Three Phase Meter Lab
Track B
Groups I and II

Three Phase Meter Lab
Track B - Groups I & II

Three Phase Lab Introduction -
This lab will give you a chance to work with six different styles of three phase meter installations and to increase your understanding of the voltage and current relationships in the represented installations.

Lab Projects:
The labs available are:
Lab #1 - Three phase, four wire WYE with a Form 9S meter (there are two identical set-ups like this one)
Lab #2 - Three phase, four wire DELTA with a Form 8S meter
Lab #3 - Three phase, four wire DELTA with a Form 5S meter - with Two CTs
Lab #4 - Three phase, four wire WYE with a Form 6S meter
Lab #5 - Three phase, four wire WYE with a Form 5S meter - with DELTA connected CTs
Lab #6 - Three phase, three wire DELTA with a Form 5S meter (there are two identical set-ups like this one)

Create an Expectation:
Before starting any and all of the lab projects please take time to create an expectation of the three phase metering characteristics that will take place as you progress through the steps of each lab. Take some time as a lab group to talk through what effect each step in the lab will create and then why you believe this is true. The lab proof process should be used to prove if your understanding of the different three phase metering connections and phase relationships are correct or not. The only way to prove this is by creating an expectation and then proving it or disproving it.

Three Phase Meter Lab
Track B - Groups I & II

General Instructions -

1) Break-up into equal size groups and proceed to your first lab location. There are eight set-ups with six different lab projects available.

2) On the load boxes the Unity - PF toggle switches will be set to the Unity power factor setting for this lab. Please leave these switches on the Unity setting, other power factor settings are available but will not be used in this lab.

3) The load current magnitudes (providing the driving torque for the meters) will be set by adjusting the dials on the front of the load box at each lab location. Try to set the dials equally so that each meter element has a similar amount of load.

4) The load boxes contain the CTs (except in Lab Project #3 which has external CTs) and their secondary output is available from the front panel on them. The CT output for Lab Project #3 is at the external CTs.

5) There are different meter test switches used in the labs so make sure that your group becomes familiar with the test switch and full lab set-up at each location (including color code).

6) A stopwatch load check will be used to calculate the active loads the watthour meters are measuring.

7) Stopwatch load calculations will be done on the meter with all the elements active and then with individual elements active (to do single element load tests leave the voltage switches closed on the meter test switch and manipulate the current switches to activate the individual elements).

$$\text{Stopwatch Load Check Formula} = \frac{3600 \times \#\text{ of Meter Revs} \times \text{Meter Kh}}{\text{Time in Seconds (for the Meter Revs)}} = \text{Watts or Active Power}$$

8) This lab uses electromechanical meters so that each participant in the group can view the status of the meters as the lab progresses.

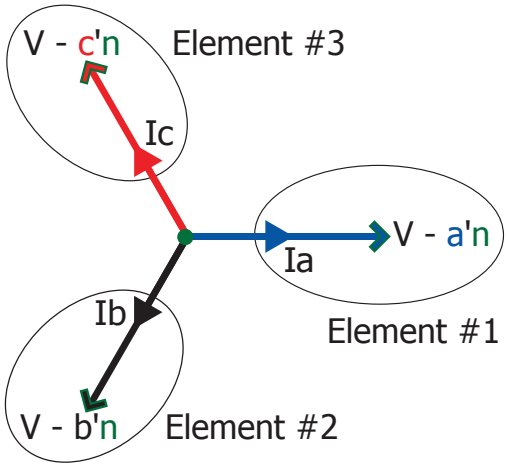
Getting Started:

Turn on the power to the lab by toggling the main power switch to the on position. Dial up current on the variac dials on the load box. Verify that the lab set-up is correctly wired and that there is current flowing in the current coils in the meter (this can be accomplished by switching the current switches on the meter test switch). Once the load box is energized and current is flowing, (do not adjust the variacs - this is to help the lab proof process) use a stopwatch to calculate the load for the full meter and by each element. Proceed through the lab steps making the changes to the connection and then doing stopwatch load tests with each new lab step connection. If you or anyone in your group has any questions about the lab set-up please ask for assistance from the lab facilitator or lab assistants before getting starting.

Once you have finished with the steps of the lab turn the variacs back to no load and switch off the main power toggle switch.

Lab Project #1
Three Phase Four Wire WYE
Three Element - Form 9

Vector Diagram for a 3-Phase 4 Wire WYE - Form 9 Meter
ABC Phase Sequence - Unity PF - Balanced 3 Phase Load



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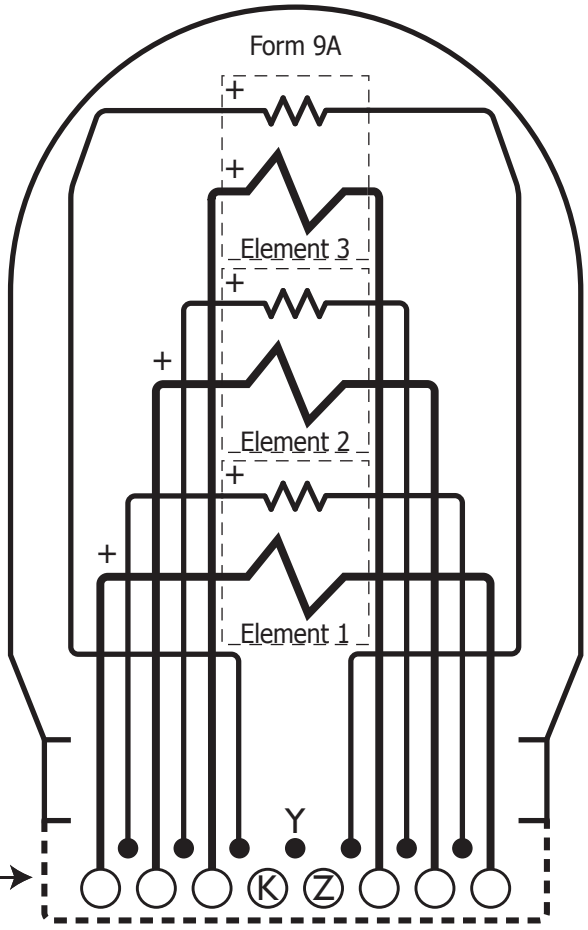
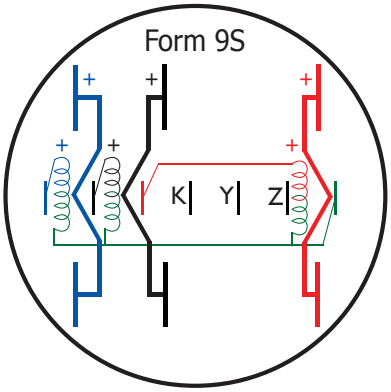
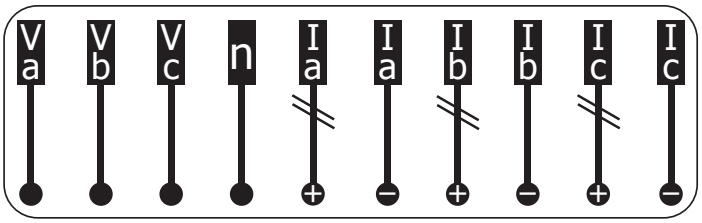


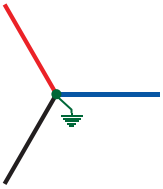
Wired Connection Holes
are as Viewed from the
Bottom of the Meter

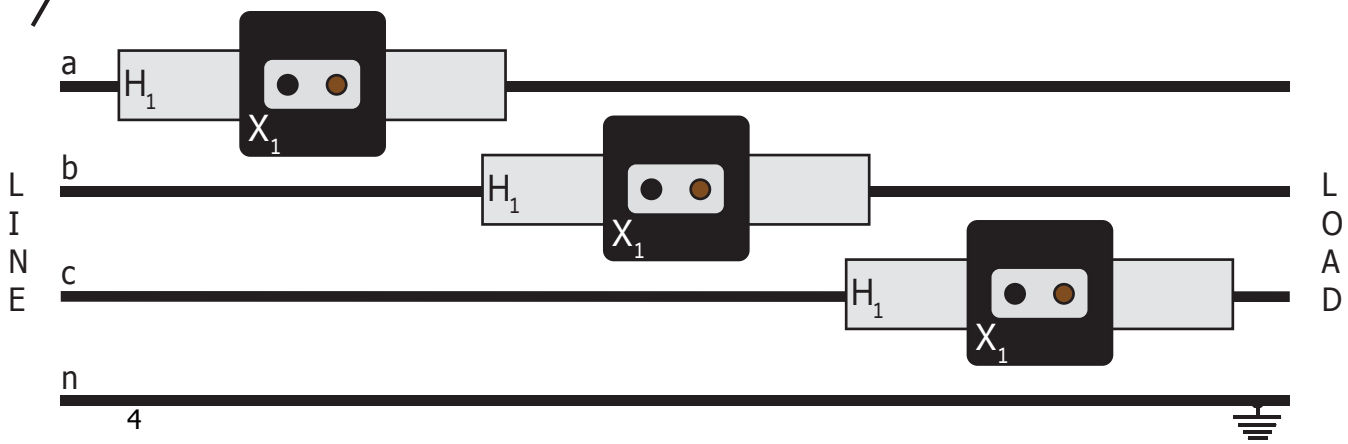




Sample Test Switch Only
Lab Test Switches Vary

Four Wire WYE Line





1

Three Phase Meter Lab Project #1 Worksheet
Three Phase Four Wire WYE
Three Element - Form 9

LAB PROCEDURE STEPS: (Active Power being measured @ unity power factor)
*Important Note: Return lab set-up to its normal connection before beginning this step.

STEP 1 - Meter Connected Correctly (prove this is true) (What are your expectations?)

Step 1 is the baseline connection -

a) Three Element Connection — Stopwatch Watts _____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #3 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

STEP 2 - Reverse Phase A CT connection at the load box (Expectations?)

a) Three Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #3 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 3 - Exchange A & C potentials at the load box (Expectations?)

a) Three Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #3 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 4 - Short Phase C CT at the meter test switch (jumper provided) (Expectations?)

a) Three Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

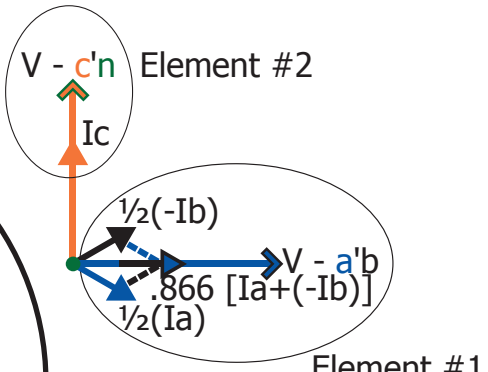
Element #2 (Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #3 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

Very Important Safety Warning:
When doing single element stopwatch tests, shunt the selected currents at the meter test switch and leave all voltages energized.

Lab Project #2
Three Phase Four Wire DELTA
Two Element - Form 8

3-Phase 4 Wire Delta - Form 8 Meter Vector Diagram
ABC Phase Sequence - Unity PF - Balanced 3 Phase Load



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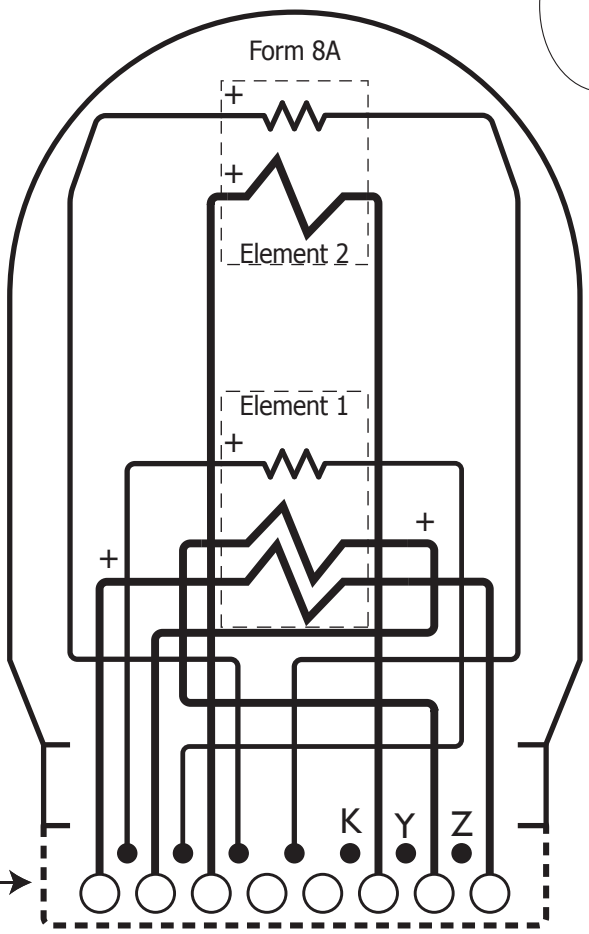
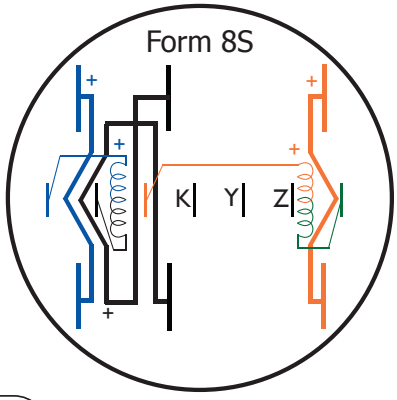
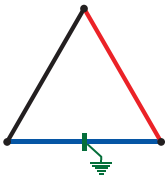
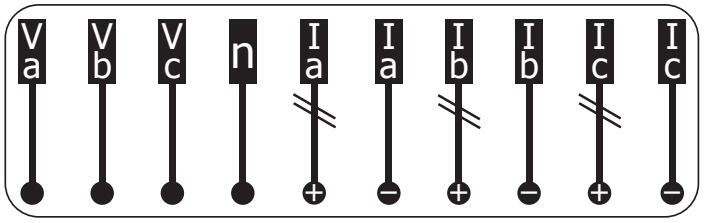


Wired Connection Holes
are as Viewed from the
Bottom of the Meter

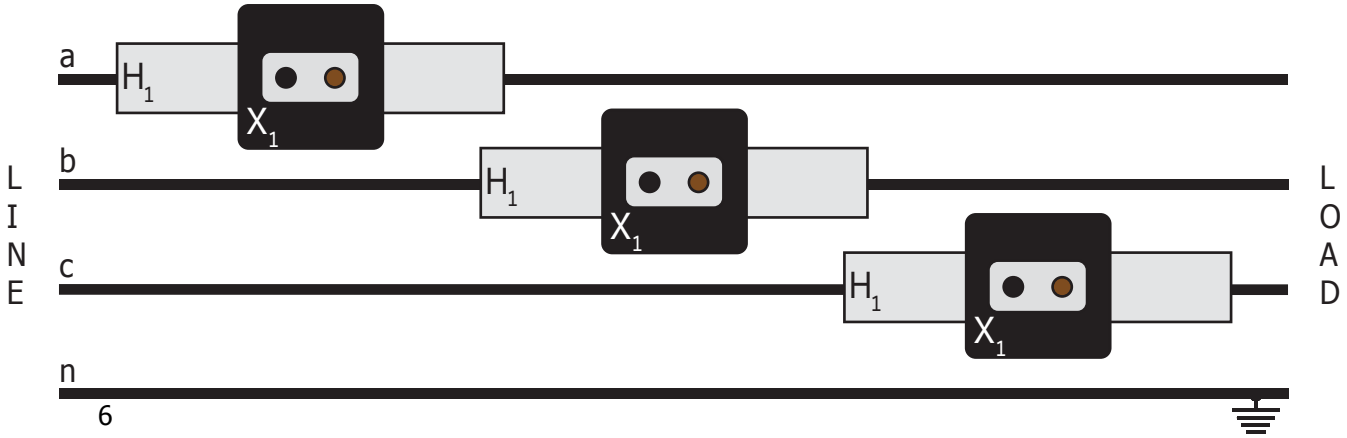


Four Wire DELTA Line





Sample Test Switch Only
Lab Test Switches Vary



2

Three Phase Meter Lab Project #2 Worksheet
Three Phase Four Wire DELTA
Two Element - Form 8

LAB PROCEDURE STEPS: (Active Power being measured @ unity power factor)
*Important Note: Return lab set-up to its normal connection before beginning this step.

STEP 1 - Meter Connected Correctly (prove this is true) (What are your expectations?)

Step 1 is the baseline connection -

a) Two Element Connection — Stopwatch Watts _____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

STEP 2 - Reverse Phase A CT connection at the load box (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 3 - Exchange A & B potentials at the load box (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 4 - Short Phase C CT at the meter test switch (jumper provided) (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

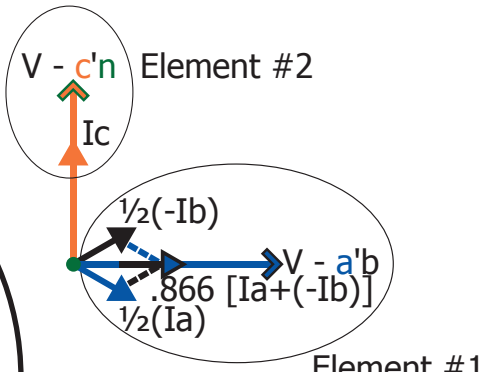
Element #1 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

Very Important Safety Warning:
When doing single element stopwatch tests, shunt the selected currents at the meter test switch and leave all voltages energized.

Lab Project #3
Three Phase Four Wire DELTA
Two Element - Form 5
(CTs have the same ratio
and similar primary turns)

3-Phase 4 Wire Delta - Form 5, 35, 45 Meter Vector Diagram
ABC Phase Sequence - Unity PF - Balanced 3 Phase Load



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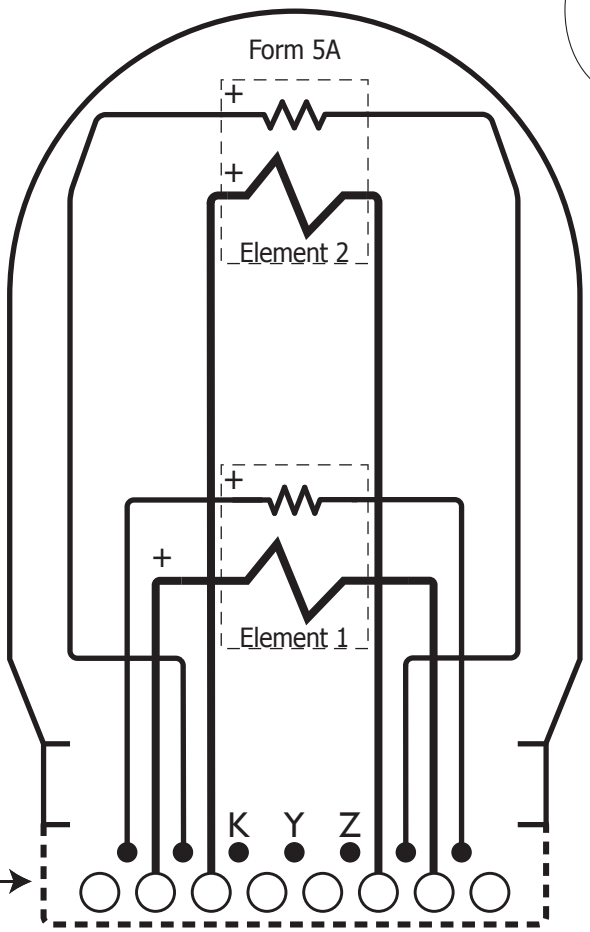
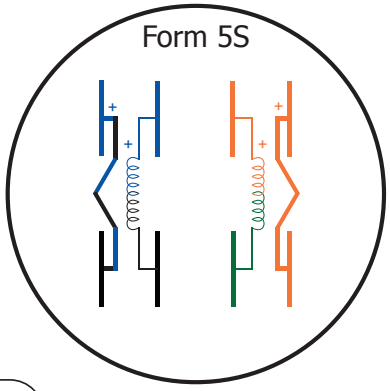
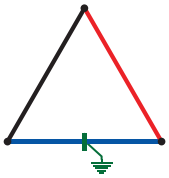
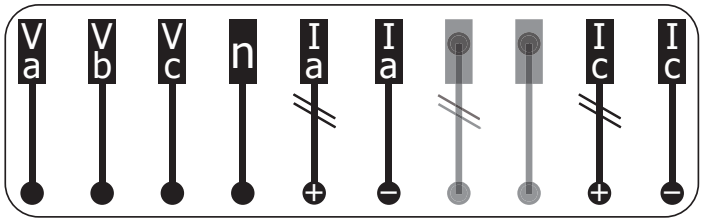


Wired Connection Holes
are as Viewed from the
Bottom of the Meter

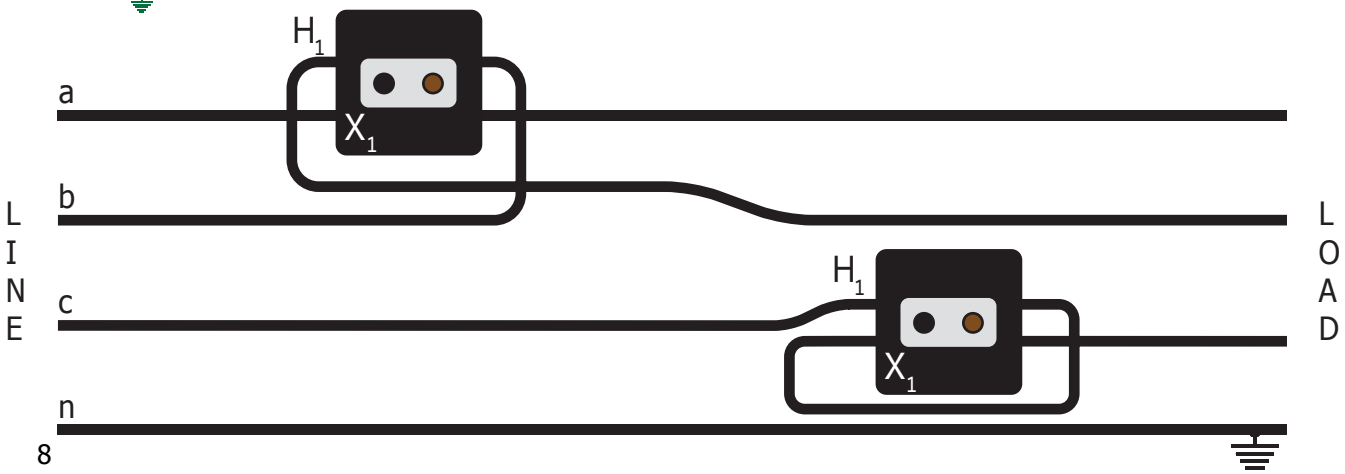


Four Wire DELTA Line





Sample Test Switch Only
Lab Test Switches Vary



3

Three Phase Meter Lab Project #3 Worksheet
Three Phase Four Wire DELTA
Two Element - Form 5

LAB PROCEDURE STEPS: (Active Power being measured @ unity power factor)
*Important Note: Return lab set-up to its normal connection before beginning this step.

STEP 1 - Meter Connected Correctly (prove this is true) (What are your expectations?)

Step 1 is the baseline connection -

a) Two Element Connection Stopwatch Watts _____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs Stopwatch Watts _____

STEP 2 - Reverse Element #1 CT connection at the CT secondary (Expectations?)

a) Two Element Connection Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs Stopwatch Watts _____

*STEP 3 - Exchange A & B potentials at the load box (Expectations?)

a) Two Element Connection Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs Stopwatch Watts _____

*STEP 4 - Short Phase C CT at the meter test switch (jumper provided) (Expectations?)

a) Two Element Connection Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

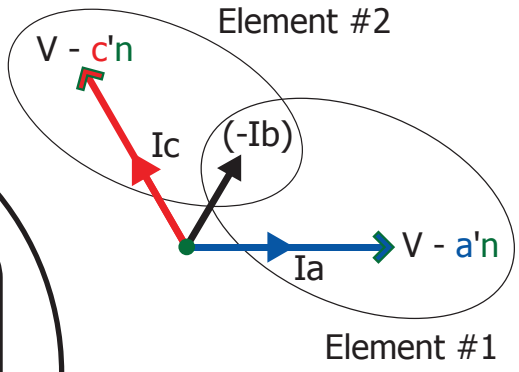
Element #2 (Ic Current) - Fwd or Rvs Stopwatch Watts _____

Very Important Safety Warning:

When doing single element stopwatch tests, shunt the selected currents at the meter test switch and leave all voltages energized.

Lab Project #4
Three Phase Four Wire WYE
Two Element - Form 6
(2½ Element Meter)

3-Phase 4 Wire WYE - Form 6 Meter Vector Diagram
ABC Phase Sequence - Unity PF - Balanced 3 Phase Load



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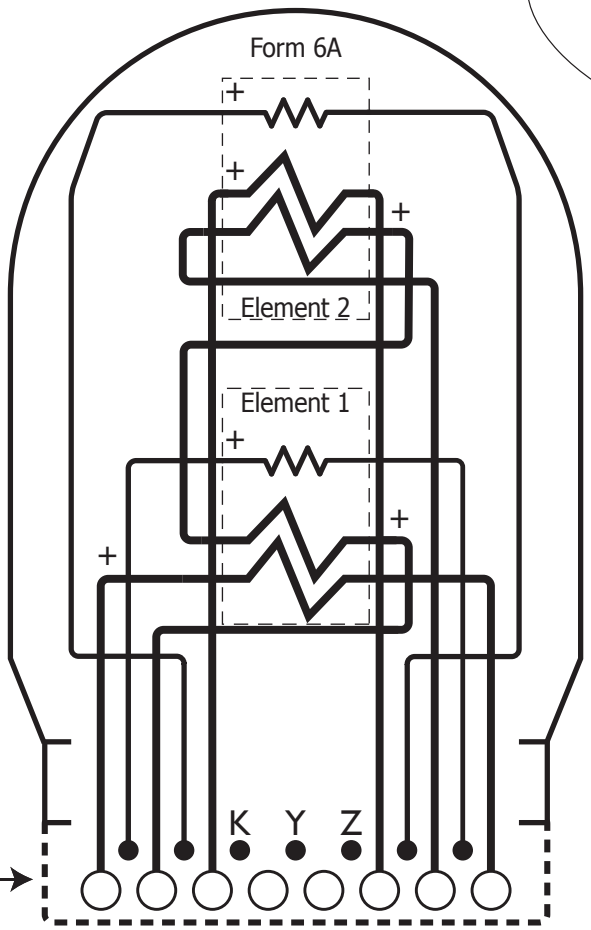
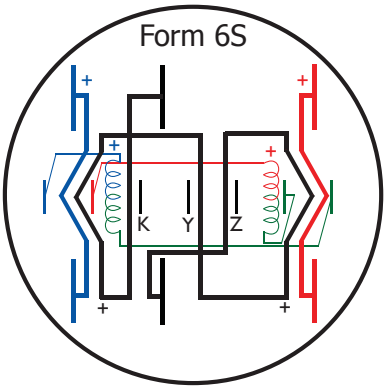
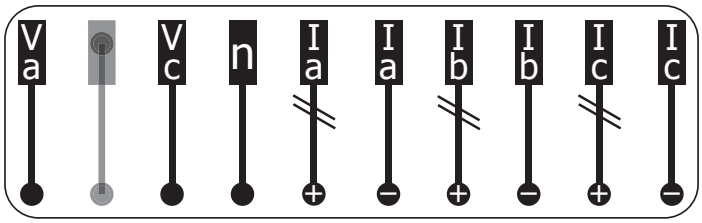


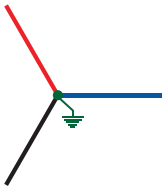
Wired Connection Holes
are as Viewed from the
Bottom of the Meter

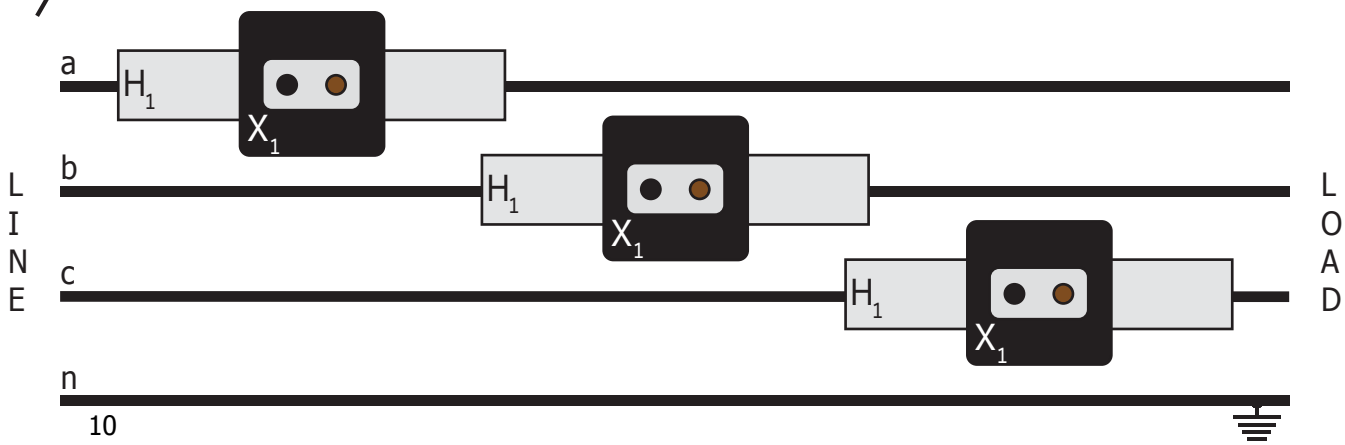




Sample Test Switch Only
Lab Test Switches Vary

Four Wire WYE Line





4

Three Phase Meter Lab Project #4 Worksheet
Three Phase Four Wire WYE
Two Element (2½ element) - Form 6

LAB PROCEDURE STEPS: (Active Power being measured @ unity power factor)
*Important Note: Return lab set-up to its normal connection before beginning this step.

STEP 1 - Meter Connected Correctly (prove this is true) (What are your expectations?)

Step 1 is the baseline connection -

a) Two Element Connection — Stopwatch Watts _____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 & #2 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

STEP 2 - Reverse Phase A CT connection at the load box (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 & #2 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 3 - Exchange A & C potentials at the load box (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 & #2 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 4 - Short Phase C CT at the meter test switch (jumper provided) (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #1 & #2 (-Ib Current) - Fwd or Rvs — Stopwatch Watts _____

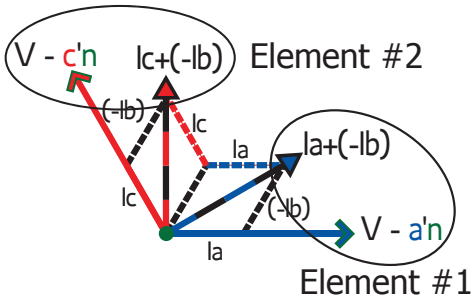
Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

Very Important Safety Warning:

When doing single element stopwatch tests, shunt the selected currents at the meter test switch and leave all voltages energized.

Lab Project #5
Three Phase Four Wire WYE
Two Element - Form 5
(Delta Connected CTs at
the Test Switch)

Vector Diagram for a 3-Phase 4 Wire WYE - Form 5, 35, 45 Meter
ABC Phase Sequence - Unity PF - Balanced 3 Phase Load



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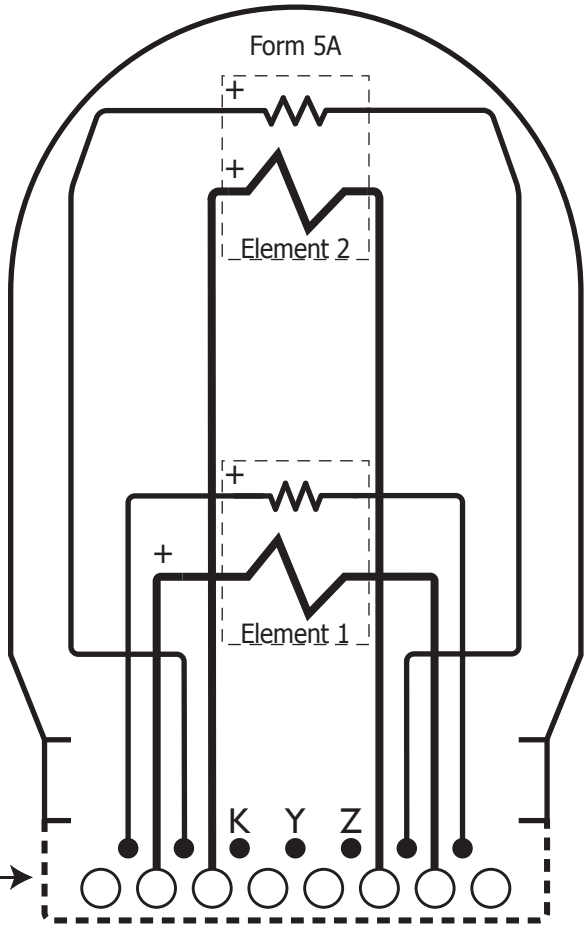
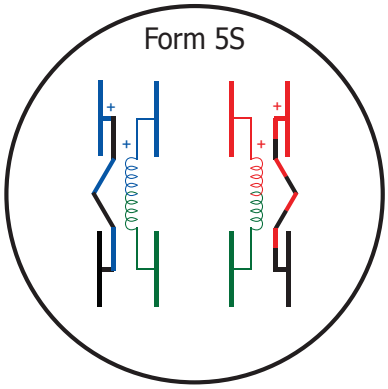
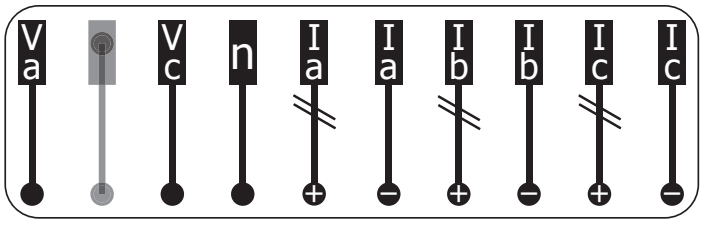


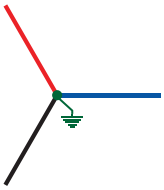
Wired Connection Holes
are as Viewed from the
Bottom of the Meter

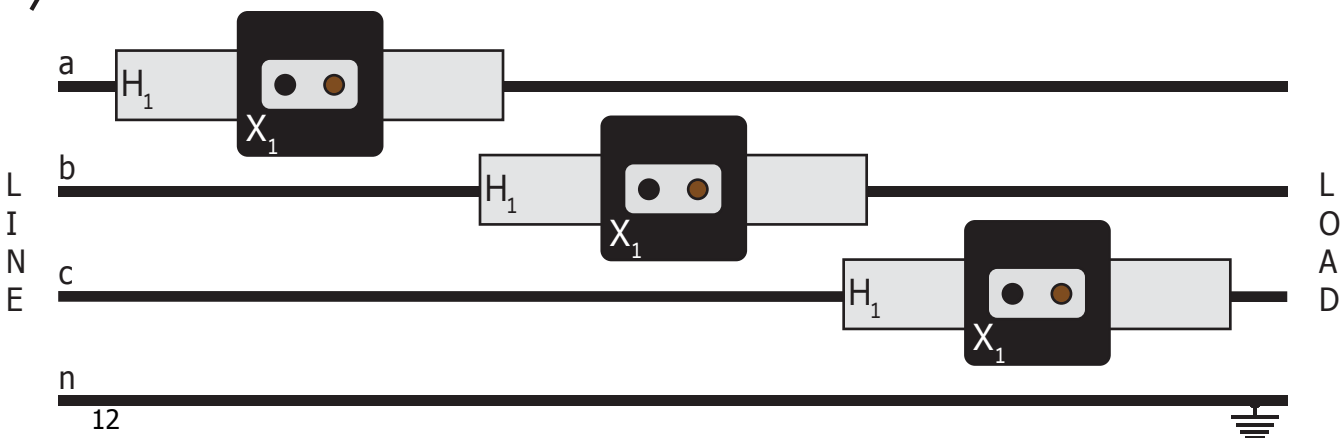




Sample Test Switch Only
Lab Test Switches Vary

Four Wire WYE Line





5

Three Phase Meter Lab Project #5 Worksheet
Three Phase Four Wire WYE
Two Element - Form 5 - Delta Connected CTs

LAB PROCEDURE STEPS: (Active Power being measured @ unity power factor)
*Important Note: Return lab set-up to its normal connection before beginning this step.

STEP 1 - Meter Connected Correctly (prove this is true) (What are your expectations?)

Step 1 is the baseline connection -

a) Two Element Connection Stopwatch Watts _____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Element #2 (Ic + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

STEP 2 - Reverse Phase A CT connection at the load box (Expectations?)

a) Two Element Connection Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Element #2 (Ic + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

*STEP 3 - Exchange A & C potentials at the load box (Expectations?)

a) Two Element Connection Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Element #2 (Ic + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

*STEP 4 - Short Phase C CT at the meter test switch (jumper provided) (Expectations?)

a) Two Element Connection Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

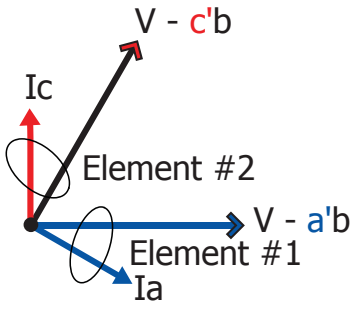
Element #2 (Ic + -Ib Currents) - Fwd or Rvs Stopwatch Watts _____

Very Important Safety Warning:

When doing single element stopwatch tests, shunt the selected currents at the meter test switch and leave all voltages energized.

Lab Project #6
Three Phase Three Wire DELTA
Two Element - Form 5

Vector Diagram for a 3-Phase 3 Wire DELTA - Form 5 Meter
ABC Phase Sequence - Unity PF - Balanced 3 Phase Load



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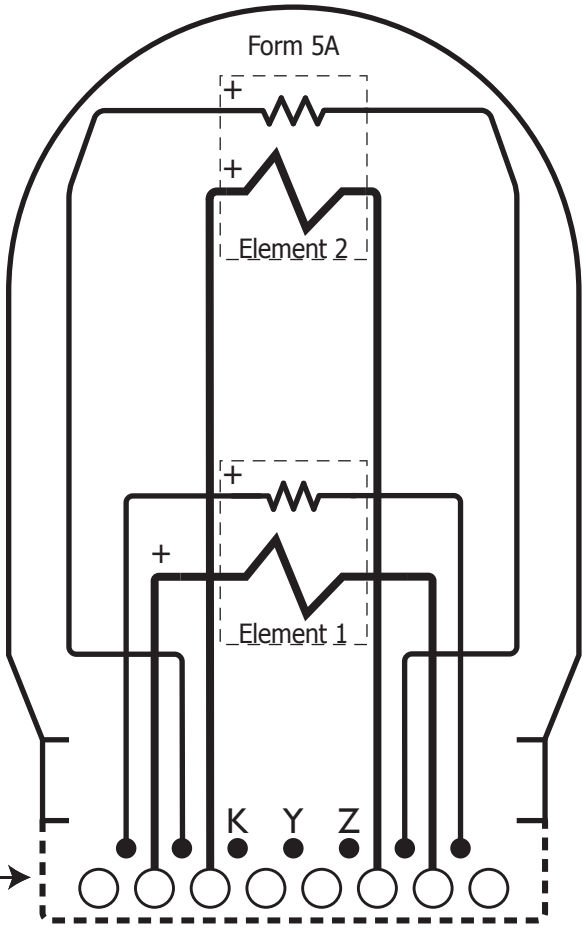
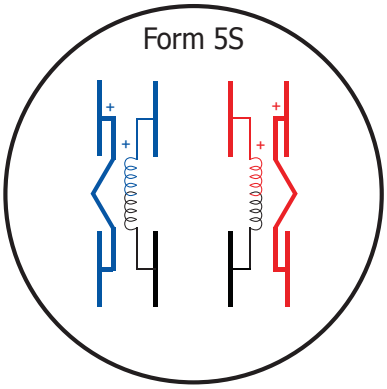
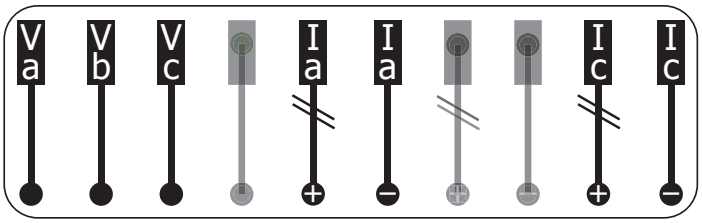


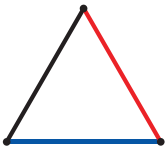
Wired Connection Holes
are as Viewed from the
Bottom of the Meter

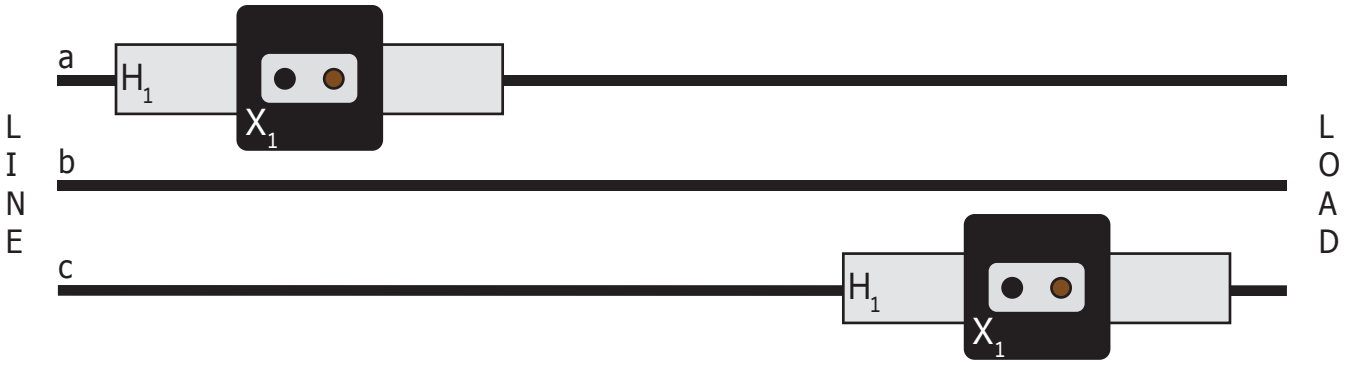




Sample Test Switch Only
Lab Test Switches Vary

Three Wire DELTA Line





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Three Phase Meter Lab Project #6 Worksheet
Three Phase Three Wire DELTA
Two Element - Form 5

LAB PROCEDURE STEPS: (Active Power being measured @ unity power factor)
*Important Note: Return lab set-up to its normal connection before beginning this step.

STEP 1 - Meter Connected Correctly (prove this is true) (What are your expectations?)

Step 1 is the baseline connection -

a) Two Element Connection — Stopwatch Watts _____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

STEP 2 - Reverse Phase A CT connection at the load box (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 3 - Exchange A & C potentials at the load box (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

*STEP 4 - Short Phase C CT at the meter test switch (jumper provided) (Expectations?)

a) Two Element Connection — Stopwatch Watts_____

b) Per Element Connection

Circle Disk Rotation Direction

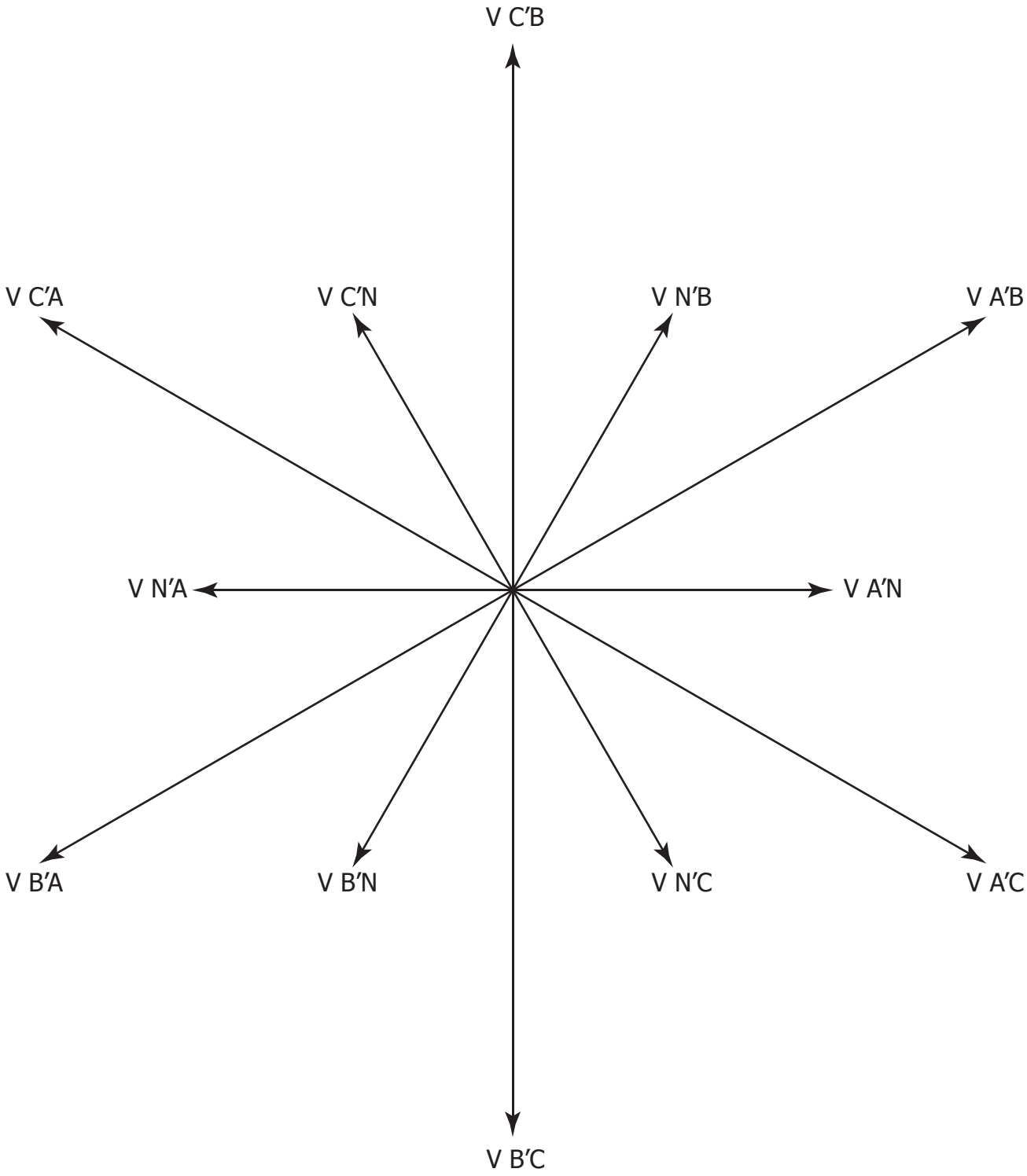
Element #1 (Ia Current) - Fwd or Rvs — Stopwatch Watts _____

Element #2 (Ic Current) - Fwd or Rvs — Stopwatch Watts _____

Very Important Safety Warning:

When doing single element stopwatch tests, shunt the selected currents at the meter test switch and leave all voltages energized.

Reference Three Phase Voltage Vectors
Phase to Neutral and Phase to Phase (by polarity)

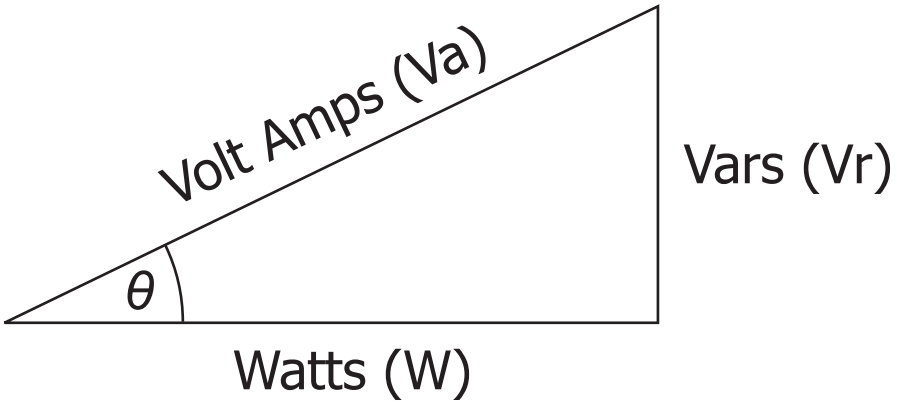


RIGHT TRIANGLE RELATIONSHIPS for Electrical Power

Volt Amps = Apparent Power

Watts = Active Power

Vars = Reactive Power



Trigonometric Functions for a Power Triangle

Formula 1
Sine of Angle θ = $\frac{\text{Vars}}{\text{Volt Amps}}$

Formula 2
Cosine of Angle θ = $\frac{\text{Watts}}{\text{Volt Amps}}$

Formula 3
Tangent of Angle θ = $\frac{\text{Vars}}{\text{Watts}}$

Formula 4
Volt Amps x Sine of Angle θ = Vars

Formula 5
Volt Amps x Cosine of Angle θ = Watts

Formula 6
Watts x Tangent of Angle θ = Vars

Formula 7
Volt Amps = $\frac{\text{Vars}}{\text{Sine of Angle } \theta}$

Formula 8
Volt Amps = $\frac{\text{Watts}}{\text{Cosine of Angle } \theta}$

Formula 9
Watts = $\frac{\text{Vars}}{\text{Tangent of Angle } \theta}$

Pythagorean Theorem Formulas for a Power Triangle

Formula 10 - Volt Amps = $\sqrt{\text{Watts}^2 + \text{Vars}^2}$

Formula 11- Watts = $\sqrt{\text{Volt Amps}^2 - \text{Vars}^2}$

Formula 12 - Vars = $\sqrt{\text{Volt Amps}^2 - \text{Watts}^2}$

Related Information on Power Factor and Phase Angles

Power Factor for the Circuit = Cosine of Angle θ or $\frac{\text{Watts}}{\text{Volt Amps}}$ or $\frac{\text{Active Power}}{\text{Apparent Power}}$

The degree value of Angle θ = Inverse of the Tangent of Angle θ or $\frac{\text{Vars}}{\text{Watts}}$ (Arc tangent or TAN^{-1}) = Phase Angle θ

Additionally, the degree value of Angle θ also equals the inverse of the Sine of Angle θ or the inverse of the Cosine of Angle θ