UTS

University of Technology, Sydney
Faculty of Engineering and Information Technology

Subject:	**48521 Fundamentals of Electrical Engineering**
Assessment Number:	**3**
Assessment Title:	**Lab 3 – Transformers**
Tutorial Group:	

Students Name(s) and Number(s)

Student Number	Family Name	First Name

Declaration of Originality:

The work contained in this assignment, other than that specifically attributed to another source, is that of the author(s). It is recognised that, should this declaration be found to be false, disciplinary action could be taken and the assignments of all students involved will be given zero marks. In the statement below, I have indicated the extent to which I have collaborated with other students, whom I have named.

Statement of Collaboration:

Signature(s)

Marks

Lab work	/2
Analysis	/1
Questions	/2
TOTAL	/5

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key

Assessment Submission Receipt

Assessment Title:	**Lab 3 – Transformers**
Student's Name:	
Date Submitted:	
Tutor Signature:	

Lab 3 – Transformers

Open-circuit and short-circuit tests. Resistance. Leakage and magnetising reactance.

Introduction

The measurement of equivalent circuit parameters is an important concept in electrical engineering. We will measure the equivalent circuit of a single-phase transformer.

Objectives

1. To observe safe operating procedures when working with a power transformer.

2. To measure AC voltage, current and power at mains frequency and amplitude (50 Hz, 240 V).

3. To measure the equivalent circuit parameters of a power transformer.

4. To calculate the transformer performance with a resistor and capacitor load and compare with measured performance.

L3.2

Equipment

- 1 single-phase 240 V, 8A autotransformer – Warburton Franki Variac,
- 1 single-phase 240 V : 120 V, 1.5 kVA, 50 Hz isolating transformer – Standard Waygood
- 1 DC/AC current probe – Prova Model 15
- 1 digital multimeter
- 1 three-phase resistive load, 110 Ω per phase
- 1 three-phase capacitive load, 60 μF per phase
- 2 AC voltmeter / ammeters – YEW
- 1 clip-on power quality clamp meter – Fluke 345
- 1 x10 voltage probe

Safety

Cat. B lab

This is a Category B laboratory experiment. Please adhere to the Category B safety guidelines (issued separately).

Warning!

Remember:

1. **Choose suitable METER SCALES and <u>WIND DOWN</u> and <u>SWITCH OFF</u> the supply Variac when making circuit connections.**
2. **<u>Ensure equipment is earthed.</u>**

Theory

1. Winding Arrangement

There are several windings on the iron core. The ends of each winding are brought out to terminals and therefore more than one transformer connection can be made. The primary and secondary windings are concentric. A diagram is shown below:

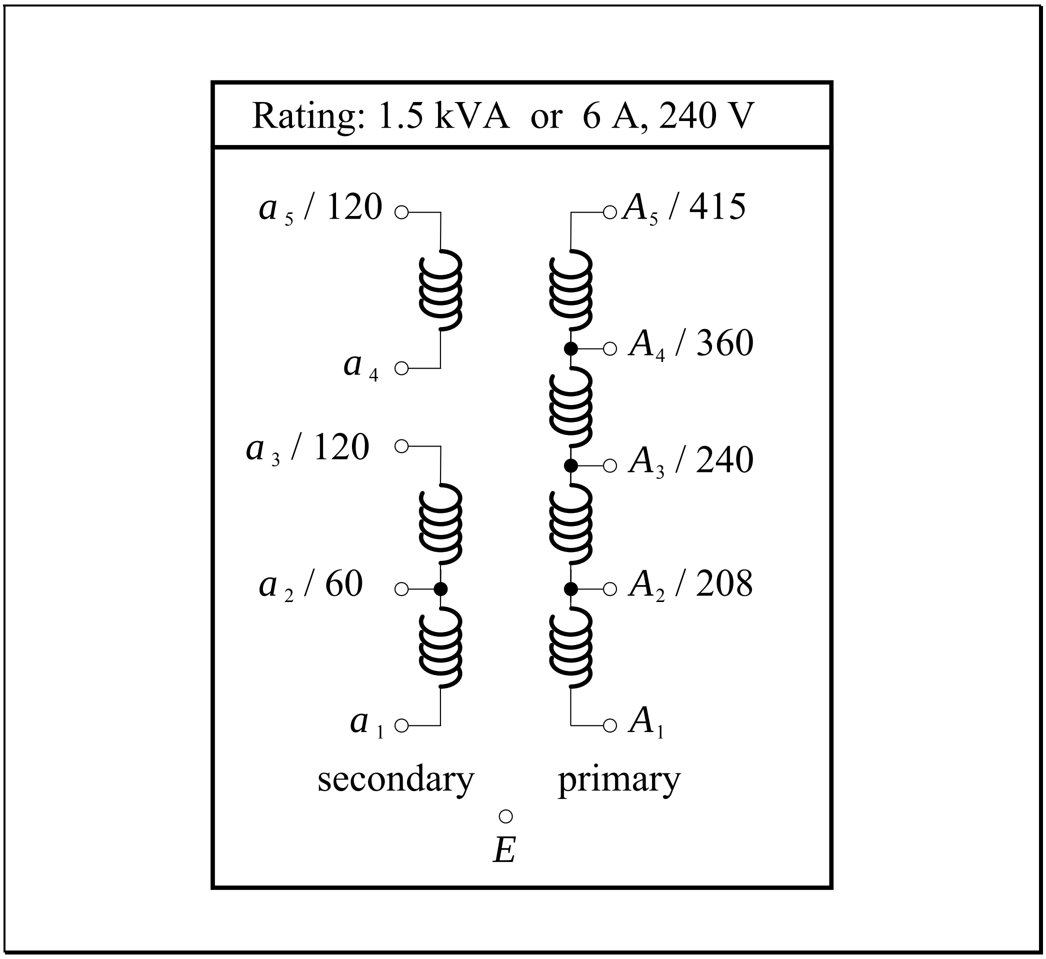


Figure 3.1 – Single-phase transformer windings

2. Magnetic Circuit

The transformer is a core-type transformer with concentric windings on one limb. The primary (the high voltage exciting winding) is on the outside:

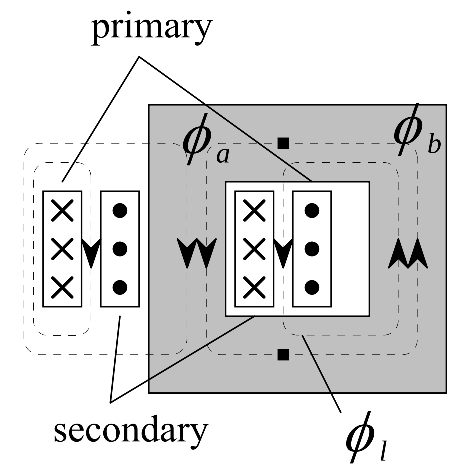


Figure 3.2 – Single-phase transformer construction

The magnetic equivalent circuit is:

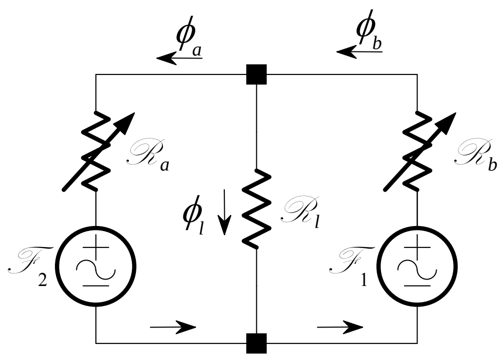


Figure 3.3 – Single-phase transformer magnetic equivalent circuit

3. Electric Circuit

The electric equivalent circuit is:

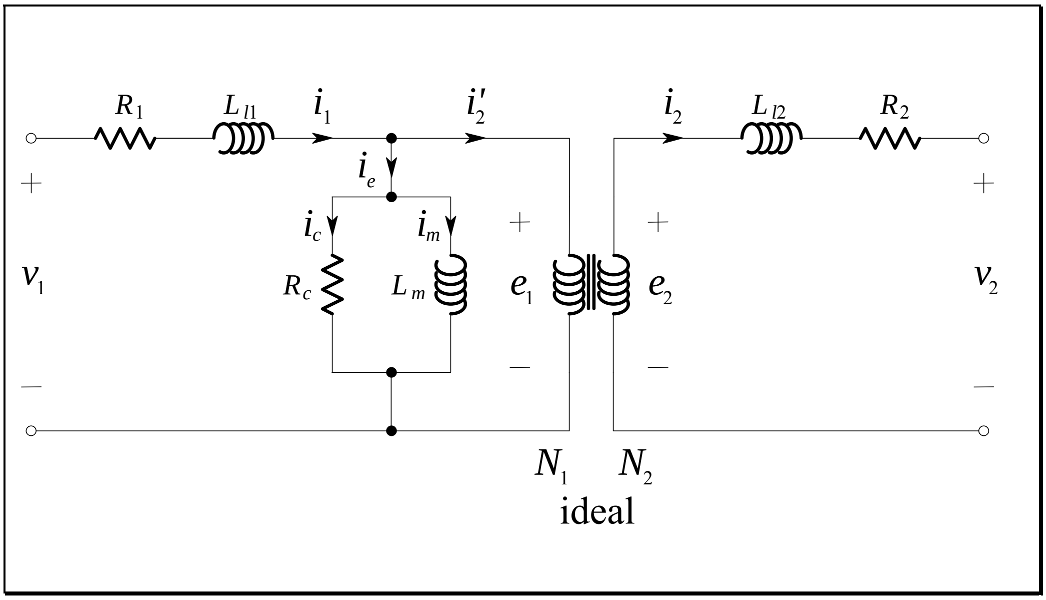


Figure 3.4 – Single-phase transformer magnetic equivalent circuit

Lab Work [3 marks]

I – DC Resistance

1. The resistance of the windings is very low. Therefore, we need to measure the resistance of the leads used to take the measurement, and subtract this from the recorded value for the windings:

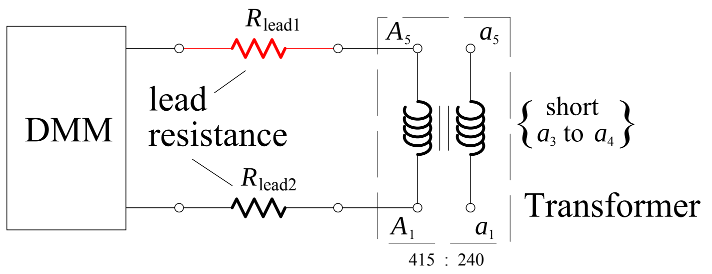


Figure 3.5 – Measurement of winding resistance for a transformer

2. Using the DMM, measure the DC resistance of the two leads used to take the measurement (plug one lead into the other):

$$R_{\text{leads}} = R_{\text{lead1}} + R_{\text{lead2}} =$$

3. Using the DMM, measure the DC resistance of the primary 415 V winding and the secondary 240 V winding (short a_3 to a_4). Remember to correct for the lead resistance.

$$R_1 = \qquad\qquad\qquad R_2 =$$

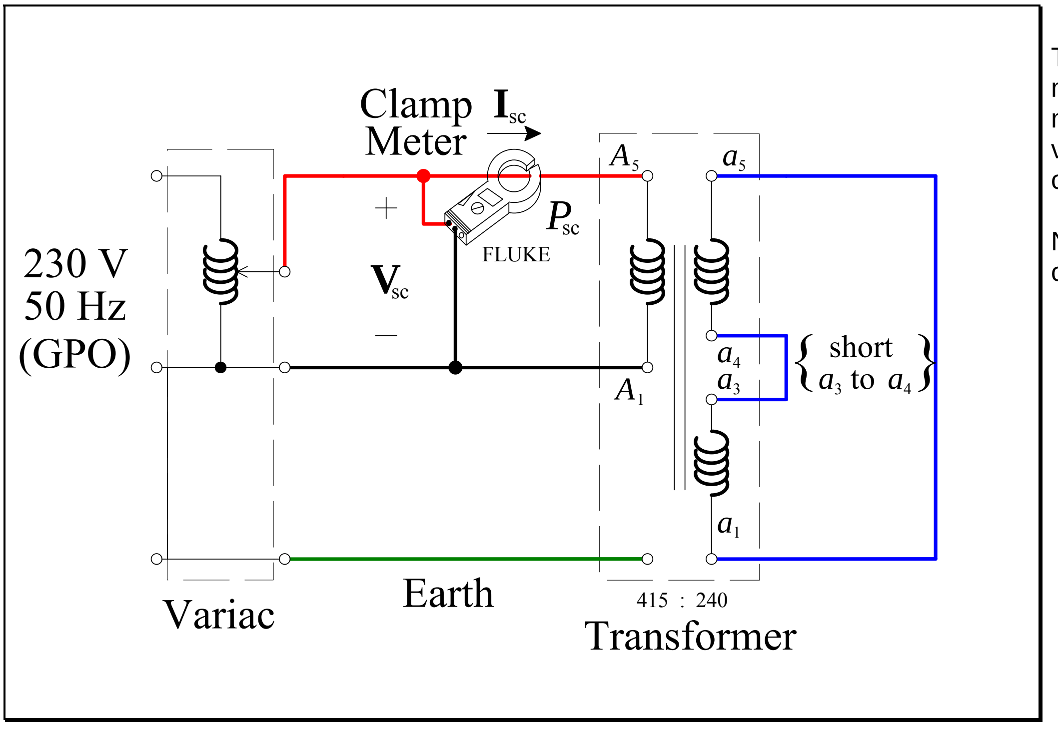
4. Calculate the transformer's resistance (referred to the primary), when $N_1/N_2 = 415/240$:

$$R_{\text{DC}} = R_1 + \left(\frac{N_1}{N_2}\right)^2 R_2 =$$

II – Short-Circuit Test

1. **<u>Do not connect the supply or turn on the power until circuit connections are checked by a lab tutor.</u>**

2. Wire up the circuit shown below – the turns ratio is **415:240**.



The Fluke clamp meter is used to measure the source voltage and any currents.

Note the earth connection!

Figure 3.6 – Short-circuit test circuit for a transformer

3. The Variac makes the earth connection from the GPO available at a green terminal. **Ensure that the earth (frame) of the transformer is connected to the earth terminal of the Variac**.

4. The clamp meter has an arrow (moulded into the plastic) that indicates the assumed polarity of the current. **Ensure that the "positive" current (from left to right in the red lead in the diagram above) is passed through the clamp in alignment with the arrow**.

5. After the circuit has been checked, turn on the Variac and bring up the voltage **SLOWLY** until the current $|\mathbf{I}_{sc}| = 5\text{ A}$ RMS.

6. Measure voltage, current and power on the primary side of the transformer:

Primary voltage:	$\lvert \mathbf{V}_{\mathrm{sc}} \rvert =$
Primary current:	$\lvert \mathbf{I}_{\mathrm{sc}} \rvert =$
Primary power:	$P_{\mathrm{sc}} =$

7. Calculate the transformer's parameters (referred to the primary):

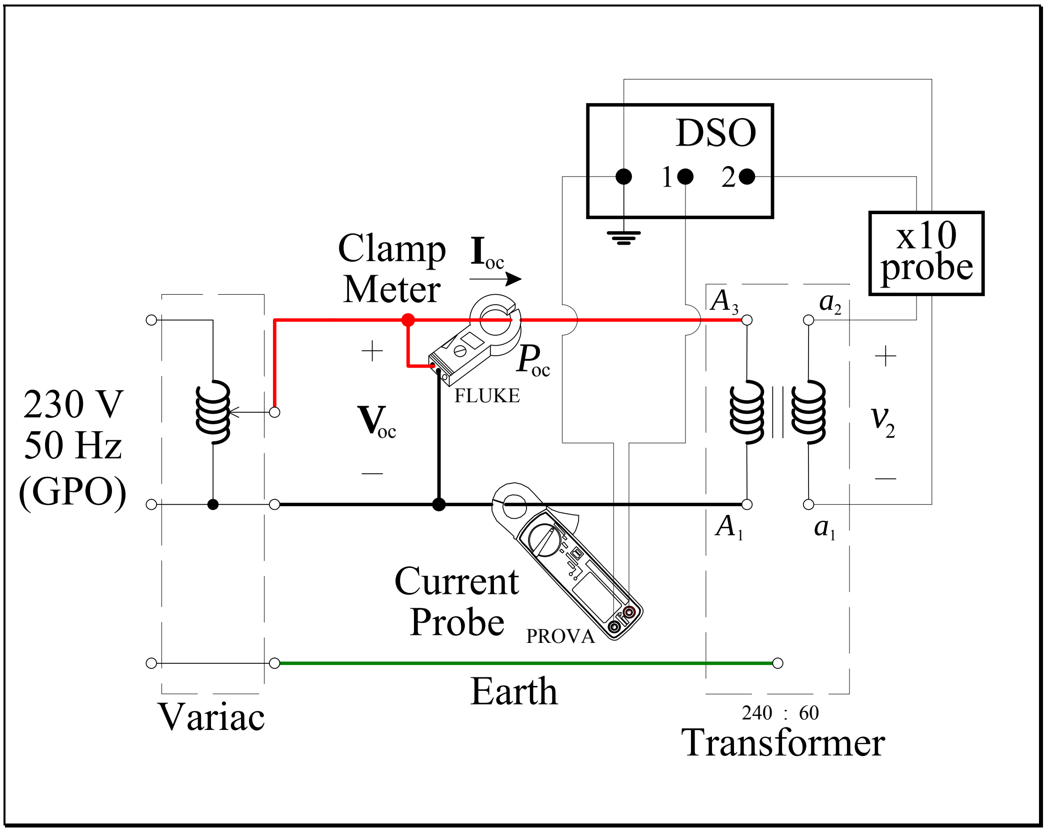
$R'_{\mathrm{eq}} = \dfrac{P_{\mathrm{sc}}}{\lvert \mathbf{I}_{\mathrm{sc}} \rvert^2} =$
$\lvert \mathbf{Z}'_{\mathrm{eq}} \rvert = \dfrac{\lvert \mathbf{V}_{\mathrm{sc}} \rvert}{\lvert \mathbf{I}_{\mathrm{sc}} \rvert} =$
$X'_{\mathrm{eq}} = \sqrt{\lvert \mathbf{Z}'_{\mathrm{eq}} \rvert^2 - R'^2_{\mathrm{eq}}} =$

8. **<u>Wind down and switch off the Variac.</u>**

III – Open-Circuit Test

1. **<u>Do not connect the supply or turn on the power until circuit connections are checked by a lab tutor.</u>**

2. Wire up the circuit shown below – the transformer turns ratio is **240:60**.



Note the earth connection!

Figure 3.7 – Open-circuit test circuit for a transformer

3. Set the current probe's range to 400 mA and press the ZERO button. **Note that the 400 mA range gives 1 mV / 1 mA at the output**.

4. On the DSOs Channel 1 menu, push the `Probe` softkey. Set the `Units` to `Amps`.

5. Trigger the DSO using `Ext-Line`.

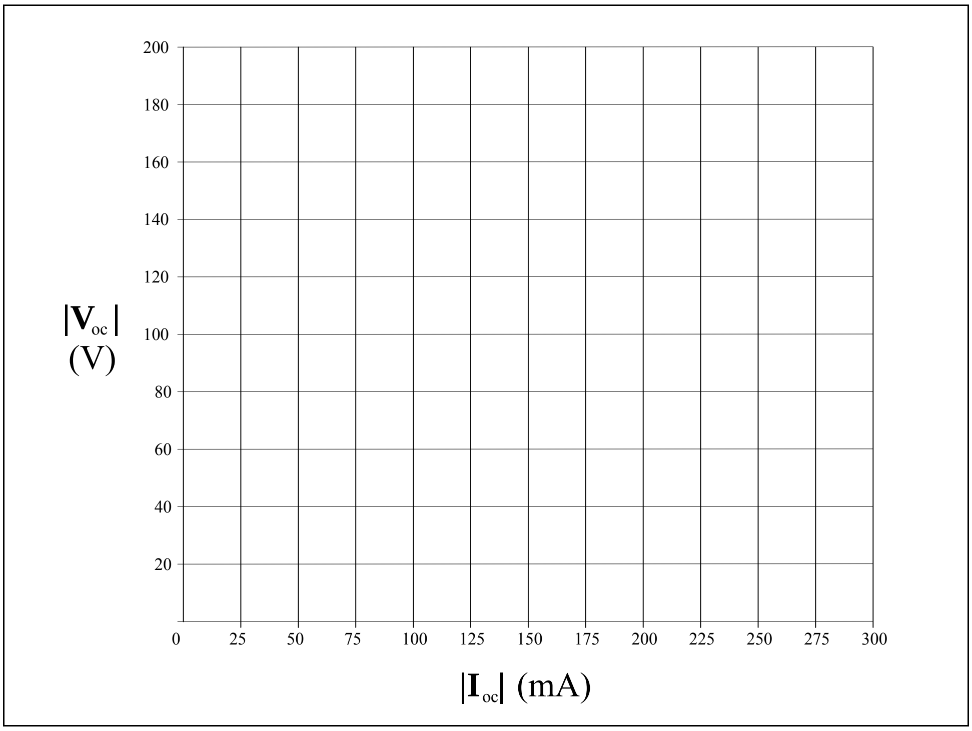
6. Push the `Acquire` key (in the Waveform section) and choose `Averaging` to reduce the noise on the display.

7. After the circuit has been checked, turn on the Variac and bring up the voltage **SLOWLY** in steps until the voltage $|\mathbf{V}_{oc}| = 200\text{ V}$ RMS. Using the `Quick Measure` feature of the DSO, measure the RMS value of the primary current and tabulate below:

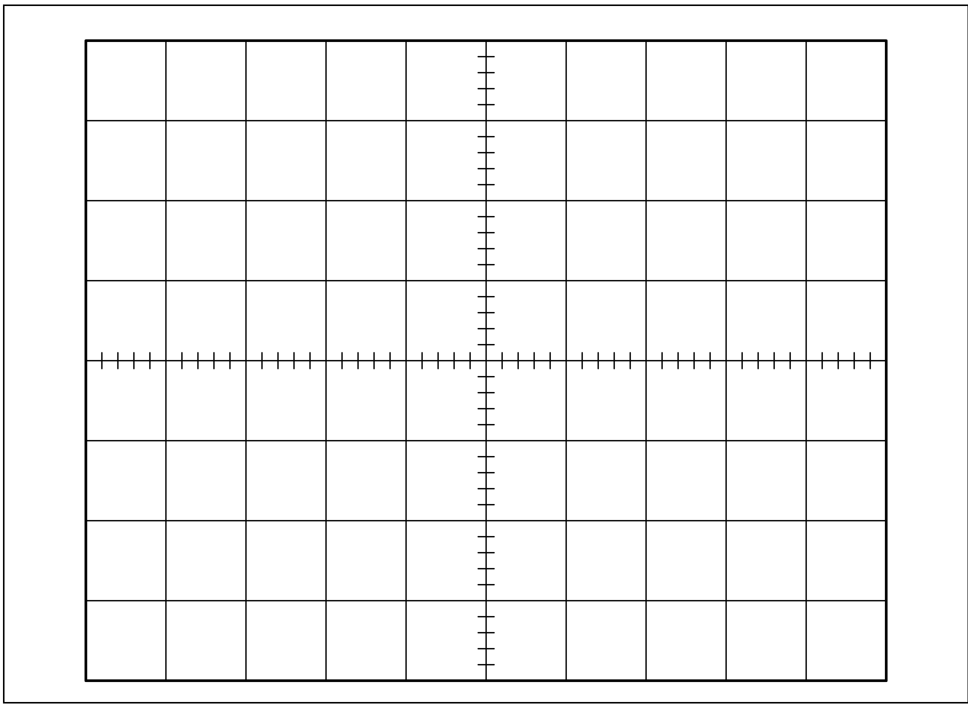
$\lvert\mathbf{V}_{oc}\rvert$ (V)	40	80	100	140	160	200
$\lvert\mathbf{I}_{oc}\rvert$ (mA)						

8. Plot $|\mathbf{V}_{oc}| \sim |\mathbf{I}_{oc}|$.

Open-circuit |**V**|-|**I**| characteristic



9. For $|\mathbf{V}_{oc}| = 200\text{ V}$ RMS, accurately sketch the waveforms of v_2 and i_{oc}, noting both horizontal and vertical scales.



Open-circuit test waveforms

Remember: the Channel 1 scale on the DSO is the voltage produced by the current probe, so you will have to scale the voltage to get the current.

10. For $|\mathbf{V}_{oc}| = 200\text{ V}$ RMS, use the DSO cursors to measure the phase angle between v_{oc} and i_{oc} (use "zero crossings" as reference):

Phase angle: $\phi =$

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11. Using the clamp meter, measure the power factor:

$$\cos\phi = \frac{P_{\mathrm{oc}}}{|\mathbf{V}_{\mathrm{oc}}||\mathbf{I}_{\mathrm{oc}}|} =$$

Hence determine:

Phase angle: $\phi =$

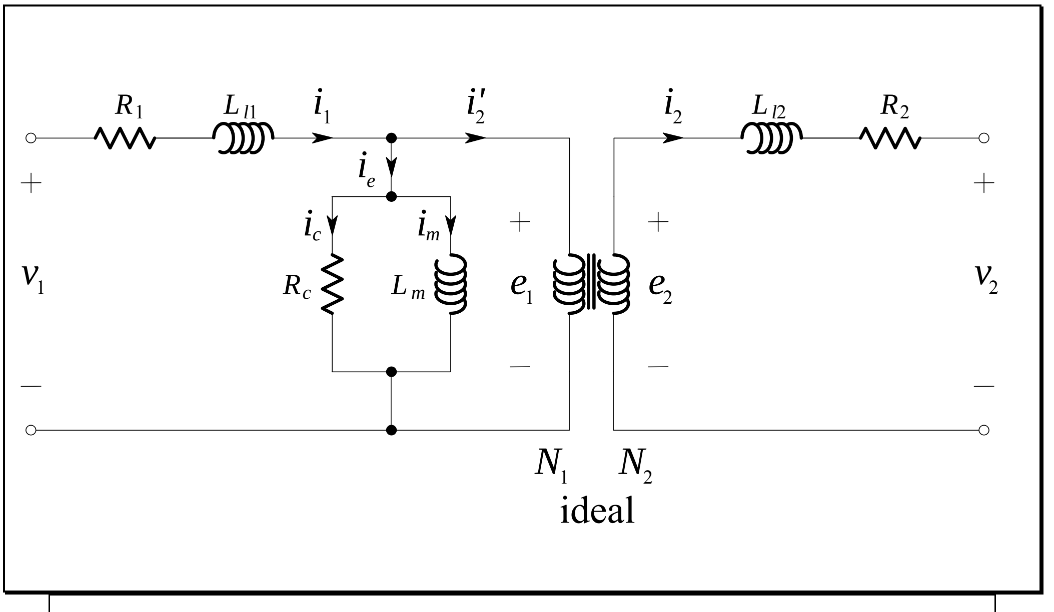
Comment on the accuracy of the DSO and clamp meter in measuring the phase angle. Which measurement is more useful, and why?

12. Calculate the transformer's parameters (referred to the primary):

$R_c = \dfrac{\lvert \mathbf{V}_{\text{oc}} \rvert}{\lvert \mathbf{I}_{\text{oc}} \rvert \cos\phi} =$
$X_m = \dfrac{\lvert \mathbf{V}_{\text{oc}} \rvert}{\lvert \mathbf{I}_{\text{oc}} \rvert \sin\phi} =$

13. **Wind down and switch off the Variac. Turn off the PROVA 15.**

14. In the model of the transformer, show the element values:



$R_1 =$
$L_{l1} =$
$R_c =$
$L_m =$
$L_{l2} =$
$R_2 =$

IV – Load Test with Resistor

1. **Do not connect the supply or turn on the power until circuit connections are checked by a lab tutor.**

2. Wire up the circuit shown below – the turns ratio is **415:240**.

The V and A meters are YEW meters on appropriate settings.

Note the earth connection!

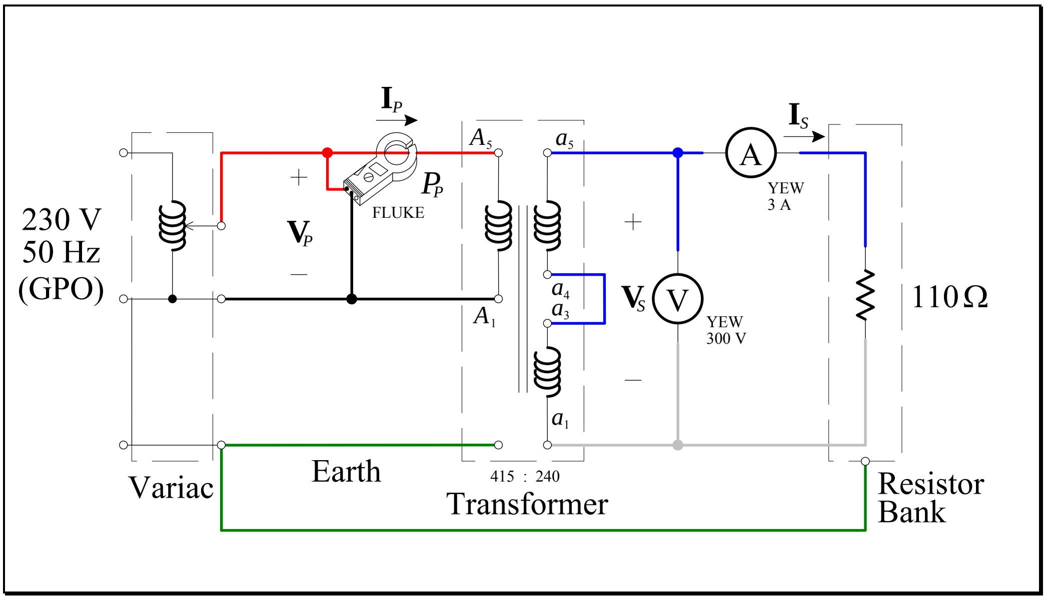


Figure 3.8 – Load test circuit for a transformer

3. After the circuit has been checked, turn on the Variac and bring up the voltage **SLOWLY** until the primary voltage is 240 V.

4. Measure voltage, current and power on the primary side of the transformer:

Primary voltage:	$\left\|\mathbf{V}_P\right\| =$
Primary current:	$\left\|\mathbf{I}_P\right\| =$
Primary power:	$P_P =$

5. Measure voltage and current on the secondary side of the transformer:

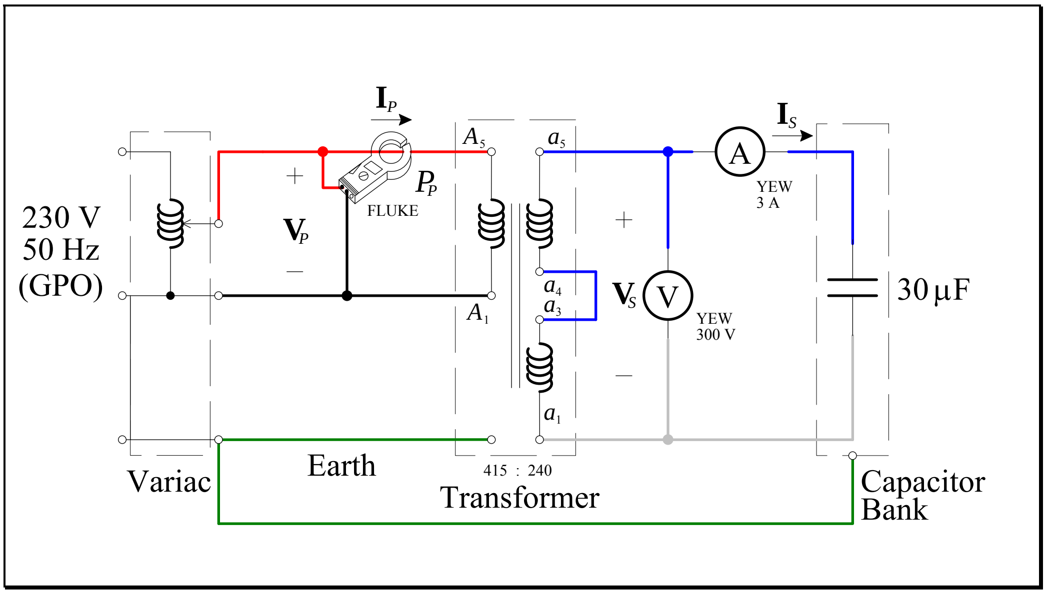
Secondary voltage:	$\left\|\mathbf{V}_S\right\| =$
Secondary current:	$\left\|\mathbf{I}_S\right\| =$

6. **Wind down and switch off the Variac.**

IV – Load Test with Capacitor

1. **<u>Do not connect the supply or turn on the power until circuit connections are checked by a lab tutor.</u>**

2. Wire up the circuit shown below – the turns ratio is **415:240**.



The V and A meters are YEW meters on appropriate settings.

Note the earth connection!

Figure 3.9 – Load test circuit for a transformer

3. After the circuit has been checked, turn on the Variac and bring up the voltage **SLOWLY** until the primary voltage is 240 V.

4. Measure voltage, current and power on the primary side of the transformer:

Primary voltage:	$\lvert \mathbf{V}_P \rvert =$
Primary current:	$\lvert \mathbf{I}_P \rvert =$
Primary power:	$P_P =$

5. Measure voltage and current on the secondary side of the transformer:

Secondary voltage:	$\lvert \mathbf{V}_S \rvert =$
Secondary current:	$\lvert \mathbf{I}_S \rvert =$

6. **<u>Wind down and switch off the Variac.</u>**

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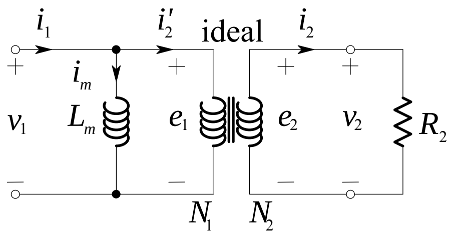
Questions [2 marks]

Encircle the correct answer, cross out the wrong answers. [one or none correct]

All questions are worth 0.2 marks each.

(i)



A transformer model.

The relations are:

(a) $\dfrac{v_1}{N_1} = \dfrac{v_2}{N_2}$, $\quad N_1 i_1 = N_1 i_m + N_2 i_2$, $\quad R_2' = R_2 \dfrac{N_1}{N_2}$

(b) $\dfrac{e_1}{N_1} = \dfrac{e_2}{N_2}$, $\quad N_1 i_2' = N_2 i_2$, $\quad R_2' = R_2 \left(\dfrac{N_1}{N_2}\right)^2$

(c) $\dfrac{i_1}{N_1} = \dfrac{i_2'}{N_2}$, $\quad N_1 e_1 = N_2 e_2$, $\quad R_2' = R_2 \left(\dfrac{N_1}{N_2}\right)^2$

(ii)

The magnetising reactance of a transformer is:

(a) negligible (b) linear (c) nonlinear

(iii)

A lossless transformer has $N_1 = 15000$, $N_2 = 100$. The mean length of the core is 150 mm and its c.s.a. is 100 mm^2. $\mu_r = 10^4/4\pi$. The secondary self and primary to secondary mutual inductances are respectively:

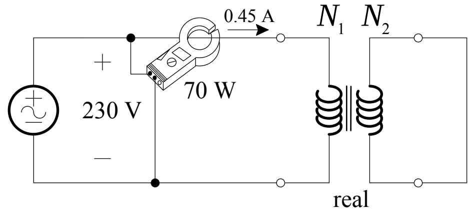
(a) 150 H, 1H (b) $1/150$ H, 1H (c) 1.5 H, $10^{-3}/15$ H

(iv)

An ideal transformer is rated as 240 V : 12 V. It supplies a load with 500 mA at 6 V (RMS AC). The primary current is:

(a) 25 mA (b) 10 A (c) 250 mA

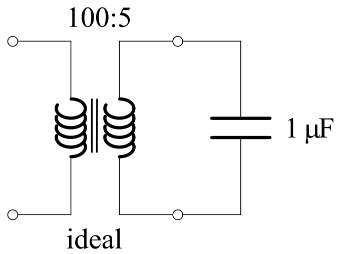
(v)



Short-circuit test on a real transformer. $R'_{eq} =$

(a) 346 Ω (b) 756 Ω (c) 376 Ω

(vi)



The primary equivalent of the capacitive load is:

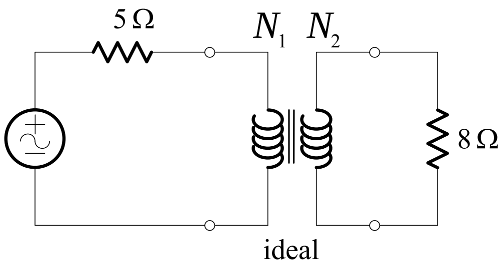
(a) 400 μF (b) 50 nF (c) 2.5 nF

(vii)

A lossless transformer is to operate from a 230 V, 50 Hz supply and the maximum flux density in the core must not exceed 1.4 T. The minimum core cross-section for a 100 turn primary coil is:

(a) 7.40×10^{-3} m^2 (b) 5.23×10^{-3} m^2 (c) 46.5×10^{-3} m^2

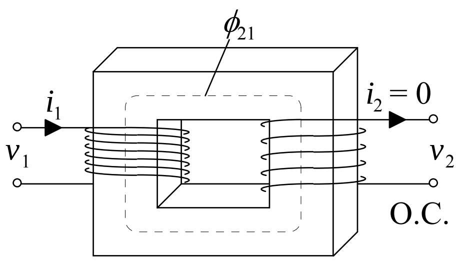
(viii)



To achieve maximum power transfer to the load, the turns ratio should be:

(a) 0.6250 (b) 0.7906 (c) 1.265

(ix)



In the transformer shown, the mutual inductance is:

(a) 0 (since $i_2 = 0$) (b) $L_{21} = N_1 N_2 \dfrac{d\phi_{21}}{dt}$ (c) $L_{21} = N_2 \phi_{21}$

(x)

The leakage reactance of a transformer is:

(a) negligible (b) linear (c) nonlinear

Report

Only submit ***ONE*** report per lab group.

Complete the assignment cover sheet.

Ensure you have completed:

1. ***Lab Work*** – waveforms, readings, calculations.

2. ***Analysis*** – explanations where required.

3. ***Questions*** – multiple choice questions.

The lab report is due at the time stated in the Learning Guide.

You should hand the report directly to your tutor.