EMII NOTES

Unit-1 Measurements of Voltage and Current

1.1 Significance of measurement:

Measurement refers to the process of quantitatively determining the size, quantity, or extent of something. It involves assigning numbers or values to physical quantities or properties of objects, events, or phenomena. Measurements provide a standardized and objective way of describing and comparing the attributes of the things being measured.

In order to make measurements, various tools and instruments are used, such as rulers, thermometers, scales, timers, and spectrometers, depending on the nature of the quantity being measured. The result of a measurement is typically expressed using a specific unit of measurement, such as meters, grams, seconds, or degrees Celsius.

Measurement involves two key components: the measurement itself, which is the numerical value, and the unit of measurement, which provides the context and scale for the measurement. For example, measuring the length of an object as "10 centimeters" involves the numerical value "10" (measurement) and the unit "centimeters" (unit of measurement).

Accurate and precise measurement is essential for obtaining reliable data, making scientific observations, performing experiments, manufacturing products, conducting research, and solving problems. It allows for consistency, repeatability, and the ability to compare and communicate measurements effectively.

* Measurement plays a crucial role in various fields, including science, engineering, industry, and everyday life.
* It involves the quantification and comparison of physical quantities to obtain meaningful information and make informed decisions
* we will explore the significance of measurement and its impact on different aspects of our lives.

I. Obtaining Objective Information:

A. Measurements provide objective and quantitative data about physical phenomena, eliminating subjective biases.

B. They allow us to describe, compare, and analyze various properties, such as length, mass, time, temperature, and more.

C. Objective measurements serve as a basis for scientific investigations, technological advancements, and quality control in industries.

II. Precision and Accuracy:

A. Precision refers to the degree of consistency or reproducibility in measurements. B. Accuracy refers to how close the measured value is to the true or accepted value. C. Precise and accurate measurements ensure reliable results and reduce errors in scientific experiments, engineering designs, and manufacturing processes.

III. Quantifying and Monitoring Change:

A. Measurement enables us to quantify changes in physical quantities over time or under different conditions.

B. It helps track trends, identify patterns, and assess the impact of variables in scientific research, environmental monitoring, and economic analysis.

C. Precise measurements of small changes can lead to significant advancements, such as detecting gravitational waves or monitoring climate change.

IV. Making Informed Decisions:

A. Measurements provide data that informs decision-making processes.

B. In fields like medicine, measurements of vital signs, blood pressure, or laboratory tests help diagnose diseases, determine treatment effectiveness, and monitor patient health.

C. In finance and economics, measurements of economic indicators, market trends, and performance metrics guide investment decisions and policy-making.

V. Standardization and Interoperability:

A. Standard units of measurement, such as the International System of Units (SI), ensure consistency and facilitate communication across different regions and disciplines.

B. Standardization allows for interoperability of measurement systems, exchange of data, and collaboration in global scientific research and international trade.

VI. Quality Control and Safety:

A. Measurements play a crucial role in quality control processes, ensuring products meet specifications and standards.

B. They enable the monitoring and adjustment of manufacturing processes to maintain consistency, minimize defects, and improve efficiency.

C. In fields like construction, aviation, and healthcare, accurate measurements are vital for ensuring safety, preventing accidents, and minimizing risks.

Conclusion:

* The significance of measurement extends across various domains, providing us with objective information, enabling informed decision-making, driving scientific and technological advancements, and ensuring quality and safety.
* Developing measurement skills and utilizing accurate measurement techniques are essential for professionals in numerous fields.
* Embracing the importance of measurement enhances our understanding of the physical world and empowers us to make meaningful contributions to society.

MCQ questions on Significance of measurement

1. Which of the following best describes the significance of measurement?

a) It provides subjective and qualitative data. b) It eliminates the need for scientific investigations. c) It allows for the quantification and comparison of physical quantities. d) It is only relevant in industrial settings.

Answer: c) It allows for the quantification and comparison of physical quantities.

1. Why is precision important in measurement?

a) It ensures the measured value is close to the true value. b) It eliminates errors in scientific experiments. c) It provides subjective biases in data. d) It helps track trends and patterns.

Answer: a) It ensures the measured value is close to the true value.

1. Measurements help in quantifying and monitoring changes in physical quantities. This is valuable in which of the following scenarios?

a) Economic analysis b) Artistic expression c) Personal preferences d) Entertainment purposes

Answer: a) Economic analysis

1. Which of the following is true regarding standardization and interoperability in measurement?

a) It allows for inconsistency and communication barriers. b) It facilitates data exchange and collaboration. c) It only applies to local regions. d) It is unnecessary in global scientific research.

Answer: b) It facilitates data exchange and collaboration.

1. What role does measurement play in quality control?

a) It ensures products meet specifications and standards. b) It minimizes defects in manufacturing processes. c) It has no impact on safety. d) It is not relevant in the field of construction.

Answer: a) It ensures products meet specifications and standards.

1. Why is measurement important in scientific experiments?

a) To establish causality b) To determine statistical significance c) To ensure accuracy and precision d) To create visual representations

1. What is the significance of measurement in engineering and construction?

a) To estimate costs and budgets b) To comply with legal regulations c) To ensure safety and quality d) To improve project management

1. Why is measurement crucial in medicine and healthcare?

a) To diagnose diseases and conditions b) To monitor patient progress and treatment effectiveness c) To prescribe appropriate medications d) To maintain patient confidentiality

1. What is the significance of measurement in education?

a) To evaluate student performance and progress b) To determine teaching effectiveness c) To establish curriculum standards d) To promote lifelong learning

1. Why is measurement important in business and economics?

a) To assess profitability and financial performance b) To conduct market research and analyze consumer behavior c) To evaluate investment opportunities d) To establish ethical business practices

Answers:

1. c) To ensure accuracy and precision
2. c) To ensure safety and quality
3. a) To diagnose diseases and conditions
4. a) To evaluate student performance and progress
5. a) To assess profitability and financial performance

Measurement can be done using various methods and instruments depending on the quantity being measured. Here are some common methods of measurement:

1. Direct Measurement: This involves using instruments to directly measure a quantity. For example, using a ruler to measure the length of an object or using a scale to measure weight.
2. Indirect Measurement: In some cases, it may not be possible or practical to measure a quantity directly. In such cases, indirect measurement methods are used. This involves measuring related quantities and using mathematical formulas or equations to calculate the desired quantity. For example, measuring the diameter and using a formula to calculate the area of a circle.
3. Time-Based Measurement: This method involves measuring the time taken for an event or process to occur. For instance, using a stopwatch to measure the time it takes for a runner to complete a race.
4. Non-Contact Measurement: Certain measurements can be performed without physical contact using specialized instruments. For example, using infrared thermometers to measure temperature without touching the object, or using ultrasonic sensors to measure distance or level.
5. Standardization: To ensure accuracy and consistency, measurements are often compared to standardized units. International systems of units, such as the metric system (SI units), provide standardized units for various quantities like length (meter), mass (kilogram), time (second), and so on.
6. Calibration: Instruments used for measurement need to be calibrated periodically to ensure accuracy. Calibration involves comparing the measurement instrument to a known standard and adjusting it if necessary.
7. Digital Measurement: With the advancement of technology, digital instruments and sensors are widely used for measurements. They provide precise and automated measurements, often with digital displays or computer interfaces.

It's important to follow proper measurement techniques, choose appropriate instruments, and account for any sources of error to ensure accurate and reliable measurements. Additionally, understanding the units and conventions associated with the quantity being measured is crucial for meaningful and consistent communication of measurement results.

Type of measuring instruments:

1. Absolute Instruments: Absolute instruments are those that do not require calibration with reference to any other instrument. They provide direct readings without any additional adjustments. Examples of absolute instruments include:
   * Stopwatch: Measures time intervals directly and does not rely on any other timekeeping device.
   * Thermocouple: Measures temperature directly based on the voltage generated by the junction of two dissimilar metals.
   * Manometer: Measures pressure directly by comparing the pressure of a fluid against a reference pressure.
   * Anemometer: Measures wind speed directly by the rotation of a propeller or cups.
2. An absolute instrument, like the tangent galvanometer, provides direct measurements without the need for calibration or comparison with another standard. In the case of the tangent galvanometer, it is designed to directly measure the magnitude of electrical current flowing through a circuit.

The tangent galvanometer uses the tangent law of magnetism to relate the angle of deflection of a magnetic needle to the magnitude of the current. By observing the deflection angle, the current in the circuit can be determined without the need for comparison to a known standard.

1. Secondary Instruments: Secondary instruments, also known as comparative instruments, require calibration or comparison with a known reference instrument. These instruments provide readings based on a comparison with a standard, rather than giving direct measurements. Examples of secondary instruments include:
   * Vernier Caliper: Measures length or thickness by comparing the position of a sliding jaw against a fixed scale.
   * Analog Voltmeter: Measures voltage by comparing it with the known value of a reference voltage.
   * Analog Ammeter: Measures current by comparing it with the known value of a reference current.
   * Pressure Gauge: Measures pressure by comparing it with a known reference pressure.
   * pH Indicator Paper: Determines the acidity or alkalinity of a solution by comparing the color change of the indicator paper with a standardized pH chart.

Secondary instruments typically require periodic calibration to ensure accuracy, as their readings depend on the accuracy of the reference instrument. Absolute instruments, on the other hand, are inherently self-referencing and do not require external calibration.

Measuring instruments can be classified into three main categories based on their functions: indicating instruments, recording instruments, and integrating instruments. Let's explore each category:

1. Indicating Instruments: Indicating instruments provide a real-time display or readout of the measured quantity. They are primarily used to show the instantaneous value of the parameter being measured. Examples of indicating instruments include:

* Analog Voltmeter: Displays the voltage level on a scale using a pointer and a dial.
* Digital Thermometer: Shows the temperature reading on a digital display.
* Pressure Gauge: Indicates the pressure value using a pointer and a scale.
* Analog Ammeter: Displays the current value on a scale using a pointer and a dial.

1. Recording Instruments: Recording instruments continuously record the variations or changes in the measured quantity over time. They provide a permanent graphical representation of the measured data, allowing for analysis and review. Examples of recording instruments include:

* Chart Recorder: Records the data on a moving chart paper or disk, creating a graph of the measured parameter.
* Data Logger: Automatically records the measured data in digital format for later analysis.

Strip Chart Recorder: Creates a continuous strip chart that displays the variations of the measured quantity. ECG (Electrocardiogram) and EEG (Electroencephalogram) are examples of recording instruments in the field of medical diagnostics.

1. ECG: An ECG is a recording instrument used to measure and record the electrical activity of the heart. It captures and displays the electrical signals generated by the heart as it beats. The instrument consists of electrodes placed on the patient's skin, which detect the electrical impulses and transmit them to the ECG machine. The ECG machine then records the data, typically in the form of a graph or waveform, showing the electrical activity of the heart over time. This allows healthcare professionals to analyze the heart's rhythm, detect abnormalities, and diagnose various cardiac conditions.
2. EEG: An EEG is a recording instrument that measures and records the electrical activity of the brain. It is used to study brain function and diagnose conditions related to the brain's electrical signals. Electrodes are attached to the scalp, and the EEG machine detects and records the electrical signals produced by the brain's neurons. The resulting EEG recording provides information about brain wave patterns, helping medical professionals diagnose conditions such as epilepsy, sleep disorders, and brain injuries.

Both ECG and EEG instruments are recording instruments because they continuously record the electrical signals produced by the heart or brain, respectively. These recordings are essential for medical professionals to analyze and interpret the data to make accurate diagnoses and monitor patients' conditions over time.

1. Integrating Instruments: Integrating instruments measure and accumulate the total quantity or energy consumed over a period of time. They are used to determine the totalized value or integrated sum of a variable. Examples of integrating instruments include:

* Energy Meter: Measures and records the total energy consumption in kilowatt-hours (kWh).
* Flow Totalizer: Determines the total volume or mass flow of a fluid.
* Whirling Hygrometer: Measures and accumulates the humidity over a specific period.

These categories are not mutually exclusive, and some instruments may have capabilities that span multiple categories. The classification helps in understanding the primary function and purpose of the measuring instruments based on their output and operation.

The essential requirements of an indicating instrument are:

* Deflecting torque: This is the torque that causes the pointer to move from its zero position. It is produced by the instrument's sensing element, such as a coil or a moving magnet.

There are several methods of producing deflecting torque in indicating instruments. Some of the most common methods are:

* Electromagnetic induction: This method is used in moving coil instruments. A current-carrying coil is placed in a magnetic field. The magnetic field exerts a force on the coil, which causes it to deflect. The amount of deflection is proportional to the current flowing through the coil.
* Electrostatic induction: This method is used in electrostatic instruments. A charged plate is placed in a uniform electric field. The electric field exerts a force on the plate, which causes it to deflect. The amount of deflection is proportional to the charge on the plate.
* Thermoelectric effect: This method is used in thermocouple instruments. A thermocouple is a device that produces an electric current when there is a temperature difference between its two junctions. The amount of current produced is proportional to the temperature difference.
* Hall effect: This method is used in Hall effect instruments. A Hall element is a device that produces a voltage when it is placed in a magnetic field and a current is flowing through it. The voltage produced is proportional to the strength of the magnetic field and the current flowing through the element.
* Controlling torque: This is the torque that opposes the deflecting torque and brings the pointer back to zero when the deflecting torque is removed. It is produced by a spring or a weight.
* Spring control uses two hairsprings that are wound on the spindle and are coiled in such a way that they are opposite to each other and act against each other. When deflecting torque gets applied on the pointer, the springs start to unwind and produce a controlling torque in the opposite direction. The amount of controlling torque produced by the springs is proportional to the deflection angle.
* Gravity control uses a small weight attached to the moving arm. When the pointer deflects, the weight moves in the opposite direction and produces a controlling torque. The amount of controlling torque produced by the weight is proportional to the sine of the deflection angle.
* Both spring and gravity control methods have their own advantages and disadvantages. Spring control is more accurate and provides a linear scale, but it is more sensitive to temperature changes. Gravity control is less accurate and provides a non-linear scale, but it is less sensitive to temperature changes.
* In general, spring control is used in more accurate instruments, such as ammeters and voltmeters. Gravity control is used in less accurate instruments, such as wattmeter's and power factor meters.
* Here is a table summarizing the advantages and disadvantages of spring and gravity control:

|  |  |  |
| --- | --- | --- |
| Feature | Spring Control | Gravity Control |
| Accuracy | More accurate | Less accurate |
| Temperature sensitivity | More sensitive | Less sensitive |
| Scale linearity | Linear | Non-linear |
| Cost | More expensive | Less expensive |

* Damping torque: This is the torque that prevents the pointer from oscillating after it has been deflected. It is produced by air friction or eddy currents.

There are four methods to produce damping torque:

* Air friction damping uses a piston moving in and out of an air chamber to create a damping torque. The piston is connected to the pointer, and as it moves, it creates air resistance that opposes the motion of the pointer.
* Fluid friction damping uses a fluid, such as oil or mercury, to create a damping torque. The fluid is placed in a chamber around the pointer, and as the pointer moves, it creates friction against the fluid that opposes the motion of the pointer.
* Eddy current damping uses an electric current to create a damping torque. A coil is placed around the pointer, and as the pointer moves, it creates eddy currents in the coil that oppose the motion of the pointer.
* Electromagnetic damping uses an electromagnet to create a damping torque. The electromagnet is placed around the pointer, and as the pointer moves, it creates a magnetic field that opposes the motion of the pointer.

The type of damping torque used depends on the specific application. Air friction damping is the most common type of damping torque, as it is relatively inexpensive and easy to implement. Fluid friction damping is more expensive than air friction damping, but it provides better damping performance. Eddy current damping is the most expensive type of damping torque, but it provides the best damping performance. Electromagnetic damping is a good choice for applications where the pointer must move very quickly, as it provides instant damping.

Here is a table summarizing the advantages and disadvantages of the four methods of damping torque:

|  |  |  |
| --- | --- | --- |
| Method | Advantages | Disadvantages |
| Air friction damping | Inexpensive | Not as effective as other methods |
| Fluid friction damping | More effective than air friction damping | More expensive |
| Eddy current damping | Most effective type of damping | Most expensive |
| Electromagnetic damping | Provides instant damping | Expensive |

There are three main types of errors in measurement:

* Gross errors are mistakes that are made by the observer or the measuring instrument. These errors are usually large and can be easily identified. For example, if an observer misreads the scale on a measuring instrument, this would be a gross error.

Sure, here are some examples of gross errors:

* Misreading the scale on a measuring instrument. For example, reading 23 as 28 on a ruler.
* Using the wrong measuring instrument for the task. For example, using a ruler to measure the volume of a liquid.
* Not following the correct procedure for taking a measurement. For example, not zeroing the instrument before taking a reading.
* Making a calculation error. For example, adding 10 instead of 20 when calculating the final result.
* Accidentally dropping or damaging the measuring instrument. This can cause the instrument to become inaccurate.

Gross errors are usually easy to identify, as they are large and obvious. However, they can still have a significant impact on the accuracy of a measurement. It is important to take steps to minimize gross errors, such as by carefully following the correct procedure for taking a measurement and using a well-calibrated measuring instrument.

Here are some additional tips for avoiding gross errors:

* Pay attention to detail. When taking a measurement, take your time and be careful not to make any mistakes.
* Double-check your work. Once you have taken a measurement, double-check your work to make sure that you have read the scale correctly and made no calculation errors.
* Ask for help if you are unsure. If you are not sure how to take a measurement, ask for help from a more experienced person.
* Systematic errors are errors that are introduced by the measuring instrument or the method of measurement. These errors are consistent in direction and magnitude, and they can be difficult to identify. For example, if a measuring instrument is not calibrated properly, this could introduce a systematic error.

Sure, here are some examples of systematic errors:

* Instrumental errors. These errors are caused by the measuring instrument itself. For example, a thermometer that is not calibrated correctly may always read a few degrees too high or too low.
* Methodological errors. These errors are caused by the method of measurement. For example, if you are measuring the weight of an object, and you do not zero the scale before taking a reading, you will introduce a systematic error.
* Environmental errors. These errors are caused by changes in the environment. For example, if you are measuring the temperature of a liquid, and the temperature of the room changes, you will introduce a systematic error.
* Human errors. These errors are caused by the observer. For example, if you are not careful when taking a measurement, you may introduce a systematic error.

Systematic errors are usually more difficult to identify than gross errors. However, there are a few things that you can do to minimize systematic errors:

* Use a well-calibrated measuring instrument. This will help to ensure that the instrument is not introducing any systematic errors.
* Follow a standardized method of measurement. This will help to ensure that you are taking the measurements in a consistent way.
* Take multiple measurements and average them. This will help to reduce the impact of any systematic errors.
* Be aware of the potential sources of systematic errors. This will help you to identify and minimize these errors.

By following these tips, you can help to minimize systematic errors and ensure that your measurements are accurate.

Here are some additional examples of systematic errors:

* A scale that is not calibrated correctly will always read a few pounds too high or too low.
* A thermometer that is not properly shielded from the sun will always read a few degrees higher than the actual temperature.
* A method of measuring the length of a piece of wire that always produces a result that is slightly too long.
* A person who consistently underestimates the weight of objects.

Systematic errors can be difficult to identify, but they can have a significant impact on the accuracy of a measurement. By following the tips above, you can help to minimize systematic errors and ensure that your measurements are accurate.

* Random errors are errors that are caused by random fluctuations in the system being measured or in the measuring instrument. These errors are unpredictable and cannot be completely eliminated. For example, if the temperature in a room fluctuates slightly, this could introduce random errors in a measurement.

Sure, here are some examples of random errors:

* Variations in the environment. For example, if you are measuring the temperature of a liquid, and the temperature of the room fluctuates slightly, this will introduce random errors in your measurements.
* Variations in the observer. For example, if you are measuring the weight of an object, and you take multiple measurements, you may get slightly different results each time due to random factors such as your own concentration level or the way you hold the object.
* Variations in the measuring instrument. For example, if you are measuring the length of a piece of wire, and you take multiple measurements, you may get slightly different results each time due to random factors such as the way the wire is positioned on the measuring instrument.

Random errors are unpredictable and cannot be completely eliminated. However, there are a few things that you can do to minimize random errors:

* Take multiple measurements and average them. This will help to reduce the impact of random errors.
* Use a well-calibrated measuring instrument. This will help to ensure that the instrument is not introducing any additional random errors.
* Follow a standardized method of measurement. This will help to ensure that you are taking the measurements in a consistent way.
* Be aware of the potential sources of random errors. This will help you to identify and minimize these errors.

By following these tips, you can help to minimize random errors and ensure that your measurements are accurate.

Here are some additional examples of random errors:

* The wind blowing on a thermometer will cause the temperature reading to fluctuate slightly.
* The person taking a measurement may not hold the object perfectly still, which will cause the weight measurement to fluctuate slightly.
* The measuring instrument may not be perfectly calibrated, which will cause the length measurement to fluctuate slightly.

Random errors are unavoidable, but they can be minimized by taking multiple measurements and averaging them. By following the tips above, you can help to ensure that your measurements are accurate despite the presence of random errors.

Here is a table summarizing the three main types of errors in measurement:

|  |  |
| --- | --- |
| Type of Error | Description |
| Gross error | Large, easily identifiable errors that are made by the observer or the measuring instrument. |
| Systematic error | Consistent errors that are introduced by the measuring instrument or the method of measurement. |
| Random error | Unpredictable errors that are caused by random fluctuations in the system being measured or in the measuring instrument. |