1 a) Measurement is the process by which an unknown quantity is compared with predefined standard values with significant units — ½ mark

Significance:
1. Knowledge of any quantity is accurately judged accurately. — ½ mark each pt
2. Suitable modification in quantity can be done.
3. Improved product quality, quantity and efficiency in industry.

1 b) i) Direct measurement: Secondary instruments read the quantity under measurement directly. i.e. if it is ammeter, it reads directly in ampere. — 1 mark
Examples: Ammeter, Voltmeter, Wattmeters.

ii) Indirect measurement: Absolute instruments reads the quantity under measurement directly i. e. in terms of degrees, deflection and meter constant. — 1 mark
Examples: Tangent galvanometer, current balance meter

1 c)

	Accuracy	Precision	
1	Closeness with which an instrument reading approaches the true value of the quantity under measurements.	Consistency or repeatability of measurements.	½ mark
2	Ability of a device to respond to a true value of measured variable under reference condition.	Degree of exactness for which an instrument is designed	½ mark
3	Accuracy of a measurement means conformity to truth.	Two characteristics: a) Conformity b) Significant figures.	½ mark
4	It is expressed as the limit of errors.	Precision is a necessary, but not sufficient condition for accuracy.	½ mark

1 d) Methods of providing controlling torque in indicating instrument:
a) Spring control — 1 mark
b) Gravity control — 1 mark

1 e) Two applications of Polyphase wattmeter :
a) Measurement of power in three phase star connected balanced /unbalanced systems. — 1 mark
b) Measurement of power in three phase delta connected balanced /unbalanced systems. — 1 mark

1 f) Multiplying factor of wattmeter $= \frac{\text{Current coil range*voltage coil range}}{\text{Full scale deflection}}$ — 1 mark

$$= \frac{10*250}{1500}$$

$$= 1.66$$ — 1 mark

1	g)	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.	2 marks
		OR	OR
		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.	2 marks
1	h)	Connecting an incoming alternator to the bus bar (Parallel operation) to share the load is known as synchronizing.	½ mark
		The correct instant of synchronizing is when the busbar and incoming voltages are equal in magnitude as well as in phase and have the same frequency.	½ mark
		A synchroscope is used to determine correct instant of closing the switch which connects the alternator to power station busbar.	1 mark
1	i)	In rotating type phase sequence indicator disc is marked with the arrow. If disc rotate in same direction as arrow then phase sequence is RYB.	1 mark
		If it rotates in opposite direction the phase sequence is RBY.	1 mark
1	j)	Kelvin's double bridge:	
		• It is used for measurement of low resistance and it is modified form of Wheatstone bridge.	½ mark.
		• To avoid contact resistance, low resistances are constructed with four terminals (C_1 C_2,P_1 P_2)	½ mark
		• The bridge is balanced when galvanometer deflection shows zero deflection.	½ mark
		• At balanced condition of bridge unknown resistance, R =(P/Q)*S	½ mark
1	k)	Classification of resistances: (low, medium and high resistances) Low resistances: less than 1 ohm. Medium resistances: 1 ohm to 0.1 Mega ohms. High resistances: greater than 0.1 Mega ohms.	Classification 1 mark. Ranges 1 mark
1	l)	Classification of A.C. bridges:	
		1. Inductance Measurement: Maxwell's bridge, Anderson's bridge	1 mark
		2. Capacitance Measurement: Schering Bridge.	½ mark
		3. Frequency Measurement: Wien Bridge.	½ mark
1	m)	Types of torque in analog instruments: 1. Deflecting torque 2. Controlling / restraining torque. 3. Damping torque.	2 torques 1 mark, 3 torques 2 marks

1 n) Classification of Measuring Instruments:

1. Absolute instruments and
2. Secondary instruments — 1 mark

Secondary instrument classification: — Any (of A, B, C) two 1 mark.

A) Depending on the principle of operation:
   1. Magnetic meters 2. Induction meters
   3. Hot wire meters 4. Electrostatic meters
B) Depending on the permissible errors:
   1. Standard meters 2. Substandard meters
   3. First grade instrument 4. Second grade instrument
C) Depending on application:
   1. Indicating instrument 2. Recording 3. Integrating

2 a) Types of Errors:

1) Gross Error: Due to human mistakes — 1 mark
2) Systematic Errors: — 1 mark each (any two of I, II, III) = 2marks
   I) Instrumental error:
   Inherent shortcomings of instruments, misuse of instrument, loading effects.
   II) Environmental error:
   Surrounding conditions of the M. I. such as temperature, pressure, humidity, dust, vibrations, and external magnetic fields affects performance.
   III) Observational error: Parallax error.
3) Random errors: due to unknown causes, not determinable. — 1 mark

2 b) Magnetic effect, Thermal effect, Electrostatic effect, Induction effect and Hall effect: — 1 mark

a) Magnetic effect: When a current carrying conductor is placed in a magnetic field it experiences a force given by $\mathbf{F_{conductor} = B\ I\ L}$, whose direction is given by Fleming's Left Hand Rule. (B = magnetic field, I = current in the conductor, L = effective length of conductor in field at right angle) deflection is proportional to the current.
b) Thermal effect: quantity under measurement (current) is passed through a heating element, $I^2Rt \propto$ quantity. Example: hotwire instruments.
c) Electrostatic effect: two charged plates experience force between themselves. Force α charges. — 1 mark for 1 effect max. 3 marks.
d) Induction effect: torque / deflection / rotation produced by fluxes (created due to currents) in conducting disc/plates is proportional to the currents of circuits under measurement.
e) Hall effect: emf produced across two edges at right angles to direction of current and magnetic field of conductor/plate is proportional to the current / flux. Measurement of this emf.(α to current / magnetic flux)

2 c) **Construction of PMMC Instrument**

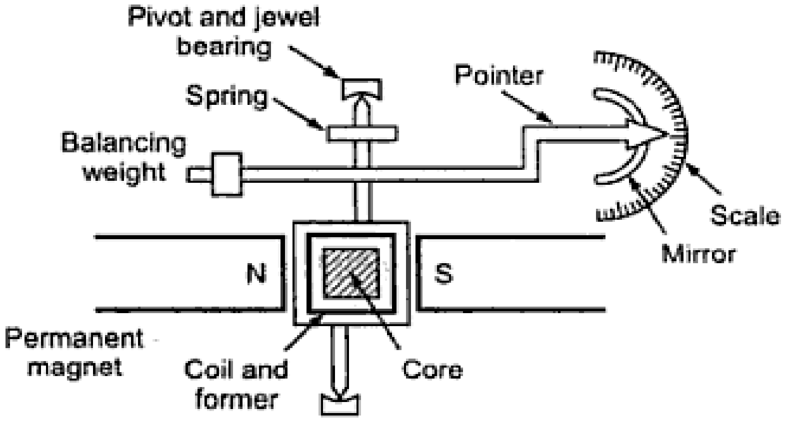


Diagram: labeled 3 marks, unlabeled 1 mark, partially labeled 2 marks.

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. 1 mark

2 d) Given for full scale deflection current I_G = 10 mA. Resistance of MC,
R_G = 10 ohms.
Shunt resistance R_{sh} for full scale deflection when the arrangement carries current of I = 5 A. ½ mark

i) Using the principle of equal voltage across parallel resistances of R_G and R_{sh},
We have $I_G.R_G = (I - I_G) R_{sh}$, which gives us ½ mark
$R_{sh} = I_G.R_G/(I - I_G)$
$= 10 \times 10^{-3} \times 100/(5 - 10 \times 10^{-3})$
= 0.2 ohms is shunt resistance for using it as an ammeter to read 5A. 1 mark

ii) With V_M = 200 V, applied to the series combination of MC and the series resistance R_S to use it as voltmeter of max. 200 V we have max current allowed of 10 mA. ½ mark
200 V = 10 mA X $(R_S + R_G)$ from which ½ mark
$R_S = (200/ 10 \times 10^{-3)} - 100 = 19900$ ohms.
is series resistance for using it as a voltmeter to read max 200 V 1 mark

2 e) Advantages of M I type instrument:

1. Can be used for AC and DC quantity measurement.
2. Construction is simple, hence cheap as compared to PMMC type.
3. Construction is robust as no coils are to be attached to the spindle.

Any two 1 mark each

Disadvantages of M I type instrument:

1. Scale is non-uniform.
2. Different calibrations are required for measurement of AC and DC quantities.
3. It is less sensitive as compared to PMMC type.
4. The torque to weight ratio is less as compared to PMMC type.

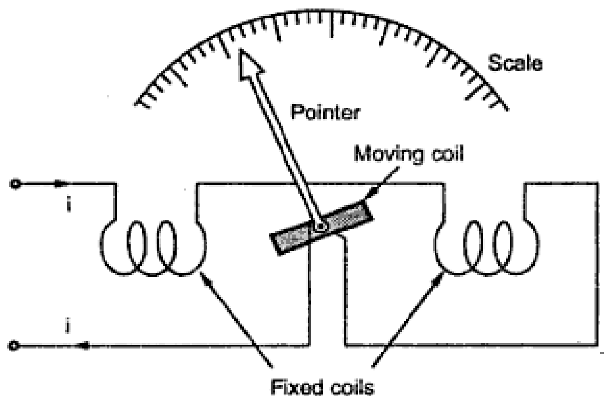
Any two 1 mark each

2 f)

- The operating principle of analog ammeters and voltmeters is same. The ammeters and voltmeters are current actuated devices.
- In ammeter, deflecting torque T_D proportional to current to be measured
- In voltmeters, T_D proportional to current which is proportional to the voltage under measurment.
- Their construction is similar except their meter resistanace values. The resistance of ammeter is low while resistance of voltmeter is high.
- Ammeter connected connected in series and voltmeter connected in parallel with the load.

Any four points 1 mark each

3 a) Working of dynamometer type instrument:



Electrodynamometer type instrument

Diagram: Labeled 2 marks, unlabeled 1 mark.

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 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.

1 mark

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

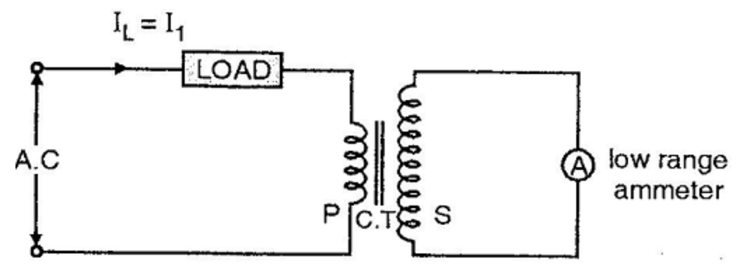
3 b) PMMC instruments used only for DC measurements

The torque on the moving coil is proportional to the product of permanent magnet field and current in the moving coil. 1 mark

For DC as the current is unidirectional the torque is unidirectional and hence deflection is properly seen and measured. 2 marks

For AC as current is alternating the torque is also alternating due to which the moving coil vibrates and is not able to give the visible deflection as average torque over a cycle is zero. 1 mark

3 c) Use of CT for ammeter range extention



Unlabeled 1 mark, labeled 2 marks

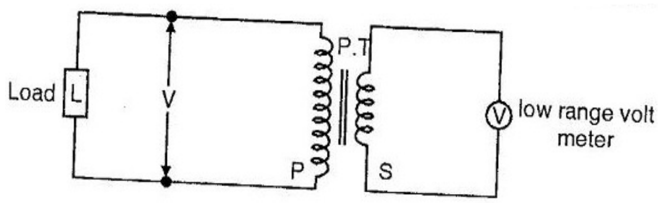
-The high current to be measured is passed through the primary of transformer. The low range ammeter is connected in series with the secondary winding.

-C.T. is step up voltage transformer.Hence step down current transformer. Hence the number of turns of secondary winding is greater than number of turns of primary windings. 1 mark

-The actual value of high current under measurement= Reading of low range meter *nominal ratio of C.T. 1 mark

For students ans. As below (PT)

For PT (used for HV measurements)



Unlabeled 1 mark, labeled 2 marks

Use to read high voltages on low range voltmeters. 1mark

The actual value of high voltage under measurement= Reading of low range meter *nominal ratio of P.T. 1 mark

3 d) Errors in wattmeter:

1.Errors due to method of connection.

In uncompensated wattmeter , the reading of wattmeter includes the Any four powerloss in coil errors

By using compensating coil , the error due to current coil which carris the current of PC in addition to the load current is eliminated expected.

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 PC 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.

List any four, ½ mark each (2 marks)

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.

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.

Remedies ½ mark each (2 marks)

3 e) <u>One wattmeter connection for three phase balanced load power measurement</u>

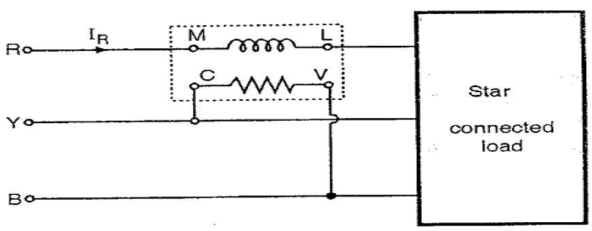
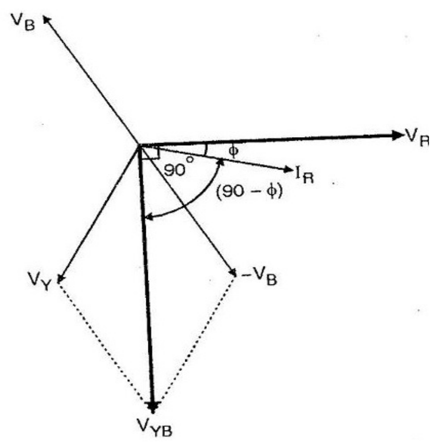


Diagram 2 marks



2 marks

3 f) Polyphase wattmeter (Three phase two element wattmeter):

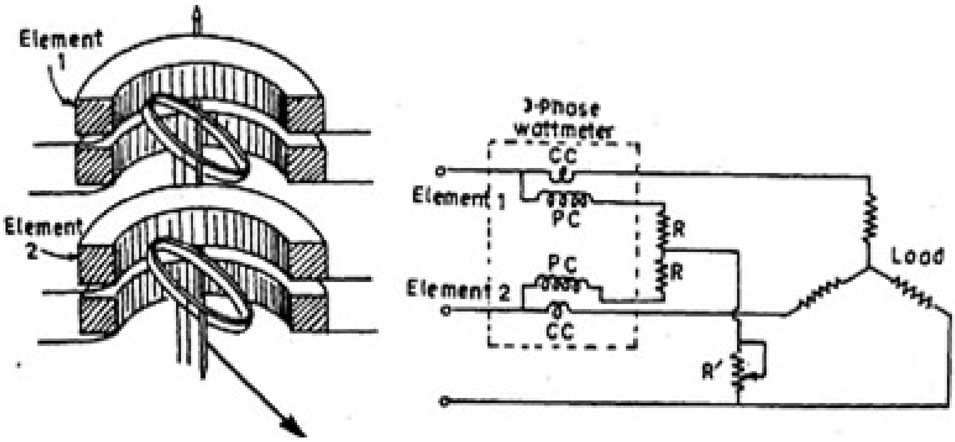
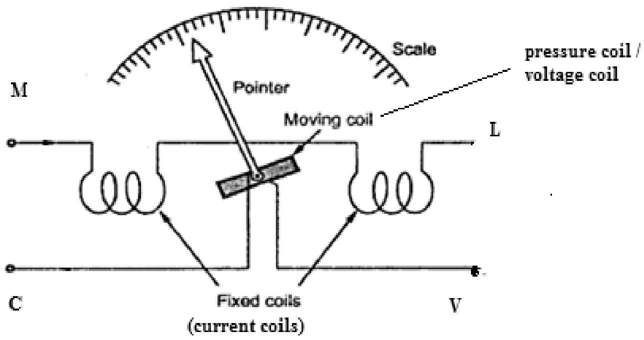


Diagram Labeled 4 marks, unlabeled 2 marks, (compensation resistance optional)

4 a) Electrodynamometer type instrument:



Electrodynamometer type instrument

Diagram: Labeled 4 marks, partially labeled 2 marks unlabeled 1 mark.

4 b) In two wattmeter method the reading of two watt meters are given by equations-

W_1=V I cos(30+Ø) and W_2=V I cos (30-Ø) — 1mark

We will consider different cases of power factors

1. If power factor is unity i.e. p.f.=1 (Ø=0^0)
   W_1=V I cos (30+0) and W_2=V I cos (30-0)
   W_1=V I cos 30 and also W_2=V I cos 30
   Thus both the watt meters have equal readings and unidirectional deflection.
2. If power factor is 0.5 lagging i.e.Ø=60^0
   W_1=V I cos (30+60) and W_2=V I cos (30-60)
   W_1=V I cos 90 and W_2=V I cos (-30)
   W_1=V I (0) and W_2=V I cos (-30)
   W_1=0 and W_2=V I cos (-30)
   Thus it is observed that one of the wattmeter W_1 reads zero and all the power is measured by second wattmeter W_2.
3. If power factor is between 0.5 and 0. i.e Ø is greater than 60^0 & less than 90.
   In this case one of the wattmeter gives positive reading and second wattmeter

give negative reading.

Hence for taking reading of second wattmeter its pressure coil connections or current coil connections is to be changed.

4. If power factor is 0 i.e.$\varnothing=90^0$

   W_1=V I cos(30+90) and W_2=V I cos(30-90)

   W_1=V I cos120 and W_2=V I cos(-60)

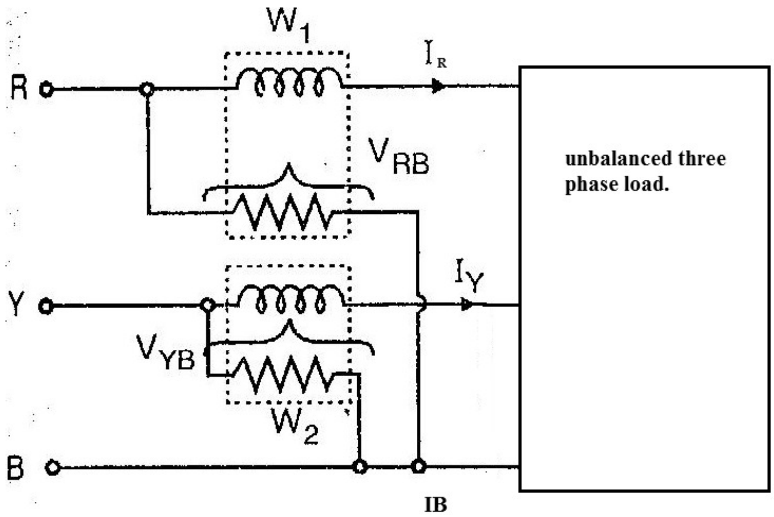
   W_1= - 0.5* V I and W_2=V I*(0.5)

Thus it is observed that both the wattmeter reads equal and opposite power.

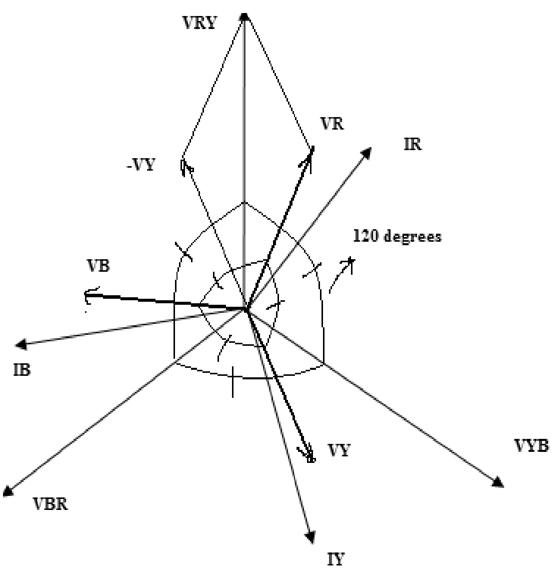
5. For leading power factors:- The readings of two watt meters compared to lagging cases above only interchange.

Any three cases with effect 1mark each

4 c)



2 marks

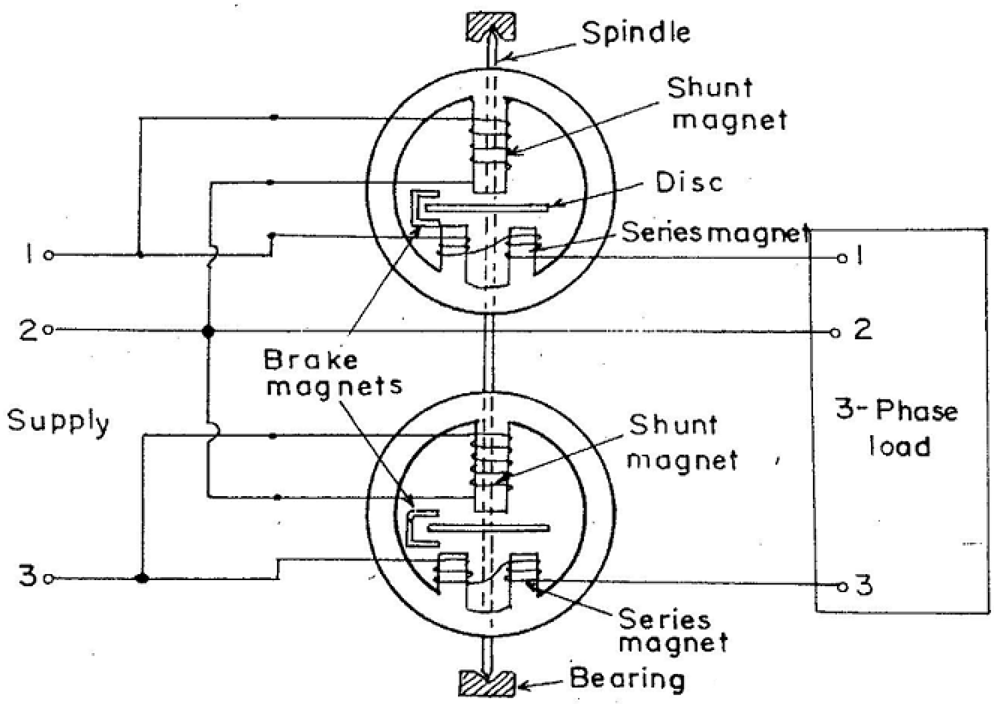


2 marks

phasor diagram of unbalanced load, note the different magnitudes and phase angles of the currents w.r.t the phase voltages.

VRY , VYB, VBR are line voltages, IR, IY, IB are line currents

4 d)



3 phase induction type (2 element energy meter)

Labeled diagram 4 marks,

Partial label 2 marks,

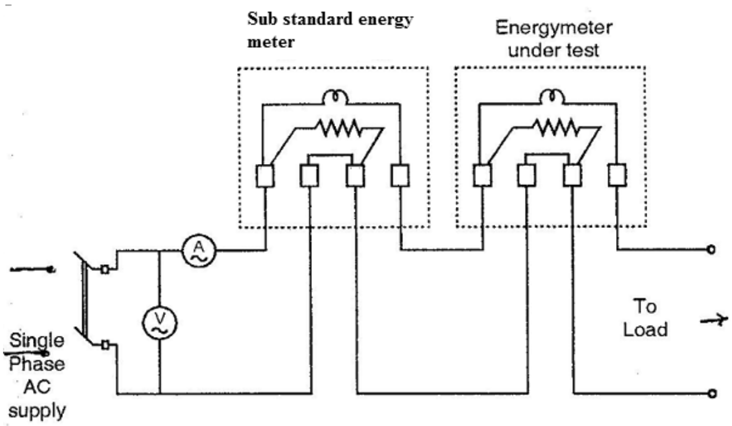
Unlabeled 1 mark

4 e) There are three methods for calibration such as-

1. Long period dial test
2. Using rotary sub standard meter
3. Using precision grade instruments.

1mark

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



Calibration of energymeter

Diagram 1 marks

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. And the meter is corrected.

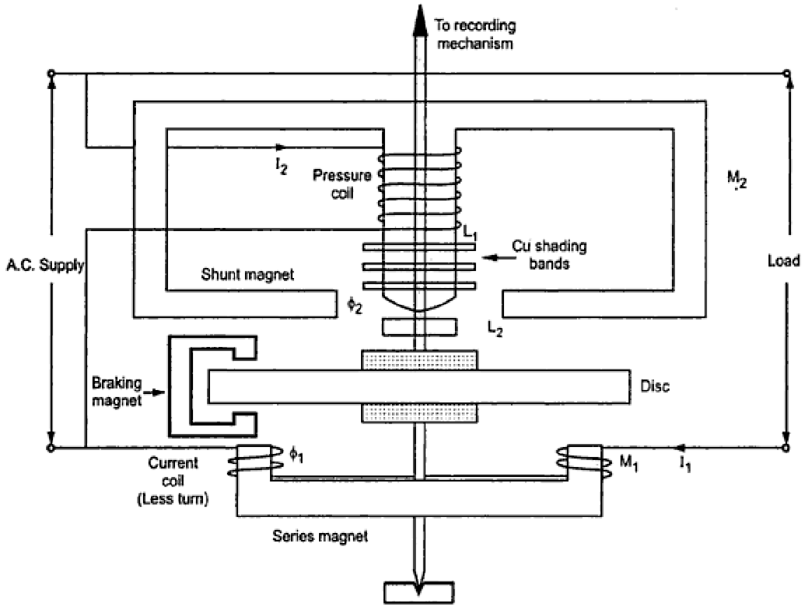
1 mark

Let D= registration of meter under test in kWh. & Ds = registration of substandard

1 mark

meter in kWh.
Then % error = [(D - D_S)/D_S] x 100.

4 f) Single phase induction type energy meter principle.
As shown in the diagram the disc is placed between the two electromagnets, eddy currents will be induced in the disc by two fluxes i.e. flux due to pressure coil and flux due to current coil, which will set up torque on the disc which is proportional to power causing the disc to rotate. The no of revolutions are proportional to the product of the power and the time which gives the energy drawn. 2 mark



2 marks

5 a) Electronic Energy Meter diagram: Any one diagram

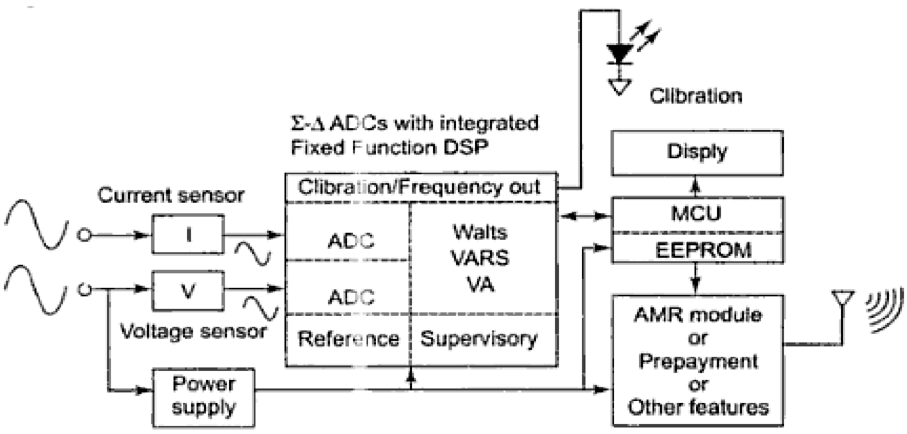
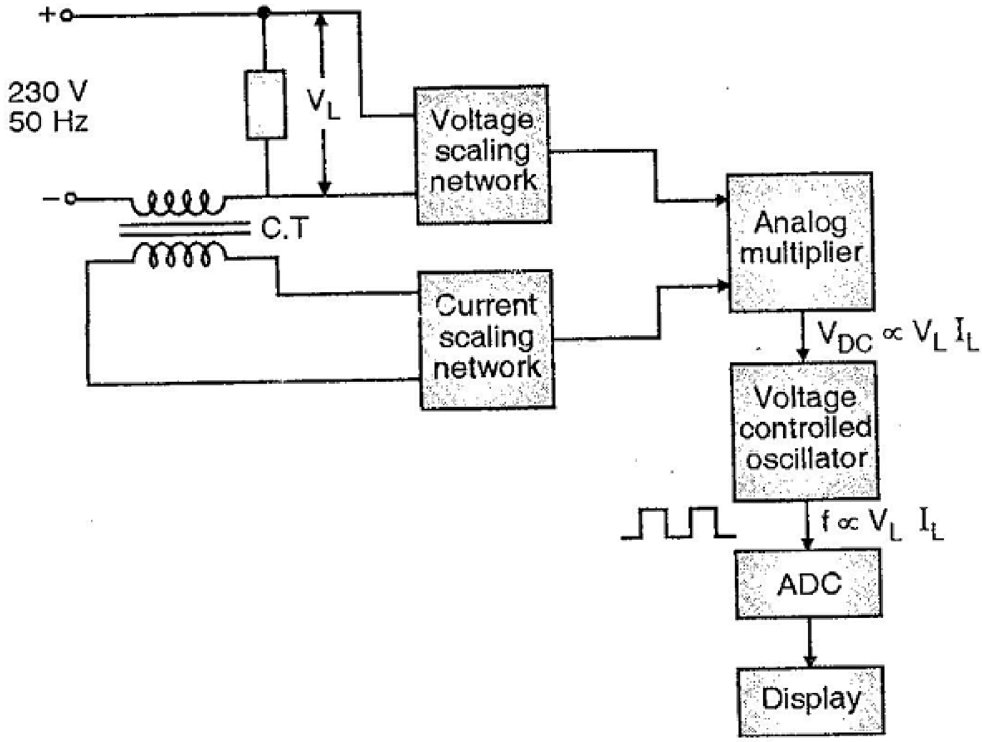


Diagram labeled 4 marks

Partially labeled 2 marks

Unlabeled 1 marks

OR



5 b) The meter constant is 6000 revolutions per kWh

6000 rev =1kWh = 1000 watt hour

=1000*60*60 watt second

=3600000 watt second — 1 mark

Therefore 1 revolution = 3600000/6000 = 600 watt second

Hence 40 revolutions = 40 x 600 = 24000 watt second have been recorded. — 1 mark

Now power consumed= 110 x 3

= 330 watt

Energy to be actually recorded within 60 seconds will be = 330 x 60

= 19800 watt second. — 1 mark

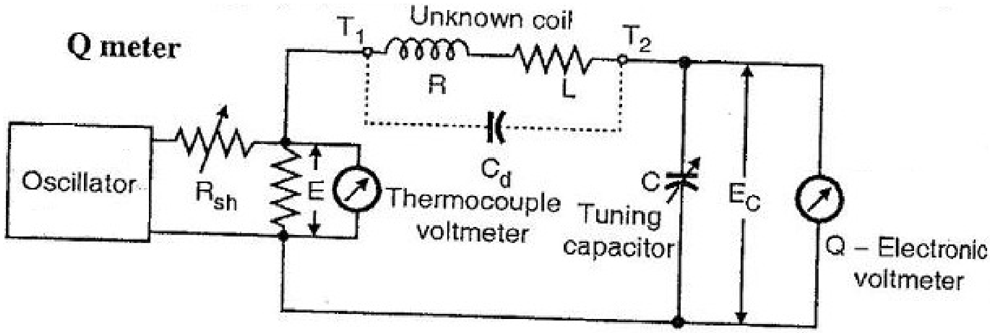
Therefore % error = = {[true value – registered (reading) value]/ true value} x 100

Therefore percentage error = [(19800 – 24000) / 19800] x 100.

= -21.21 %

1 mark

5 c)



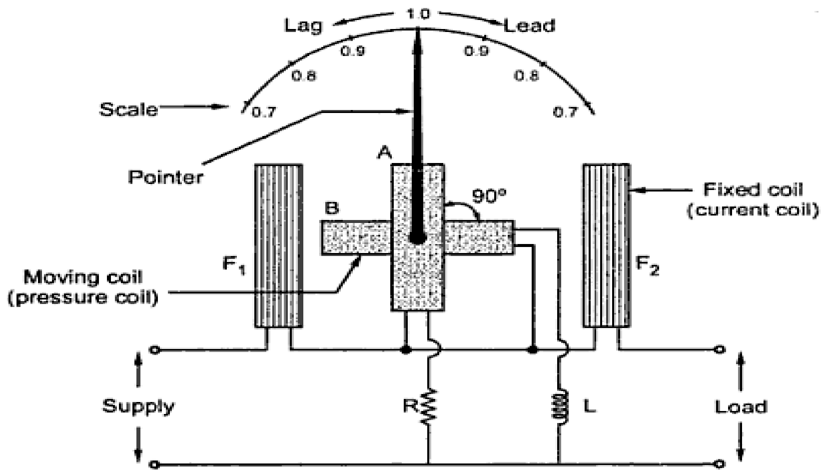
Unlabeled diagram 1 marks

Labeled diagram 2 marks

Any two applications 1 mark each = 2 marks

Applications: a) Measurement of Q, b) Measurement of inductance,
c) Measurement of effective resistance, d) Measurement of capacitance,
e) Measurement of bandwidth.

5 d) Single phase dynamometer type power factor meter.



Single phase electrodynamometer type power factor meter

Diagram 2 marks

It consist of two circuits similar to a watt meter. One is pressure coil circuit and another is current coil circuit. The current coil circuit consist of two fixed coils F_1-F_2 of equal turns and connected in series. The pressure coil circuit also consist of two coils A &B of fine wire, pivoted on the same spindle and fixed at 90^0 to each other and consists of a moving system of the meter. They are placed inside the magnetic field produced by coil F_1- F_2 . 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 $90^{0.}$

1mark

1 mark

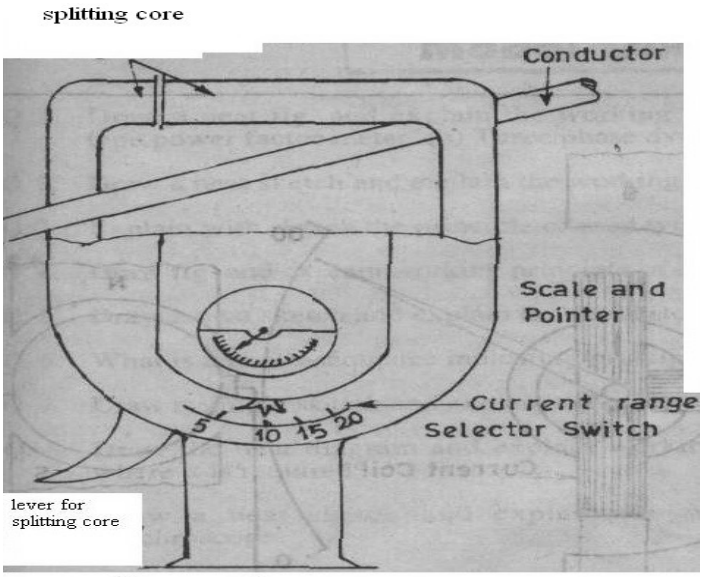
5 e) Synchroscope:

Working Principle- Sensing the instant when the 3 phase line voltages of the incoming alternator are matching with the corresponding ones of the infinite busbar system is the principle under lying the principle of working of synchroscope. Thus the two sets of voltages are made to act on a common device / magnetic circuit which gets balanced when the two sets are identical in terms of frequency, phase sequence and magnitudes. The synchroscope indicates this instant. For all other conditions the synchroscope gives indication of the respective quantity difference. Thus it a comparator. 2 marks

Advantages: 2 marks

1. Helps to avoid faulty parallel operation of 3 phase generators.
2. Indicates the differences in the quantities required to be matched between the generators stated above before paralleling.

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



clip on ammeter

Diagram 2 marks

They consist of split core current transformer whose secondary winding is connected to rectifier type moving coil instrument. The primary become conductor through is to be measured. The split core gets aligned by the force of a spring tension. While the core is covered with insulating material. Hence higher currents through bare conductors up to 600 volts can be measured. 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 will record the current directly. Description 2 marks

6 a) Weston frequency meter:

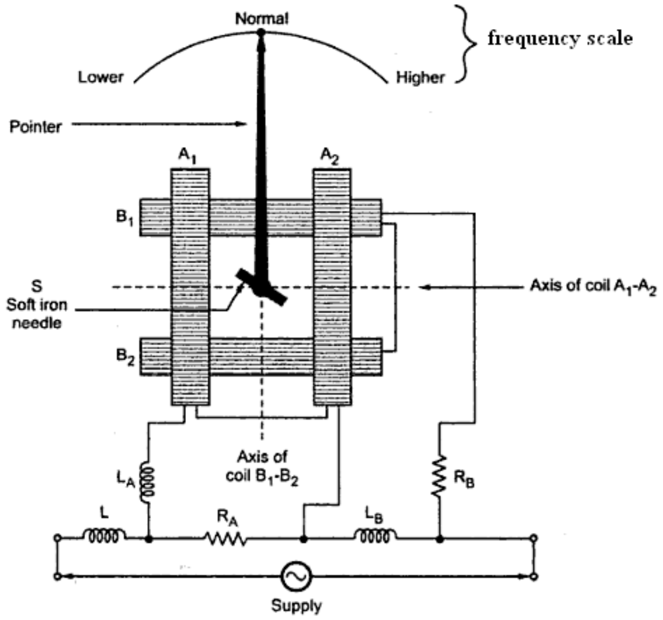


Diagram 2 marks

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.

2 marks

6 b) Methods of measurement of:

i) Low resistance:

1) Ammeter – voltmeter method,
2) Kelvin's double bridge,
3) Potentiometer method.

Any one method 1 mark

ii) High resistance:

1) Direct deflection method,
2) Loss of charge method,
3) Mega ohm bridge.

Any one method 1 mark.

iii) Insulation resistance,

1) Megger.

1 mark

iv) Earth resistance:

1) Earth tester,
2) Fall of potential method.

Any one method 1 mark

6 c) Factors affecting resistance of earthing systems:

1. Shape of earth electrode.
2. Material of earth electrode.
3. Type of soil / Soil resistivity/specific resistivity of soil.

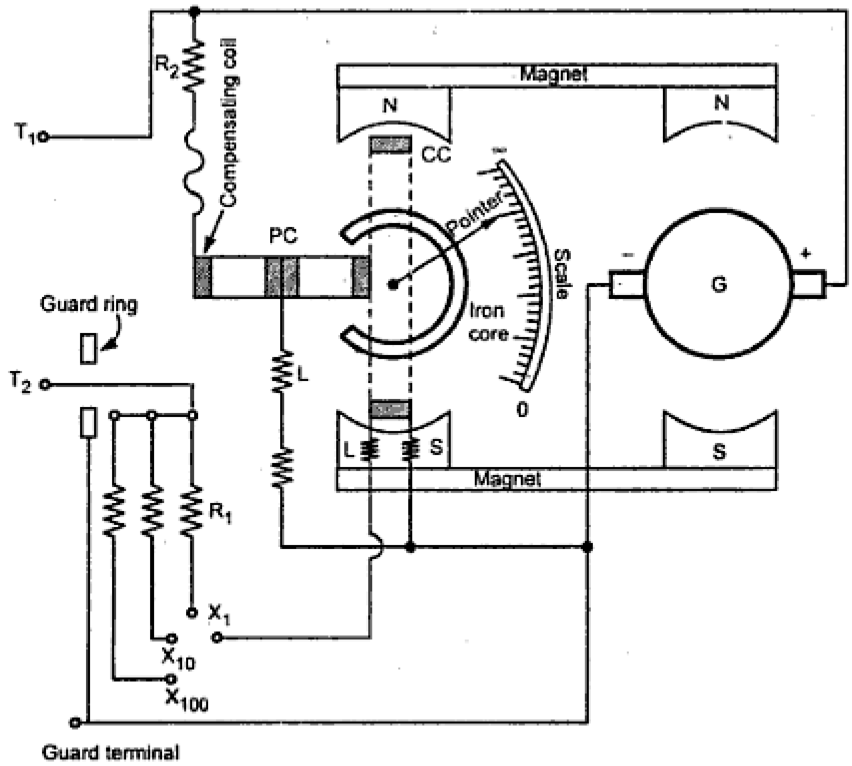
2 factors 1 mark,
4 factors 2 marks,

4. Moisture content of soil.
5. Depth of electrodes buried.
6. Seasons of the year.

6 factors 3 mark

The specific resistivity of the soil varies from one type to other. Amount of moisture is not a constant factor but varies by seasons. Hence periodic testing / measurement of soil resistance / earthing system resistance to ensure that the earthing is effective. 1 mark

6 d) Principle of operation of Megger: The deflection produced by a two coil system is directly proportional to the ratio of the voltage of one coil (voltage coil) to the current in the other coil (current coil). The two coils are mounted rigidly with respect to one other such that their axes are at right angles to each other.
The voltage coil is supplied current proportional to the voltage applied to the insulation resistance while the current coil has current proportional to the one in the insulation resistance to be measured. The position of equilibrium when the two coil torques are equal is proportional to the insulation resistance. Description 1 mark



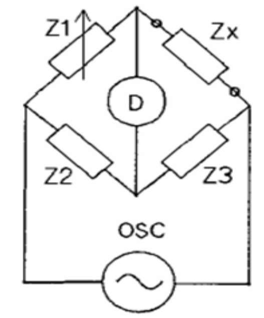
unlabeled diagram 2 marks

Labeled diagram 3 marks

6 e) LCR meter: **LCR meter** (Inductance (L), Capacitance (C), and Resistance (R)) is used to measure the inductance, capacitance, and resistance of a component.
Usually the device under test (DUT) is subjected to an AC voltage source. The meter measures the voltage across and the current through the DUT. From the ratio of these the meter can determine the magnitude of the impedance. The phase angle between the voltage and current is also measured in more advanced instruments; in combination with the impedance, the equivalent capacitance or inductance, and resistance, of the DUT can be calculated and displayed. The meter must be either in parallel or series for these two elements. The most useful assumption, and the one 1 mark

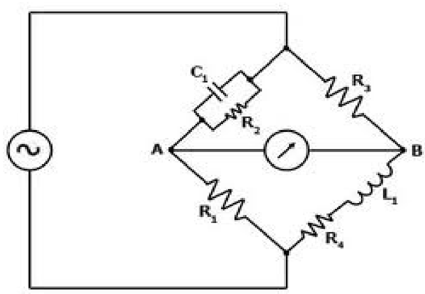
usually adopted, is that LR measurements have the elements in series (as would be encountered in an inductor coil) and that CR measurements have the elements in parallel (as would be encountered in measuring a capacitor with a leaky dielectric). An LCR meter can also be used to judge the inductance variation with respect to the rotor position in permanent magnet machines. Equation 1 mark

$Z_X = Z_{DUT} = (Z_3/Z_2)Z_1$



Any one diagram 2 marks

Maxwell's bridge is one such example



R_2, C_2 are adjustable, R_1 , R_3 are known and L_1, R_4 are unknown.

6 f) Advantages of digital multimeter:

1) High accuracy,
2) Output can be interfaced with external devices,
3) Compact and light,
4) Many quantities are measured with large ranges with no loss of accuracy,
5) Has high input impedance & hence does not load the terminals across which connected.
6) Has fairly high sensitivity of around 20 kilo-ohm per volt.

1 advantage 1 mark max. 2 marks.

Applications of digital multimeter:

Measure:

1) Direct voltages and currents with large ranges.
2) Alternating voltages and currents with large ranges.
3) Resistances (large ranges from ohms to megaohm) and continuity.
4) Frequency.

1 pt ½ mark max. 2 marks.