DIPLOMA BOARD EXAMINATION - APRIL 2024

Answer key for Question Code: 535

MEASUREMENTS, INSTRUMENTS & TRANSDUCERS

PART - A

1. Define Accuracy. 3 marks

- Accuracy is defined as the closeness with which an instrument reading approaches the true value of a quantity being measured.
- Accuracy of a measurement means Confirmative to truth.

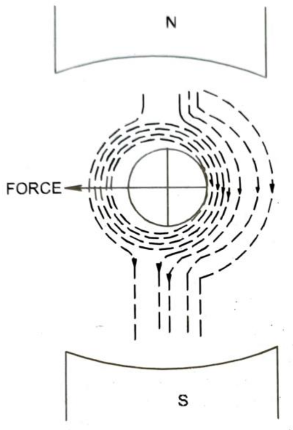
2. Write short notes on magnetic effects and thermal effects of instruments. 3 marks

Magnetic Effect:

- Magnetic poles of like nature repel and unlike poles attract. This effect is used to create a deflecting force for the moving system.

Example:

If two permanent magnet poles are brought nearer to a current carrying conductor, then there will be a force between the permanent poles and the conductor (electromagnetic poles).



Magnetic effect

Thermal Effect:

- When the current to be measured is passed through a small wire, it produces a heat in the wire. This heat effect is used in some instruments called 'hot-wire instruments' mostly to measure the currents (r.m.s).
- In such instruments the temperature rise is converted into electric current with the help of a thermocouple acting as a heat to electric converter (transducer).

3. State the advantages of dynamometer type instruments. 3 marks

- It is free from hysteresis and eddy current losses because there is no iron core.
- It can be used for ac as well as dc measurements.
- It has a fairly high degree of accuracy.

4. Write the working of CT. 3 marks

- The primary winding of current transformer carries the load current.
- The product of several amperes and few turns in primary are equal to the product of several turns and secondary current. So, the secondary current will be less.
- The power handled by a CT is very small.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$I_2 = N_1 I_1 / N_2$$

5. Write notes on power measurements in AC circuits. 3 marks

- In A.C. circuits the voltage and current are changing their magnitude and polarities with reference to time.
- The power in a circuit at any instant is equal to the product of voltage, current and power factor at that instant.
- P = **VI cosφ watts**

  Where, V - r.m.s value of voltage
  I - V - r.m.s value of current.
  Cos φ – Power factor of the circuit.

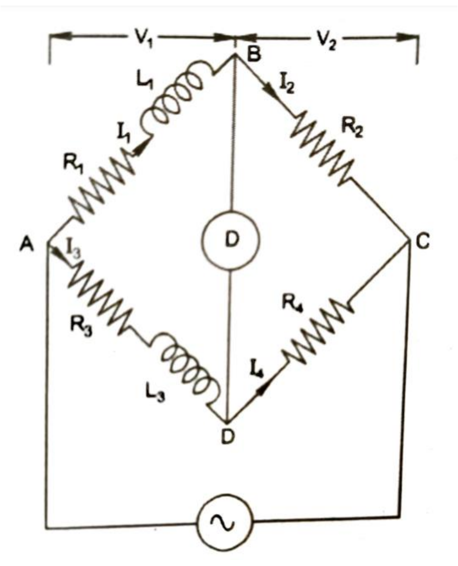
6. What is digital frequency meter? 3 marks

- A digital frequency meter is an electronic device that is used to measure the unknown frequency of the input signal and displays it on the digital display unit.

Principle:

- It has an AND Gate to which one input is the input signal (given after amplification and converting it to pulses by Schmitt trigger). The second signal is a known timing pulse.
- The frequency measurement is performed by counting the output of the AND gate. The total count is proportional to the unknown input frequency.

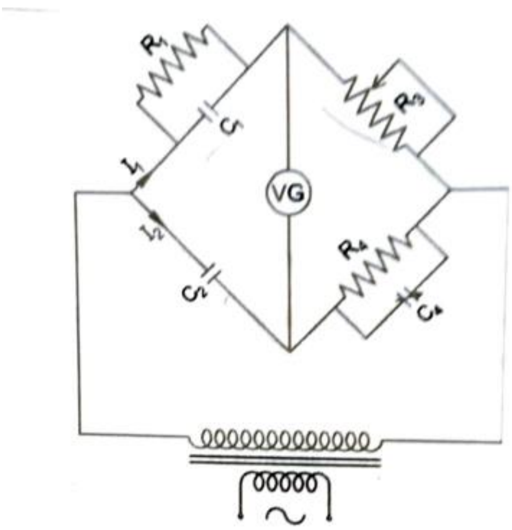
7. Draw Maxwell's bridge. 3 marks



L_1 – Unknown Inductance ; R_1 – Unknown Resistance

Maxwell's bridge

8. Draw the circuit of Schering bridge. 3 marks



C_1 – Unknown capacitance

Schering Bridge

9. What is the application of LVDT? 3 marks

[Any three applications]

LVDT is a passive inductive transducer, which is used to measure

- force
- pressure
- weight
- displacement
- acceleration

10. Write short notes on thermistor. 3 marks

[Any 3 points]

- Thermistor is basically a thermal resistor with negative temperature coefficient.
- It is made up of semiconductor material.
- Thermistor can detect small changes in temperature which could not observed with RTD or thermocouple.
- Thermistors are widely used to measure the temperature in the range - 60°C to 15°C.
- The resistance of thermistors ranges from 0.5 Ω to 0.75 M Ω.

PART- B

11.(a) Explain the terms True value, Precision, Static Error, Static error correction and Instruments Efficiency. 14 marks

True Value:

- It is the exact value or the perfectly correct value in any measuring scheme.
- It is defined as the average of infinite values taken when the average deviation due to various contributing factors tends to zero.
- True value is something we can never reach by experimental methods.
- In actual practice true value is usually taken from a laboratory standard or obtained with all possible error cancelling provisions.

Precision:

- It is the ability of an instrument to give consistent readings. i.e., successive readings do not differ and the instrument will give uniform equal readings repeatedly, for a given quantity measurement.

Static Error:

- Error is defined as the difference between the measured value and the true value of the quantity.
- Error = Measured value - True value = $E_m – E_t$
  - E_m = Measured value of the quantity
  - E_t = True value of the quantity.

Static Error correction:

- It is just the complement of error.
- Error correction is defined as the difference between the true value and the measured value of the quantity. Error correction = True value - Measured value = $E_t – E_m$
  - E_m = Measured value of the quantity
  - E_t = True value of the quantity.
- Error correction = - Error
- So, when there is an error of - 3% the correction required is + 3%.

Instrument efficiency:

- The efficiency of any instrument is defined as the ratio of measured quantity at full scale to the power taken by the instrument at full scale.
- $h_{inst} = \dfrac{\text{Measuring quantity at full scale}}{\text{Power taken by the instrument at full scale}}$

11.(b) What is measurement? Explain the functions of measurement systems.

14 marks

[Definition – 3 marks; Function – 11 marks]

Measurement:

Measurement of a given quantity, whether physical or electrical, is an act of comparison between the quantity and an already known standard quantity.

Functions Of Measurement Systems:

The three main functions of measurement systems are:

1. Indicating function
2. Recording function
3. Controlling function

Indicating Function:

- Instruments and systems use different methods for supplying information concerning the variable quantity under measurement.
- Most of the time this information is obtained as a deflection of a pointer of a measuring instrument. Instrument which performs such a function is known as indicating function.
- Example:
  Ammeter, Voltmeter, etc.

Recording Functions:

- In many cases the instrument makes a written record, usually on paper.
- The value of the quantity under measurements is against time or against some other variable recorded. Thus, the instrument performs a recording function.
- Example:

1. Strip chart recorder
   - To measure voltage against time
   - To measure of current against time
2. X-Y recorders
   - Speed -Torque characteristics of motor
   - Plotting the V-l characteristics of zener and semiconductor diode.
   - Regulation curves for power supplies.

Controlling Function:

- This is one of the most important functions especially in the field of industrial control processes.
- In this case, the information is used by the instrument or the system to control the original measured quantity.
- Example:
  1. Thermostats for temperature control in refrigeration system.
  2. Floats for liquid level control.

12.(a) Draw and explain the construction and working of moving iron instruments.

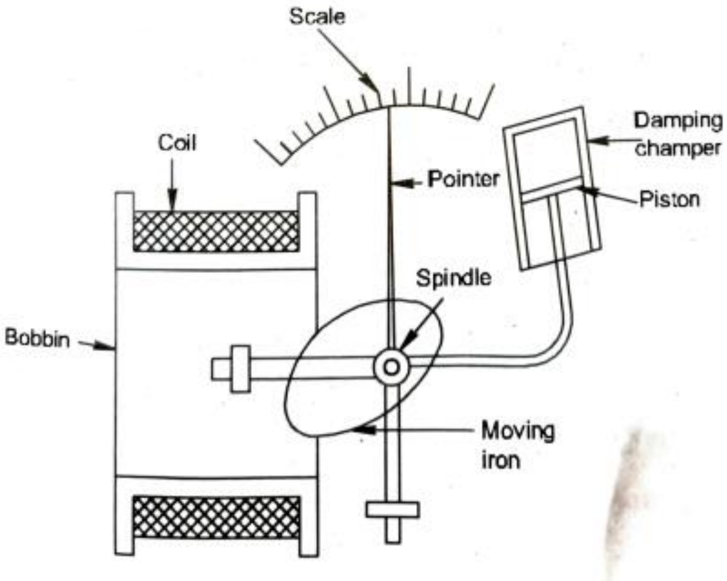
14 marks

[Diagram – 7 marks; Explanation – 7 marks]

Attraction type M.l Instrument:

Construction:

- It consists of a coil wound on a hollow cylindrical bobbin. A small piece of soft iron is eccentrically pivoted just outside the coil.
- A pointer is attached to the spindle. The spindle is pivoted to jewel bearings.
- Air friction damping may be used. A piston, attached to the spindle, moves inside an air chamber and gives the necessary damping.
- Spring control is almost universally used, but gravity control can be used in panel type instruments which are vertically mounted.
- A hair spring made of phosphor bronze, is attached to the spindle turns. The spring gets coiled and exerts controlling torque.



Attraction type moving iron instrument

Operation:

- When the current to be measured is passed through the coil, the magnetic field is produced by the coil.
- The field thus produced will be very strong inside the hollow space of the coil and less strong outside the coil.
- It attracts the iron inwards thereby deflecting the pointer which moves over a calibrated scale to give reading of voltage or current.
- The meter may be a voltmeter or Ammeter.
- Voltmeter: In case of Voltmeter, the coil has several turns of fine copper wire, and the coil has high impedance.
- Ammeter: In case of Ammeter, the coil has few turns of thick insulated copper wire and the coil has low impedance.

Equation:

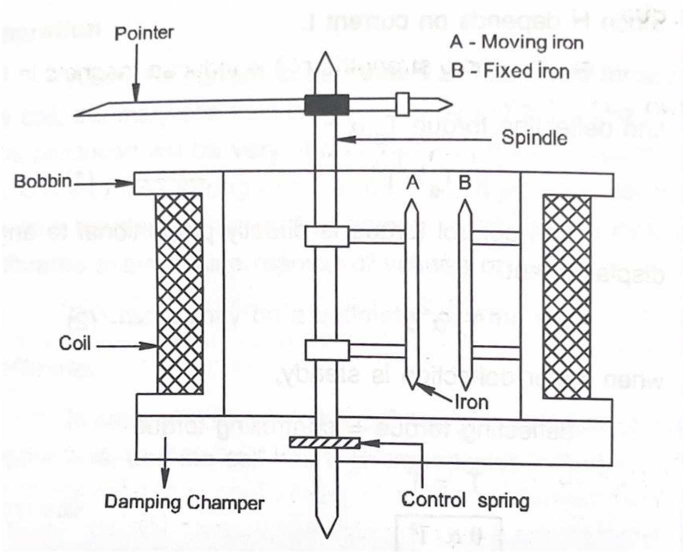
- The force (F) pulling soft iron piece inward depends $F \alpha mH$
  Where, H - magnetic field strength
  m - magnetic pole strength
- However, the pole strength m depends on magnetic field strength H. So, $F \alpha H^2$
- Since H depends on current I, $F \alpha I^2$
- Deflecting torque $T_d \alpha F$, So, $T_d \alpha I^2$
- The control torque is directly proportional to angular displacement ➔ $T_c \alpha \theta$
- When meter deflection is steady, deflecting torque = Controlling torque of the current.
  $T_d = T_c$ ➔ $\theta \alpha I^2$.
- **The deflection angle is directly proportional to square of the current**.

Repulsion type M.l instrument:

Construction:

- It consists of a hollow cylindrical bobbin carrying a coil. Two soft iron pieces A & B are fixed inside the bobbin. One piece (A) is fixed to the spindle and the other piece (B) is fixed on the bobbin wall.
- A pointer is attached to the spindle. The spindle is pivoted to jewel bearings. Pointer moves over a graduated scale.

- Air friction damping may be used. Spring control arrangement is provided on spindle for spring control.



Repulsion type M.I. instrument

Operation:
- When the current to be measured is passed through the coil, a magnetic field is set up within the hollow cylindrical space.
- Then the two iron pieces get magnetised. The polarities of the two induced magnets are the same at both ends.
- Hence, they repel each other with the result that the pointer which moves over a graduated scale is deflected.

Equation:
- m_1, m_2 - pole strengths of the induced magnets in the two iron pieces, $F \alpha m_1 m_2$.
- m depends on H. So, $F \alpha H^2$.
- $T_d \alpha F$, So, $T_d \alpha H^2$
- Since H depends on current I, $T_d \alpha I^2$ and $T_c \alpha \theta$.
- Under steady state condition, T_d=T_c ➔ $\boldsymbol{\theta \alpha I^2}$.
- **The scale is non uniform**.

Advantages:
1. Simple and robust in construction.
2. Can be used in D.C. as well as A.C. circuits.
3. High deflecting torque.
4. Low cost.
5. Can withstand overloads momentarily.

Disadvantages:
1. Scales are not uniform.
2. Power consumption is high.
3. Stiffness of spring decreases with rise in temperature.
4. Errors are introduced due to hysteresis and stray magnetic fields.
5. Changes in supply frequency cause serious errors in reading.

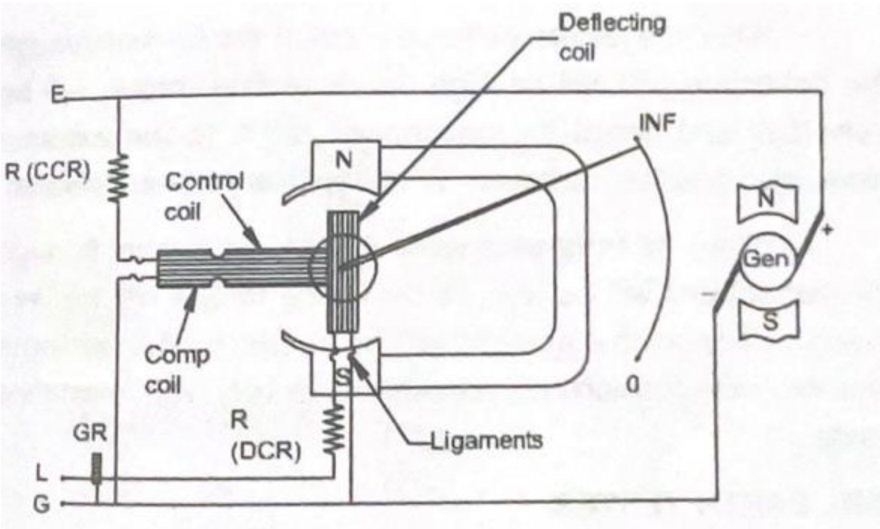
12.(b) Explain the measurement of high resistance using Megger with a neat sketch.

14 marks

[Diagram – 7 marks; Explanation – 7 marks]

- The Meggar is an instrument used for the measurement of high resistance and insulation resistance.

- The constructional details are shown in below figure.



Meggar

Construction:
- There are two pairs of permanent magnets, one set for ohm meter side and the other for the generator.
- The moving coil consists of three coils namely,
  - (a) control coil
  - (b) deflecting coil
  - (c) compensating coil
- The control coil and deflecting coil are fixed at right angles to one another and free to move on a stationary C shaped iron core.
- The compensating coil in series with a control coil and protection resistance R is connected across the generator terminals.
- The coils are connected to the circuits system through flexible leads.
- These leads do not exert any force on the moving system at any time which will therefore take up any position when the generator is not driven.
- A resistor R is connected in series with deflecting coil to protect the deflecting coil under short circuit condition.
- The guard ring bypasses the leakage current, if any to negative terminal of the generation and prevents leakage current from entering the deflecting coil.

Operation:
- The unknown resistance is connected between the terminals L & E (Line & Earth).
- The generator handle is then steadily turned at uniform speed.
- There is a slip mechanism in the drive which ensures a limited speed.
- When the resistance value is small, the current through the deflecting coil will be high, its deflecting torque will be very high and hence the pointer will move to the extreme clock wise position indicating 'O' or very low resistance value.
- When the resistance value is high, the current through the current coil will be low, its deflecting torque will be very low and hence the pointer will be taken to the extreme anticlockwise position indicating infinity or very high resistance value.

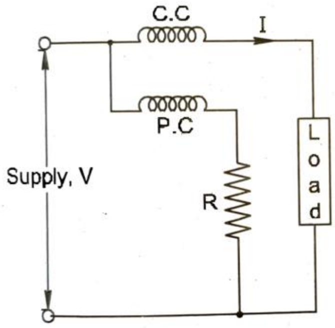
13.(a) Describe the Wattmeters in power measurement. 14 marks

[Diagram – 6 marks; Explanation – 8 marks]

Methods of connecting a wattmeter in the circuit:

There are two alternative methods of connecting a wattmeter in a circuit.

First method:



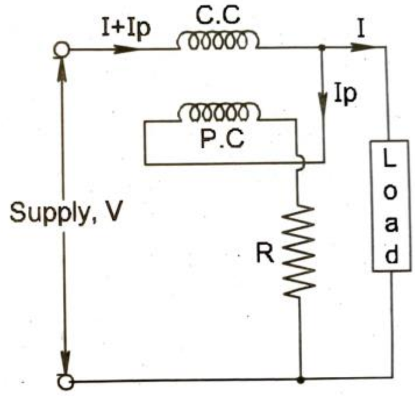
Method 1 of Wattmeter Connection

- In the first method of connection the pressure coil is connected on the supply side and therefore, the voltage applied to the pressure coil is the voltage across the load plus the voltage drop across the current coil.
- Thus, the wattmeter measures the power loss in its current coil in addition to the power consumed by load.

- Power Indicated by wattmeter = power consumed by load + Power loss is current coil
  = power consumed by load + I^2 Rc

- Where, Rc is the resistance of the current coil

Second method:

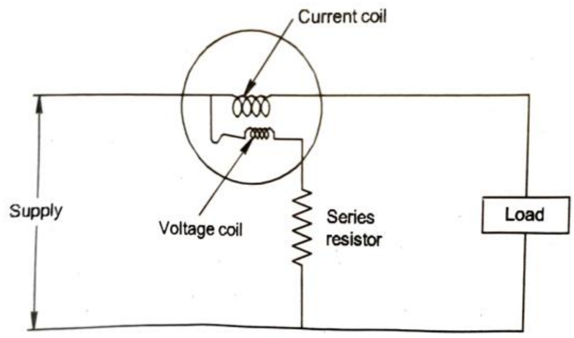


Second method of Wattmeter Connection

- In the second method of connection the current coil is on supply side and therefore it carries the pressure coil Current plus the load current.
- Hence the wattmeter reads the power consumed in the load plus the power loss in the pressure coil.
- Power indicated by wattmeter = Power consumed by load + power loss in the pressure coil
  = Power consumed by load + V^2 / Rp

- If the load current is small the voltage drop in the current coil is small so that the first method of connection introduces a very small error.
- On the other hand, if the load current is large the value of pressure coil current is very small as compared with the load Current and hence power loss in pressure coil will be small compare with the load power and therefore the second method connection in preferable.

Wattmeter In Power Measurement:

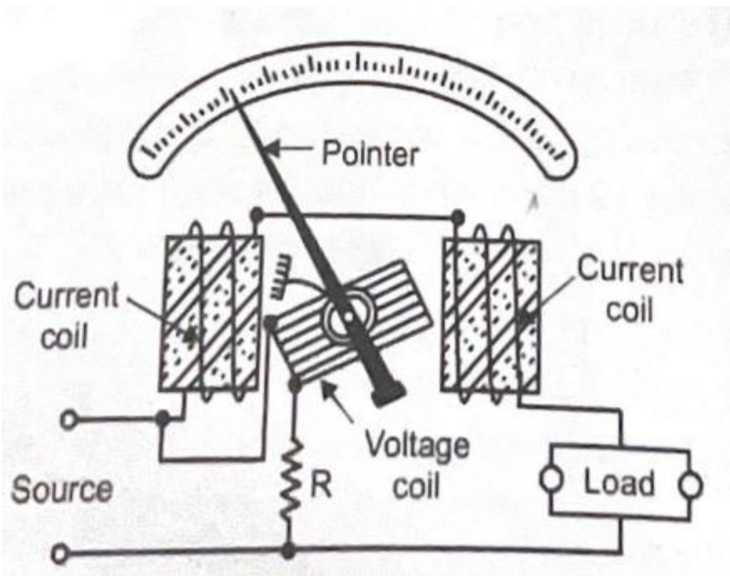


Wattmeter Connection

- Above figure shows a wattmeter connected in a single phase a.c. circuit.
- The current coil of the instrument carries the load current.
- The voltage coil or pressure coil carries a current proportional to and in phase with the voltage.
- The deflection of the wattmeter depends upon the current flow in these two coils and upon the power factor.
- A high non inductive resistance is connected in series with the voltage coil in order to keep the reactance of the pressure coil low when compared to the resistance of the whole pressure coil and to reduce the current taken by the pressure coil.

13.(b) Describe Electro dynamometer type wattmeter. 14 marks

[Diagram – 7 marks; Explanation – 7 marks]



Electro dynamometer type wattmeter

Construction:

- The circuit diagram of electrodynamometer is shown in above figure.
- The significant elements of electrodynamometer wattmeter are fixed coil, moving coil, Control element, Damping element, Scale and pointer.

1. **Fixed Coil (Current Coil):**
   - The fixed coil is connected in series with the load.
   - It is considered as a current coil because the load current flows through it.
   - The fixed coil is divided into two parts and these two elements are parallel connected to each other. The fixed coils are wound with heavy wires and it produces uniform electric field.

2. **Moving Coil (Voltage Coil / Pressure Coil):**
   - The moving coil is considered as the voltage (pressure) coil of the instruments.
   - It is connected in parallel with the supply voltage.
   - The current flows through it is directly proportional to the supply voltage.
   - A pointer is mounted on the moving coil. The movement of the pointer is controlled with the help of the spring.
   - The flow of current is limited with the help of resistor which is connected in series with the moving coil.

3. **Control**: Spring control is used for the instrument.

4. **Damping**: Air friction Damping is used.

5. **Scales and Pointers**: The instruments use a linear scale because their moving coil moves linearly. The apparatus uses the knife edge pointer for removing the parallax error.

Operation:

- In this meter, the current coil carries the load current and the voltage coil carries the current proportional to the voltage across the circuit.
- The interaction of two magnetic fields produced by the current flowing through the fixed coils and moving coil causes the moving coil to turn about its axis.
- It is directly proportional to the product of voltage and current.

Power = Current × Voltage

Theory:

- The average value of deflecting torque can be given as

$$T_d = \frac{V\,I}{R_p} \cos\phi \times \frac{dM}{d\theta}$$

Where, M - Mutual inductance between CC and PC
Rp - Resistance of the pressure coil

- The controlling torque can be given as, Tc = K θ

Where, K - Spring constant
θ - Angle of deflection

- At balanced position, **Td = Tc**

- So,

$$K\theta = \frac{V I \cos\phi}{R_p} \cdot \frac{dM}{d\theta}$$

$$\theta = \left(K_1 \frac{dM}{d\theta}\right) . P$$

- Where, $K_1 = 1/R_p K$

⇨ **θ α P**

- The deflection of the pointer is directly proportional to average power in circuit.

Advantages:

1. It can be used to measure both ac as well dc quantities.
2. It is free from hysteresis and eddy current errors.
3. Accuracy of this instrument is high.
4. Power consumption is less.
5. The scale is uniform.

Disadvantages:

1. It has low torque / weight ratio and hence low sensitivity.
2. They are more expensive than PMMC or moving iron instrument.
3. Low torque / weight ratio gives increased frictional losses.
4. Stray field may affect the reading of the instrument.

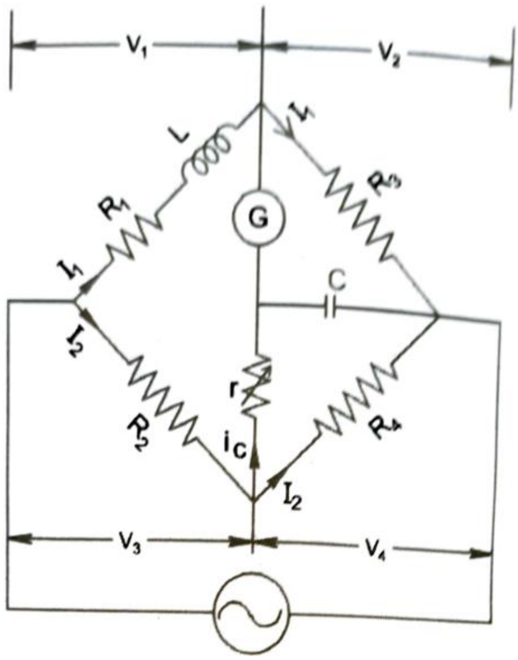
14.(a) Explain Anderson bridge with the circuit diagram. 14 marks

[Diagram – 7 marks; Explanation – 7 marks]

- Anderson bridge is an AC bridge used to measure inductance ranging from a few microhenries to few Henries.
- It is the modification of the Maxwell's induction or inductance capacitance bridge.

Construction:

- In this method the unknown self-inductance is measured in terms of a known capacitance and resistance by comparison.
- Here,
  - L - Self-inductance to be measured.
  - R1 - Resistance of the coil under test.
  - R2, R3, R4 - Known non-inductive resistor
  - r - Variable resistor.
  - C - Fixed standard capacitor



Anderson Bridge

Operation:

- Balance is obtained by varying 'r' after substituting proper values R2, R3 and R4.
- The bridge is balanced when the potential difference across the galvanometer is '0' V.
- At balance the voltage drop across arm 1 is equal to voltage drop across arm 2.
- Under balance, the real and imaginary parts of voltage drops V1 & V2 are equated.
- Then we get the following results.

$$R_1 = R_2 \frac{R_3}{R_4}$$

$$L = C \frac{R_3}{R_4} [r(R_2 + R_4) + R_2 R_4]$$

- The value of unknown self-inductance L is found by using above formula.

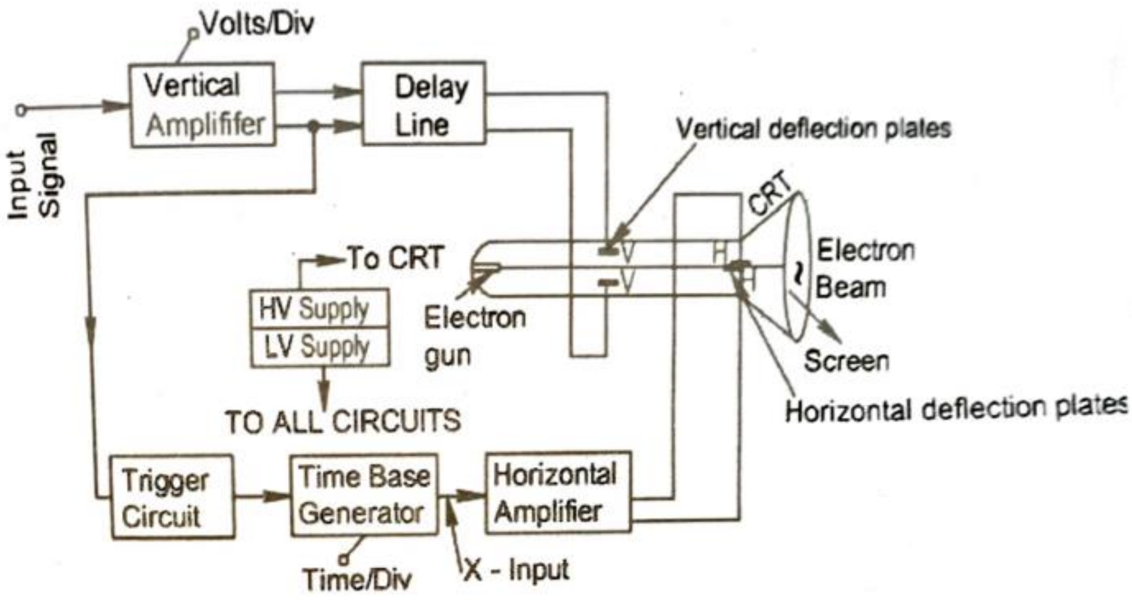
14.(b) Draw the block diagram of a general purpose CRO and explain. 14 marks

[Diagram – 7 marks; Explanation – 7 marks]

- The cathode ray oscilloscope (CRO) is an electronic instrument. It is basically a very fast X-Y plotter.
- The style of this plotter is a luminous spot.
- The luminous spot moves Over the display area in response to input voltage.

- The CRO has the following sub-systems:
  1. Cathode ray tube (CRT)
  2. Vertical amplifier
  3. Horizontal amplifier
  4. Time-base generator
  5. Trigger circuit
  6. Delay Line

BLOCK DIAGRAM OF CRO:



Block Diagram of CRO

Cathode Ray Tube (CRT):

- It is the main part of the CRO. It produces a sharply focussed beam of electrons, and is accelerated to a very high velocity.
- The beam of electrons travels from its source (Electron gun) to the screen of the CRT. The screen is coated with fluorescent material and produces small spot of light on the screen.

Vertical amplifier:

- Vertical amplifier is also called Y-amplifier. It controls the amplitude of the displayed voltage signal.
- It has a calibrated step attenuator.
- A change in the attenuator varies the total amplification of the input signal and in turn the vertical displacement of the electron beam on the CRT.
- The calibration setting on the attenuator switch gives the rate of deflection in Volts/cm or Volts/division.

Horizontal amplifier:

- Horizontal amplifier is also called X-amplifier.
- It controls the time relationship or frequency of the voltage signals.
- Therefore, it has to be accompanied with the time base generator circuit.

Time base generator:

- Time base generator is used to reproduce the Waveform accurately.
- It generates ramp voltage which is having constant horizontal velocity which is the function of deflecting voltage and expressed in time/div.

Tigger Circuit:

- If each horizontal sweep is started at the same point on the signal waveform, a stable display can be maintained on the screen for an input signal which is of a recurrent nature.
- To achieve this, a sample of the input waveform is fed to a trigger circuit. Trigger circuit produces a trigger pulse at some selected point on the input waveform.
- This trigger pulse is used to start the time base generator.

Delay Line:

- Delay line is mainly used to delay the transmissions signal voltage to deflection plates.

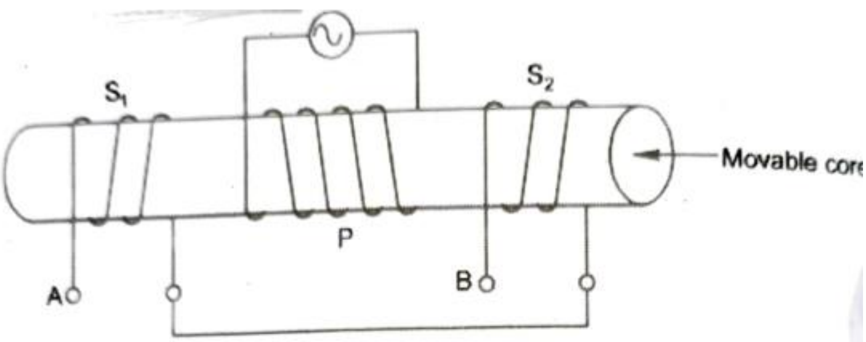
Power supply:

- The power supply consists of power transformer, filters and stabilisers.
- A low-tension voltage is required for the CR tube filament which is obtained from the L.T. secondary of the power transformer of the power supply.
- And in the same way H.T supply for accelerating anode is also taken from the secondary of the transformer.
- Hence the power Supply must have a provision to provide several voltages for different electrodes and filaments.

15.(a) Describe with the neat diagram about the construction and working principle of LVDT. 14 marks

[Diagram – 7 marks; Explanation – 7 marks]

- LVDT (Linear Variable Differential Transformer) is a passive inductive transducer, which used to measure force, pressure and acceleration etc.,



Linear Variable Differential Transformer

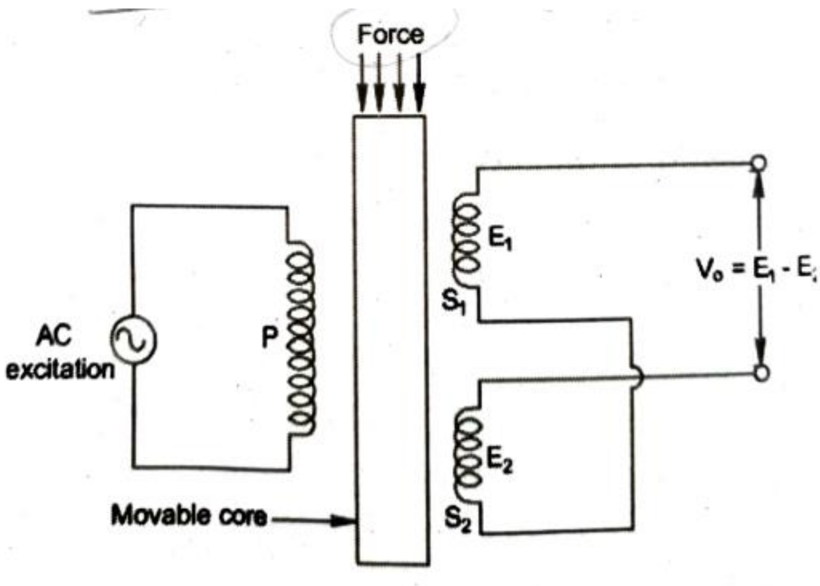
Construction:

- It consists of a single primary winding (P) and two secondary windings (S1 & S2) which are placed on either side of the primary winding as shown in figure.
- The two secondary windings have equal number of turns but are connected in series opposition.
- The primary winding is excited with an ac Source.
- All the windings are mounted on the same magnetic core.
- A movable soft iron core is placed inside the coil.
- The core is mechanically coupled with moving object.

Working:

- When an A.C voltage is applied to the primary, voltages induced in the two secondary windings which are the functions of the relative position of the iron core with respect to the coil.
- The output voltage (Vo) is equal to the difference between the two output voltages (E_1 & E_2).

$$V_o = E_1 \sim E_2$$



Working of LVDT

Case 1:

- When the core is in the centre, the two secondary induced voltages are equal and opposite. Hence the net output will be zero.

Case 2:

- When the iron core moves upwards, the voltage induced in the upper winding is more than the voltage induced in the lower winding. Hence the net output is positive.

$$V_o = E1 - E2$$

Case 3:

- When the iron core moves downwards, the voltage induced in upper winding is less than the voltage induced in the lower winding. Hence the net output is negative.

$$V_o = E2 - E1$$

- The magnitude of V_o is a function of the distance moved by the core and its polarity indicates the direction it has moved.

15.(b) Explain the construction and working principle of Photovoltaic Transducer with neat diagram. 14 marks

[Diagram – 7 marks; Explanation – 7 marks]

- Photo voltaic transducer is an important class of photo detectors.
- They generate a voltage which is proportional to EM radiation intensity.
- The solar cell converts EM energy into electrical energy.
- The solar cells are passive transducers, i.e., they do not need any external sources to power them.
- The structure of a photovoltaic cell is shown in the figure.

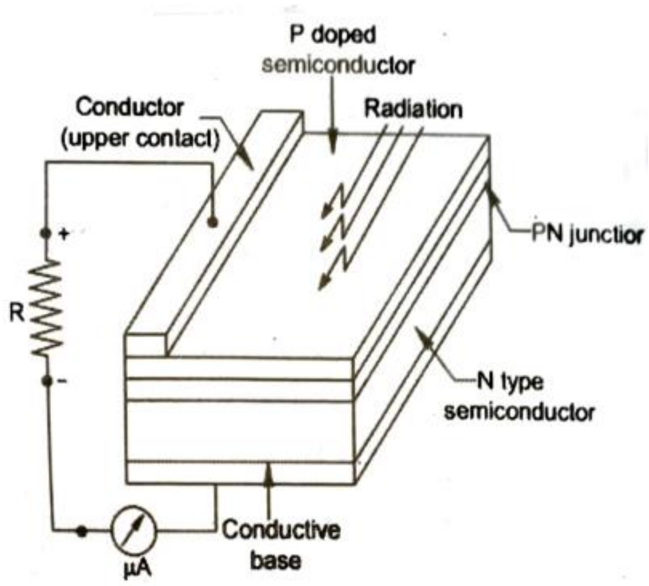


Photo Voltaic cell

- The cell is a giant diode, constructing a PN junction between appropriately doped semiconductors.
- Photon striking the cell passes through the thin P doped upper layer and is absorbed by electrons in the lower N layer, causing formation of conduction electrons and holes.
- The PN junction depletion potential then separates these conduction holes and electrons causing a difference of potential to develop across the junction.
- The photovoltaic cells can operate satisfactorily in the temperature range of -100 to 125° C.
- The voltage produced from the solar cell is proportional to the area of the cell and increases with illuminance.
- The generation of emf within the cell takes place within a microsecond after exposure to light, but the build-up of the output voltage is delayed by the large internal capacitance of the barrier layer system.
- The solar cell is affected by temperature.
- The voltage and current decrease rapidly with increase in temperature.

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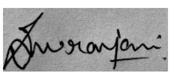

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