Hand Rule

Thumb → Current direction

Fingers → Magnetic field direction

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### Formula

$$B = \mu_0 I / 2\pi r$$

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## Applications

- Electromagnets
  - Motors
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## 9. FORCE ON CURRENT CARRYING CONDUCTOR

### Definition

Conductor carrying current in magnetic field experiences force.

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### Formula

$$F = BIL\sin\theta$$

Where:

- B = Magnetic flux density
  - I = Current
  - L = Length
  - $\theta$  = Angle
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## Applications

- Electric motors
  - Loudspeakers
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## 10. ELECTROMAGNETIC INDUCTION

### Definition

EMF induced due to change in magnetic flux.

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# Faraday's Laws

## First Law

Changing magnetic flux induces emf.

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## Second Law

Magnitude of induced emf proportional to rate of change of flux.

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## Formula

$$e = -N(d\Phi/dt)$$

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## Lenz's Law

Induced emf opposes cause producing it.

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## Applications

- Generators
  - Transformers
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# 11. SINGLE PHASE TRANSFORMER

## Definition

Static device transferring electrical energy from one circuit to another through mutual induction.

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# Construction

Main parts:

- Core
  - Primary winding
  - Secondary winding
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# Working Principle

Works on mutual induction.

AC supplied to primary winding produces alternating flux.

Flux links secondary winding and induces emf.

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# EMF Equation

$$E = 4.44fN\Phi_m$$

Where:

- E = Induced emf
  - f = Frequency
  - N = Number of turns
  - $\Phi_m$  = Maximum flux
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# Transformer Ratio

$$V_1/V_2 = N_1/N_2$$

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# Types of Transformer

## Step-Up Transformer

Increases voltage.

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## Step-Down Transformer

Decreases voltage.

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## 12. EQUIVALENT CIRCUIT OF TRANSFORMER

Represents transformer parameters using resistances and reactances.

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### Components

- Copper loss resistance
  - Leakage reactance
  - Magnetizing branch
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### Applications

- Performance analysis
  - Voltage regulation calculation
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## 13. PHASOR DIAGRAM OF TRANSFORMER

### Definition

Vector representation of transformer voltages and currents.

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### Importance

- Shows phase relationships
  - Used for analysis
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# 14. VOLTAGE REGULATION

## Definition

Change in secondary voltage from no-load to full-load.

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## Formula

$$\%VR = [(VNL - VFL)/VFL] \times 100$$

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## Importance

- Indicates transformer performance
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# 15. TRANSFORMER LOSSES

## 1. Iron Losses

- Hysteresis loss
  - Eddy current loss
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## 2. Copper Losses

Losses due to winding resistance.

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## 3. Leakage Losses

Due to leakage flux.

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## 16. TRANSFORMER EFFICIENCY

### Formula

$$\eta = (\text{Output/Input}) \times 100$$

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### Importance

Higher efficiency means lower losses.

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## 17. OPEN CIRCUIT TEST

### Purpose

Determines iron losses.

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### Characteristics

- Secondary open
  - Low current drawn
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## 18. SHORT CIRCUIT TEST

### Purpose

Determines copper losses.

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### Characteristics

- Secondary short circuited
  - Low voltage applied
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# MOST IMPORTANT 14 MARK QUESTIONS

1. Explain magnetic circuit with comparison to electric circuit.
  2. Explain magnetization characteristics of ferromagnetic materials.
  3. Explain self inductance and mutual inductance.
  4. Explain electromagnetic induction and Faraday's laws.
  5. Explain force on current carrying conductor.
  6. Explain construction and working of single phase transformer.
  7. Derive EMF equation of transformer.
  8. Explain equivalent circuit and phasor diagram.
  9. Explain transformer losses and efficiency.
  10. Explain open circuit and short circuit tests.
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# IMPORTANT NUMERICALS

1. Magnetic flux calculation
  2. MMF calculation
  3. Inductance calculation
  4. Transformer EMF equation
  5. Voltage regulation
  6. Efficiency calculation
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# QUICK REVISION FORMULAS

Energy Stored:

$$W = \frac{1}{2} LI^2$$

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Induced EMF:

$$e = -N(d\Phi/dt)$$

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Transformer EMF:

$$E = 4.44fN\Phi_m$$

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Efficiency:

$$\eta = (\text{Output/Input}) \times 100$$

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## **EXAM TIPS**

- ✓ Draw transformer diagrams neatly
  - ✓ Practice numerical problems
  - ✓ Learn Faraday's laws properly
  - ✓ Remember transformer formulas
  - ✓ Revise losses and efficiency carefully
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## **END OF UNIT-3 NOTES**