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## Power in AC Circuits

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- All relevant equations and working are to be shown in the case of calculation type questions.

### SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. True power is measured in\_\_\_\_\_and is a measure of the\_\_\_\_\_.
    - (a) volt-amps; power supplied
    - (b) volt-amps ; power consumed
    - (c) watts; power consumed
    - (d) watts; power supplied
  
  2. In a purely resistive circuit there is no:
    - (a) apparent power
    - (b) true power
    - (c) average power
    - (d) reactive power
  
  3. In a power triangle, apparent power is represented by the:
    - (a) side adjacent the phase angle
    - (b) hypotenuse
    - (c) side opposite the phase angle
    - (d) cosine of the phase angle
  
  4. Power factor is a ratio of:
    - (a) reactive power to apparent
    - (b) true power to reactive power
    - (c) apparent power to true power
    - (d) true power to apparent power
-



5. The power consumed in a circuit is determined by:

- (a) apparent power times the power factor
- (b) apparent power divided by the power factor
- (c) reactive power times the power factor
- (d) true power plus the power factor

### SECTION B

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

1. Neatly copy the diagram of figure 1 on your answer sheet. On the diagram of figure 1, label which sides represent the:

- (a) apparent power,
- (b) true power;
- (c) reactive power;
- (d) also show which angle represents the phase angle for the circuit.

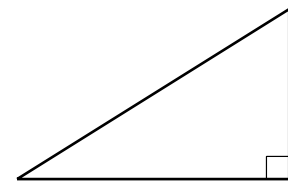
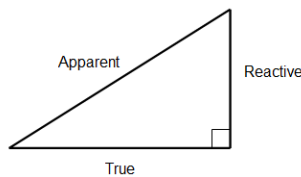


Figure 1



2. The power factor for a circuit can be found by either using the ratio of

\_\_\_\_(a)\_\_\_\_ or by the \_\_\_\_ (b) \_\_\_\_ of the phase angle, and uses the symbol \_\_\_\_ (c) \_\_\_\_.

Real power to Apparent power , Cosine , PF

3. True power is measured in \_\_\_\_ (a) \_\_\_\_, and uses the circuit symbol \_\_\_\_ (b) \_\_\_\_.

Watt, P

4. Apparent power is measured in \_\_\_\_ (a) \_\_\_\_, and uses the circuit symbol \_\_\_\_ (b) \_\_\_\_.

VoltAmp, VA

5. Reactive power is measured in \_\_\_\_ (c) \_\_\_\_, and uses the circuit symbol \_\_\_\_ (b) \_\_\_\_.

Var, VAR

6. Reactive power is the power \_\_\_\_ (a) \_\_\_\_ to the supply when either the magnetic field of an \_\_\_\_ (b) \_\_\_\_ collapses or a capacitor \_\_\_\_ (c) \_\_\_\_.

Added , Inductor , charged

7. Power factor has a range of \_\_\_\_ (a) \_\_\_\_ to \_\_\_\_ (b) \_\_\_\_, and can be either \_\_\_\_ (c) \_\_\_\_ for an inductive circuit or \_\_\_\_ (d) \_\_\_\_ for a capacitive circuit.

0 to 1 , Lagging , Leading

8. In a purely resistive circuit, the power factor is equal to (a)\_\_\_\_, or is said to be (b)\_\_\_\_ power factor.

**1, Unity**

9. If you wished to determine the power factor of a circuit, you would need a (a)\_\_\_\_ to measure true power, a (b)\_\_\_\_ and an (c)\_\_\_\_ to measure apparent power, and you would use the ratio of (d)\_\_\_\_ to calculate the power factor.

**Wattmeter, Voltmeter, Ammeter , True power to Apparent power**

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NOTES

**SECTION C SEE TEACHER CALCULATION**

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

1. A heating element connected to a 240V, 50Hz supply draws 10A. Determine the:
    - (a) the circuit phase angle. ( $0^\circ$ )
    - (b) apparent power of the circuit; (2400VA)
    - (c) true power consumed by the circuit. (2400W)
  2. A capacitor connected to a 240V, 50Hz supply draws 12A. Determine the:
    - (a) the circuit phase angle. ( $90^\circ$  leading)
    - (b) apparent power of the circuit; (2880VA)
    - (c) true power consumed by the circuit. (0W)
  3. A single phase 240V, 50Hz circuit draws 5A from the power supply, and operates at a lagging power factor of 0.8. Determine the:
    - (a) the circuit impedance; ( $48\Omega$ )
    - (b) the circuit phase angle. ( $36.8^\circ$ )
    - (c) true power consumed by the circuit; (960W)
  4. A single phase load draws 2.5A from a 32V, 50Hz supply. If the power consumed by the circuit is 60W, determine the:
    - (a) the circuit impedance; ( $12.8\Omega$ )
    - (b) apparent power of the circuit; (80VA)
    - (c) circuit power factor; (0.75)
    - (d) circuit phase angle; ( $41.4^\circ$ )
    - (e) reactive power of the circuit; (52.9VAr)
  5. A 240V, 50Hz, single phase circuit operates at a lagging phase angle of  $30^\circ$ . If the power consumed is 1.5kW, use a power triangle to determine the apparent and reactive power for the circuit. Use a scale of 1mm = 15VA/W/VAr (S = 1.732kVA; Q = 863VAr)
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# POWER FACTOR IMPROVEMENT

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## SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. Poor power factor is usually caused by:
  - (a) inductive loads
  - (b) resistive loads
  - (c) low power consumption loads
  - (d) high power consumption loads
2. In a purely resistive circuit the power factor is:
  - (a) 0 - 1 leading
  - (b) 0 - 1 lagging
  - (c) unity
  - (d) reactive power
3. Power factor correction is usually achieved by:
  - (a) connecting a resistor in series with the load
  - (b) connecting a capacitor in parallel with the load
  - (c) connecting a special electronic correcting device to the load
  - (d) any of the above methods.
4. When power factor correction is used, the:
  - (a) circuit current decreases
  - (b) true power decreases
  - (c) reactive power power increases
  - (d) apparent power remains constant

NOTES

5. The value of power factor correction capacitor used is often given in:
- (a) VA
  - (b) W
  - (c) VAR
  - (d)  $\Omega$  (Xc)

### SECTION B

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

1. List five effects of having low or poor power factor.

If the power factor is low, the increased current will increase the copper losses ( $I^2R$ ) in the transformer, transmission line, and load. Poor voltage regulation: If the power factor is low, large line current is drawn, which causes a voltage drop in the generator, transformer, and transmission line.

2. Generally, the power factor in a customer's installation should not be less than\_\_(a)\_. The publication this figure is given in is the\_(b)\_.

0.9 NSWSIR

3. When power factor is improved, the circuit \_\_\_(a)\_\_\_ will decrease; the apparent power for the circuit will\_\_\_(b)\_\_\_; the true power for the circuit will \_\_\_(c)\_\_\_; and the reactive power for the circuit will\_(d)\_.

Current, decrease, increase, decrease

4. For the following loads, state the power factor you would expect to find.

- (a) A 40W fluorescent lamp ballast.
- (b) A 2.4kW hot water heater.
- (c) A 1kW pool pump motor.
- (d) A 60W incandescent lamp.

5. Whilst operating at no load, the power factor of an induction is \_\_\_(a)\_\_\_, but will \_\_\_(b)\_\_\_ as the motor is loaded.

Poor, increase

### SECTION C

SEE TEACHER CALCULATION

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

1. A 240V, 50Hz single phase inductive load operates at a constant 2.4kW input power. Determine the circuit current when:
- (a) the power factor is at 0.2 lag; (50A)



(b) the power factor has been improved to 0.9 lag. (11.1A)

2. Draw a power triangle for a 1500W load operating at 0.5 lagging power factor, using a scale of 1mm = 50W = 50VA = 50 VAr. Also show on your power triangle the new apparent and reactive power if the power factor is improved to 0.95 lagging. (1600VA, 500VAr)

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NOTES

3. For the circuit of figure 1, determine:
- (a) the supply current (scale: 1mm = 0.25A). (19.5A)
  - (b) the phase angle ( $16.5^\circ$  lag)
  - (c) the power factor; (0.96 lag)
  - (d) the apparent power; (4.68kVA)
  - (e) the true power; (4.49kW)
  - (f) the reactive power. (1.33kVAr)

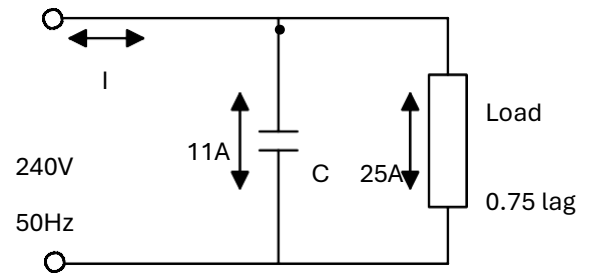


Figure 1

4. For the circuit of figure 2, determine:
- (a) the kVAr rating of a capacitor required to improve the power factor to 0.9 lag. Use a scale of 1mm = 100W = 100VA = 100VAr. (10.1kVAr)
  - (b) the new value of apparent power. (3.4kVA)
  - (c) the new value of circuit current. (14.2A)

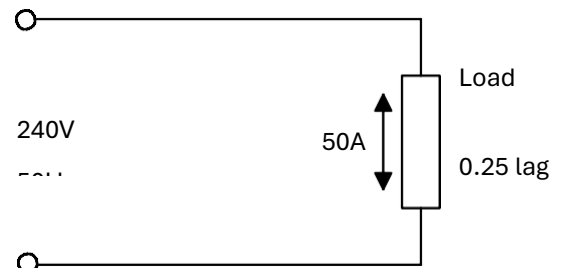


Figure 2

5. For the circuit of figure 2, determine the value of capacitance required to reduce the current to half of its original value. Use a scale of 1mm = 0.5A. (345 $\mu$ F)

6. A single phase 240V, 50Hz circuit draws 15A from the power supply, and operates at a lagging power factor of 0.8. Determine the kVAr rating and value of capacitance required to improve the power factor to unity. (2.16kVAr; 119 $\mu$ F)

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## THREE PHASE GENERATION

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### SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. One advantage of a three phase supply over a single phase supply is:
    - (a) only three conductors are required for three phase systems
    - (b) three phase voltages are lower than single phase voltages
    - (c) three phase machines are larger for a given output power
    - (d) three phase motors produce a constant torque
  2. Positive phase sequence is represented by:
    - (a) B-A-C
    - (b) C-B-A
    - (c) A-B-C
    - (d) A-C-B
  3. Single phase loads can be connected to a three phase distribution system that is:
    - (a) delta connected with three wires
    - (b) delta connected with four wires
    - (c) star connected with three wires
    - (d) star connected with four wires
  4. When transmitting a given amount of power using a three phase system compared to a singlephase system:
    - (a) more conductor material is required
    - (b) less conductor material is required
    - (c) the same amount of conductor material is required
    - (d) a different conductor material is required
-

5. In a three phase alternator, the angle between the windings is:

- (a)  $120^\circ$
- (b)  $180^\circ$
- (c)  $90^\circ$
- (d)  $60^\circ$

### SECTION B

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

The order in which the phases of a three phase supply reach their maximum value is known as the \_\_\_\_ (1) \_\_\_\_

**Phase sequence**

Two methods of connecting a three phase supply or load are \_\_\_\_ (2) \_\_\_\_ and \_\_\_\_ (3) \_\_\_\_

**Star / Delta**

The colours used to identify the three phase conductors of a three phase system are \_\_\_\_ (4) \_\_\_\_, \_\_\_\_ (5) \_\_\_\_ and \_\_\_\_ (6) \_\_\_\_

**Red, White Blue**

If a three phase motor is used in preference to single phase motor of the same physical size, the three phase motor will have a \_\_\_\_ (7) \_\_\_\_ power output and a higher \_\_\_\_ (8) \_\_\_\_

**Larger, Torque**

A poly phase system uses \_\_\_\_ (9) \_\_\_\_ or more phases.

**Two**

If connected in star, a three phase supply will have two voltages available, known as the \_\_\_\_ (10) \_\_\_\_ voltage (measured between an active conductor and the \_\_\_\_ (11) \_\_\_\_ conductor) and the \_\_\_\_ (12) \_\_\_\_ voltage (measured between any two \_\_\_\_ (13) \_\_\_\_ conductors).

**Phase, Active, Neutral, Line, active**

14. List two functions of the neutral conductor in a star connected supply.

The neutral conductor is used to increase the voltage between two phases, and it assists in load balancing. The neutral conductor is used for grounding the system, and it helps in equalising phase voltages. The neutral conductor is used for phase shifting, and it helps in generating higher voltage.

15. Figures 1 and 2 represent the windings of a three phase alternator. Show how you would connect figure 1 in star configuration, and how would connect figure 2 in delta configuration. Also show how would connect the neutral conductor in figure 1.

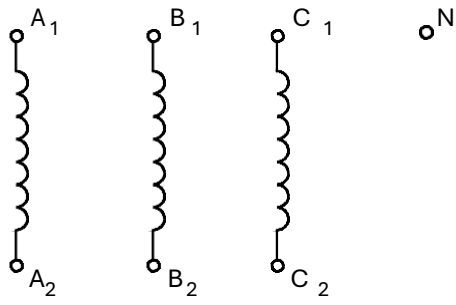


Figure 1

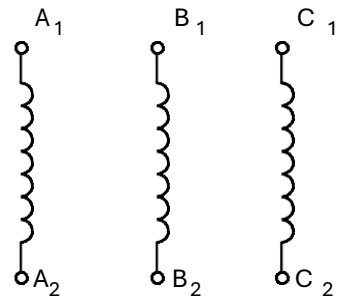


Figure 2

Both figures 1 and 2 are reproduced on page 66 for you to cut and paste to your submitted assignment sheets.

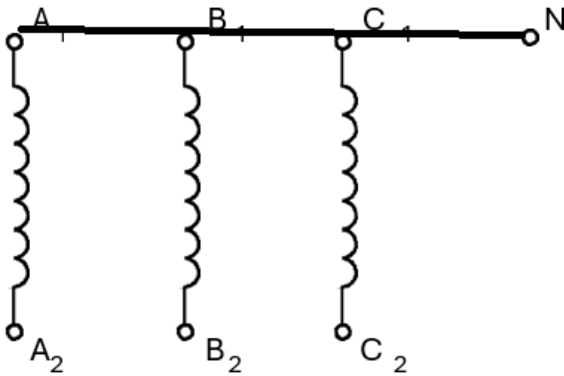


Figure 1

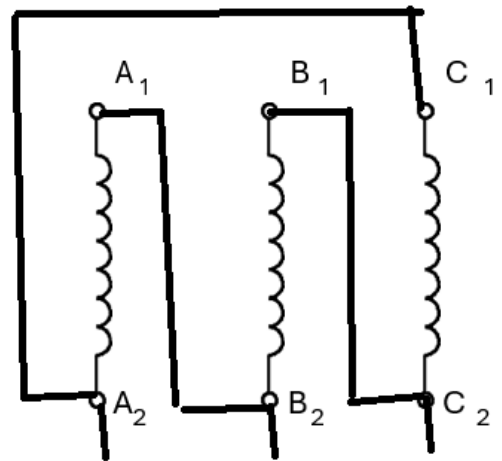


Figure 2

*SECTION C*

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

1. A three phase generator has a phase voltage of 19kV. Determine the generators line voltage if connected in:
  - (a) star. (33kV)
  - (b) delta. (19kV)
  
2. A three phase supply has a line voltage of 415V. Determine the supply phase voltage if connected in:
  - (a) star. (240V)
  - (b) delta. (415V)
  
3. A three phase generator has a maximum generated voltage of 340V. Determine the instantaneous value of voltage for all three phases when A phase is at an angle of  $45^\circ$ . (A phase: 240V; B phase: 88V; C phase: -328V)

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## THREE PHASE STAR CONNECTED SYSTEMS

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### SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. The line voltage of a star connected system is:
    - (a)  $\sqrt{3} V_p$
    - (b)  $\frac{1}{\sqrt{2}} V_p$
    - (c)  $0.5V_p$
    - (d) equal to  $V_p$
  2. The purpose of the neutral conductor in an unbalanced star connected system is to:
    - (a) provide an earth point
    - (b) provide a protective circuit
    - (c) carry out of balance currents
    - (d) reduce the supply voltage
  3. In a star connected system, the phase angle between the line current and phase current is:
    - (a)  $120^\circ$
    - (b)  $90^\circ$
    - (c)  $30^\circ$
    - (d)  $0^\circ$
  4. The neutral current in an unbalanced star connected load is the:
    - (a) algebraic sum of the phase currents
    - (b) phasor sum of the line currents
    - (c) algebraic sum of the line currents
    - (d) numerical difference of the phase currents
-



5. In a star connected system, the phase angle between the line voltage and phase voltage is:
- (a)  $120^\circ$
  - (b)  $90^\circ$
  - (c)  $30^\circ$
  - (d)  $0^\circ$
6. If a star connected system uses  $16\text{mm}^2$  active conductors and is used to supply single phaseloads, the correct size of the neutral conductor would be:
- (a)  $35\text{mm}^2$
  - (b)  $25\text{mm}^2$
  - (c)  $16\text{mm}^2$
  - (d)  $10\text{mm}^2$
7. In a star connected supply, the neutral is connected to:
- (a) the star point
  - (b) any one of the line terminals
  - (c) any one of the phase terminals
  - (d) where ever you like
8. The line current of a star connected system is:
- (a)  $\sqrt{3} I_p$
  - (b)  $\sqrt{2} I_p$
  - (c)  $0.5I_p$
  - (d) equal to  $I_p$

### SECTION B

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

In a star connected supply, the neutral is normally connected to \_\_\_(1)\_\_. This connection maintains the neutral at a reference voltage of \_\_\_(2)\_\_.

#### Star point, Zero

There are two voltages available in a star connected system. The \_\_\_(3)\_\_\_ voltage is measured between any \_\_\_(4)\_\_\_ conductor and the neutral conductor, whilst the \_\_\_(5)\_\_\_ voltage is measured between any two active conductors.

#### Line, Active, Phase

6. List the five basic types of loads that can be connected to a three phase, four wire system.

#### Resistive, Capacitive, Reactive, Combined, Domestic, Commercial

A \_\_\_(7)\_\_\_ load will have impedances of equal value, whilst an \_\_\_(8)\_\_\_ load has impedances which are unequal.

## Balanced , Unbalanced

The \_\_\_(9)\_\_\_ currents of a star connected load are equal to line currents.

Phase

10. List two adverse effects of a disconnected or high impedance neutral on a three phase, fourwire system.

In the event of three-phase load unbalance after disconnection of the N conductor, potential drift of the neutral point will occur, causing voltage rise on a phase and thus burning of single-phase equipment;

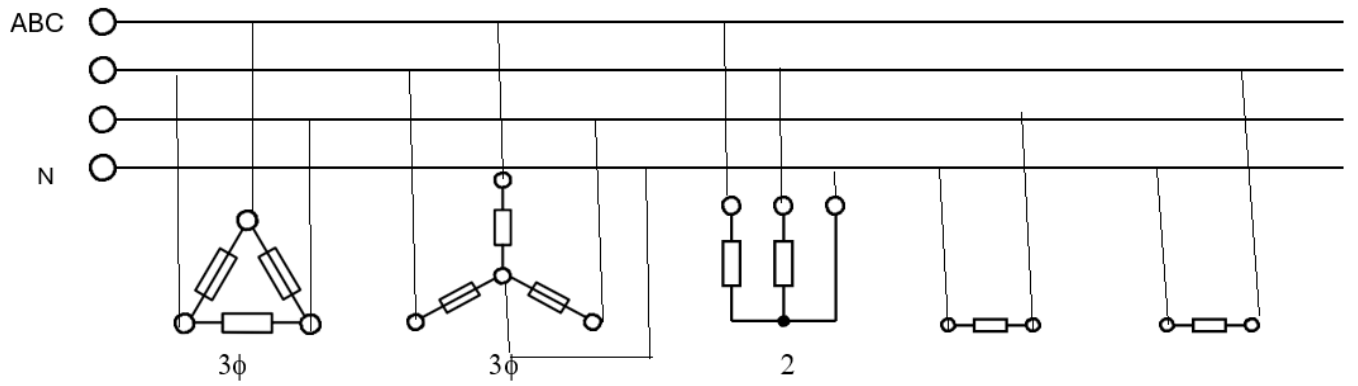
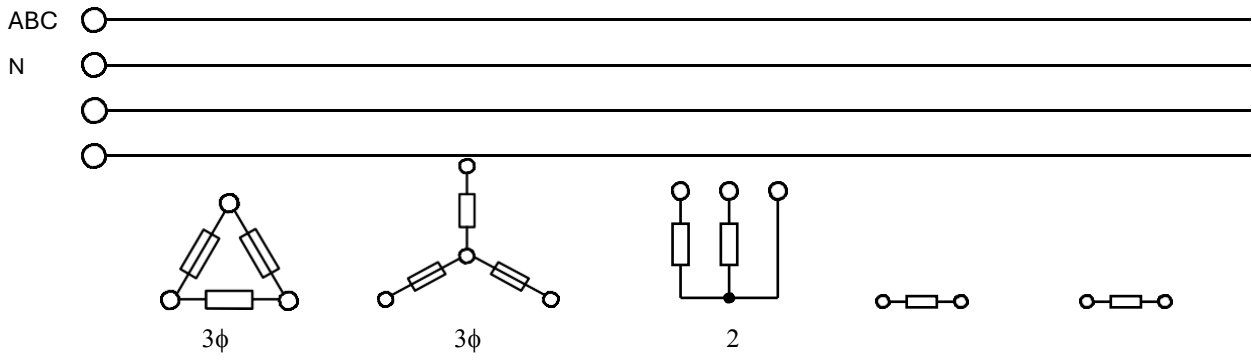
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## SECTION C

## SEE TEACHER CALCULATION

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- Three  $57\Omega$  resistors are connected in star to a three phase supply. If the voltage across each resistor is 240V, determine the:
  - phase current drawn by each resistor; ( $I_p = 4.21A$ )
  - current in each supply line; ( $I_L = 4.21A$ )
  - line voltage. ( $V_L = 415V$ )
- Three heating elements of  $36\Omega$  are connected in star to a 415V, three phase supply. Determine the:
  - phase voltage across each element; ( $V_p = 240V$ )
  - phase current in each element; ( $I_p = 6.67A$ )
  - current in each supply line; ( $I_L = 6.67A$ )
  - power in kW dissipated by each element. ( $P = 1.6kW$ )
- Three heating elements each of  $15\Omega$  are connected in star to a 415V, 50Hz three phase, four wire supply. Using a scale of  $1mm = 0.5A$ , determine the value of neutral current. ( $I_N = 0A$ )
- A three phase, four wire system has the following single phase resistive loads connected to it:
  - A phase: 3A;
  - B phase: 2A;
  - C phase: 4A.Using a scale of  $1mm = 0.1A$ , determine the current flowing in the neutral conductor. ( $I_N = 1.7A$ )
- A three phase, four wire system has the following single phase loads connected to it:
  - A phase: a single phase motor drawing 10A at 0.9 lag
  - B phase: a single phase motor drawing 15A at 0.65 lag
  - c phase: a 2.4kW radiatorUsing a scale of  $1mm = 0.25A$ , determine the current flowing in the neutral conductor. ( $I_N = 10.5A$ )
- Cut and paste** the diagram of figure 1 on your answer sheet. On the diagram of figure 1 correctly connect the loads as shown to the three phase, four wire supply.



## THREE PHASE DELTA CONNECTED SYSTEMS

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### SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. To correctly connect three windings labelled A1 - A2, B1 - B2 and C1 - C2 in delta, the wiring connections would be:
  - A2 to B1, B2 to C1 and C2 to A1
  - A1 to B1 to C1
  - A1 to B2, B1 to C2 and C1 to A2
  - B2 to C2 to A2
2. In a delta connected system, the phase angle between the line current and phase current is:()  $120^\circ$ 
  - $90^\circ$
  - $30^\circ$
  - $0^\circ$
3. The line voltage of a delta connected system is:

- $3 V_p$
- $V_p \sqrt{3}$
- $0.5V_p$
- equal to  $V_p$

4. When connecting a delta system, a neutral conductor is not used as:() there are no out of balance currents in delta
- a neutral connection would create a short of one active to neutral
  - two voltages can be obtained without a neutral
  - there would be no return path for the phase currents
-

5. In a star connected system, the phase angle between the line voltage and phase voltage is:()  $120^\circ$
- ( )  $90^\circ$
- ( )  $30^\circ$
- ( )  $0^\circ$
6. The line current of a star connected system is:
- ( )  $\sqrt{3} I_p$
- ( )  $I_p / \sqrt{3}$
- ( )  $0.5I_p$
- ( ) equal to  $I_p$

### SECTION B

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

The ratio of line currents to phase currents in a delta connected system is \_\_\_(1)\_\_\_

**1.7321**

2. List three commonly connected delta loads.

**Distribution Transformers, Three phase motor, Delta connection network**

If a delta connected load is unbalanced the line currents will be \_\_\_(3)\_\_\_

The current in each load phase is equal to the line voltage divided by the impedance of that phase. The line current will be the phasor difference of the corresponding phase currents, taking VRY as the reference phasor.

he currents will be unequal and will not have the symmetry of the balanced case.

If a star connected load is reconnected in delta configuration, the line currents in delta will be \_\_\_(4)\_\_\_ the line currents in star.

**0.58%**

A delta connected system will always be a \_\_\_(5)\_\_\_ wire system, whilst a star connected system can be a \_\_\_(6)\_\_\_ wire or a \_\_\_(7)\_\_\_ wire system.

The ratio of line voltages to phase voltages in a delta connected system is \_\_\_(8)\_\_\_

**Three, Three ,four**

### SECTION C

**See Teacher Solution**

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

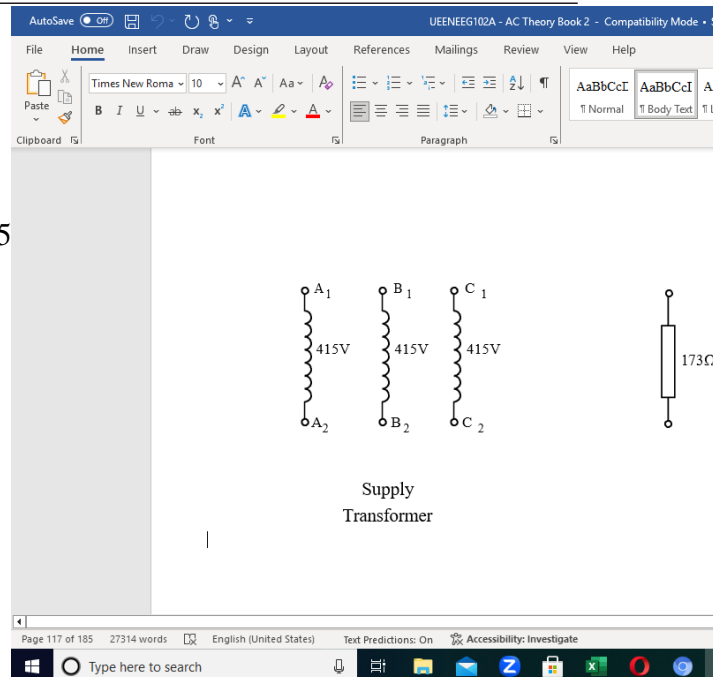
1. Three  $47\Omega$  heating elements are connected in delta to a 415 volt three phase supply.

Determine the:

- ( ) phase current drawn by each resistor; ( $I_p = 8.83A$ )
- ( ) current in each supply line; ( $I_L = 15.3A$ )
- ( ) line voltage. ( $V_L = 415V$ )

### Tutorial 5

2. Three heating elements of  $36\Omega$  are connected in delta to a  $415V$ , three phase supply. Determine the:
  - ( ) phase voltage across each element; ( $V_p = 415$ )
  - ( ) current in each supply line; ( $I_L = 20A$ )
  - ( ) power in kW dissipated by each element. ( $P = 8.3kW$ )
3. A  $415V$ , delta connected three phase transformer has  $20A$  flowing in each of its windings. If connected to a delta connected three phase load, determine:
  - ( ) the current in each line; ( $I_L = 34.6A$ )
  - ( ) the impedance in each phase of the load. ( $Z = 20.75\Omega$ )
4. **Cut and paste** the diagram of figure 1 on your answer sheet.
  - ( ) On the diagram of figure 1 correctly connect the supply transformer in delta and the load in delta, then connect the load to the supply;
  - ( ) For the circuit of figure 1, determine the current flowing in the windings of the supply transformer. ( $I_p = 2.39A$ )





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## THREE PHASE POWER & POWER FACTOR

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Please note the following requirements in relation to tutorial work -

- All tutorial work is to be completed on ruled A4 pad paper, with multiple pages stapled together. Write on one side only of the answer sheets, and all work is to be completed in ink.
- In the case of multiple choice type questions, the question number and corresponding answer letter are to be written on the answer sheet.
- In the case of short answer type questions, the question with your word or phrase choice is to be written on the answer sheet.
- All relevant equations and working are to be shown in the case of calculation type questions.

### SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. The minimum number of fixed wattmeters required to measure the power consumed by a three phase, four wire unbalanced system is:
    - one
    - two
    - three
    - four
  2. If the phase currents and power factors are equal in a three phase system, then the system is said to be:
    - balanced
    - unbalanced
    - star connected
    - delta connected
  3. The power factor for a balanced three phase system is the ratio of:
    - true power to reactive power
    - apparent power to reactive power
    - true power to apparent power
    - reactive power to true power
-



4. The total power in a three phase system can be measured using a single wattmeter provided the:
- load is balanced
  - load is unbalanced
  - load is star connected
  - neutral is not connected
5. Power factor correction applied to a three phase system is applied to:
- all three phases
  - the phase with the largest power factor
  - the phase with the smallest power factor
  - any one of the three phases

### SECTION B

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

If a three phase load is unbalanced, then either the currents or the \_\_\_(1)\_\_\_ in all three phases of the load will be \_\_\_(2)\_\_\_

**Power factor , unequal**

In a three phase system, the power consumed by one phase can be used to determine the total power if the system is \_\_\_(3)\_\_\_

**balanced**

If a three phase load is \_\_\_(4)\_\_\_, the power consumption of each phase must be determined separately then added together to determine the \_\_\_(5)\_\_\_ power consumption of the system.

**Unbalanced , total**

If a load is connected in star, the power consumed can be determined by  $P = \text{___(6)___}$ , but if the load is connected in delta, the power consumed can be determined by  $P = \text{___(7)___}$

**$P = E_{ph1} \times I_{ph1} + E_{ph2} \times I_{ph2} + E_{ph3} \times I_{ph3}$  /  $E_{l1} \times I_{ph1} + E_{l2} \times I_{ph2} + E_{l3} \times I_{ph3}$**

If a three phase system is balanced, then the power taken by one phase will be \_\_\_(8)\_\_\_ the total power taken by the system.

**1/3 of**

When connecting capacitors for power factor correction, the capacitors are connected in either \_\_\_(9)\_\_\_ or \_\_\_(10)\_\_\_ configuration across the supply.

**Star / Delta**

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## SECTION C

## SEE TEACHER SOLUTION

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

1. A three phase load draws 16A when connected to a 415 volt three phase supply with a 0.8lagging power factor. Determine the power consumed by the load. (9.2kW)
2. A three phase induction motor consumes 12kW at 0.759 power factor when connected to a 415V, three phase supply. Determine the:
  - ( ) line current drawn by the load; (22A)
  - ( ) apparent power of the circuit; (15.8kVA)
  - ( ) reactive power of the circuit; (10.3kVAr)

3. For the circuit of figure 1, determine the:
  - ( ) total power consumed by the circuit. (4968W)
  - ( ) total reactive power for the circuit; (2130VAr)
  - ( ) total apparent power for the circuit; (5405VA)

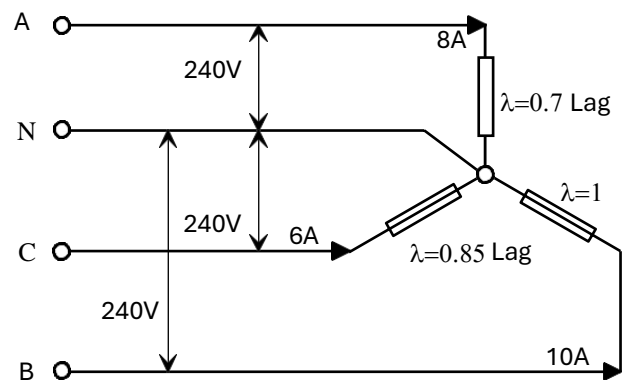


Figure 1

4. A 6.6kV, three phase delta connected induction motor takes 500kW and draws a current of 50.5A. Determine the:
  - ( ) power factor of the motor; (0.866lag)
  - ( ) phase angle of the motor currents; ( $30^\circ$ )
  - ( ) reactive power of the load. (288kVAr)
5. When supplied from a 132kV, three phase supply, an aluminium smelter takes 6MW when operating at a power factor of 0.437 lag. Determine the:
  - ( ) line current taken by the load; (60A)
  - ( ) MVar rating of a capacitor bank required to improve the overall power factor to 0.94 lagging; (10MVar) Scale: 1mm = 100kW = 100kVA = 100kVAr
  - ( ) capacitance per phase of a star connected capacitor bank; ( $1.8\mu\text{F}$ )
  - ( ) line current for the smelter when the power factor improvement is applied. (28A)

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# POWER MEASUREMENT AND HARMONICS

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Please note the following requirements in relation to tutorial work -

- All tutorial work is to be completed on ruled A4 pad paper, with multiple pages stapled together. Write on one side only of the answer sheets, and all work is to be completed in ink.
- In the case of multiple choice type questions, the question number and corresponding answer letter are to be written on the answer sheet.
- In the case of short answer type questions, the question and part number with your word or phrase choice is to be written on the answer sheet.
- All relevant equations and working are to be shown in the case of calculation type questions.

## SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter of your choice on your answer sheet.

1. The power factor of a three phase load can be determined using the two watt meter method provided:
    - (a) the power factor is greater than 0.5
    - (b) the neutral is not connected
    - (c) the load is balanced
    - (d) there is no current in the middle phase
  2. An indication that harmonics are present in a three phase supply system would be:
    - (a) erratic motor behaviour
    - (b) low transformer currents
    - (c) low neutral currents
    - (d) lower power consumption
  3. When measuring power using the two watt meter method, if W1 reads zero, and W2 reads 100W, the circuit power factor will be:
    - (a) unity
    - (b) zero
    - (c) 0.5 leading
    - (d) 0.5 lagging
-

4. When measuring a balanced three phase load using the two watt meter method, if both wattmeter readings are equal, the power factor is equal to:
- unity
  - zero
  - 0.5 leading
  - 0.5 lagging
5. To measure the total power in any three phase unbalanced load, the minimum number of wattmeters required is:
- 1
  - 2
  - 3
  - 4

### SECTION B

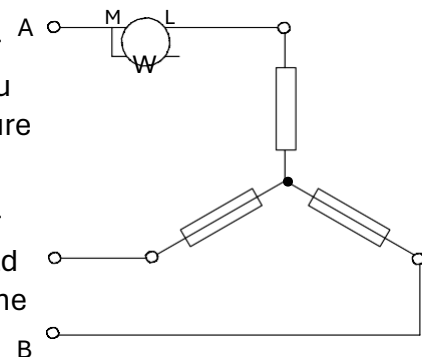
For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

List the relative wattmeter readings (ie comparing W1 to W2 etc..) that will give the following power factor indications when using the two wattmeter method of measuring power:

- Unity
- 0.7 leading
- 0.5 lagging
- 0.25 leading
- 0.1 lagging

6. Neatly reproduce the diagram of figure 1 on your answer sheet, then complete the circuit of figure 1 to show how you would connect the circuit to use one wattmeter to measure the total power for the circuit.

7. Neatly reproduce the diagram of figure 1 on your answer sheet, then complete the diagram to show how you would connect the circuit to use two wattmeters to measure the total power for the circuit.



The frequency of a fourth harmonic with a fundamental frequency of 50Hz is \_\_\_(8)\_\_\_

**200HZ**

9. List four symptoms that would indicate the presence of harmonics in a three phase supply system.

## Equipment failure and misoperation

- Overheating (motors, cables, transformers, neutrals)
- Motor vibrations.
- Audible noise in transformers and rotating machines.
- Nuisance circuit breaker operation.
- Electrical fires.
- Voltage notching.
- Erratic electronic equipment operation.
- Computer and/or PLC lockups.

Figure 1

The term “triplens” is used to describe harmonics that are the\_\_\_\_(10)\_\_\_\_

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**SECTION C**

See Teacher Solution

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

1. A single wattmeter is connected to A phase of a balanced 415V, three phase star connected heating load and is used to measure the total power consumption. If the wattmeter indication is 1500W, determine the:
  - (a) total power consumed by the load (4.5kW)
  - (b) impedance of each phase of the load. (38.3Ω)
2. A balanced, delta connected induction motor is supplied from a three phase 415V supply. If the line current to the motor is 30A, and a single wattmeter connected to C phase indicates 4.5kW, determine the:
  - (a) apparent power of the supply; (21.56 kVA)
  - (b) total power taken by the load; (13.5 kW)
  - (c) power factor and phase angle of the load; (0.626 lag, 51.3° lag)
  - (d) reactive power of the load; (16.8 kVAr)
  - (e) impedance of each phase of the load. (23.9Ω)
3. A 415V, inductive three phase load has its total power consumption measured using the two wattmeter method. If W1 indicates 250W and W2 indicates 1000W, determine the:
  - (a) total power taken by the load; (1250W)
  - (b) phase angle for the load; (46.1° lag)
  - (c) factor of the load; (0.693 lag)
4. A 415V uses the two wattmeter method to measure its total power consumption. If W1 indicates -750W and W2 indicates 2 kW, determine:
  - (a) the Total power supplied to the load; (1250W)
  - (b) the Power factor for the load; (0.254 lead)
  - (c) the Line current for the load; (6.85A)
  - (d) the Impedance of each phase of the load if the load is star connected.

(35Ω) Explain why the power factor is leading from these results.

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## STAR-DELTA INTERCONNECTED SYSTEMS

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Please note the following requirements in relation to tutorial work -

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- In the case of short answer type questions, the question and part number with your word or phrase choice is to be written on the answer sheet.
- All relevant equations and working are to be shown in the case of calculation type questions.

### SECTION A

For the following questions, complete the statements on your answer sheet with the word or phrase you think fits best.

1. Refer to questions 2 & 3 below when setting your answer to this question. Draw 2 circuit diagrams, one for a star connected load and one for a delta connected load. Fully label your diagrams to include:
    - (a) line and phase currents;
    - (b) line and phase voltages;
    - (c) phase impedance's;
    - (d) a single wattmeter to measure A phase power;
    - (e) labelling of the line terminals supplying each load.
  2. Below your circuit diagram for a star connected load, complete a table to show how you would determine the following:
    - (a) phase current;
    - (b) line current;
    - (c) line voltage;
    - (d) total power for a balanced load;
    - (e) total power for an unbalanced load;
    - (f) current in the neutral conductor.
  3. Below your circuit diagram for a delta connected load, complete a table to show how you would determine the following:
    - (a) phase current;
    - (b) line current;
    - (c) line voltage;
    - (d) total power for a balanced load;
    - (e) total power for an unbalanced load.
-

4. Describe the effect of a phase reversal in a:

- (a) star connected supply;
- (b) a delta connected supply.

Phase Reversal is when the phase sequence of a three-phase system is incorrect, the connected three-phase motors and other rotating equipment runs in the opposite direction. In many cases, this can cause a hazardous condition that may destroy product, damage machinery, and injure persone

5. Describe how you can test for a phase reversal in a delta connected load. Accompany your answer with a circuit diagram.

The phase-reversal fault can be detected by monitoring the phase sequence of the three-phase power supply. The correct phase sequence is required for driving the load properly in the three-phase AC system. It ensures that the load works as desired.

6. Describe the effect of the loss of one supply line in a:

- (a) star connected supply;

You would loose supply to one third of your single phase 230 V equipment. Any 3 phase equipment will continue to operate at reduced efficiency. Motors would be noisy and would overheat.

- (b) delta connected supply.

If one phase incoming supply is lost on the primary (delta) side, delta winding will receive single phase supply with one coil getting full voltage while other two getting half the voltage. Accordingly, single phase unequal voltages will be induced in secondary which will not serve any purpose for three phase loads.

## SECTION B

### SEE TEACHER SOLUTION

The following problems are to be solved with the aid of a calculator. Any working for a problem is to be fully shown. Where a problem involves calculating for circuit conditions, a neat and fully labelled circuit diagram (if not provided) is to accompany the question. Answers are to be expressed in the appropriate multiple or sub-multiple.

1. For the circuit of figure 1, if the load represents heating elements, determine the:

- (a) load phase current; (19.2A)
- (b) line current supplying the load; (15.9A)
- (c) total power consumed by the load. (11.48kW)

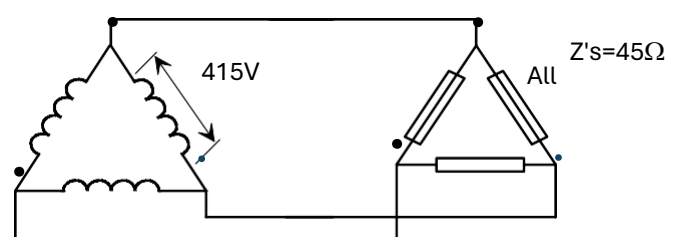


Figure 1

2. A star connected 415V emergency generator supplies a delta connected three phase induction motor. If the motor winding impedance's are  $20\Omega$  each and the motor operates at a lagging power factor of 0.773, determine the:
- phase currents in the motor; ( $20.75A$ )
  - phase currents in the generator; ( $36A$ )
  - total power consumed by the load ( $20kW$ )

3. For the circuit of figure 2, determine the:
- voltage across each phase of the load; ( $V_B=V_{BC}=415V$ ;  $V_A=V_C=207.5V$ )
  - current in each phase of the load; ( $I_A=I_B=2.5A$ ;  $I_C=5A$ )

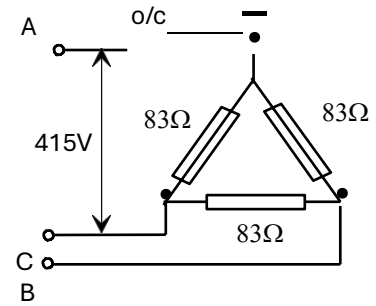
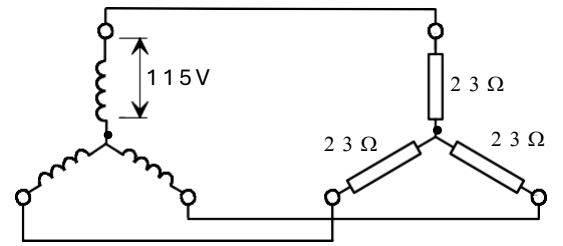


Figure 2

4. For the circuit of figure 3, determine the:
- line voltage output of the transformer secondary; (200V)
  - phase voltage of the heating load; (115V)
  - line current from the transformer to the load; (5A)
  - power used by the load, assuming the power factor is unity (1.732kW)



Transformer  
Secondary

3 Phase  
Heater

Figure 3

5. A delta connected transformer secondary supplies a star connected inductive load. The power consumption of the load is measured at 15kW at a power factor of 0.695. If the phase current of the load is 30A, determine the:
- line voltage output of the transformer; (415V)
  - phase voltage of the load; (240V)
  - phase angle for the load; ( $46^\circ$  lag)
  - current in the transformer windings. (17.32A)

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