Peter Philips Resource

UEE30811 Certificate III Electrotechnology Electrician

UEENEEG006A
Solve Problems in Single Phase & Three Phase Low Voltage Machines.

Transformers

Tutorial & Practical (Philips)

Student Name: ______________________ **Day:** ____________

Teacher Name: ______________________ **Class:** ____________

Contents

Lesson Structure

Lesson	Duration	Topic	Practical
1	4hours	21.2 The Ideal Transformer 21.3 The Practical Transformer	Transformer Ratios
2	4 hours	21.4 Transformer Operation	Transformer Performance
3	4hours	21.5 Voltage Regulation	Transformer Regulation
4	4 hours	21.6 Transformer Performance	Transformers Efficiency
5	1 hour	TEST (Only 1Hr duration)	NO PRACTICAL
	3 hours	21.7 Transformer Connections & Harmonics	Harmonics
6	4 hours	21.8 Transformers in Parallel 21.9 High Voltage Safety	Paralleling Single Phase Transformers
7	4 hours	21.10 Auto Transformers 21.11 Instrument Transformers 21.12 Insulation resistance test	Auto Transformers
8	4 hours	Final Test	Practical Test

Assessments

To Achieve Competence for the UEENEEG006A unit a pass mark of 50% is required in both Transformers & AC Machines components, i.e. the student MUST PASS both sections.

Assessment	Type of Assessment	Duration	Weighting %
1	Transformer Theory Test 1	1 Hour	20%
2	Transformer Theory Test 2	2 Hours	20%
3	Transformer Practical Test 2	45 Min	10%
4	AC Machines Theory Test 1	2 hours	20%
5	AC Machines Practical Test 1	45 Min	5%
6	AC Machines Theory Test 2	2 Hours	20%
7	AC Machines Practical Test 2	45 min	5%

Practical Exercise 1: Transformer Ratios

Task

To measure primary voltages and currents for a range of load conditions on a single phase transformer and compare the ratio of the results to the known transformer turns ratio.

Number	EQUIPMENT
1	41.5Va.c Variac
1	41.5V-24V Single Phase Transformer
1	Digital Multimeter
1	Clip on Ammeter
2	Single pole switches
1	Contact Leads

Procedure

1. Connect the equipment as shown in Figure 1 below

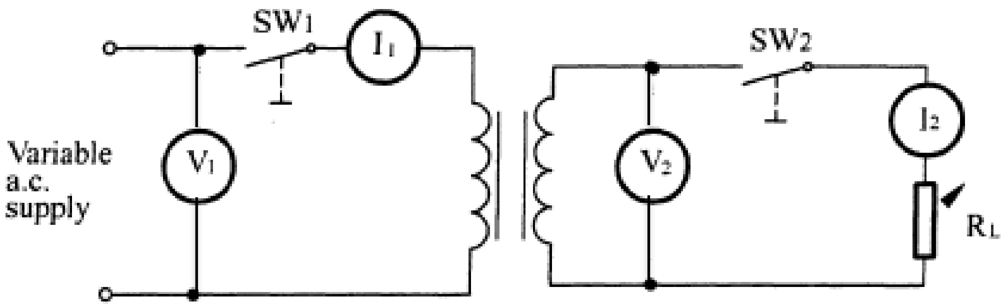


Figure 1

2. SAFETY CHECK: Before proceeding, ask the teacher to check that the equipment is properly connected.

3. Turn on the Variac and close SW1 **(SW2 remains open- No Load).**

4. Vary the A.C. supply in incremental steps to give the values shown in Table 1.

TABLE 1		
Primary Voltage	**Secondary Voltage**	**Calculate ratios**
10V		
20V		
30V		
40V		

5. Record all corresponding values V_2 and calculate Voltage ratios

6. Turn on the power supply and adjust the Variac to supply the transformer with its primary voltage.

7. Close SW1 **(SW 2 open)** and record the value of I_1 in table 2 below.

8. Select RL for maximum resistance as shown in table 2 and close SW 2 and record the primary & secondary currents.

9. Change the resistor as shown in table 2 and complete the table.

10. Disconnect all equipment then calculate current ratios.

	TABLE 2		
Resistor Values	**Primary Current**	**Secondary Current**	**Calculate Current ratios**
Open Circuit			
30Ω			
15Ω			
10Ω			

Progress Table		
First Attempt	**Second Attempt**	**Teacher Assist**

<u>Observations</u>

11. Using the transformers primary and secondary rated voltages 41.5V / 24V, determine its voltage ratio.

12. Compare this with the voltage ratio values in table 1 are they similar.

13. Calculate the primary and secondary maximum currents from the 70VA Transformer when connected to a resistive load.

14. Compare these currents with the values recorded in table 2. Was the transformer overloaded or operating within its limits?

15. Calculate the minimum resistive load which could be connected to the 70VA transformer.

END

Ideal & Practical Transformers (Philips pp. 475-487)

<u>Tutorial 1</u>

Multiple Choice

1. Transformer laminations are manufactured from:
   a. Copper
   b. Corrosion Resistant Steel
   c. Silicon Steel
   d. Iron

2. Transformer laminations are insulated from each other by:
   a. An oxide layer on each lamination
   b. Using spacing blocks to provide air gaps
   c. Sandwiching PVC sheets between laminations
   d. Painting the sides of the laminations.

3. The material most commonly used for transformer windings is:
   a. Aluminum
   b. Copper
   c. Silicon steel
   d. Iron

4. The cross-sectional shape most commonly used for high power transformer ***winding conductors*** is:
   a. circular
   b. Rectangular flat strip
   c. hexagonal
   d. square

5. The lid of a transformer tank is secured to the main tank by:
   a. welding
   b. bolting
   c. hinging
   d. clamping

6. Most high-voltage transformers operate in a medium of:
   a. synthetic oil
   b. air
   c. mineral oil
   d. solid insulant

7. The most common insulation used for the conductors of oil-immersed power transformers is
   a. glass fibre
   b. cotton
   c. mica
   d. Oil impregnated paper.

8. A transformer's rating is determined by
   a. the viscosity of the transformer oil
   b. the size of conductors used in the windings
   c. the type of material used for conductors
   d. its ability to dissipate heat

9. If a transformer's heat dissipation is increased:
   a. the efficiency of the transformer will improve
   b. the efficiency of the transformer will decrease
   c. the rating of the transformer will increase
   d. the transformer will produce more "hum".

10. Dry transformers are cooled by:
    a. ambient air
    b. dry ice
    c. transformer oil with low moisture content
    d. dehumidified air.

11. An oil-immersed transformer fitted with external cooling banks and air fans would have its cooling method designated as:
    a. ONAN
    b. ONAF
    c. ONAN/ONAF
    d. OFAF

12. A dry transformer housed in a louvered enclosure would have its cooling method designated as:
    a. ONAN
    b. ANAF
    c. AN
    d. ON

13. An oil-immersed transformer fitted with cooling fans could have its cooling method designated as:
    a. ONAN
    b. OFAN
    c. ONAF
    d. ON

14. The limiting factor to the temperature rise in a transformer is:
    a. the boiling point of transformer oil
    b. the breakdown of winding insulation
    c. the increase of winding resistance with temperature
    d. the flash point of transformer oil.

15. Transformer oil expands due to:
    a. heating of the oil
    b. the generation of gas bubbles due to a fault
    c. expansion in the winding at full-load
    d. expansion in the core at full-load

16. The hygroscopic nature of oil refers to:
    a. its ability to expand and contract in volume
    b. its high flammability
    c. its ability to absorb moisture
    d. its dielectric strength.

17. The material used to remove moisture from transformer oil is:
    a. ammonium sulphate
    b. lime
    c. potassium hydroxide
    d. silica gel

18. Buchholz relays usually provide:
    a. local alarm indication only
    b. transformer trip only
    c. alarm and trip functions
    d. gas sampling only

19. A conservator purpose in a power transformer is:
    a. to allow for air expansion
    b. hold water for fire extinguishing
    c. to hold cooling oil
    d. to store silica gel

20. Surge arrestors protect the transformer from:
    a. oil surges due to gas igniting
    b. lightning strikes
    c. power output surges
    d. Low input current

Short Answer

1. Complete the typical transformer step up or step down voltages below?

Primary Voltage	Secondary voltage	Step up or step down
66kV		Down
	400	Up
11kV	400/230	

2. What are the main parts that make up a high-voltage transformer?

3. Does hot-rolled or cold-rolled (grain orientated. silicon sheet provide a better material for transformer laminations? Why?

4. What is the ideal cross-sectional shape for a Power Transformer core?

5. Name two methods used to insulate transformer laminations.

6. Explain the term mutual inductance in relation to a transformer

7. Which winding of a transformer is wound closest to the core and why?

8. Describe **two** ways in which it would be possible to differentiate between the LV and HV windings of a transformer.

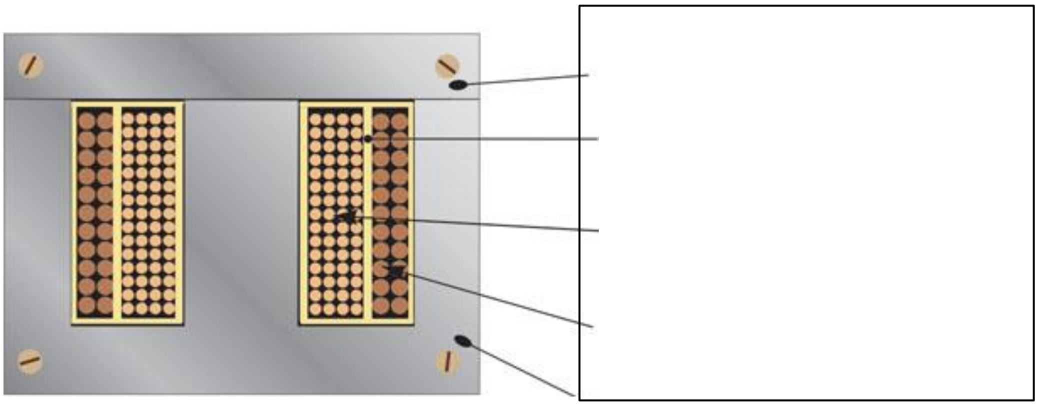
9. List four dangerous gases which may be found in transformer oil?

10. Two types of faults that a Buchholz alarm could indicate are:

11. Explain the difference between an ideal and practical transformer.

12. What is the purpose of a laminated grain oriented silicon steel core in a transformer?

13. Label the transformer components?



Calculation

1. Calculate the induced voltage in a coil of 433 turns which is connected to a 50 Hz supply, when the maximum flux is 2.5mWb.
(Ans: 240V)

2. A single-phase transformer is wound with 200 turns on the primary and 60 turns on the secondary. The maximum value of core flux is 12.5 mWb and the frequency is 50 Hz. Determine the Primary & Secondary Voltage.
(Ans: 555Vp, 166.5Vs)

3. How many turns are required on each winding of an 11kV/415V, 50Hz single-phase transformer if the core flux is 30mWb?
(Ans: Np = 1651, Ns = 62)

4. A 230V / 110V transformer has 80 turns on its primary winding. Calculate the number of turns on the secondary winding.
(Ans: Ns = 38)

5. A 300/32V, 50 Hz single-phase transformer has 600 turns on the primary winding. Determine the maximum value of core flux.
(Ans: *2.25mWb)*

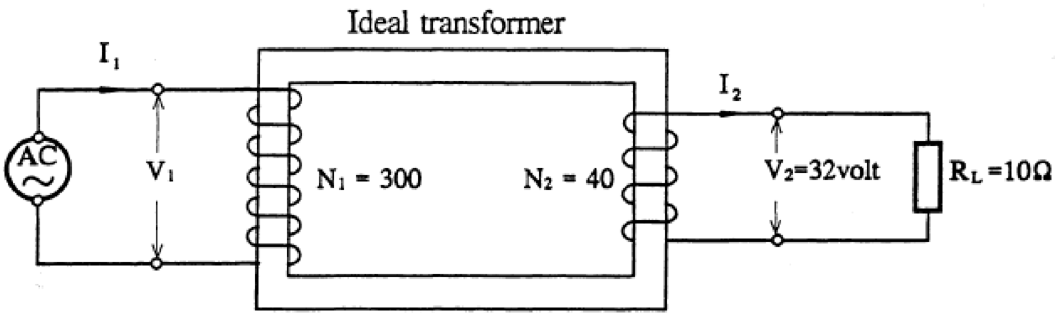
6. The transformer in question 5 has a supply current of 16A. Calculate the secondary current. *(Ans: Is = 150A)*

7. A transformer supply's a 50V, 2A load. It has 180 primary turns and 75 secondary turns. Determine the primary voltage and current values.
(Ans: Vp = 120V, Ip = 0.833A)

8. A transformer has a ratio of 5:1. Calculate its output voltage when connected to a 41.5V supply.
(Ans: Vs = 8.33V)

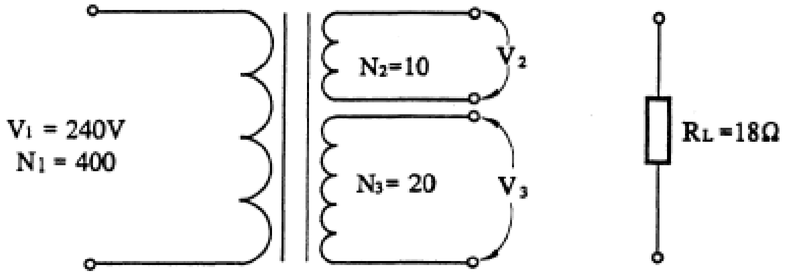
9. A 70VA, 230V/50V transformer supplies a low voltage lighting bank. Calculate the maximum input and output current values. (*Note- why would you need to know this?)*
(Ans: Ip = 304mA, Is = 1.4A)

10. In the IDEAL transformer below, calculate the primary voltage, currents and transformer ratio.
(Ans: *Vp = 240, Is = 3.2A, Ip = 427mA. Ratio = 7.5:1 or 15:2)*



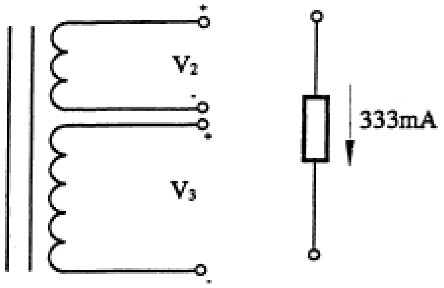
11. Given the primary voltage, coil turns and load resistance of the transformer shown in diagram A below, calculate the secondary voltages V2 & V3 and connect the resistors to the suitable voltage source in diagrams B, C and D to give the load currents shown.

A

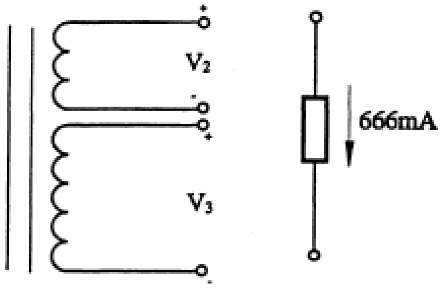


Note: Instantaneous secondary polarities are shown in diagrams B, C and D.

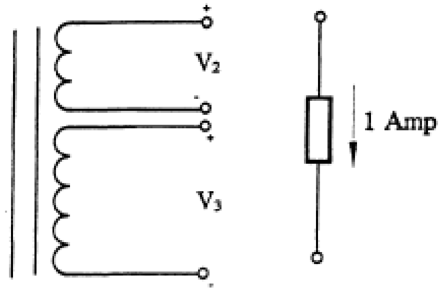
B



C



D



Practical Exercise 2A: Transformer Operation

Task

To measure primary voltages and currents for a range of load conditions on a single phase transformer and compare the ratio of the results to the known transformer turns ratio.

Number	EQUIPMENT
1	41.5Va.c Variac
1	41.5V-24V Single Phase Transformer
1	Digital Multimeter
1	Clip on Ammeter
1	Wattmeter
1	15Ω Resistor 30W
1	Switch
1	Contact Leads

Procedure:

No Load Conditions

1. Connect the equipment as shown in figure 1 below.

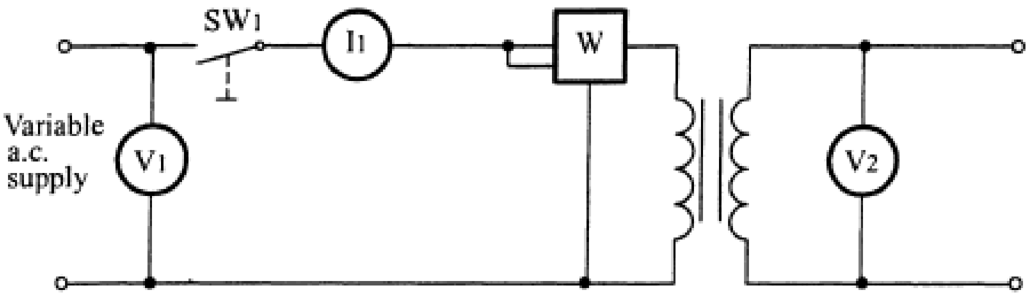


Figure 1

2. SAFETY CHECK: Ask the teacher to check that the equipment is safely connected
3. Turn on the variable A.C. supply and adjust the Variac until V_1 indicates the rated primary volts of the transformer.
4. Close SW1 and record all values as indicated in Table 1 below.

TABLE 1			
Primary Voltage	**Secondary Voltage**	**No-Load Current**	**No-load Power**

5. Open SW 1 and turn off the power supply.

On Load Conditions.

6. Connect the equipment as shown in Figure 2 below.

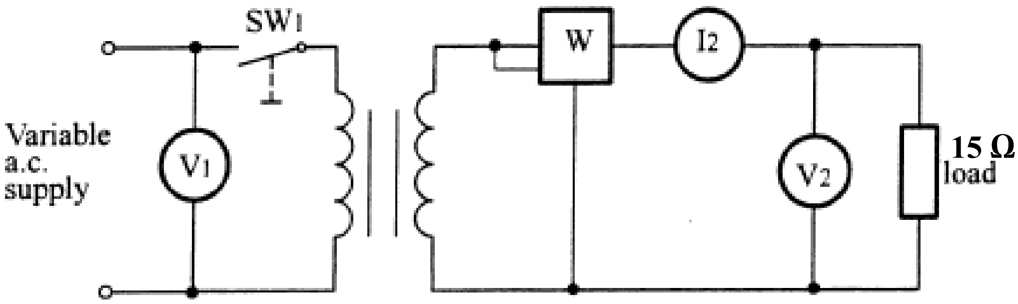


Figure 2

7. SAFETY CHECK: Ask the teacher to check that the equipment is safely connected.

8. Turn on the variable A.C. supply and adjust the Variac until V_1 indicates the rated primary volts of the transformer.

9. Close SW1 and record all values as indicated in Table 2 below.

TABLE 2			
Primary Voltage	**Secondary Voltage**	**Load Current**	**Load Power**

Progress Table		
First Attempt	**Second Attempt**	**Teacher Assist**

Observations

10. From the information you have gathered, calculate the no load power factor & phase angle.

11. From the information you have gathered, calculate the **'On-load'** power factor & phase angle.

12. Using your measured and calculated results, draw the complete phasor diagram for the transformer.

PHASOR DIAGRAM

Practical Exercise 2B: Voltage Regulation

Task

Carry out an open and short circuit test on a transformer and calculate the efficiency, percentage impedance and percentage regulation from the results.

Number	EQUIPMENT
1	41.5Va.c Variac
1	41.5V-24V Single Phase Transformer
1	Digital Multimeter
1	Clip on Ammeter
2	Single pole switch
1	Contact Leads

Procedure:

1. Connect the equipment as shown in Figure 1 below

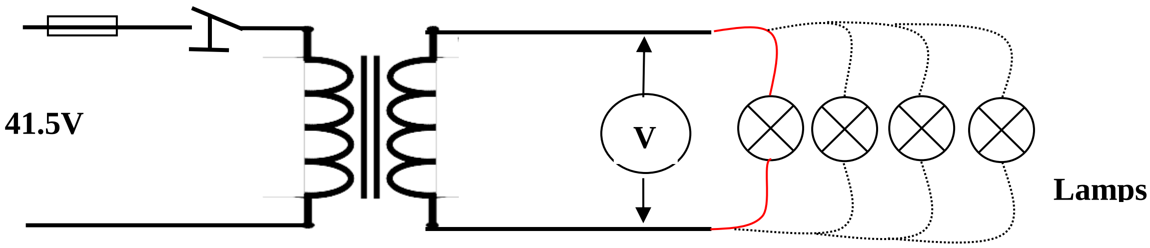


Figure 1

2. SAFETY CHECK: Before proceeding, ask the teacher to check that the equipment is properly connected

3. Connect 1 lamp and adjust the supply voltage to rated voltage.

4. Measure and record secondary voltage & current in table 1 below.

5. Add additional lamps one at a time (max 6. and measure and record secondary voltage at each stage

TABLE 1	**Voltage Regulation**						
	No Load	1 Lamp	2 Lamps	3 Lamps	4 Lamps	5 Lamps	6 Lamps
Primary Voltage	**41.5V**	**41.5V**	**41.5V**	**41.5V**	**41.5V**	**41.5V**	**41.5V**
Secondary Voltage							
Secondary Current							

6. Isolate the power and disconnect all equipment. Return it to its proper place.

Observations & Calculations

7. Calculate the voltage regulation of the transformer at full load?

8. Plot a graph of for load current against secondary voltage to represent the transformers voltage regulation.

Progress Table		
First Attempt	Second Attempt	Teacher Assist

Transformer Operation & Voltage Regulation (Philips pp. 487 – 495)

Tutorial 2

Multiple Choice

1. The primary and secondary windings of a double wound transformer are:
   a. both electrically and magnetically isolated
   b. electrically linked but mechanically isolated
   c. magnetically linked but electrically isolated
   d. both electrically and magnetically linked

2. With an increasing non-inductive load the secondary terminal voltage of a transformer would:
   a. remain unchanged
   b. rise slightly
   c. fall slightly
   d. become unstable

3. Transformers are usually rated in:
   a. watts
   b. reactive volt-amps
   c. watt-hours
   d. volt-amps

4. The drop in voltage of the secondary terminal from no load to full load of a transformer is the:
   a. combined primary and secondary resistance & reactance voltage drop
   b. secondary impedance voltage drop
   c. reactive voltage drop
   d. resistive voltage drop

5. In a transformer the component of *no load* current which lags the primary voltage by 90^o is the:
   a. magnetising current
   b. iron loss current
   c. secondary current
   d. primary current

Short Answer

1. Transformers operate due to the principle of ______________________

2. What is the term for the transformer winding connected to the supply?

3. What effect does the no-load current of a transformer have on its transformation ratio?

4. What effect does the secondary load current have on the primary power factor?

5. What is the cause of the drop in secondary voltage as the load increases on a transformer?

6. What is the expected power factor of an unloaded transformer? (Low or High.

7. Calculate the maximum load current on a single phase 6kVA 400V/230V transformer?

8. Name the tap changers suitable for:

   a. Distribution Transformer __________________________________.

   b. Transmission Transformer ________________________________.

9. Explain the purpose of diverter contacts on a tap changer.

10. State the typical time taken for a motorized tap changer to switch between

    contacts ____.

Calculation

1. Calculate the No-load current on a transformer, which has a magnetising current of 180mA and a core loss current (F_E. of 47mA. *(Ans: = 186mA)*

2. Using trigonometry, calculate the power factor and phase angle on the no-load current. *(Ans: = 75.3^0)*

3. Draw to scale a phasor diagram to determine the primary supply current and power factor from the following specifications:

Transformer type	Single Phase
Primary Voltage	41.5V
Secondary Voltage	24V
No load current	0.8A, pf 0.2
Load secondary current	2.9A pf 0.9

4. Draw the phasor diagram for the following transformer specifications and determine the:

- No-Load Current
- Magnetising Current
- Core Loss Current (F_E.

Transformer type	Single Phase
Primary Voltage	230V
Secondary Voltage	110V
No Load Power	125.4W
No Load phase angle	84^0

5. Calculate the voltage regulation of 400V/240V transformer when its load voltage is 230V. *(Ans: = 4.17%)*

6. Calculate the voltage regulation for a 33kV /11kV transformer when its internal volt drop under load is 800V. *(Ans: = 7.27%)*

7. A single-phase transformer having 360 turns on the primary and 48 on the secondary, steps down from 240V to 32V. If the no-load current is 3 amps lagging at 80° determine the primary current and power factor if the secondary current is 40 amps at a power factor of 0.866 lagging.

____________________________END____

Practical Exercise 3: Transformer Performance & Efficiency

Task

To determine the full load efficiency of a single-phase transformer and to draw a curve of efficiency, copper loss and iron loss with respect to the secondary load current.

Number	EQUIPMENT
1	41.5Va.c Variac
1	41.5V-24V Single Phase Transformer
1	Digital Multimeter
1	Clip on Ammeter
1	Wattmeter
1	Known resistor panel
1	Switch
1	Contact Leads

Procedure:

Open Circuit Test – Iron Loss

1. Connect the equipment as shown in figure 1 below.

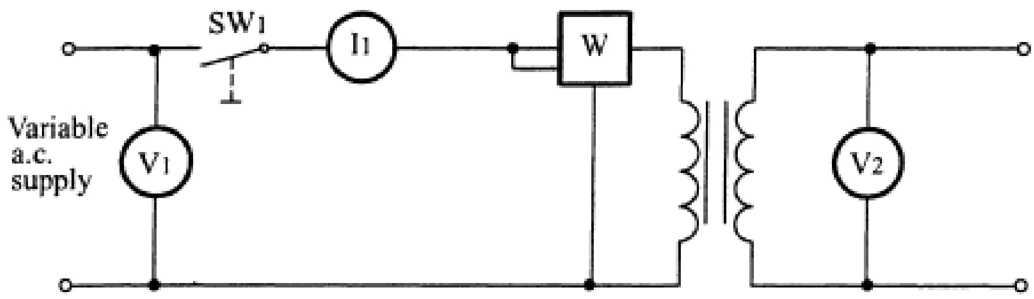


Figure 1

2. SAFETY CHECK: Ask the teacher to check that the equipment is safely connected.

3. Turn on the variable A.C. supply and adjust the Variac until V_1 indicates the rated primary volts of the transformer.

4. Close SW1 and record all values as indicated in Table 1 below.

TABLE 1		
Primary Voltage	No-Load Current	No-load Power

5. Open SW 1 and turn off the power supply.

Procedure:
Short Circuit Test – Copper Loss.

6. Connect the equipment as shown in Figure 2 below.

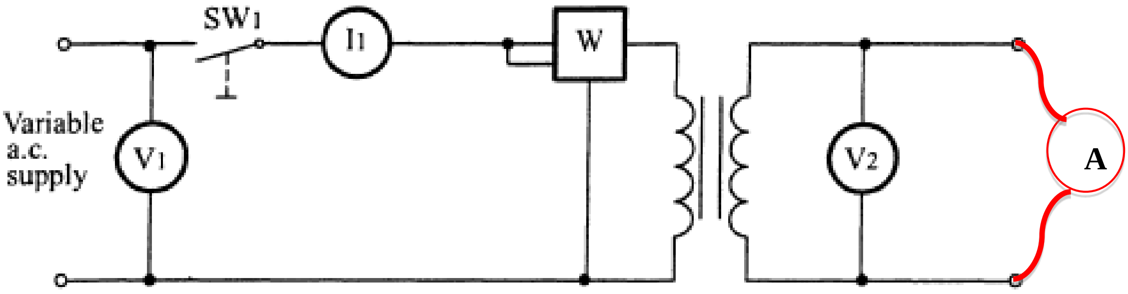


Figure 2

7. SAFETY CHECK: Ask the teacher to check that the equipment is safely connected.

8. Turn on the variable A.C. supply and **SLOWLY** adjust the Variac until I_2 indicates 25% of the rated current of the transformer. Record the Primary Voltage & Power in table 2

9. Repeat the steps above for all current values in table 2. Record all values as indicated in Table 2 below.

TABLE 2			
Load %	**Primary Voltage (Supply)**	**Secondary Current I_2 (Load)**	**Primary Power**
25		0.725 A	
50		1.45 A	
75		2.18 A	
100		2.9 A	
125		3.63 A	

10. Reduce the supply voltage and open SW1. Disconnect the short circuit.

Procedure
Load Test

11. Connect the equipment as shown in figure 3 below.

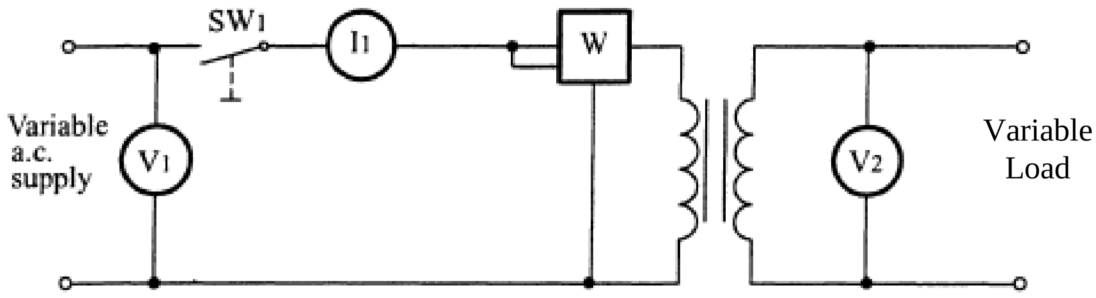


Figure 3

12. SAFETY CHECK: Ask the teacher to check that the equipment is safely connected.

13. Adjust the supply voltage to rated primary voltage on no load. Record results in Table 3. (ENSURE INPUT STAYS AT 41.5V.

14. Connect the 30Ω resistor to the load as shown in table 3 and record your results. Change the load resistor as shown and repeat the process.

15. **NOTE:** Calculate the output power and efficiency and record in table 3

TABLE 3					**CALCULATE**
Load Resistors	Primary Input power	Secondary output values			Transformer Efficiency
		V2	I2	P2	
No Resistor					
30Ω					
25Ω					
15Ω					
10Ω					

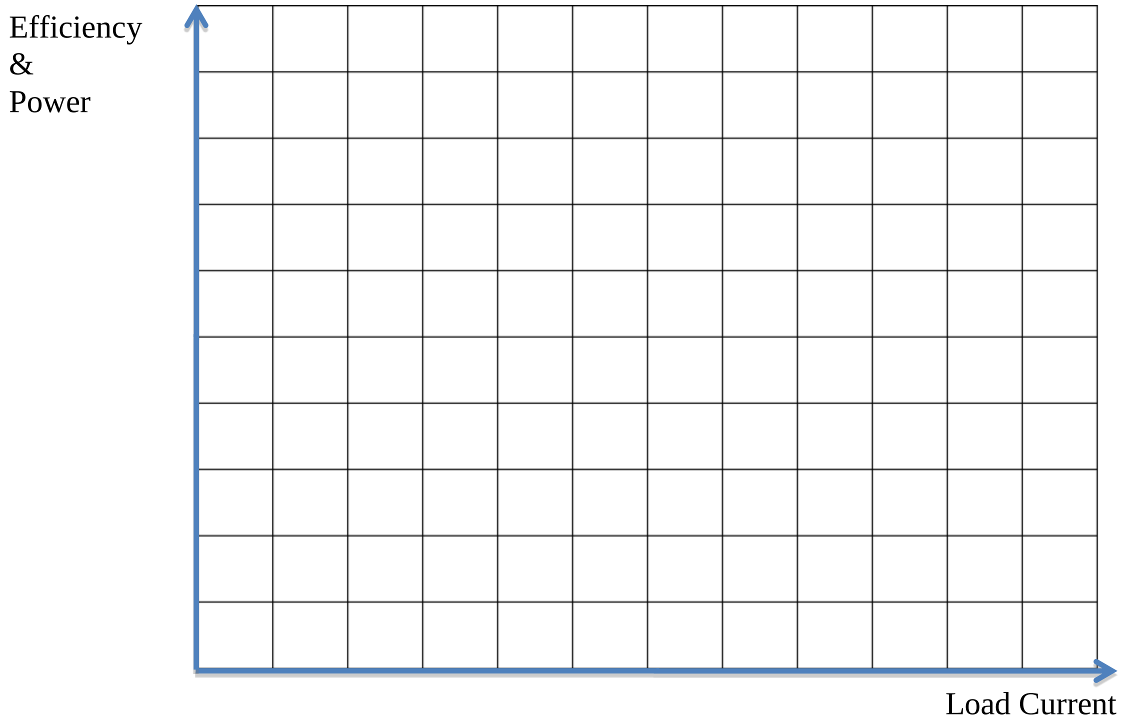
16. Isolate the power, disconnect all equipment and return it all to its appropriate place.

Progress Table		
First Attempt	**Second Attempt**	**Teacher Assist**

Observations

Finalise your results by completing the following observations and calculations.

17. Using the axes below draw the efficiency graph representing copper losses, iron losses, load current and efficiency.



18. Why can the copper loss be neglected on the open circuit test?

19. Why can the iron loss be neglected on the short circuit test?

20. From the curves you have drawn, at what value of iron and copper loss does the transformer reach maximum efficiency.

21. The heat losses of a transformer increase at a greater rate than the increase in loading. Why is this?

__________________END__________________

Transformer Performance (Philips pg. 495-501)

Tutorial 3

Multiple Choice

1. The iron loss of a distribution transformer is 400 W at full load, what is the iron loss at half full load:
   a. 100 W
   b. 200 W
   c. 300 W
   d. 400 W

2. The efficiency of a transformer:
   a. is constant over a wide range
   b. varies with the load
   c. varies with the iron losses
   d. has a maximum of 90%

3. The copper loss of a distribution transformer is 1600W at full load. What is the copper loss at half full load?
   a. 1600 W
   b. 800 W
   c. 400 W
   d. 200 W

4. The short circuit test on a transformer is used to determine the:
   a. apparent losses
   b. reactive losses
   c. copper losses
   d. iron losses

5. The constant iron losses in a transformer are present at:
   a. Full load current
   b. Full supply voltage
   c. Maximum efficiency
   d. Maximum output power

Short Answer

1. What approximate percentage of the primary voltage is applied to a transformer during a short circuit test?

2. What happens to the iron losses of a transformer as the load is increased from no load to full load?

3. When is a transformer working at its maximum efficiency?

4. What are the two main sources of power loss in a transformer?

5. Which type of loss is associated with the core of a transformer?

6. Which loss is associated with the windings of a transformer?

7. How can the iron losses be determined for a transformer?

8. How can the copper losses be determined for a transformer?

9. Sketch a transformer efficiency graph showing the iron losses, variable copper losses and the point maximum efficiency occurs.
(Not in Philips. Teacher guidance may be required)

Calculations

1. A 230V/110V single-phase transformer supplies a current of 27 amps at unity power factor. Calculate:
   a. Apparent Power (Ans: S = 2.97kVA)
   b. True output Power (Ans: P = 2.97kW)

2. A 230V/110V single-phase transformer supplies a current of 27 amps at 0.9-power factor. Calculate:
   a. Apparent Power (Ans: S = 2.97kVA)
   b. True output Power (Ans: P = 2.67kW)
   c. Reactive power (Ans: Q = 1.29kVAr)

3. A 3ph 11kV/400V transformer supplies a current of 80 amps at 0.85-power factor. Determine: **(NOTE 3PH, refer to formula sheet 3ph power formula)**
   a. Apparent Power (Ans: S = 55.4kVA)
   b. True output Power (Ans: P = 47kW)
   c. Reactive power (Ans: Q = 29.1kVAr)

4. A single-phase100VA transformer has an iron loss of 8.8W and a copper loss of 9.4W at full load. Calculate the efficiency of the transformer when operating with unity power factor at:
   a. Full Load (Ans: 84%)
   b. 25% load (Ans: 72.7%)

5. Calculate the efficiency for a 3ph, 500kVA distribution transformer when operating at full-load with a power factor of 0.9. The total losses are 15kW. (Ans: 96.8%)

6. Calculate the total losses for a transformer when the short circuit and open circuit tests gave results of 2000W and 3700W respectively.
   (Ans: 5700W)

7. A 3ph, 10 MVA transformer operates at full-load with a power factor of 0.87. Constant losses for the transformer are 120kW and variable losses at that load are 95kW. Calculate the efficiency of the transformer.
   (Ans: 97.6%)

8. A 30kVA 3ph, transformer connected to non-inductive loads has full-load copper losses of 840W and iron losses of 220W. Calculate the efficiency at:
   a. Full Load (Ans: 96.6%)
   b. 75% of Full Load (Ans: 97%)

9. A transformer has a copper loss of 1200W at full load. Calculate the copper loss when the transformer is operating at 75% of full load.
(Ans: 675W)

10. A single-phase 240V, 50Hz transformer is rated at 25kVA. Calculate:
   a. Power output at unity pf (Ans: 25kW)
   b. Full load secondary current. (Ans: 104.2A)
   c. Power output at 0.8 p.f. (Ans: 20kW)
   d. Secondary current when transformer supplies 25kW at 0.8 p.f. (Ans: 130A)
   e. **Is the transformer overloaded**?

11. Calculate the 24hr efficiency for a transformer whose output over a 24hr period is 2.1MWh and where losses total over the same 24hr period is 148 kWh. (Ans: 93.4%)

12. A 3ph, 5 MVA, 33/1 1 kV transformer is short circuited on the secondary side. A variable voltage is applied to the primary winding; this voltage is adjusted so that full load current circulates in the secondary winding. When this occurred the primary voltage was 2.97 kV. Determine the percentage impedance of the transformer. (Ans: 9%)

13. A three-phase 11kV/400 70kVA power transformer has a percentage impedance of 12%. Calculate the transformers:
    a. Rated secondary line current. (Ans: 101A)
    b. Prospective short circuit current. (Ans: 841.6A)

14. A three phase 150kVA transformer is connected star/delta to 1kV 3ph supply. If the turn's ratio on the windings is 6:1 determine: (note: Sketch the circuit.)

    a. Primary phase and line voltages. (Ans: VL = 1KV, Vp = 577V)
    b. Primary phase and line currents. (Ans: IL = Ip = 86.6A)
    c. Secondary phase and line voltages. (Ans: Vp = VL = 96.2V)
    d. Secondary phase and line currents (Ans: IL = 900A, Ip = 519A)

15. A 3ph 11kV/230V transformer is connected delta/star. If a delta load with phase impedance of 20.5Ω is connected determine the: (note: Sketch the circuit)

    a. Transformer ratio. (Ans: 82.8:1)
    b. Primary line and phase voltages. (Ans: VL = Vp = 11kV)
    c. Secondary line and phase voltages. (Ans: VL = 230V, Vp = 132.8V)
    d. Secondary phase current (Ans: Ip = 19.4A)
    e. Primary phase current (Ans: Ip = 230mA)
    f. Primary line current. (Ans: IL = 410mA)

Practical Exercise 4A: Transformer Harmonics

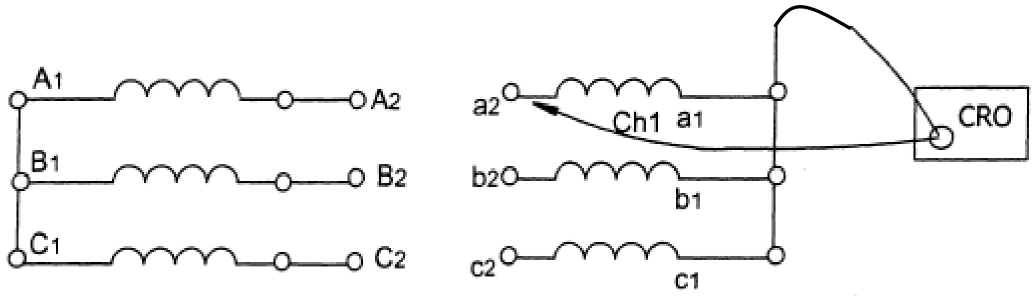
Task

Connect transformers in star and delta, and observe the effects of harmonics in three phase transformers.

Number	EQUIPMENT
3	41.5V / 24V Transformers
1	Oscilloscope
1	Oscilloscope Probe
1	Fuse bank
1	Contact Leads

Procedure 1:
Harmonics in a Star/Star system

1. Connect the three transformers in a star/star configuration and connect to a 41.5V three phase supply as shown below. Ensure fuses are used.

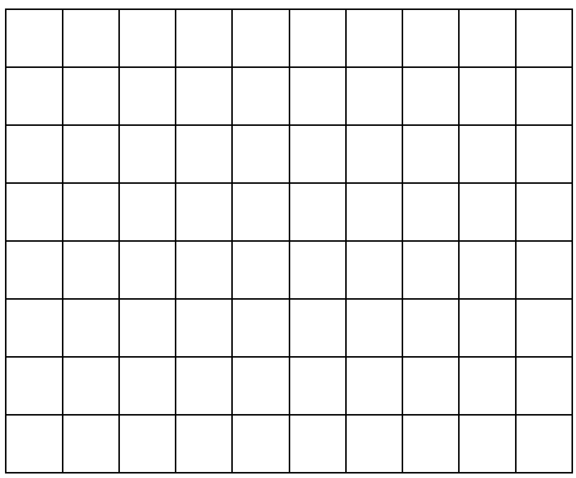


PRIMARY SECONDARY

2. Connect the CRO onto the secondary output between line and star point.

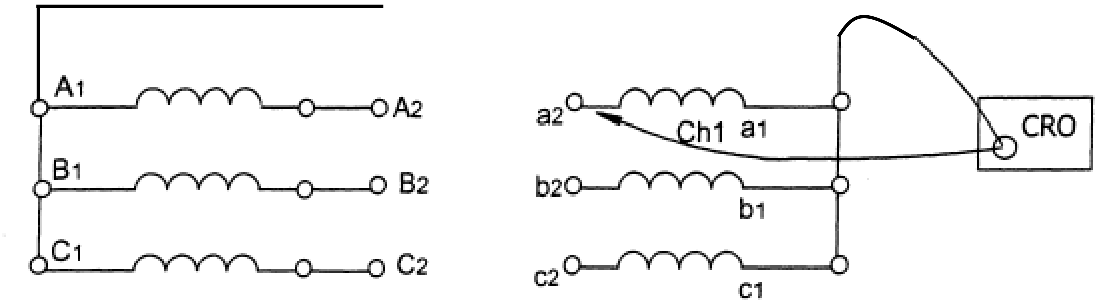
3. Adjust the CRO until an appropriate wave form is displayed showing the presence of harmonics.

4. Sketch the wave form on the graph below.



<u>Procedure 2:</u>
Harmonics in a Star/Star System 4-Wire

5. Connect the three transformers in a star/star configuration with a neutral from the star point and connect to a 41.5V three phase supply as shown below. Ensure fuses are used.

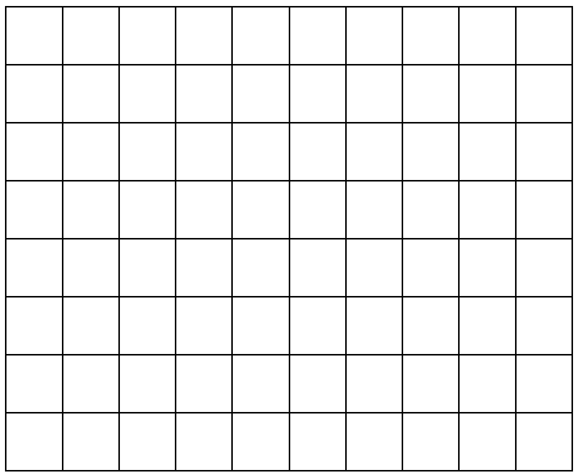


PRIMARY SECONDARY

6. Connect the CRO onto the secondary output between line and star point.

7. Adjust the CRO until an appropriate wave form is displayed.

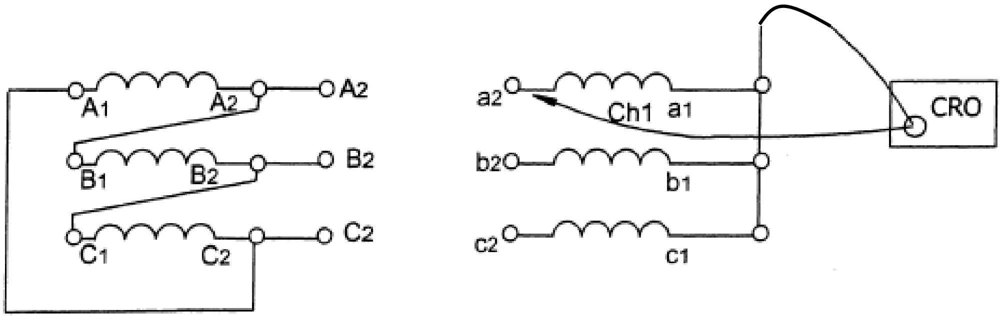
8. Sketch the wave form on the graph below.



9. Compare the wave form to the Star/Star 3–wire system and explain any difference.

Procedure 3:
Harmonics in a Delta/Star System.

10. Connect the three transformers in a delta/star configuration and connect to a 41.5V three phase supply as shown below. Ensure fuses are used.

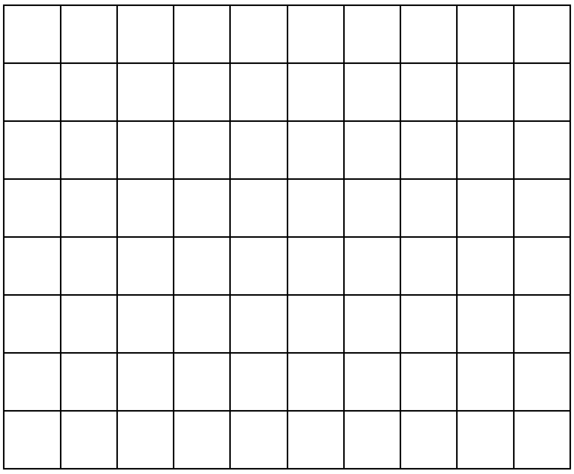


PRIMARY SECONDARY

11. Connect the CRO onto the secondary output between line and star point.

12. Adjust the CRO until an appropriate wave form is displayed.

13. Sketch the wave form on the graph below.



14. Compare the wave form to the Star/Star 3–wire system and explain any difference.

____

____

15. Isolate the supply, disconnect the circuit and return all equipment to its proper place.

Progress Table		
First Attempt	**Second Attempt**	**Teacher Assist**

Practical Exercise 4B: Paralleling Single Phase Transformers

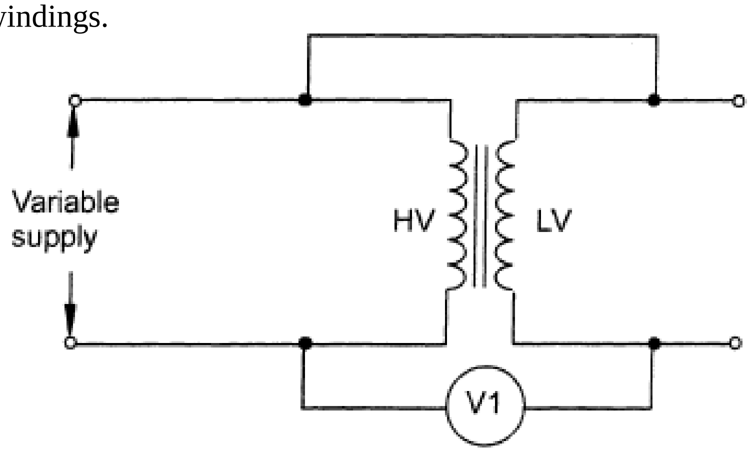
Task

To connect two single phase double wound transformer in parallel.

Number	EQUIPMENT
1	41.5V Variac
2	41.5V Single Phase Transformer 4 TPV
1	41.5V Single Phase Transformer 5 TPV
1	Digital Multimeter
1	Clip on Ammeter
1	30 Ω & 50Ω Resistor 30W
1	Switch
1	Contact Leads

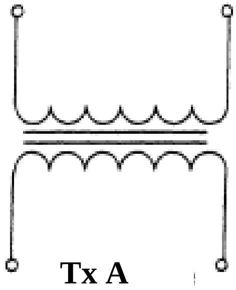
Procedure 1:
Polarity check on a transformer.

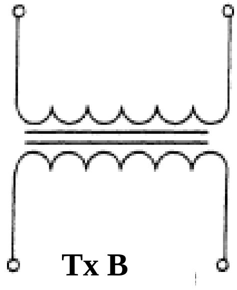
1. Using the circuit shown below carry out a polarity check on all transformer windings.



2. Label the LV windings and HV windings with the appropriate letter and number to identify subtractive or additive construction.

3. Label the diagrams below in accordance with your transformers and have your results checked by your teacher.





Procedure 2:
Paralleling transformers with similar percentage impedance

4. Correctly draw the load connections in the circuit below and ask your teacher to check your diagram.

5. Connect the circuit to the load and adjust the Variac to the rated input voltage

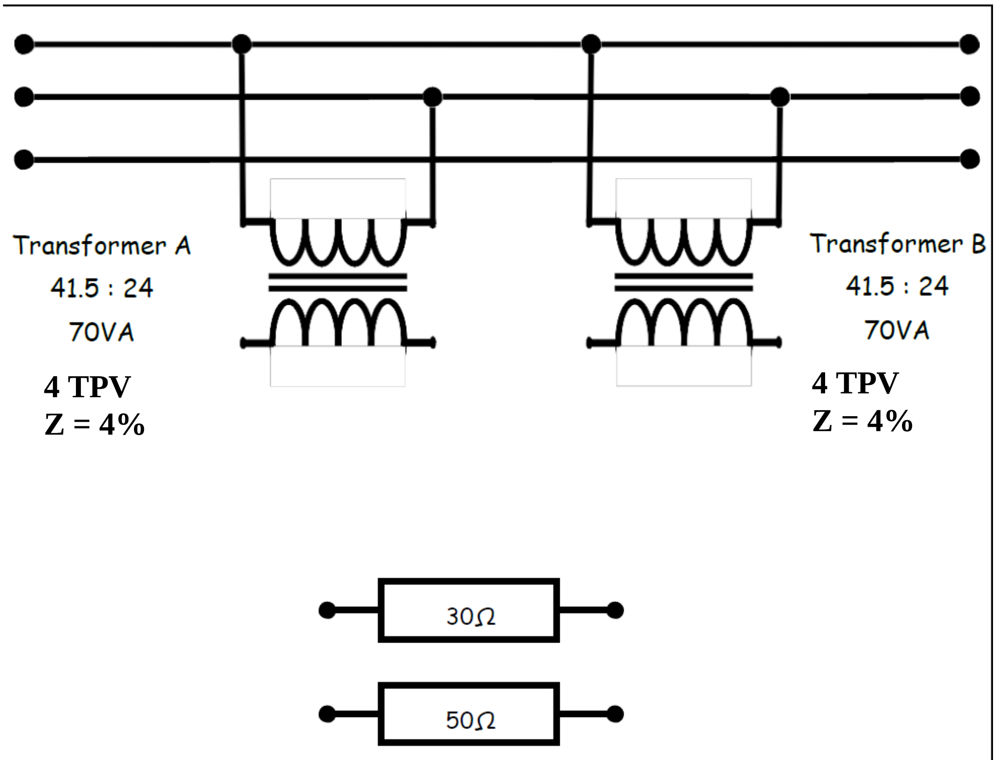


Figure 1 – Parallel Operation

6. Turn on the power supply and record all values as indicated in Table 1 below.

Table 1			
Measurement			
	Tx A 4TPV	**Tx B 4TPV**	**I Load**
Secondary Current			
Secondary Voltage			

7. Open SW 1 and turn off the power supply.

Procedure 3:
Paralleling transformers with *different* percentage impedance

8. Correctly draw the load connections in the circuit below and ask your teacher to check your diagram.

9. Connect the circuit to the load and adjust the Variac to the rated input voltage

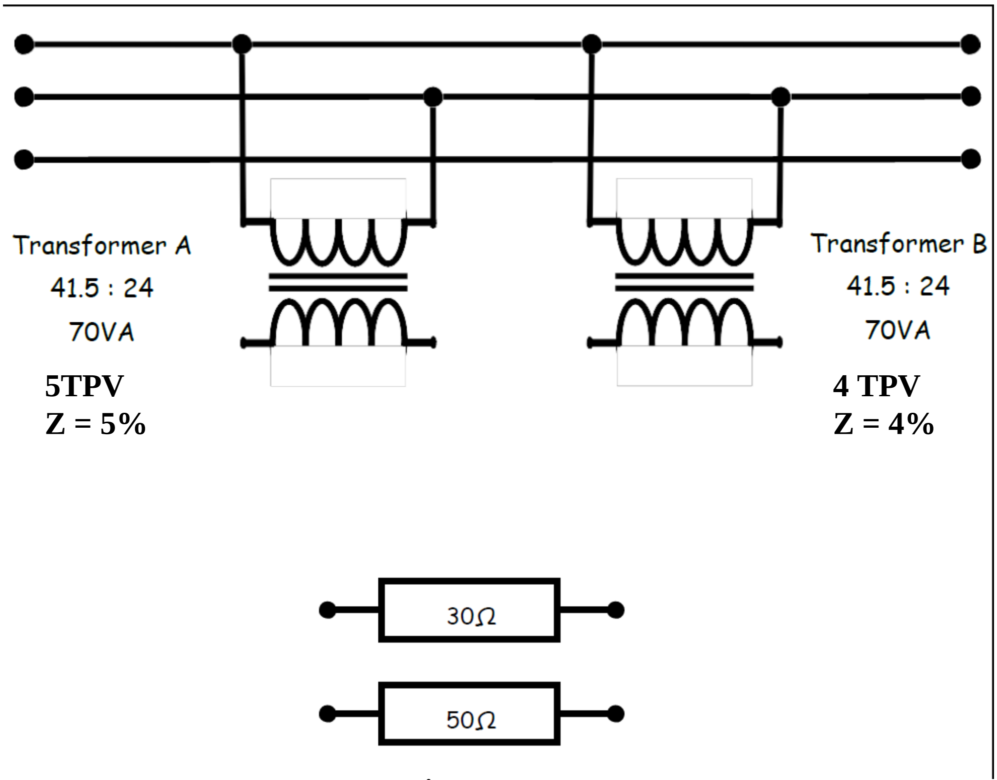


Figure 2

10. Turn on the power supply and record all values as indicated in Table 2 below.

Table 2			
Measurement			
	Tx A 5TPV	**Tx B 4TPV**	**I Load**
Secondary Current			
Secondary Voltage			

11. Isolate the power, disconnect all equipment and return it all to its appropriate place.

Progress Table		
First Attempt	**Second Attempt**	**Teacher Assist**

Observations

12. Calculate the LV winding current of each transformer and the load current when paralleling two, 4TPV transformers connected to a 30Ω & 50Ω resistors in parallel.

13. Calculate the LV winding current of each transformer and the load current when paralleling a 5TPV and a 4TPV transformer connected to a 30Ω & 50Ω resistors in parallel.

14. Compare your results to your measured values. Does it prove the method of calculation is acceptable and a similar value to the measured values.

15. Are all transformers working with their capability?

END

Transformer Connections, Harmonics, Paralleling & High Voltage Safety. (Philips pg. 501-510)

Tutorial 4

Multiple Choices

1. Which is the correct configuration for a Delta/Star transformer
   a. Dy -30
   b. Dy+30
   c. DY 11
   d. Dy 1

2. Before any work is carried out on high voltage conductors or equipment
   a. An access path must be opened.
   b. Danger tags must be carried.
   c. An access permit must be obtained.
   d. All conductors must be exposed.

3. A Star/Star transformer with a phase shift of 180^0would have a vector grouping of:
   a. YY 3
   b. Yy 12
   c. YY 6
   d. Yy 6

4. A three phase transformer marked ***Dy11*** has a:
   a. Delta connected Primary, and a star connected Secondary with a lagging phase angle of 30°.
   b. Delta connected Primary, and a star connected Secondary with a leading phase angle of 30°.
   c. Delta connected Secondary, and a star connected Primary with a lagging phase angle of 30°.1
   d. Delta connected Secondary, and a star connected Primary with a leading phase angle of 30°.

5. Before an access permit is issued isolated conductors must be:
   a. Shorted together.
   b. Visually inspected.
   c. Temporarily earthed.
   d. All conductors must be labeled.

6. For three phase transformers to operate in parallel their
   a. Percentage impedance must be the same.
   b. Secondary terminal voltage and phase sequence must be identical.
   c. Load ratings must be similar.
   d. Ability to dissipate heat must be in proportion to their rating.

7. An access permit is:
   a. An authority to work in an area which has been isolated and made safe.
   b. An authority to work anywhere.
   c. A verbal agreement to start work.
   d. An authority to enter an area but not to do any work on equipment in that area.

8. A 230/400 volt Star/Delta transformer would a vector grouping of:
   a. yD 11
   b. yD 1
   c. Yd 11
   d. Yd 1

9. When conducting a polarity test on a 230V/50V transformer, your voltmeter readings displayed 180V. The transformer is:
   a. Additive with V2 being opposite polarity to V1
   b. Additive with V2 having the same polarity to V1
   c. Subtractive with V2 having the same polarity to V1
   d. Subtractive V2 being opposite polarity to V1

10. AS/NZS 3000 defines high voltage as
    a. Above 600Va.c to 1000Vd.c
    b. Below 1000Va.c or 1500Vd.c
    c. Above 1000Va.c or 1500Vd.c
    d. Above 100Va.c or 600Vd.c

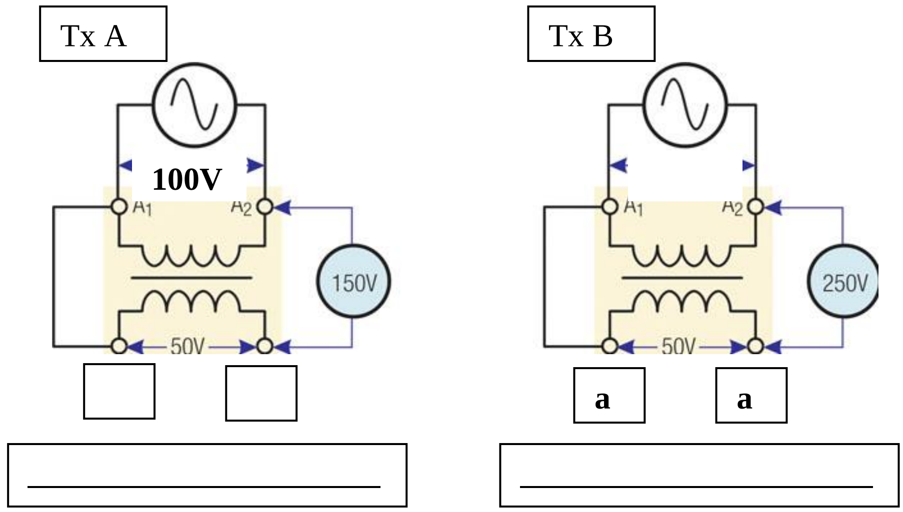
11. AS/NZS 3000 section 7.6 applies to high voltage in:
    a. Radio transmitters
    b. substations
    c. Neon signs
    d. Television sets

12. Before an access permit is issued the conductors must be:
    a. Shorted together
    b. Earthed
    c. De-energised
    d. All of the above.

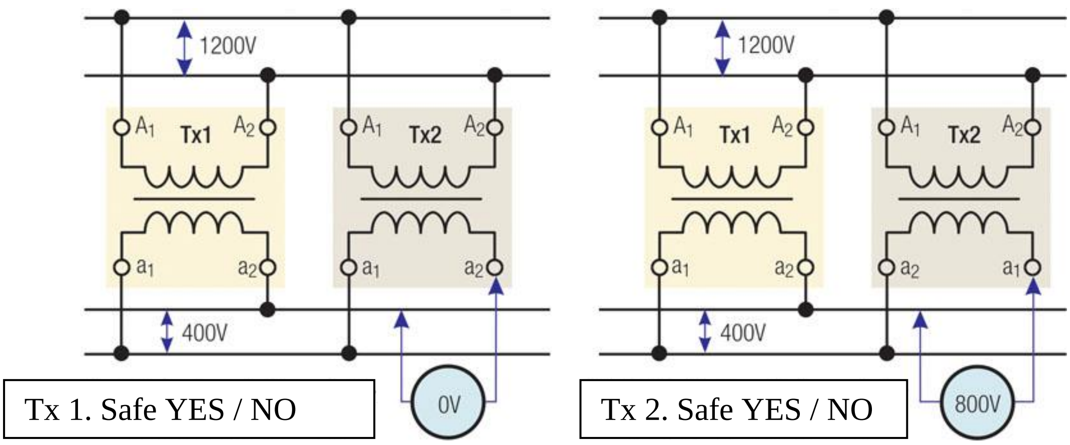
13. If an access permit has not been issued all conductors are regarded as:
    a. Dead
    b. Isolated
    c. Live.
    d. De-energised.

Short Answer & Diagrams

1. On the diagram below;
   a. Write polarity markings on both secondary windings
   b. Place the primary voltage reading in Tx B.
   c. State if the transformers are subtractive or additive.



2. Which Transformer configuration can be safely connected in parallel?



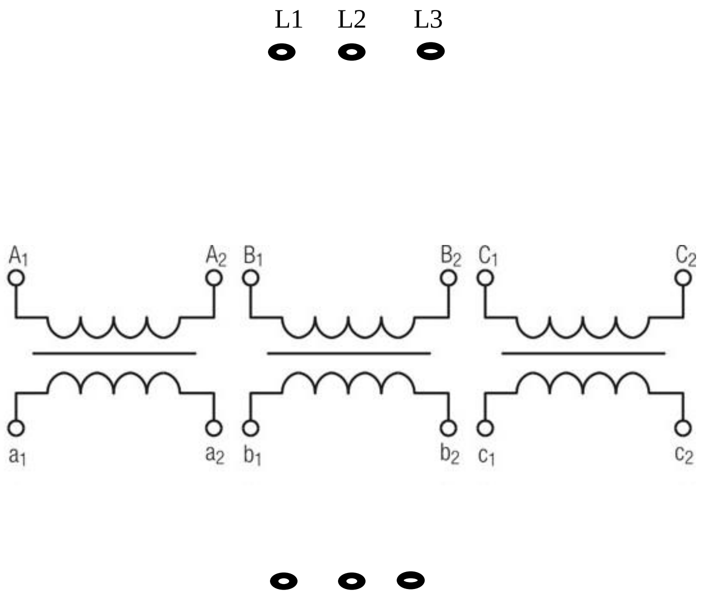
3. In reference to transformer markings;

   a. What do the capital letters refer to?

   b. What do the numbers refer to?

4. What other symbol denotes the polarity of a transformer.

5. Connect the following three phase transformer to supply a 400V load. The transformer ratio is 26:1 and is connected to a 6kV supply.



400V Load

6. List three requirements, which **MUST** be met to allow paralleling of transformers.

____

____

____

7. List two requirements, which **SHOULD** be met to allow paralleling of transformers.

____

____

8. Name three methods, which would be suitable to reduce harmonics in three phase systems.

____

____

____

9. Name the following harmonics for a 50 Hz base signal.

50Hz ______________________________

150Hz ______________________________

10. State two adverse effects of harmonics in power systems?

____

____

Calculations.

1. Two star/star transformers A and B of equal rating share a load current of 300 A. The percentage impedance corresponding to full load currents is 5.1% for transformer A and 4.3% for transformer B. Calculate the load current of each transformer. *(Ans: Tx A = 137.2, Tx B = 162.8A)*

2. Two, three phase transformer rated at 1000 kVA, 33/1 IkV, are connected in parallel with to a 2MVA load. Both are connected Dyl. At full load the percentage impedance of Tx A is 5.4% and for Tx B is 6.7%.
   a. Calculate the kVA load on each transformer. *(1.1MVA,-893kVA)*
   b. Calculate the load current supplied by each transformer
   (58.6A – 46.87A)

3. Two 33KV/5kV transformers are selected to be paralleled. Show by calculation if they will operate satisfactorily together supplying a 25 MVA load.
   a. Transformer A - 15 MVA 5%Z. *(Ans: Tx A = 13.9MVA)*
   b. Transformer B - 12 MVA 6%Z. *(Ans: Tx B = 11.1MVA)*

Practical Exercise 5: Auto-Transformers

Task

Examine the operating principles of an auto-transformer by measuring its winding resistance, correctly connecting the auto transformer to the supply and load, and measuring the relative currents and voltages.

Number	EQUIPMENT
1	41.5Va.c Variac
1	41.5V Auto-Transformer
1	Digital Multimeter
1	Clip on Ammeter
1	30Ω Resistor 30W
1	Switch
1	Contact Leads

Procedure 1:
Auto-Transformer Winding Characteristics

1. Using a digital multimeter, measure the primary and secondary winding resistance and complete table 1**. (NOTE: NO POWER REQUIRED.**

TABLE 1			
Resistance - Ohms			
Primary Resistance	Secondary Resistance 100%	Secondary Resistance 80%	Secondary Resistance 50%

2. Connect up the auto-transformer as shown in figure 1.

3. SAFETY CHECK: Ask the teacher to check that the equipment is safely connected.

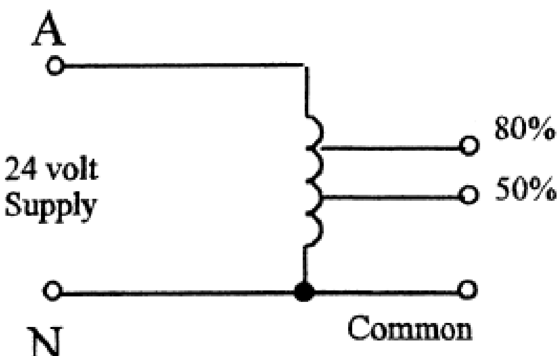


Figure 1

Table 2			
	Primary Voltage	80% Tapping	50% Tapping
Measured			

4. Measure the input and output voltages. Complete table 2.

Procedure 2:
Load Conditions

5. Connect the load resistor (30Ω. to the 80% tapping as shown in figure 2 below. Measure the primary and secondary current and record in Table 3.

6. Connect the load resistor (30Ω. to the 50% tapping as shown in figure 2 below. Measure the primary and secondary current and record in Table 3.

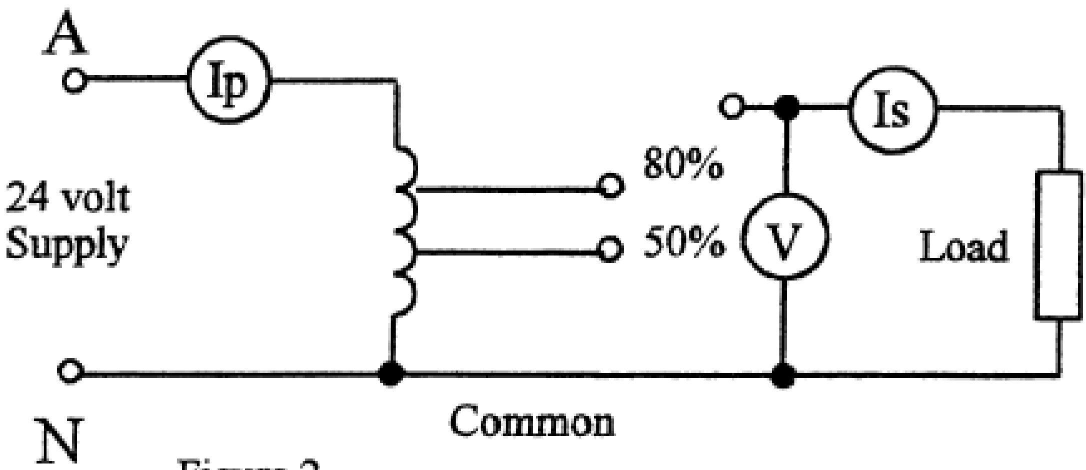


Figure 2

Table 3			
	Primary Current	80% Tapping	50% Tapping
Measured			

7. Isolate the supply, disconnect the circuit and return all equipment to its proper place.

Progress Table		
First Attempt	**Second Attempt**	**Teacher Assist**

Observations

8. Look at the resistance values in table 1 and compare the primary resistance to 80% & 50% values. Are they what you expect?

9. Calculate the secondary voltages for the 80% & 50% tapping using your measured primary voltage in table 2. Compare these to your measure values, are they similar?

10. Calculate the secondary current for the 80% & 50% tapping using your measured secondary voltage in table 2. Compare these to your measured current values from table 3, are they similar? (resistance = 30Ω)

11. Calculate the current in the common part of the transformer winding using the calculated results above.

END

Auto & Instrument Transformers & Testing
(Philips pg. 510 – 516)
<u>Tutorial 5</u>
Multiple Choice

1. Compared with a double wound transformer of the same rating, an auto-transformer:
   a. is larger in physical size
   b. require less material to manufacture
   c. has lower efficiency
   d. has higher losses

2. The current in the common section of the winding of an auto-transformer when on load, is equal to:
   a. the phasor sum of the primary and secondary currents
   b. the phasor difference of the primary and secondary currents
   c. the sum of the primary and secondary currents
   d. the difference of the primary and secondary' currents.

3. An auto-transformer
   a. has two electrically isolated windings
   b. has electrical and magnetic isolation
   c. has the same number of primary and secondary turns
   d. has a part of the primary and secondary winding electrically common

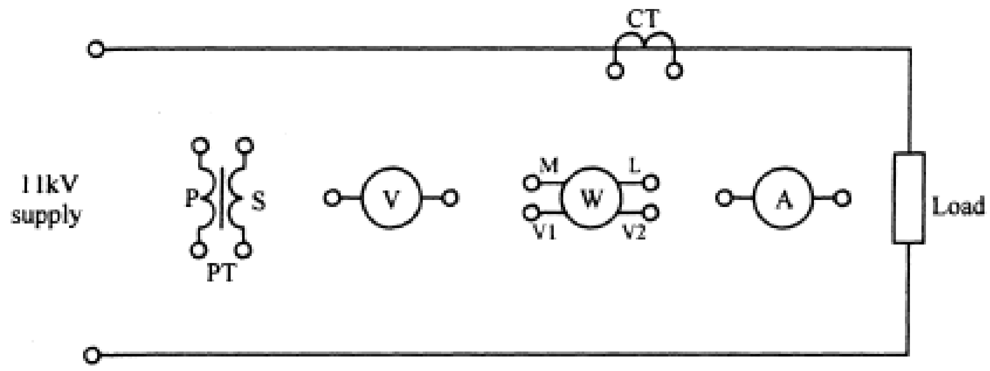
4. The secondary current of a standard current transformer is:
   a. 0.6A
   b. 5A
   c. 10A
   d. 25A

5. The standard secondary voltage of an instrument type potential transformer is:
   a. 400V
   b. 230V
   c. 120V
   d. 110V

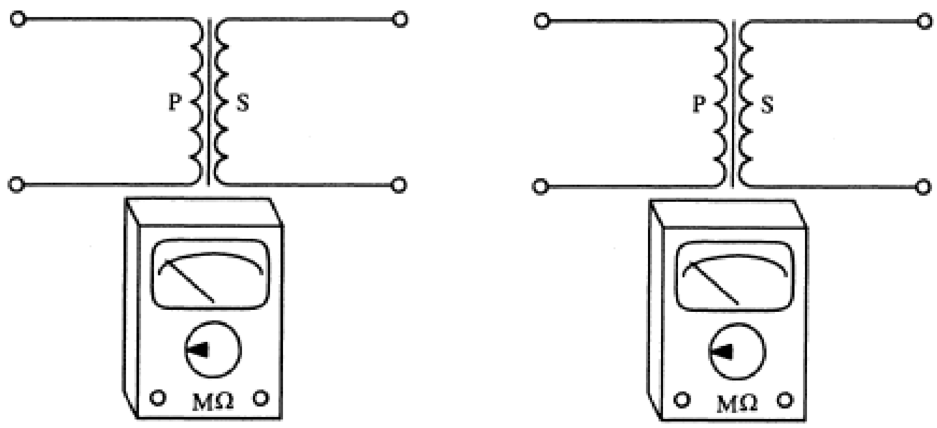
6. If the instrument is to be removed from the secondary of a current transformer it is necessary to:
   a. short circuit the primary terminals
   b. short circuit the secondary terminals
   c. open circuit the secondary leads
   d. open circuit the primary leads

Short Answer & Diagrams

1. Connect the components shown below to allow the load voltage, current and power to be measured.



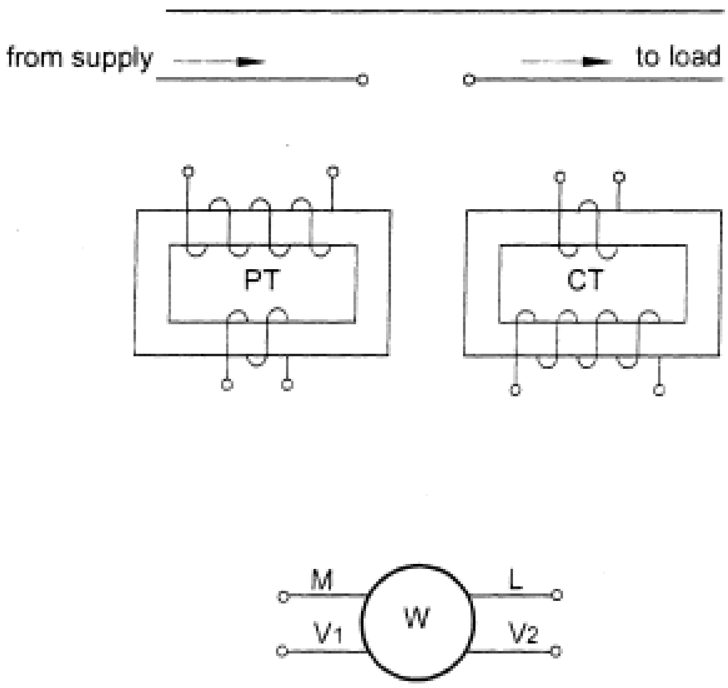
2. Draw the connections required to measure the insulation resistance between:
   a. Windings and earth
   b. Primary and secondary windings



3. State the voltage range setting for the IR meter for a 400V transformer.

4. State the minimum acceptable insulation resistance value for question 2.

5. On the diagram below show how the wattmeter should be connected to the instrument transformers, and how the instrument transformers should be connected to the supply.

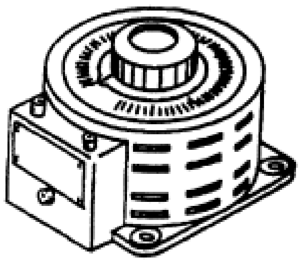


6. The figure below shows an example of one type of auto-transformer. Explain why auto transformers are used in the three main applications below?

a. Long transmission lines.________________________________

b. Electrical Motors._____________________________________

c. Variable loads. _______________________________________



7. State three advantages of an auto-transformer over a standard double wound transformer.

a. ____

b. ____

c. ____

8. State the standard secondary current for a CT coil.

____

9. State the standard secondary voltage for a potential transformer.

____

10. What are current and voltage transformers rated in?

____

11. What is unique about an auto-transformers primary and secondary windings?

____

12. What protection must be placed on the secondary side of a Potential transformer?

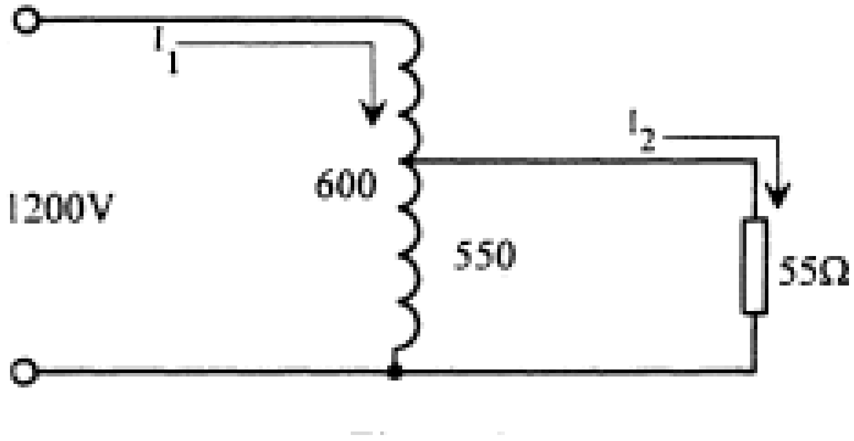
____

13. State the main disadvantage of an auto-transformer.

____

Calculations

1. For a step down auto-transformer shown below determine the:
   a. Secondary voltage *(Ans: Vs = 1100)*
   b. Secondary current *(Ans: Is = 20)*
   c. Primary current *(Ans: Ip = 18.3A)*
   d. Current in the common section of the winding *(Ans: Ic = 1.7A)*



2. Determine the current in the common section of the winding of a 240V/220V auto-transformer supplying a 1kW load at unity power factor. *(Ans: Ic = 0.34A)*

3. A CT with a ratio of 200A/5A is used to measure the current taken by an induction motor. If the motor current is 175A determine the current flowing in the CT secondary. *(Ans: I = 4.37A)*

4. A PT with a ratio of 11kV/110v is used to supply the potential coil of a wattmeter. If the line voltage drops to 10.5kV, determine the voltage supplied to the wattmeter. (Secondary on PT)

5. An auto-transformer is used to step-down from 300V to 250V. The complete winding consists of 570 turns and primary current is 36 amperes. Calculate:
   a. Secondary turns. (475t)
   b. Secondary load current (43.2A)
   c. Current in the common part of the winding. (7.2A)

6. An auto-transformer has 500 turns and is tapped at 300 turn. The high voltage current is 30 amperes. The low voltage is 330 volts. Calculate the:
   a. Primary voltage (550V)
   b. Secondary load current. (50A)
   c. Current in the common part of the winding. (20A)

________________END_________________________

Formulae Sheets

Note: The symbols used on this sheet follow AS1046 Part 1. There are alternate recognised symbols in use. The list does not contain every equation used in the course. Transposition of equations will be necessary to solve problems

$$\cos\phi = \frac{P}{S} \qquad \cos\phi = \frac{R}{Z} \qquad S = \sqrt{P^2 + Q^2}$$

$$S = VI \qquad P = VI\cos\phi \qquad Q = VI\sin\phi$$

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad V_L = \sqrt{3}V_P \qquad I_L = \sqrt{3}I_P$$

$$S = \sqrt{3}V_L I_L \qquad P = \sqrt{3}V_L I_L\cos\phi \qquad Q = \sqrt{3}V_L I_L\sin\phi$$

$$\tan\phi = \sqrt{3}\left(\frac{W_2 - W_1}{W_2 + W_1}\right) \qquad Q = mC\Delta t$$

$$V' = 4.44\Phi fN \qquad \frac{V_1}{V_2} = \frac{N_1}{N_2} \qquad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

$$N_{syn} = \frac{120f}{p} \qquad s\% = \frac{(n_{syn} - n)}{n_{syn}} \times \frac{100}{1} \qquad f_r = \frac{s\% \times f}{100}$$

$$V_{reg}\% = \frac{(V_{NL} - V_{FL})}{V_{FL}} \times \frac{100}{1} \qquad V_{reg}\% = \frac{(V_{NL} - V_{FL})}{V_{NL}} \times \frac{100}{1} \qquad T = \frac{\Phi ZIP}{2\pi a}$$

$$I_{ST} = \frac{1}{3} \times I_{DOL} \qquad T_{ST} = \frac{1}{3} \times T_{DOL} \qquad I_{ST} = \frac{V_{ST}}{V} \times I_{DOL}$$

$$T_{ST} = \left(\frac{V_{ST}}{V}\right)^2 \times T_{DOL} \qquad I_{motor\,st} = \frac{\%TAP}{100} \times I_{DOL} \qquad I_{line\,st} = \left(\frac{\%TAP}{100}\right)^2 \times I_{DOL}$$

$$E = \frac{\Phi_v}{A} \qquad E = \frac{I}{d^2} \qquad \eta_v = \frac{\Phi_v}{P}$$

$$V_L = 0.45V_{ac} \qquad V_L = 0.9V_{ac} \qquad V_L = 1.17V_{phase}$$

$$V_L = 1.35V_{line} \qquad PRV = \sqrt{2}V_{ac} \qquad PRV = 2\sqrt{2}V_{ac}$$

$$PRV = 2.45V_{ac} \qquad V_{ripple} = \sqrt{2}V_{ac} \qquad V_{ripple} = 0.707V_{phase}$$

$$V_{ripple} = 0.1895V_{line}$$

$Q = It$	$v = \frac{s}{t}$	$a = \frac{\Delta v}{t}$
$F = ma$	$W = Fs$	$W = mgh$
$W = Pt$	$\eta\% = \frac{output}{input} \times \frac{100}{1}$	$I = \frac{V}{R}$
$P = VI$	$P = I^2 R$	$P = \frac{V^2}{R}$
$R_2 = \frac{R_1 A_1 l_2}{A_2 l_1}$	$R_h = R_c(1 + \alpha \Delta t)$	$R = \frac{\rho l}{A}$
$R_T = R_1 + R_2 + R_3$	$V_T = V_1 + V_2 + V_3$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
$I_T = I_1 + I_2 + I_3$	$V_2 = V_T \frac{R_2}{R_1 + R_2}$	$I_2 = I_T \frac{R_1}{R_1 + R_2}$
$R_x = \frac{R_A R}{R_B}$	$C = \frac{Q}{V}$	$\tau = RC$
$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	$C_T = C_1 + C_2 + C_3$	$C = \frac{A \varepsilon_o \varepsilon_r}{d}$
$F_m = IN$	$H = \frac{F_m}{l}$	$B = \frac{\Phi}{A}$
$\Phi = \frac{F_m}{S}$	$S = \frac{l}{\mu_o \mu_r A}$	$V = N \frac{\Delta \Phi}{\Delta t}$
$e = Blv$	$L = \frac{\mu_o \mu_r A N^2}{l}$	$L = N \frac{\Delta \Phi}{\Delta I}$
$V = L \frac{\Delta I}{\Delta t}$	$\tau = \frac{L}{R}$	$F = Bil$
$T = Fr$	$E_g = \frac{\Phi Z n P}{60a}$	$P = \frac{2\pi n T}{60}$
$t = \frac{1}{f}$	$f = \frac{np}{120}$	$V = 0.707 V_{\max}$
$I = 0.707 I_{\max}$	$V_{ave} = 0.637 V_{\max}$	$I_{ave} = 0.637 I_{\max}$
$v = V_{\max} \sin \phi$	$i = I_{\max} \sin \phi$	$I = \frac{V}{Z}$
$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$X_L = 2\pi f L$	$X_C = \frac{1}{2\pi f C}$