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 judgment 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. **Resolution:** Resolution is the least incremental value at input or that can be discriminated/ detected by the measuring device. 1 mark
2. **Accuracy:** It is the closeness with an instrument reading approaches the true value of the quantity under measurement.
   OR 1 mark
   It is defined as the ability of a device or a system to respond to a true value of a measured variable under reference conditions.

1 b) **Effects of Electric Current:** Any four effects ½ marks each

1. Magnetic Effect
2. Electromagnetic induction effect
3. Induction effect
4. Heating effect
5. Electrostatic effect
6. Hall effect

1 c) Indicating instruments: Any one 1 mark

1. Ammeter
2. Voltmeter
3. Wattmeter

Integrating Instruments: Any one 1 mark

1. Energy meter
2. Ampere-hour meter

1 d) Classification of Measuring Instrument:

A) Absolute Instruments
B) Secondary Instruments:

1. Depending on the principle of operation:
   i) Magnetic meters
   ii) Induction meters
   iii) Hot wire meters ½ mark each
   iv) Electrostatic meters any four
2. Depending on construction: = 2 marks
   i) Indicating instruments
   ii) Recording instruments
   iii) Integrating instruments
3. Depending on permissible error:
   i) Standard meters
   ii) Substandard meters
   iii) First grade instruments
   iv) Second grade instruments

1 e) **Principle of PMMC instrument:**

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), the deflection of the moving 1 mark 1 mark conductor system (coil) is made proportional to the force acting on it which is proportional to the current in coil.

1 f) Range extension :

A) d. c. Ammeter — 1 mark
By using Shunt

B) a. c. ammeter — 1 mark
By using Current Transformer.

1 g) Multiplying Factor = (Current Range * Voltage Range) / Full Scale Deflection — 1 mark

M. F. = (500*10) / 1250 = 4 — 1 mark

1 h) Methods of measurement of power in 3-phase circuit: — ½ mark each point

1. One single phase wattmeter method
2. Two single phase wattmeter method
3. Three single phase wattmeter method
4. One 3-phase wattmeter method

1 i) **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). — 1 mark

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 j) **Classification of resistances:** (low, medium and high resistances) — Classification 1 mark. Ranges 1 mark

Low resistances: less than 1 ohm.
Medium resistances: 1 ohm to 0.1 Mega ohm.
High resistances: greater than 0.1 Mega ohm.

1 k) **Use of Megger:** — Any two use 1 mark

1. For measurement of insulation resistance of cables
2. For installation resistance testing
3. Testing of electrical machines

Use of LCR meter: — Any two use 1 mark

1. Measurement of inductance
2. Measurement of resistance
3. Measurement of capacitance

1 l) Storage oscilloscopes can be used for capturing transient signals and display them for a periods which may vary from few minutes to several years. — 2 mark

2 a) **Systematic Error:**

i) Instrumental Error: These errors are caused due to the mechanical structure of measuring instrument.

a) Inherent shortcomings of instruments: Instrument may read too low or too high. — 2 marks for types

b) improper use of instruments: Improper handling e.g. overloading, overheating, failure to adjust zero, use of high resistance leads. — 2 marks for causes

c) Loading effect: cause distortion in original signal.

ii) Environmental Error: causes are surrounding conditions such as temperature, pressure, humidity, dust, vibrations, or external magnetic fields or electrostatic fields.

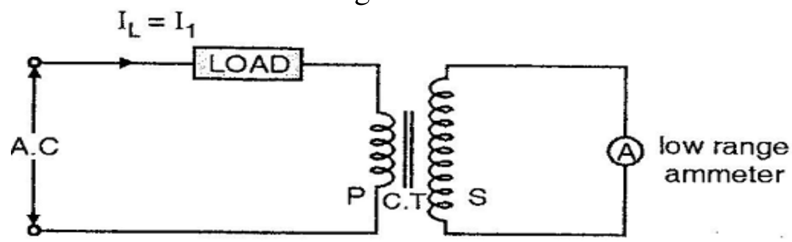
iii)Observational Error: Parallax errors.

2 b)

Comparison between MI and PMMC instruments: — 1 mark each point

	Points	MI	PMMC
i)	Principle	Piece of iron attract/repel by magnet	current carrying conductor is placed in a magnetic field it experiences a force
ii)	Torque/Weight Ratio	Higher weight for same torque	Comparatively higher along with more features
iii)	Scale	Non-uniform (non-linear)	Accommodated in smaller space
iv)	Use	Used for AC and DC measurements	Used for only DC measurements

2 c) Use of CT for ammeter range extension:



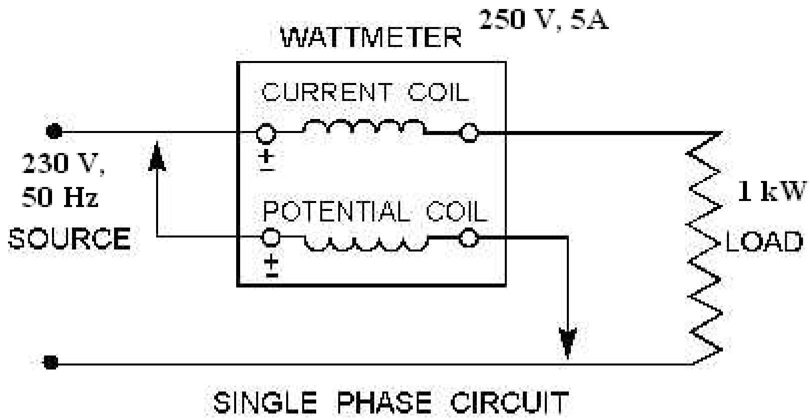
1 mark

- 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. — 1 mark
- 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. — 1 mark

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

2 d) Wattmeter specifications: 5A, 250V. 2 mark

Diagram:

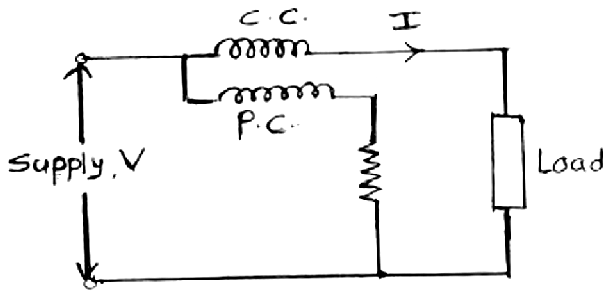


2 marks

2 e) Error due to connection- The error due to connection of current coil w.r.t. pressure coil will cause error in power measurement. 1 mark

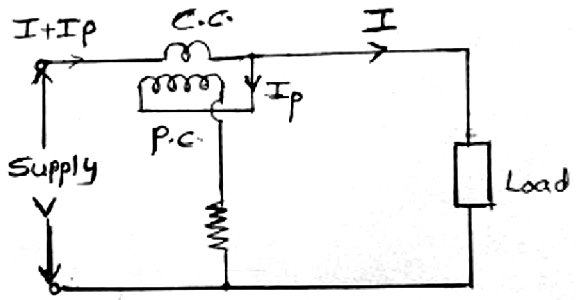
1)

1 mark



The error in measurement can be reduced by using this connection for loads having low current values.

2)



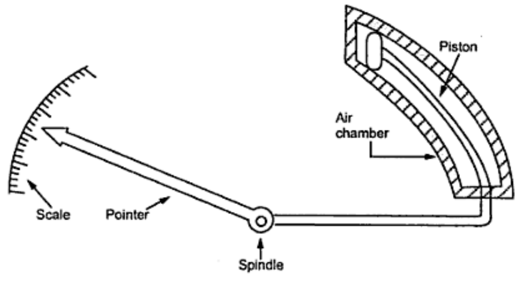
1 mark

These losses reduced when Ipc is very much less as compared to load current. This connection is preferred for high current loads.

3) This error can be minimized by using compensating coil. 1 mark

2 f) Multiplying Factor= (Current Range * Voltage Range)/ Full Scale Deflection
M. F. = (600*10) / 1500 = 4 — 2 mark
Power consumed, P= Wattmeter Rearing * M.F.
= 1000 * 4 = 4000 Watt — 2 mark

3 a)

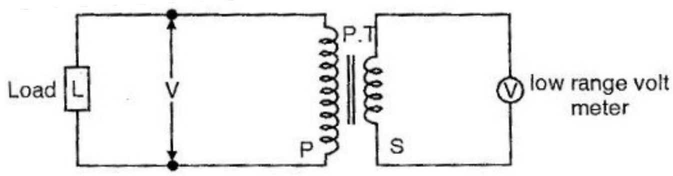


Air friction damping

Diagram 2 mark

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. — Working 2 mark

3 b) For PT (used for HV measurements)



1 mark each step

- 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.

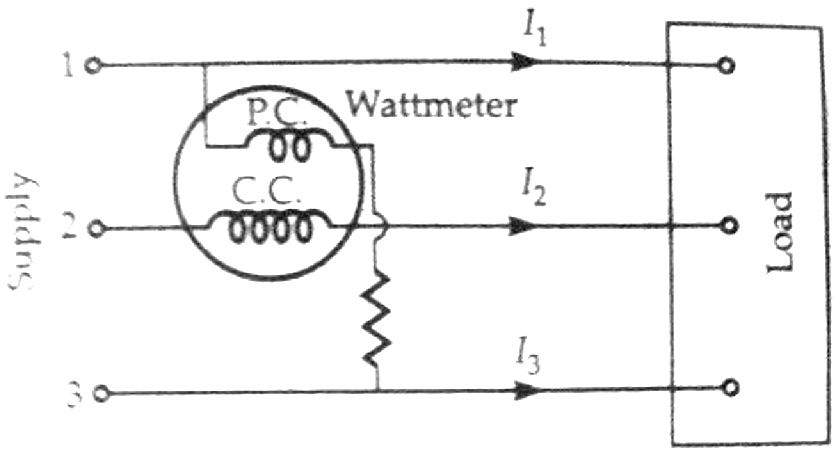
3 c) Given for full scale deflection current I_G = 10 mA & Resistance of MC, R_G = 50 ohms.
Shunt resistance R_{sh} for full scale deflection when the arrangement carries current of I = 5 A. — 1 mark
Using the principle of equal voltage across parallel resistances of R_G and R_{sh},
We have $I_G.R_G = (I - I_G) R_{sh}$, which gives us
$R_{sh} = I_G.R_G/(I - I_G) = 10 \times 10^{-3} \times 50/(5 - 10 \times 10^{-3})$
= 0.1 ohms is shunt resistance for using it as an ammeter to read 5A. — 1 mark

With (V_M = 250 V) applied to the series combination of MC and the series resistance R_S to use it as voltmeter of max. 250 V we have max current allowed of 10 mA. 1 mark

250 V = 10 mA X (R_S + R_G) from which

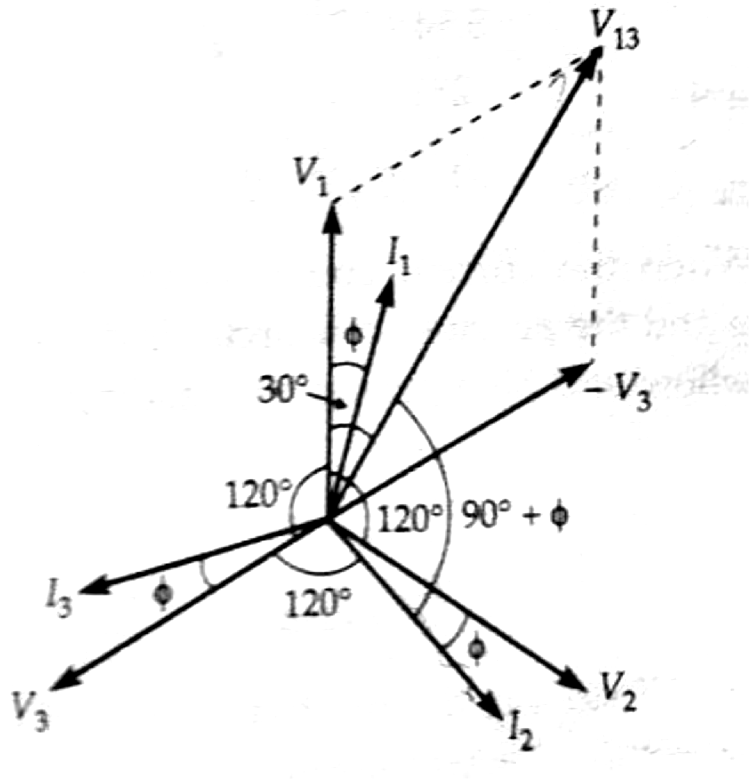
R_S = 25 X 10^3 – R_G = 25 X 10^3 – 50 = 24950 ohms is series resistance for using it as a voltmeter to read max 250V 1 mark

3 d) **Circuit diagram for reactive power measurement:**



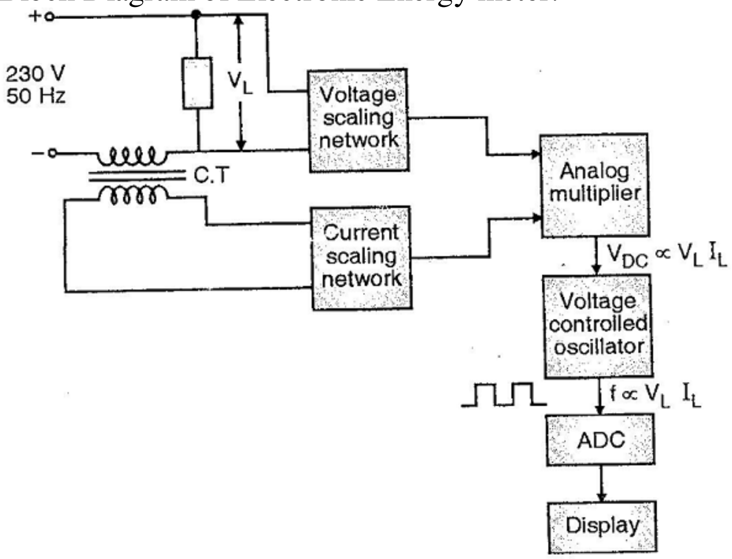
2mark

Vector diagram-



2 mark

3 e) Block Diagram of Electronic Energy meter:



Labeled diagram 2 marks, Unlabeled 1 mark.

Functions of components/blocks:

- 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.
- 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.

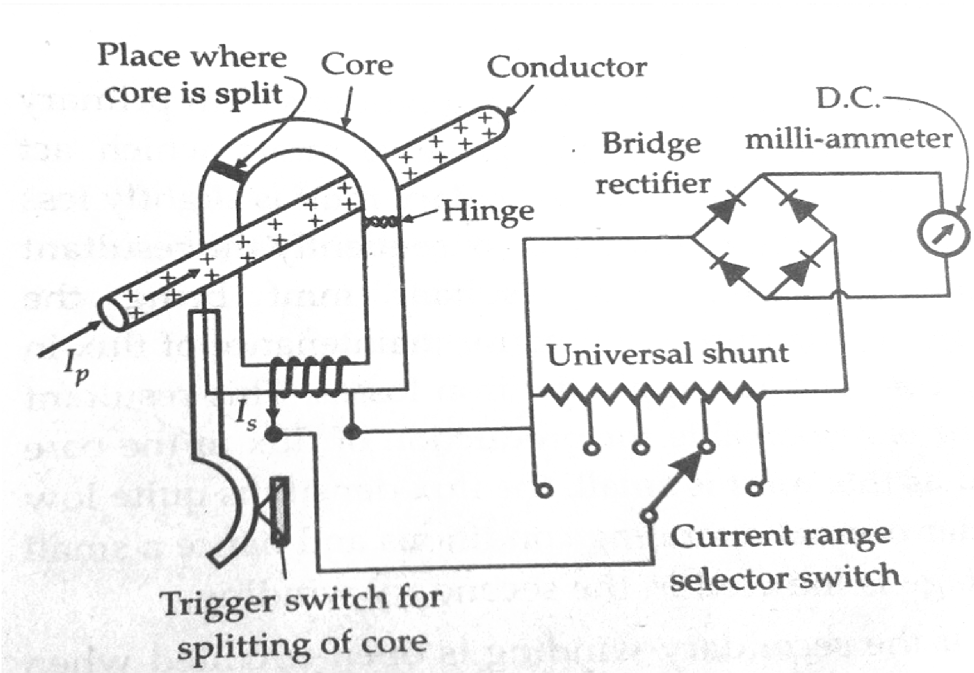
Any four ½ mark each = 2 marks

3 f) **Explain working of clip on meter.**

Clip on ammeters are used to measure the high current flowing through bus bar, cable or fuse holders carrying currents. They consist of split core current transformer whose secondary winding is connected to rectifier type moving coil instrument. The primary become conductor, whose current 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 current through conductors can be measured. A selector switch is provided to select secondary number of turns which ultimately changes the current range. For measuring current 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

Diagram 2 marks



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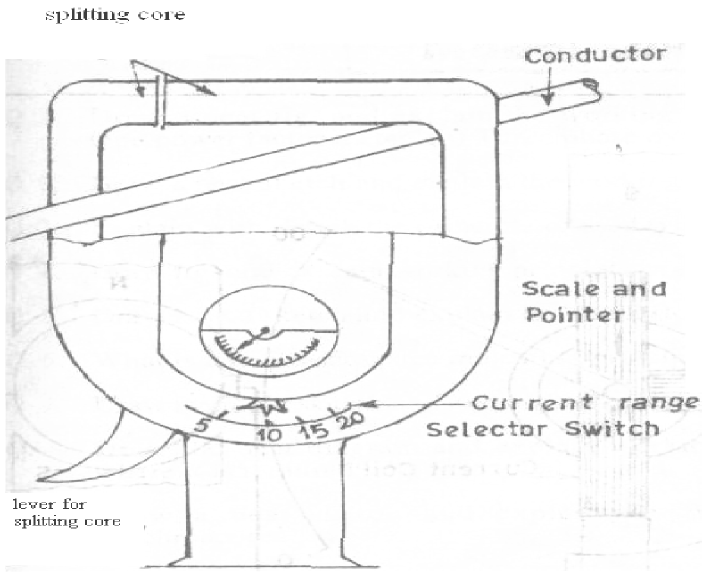


clip on ammeter

4 a) Advantages of MI instrument: — Any two Advantages 2 mark

1. Universal use: These intruments can be used for both AC & DC
2. Less friction errors
3. Cheaper
4. Robust contruction
5. More accuracy

Disadvantages of MI instrument: — Any two Disadvant. 2 mark

1. Scale is non uniform
2. Different calibrtions are needed for measurment of AC & DC quantities
3. Less sinsetiv as compared with PMMC type
4. The toque to weight ratio is less as compared with PMMC type.

4 b) **Here** $\Phi = \cos^{-1} 0.4^0$

$= 66.421^0$

Total power= $\sqrt{3} * V_L * I_L * \cos \Phi$ — 1mark

30000 watt= $\sqrt{3} * 500 * I_L * 0.4$

Therefore I_L=86.5 amp

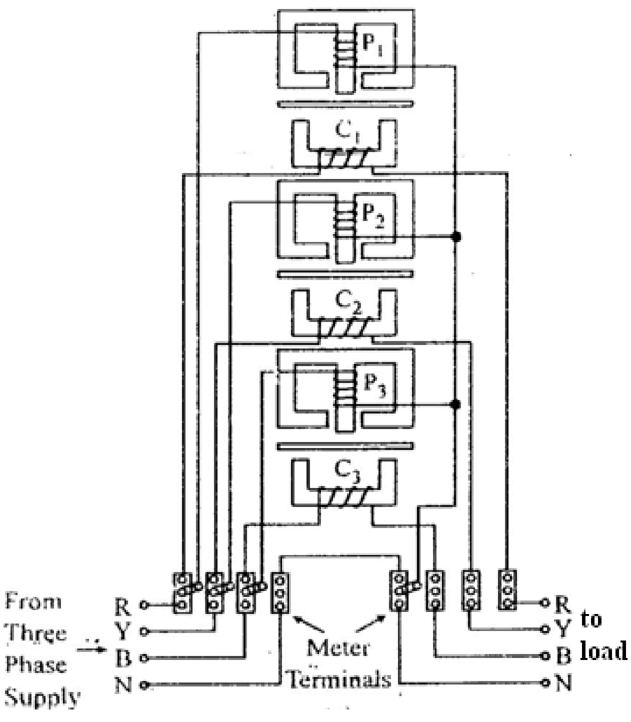
W_1=V I cos $(30+66.421^0)$ =500*86.5*cos(96.421) — 1mark

and W_2=V I cos $(30-66.421^0)$ =500*86.5*cos(-36.421)

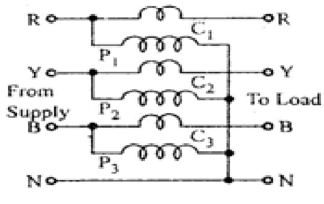
W_1= - 4836.78 watt — 1mark

W_2= 34802.69 W — 1mark

4 c) Three phase four wire energy meter (Three element energy meter):

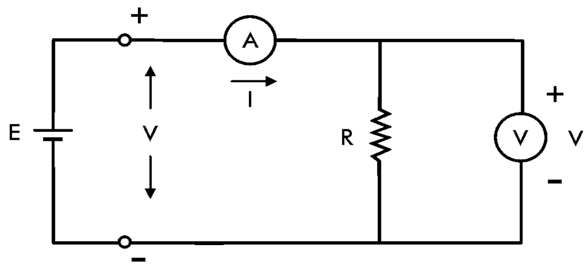


Three phase four wire induction type energy meter



Connection diagram

4 d) Take reading of voltmeter and ammeter, then measured resistance = $R_m = V/I$
To minimise the error take 4 to 5 observation for the same resistance 2 mark



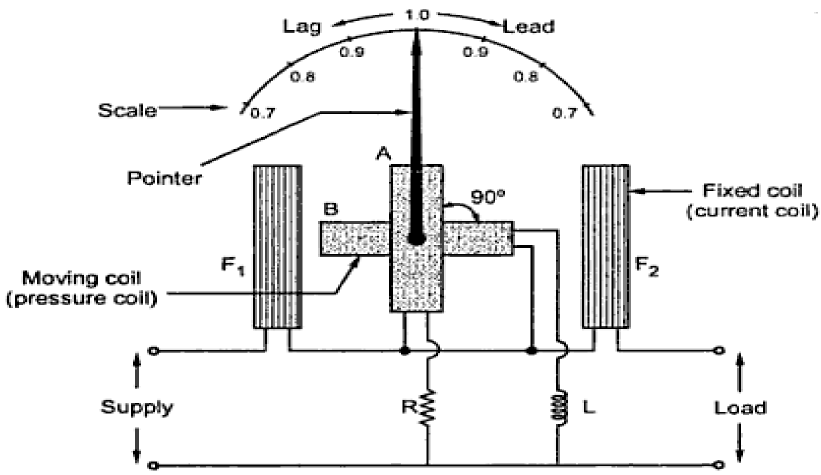
Diag. 2mark

4 e) Applications of digital multi-meter:

1. Measurement of DC voltage
2. Measurement of DC current
3. Measurement of AC voltage
4. Measurement of AC voltage
5. Measurement of resistance
6. Continuity testing
7. Testing of transistors
8. Measurement of frequency
9. Diode testing.

Eight applications ½ mark each

4 f) Single phase dynamometer type power factor meter.



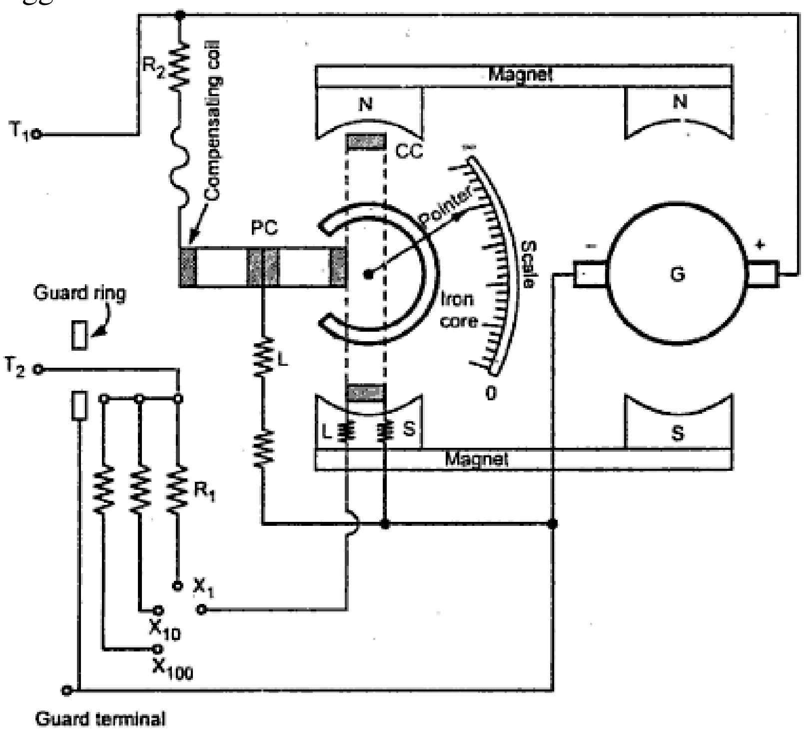
Single phase electrodynamometer type power factor meter

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 a) Megger is used to measure insulation resistance.



Labeled Diag. 4 marks, unlabeled 2 mark

5 b) 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 21 revolutions = 21 x 600 = 12600
= 12600 watt second has been recorded (registered). 1 mark

Now power consumed= 110 x 2
= 220 watt

Energy to be actually recorded within 60 seconds will be (true value)
= 220 x 60 1 mark
= 13200 watt second.

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

Therefore percentage error = [(13200 – 12600)/13200] x 100 = 4.54 % 1 mark

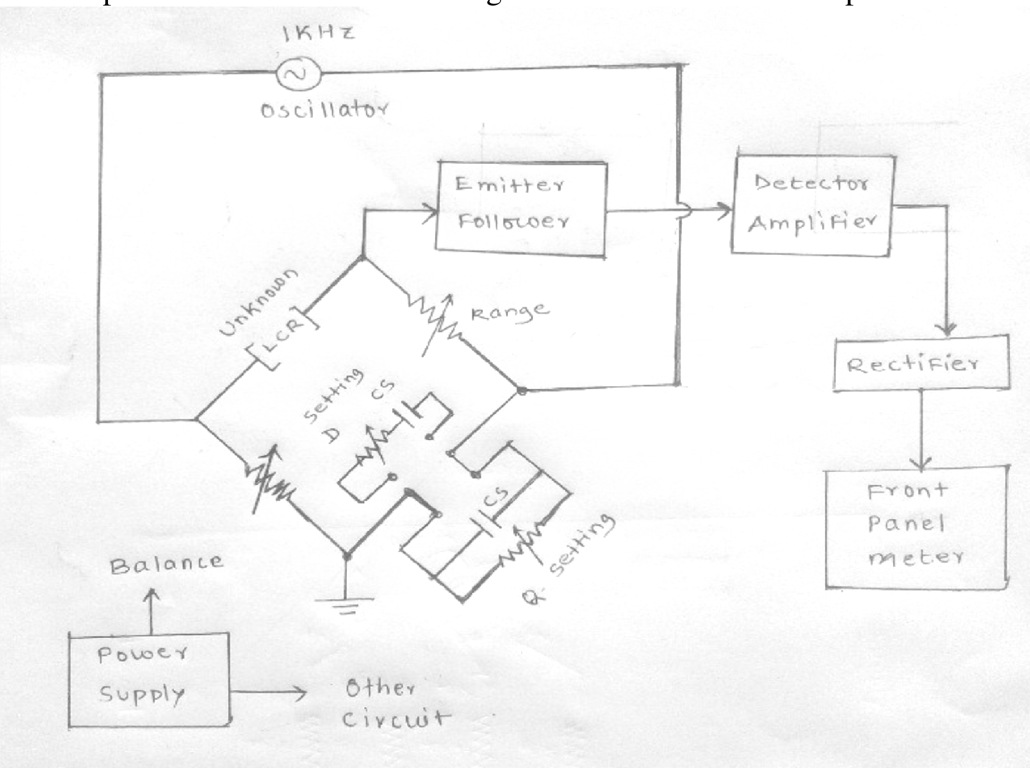
5 c) The arrow marked on the disc represents the direction of rotation. If the phase sequence of supply is same as that of the terminals marked on the indicator the disc will rotate in the direction of rotation.

i)RYB: Direction of rotation clockwise 2 marks

ii) BRY: Direction of rotation anti-clockwise. 2 marks

5 d) **Working of LCR meter**

A LCR meter (Inductance (L), Capacitance (C), and Resistance (R) test equipment used to measure the inductance, capacitance and, resistance of a component. It works on the principle of impedance measurement.
In general versions of LCR meter, these quantities are not measured directly, but determined from a measurement of impedance. The necessary calculations are, incorporated in the instrument's circuitry; the meter reads L, C and R directly with no human calculation required. It will determine the relative change in magnitude of the repetitive variations of the voltage and current known as amplitudes.



02 marks for neat labeled diagram

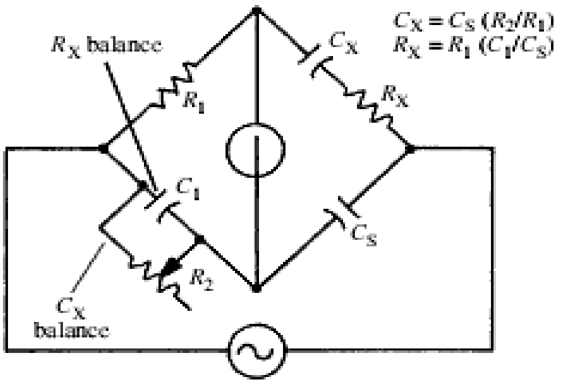
and

02 marks for Working.

Working –

- The device under test is subjected to an AC voltage source.
- The LCR meter detects the voltage over and the current through the device under test.
- From the ratio of these, the meter can determine the magnitude of the impedance.
- The phase angle between the voltage and current is also detected.
- The most useful assumption, and the one 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).
- It can also be used to judge the inductance variation with respect to the rotor position in permanent magnet machines.
- The full LCR meter test can be conducted very quickly depending on the device tested.

OR



Schering bridge

5 e)
i) Fixed coil: Flux production- enameled copper winding coil.
ii) Moving iron: Force production due to magnetization- electromagnetic iron piece.
iii) Iron Ring: Uniform flux distribution in space - electromagnetic iron material.
iv) Control spring: To produce control torque – Phosphor bronze material.

½ mark for function & ½ mark for material each

5 f) In two wattmeter method the reading of two wattmeters are given by equations-
W_1=V I cos(30-Φ) and W_2=V I cos (30+Φ)
We will consider different cases of power factors

i) If power factor is 0.5 lagging i.e.Φ= 60^0
W_1=V I cos (30- 60) and W_2=V I cos (30+60)
W_1=V I cos(-30) and W_2=V I cos (90)
W_1=V I (-30) and W_2=V I cos(0)
W_1= (-30) and W_2= V I cos 0
Thus it is observed that one of the wattmeter reads zero and all the power is measured by other wattmeter.

ii) If power factor is 0 lag i.e. Φ= 90^0
W_1=V I cos(30- 90) and W_2=V I cos(30+ 90)
W_1=V I cos-60 and W_2=V I cos(120)
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.

four cases with effect 1mark each

iii) If power factor is unity i.e. p.f.=1 (Φ=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 read equal readings.

iv) Pf = 0.4 lag.
If power factor is between 0.5 and 0. i.e. angle of lag is greater than 60^0 & less than 90. In this case one of the wattmeter gives positive reading and

second wattmeter give negative reading.

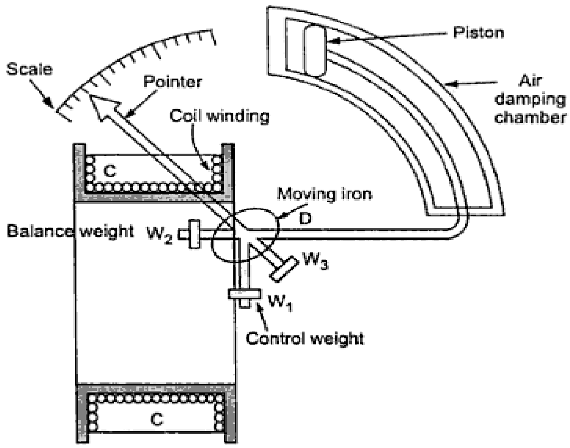
$\cos^{-1}0.4 = 66.42^{o}$.

W_1=V I cos (30- 66.42) and W_2=V I cos (30+ 66.42)

W_1=V I cos(-36.42) and also W_2=V I cos 96.42

One meter reads positive and other reads negative.

6 a) Gravity control method:



Labeled Diagram 2 marks, Unlabeled 1 mark

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 also provided by control weights shown in figure above.

2 marks

6 b) PMMC instrument can only measure D.C. quantities:

1. The direction of force exerted on moving coil depends on the direction of current flowing through moving coil.
2. If the direction of magnetic field kept constant it produces unidirectional torque. Thus the D.C. current is passed through the coil; unidirectional torque is created as the direction of current is constant.
3. But in case of A.C. the direction of current reverses in the positive and negative half cycle of A.C.
4. Hence force exerted on moving coil in positive half cycle acts in opposite direction that will be the coil in negative half cycle.
5. Making the average torque acting on the coil in one cycle to zero. Hence the meter cannot read A.C. quantities.

Any 4 pts. ½ mark each= 2 marks

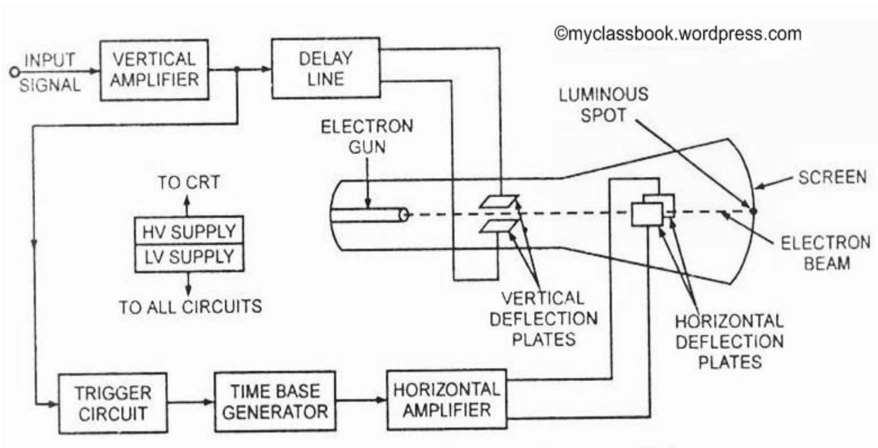
6 c)
- The purpose of calibration is to ensure that readings from an instrument are consistent globally with other instruments. It is also important in determining the accuracy of the instrument. 1 mark
- Calibration needed for evaluating and adjusting the precision and accuracy of measurement equipment. Instrument calibration is done to eliminate or reduce error in an instrument's readings. 1 mark
- Send the instrument for calibration after the test helps user decide whether the data obtained were reliable and correct or not.

- If instrument is kept idle for a long time, the instrument's conditions will change, thus calibration in needed.
- Every instrument will need to be calibrated periodically to make sure it can function properly and safely. 1 mark

Standard meters:

- These meters are most accurate meters which are used for calibration of meters. The permissible error in this meter is less than or equal to 0.2% . 1 mark

6 d)



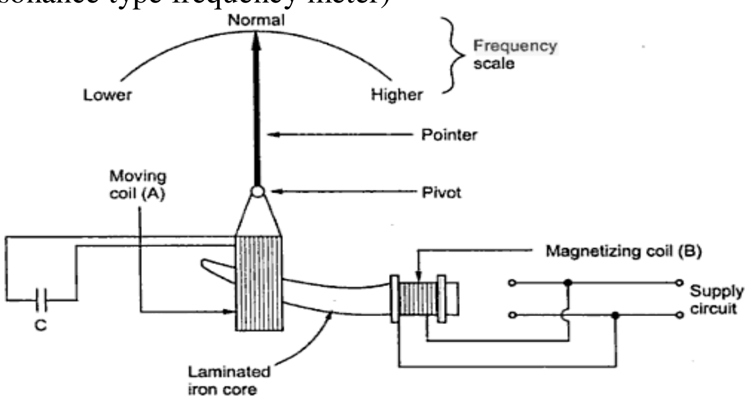
Labeled diag. 2 marks, Unlabeled 1 mark

- Vertical amplifier strengthens the input signal applied to vertical depleting plates
- Trigger circuit gives input to time base circuit
- The output of time base generator is amplified by horizontal amplifier and then applied to horizontal deflecting plates of CRT
- CRT consists of electron gun assembly which include thermally heated cathode, accelerating anode, focusing anode
- The electron beam coming out from electron gun assembly enters to deflecting plates.
- The screen of CRT internally coated with Phosphors material on which we observe waveform of the input signal.

Function of each Block 2 mark

6 e) Constructional details of ferro-dynamic type frequency meter. (Electrical resonance type frequency meter)

Diagram 2 marks



Ferrodynamic frequency meter

It consists of a fixed coil. The supply whose frequency is to be measured is connected across it. This coil is also known as magnetizing coil. It is mounted on a laminated iron core. The core has a typical varying cross section. It varies along the length and is maximum at the end of core. The moving coil of it is pivoted over this iron core. The pointer is fixed to the spindle and the terminals of moving coil are connected to a suitable capacitor C .No controlling torque is required. 1mark

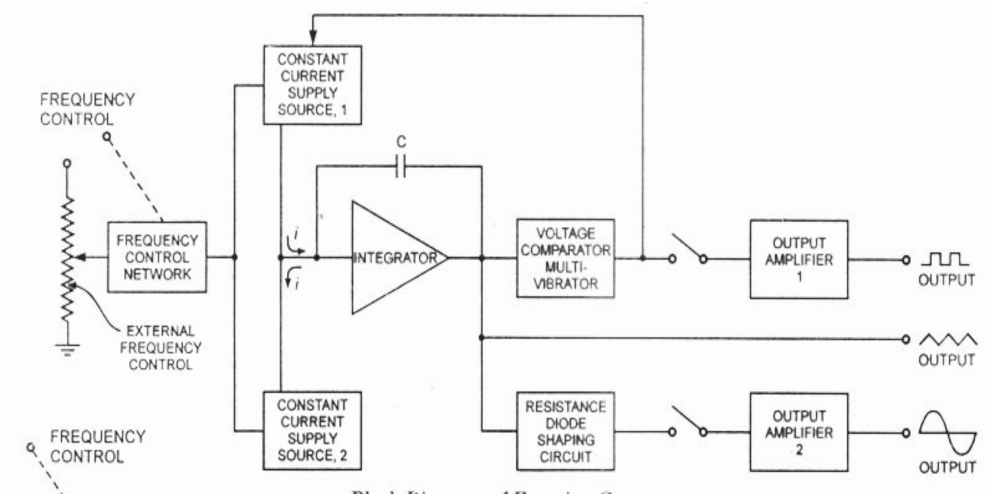
Working: - Current flowing through magnetizing coil produces flux in the iron core which will set up an emf in the moving coil .This emf lags the flux Φ by almost 90^0. This will cause current I to flow through capacitor C. If current is inductive it will lag induced emf and a torque will act on the coil. If current is capacitive then also the torque will act, but if the inductive reactance is equal to capacitive reactance two torques will act on the moving coil. The capacitive reactance is constant for given frequency but the inductive reactance depends upon the position of pivoted coil on the core. The nearer the coil approaches the magnetizing coil, the greater is it's inductance .The moving coil is pulled towards the magnetizing coil until both the reactances are exactly equal. i.e. when torque is zero. The value of capacitor is so selected that the moving coil takes up a convenient position when frequency is of normal value. 1mark

6 f) **Function Generator:**

- This instrument can deliver sine, triangular & square waves with frequency range of 0.01 Hz to 100 kHz.
- The frequency control network is governed by a frequency dial on the front panel of the instrument
- The frequency control voltage regulates two current sources.
- The upper current source supplies a constant current to the integrator whose output voltage increases with time.
- The voltage comparator multi-vibrator changes state at a predetermined level on the positive slope of the integrator's output voltage.
- The lower current source supplies a reverse current to the integrator so that its output voltage reaches a predetermined level on the negative slope of the integrator's output voltage.

Functions 2 marks (any four blocks)

Labeled diag. 2 marks, Unlabeled 1 mark



Block Diagram of Function Generator