Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

1 a) Definitions:

1. Sensitivity: smallest change in measured value to which instrument responds. Given by ($= \Delta q_o / \Delta q_i$) = (infinitesimal change in output)/(infinitesimal change in input) — 1 mark
2. Repeatability: degree of closeness with which a given value may be repeatedly measured. Variation of scale reading for a given value is a measure of the repeatability. — 1 mark

1 b)

	Absolute instrument	Secondary instrument
1	Gives magnitude of quantity in terms of	Gives reading directly of the quantity

	physical constants of instrument	measured.	1 mark
2	Need no calibration	Calibrated with respect to absolute instruments	Any two from pt 2 to pt4 ½ mark each = 1 mark
3	Measurement is tedious and time consuming (as indirect) due to calculations needed to be done	Quick method as direct method of reading.	
4	Very rarely used.	Very widely used.	

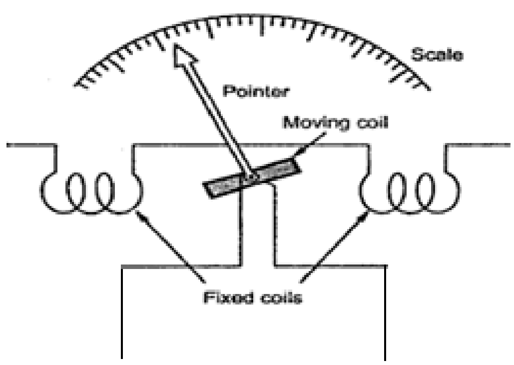
c) Due to under damping. 1 mark

Which might be due to low damping on aging of instrument or improper design / repair of damping system. 1 mark

1 d) Principle of dynamometer instruments:

The electrodynamometer instruments consist of two sets of coils whose fluxes are made to interact to produce the required torque. Of the two coils one of them is the moving coil while the other is the fixed coil (divided in to two sectional coils). The torque produced on the moving coil is directly proportional to the product of the currents in the two coils. Here the two coils are connected in to carry the current proportional to the quantities whose product is to be measured. 1 mark

Torque T α $|I_1|$ x $|I_2|$ x cosØ where Ø = angle between the two currents.



Electrodynamometer type instrument

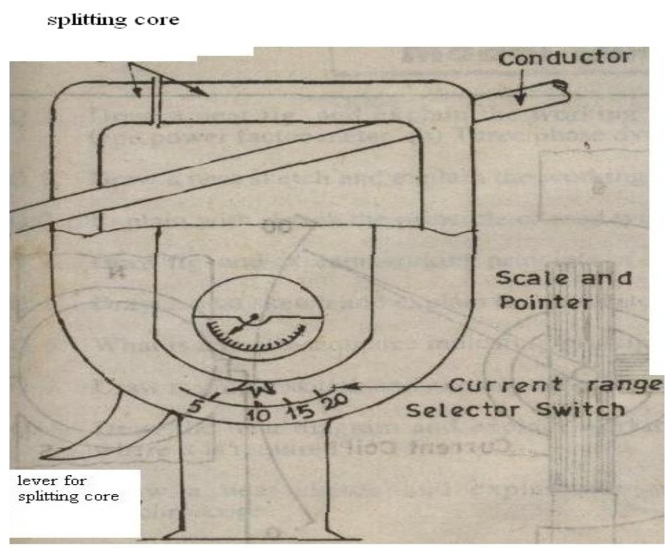
1 mark

1	e)	Errors in wattmeter:	
		1.Errors due to method of connection.	
		2.Error due to pressure coil inductance.	½ mark
		3.Error due to PC Capacitance.	each point
		4.Error due to mutual inductance effect.	any four pts.,
		5.Error due to stray magnetic fields.	
		6.Error due to eddy currents	
		7.Temperature error.	
		8.Error due to vibration of moving system	
1	f)	Interchange the terminal connections to the current coil or pressure coil to make the pointer move along the direction of the scale (clockwise).	1 mark
		The power read/deflection is proportional to product of voltage, current and cosine of angle between voltage applied and current drawn. When one of the phasors is applied in reverse manner cosine becomes negative and hence torque is negative. To correct the terminals are reversed.	1 mark
1	g)	Advantages of electronic energy meter:	
		1. Accuracy is higher with proper design.	½ mark each
		2. Compact and Low weight.	point any
		3. Pleasant display.	four pts.
		4. Noiseless operation.	
		5. Highly tamper proof.	
		6. Additional parameters are also read if required.	
1	h)	Absence of brake magnet in electromagnetic energy meter will lead to absence of controlling torque on the disc. Thus steady speed of rotation for the power drawn is not possible as driving torque keeps on accelerating the disc. Thus energy consumed cannot be measured / registered.	1 mark 1 mark

1 i) Power factor meters classification:

- Moving iron type, 1 mark each
- Dynamometer type.

1 j) Clip on ammeters are used to measure the current flowing through existing bus bar, cable or fuse holders carrying currents.



clip on ammeter

Diagram 1 mark

They consist of split core current transformer whose secondary winding is connected to rectifier type moving coil instrument. The primary is conductor whose current is to be measured. The split core gets aligned by the force of a spring tension. A selector switch is provided to select secondary number of turns which ultimately changes the current range. For measuring currents the core is opened by pressing trigger shown and then clipped over the conductor carrying current. The dial calibrated to read line values will show the current directly.

Description 1 marks

1 k) Classification of resistances: (low, medium and high resistances)
Low resistances: less than 1 ohm.
Medium resistances: 1 ohm to 0.1 Mega ohm.
High resistances: greater than 0.1 Mega ohm.

Classification 1 mark.
Ranges 1 mark

1 l) Advantages of Kelvin's double bridge over Wheatstone's bridge:

a) Highly accurate measurements of low resistances whereas Wheatstone's bridge is used only for medium resistances only. 1 mark each

b) Contact resistance effect of terminals is eliminated.

1 m) Bridges used for measurement of:

- Inductance: AC bridges: Maxwell's Bridge, Anderson's Bridge. 1 mark
- Capacitance: AC bridges: Schering bridge, Wien bridge. 1 mark

2 a) Various electricity effects employed in measuring instruments for deflecting torque production:

1) MI instruments: induced magnetism due to current carrying coil on iron piece/s. Actuating current through coil produces magnetic field that attracts iron piece (attraction type) or this field induces similar magnetism in two iron pieces that then repel each other with some force. The attraction force and repulsion force are proportional to the square of the coil current. 2 marks

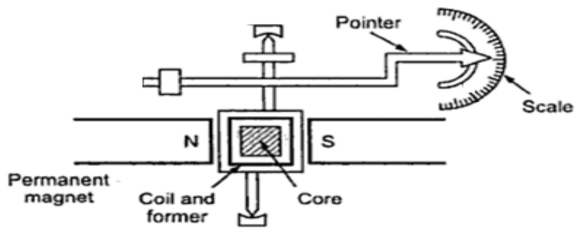
2) Induction type instruments: deflection torque is produced on moving member (normally light aluminum disc) due to interaction of eddy currents (produced by flux proportional to quantity to be measured) and their inducing flux. 2 marks

2 b) List of torques in analog instruments: 2 torques 1 mark, 3 torques 2 marks.

1. Deflecting torque
2. Controlling / restraining torque.
3. Damping torque.

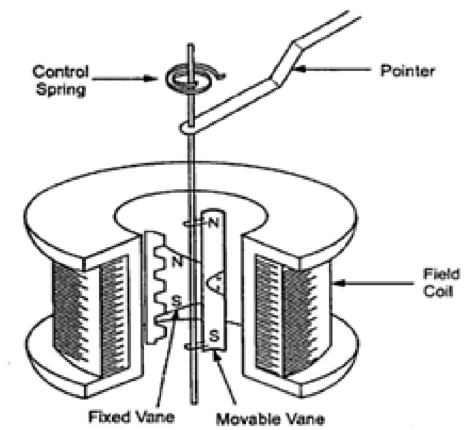
1. Deflecting torque: to create deflection proportional to the quantity to be measured; this is normally current.

- In PMMC instruments it is produced due to interaction of magnetic fields due to permanent magnet and current coil placed in it.
  Deflecting force is proportional to the permanent magnetic field and the current in the coil.

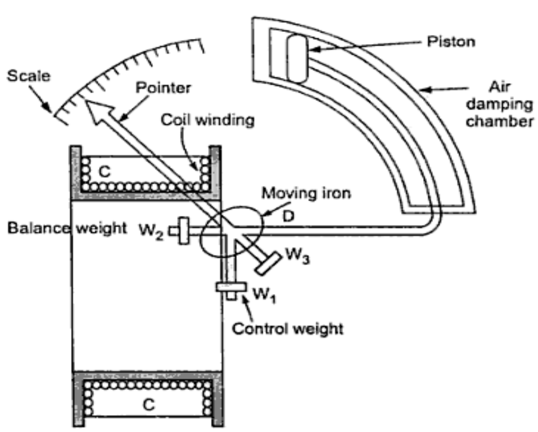


Any one deflection system 2 marks with figure.

- Moving iron instruments: current in field coil induces similar fields in the two iron vanes that repel each other to give the deflecting torque proportional to square of current in coil.



- Moving iron instruments with one coil producing magnetic field while the iron piece is attracted towards the coil where the force of attraction is proportional to the square of current in the coil



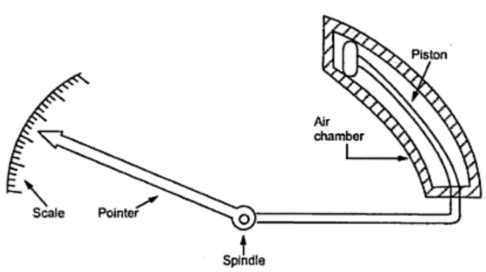
2. Controlling / restraining torque:
   - To restrict the motion of pointer/spindle and stop the pointer at the relevant position to get correct reading.

- To bring back pointer to zero position when the quantity under measurement is removed.

  This is provided by springs normally made of phosphor bronze that are used to hold the moving member along with spindle in the magnetic field producing the deflecting torque/force.
- This is also provided by control weights shown in figure above.

3. Damping torque:

For air damping: air trapped in the chamber works as damping medium for the piston movement connected to the spindle. The piston moves in the air chamber. The clearance between piston and air chamber wall is very small. When the pointer system moves in either direction the piston arm experiences an opposing force due to either compression action on one side and opposition to expansion on the other side. Thus the oscillations of the pointer system are damped by the opposition by the damping system. The damping torque is directly proportional to the speed at which the piston (pointer/spindle) moves. Hence greater the speed higher will be the damping torque bringing the pointer to the equilibrium position quickly.



Air friction damping

2 c) In MI instruments the torque is proportional to square of the current in the coil producing the magnetic field. The deflection is proportional to the torque. Hence the deflection becomes proportional to square of current till saturation of the core occurs. The scales of such instruments are thus non-uniform / cramped at low values of the coil current. 2 marks 2 marks

2 d) $\theta = \pi/2$ rad.

At equilibrium $T_D = T_C$; 1 mark

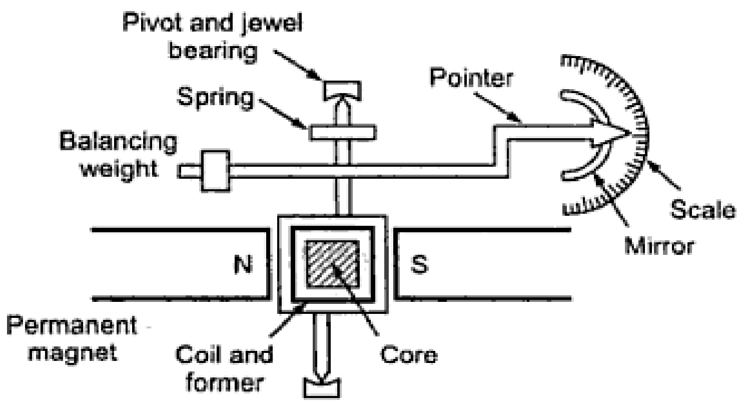
i.e N.B.l.d.I = K θ. 1 mark

Hence N = K θ/(B.l.d.I),

$N = [0.14\text{x}10^{-6}\text{x } \pi/2] / (1.6\text{x}10^{-3}\text{x } 10 \text{ x } 10^{-3}\text{x } 8 \text{ x}10^{-3}\text{x } 4 \text{ x } 10^{-3})$ 1 mark

N = 429.51 turns = 430 turns. 1 mark

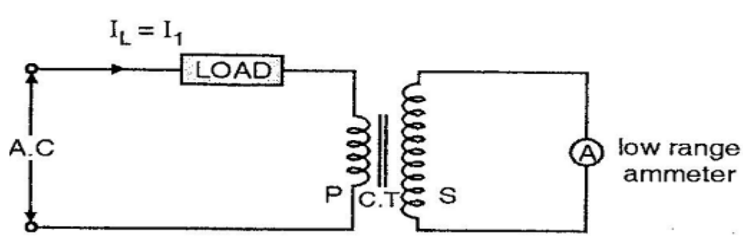
2 e) PMMC instrument:



Labeled Diag. 2 marks
Unlabeled 1 mark

Consists of the parts shown in the diagram. The coil is suspended as shown to rotate in the air gap between the permanent poles. The pointer attached to the spindle of the coil moves over the scale whenever the coil rotAtes. The spring attached to the spindle provides the restraining/ opposing torque and brings the system to standstill when the operating and restraining torques are equal. The pivot and jewel bearing has the minimum frictional resistance when the spindle is rotating. The balancing weight makes sure that the CG of the system coincides with the axis of spindle for positions of the spindle and thus ensures uniform wear for all positions of the spindle. Operation 2 marks

2 f) Use of CT for ammeter range extension:

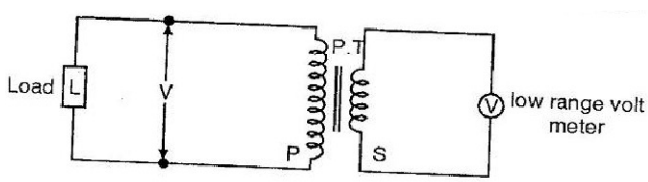


Diag. 1 mark

- The high current to be measured is passed through the primary of transformer. The low range ammeter is connected in series with the secondary winding.

- C.T. is step up voltage transformer. Hence step down current transformer. 1 mark
- Hence the number of turns of secondary winding is greater than number of turns of primary windings.
- The actual value of high current under measurement= Reading of low range meter *nominal ratio of C.T.

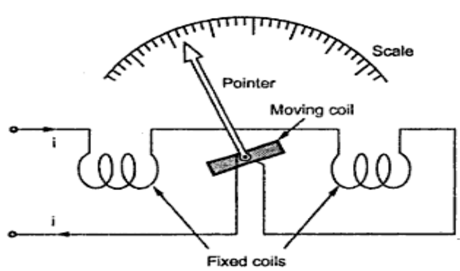
For PT (used for HV measurements)



1 mark

- Use to read high voltages on low range voltmeters.
- PT is step down transformer.
- The actual value of high voltage under measurement= Reading of low range meter *nominal ratio of P.T. 1 mark

3 a) Operation of dynamometer type instrument:



Electrodynamometer type instrument

Diagram: Labeled 2 marks, unlabeled 1 mark.

The dynamometer instruments consist of two sets of coils whose fluxes are made to interact to produce the required torque. Of the two coils one of them is the moving coil while the other is the fixed coil (divided in to two sectional coils). The torque produced on the moving coil is directly proportional to the product of the currents in the two coils. Here the two coils if connected in series to carry the current proportional to the quantity to be measured. Hence even in ac applications the torque is directly proportional to the square (product) of the current I.

Hence as Torque T α I^2, the torque is always positive and hence can be used for DC and AC applications. 1 mark

Further if the two coils are made current coil and voltage coil (wattmeter) then we can measure power as the deflection is proportional to products of the voltage, current and cosine of phase angle between them. 1 mark.

3 b) Comparison between MI and PMMC instruments:

	Points	MI	PMMC	
i)	Scale	Non-uniform (non-linear)	Accommodated in smaller space with more no. of features.	
ii)	Weight	Higher weight for same torque	Comparatively higher along with more features	
iii	Application	Used for AC and DC measurements	Used for only DC measurements	1 mark each
iv	Cost	Cheaper for same range	Higher cost for same range.	

3 c) R_C = 100 ohms. Current in coil for full scale deflection i = 50 mA = 0.05 A

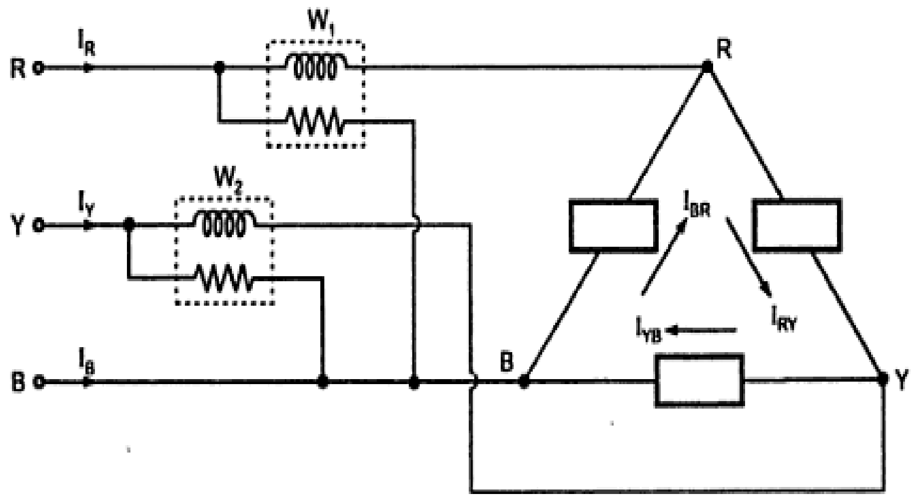
Max. Current to be measured I = 10 A. 1 mark

Shunt resistance S = i R_C/(I – i) 1 mark

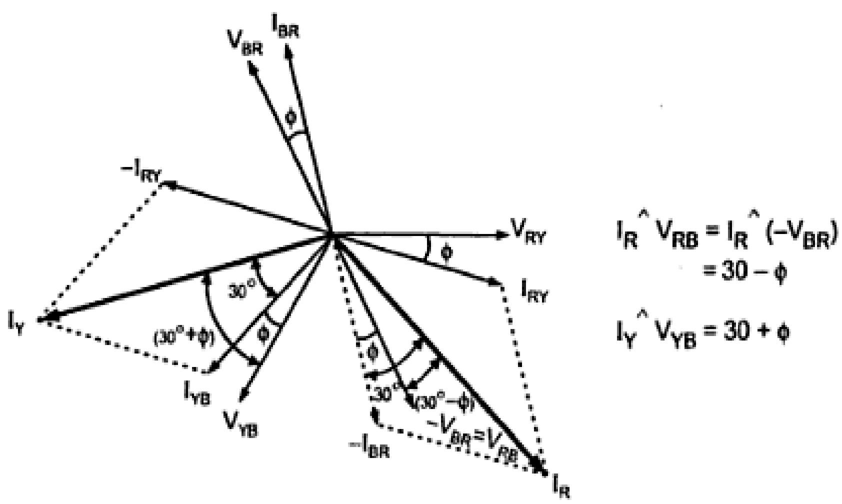
= 0.05 x 100/ (10 – 0.05) 1 mark

= 0.5 ohms. 1 mark

3 d)



1 mark



1 mark

$V_L = V_{RB}$, $I_L = I_R$

Ø = phase angle between voltage and current of the phases.

Reading $W_1 = V_L I_L \cos(30 - Ø)$ & $W_2 = V_L I_L \cos(30 + Ø)$. 1 mark

Total power $W = W_1 + W_2 = \sqrt{3} V_L I_L \cos(Ø)$ 1 mark

3 e) $V_{YB} = 400$ V.

Wattmeter reads = $\sqrt{3} V_L I_L \sin(Ø)$, (3 phase reactive power measurement) 1 mark

$Ø = \cos^{-1}0.6 = 53.13^o$

Hence $3.2 \times 10^3 = \sqrt{3} \times 400 \times I_L \sin(53.13)$

Line current of R = $I_R = I_L = 3.2 \times 10^3 / (\sqrt{3} \times 400 \times 0.8)$ 1 mark

= 5.77 A

Real power = $\sqrt{3}\ V_L\ I_L \cos(\text{Ø})$

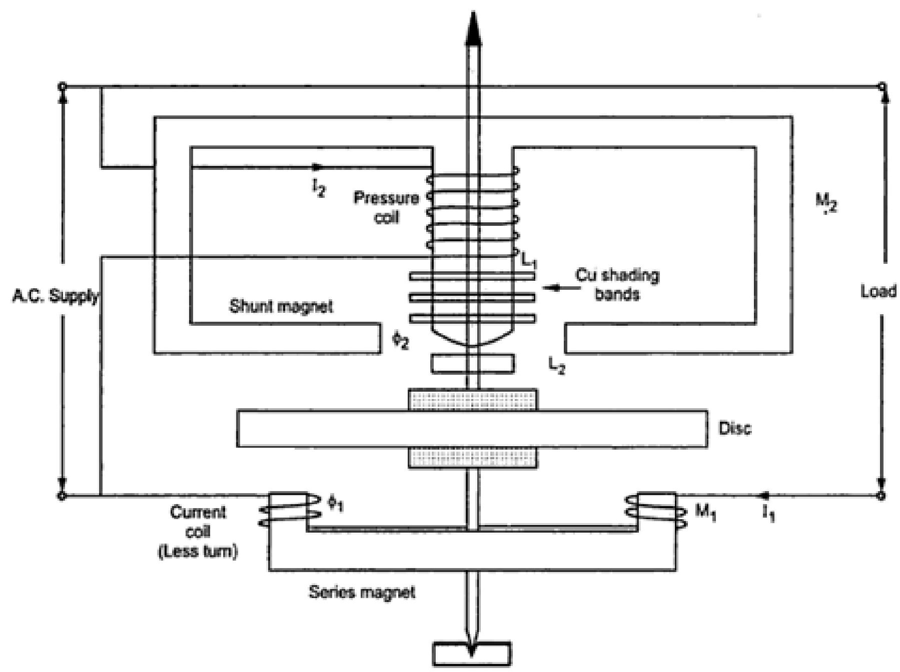
= √3 x 400 x 5.77 x 0.6

= 2398.5 W = 2.398 kW. 1 mark

Reactive power = $\sqrt{3}\ V_L\ I_L \sin(\text{Ø})$

= 3.2 kVA (given . 1 mark

3 f) Induction wattmeter:



Labeled diag. 3 marks,

Partially labeled 2 marks,

Unlabeled 1 mark.

Disadvantages:

1. Heavy moving system.
2. Only for AC circuits.
3. Less accuracy.
4. Higher power consumption for circuit parameters.

½ mark each any two.

4	a)	Errors in wattmeter:	
		1.Errors due to method of connection.	
		In uncompensated wattmeter , the reading of wattmeter includes the powerloss in coil	
		By using compensating coil , the error due to current coil which carris the current of PC in addition to the load current is eliminated	Any four errors expected. (1/2 mark each) 2 marks.
		2.Error due to pressure coil inductance.	
		Pressure coil inductance causes wattmeter to read more power than actual . To reduce this error capacitnce is connected in parallel with PC.	
		3.Error due to Pressure Coil Capacitance.	
		The wattmeter reads less power.	
		This error can be reduced by designing the PC circuit such that inductive reactance i.e. $X_L=X_C$.	
		4.Error due to mutual inductance effect.	
		For high loads, the fixed and moving coils are placed such that the mutual inductance effect is zero.	List any four remedies , ½ mark each (2 marks)
		5.Error due to stray magnetic fields.	
		To avoid this error, magnetic shield is placed over CC & PC.	
		6.Error due to eddy currents	
		Is very small and is neglected.	
		7.Temperature error.	
		Using low temp. coeff. materials for coils and components this can be minimised.	
		8.Error due to vibration of moving system.	
		Avoided by designing the moving system such that its natural freq is greater than 2 times the freq of deflecting torque of the wattmeter.	
4	b)	i) Full scale deflection = 5 A x 150 V = 750 W.	2 marks
		ii) Multiplifying factor for 10 A, 300 V connection is	
		= 10 x 300 / 750	1 mark
		= 4.	1 mark

4 c) $W_1 = 5$ kW, $W_2 = -0.5$ kW.

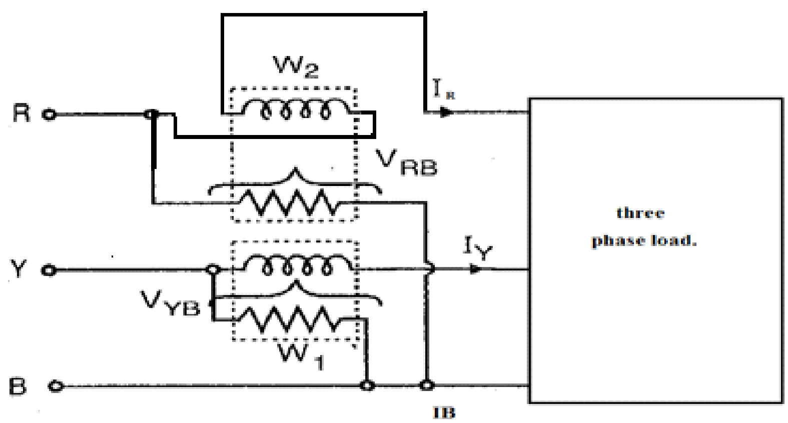
Total power of load = $W_1 + W_2$,

= 5 – 0.5 = 4.5 kW. 1 mark

p.f = $\cos\{\tan^{-1}[\sqrt{3}(W_1 - W_2)/(W_1 + W_2)]\}$ 1 mark

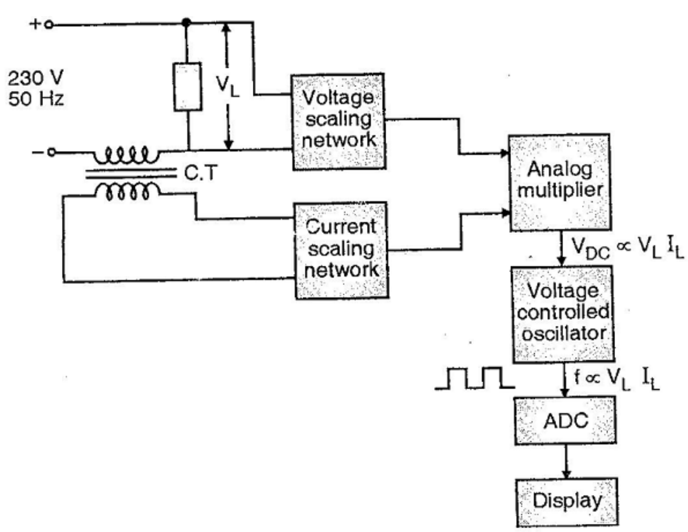
= $\cos\{\tan^{-1}[\sqrt{3}(5 + 0.5)/(5 - 0.5)]\}$

= $\cos 64.72^o = 0.427$ lag. 1 mark



Diag. 1 mark

4 d)



Labeled diagram 2 marks, Unlabeled 1 mark.

Functions of components/blocks:

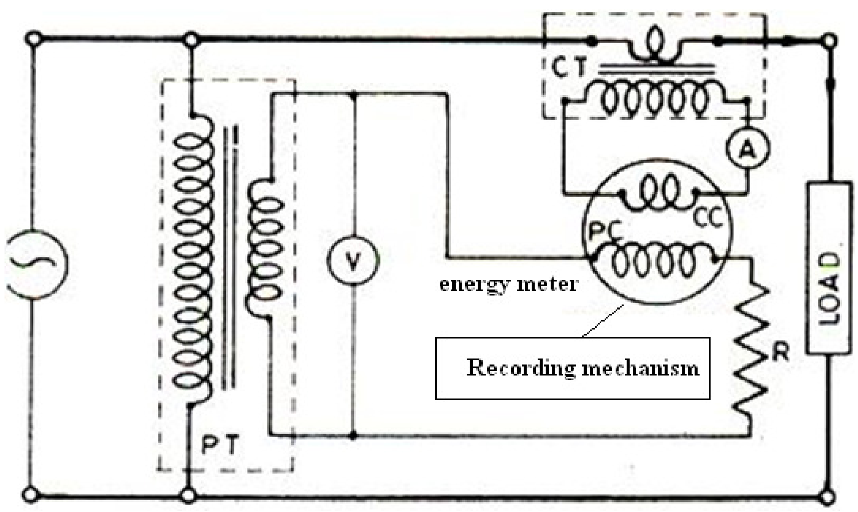
Any four ½ mark each =

- CT reduces current to reasonable value for current scaling network.
- Voltage & current scaling networks reduce proportionally the voltage

& current to values suitable for the analog multiplier. 2 marks

- Analog multiplier gives a dc voltage proportional to the product of the voltage and current drawn from supply that is the power drawn.
- The voltage controlled oscillator gives a frequency proportional to its input (which is proportional to the power).
- The ADC converts the square wave frequency analog output to display the energy in watthour.

4 e) Use of instrument transformers in energy measurements:



CT connection 1 mark

PT conn. 1 mark

Energy meter conn. 1 mark

The CT and PT reduce the higher values of current & voltage respectively to lower proportional values that drive the energy meter to record. The meter constant is multiplied by the CT and PT ratios to get the energy readings. 1 mark

4 f) The meter constant is 6000 revolutions per kWh

6000 rev =1kWh = 1000 watt hour

=1000*60*60 watt second

=3600000 watt second

Therefore 1 revolution = 3600000/6000 = 600 watt second

Hence 40 revolutions = 40 x 600 =

= 24000 watt second have been recorded (registered). 1 mark

Now power consumed= 230 x 2

= 460 watt

Energy to be actually recorded within 60 seconds will be (true value)

= 460 x 60

= 27600 watt second. 1 mark

Therefore % error = {[true value - registered(reading) value]/true value} x 100 1 mark

Therefore percentage error = [(24000 – 27600)/24000] x 100

= - 15= Ans. Error = -15 %. 1 mark

5 a) There are three methods for testing/calibration:

1.Long period dial test

2. Using rotary sub standard meter

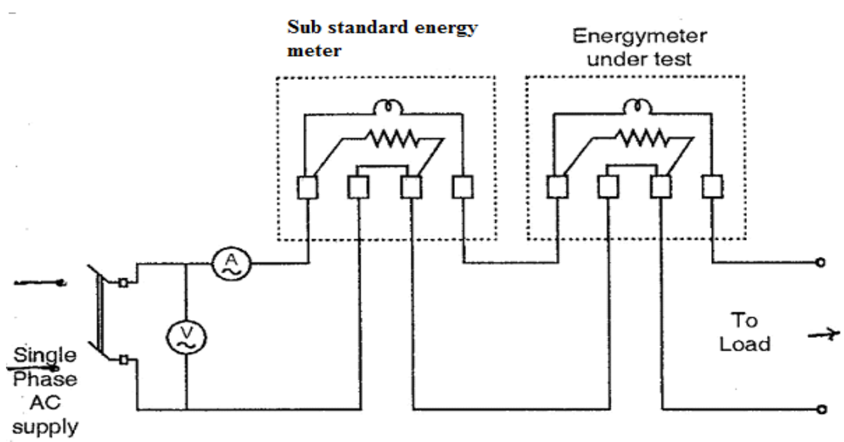
3. Using precision grade instruments.

2 methods ½ mark, Three methods 1 mark.

All above methods uses connection of energy meter under test in parallel with rotary substandard meter or precision grade meter.

As in figure the current coils are connected in series hence both the instruments carry same currents and pressure coils are connected in parallel so that same voltage is applied across them. The meters are started and stopped at the same time. The energy readings at the end are compared and error can be calculated, meter is corrected. 1 mark

Let D= registration of meter under test in kWh & Ds=registration of substandard meter in kWh Then % error = $[(D - D_S)/D_S] \times 100$. 1 mark



Calibration of energymeter

Diag. 1 mark

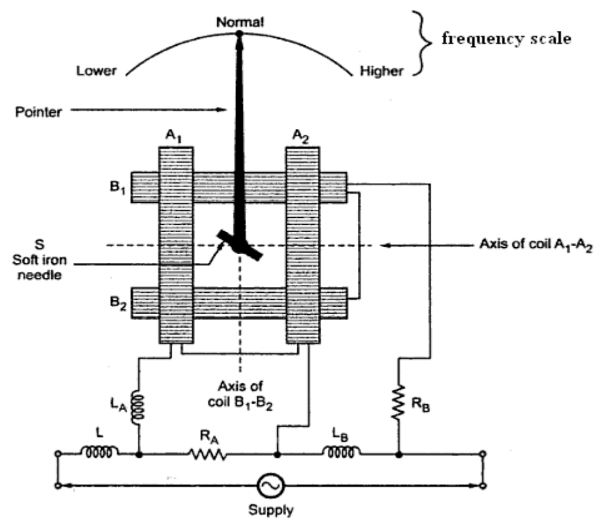
5 b) **Creeping:**

It is defined as the slow and continuous rotation of the disc of the energy-meter when only pressure coil is energized with no current in the current in the current coil (load current = 0). 2 marks

In order to prevent the creeping on no load, two holes are drilled in the disc on diametrically opposite sides of the spindle. This causes sufficient distortion of the field to prevent rotation of the disc when one of the holes comes under the pole of shunt magnet. 1 mark

Also in other case, small piece of iron wire is attached to the edge of the disc. The force of attraction is exerted by the brake magnet on this iron wire is sufficient to prevent continues rotation of the disc on no load condition. 1 mark

5 c) Weston frequency meter:

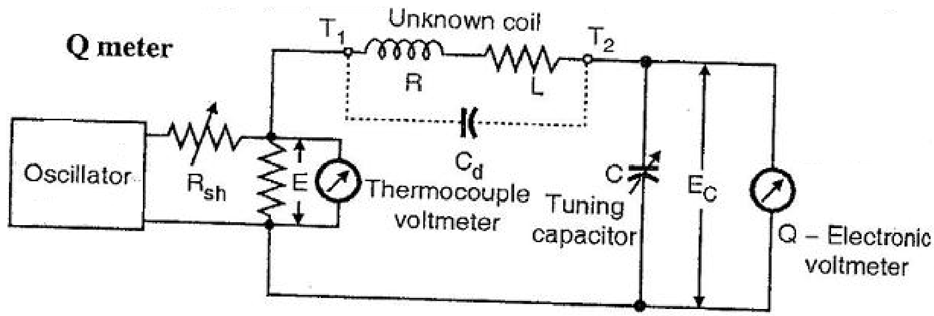


Diag. labeled 2 marks, unlabeled 1 mark

The mounting and connections are shown in the figure. Inductor L damps the harmonics in the current. When connected across the supply coils A and B draw currents to produce magnetic fields that act on the soft iron needle to deflect it. The position of the needle depends on these currents. Under normal frequency (due to proper selection of R_A, R_B, L_A, $L_{B,}$) two forces make the pointer to show normal freq. when the frequency is other than normal the reactances of L_A and L_B will be different with resistances unchanged leading to deflections in either direction depending on the currents therein due to changed impedances.

Operation 2 marks

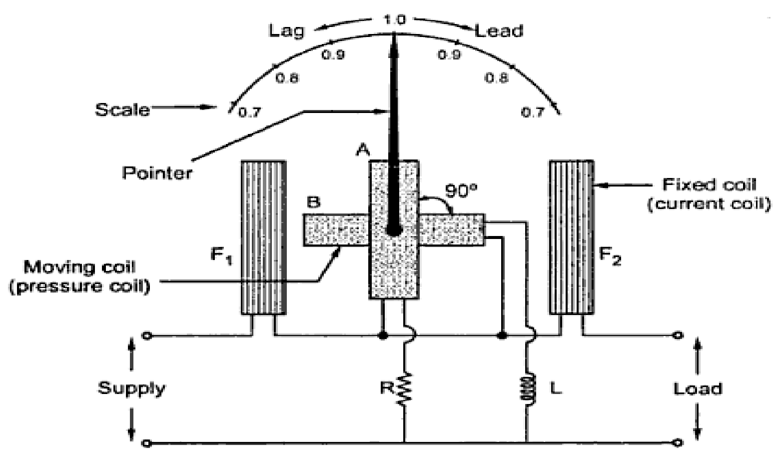
5 d)



Diag. 2 marks

- Basically series resonance circuit. At resonance Q $= E_C / E$. 1 mark
- Hence the ratio of voltage across tuning capacitor E_C to the applied voltage E is directly on the electronic voltmeter by calibrating it accordingly. 1 mark

5 e) Single phase dynamometer type power factor meter.



Single phase electrodynamometer type power factor meter

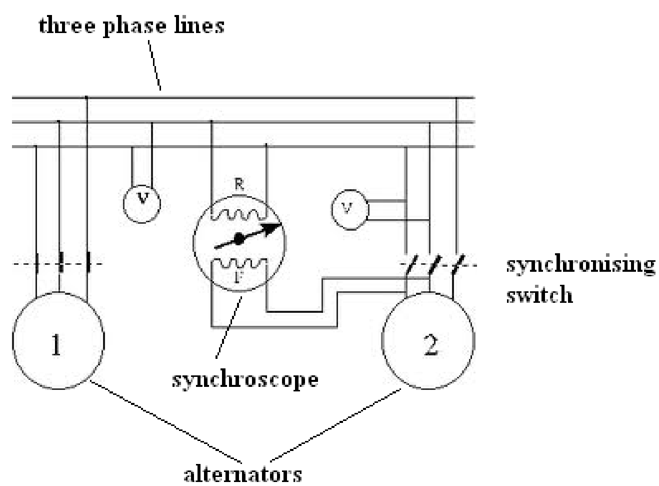
Diagram 2 marks

No controlling torque is required in this meter. Current flows in the pressure coil through ligaments of silver. The coil A is connected in series with a non inductive resistance R. So that current flowing through it is in phase with the applied voltage. The coil B is connected in series with a highly inductive reactance L ,so that current flowing through it lags the voltage by 90^0. 2 marks

The coil system of A and B takes up position of equilibrium where their torques are equal. At this the angular position θ of A with respect to horizontal line is the power factor angle Φ.

5 f) Synchronising: it is the procedure of connecting two polyphase generators in parallel at the instant when their line voltages are coincident with equal frequency and have the same phase sequence. 2 marks

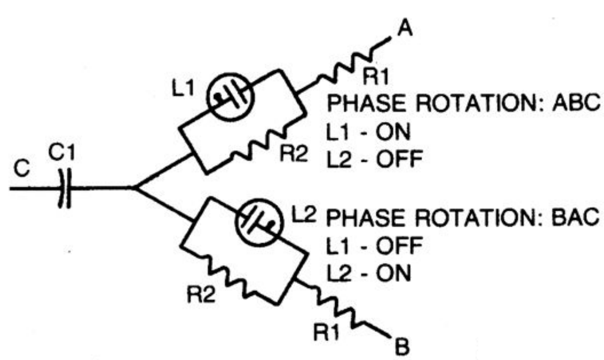
The synchroscope is used to determine the exact instant of switching required to connect the alternators in parallel. Its pointer gives the idea of the faster and slower machine to make adjustments of speed of alternators for synchronising. 1 mark



1 mark

6 a) Phase sequence is the order in which the electrical voltages of different phases achieve their corresponding maximum values (or vary in a similar manner). 2 marks

Phase sequence indicator:



Labeled Diagram 2 marks, Unlabeled 1 mark

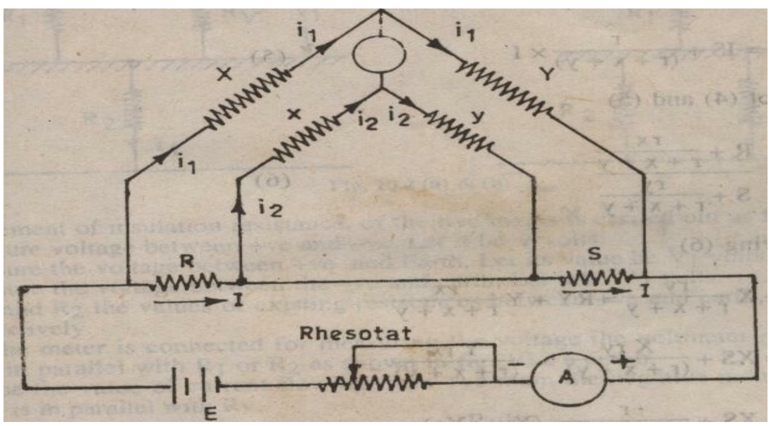
6 b) The earth resistance is the resistance offered by the soil to the passage of electric current through it. Depends on the composition of soil, its Moisture content, & electrolyte content, Dissolved salts, grain size and its distribution, seasonal variation, temperature and current magnitude. 2 marks

Features of digital earth resistance tester:

1. Precise reading possible due to digital display.
2. Low weight and more handy.
3. Powered by rechargeable batteries.
4. Data storage / hold function is available.
5. Measures earth voltage.
6. Disturbances due to power frequency and its related harmonics are eliminated.
7. Many ranges for selection to measure earth resistance.
8. Low value of current (less than 3 mA) permits its use without tripping of the ELCB.

Any 4 pts. ½ mark each= 2 marks

6 c) Kelvin's double bridge method for measurement of low resistance.



Labeled 3 marks Partially labeled 2 marks, Unlabeled 1 mark.

(R/S) = (X/Y) = (x/y);

Unknown resistance R = (X/Y)S 1 mark

Thus the unknown resistance can be found in terms of X,Y and S.

6 d) (P/Q) = (R/S); 1 mark

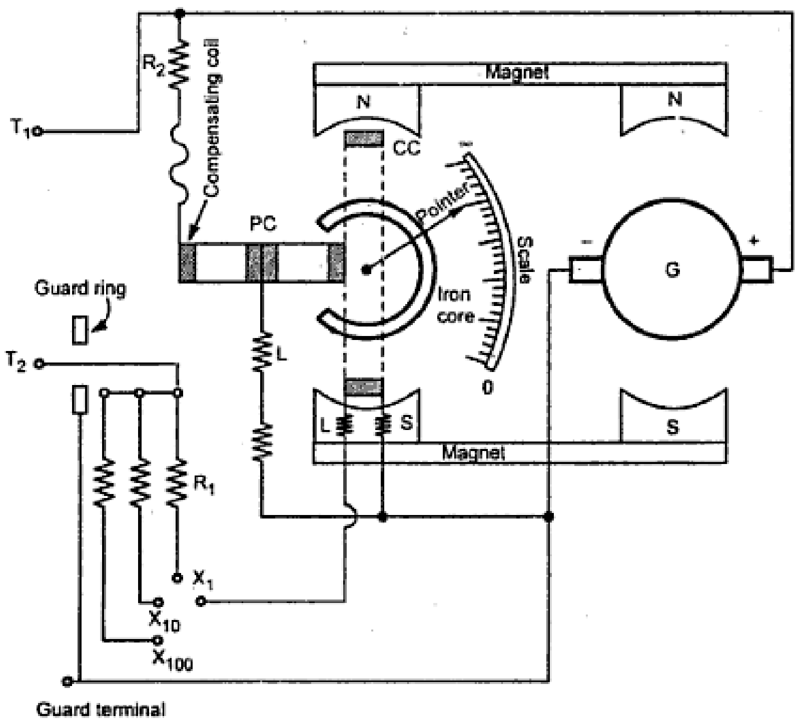
R = (P/Q) S = (10/6)6 = 10 ohms. 1 mark

Limitations:

1. Effect of lead and contact resistance is significant while measuring low resistances. Hence low resistances cannot be measured fairly. Any two pts

2. Cannot be used for high resistance measurements, only medium resistances. — 1 mark each = 2 marks.
3. Heating effect of large currents if used affects the resistances used and hence it is temperature sensitive.
4. Errors in resistances of the arms may compound the total error in measurements.

6 e) Megger is used to measure insulation resistance.



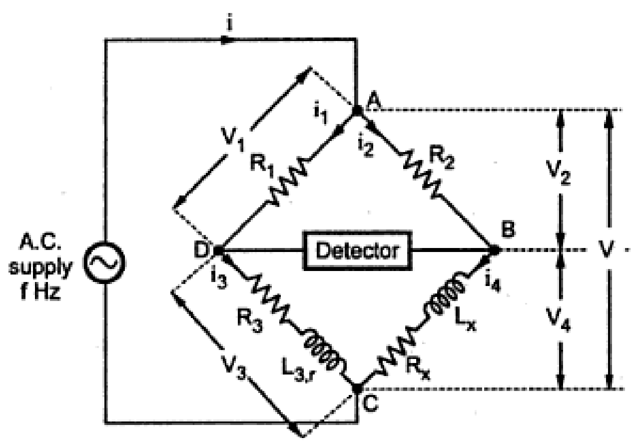
Labeled Diag. 2 marks, unlabeled 1 mark

Two coils the current coil and pressure coil are mounted at an angle on the same spindle and form the part of the moving system. These coils are connected to a small hand driven generator, with polarities such that torque produced by them will act in opposition to each other. The coils being placed in the air gap of a permanent magnet will move in it, the potential coil is connected in series with a fixed control resistance and also the current coil I sin series with a resistance to control the current flowing through it and the resistance under test .When the resistance under test is infinity no current flows through the current coil ,the pressure coil, the pressure coil will therefore set itself perpendicular to the

Operation 2 marks

magnetic axis , and the pointer indicates infinity on dial. If the resistance under test is very low, the high current will flow through the current coil ,it makes the pressure coil ,to lie in the direction of axis of permanent magnet, as the effect of pressure coil will be negligible the position of the pointer in this case is marked as zero. For value in between the pointer will indicate values in between zero and infinity, The dial is marked with values of resistances in mega ohms by calibration. When the instrument is not working the pointer may rest at any position on the dial.

6 f) Maxwell's inductance bridge:



Labeled diag. 2 marks, Unlabeled 1 mark

Relations/Equations:

$$\boxed{L_x = \frac{R_3}{R_1} L_3}$$ 1 mark

$$\boxed{R_x = \frac{R_2}{R_1}(R_3 + r)}$$ 1 mark