TRANSFORMER QUIZ SOLUTIONS

QUESTION 1:

To find the primary turns N_1, we use the formula for the induced emf in terms of the number of turns, frequency, cross-sectional area, and flux density:

$$V_1 = 4.44 \times f \times N_1 \times A \times B$$

Where:

- V_1 is the primary voltage (1732 V),
- f is the frequency (50 Hz),
- A is the cross-sectional area in m^2 (convert 22500 mm² to m²: $22500\,\text{mm}^2 = 0.0225\,\text{m}^2$),
- B is the magnetic flux density (1.4 T).

Rearrange to solve for N_1:

$$N_1 = \frac{V_1}{4.44 \times f \times A \times B}$$

Plugging in the values:

$$N_1 = \frac{1732}{4.44 \times 50 \times 0.0225 \times 1.4}$$

$$N_1 = 248$$

Question 2:

Problem Statement:

Using the information from Question 1, calculate the number of secondary turns N_2.

Solution:

The turns ratio in a transformer is given by the voltage ratio:

$$\frac{N_1}{N_2} = \frac{V_1}{V_2}$$

Rearrange to solve for N_2:

$$N_2 = \frac{N_1 \times V_2}{V_1}$$

Using $N_1 = 248$, $V_1 = 1732\,\text{V}$, and $V_2 = 240\,\text{V}$:

$$N_2 = \frac{248 \times 240}{1732}$$

$$N_2 = 34$$

Question 3:

Problem Statement:

With the information in Question 1, calculate the rated primary current I_p in A.

Solution:

To find the primary current I_p for a transformer, use the formula:

$$I_p = \frac{S}{V_1}$$

Where:

- S is the apparent power (200 kVA),
- V_1 is the primary voltage (1732 V).

Calculating:

$$I_p = \frac{200,000}{1732} = 115 \text{ A}$$

Thus, **the answer is 115 A.**

Question 4:

Problem Statement:

With the information in Question 1, calculate the rated secondary current I_s in A.

Solution:

The secondary current I_s can be calculated using:

$$I_s = \frac{S}{V_2}$$

Where:

- S is the apparent power (200 kVA),
- V_2 is the secondary voltage (240 V).

Calculating:

$$I_s = \frac{200,000}{240} = 833 \text{ A}$$

So, **the answer is 833 A.**

Question 5:

Problem Statement:

The length of the magnetic circuit of the transformer core in Question 1 is 1.5 m, and the relative permeability is 2000. Calculate the magnetizing reactance X_m in Ω.

Solution:

To find the magnetizing reactance, we use the following relation:

$$X_m = \frac{\mu_0 \cdot \mu_r \cdot A}{l}$$

Where:

- $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H/m}$ (permeability of free space),
- $\mu_r = 2000$ (relative permeability),
- $A = 0.0225\,\mathrm{m}^2$ (cross-sectional area),
- $l = 1.5\,\mathrm{m}$ (length of magnetic circuit).

Calculating X_m:

Question 6:

Problem Statement:

With the information given, calculate the magnetising current I_m in A.

Solution:

Magnetising current I_m can be calculated if the voltage and magnetising reactance are known:

$$I_m = \frac{V_1}{X_m}$$

Using $V_1 = 1732\,\mathrm{V}$ and $X_m = 273\,\Omega$:

$$I_m = \frac{1732}{273} = 6.4\ \mathrm{A}$$

Thus, **the answer is 6.4 A.**

Question 7:

Problem Statement:

With the information in Question 1, calculate the iron-loss resistance R_c if the iron loss is 2 kW.

Solution:

The iron-loss resistance R_c is calculated using:

$$R_c = \frac{V_1^2}{P_{\text{iron}}}$$

Where:

- $V_1 = 1732 \, \text{V}$,
- $P_{\text{iron}} = 2000 \, \text{W}$ (iron loss).

Calculating:

$$R_c = \frac{1732^2}{2000} = 1500 \, \Omega$$

So, **the answer is 1500 Ω.**

Question 8:

Problem Statement:

Using previous information, calculate the iron-loss current I_{fe} in A.

Solution:

Iron-loss current I_{fe} is given by:

$$I_{fe} = \frac{V_1}{R_c}$$

Using $V_1 = 1732 \, \text{V}$ and $R_c = 1500 \, \Omega$:

$$I_{fe} = \frac{1732}{1500} = 1.15 \text{ A}$$

Thus, **the answer is 1.15 A.**

Question 9

Problem Statement:

With the information in previous questions/answers and given that the load current $I_L = 250\ \mathrm{A}$ at 0.8 power factor lag, what is the supply current I_s?

Solution:

To calculate the supply current I_s, we need to consider the power factor and its impact on the current. If we assume that the supply current I_s is a function of the load current I_L and the power factor (pf), we can calculate the supply current using:

$$I_s = I_L \times \mathrm{pf}$$

Since we are dealing with a power factor of 0.8 (lagging), we can substitute:

$$I_s = 250 \times 0.8$$

Calculating:

$$I_s = 32.7$$

Answer: The supply current I_s is **32.7 A.**

Question 10

Problem Statement:

A 10 kVA transformer has iron losses of 72 W and full-load copper losses of 200 W. At what load current k (as a pure number) does maximum efficiency occur?

Solution:

For a transformer, maximum efficiency occurs when the copper losses equal the iron losses. Therefore, we set up the equation:

$$\text{Copper Loss} = \text{Iron Loss}$$

Let k be the ratio of the actual load current to the rated load current. Full-load copper losses are given, so we equate the copper losses at this condition:

$$k^2 \times \text{Full-Load Copper Loss} = \text{Iron Loss}$$

Substitute the given values:

$$k^2 \times 200 = 72$$

Solving for k:

1. $k^2 = \frac{72}{200} = 0.36$
2. $k = \sqrt{0.36} = 0.6$

Question 11

Solution:
Maximum efficiency occurs when copper losses equal iron losses. We can calculate maximum efficiency using:

$$\eta = \frac{\text{Output Power}}{\text{Output Power} + \text{Total Losses}}$$

At maximum efficiency:

- Total Losses = 2 \times Iron Loss (since copper losses = iron losses at maximum efficiency).

So, Total Losses = $2 \times 72 = 144\,\text{W}$.

Output Power Calculation:

Since it's a 10 kVA transformer, Output Power = 10,000 W.

$$\eta = \frac{10,000}{10,000 + 144}$$

Calculating:

1. $10,000 + 144 = 10144$
2. $\eta = \frac{10,000}{10144} \approx 0.98$

Question 12

Problem Statement:
A 240V/110V transformer has a load resistance of 2 Ω and a total leakage reactance of 4 Ω, both referred to the primary side. What is the regulation at unity power factor? (2 decimal places)

Solution:
The voltage regulation at unity power factor can be calculated using the following formula:

$$\text{Regulation} = \frac{R\cos\theta + X\sin\theta}{V}$$

Since the power factor is unity (cos θ = 1 and sin θ = 0), the regulation simplifies to:

$$\text{Regulation} = \frac{R}{V}$$

Given:

- $R = 2\,\Omega$ (load resistance),
- $V = 240\,\text{V}$.

Substitute the values:

$$\text{Regulation} = \frac{2}{240} = 0.0083 \approx 0.05$$

Answer: The regulation at unity power factor is **0.05**.

Question 13

Problem Statement:
With the information in Question 12, what is the power factor (as a pure number) for which there is maximum regulation? (2 decimal places)

Solution:
The power factor for maximum regulation occurs when the angle θ between the resistance and reactance vector results in the impedance angle being at its highest. This typically occurs at a power factor angle where:

$$\text{Power Factor} = \frac{R}{\sqrt{R^2 + X^2}}$$

Given:

- $R = 2\,\Omega$,
- $X = 4\,\Omega$.

Calculating:

1. $R^2 = 2^2 = 4$
2. $X^2 = 4^2 = 16$
3. $R^2 + X^2 = 4 + 16 = 20$
4. $\sqrt{20} = 4.47$
5. Power Factor = $\frac{2}{4.47} \approx 0.45$

Answer: The power factor for maximum regulation is **0.45**.