

## **1. What is the basic principle of operation of deflection-type meters?**

Deflection-type meters operate on the principle that a mechanical force is created by the quantity being measured, such as current or voltage. This force acts upon a movable element, causing it to displace from its zero position. The movement is typically opposed by a controlling force, such as a spring, which ensures the deflection is proportional to the magnitude of the measured quantity. Once the deflecting torque and controlling torque balance out, the pointer comes to rest at a specific point on a calibrated scale. This allows the user to read the value of the electrical parameter directly.

## **2. What is the relevance of controlling torque in such meters and how is this attained?**

Controlling torque is essential because, without it, the pointer would move to the maximum position regardless of the magnitude of the measured quantity. It serves to oppose the deflecting torque and ensures that the deflection of the pointer is limited and proportional to the input signal. This torque also brings the moving system and pointer back to the zero position once the measurement is removed. It is typically attained using gravity control or spring control, with hairsprings made of phosphorous-bronze being the most common method.

## **3. What do you mean by grounding? Explain, citing an example.**

Grounding refers to the process of connecting the non-current-carrying metallic parts of an electrical instrument or system to the earth. This provides a low-resistance path for leakage currents, ensuring they do not build up on the chassis or enclosure. By doing so, it protects users from electric shocks and prevents damage to sensitive electronic components. For example, in a high-voltage measurement system, grounding the metal case of a voltmeter ensures that if an internal fault occurs, the fault current flows to the earth rather than through a person touching the case.

## **4. Explain the significance of damping in deflection-type instruments.**

Damping is necessary to prevent the pointer from oscillating around its final steady-state position due to inertia. Without damping, the pointer would take a long time to settle, making it difficult to take quick and accurate readings. Damping forces act only when the pointer is in motion and disappear once it reaches a steady position. Common methods include air friction damping, fluid friction damping, and eddy current damping. This ensures the instrument is "dead-beat," meaning the pointer reaches its final value quickly without excessive swinging.

## **5. Write a short note on the sources and detectors used in the a.c.**

## **bridge.**

A.C. bridges require a stable power source and a sensitive detector to identify the null or balanced condition. For low-frequency applications, power oscillators or the mains supply (with a transformer) are typically used as sources. For detectors, common choices include headphones (for audio frequencies), vibration galvanometers (for low frequencies), or tunable amplifier detectors. The choice of detector depends heavily on the frequency range of the bridge being used. These components work together to ensure that unknown impedances can be measured with high precision.

## **6. Illustrate an electrodynamic instrument.**

An electrodynamic instrument, or dynamometer, consists of two fixed coils and one moving coil. The fixed coils are usually split into two halves to produce a uniform magnetic field in the center. The moving coil is mounted on a spindle between the fixed coils and is attached to a pointer. When current flows through both the fixed and moving coils, a magnetic field interaction occurs, creating a torque that deflects the pointer. This type of instrument is unique because it can measure both AC and DC accurately since the torque direction remains the same even if the current reverses.

## **7. List the disadvantages of a moving iron meter.**

Moving iron meters suffer from several limitations, primarily their non-linear or "squared" scale, which is cramped at the lower end. They are subject to errors caused by hysteresis in the iron parts when used with AC. Stray magnetic fields can also easily interfere with their accuracy because their internal operating magnetic field is relatively weak. Furthermore, they are sensitive to changes in frequency, which can affect the reactance of the coil and thus the reading. Finally, they generally have higher power consumption compared to permanent magnet moving coil (PMMC) instruments.

## **8. What is the working principle of a deflection-type indicating instrument?**

The working principle involves the conversion of electrical energy into mechanical energy to produce a deflecting torque. When the quantity to be measured flows through the instrument, it interacts with a magnetic or electrostatic field to produce a force. This force moves a pointer across a scale until it is balanced by a controlling torque, usually provided by a spring. Damping torque is also applied to ensure the pointer settles quickly at the correct value. The final position of the pointer represents the magnitude of the current, voltage, or power being measured.

## **9. Explain the construction and working of a D'Arsonval Galvanometer.**

The D'Arsonval Galvanometer consists of a light rectangular coil of thin wire suspended in a permanent magnetic field. A soft iron core is placed inside the coil to concentrate the magnetic flux and ensure a radial field. When a small DC current passes through the coil, it experiences a Lorentz force, creating a deflecting torque. This torque causes the coil to rotate, and the rotation is indicated by a pointer or a light beam reflected from a mirror. The movement is opposed by the torsion of the suspension wire or a spring, providing the necessary controlling torque.

## **10. Differentiate between moving iron and moving coil instruments.**

Moving coil (PMMC) instruments use a permanent magnet and a moving coil, whereas moving iron instruments use a stationary coil and a moving piece of soft iron. PMMC instruments are only suitable for DC measurements, while moving iron instruments can measure both AC and DC. The scale of a PMMC instrument is linear, but the scale of a moving iron instrument is non-linear (square law). PMMC instruments are generally more accurate and sensitive but more expensive than moving iron types. Additionally, damping in PMMC is eddy-current based, while moving iron typically uses air friction damping.

## **11. Why are moving coil instruments not used for AC measurements?**

Moving coil (PMMC) instruments are not used for AC because the direction of the torque depends on the direction of the current. In an AC circuit, the current reverses its direction rapidly (e.g., 50 or 60 times per second). This causes the torque to reverse just as quickly, and due to the inertia of the moving system, the pointer cannot follow these rapid changes. Consequently, the pointer simply vibrates at the zero position or shows a net average reading of zero. To measure AC with this technology, a rectifier must be used to convert AC to DC first.

## **12. What is the function of damping in indicating instruments?**

Damping is utilized to bring the moving system of an instrument to rest at its final position quickly and without oscillation. When the deflecting and controlling torques are equal, the pointer has kinetic energy that causes it to "overshoot" the correct mark. Damping provides an opposing force that is proportional to the velocity of the moving system, absorbing this excess energy. It ensures that the measurement can be read immediately, improving the efficiency of the operator. Without damping, the pointer would swing back and forth for several seconds, leading to uncertainty in the reading.

## **13. A 0–10 A moving coil ammeter has a resistance of 1 $\Omega$ . What shunt resistance is required to measure up to 50 A?**

To extend the range of an ammeter, a shunt resistance ( $R_s$ ) must be connected in parallel with the meter. The formula used is  $R_s = R_m / (n - 1)$ , where  $R_m$  is the meter resistance and  $n$  is the multiplying factor. In this case, the multiplying factor  $n$  is the new maximum current divided by the original full-scale deflection current ( $50/10 = 5$ ). Using the formula:  $R_s = 1 / (5 - 1) = 1 / 4 = 0.25 \Omega$ . Therefore, a shunt resistance of  $0.25 \Omega$  is required to measure up to  $50 \text{ A}$ .

#### **14. How are instrument transformers used for protection and metering in high-voltage systems?**

Instrument transformers, which include Current Transformers (CT) and Potential Transformers (PT), isolate measuring instruments from high-voltage circuits. They step down high currents and voltages to standardized low values (typically  $5 \text{ A}$  or  $110 \text{ V}$ ) that are safe for standard meters. For protection, they provide signals to relays that can trigger circuit breakers during a fault. For metering, they allow for the accurate measurement of power and energy consumption in the grid. This ensures both the safety of the personnel and the longevity of the measurement equipment.

#### **15. Describe how current probes measure DC current in a live wire.**

DC current probes often utilize the Hall Effect or a fluxgate magnetometer to measure the magnetic field generated by the current. Unlike standard AC-only clamps, these probes can detect the static magnetic field produced by direct current. The probe is "clamped" around the live wire, and the internal sensor generates a voltage proportional to the strength of the magnetic field. This voltage is then processed and displayed as a current reading on a digital meter. This method is non-invasive, meaning the circuit does not need to be broken to take a measurement.

#### **16. Explain the necessity of shielding in a measurement system with an example.**

Shielding is necessary to protect sensitive measurement signals from external electromagnetic interference (EMI) and electrostatic noise. External fields from power lines or nearby electronic devices can induce unwanted voltages in the measurement leads, leading to errors. For example, when measuring low-level signals from a pH sensor or a thermocouple, a metal "shield" or braid is wrapped around the signal wires. This shield is usually grounded, so the external noise is intercepted and drained to the earth rather than affecting the signal. This ensures the integrity and accuracy of the data being collected.

#### **17. How does improper grounding affect instrument accuracy and**

## **safety?**

Improper grounding can create "ground loops," where small potential differences between different ground points cause unwanted current to flow through the signal lines. This introduces noise and offsets that significantly degrade the accuracy of the instrument. From a safety perspective, poor grounding can leave the metal chassis of an instrument at a high potential if an internal insulation failure occurs. This creates a severe electric shock hazard for any operator who touches the device. In summary, it compromises both the reliability of the data and the physical safety of the user.

## **18. Draw and label the internal structure of a moving coil instrument.**

The internal structure of a moving coil (PMMC) instrument features a permanent magnet with pole pieces that create a steady magnetic field. Inside this field, a lightweight aluminum former carries a coil of fine wire. A soft iron core is situated inside the former to ensure the magnetic flux is radial and uniform. The coil assembly is mounted on a spindle supported by jewel bearings to minimize friction. Hairsprings provide the controlling torque and serve as electrical connections to the coil, while a pointer is attached to the spindle to indicate readings.

## **19. What are the essential components of an indicating instrument?**

### **Briefly explain each.**

The essential components of an indicating instrument are the deflecting system, controlling system, and damping system. The **deflecting system** uses the measured quantity to produce a mechanical force that moves the pointer. The **controlling system** provides an opposing force to ensure the deflection is proportional to the input and returns the pointer to zero. The **damping system** prevents the pointer from oscillating and helps it settle quickly. Finally, the **pointer and scale** serve as the visual interface for the user to read the measurement.

## **20. Describe the principle of operation of a deflection-type instrument.**

A deflection-type instrument operates by converting an electrical signal into a mechanical displacement. When current or voltage is applied, it generates a deflecting torque through electromagnetic, electrostatic, or induction means. This torque moves a moving element against a restoring or controlling torque. The moving element stops when these two opposing torques are equal, providing a steady reading. Damping is used to ensure this steady state is reached rapidly without vibration.

## **21. What is the difference between controlling torque and deflecting torque in measuring instruments?**

Deflecting torque is the force produced by the electrical quantity (current or voltage) being measured, causing the pointer to move from its zero position. Controlling torque, on the other hand, is the force that opposes the deflecting torque and increases as the pointer moves further. While deflecting torque tries to move the pointer to the end of the scale, controlling torque ensures it stops at a point proportional to the input. Without deflecting torque, there is no measurement; without controlling torque, the pointer would simply fly to the maximum stop. Additionally, controlling torque is responsible for returning the pointer to zero when the input is removed.

## **22. Compare and contrast attraction and repulsion types of moving iron instruments.**

Attraction-type instruments work by pulling a single soft iron vane into a stationary coil when current flows through it. Repulsion-type instruments use two iron vanes (one fixed and one moving) placed inside a coil; when current flows, both vanes are magnetized with the same polarity and repel each other. While both can measure AC and DC, repulsion types generally offer a more uniform (though still non-linear) scale. Both utilize air friction damping and spring control for their operation. The attraction type is generally simpler in construction, but the repulsion type is more commonly used in modern panels.

## **23. What are the limitations of moving iron instruments in AC measurements?**

Moving iron instruments are limited by frequency errors, as the impedance of the coil changes with the frequency of the AC signal. They are also prone to hysteresis errors, where the magnetization of the iron vane lags behind the current, leading to different readings for increasing and decreasing values. Stray magnetic fields significantly impact their accuracy because their internal field is relatively weak. Eddy currents induced in the metal parts of the instrument at high frequencies can also cause heating and errors. Lastly, their scale is non-linear, making it difficult to read small values accurately.

## **24. What are deflection-type meters, and how do they differ from other types of measuring instruments?**

Deflection-type meters are instruments where the measured value is indicated by the displacement of a pointer over a calibrated scale. They differ from "null-type" instruments (like bridges) because they don't require balancing; they provide a direct reading. They also differ from digital meters, which use electronic sampling and numerical displays instead of mechanical movement. Deflection meters are generally preferred for monitoring trends or rapid changes in a signal because the movement of the pointer is easy to track visually. They are categorized by their operating principles, such as PMMC, moving iron, or

electrodynamometer.

## 25. What is the principle behind the operation of electrostatic instruments?

Electrostatic instruments operate based on the force of attraction or repulsion between two or more charged conductors. These instruments essentially act as a variable capacitor, where the voltage to be measured is applied across fixed and moving plates. The resulting electrostatic force creates a deflecting torque that moves the plates and an attached pointer. Because they rely on static charges, they draw virtually no current from the circuit, making them ideal for high-voltage DC and AC measurements. Their main advantage is their extremely high input impedance, which prevents loading the circuit being measured.

## 26. Explain the principle of operation for induction type instruments.

Induction-type instruments operate on the principle of electromagnetic induction and are only suitable for AC measurements. They consist of two electromagnets that produce an alternating magnetic flux, which induces eddy currents in a conducting disc or drum. The interaction between these induced eddy currents and the alternating magnetic flux creates a torque that rotates the disc. This torque is proportional to the square of the current or the product of voltage and current, depending on the instrument type. A spring provides the controlling torque, and a pointer attached to the disc indicates the value.

## 27. Why is damping necessary in an indicating instrument? What are the types of damping used?

Damping is necessary because the moving system of an instrument has inertia, causing the pointer to oscillate around the steady-state position before settling. This makes it difficult to take an immediate, accurate reading. There are three main types of damping: **Air friction damping**, which uses a piston in a chamber; **Fluid friction damping**, which uses vanes in a viscous oil; and **Eddy current damping**, which uses a metal disc moving in a magnetic field. Eddy current damping is generally the most efficient and is widely used in PMMC instruments.

## 28. What is the principle of operation of a D'Arsonval galvanometer? Obtain the torque equation in terms of the current measured.

The D'Arsonval galvanometer operates on the principle that a current-carrying coil in a magnetic field experiences a torque. The deflecting torque ( $T_d$ ) is given by the equation  $T_d = NBI A$ , where  $N$  is the number of turns,  $B$  is the magnetic flux density,  $I$  is the current, and  $A$  is the area of the coil. In a steady state, this is balanced by the controlling torque  $T_c = K\theta$ , where  $K$  is the spring constant and  $\theta$  is the deflection angle.

Equating the two, we get  $\theta = NBI$ , which shows that the deflection  $\theta$  is directly proportional to the current  $I$ .

### **29. What are the applications of the current transformers?**

Current transformers (CTs) are primarily used to measure high currents by stepping them down to a safer, lower level (usually 5 A). They are widely used in power plants and substations for metering electricity consumption. Another critical application is in protective relaying, where they sense overcurrent or fault conditions and signal a circuit breaker to trip. They are also used in industrial control systems to monitor the load on large motors or heaters. Because they provide electrical isolation, they protect both the equipment and the operators from high-voltage hazards.

### **30. Describe the construction and working principle of a moving coil instrument.**

A moving coil (PMMC) instrument consists of a light, rectangular coil wound on an aluminum former and placed in the field of a permanent magnet. A soft iron core is fixed inside the coil to ensure the magnetic field is radial and uniform. When current passes through the coil, the interaction with the permanent magnet produces a deflecting torque. This causes the coil and the attached pointer to rotate against the force of two hairsprings. The aluminum former also serves to provide eddy current damping, ensuring the pointer settles quickly.

### **31. What are the applications of the potential transformers?**

Potential transformers (PTs) are used to step down high voltages to a standard low voltage (usually 110 V) for measurement and control. They are essential for operating voltmeters, wattmeters, and energy meters on high-voltage transmission lines. PTs also provide the necessary voltage signals for protective relays that monitor for under-voltage or over-voltage conditions. They ensure that instruments are electrically isolated from the high-voltage side, enhancing safety for personnel. Additionally, they are used in synchronizing circuits where two parts of a power system need to be connected.

### **32. Explain the method used in moving iron instruments to achieve calibration and accurate measurements.**

Calibration in moving iron instruments is achieved by adjusting the position of the iron vanes and the strength of the controlling springs. Since the torque is proportional to the square of the current, the scale is naturally non-linear; manufacturers often shape the iron vanes to make the scale more uniform. To ensure accuracy, high-permeability materials like Mu-metal are used for the vanes to reduce hysteresis errors. Magnetic shielding is often added to protect the instrument from external stray fields. Final calibration involves comparing the meter readings

against a standard instrument and adjusting the scale markings accordingly.

### **33. Discuss the advantages and limitations of using a dynamometer instrument compared to other types of indicating instruments.**

Dynamometer instruments are highly accurate and can be used as "transfer instruments," meaning they can be calibrated on DC and then used to measure AC. They are free from hysteresis and eddy current errors because they do not use iron cores. However, they have a weak operating magnetic field, making them very sensitive to external stray magnetic fields. They also have high power consumption because they need to energize both fixed and moving coils. Furthermore, their scale is non-linear (square law), which can make them harder to read at the lower end.

### **34. Explain the method used in dynamometer instruments to achieve calibration and accurate measurements.**

To achieve high accuracy in dynamometer instruments, they are constructed without iron to eliminate hysteresis and eddy current errors. Calibration is typically performed using a precise DC source, as the instrument responds equally to the RMS value of AC. Magnetic shielding is often employed to mitigate the effects of external stray fields, which can easily disrupt the weak internal field. The coils are wound carefully to ensure uniformity, and the springs are aged to maintain a constant controlling torque. Finally, the scale is precisely marked by comparing the deflection against a high-precision standard meter.

### **35. Discuss the main sources of errors in electro-dynamometer type of instruments. Explain their advantages and disadvantages.**

The main sources of errors include stray magnetic fields, frequency variations, and temperature changes. Because they have no iron core, their internal magnetic field is weak and easily influenced by outside fields. Frequency changes affect the reactance of the coils, while temperature changes can alter the resistance and spring tension. Their primary advantage is their ability to measure both AC and DC with high precision (transfer instrument). Their disadvantages include a non-linear scale, high power consumption, and a higher cost compared to moving iron or PMMC meters.

### **36. Explain why the PMMC instruments are the most widely used instruments. Discuss their advantages and disadvantages.**

PMMC instruments are widely used because they have high sensitivity and a perfectly linear scale. They consume very little power and are highly accurate due to the strong magnetic field provided by the permanent magnet. Their primary disadvantage is that they can only measure

DC directly; AC measurements require a rectifier. They are also generally more expensive and delicate than moving iron instruments. Despite these drawbacks, their reliability and precision make them the standard choice for most DC measurement applications.

### **37. List the advantages of PMMC meters.**

PMMC meters offer several significant advantages, including a uniform and linear scale that is easy to read. They possess a high torque-to-weight ratio, which results in excellent sensitivity and accuracy. The power consumption is extremely low, making them efficient for various circuits. They have effective eddy current damping, which allows the pointer to settle almost instantly. Finally, because they use a strong permanent magnet, they are relatively unaffected by external stray magnetic fields.

### **38. List the errors in PMMC meters.**

Errors in PMMC meters can arise from the aging of the permanent magnet, which reduces the magnetic flux density over time. Temperature variations can also affect the resistance of the copper coil and the tension of the hairsprings. Friction in the jewel bearings can lead to "sticking" or inaccuracies, especially in older or poorly maintained units. While they are resistant to stray fields, extremely strong external magnets can still cause some interference. Finally, parallax error can occur if the user does not read the pointer from directly above the scale.

### **39. Explain the working of repulsion type of moving iron instruments with the help of a neat diagram.**

The repulsion type of moving iron instrument works by placing two soft iron vanes—one fixed and one movable—inside a stationary coil. When current flows through the coil, it creates a magnetic field that magnetizes both vanes with the same polarity at the same ends. This results in a force of repulsion between the two vanes, which pushes the movable vane away. The movable vane is attached to a spindle and pointer, which deflects across the scale. This movement is opposed by a controlling spring, and the final deflection is proportional to the square of the current.

### **40. Describe the methods of producing controlling and damping torques in moving iron instruments.**

In moving iron instruments, controlling torque is almost always produced using hairsprings made of phosphorous-bronze. Gravity control is an alternative, but it requires the instrument to be perfectly leveled, making it less common. Damping torque is typically achieved through air friction damping. This involves a lightweight aluminum piston moving inside a closed air chamber or "damping vane". Eddy current damping is usually avoided in these meters because

the presence of a damping magnet would interfere with the operation of the moving iron vane.

#### **41. Explain the working of an attraction type moving iron instrument with the help of a diagram.**

An attraction-type moving iron instrument consists of a stationary coil and a single oval-shaped soft iron vane attached to a spindle. When the quantity to be measured flows through the coil, it creates a magnetic field. The iron vane is then attracted into the center of the coil where the magnetic field is strongest. As the vane moves inward, it rotates the spindle and the attached pointer across the scale. This attraction occurs regardless of the direction of the current, allowing the instrument to measure both AC and DC.

#### **42. Explain why the electrodynamicometer instruments can be used both for ac and dc?**

Electrodynamometer instruments can be used for both AC and DC because the deflecting torque is proportional to the product of the currents in the fixed and moving coils. In a DC circuit, the torque direction is constant. In an AC circuit, the current in both the fixed and moving coils reverses at the same time. Since both currents change polarity simultaneously, the product (and thus the torque direction) remains positive. This results in a unidirectional torque that causes the pointer to deflect in the same direction regardless of the AC cycle.

#### **43. Why are these instruments used as transfer instruments?**

Dynamometer instruments are used as transfer instruments because their operating principle is identical for both AC and DC. Since they do not contain iron, they are free from errors like hysteresis that affect other meters differently on AC than on DC. This means they can be calibrated with very high precision using a DC standard (like a potentiometer) and then used to measure AC with the same level of accuracy. They essentially "transfer" the accuracy of DC measurements to AC circuits. This makes them indispensable for secondary standards in calibration laboratories.

#### **44. Write a note on the grounding and shielding practices in measurement systems.**

Effective grounding and shielding are critical for ensuring the safety and accuracy of measurement systems. Grounding involves connecting the instrument's metallic parts to the earth to prevent dangerous voltage buildups and minimize noise. Shielding involves enclosing sensitive signal wires in a conductive material to block external electromagnetic interference. Best practices include using "single-point grounding" to avoid ground loops and ensuring that shields are only grounded at one end to prevent noise current from flowing through them.

These techniques together ensure that low-level signals are not drowned out by environmental noise.

#### **45. What do you mean by shielding? Explain, with an example.**

Shielding is the use of a conductive barrier to protect electrical signals from external electromagnetic or electrostatic interference. It works by intercepting the external fields and directing them to the ground before they can induce noise in the signal-carrying wires. For example, in a medical ECG machine, the leads connected to the patient are shielded with a metal mesh. This prevents the 50/60 Hz hum from nearby power lines from appearing on the heart monitor display. Without this shielding, the delicate electrical signals of the heart would be completely obscured by environmental noise.

#### **46. How is the range of D.C. Ammeter and D.C. voltmeter extended?**

The range of a DC ammeter is extended by connecting a low-resistance "shunt" in parallel with the meter. This allows most of the current to bypass the delicate meter movement. The range of a DC voltmeter is extended by connecting a high-resistance "multiplier" in series with the meter. This limits the voltage that appears across the meter movement itself. In both cases, the added resistance is calculated based on the internal resistance of the meter and the desired full-scale reading.

#### **47. Derive the expressions to calculate shunt resistance and multiplier resistance.**

For an ammeter shunt, the resistance ( $R_s$ ) is derived using the current division principle:  $I_m R_m = I_s R_s$ , where  $I_s = I - I_m$ . This leads to  $R_s = R_m / (n - 1)$ , where  $n = I / I_m$  is the multiplying factor. For a voltmeter multiplier, the total resistance required is  $R_T = V / I_m$ , where  $V$  is the new full-scale voltage. Since the multiplier ( $R_{ser}$ ) is in series with the meter resistance ( $R_m$ ),  $R_{ser} = R_m(m - 1)$ , where  $m = V / v_m$  is the voltage multiplying factor. These formulas allow for the precise extension of any meter's measuring range.

#### **48. What are the advantage and disadvantage of induction type instruments?**

Induction-type instruments are known for being robust, reliable, and capable of producing a high torque, which makes them very durable. They are specifically designed for AC measurements and can be used to measure power (wattmeters) or energy (energy meters) effectively. However, they have the major disadvantage of being unusable for DC measurements. They are also highly sensitive to changes in frequency and temperature, which can introduce significant errors. Additionally, they generally have higher power consumption

compared to other instrument types.