PVP 23

Code: 23EE3601

III B.Tech - II Semester - Regular Examinations – APRIL 2026

ELECTRICAL MEASUREMENTS AND INSTRUMENTATION
(ELECTRICAL & ELECTRONICS ENGINEERING)

Duration: 3 hours　　　　　　　　　　Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level　　　　　　　　　　CO – Course Outcome

PART – A

		BL	CO
1.a)	State the reason for fixed coils connected in series and the moving coil connected in parallel.	L2	CO1
1.b)	Recall the difference between a Current Transformer (CT) and a Potential Transformer (PT).	L2	CO2
1.c)	List the applications of capacitive transducers.	L2	CO3
1.d)	Define the Hall effect.	L2	CO4
1.e)	Tell the basic working principle of a successive approximation DVM.	L2	CO1
1.f)	Quote the basic functions of a digital multimeter.	L2	CO1
1.g)	Interpret the remote calibration in intelligent transducers.	L2	CO3
1.h)	Name the main components of a smart energy meter.	L2	CO1

1.i)	Cite the function of the RTU in a SCADA system.	L2	CO1
1.j)	Label the key parameters measured in solar instrumentation?	L2	CO5

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Illustrate the operation of the wattmeter at Low Power Factor (LPF).	L3	CO1	5 M
	b)	With a diagram, explain how a single-phase power factor meter is connected in a circuit for power factor measurement.	L3	CO2	5 M
		OR			
3		Construct the expression for the ratio error in a Potential Transformer. Explain the causes of ratio error in detail.	L3	CO4	10 M
		UNIT-II			
4	a)	Explain the working principle and construction of a capacitive transducer. Discuss how it measures displacement, pressure, or thickness.	L3	CO1	7 M
	b)	Summarize the applications of strain gauges in various industries.	L3	CO2	3 M
		OR			
5	a)	Describe the principle of piezoelectric	L3	CO1	5 M

		transducers and the mechanism by which mechanical stress produces an electrical charge.			
	b)	Interpret how thermocouples are used in temperature measurement.	L4	CO2	5 M
UNIT-III					
6	a)	Summarize the working principle of an integrating-type digital voltmeter and the integration of the input voltage leading to a digital reading.	L3	CO1	6 M
	b)	Recall the advantages and disadvantages of a ramp-type DVM.	L3	CO2	4 M
OR					
7	a)	With the help of a diagram, explain the working principle of a digital tachometer.	L3	CO2	5 M
	b)	Illustrate the principle and applications of a Q meter.	L4	CO4	5 M
UNIT-IV					
8	a)	Analyze the concept of smart instruments and discuss their features in detail.	L4	CO1	5 M
	b)	Interpret HART communication in detail, covering its principles and working mechanism.	L3	CO3	5 M
OR					
9	a)	Develop the concept of Automatic	L3	CO3	6 M

		Meter Reading (AMR) and its key applications in modern utility systems.			
	b)	Correlate the components of a smart energy meter in detail.	L4	CO5	4 M
UNIT-V					
10		Describe the working principle of Phasor Measurement Units (PMUs) and their applications in power grid monitoring.	L3	CO5	10 M
OR					
11	a)	Outline the working principle and significance of sunshine duration measurement in solar energy systems.	L4	CO5	6 M
	b)	Compare the applications of Pyranometers and Pyrheliometers in solar energy systems.	L4	CO5	4 M

III B.Tech, II Semester, Regular Examinations, April 2026

Electrical Measurements and Instrumentation (23EE3601)

Scheme of Evaluation

PART – A

1 (a) – (j) : Answer as per key - 2*10 = 20

PART - B

2 (a) Principle (1 Mark), Operation at Low Power Factor (LPF) (2 Marks), Key Effects at LPF (2 Marks)

2 (b) Construction (1 Mark), Connection Diagram (2 Marks), Working Principle (2 Marks)

3 Definition (4 Marks), Causes of Ratio Error (6 Marks)

4 (a) Principle (1 Mark), Construction (2 Marks), Working Principle (2 Marks), Measurement Applications (2 Marks)

4 (b) Principle (1 Mark), Industrial Applications (Explain any 3 for 3 marks)

5 (a) Principle (2 Marks), Mechanism of Operation (3 Marks)

5 (b) Principle (2 Marks), Construction (1 Mark), Working Mechanism (2 Marks)

6 (a) Principle (1 Mark), Basic Working (Dual-Slope Method) (3 Marks), Mathematical Relation (1 Mark), Conversion to Digital Output (1 Mark)

6 (b) Advantages (2 Marks), Disadvantages (2 Marks)

7 (a) Principle (1 Mark), Block Diagram (2 Marks), Working Principle (2 Marks)

7 (b) Principle (2 Marks), Applications (3 Marks)

8 (a) Concept of Smart Instruments (2 Marks), Basic Structure (1 Mark), Features of Smart Instruments (Explain any 3–4) (2 Marks)

8 (b) Introduction (1 Marks), Principle (2 Marks), Working Mechanism (2 Marks)

9 (a) Concept of AMR (1 Mark), Basic Architecture (2 Marks), Working Principle (2 Marks), Key Applications (Any 2)(1 Mark)

9 (b) Major Components (3 Marks), Correlation (Integration of Components) (1 Mark)

10 Definition (1 Mark), Basic Concept (2 Marks), Block Diagram (2 Marks), Working Principle (3 Marks), Applications in Power Grid Monitoring (2 Marks)

11 (a) Definition (1 Mark), Working Principle (2 Marks), Significance in Solar Energy Systems (3 Marks)

11 (b) Comparison Based on Applications (4 Marks)

III B.Tech, II Semester, Regular Examinations, April 2026

Electrical Measurements and Instrumentation (23EE3601)

KEY

PART - A

1(a) State the reason for fixed coils connected in series and the moving coil connected in parallel.

Fixed coils carry load current → connected in series.
Moving coil carries voltage-proportional current → connected in parallel.

1(b) Recall the difference between a Current Transformer (CT) and a Potential Transformer (PT)

CT	PT
Measures current	Measures voltage
Series connection	Parallel connection
Low secondary voltage	High secondary voltage
Used for protection/metering	Used for voltage measurement

1(c) List the applications of capacitive transducers.

- Displacement measurement
- Pressure measurement
- Thickness measurement
- Liquid level measurement

1(d) Define the HALL effect

When a current-carrying conductor is placed in a magnetic field, a voltage (Hall voltage) is produced perpendicular to both current and magnetic field.

1(e) Tell the basic working principle of a successive approximation Digital Voltmeter (DVM).

- Uses DAC + comparator
- Performs binary search
- Converts analog input to digital output stepwise

1(f) Quote the basic functions of a digital multimeter.

- Voltage (AC/DC) measurement
- Current measurement
- Resistance measurement

- Continuity/diode testing

1(g) Interpret remote calibration in intelligent transducers.

Calibration performed remotely using communication protocols → improves accuracy and reduces manual effort.

1(h) Name the main components of a smart energy meter.

- Sensor
- Microcontroller
- Communication module
- Display

1(i) Cite the function of RTU in a SCADA system

- Collects field data
- Sends data to control center
- Executes control commands

1(j) Label key parameters measured in solar instrumentation

- Solar irradiance
- Temperature
- Wind speed
- Humidity

PART - B

2(a) Illustrate the operation of the wattmeter at Low Power Factor (LPF)

Principle (1 Mark)

An electrodynamometer wattmeter works on:

$$\text{Torque} \propto VI\cos\phi$$

where ϕ is the phase angle between voltage and current.

Operation at Low Power Factor (LPF) (2 Marks)

- At LPF, ϕ is large (close to 90°)
- Therefore, $\cos\phi$ is very small
- Hence, deflecting torque becomes very small

Key Effects at LPF (2 Marks)

1. Small Deflection
   - Pointer movement is very low → difficult to read

2. Phase Error

    - Pressure coil has inductance → current lags voltage
    - Causes additional phase shift
    - Leads to measurement error

3. Reduced Sensitivity

    - Small torque vs controlling torque → poor accuracy

4. Error Increases

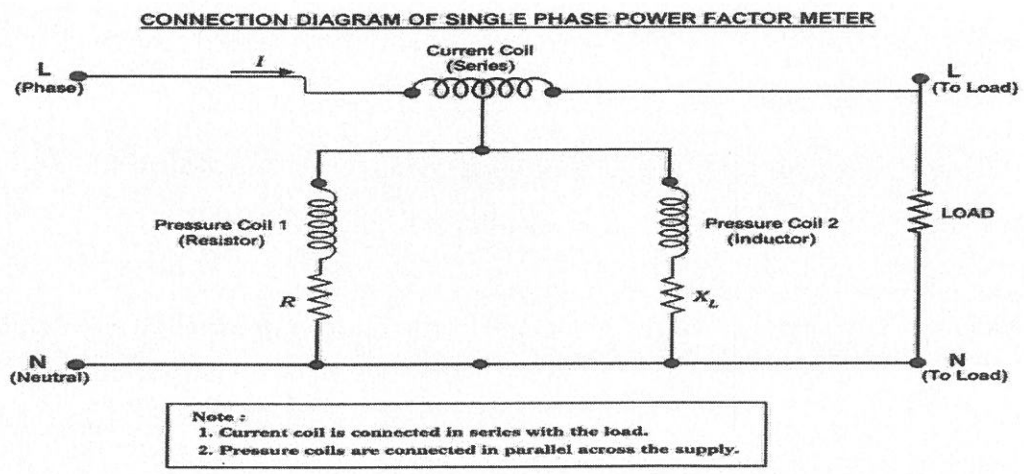
    - Wattmeter error is significant at low PF loads

2(b) With a diagram, explain how a single phase power factor meter is connected in a circuit for power factor measurement

Construction (1 Mark)

- Two fixed coils (current coils)
- Two moving coils (pressure coils)
- No controlling spring (position depends on torque balance)

Connection Diagram (2 Marks)



Working Principle (2 Marks)

- One pressure coil is resistive → current in phase with voltage
- Other pressure coil is inductive → current lags voltage by 90°
- These produce two torques
- Resultant torque depends on phase angle ϕ

Deflection

- Pointer position ∝ power factor ($\cos\phi$)

- Meter directly reads power factor (leading/lagging)

3 Construct the expression for the ratio error in a potential transformer. Explain the causes of ration error in detail.

Definition (4 Marks)

Ratio error is the difference between actual ratio and nominal ratio of a PT.

Expression for Ratio Error

$$Ratio\ Error = \frac{K_n V_s - V_p}{V_p} \times 100$$

Where:

- K_n= nominal transformation ratio
- V_p= primary voltage
- V_s= secondary voltage

Ideal Condition

$$\frac{V_p}{V_s} = K_n$$

Causes of Ratio Error (6 Marks)

1. Magnetizing Current

- Required to magnetize core
- Causes difference between ideal and actual voltage ratio

2. Core Losses

- Hysteresis and eddy current losses
- Affect flux and voltage transformation

3. Leakage Reactance

- Flux does not fully link both windings
- Leads to voltage drop

4. Burden on Secondary

- Load connected to PT affects secondary voltage
- Higher burden → larger error

5. Winding Resistance

- Causes voltage drop in windings

6. Frequency Variation

- Affects reactance and flux
- Leads to change in ratio

4(a) Explain the working principle and construction of a capacitive transducer. Discuss how it measures displacement, pressure, or thickness.

1. Principle (2 Marks)

$$C = \frac{\varepsilon A}{d}$$

Where:

- C= Capacitance
- ε= Permittivity of dielectric medium
- A= Area of plates
- d= Distance between plates

Any change in A, d, or ε causes change in capacitance.

2. Construction (2 Marks)

- Two parallel conducting plates
- Insulating dielectric medium between plates
- Movable plate arrangement for sensing
- Signal conditioning circuit

3. Working Principle (3 Marks)

- Capacitance changes due to variation in:
  - Distance between plates
  - Overlapping area
  - Dielectric constant
- Change in capacitance → converted into electrical signal
- Output proportional to physical quantity

4. Measurement Applications (3 Marks)

(i) Displacement Measurement

- Movement changes distance *d*
- Capacitance varies accordingly
- Used in precision positioning systems

(ii) Pressure Measurement

- Pressure deforms diaphragm
- Distance between plates changes
- Capacitance variation → pressure measurement

(iii) Thickness Measurement

- Thickness change alters dielectric spacing
- Capacitance changes
- Used in sheet/film industries

4(b) Summarize the applications of strain gauges in various industries.

1. Principle (1 Mark)

- Based on change in resistance due to strain
- $R = \rho \frac{L}{A}$

2. Industrial Applications (Explain any 3 for 3 marks)

1. Structural Engineering

- Stress analysis in bridges and buildings
- Detect deformation and cracks

2. Load and Weight Measurement

- Used in load cells
- Industrial weighing systems

3. Aerospace Industry

- Stress testing of aircraft components
- Monitoring wing deformation

4. Automotive Industry

- Measurement of torque in shafts
- Testing vehicle components

5. Mechanical Engineering

- Strain measurement in machine parts
- Fatigue testing

6. Biomedical Applications

- Measurement of body movements

- Prosthetics and rehabilitation devices

7. Pressure Measurement

- Used with diaphragms
- Converts pressure → strain → electrical signal

5 a)Describe the principle of piezoelectric transducers and the mechanism by which mechanical stress produces an electrical measurement

1. Principle (2 Marks)

Piezoelectric transducers work on the piezoelectric effect:

$$Q = dF$$

Where:

- Q= charge produced
- d= piezoelectric constant
- F= applied force

When mechanical stress is applied to certain crystals, electric charge is generated.

2. Mechanism of Operation (3 Marks)

1. Application of Mechanical Stress
   - Force, pressure, or vibration is applied to the crystal
2. Crystal Deformation
   - Internal structure changes → displacement of charges
3. Charge Generation
   - Positive and negative charges appear on opposite faces
4. Voltage Development
   - Generated charge produces voltage across electrodes
5. Electrical Output
   - Output voltage ∝ applied mechanical stress

5 b) Interpret how thermocouples are used in temperature measurement

1. Principle (2 Marks)

Thermocouples work on the Seebeck effect:

$$E \propto (T_1 - T_2)$$

When two dissimilar metals are joined and their junctions are at different temperatures, an EMF is generated.

2. Construction (1 Mark)

- Two different metal wires joined at one end (hot junction)
- Other ends connected to measuring instrument (cold junction)

3. Working Mechanism (2 Marks)

1. Hot Junction Exposure
   - Placed at the temperature to be measured
2. Cold Junction Reference
   - Maintained at known temperature
3. Temperature Difference
   - Creates thermoelectric EMF
4. Voltage Measurement
   - EMF measured using voltmeter
5. Temperature Calculation
   - EMF value → temperature using calibration tables

6 a) Summarize the working principle of an integrating type digital voltmeter and the integration of the input voltage leading to a digital reading

1. Principle (1 Mark)

An integrating type DVM measures voltage by integrating (averaging) the input signal over a fixed time period and converting it into a digital value.

Output is proportional to the time taken for integration, not instantaneous value.

2. Basic Working (Dual-Slope Method) (3 Marks)

Step 1: Integration Phase

- Unknown input voltage $V_{in}$is applied to an integrator.
- Output of integrator increases linearly with time.
- Integration is done for a fixed time T_1.

Step 2: De-integration Phase

- A reference voltage $V_{ref}$of opposite polarity is applied.
- Integrator output decreases back to zero.

Step 3: Time Measurement

- Time taken T_2 to return to zero is measured.
- This time is proportional to input voltage.

3. Mathematical Relation (1 Mark)

$$V_{in} = V_{ref} \times \frac{T_2}{T_1}$$

Thus, digital output is obtained by counting pulses during T_2.

4. Conversion to Digital Output (1 Mark)

- Clock pulses counted during de-integration
- Count stored and displayed digitally

6 b) Recall the advantages and disadvantages of a ramp type DVM

Advantages (2 Marks)

- Simple circuit design
- Low cost
- Easy to implement

Disadvantages (2 Marks)

1. Low Accuracy
2. Noise Sensitive
3. Slow Response
4. Less Stability

7 a) With the help of a diagram, explain the working principle of a digital tachometer

1. Principle (1 Mark)

A digital tachometer measures rotational speed (RPM) by converting mechanical rotation into electrical pulses and counting them.

2. Block Diagram (2 Marks)

Rotating Shaft → Sensor → Signal Conditioning → Pulse Shaper → Counter → Display (RPM)

3. Working Principle (2 Marks)

1. Sensing of Rotation
    - A sensor (optical / magnetic / proximity) detects rotating shaft
    - Generates pulses for each revolution

2. Signal Conditioning
    - Weak signals amplified and filtered
3. Pulse Generation
    - Pulses converted into square waves
4. Counting Mechanism
    - Pulses counted over a fixed time interval
5. Speed Calculation
    - RPM = (Number of pulses × 60) / Time
6. Display
    - Digital display shows speed in RPM

7 b) Illustrate the principle and applications of a Q meter.

1. Principle (2 Marks)

A Q meter measures the quality factor (Q) of a coil using resonance.

$$Q = \frac{X_L}{R} = \frac{\omega L}{R}$$

At resonance:

$$Q = \frac{V_C}{V}$$

2. Applications (3 Marks)

- Measurement of Q-factor of coils
- RF circuit testing
- Determination of inductance
- Testing of capacitors

8 a) Analyze the concept of smart instruments and discuss their features in detail.

1. Concept of Smart Instruments (2 Marks)

Smart instruments are advanced measuring devices that combine:

- Sensing
- Signal processing
- Microcontroller-based intelligence
- Communication capability

They not only measure but also process, analyze, and transmit data.

2. Basic Structure (1 Mark)

Sensor → Signal Conditioning → A/D Converter → Microcontroller → Communication Interface → Display/Output

3. Features of Smart Instruments (Explain any 3–4) (2 Marks)

1. Self-Calibration
   - Automatically adjusts calibration
   - Improves accuracy
2. Self-Diagnosis
   - Detects faults and errors
   - Ensures reliability
3. Digital Communication
   - Uses protocols like HART, Modbus
   - Enables remote monitoring
4. Data Processing Capability
   - Performs filtering, linearization
   - Reduces noise
5. Remote Configuration
   - Settings can be changed remotely
6. High Accuracy and Stability
   - Less human error
   - Consistent readings
7. Data Storage
   - Stores historical data
8. Interfacing Capability
   - Can connect with SCADA, PLC systems

8 b) Interpret HART communication in detail, covering its principles and working mechanism

1. Introduction (1 Marks)

HART (Highway Addressable Remote Transducer) is a hybrid communication protocol used in smart instrumentation.

Combines:

- Analog signal (4–20 mA)
- Digital communication

2. Principle (2 Marks)

HART uses Frequency Shift Keying (FSK):

- Digital signals are superimposed on analog current signal
- Two frequencies used:
    - 1200 Hz → Logic 1
    - 2200 Hz → Logic 0

3. Working Mechanism (2 Marks)

1. Analog Transmission
    - 4–20 mA carries process variable
2. Digital Signal Overlay
    - Digital data added using FSK
    - Does not disturb analog signal
3. Bidirectional Communication
    - Data flows both ways
    - Instrument ↔ Controller
4. Data Exchange
    - Transmits:
        - Device status
        - Calibration data
        - Configuration parameters

9(a) Develop the concept of Automatic Meter Reading (AMR) and its key applications in modern utility systems.

1. Concept of AMR (1 Mark)

Automatic Meter Reading (AMR) is a system that automatically collects energy consumption data from utility meters and transmits it to a central system without manual intervention.

Eliminates the need for physical meter reading.

2. Basic Architecture (2 Marks)

Energy Meter → Communication Module → Data Concentrator → Utility Server

3. Working Principle (2 Marks)

1. Data Acquisition
   - Smart meter measures energy usage
2. Data Transmission
   - Data sent via communication technologies:
     - RF (Radio Frequency)
     - GSM/GPRS
     - PLC (Power Line Communication)
3. Data Collection
   - Data concentrator gathers readings from multiple meters
4. Data Processing
   - Utility server processes data for billing and monitoring

4. Key Applications (Any 2)(1 Mark)

1. Automated Billing
   - Accurate and timely billing
   - Eliminates human errors
2. Energy Monitoring
   - Real-time consumption tracking
3. Load Management
   - Helps in demand-side management
4. Theft Detection
   - Identifies abnormal usage patterns
5. Remote Meter Reading
   - Useful in inaccessible areas

9(b) Correlate the components of a smart energy meter in detail.

1. Major Components (3 Marks)

1. Measurement Unit (Sensing Unit)
   - Measures voltage and current
   - Calculates power and energy

2. Signal Conditioning Circuit

- Amplifies and filters signals
- Converts analog signals into suitable form

3. Microcontroller / Processing Unit

- Performs calculations
- Stores data
- Controls overall operation

4. Communication Module

- Enables data transmission
- Uses:
  - GSM
  - RF
  - PLC
  - Wi-Fi

5. Display Unit

- Shows readings (kWh, voltage, current)

6. Memory Unit

- Stores historical consumption data

7. Power Supply Unit

- Provides regulated power to meter

2. Correlation (Integration of Components) (1 Mark)

- Sensor → Signal conditioning → Microcontroller → Communication → Display

  All components work together to provide accurate measurement and real-time communication

10 Describe the working principle of Phasor Measurement Units (PMUs) and their applications in power grid monitoring.

1. Definition (1 Mark)

A Phasor Measurement Unit (PMU) is a device used to measure the magnitude and phase angle of voltage and current phasors in a power system with high accuracy and time synchronization.

It provides synchrophasor measurements using a common time reference.

2. Basic Concept (2 Marks)

- Electrical quantities (voltage/current) are sinusoidal
- Represented as phasors:

$$V = V_m \angle \theta$$

- PMU measures:
  - Magnitude V_m
  - Phase angle θ

3. Block Diagram (2 Marks)

Voltage/Current → CT/PT → Signal Conditioning → Anti-Aliasing Filter → ADC → Microprocessor (Phasor Estimation) → GPS Receiver → Communication → Control Center

4. Working Principle (3 Marks)

Step 1: Signal Acquisition

- Voltage and current signals obtained through CTs and PTs

Step 2: Signal Conditioning

- Signals filtered and scaled
- Anti-aliasing filter removes noise

Step 3: Sampling

- Analog signals converted to digital using ADC

Step 4: Time Synchronization

- GPS provides precise time reference
- All PMUs synchronized globally

Step 5: Phasor Estimation

- Microprocessor calculates magnitude and phase angle

Step 6: Data Transmission

- Data sent to control center (via communication network)

5. Applications in Power Grid Monitoring (2 Marks)

1. Wide Area Monitoring System (WAMS)

- Monitors grid behavior in real time

2. Stability Analysis

- Detects voltage instability and oscillations

3. Fault Detection and Location

- Quickly identifies faults in transmission lines

4. State Estimation

- Improves accuracy of system state estimation

5. Power System Protection

- Enhances adaptive protection schemes

6. Blackout Prevention

- Early warning of system disturbances

11(a) Outline the working principle and significance of sunshine duration measurement in solar energy systems.

1. Definition (1 Mark)

Sunshine duration is the total time during which direct solar radiation exceeds a specified threshold (typically ~120 W/m²) over a day.

2. Working Principle (2 Marks)

Campbell–Stokes Sunshine Recorder (Common Method)

Principle:

- Uses solar radiation focusing to record sunshine duration.

Working:

1. A glass sphere acts as a convex lens
2. Sunlight is focused onto a calibrated recording card
3. When sunlight is strong, it burns a trace on the card
4. Length of burn mark $\propto$ duration of sunshine
5. Total burned length is converted into hours of sunshine

3. Significance in Solar Energy Systems (3 Marks)

1. Solar Resource Assessment

- Helps estimate available solar energy

2. Design of Solar Power Plants

- Determines panel size and orientation

3. Performance Evaluation

- Compares expected vs actual generation

4. Agricultural Applications

- Crop growth analysis

5. Weather Forecasting

- Used in meteorological studies

11(b) Compare applications of pyranometers and pyrheliometers in solar energy systems

Comparison Based on Applications (4 Marks)

Aspect	Pyranometer	Pyrheliometer
Radiation measured	Global solar radiation (direct + diffuse)	Direct beam radiation only
Field of view	Wide angle (180°)	Narrow beam (aligned with sun)
Applications	Solar panel design, weather stations	Solar tracking systems, research
Usage	General solar energy studies	Precise solar radiation measurement
Installation	Fixed position	Mounted on solar tracker

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