KKR & KSR INSTITUTE OF TECHNOLOGY & SCIENCES

(Approved by AICTE, New Delhi, Affiliated to JNTU Kakinada, Accredited by NAAC with 'A' Grade)

DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

Handouts

Subject: **ELECTRICAL MEASUREEMENTS**

Class : **II/IV B.Tech (EEE)**

Prepared by

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Learning Objectives

1)To study the principle of operation and working of different types of instruments. measurement of voltage and current.
2)To study the working principle of operation of different types of instruments for measurement of power and energy
3)To understand the principle of operation and working of dc and ac potentiometers.
4)To understand the principle of operation and working of various types of bridges for measurement of parameters –resistance, inductance, capacitance and frequency.
5)To study the principle of operation and working of various types of magnetic measuring instruments.
6)To study the applications of CRO for measurement of frequency, phase difference and hysteresis loop using Lissajous patterns.

SYLLABUS

II Year – II SEMESTER

L	T	P	C
4	0	0	3

ELECTRICAL MEASUREMENTS

Preamble:
This course introduces principle of operation of basic analog and digital measuring instruments for measurement of current, voltage, power, energy etc. Measurement of resistance, inductance and capacitance by using bridge circuits will be discussed in detail. It is expected that student will be thorough with various measuring techniques that are required for an electrical engineer.

UNIT–I:
Measuring Instruments
Classification – Deflecting, control and damping torques – Ammeters and Voltmeters – PMMC, moving iron type, dynamometer and electrostatic instruments – Expression for the deflecting torque and control torque – Errors and compensations– Extension of range using shunts and series resistance –CT and PT**:** Ratio and phase angle errors – Numerical problems..

UNIT –II:
Measurement of Power and Energy
Single phase and three phase dynamometer wattmeter – LPF and UPF – Expression for deflecting and control torques – Extension of range of wattmeter using instrument transformers – Measurement of active and reactive powers in balanced and unbalanced systems – Type of P.F. Meters – Single phase and three phase dynamometer and moving iron type Single phase induction type energy meter – Driving and braking torques – errors and compensations –Testing by phantom loading using R.S.S. meter– Three phase energy meter – Maximum demand meters– Electrical resonance type frequency meter and Weston type synchro-scope.

UNIT – III:
Potentiometers
Principle and operation of D.C. Crompton's potentiometer – Standardization – Measurement of unknown resistance – Current – Voltage.AC Potentiometers**:** polar and coordinate types – Standardization – Applications.

UNIT – IV:
Measurements of Parameters
Method of measuring low, medium and high resistance – Sensitivity of Wheat stone's bridge – Carey Foster's bridge– Kelvin's double bridge for measuring low resistance– Loss of charge method for measurement of high resistance – Megger– Measurement of earth resistance – Measurement of inductance – Quality Factor – Maxwell's bridge–Hay's bridge – Anderson's bridge–Measurement of capacitance and loss angle – DesautyBridge – Schering Bridge– Wagner's earthing device–Wien's bridge.

UNIT – V:

Magnetic Measurements

Ballistic galvanometer – Equation of motion – Flux meter – Constructional details– Determination of B–H Loop methods of reversals six point method – AC testing – Iron loss of bar samples– Core loss measurements by bridges and potentiometers.

UNIT – VI:

Digital Meters

Digital Voltmeter–Successive approximation – Measurement of phase difference – Frequency – Hysteresis loop using lissajious patterns in CRO – Ramp and integrating type– Digital frequency meter–Digital multimeter–Digital Tachometer.

Text Books:

1. Electrical Measurements and measuring Instruments – by E.W. Golding and F.C.Widdis, fifth Edition, Wheeler Publishing.
2. Modern Electronic Instrumentation and Measurement Techniques – A.D. Helfrick and W.D. Cooper, PHI, 5th Edition, 2002.

Reference Books:

1. Electrical & Electronic Measurement & Instruments by A.K.Sawhney DhanpatRai & Co.Publications.
2. Electrical and Electronic Measurements and instrumentation by R.K.Rajput, S.Chand.
3. Electrical Measurements – by Buckingham and Price, Prentice – Hall
4. Electrical Measurements by Forest K. Harris. John Wiley and Sons
5. Electrical Measurements: Fundamentals, Concepts, Applications – by Reissland, M.U, New Age International (P) Limited, Publishers.
6. Electrical and Electronic Measurements –by G.K.Banerjee, PHI Learning Private Ltd, New Delhi–2012.

COURSE INFORMATION

DEGREE: BTECH	DEPARTMENT: EEE
COURSE: ELECTRICAL MEASUREMENTS	SEMESTER: II CREDITS: 3
REGULATION: R16	COURSE TYPE: CORE
YEAR/SEM: II YEAR/ II SEM	CONTACT HOURS: 4+1 (Tutorial) hours/Week.
COURSE AREA / DOMAIN: BASIC ANALOG AND DIGITAL METERS	RELATED LAB NAME: ELECTRICAL MEASUREMENTS LAB

COURSE PRE-REQUISITES

COURSE NAME	DESCRIPTION	SEM
Engineering Physics	To Analyze materials and field properties	1-1
Mathematics - I	To Analyze different problems	1-1
Electrical Circuit Analysis - I	To Analyze circuits	1-2

Course Outcomes (CO's)

Course Name: **ELECTRICAL MEASUREMENTS**

C221.1	Choose right type of instrument for measurement of voltage and current for ac and dc.
C221.2	Choose right type of instrument for measurement of power, energy and power factor.
C221.3	Calibrate ammeter, voltmeter energy meter and resistance using potentiometer.
C221.4	Select suitable bridge for measurement of electrical parameters
C221.5	Explain the ballistic galvanometer and flux meter for magnetic measuring instruments.
C221.6	Explain the different types of digital instruments for electrical measurements.

CO-PO Mapping

List of POs:

PO1: Engineering knowledge, **PO2**: Problem analysis, **PO3**: Design/development of solutions, **PO4**: Conduct investigations of complex problems, **PO5**: Modern tool usage, **PO6**: The engineer and society, **PO7**: Environment and sustainability, **PO8**: Ethics, **PO9**: Individual and team work, **PO10**: Communication, **PO11**: Project management and finance, **PO12**: Life-long learning

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C221.1	√	√	√	-	-	-	-	-	-	-	-	-
C221.2	√	√	√	-	-	-	-	-	-	-	-	√
C221.3	√	-	-	-	-	-	-	-	-	-	-	-
C221.4	√	√	√	-	-	-	-	-	-	-	-	√
C221.5	√	-	-	-	-	-	-	-	-	-	-	-
C221.6	√	-	√	-	-	-	-	-	-	-	-	√

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C221.1	2	2	1	-	-	-	-	-	-	-	-	-
C221.2	3	2	1	-	-	-	-	-	-	-	-	1
C221.3	2	-	-	-	-	-	-	-	-	-	-	-
C221.4	2	2	1	-	-	-	-	-	-	-	-	2
C221.5	2	-	-	-	-	-	-	-	-	-	-	-
C221.6	3	-	1	-	-	-	-	-	-	-	-	2

Note: Enter correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High).*It there is no correlation, put "-"*

CO-PSO Mapping:

Program specified Outcomes (PSOs):

PSO1: Able to utilize the knowledge of Power Electronics in collaboration with Electrical Machines to provide an engineering solution in the areas related to Electrical Drives.

PSO2: To develop new cutting edge Technologies in Power Systems associated with efficient conversion and control of electrical power.

PSO3: Able to use software for design, simulation and analysis of electrical systems.

	PSO1	**PSO2**	**PSO3**
C221.1	-	-	-
C221.2	1	-	-
C221.3	-	-	-
C221.4	1	-	-
C221.5	-	-	-
C221.6	2	1	-

Note: Enter correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High).*It there is no correlation, put "-"*

LESSON PLAN

L / T No.	Topic Name	Teaching Aid	Text Book / Reference Book / Web	Page Number
Unit I: Measuring Instruments				
L-01	Introduction to measuring systems	GB & PC,PPT	R1	1-2
L-02	Classification of instruments	GB & PC,PPT	R1	177-178
L-03	Deflecting and control systems	GB & PC	R1	180
L-04	Control and damping systems	GB & PC, PPT	R1	181-189
T-01	Tutorial on Basic Ammeters and Voltmeters	GB & PC	R1	241-242 & 245
L-05	Extension of range using shunts and series resistances	GB & PC	R1	241-247
L-06	PMMC	GB & PC, PPT	R1	238-241
L-07	Moving iron type	GB & PC	R1	257-261
L-08	Dynamometer Instruments, Expression for the deflecting torque and control torque	GB & PC	R1	267-273
T-02	Problems on MC and MI	GB & PC	R1	263-267
L-09	Electrostatic instruments, Expression for the deflecting torque and control torque	GB & PC	R1	282-286
L-10	Errors, Types of errors and it's compensations	GB & PC	R1	19-21, 249,261, 271
L-11	CT**:** Ratio and phase angle errors – Design considerations	GB & PC,PPT	R1	315-318
L-12	PT**:** Ratio and phase angle errors – Design considerations	GB & PC,PPT	R1	333-337

T-3	Problems on CT and PT	GB & PC	R1	336-337
UNIT-II Measurement of Power and Energy				
L-13	Single phase dynamometer wattmeter	GB & PC	R1	354-358
L-14	Three phase dynamometer wattmeter	GB & PC	R1	371
L-15	LPF and UPF wattmeter, Expression for deflecting and control torques	GB & PC	R1	362-363
L-16	Extension of range of wattmeter using instrument transformers	GB & PC	R1	365-367
T-04	Problems on dynamometer wattmeter	GB & PC	R1	358-361
L-17	Measurement of active and reactive powers in balanced systems	GB & PC	R1	368-371
L-18	Measurement of active and reactive powers in unbalanced systems	GB & PC	R1	368-371
L-19	Types of P.F. Meter and Single phase Single phase	GB & PC, PPT	R1	405
L-20	Three phase dynamometer P.F meter	GB & PC, PPT	R1	405-408
T-05	Problems on active and reactive power in balanced and unbalanced systems.	GB & PC	R1	373-374
L-21	Moving iron type P.F meter	GB & PC	R1	408-409
L-22	Single phase induction type energy meter – Driving and braking- torques	GB & PC, PPT	R1	382-383
L-23	Errors and compensations	GB & PC, PPT	R1	384-387
L-24	Testing by phantom loading using R.S.S. meter	GB & PC ,PPT	R1	396
T-06	Problems on dynamometer P.F meters	GB & PC	R1	420
L-25	Three phase energy meter	GB & PC, PPT	R1	388
L-26	Tri vector meter, Maximum demand meters	GB & PC	R1	394,389
L-27	Electrical resonance type frequency meter	GB & PC	R1	411-413
L-28	Weston type synchroscope	GB & PC, PPT	R1	413

T-07	Problems on Energy meter	GB & PC	R1	399-401
UNIT-III Potentiometers				
L-29	Potentiometers, Basic slide wire potentiometer	GB & PC	R1	455-456
L-30	Principle and operation of D.C. Crompton's potentiometer - Standardization	GB & PC	R1	456-457
L-31	Applications of D.C Crompton's potentiometer – problems	GB & PC	R1	463-465
L-32	AC potentiometer - standardization- Drysdale polar potentiometer- Measurement of unknown resistance – Current – Voltage	GB & PC	R1	467-470
T-08	Applications of A.C Potentiometer, Problems on A.C and D.C potentiometer	GB & PC	R1	473-475
L-33	Gall-Tinsley (Coordinate type) A.C potentiometer- Measurement of unknown resistance – Current – Voltage	GB & PC	R1	470-471
UNIT-IV Measurements of Parameters				
L-34	Classification of resistances - Method of measuring medium resistances	GB & PC	R1	421-424
L-35	Method of measuring low resistances	GB & PC	R1	433-434
L-36	Measuring high resistances	GB & PC	R1	437-438
T-09	Problems on resistance measurement	GB & PC	R1	422-423
L-37	Sensitivity of Wheat stone's bridge	GB & PC	R1	424-427
L-38	Carey Foster's bridge	GB & PC	R1	428
L-39	Kelvin's double bridge for measuring low resistance	GB & PC,PPT	R1	434-436
L-40	Loss of charge method for measurement of high resistance	GB & PC	R1	440-441
T-10	Problems on bridges	GB & PC	R1	442-443

L-41	Megger– Measurement of earth resistance	GB & PC, PPT	R1	256, 443-445
L-42	Maxwell's bridge,	GB & PC,PPT	R1	482-483
L-43	Hay's bridge	GB & PC	R1	483-484
L-44	Andersons bridge	GB & PC	R1	485
T-11	Problems on bridges	GB & PC	R1	499-500
L-45	Measurement of capacitance and loss angle – Desauty bridge	GB & PC	R1	488-489
L-46	Measurement of capacitance and loss angle – Schering Bridge	GB & PC	R1	488-489
L-47	Wagner's earthling device	GB & PC	R1	498-499
L-48	Wien's bridge.	GB & PC	R1	496
T-12	Problems on bridges	GB & PC	R1	501-503
UNIT-V Magnetic Measurements				
L-49	Ballistic galvanometer – Equation of motion	GB & PC	R1	214-219
L-50	Flux meter – Constructional details	GB & PC, PPT	R1	214-219
L-51	Determination of B–H Loop methods of reversals six point method	GB & PC, PPT	R1	544-546
L-52	AC testing- Iron loss of bar samples	GB & PC	R1	554
T-13	Problems on magnetic measurements	GB & PC	R1	552-554
L-53	Methods of measurement of iron losses	GB & PC	R1	556-557
L-54	Core loss measurements by bridges and potentiometers	GB & PC	R1	558-561
UNIT-VI Digital Meters				
L-55	Introduction to Digital meters	GB & PC	R1,W2	1006
L-56	Digital Voltmeter	PPT	R1	1029

T-14	Applications of digital meters	GB & PC	W3	-
L-57	Successive approximation DVM	GB & PC	R6	136-138
L-58	Ramp type DVM	GB&PC	R6	129-134
L-59	Integrating type DVM	GB & PC	R6	129-134
L-60	Digital frequency meter	GB & PC	R6	152-155
T-15	Advantages of different digital meters	GB & PC	W1	-
L-61	Digital Multimeter	GB & PC, PPT	R6	148-149
L-62	Digital Tachometer	GB & PC	R6	165-166
L-63	Measurement of phase difference – Frequency – Hysteresis loop using lissajious patterns in CRO	GB & PC	R6	206-216
L-64	Measurement of phase difference – Frequency – Hysteresis loop using lissajious patterns in CRO	GB & PC	R6	206-216
T-16	previous university question papers problems	GB & PC	-	-

Note: Teaching aid: GB-Glass Board, PC-Piece of Chalk, PPT-Power Point Presentation, W- Web reference , L-Lecture, T- Tutorial….etc

TEXTBOOK:

T1. Electrical Measurements and measuring Instruments – by E.W. Golding and F.C.Widdis, fifth Edition, Wheeler Publishing.
T2. Modern Electronic Instrumentation and Measurement Techniques – A.D. Helfrick and W.D. Cooper, PHI, 5th Edition, 2002.
T3. Electrical and Electronic Measurements and instrumentation by R.K.Rajput, S.Chand

REFERENCES:

R1. Electrical & Electronic Measurement & Instruments by A.K.Sawhney Dhanpat Rai & Co. Publications.

R2. Electrical Measurements – by Buckingham and Price, Prentice – Hall
R3. Electrical Measurements by Forest K. Harris. John Wiley and Sons
R4. Electrical Measurements: Fundamentals, Concepts, Applications – by Reissland, M.U, New Age International (P) Limited, Publishers.
R5. Electrical and Electronic Measurements –by G.K.Banerjee, PHI Learning Private Ltd., New Delhi–2012.
R6. Electronic Instrumentation – H.S.Kalsi- Mc.Graw hill publications.

WEB REFERENCES:

W1: http://www.slideshare.net/bapikumar144/advantages-of-digital-meters-over-analog-meters

W2: https://www.circuitspecialists.com/blog/introduction-to-digital-multimeters/

W3: https://www.elprocus.com/multimeter-types-and-applications/

EXPERIMENTS RELATED TO ELECTRICAL MEASUREMENTS

1. Calibration and Testing of single phase energy Meter
2. Calibration of dynamometer wattmeter using phantom loading
3. Calibration of PMMC ammeter and voltmeter using Crompton D.C. Potentiometer
4. Measurement of resistance and Determination of Tolerance using Kelvin's double Bridge.
5. Capacitance Measurement using Schering bridge.
6. Inductance Measurement using Anderson bridge.
7. Measurement of 3 phase reactive power with single phase wattmeter for balanced loading.
8. Calibration of LPF wattmeter by direct loading.
9. Measurement of 3 phase power with single watt meter and using two C.Ts.
10. Testing of C.T. using mutual inductance method.
11. Testing of P.T. using absolute null method.
12. Dielectric oil testing using H.T test Kit.
13. Calibration of AC voltmeter and measurement of choke parameters using AC Potentiometer in polarform.
14. Measurement of Power by 3 Voltmeter and 3 Ammeter method

Unit wise important questions

UNIT - 1

1) Explain the working of Moving iron Instrument with a neat diagram and derive the torque equation and further comment up on the nature of scale. (10M) (C221.1) (comprehension)
2) Derive the expressions for the ratio and phase angle errors of a current transformer with a neat phasor diagram. (10M) (C221.1) (comprehension)
3) Explain the working of Moving coil Instrument with a neat diagram and derive the torque equation and further comment up on the nature of scale. (10M) (C221.1) (comprehension)
4) Derive the expressions for the ratio and phase angle errors of a potential transformer with a neat phasor diagram. (10M) (C221.1) (comprehension)
5) Explain the working of EMMC Instrument with a neat diagram and derive the torque equation and further comment up on the nature of scale. (10M) (C221.1) (comprehension)
6) a)Define i)ratio error ii)phase angle error iii)actual ratio iv)nominal ratio v)turns ratio (5M) (C221.1) (knowledge)
b)Explain spring and gravity control torques. (5M) (C221.1) (comprehension)

UNIT - 2

1) Explain with a neat circuit of Dynamometer type Wattmeter and derive the equation for deflection. (10M) (C221.2) (comprehension)
2) a)Explain the operation of three phase dynamometer type wattmeter. (5M) (C221.2) (comprehension)
b)Explain about extension of range of wattmeter using instrument transformers. (5M) (C221.2) (comprehension)
3) Explain the construction and working of Induction type single phase Energy meter with a neat diagram. And derive its equation. (10M) (C221.2) (comprehension)
4) Explain the construction and working of Dynamometer type single phase power factor meter with a neat diagram. And derive its equation. (10M) (C221.2) (comprehension)
5) Explain the construction and working of Dynamometer type three phase power factor meter with a neat diagram. And derive its equation. (10M) (C221.2) (comprehension)

6) a)Explain about LPF wattmeter. (5M) (C221.2) (comprehension)
b)Explain about creeping and phantom loading. (5M) (C221.2) (comprehension)

UNIT - 3

1) Explain the procedure for making measurements with DC Crompton's potentiometer. Write Applications and significance of a Potentiometer. (10M) (C221.3) (comprehension)
2) Explain the operation of coordinate type AC potentiometer. And how does an AC potentiometer different from a DC Potentiometer explain. (10M) (C221.3) (comprehension)
3) Explain the operation of polar type AC potentiometer. And write limitations of AC potentiometers. (10M) (C221.3) (comprehension)

4) Discuss how unknown resistance, current, voltage power and wattmeter are measured with DC potentiometer. (10M) (C221.3) (knowledge)
5) Explain the operation of basic slide wire potentiometer and its standardization procedure. (10M) (C221.3) (comprehension)
6) Explain the standardization procedure for the AC Potentiometer. Explain how AC Potentiometer can be used for the measurement of self inductance of a coil. (10M) (C221.3) (comprehension)

UNIT - 4

1) a) Describe working of low voltage **Schering bridge**. Derive equation of capacitance and dissipation factor. (5M) (C221.4) (comprehension)
b) Write briefly on measurement of high resistance by **loss of charge method**. List the precautions to be taken in this method. (5M) (C221.4) (comprehension)
2) a) Describe the circuit of **Kelvin double bridge** used for measurement of low resistance. Derive the conditions for balance. (5M) (C221.4) (comprehension)
b) Draw the circuit diagram of **Wien's bridge** and explain the measurement procedure for measuring unknown frequency using this bridge. Derive the formula used. (5M) (C221.4) (comprehension)
3) a) Sketch the circuit diagram of **Anderson's bridge**. Derive the equations for resistive and inductive components of the inductor to be measured. (5M) (C221.4) (comprehension)
b) Explain the procedure for measurement of medium resistance using **Carey Foster slide wire** bridge method and derive the necessary equation. (5M) (C221.4) (comprehension)
4) a) Deduce the **general equation** or condition for bridge balance in **AC Circuits**. (5M) (C221.4) (comprehension)
b) Explain with a neat diagram for the measurement of Inductance using **Hay bridge** and also derive the relation for inductance under balanced condition using a neat phasor diagram. (5M) (C221.4) (comprehension)
5) Describe how an unknown capacitance can be measured with the help of **D'sauty's** ridge? What are the limitations of the bridge and how are they overcome by using a modified form of D'stauty's bridge? (10M) (C221.4) (comprehension)
6) Explain working of **Megger** for Measurement of earth resistance. (10M) (C221.4) (comprehension)

UNIT - 5

1) Explain the construction and working of **Grassot flux meter** with a neat diagram and also prove that "the change in the value of flux is directly proportional to the change in deflection" in this case. (10M) (C221.5) (comprehension)
2) Explain the method for determination of **B-H curve** of a magnetic materials using **step by Step method** and **method of reversals**. (10M) (C221.5) (comprehension)
3) Explain the method for determination of **B-H loop** of a magnetic materials using **step by Step method** and **method of reversals**. (10M) (C221.5) (comprehension)
4) a) Explain the **AC bridge method** for measurement of iron losses in ferromagnetic materials. (5M) (C221.5) (comprehension)

b) Explain how magnetizing and loss components of no load current of a transformer is determined by using an **A.C. Potentiometer**. (5M) (C221.5) (comprehension)

5) a) What is a **ballistic galvanometer**? Where is it used? (4M) (C221.5) (knowledge)

b) List the advantages and disadvantages of ring and bar specimens used in magnetic testing of materials (6M) (C221.5) (comprehension)

UNIT – 6

1) Explain how **phase difference and frequency** is measured from Lissajous patterns in CRO. (10M) (C221.6) (comprehension)

2) a)Explain the operation of **ramp type** digital voltmeter with a neat block diagram. (6M) (C221.6) (comprehension)

b) Explain the operation of **digital tachometer**. (4M) (C221.6) (comprehension)

3) Explain with neat circuit diagram the working of **successive approximation** type digital voltmeter. (10M) (C221.6) (comprehension)

4) Explain the operation of **digital frequency** meters with circuit diagram and block diagram? (10M) (C221.6) (comprehension)

5) Explain the working of **Dual slope Integrating type** Digital Voltmeter with a neat schematic diagram. And write its advantages. (10M) (C221.6) (comprehension)

6) a) What is a digital voltmeter? Write the advantages and disadvantages of Digital voltmeters? (6M) (C221.6) (knowledge)

b) Explain the basic scheme of **Digital multi-meter** along with its advantages. (4M) (C221.6) (comprehension)