University of Mumbai

Syllabus Structure (R-2007)

at

S.E. Instrumentation Engineering

Semester-III

S. No.	Subject	Scheme of Instructions Periods (60 min. each) per Week		Scheme of Evaluation					
		Theory	Practical	Paper		TW	Practical & Oral	Oral	Total Marks
				Hours	Marks				
1.	Transducers-I	04	02	3	100	25	50	*25	200
2.	Analog Electronics	04	02	3	100	25	50	---	175
3.	# Engineering Mathematics-III	05	---	3	100	---	---	---	100
4.	Electrical Network	04	02	3	100	25	---	25	150
5.	Digital Electronics	04	02	3	100	25	50	---	175
6.	Presentation & Communication Techniques	01	02	---	---	50	---	---	050
	Total	22	10	---	500	150	150	50	850

*-Oral examination will be based on object-oriented industrial visit.

#- Common with Electrical Engineering & Biomedical Engineering.

Semester-IV

S. No.	Subject	Scheme of Instructions Periods (60 min. each) per Week		Scheme of Evaluation					
		Theory	Practical	Paper		TW	Practical & Oral	Oral	Total Marks
				Hours	Marks				
1.	Transducers-II	04	02	3	100	25	50	*25	200
2.	Feedback Control System	04	02	3	100	25	50	---	175
3.	Electrical Technology & Instruments	05	02	3	100	25	---	25	150
4.	Analytical Instrumentation	04	02	3	100	25	---	25	150
5.	# Engineering Mathematics-IV	05	---	3	100	---	---	---	100
6.	Application Software Practices-I	---	02	---	---	25	50	---	075
	Total	22	10		500	125	150	75	850

*-Oral examination will be based on object-oriented industrial visit.

#- Common with Electrical Engineering & Biomedical Engineering.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** III	
Subject: Analog Electronics (abbreviated as AE)			
Periods per Week (60 min. each)	Lecture	04	
	Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	03	100
	Practical & Oral	02	50
	Oral	---	---
	Term Work	---	25
	Total	05	175

Module	Contents	Hours
1	**Diode** Clipper & clamper circuit using diode.	03
2	**Bipolar Junction Transistor** Transistor biasing, different types of biasing circuit and their analysis, bias stability, stability factor, comparison of biasing circuits, thermister compensation, thermal runway.	08
3	**Transistor amplifier analysis and circuits** RC coupled amplifier, H- parameters, necessity of hybrid model and h - parameters, determination of h-parameter from transistor characteristics. Approximate conversion formulae for h- parameter for CE, CB, CC configurations, A.C. equivalent circuits of transistor amplifier using h-parameter. CE, CB, CC transistor amplifier circuits, DC and AC analysis.	08
4	**Feedback amplifier** General theory of feedback, types of feedbacks, effect of negative feedback on stability, bandwidth, noise, input resistance, output resistance. Detailed analysis of voltage series, voltage series amplifier, current series amplifier, emitter follower.	07
5	**Oscillators** RC phase shift, Weinbridge, Hartley Colpitts & Crystal oscillator.	06
6	**Field Effect Transistor** Junction field effect transistor, V-I characteristics, different configuration of JFET, different parameter of JFET, common source configuration as an amplifier, MOSFET & its classification.	08
7	**Low & high frequency response of common source amplifier** Low & high frequency FET model.	08

Theory Examination:

1. Question paper will consist of total 7 questions carrying 20 marks each.
2. Only 5 questions need to be attempted.
3. Q.1 will be compulsory and based on the entire syllabus.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Practical & Oral Examination:

Practical examination will be based on one experiment performed from the list of experiments given in the syllabus and the oral will be based on entire subject. The distribution of the marks shall be as follows,

Practical examination	: 25 marks
Oral examination	: 25 marks

Term work:

Term work consists of minimum eight experiments and a written test. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal)	:10 marks
Test (at least one)	:10 marks
Attendance (Practical and Theory)	:05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

List of Laboratory Experiments:

1. Study of diode Clipper circuit.
2. Study of diode Clamper circuit.
3. Study of input output characteristics of BJT- CB, CE & CC Configuration.
4. Study of input & transfer characteristics of FET.
5. Study of input & transfer characteristics of FET.
6. Frequency response of common emitter amplifier with & without feedback using a bypass capacitor for Re.
7. RC coupled amplifier.
8. Determination oh h parameter of a BJT.
9. Frequency response of FET amplifier with & without feedback using a bypass capacitor for Rs.
10. Wein bridge oscillator using transistors.
11. RC phase shift oscillator.
12. Any one of the following
    i) Darlington Amplifier
    ii) Cascade Amplifier

Note: The hardware results of minimum 5 experiments from the above list must be verified using simulation software like P-SPICE/Multi-Sim or equivalent.

Text Books:

1. Bell David A., *Electronics Devices & Circuits*, 5th ed., Oxford University Press, New Delhi, 2008.
2. Boylestad Robert L., Nashelsky Louis, *Electronics Devices & Circuits*, Pearson Education.

Reference Books:

1. Millman, Halkias, *Electronics Devices & Circuits*, Tata McGraw Hill, New Delhi.
2. Boghart, *Electronics Devices & Circuits*, PHI, 1995.
3. Neamen Donald A., *Electronics Ckt. Analyzer & Design*, 2nd ed., Tata McGraw Hill.
4. *Semiconductor Data Manual*, BPB Publications.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** III	
Subject: Digital Electronics (abbreviated as DE)			
Periods per Week (60 min. each)	Lecture	04	
	Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	03	100
	Practical & Oral	02	50
	Oral	---	---
	Term Work	---	25
	Total	05	175

Module	Contents	Hours
1	**Introduction** Number systems, binary, octal, hexadecimal and others. Conversion from one system to another. Arithmetic, binary BCD and hexadecimal.	04
2	**Binary codes** Weighted, reflective, sequential, gray, error detecting codes, odd, even parity, hamming codes, alphanumeric, Morse teletypewriter ASCII, EBCDIC codes, converting binary to gray & gray to binary and XS3.	04
3	**Boolean Algebra Logic Gates** AND, OR, NOT, XOR, XNOR, operations NAND, NOR use of universal gates for performing different operations. Laws of Boolean Algebra, De-Morgan's theorems. Relating a truth table to a Boolean expression. Multi level circuit.	04
4	**Combinational Circuits** K-Maps and their use in simplifying Boolean expressions, minterm, maxterm SOP and POS implementation. Implementing a logic function using universal gates. Variable entered maps for five and six variable functions: Quine McClusky tabular techniques.	08
5	**Combination Logic Circuit Design** Designing code converter circuits e.g. binary to gray, BCD to seven segment parity generator. Binary arithmetic circuits:- Adders, subtractors (half and full), BCD adder-subtractor, carry look head adder, serial adder, multiplier magnitude comparator, arithmetic logic units.	04
6	**Use of Multiplexers in logic design** Multiplexer (ULM) Shannon's theorem, ULM trees, de-Multiplexers, designing using ROMs & ULMs. Hazards in combinational circuits.	04

7	**Sequential Logic Circuits** Comparison of combinational and sequential circuits, multi-vibrators (astable, monostable and bistable), flip-flops, SR, T, D, JK. converting one flip-flop into another, use of debounce switch, counters modulus of a counter, ripple counters, up/down counter, designing sequential counters using gate IC and counter by drawing state transition diagram and state transition table. Ring counter, Johnson counter, twisted ring counter, pseudo random number generator, unused states and locked conditions.	08
8	**Registers** Serial input serial output serial input parallel output, left shift, right shift register, use of register ICs for sequence generator and counters.	05
9	**Memories** RAM, ROM the basic cell IC bipolar, CMOS, RAM dynamic RAM cell. Magnetic core NVRAM, bubble memory, CCD, PAL, PLA. Introduction to PLD's.	03
10	**Logic Families** Basics of digital integrated circuits, basic operational characteristics & parameters. TTL, schottky clamped TTL, tri-state gate ECL,IIL, MOS devices CMOS comparison of logic families. PMOS & NMOS&E^2CMOS. Introduction to FPGA.	04

Theory Examination:

6. Question paper will consist of total 7 questions carrying 20 marks each.
7. Only 5 questions need to be attempted.
8. Q.1 will be compulsory and based on the entire syllabus.
9. Remaining questions will be mixed in nature.
10. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Practical & Oral Examination:

Practical examination will be based on one experiment performed from the list of experiments given in the syllabus and the oral will be based on entire subject. The distribution of the marks shall be as follows,

Practical examination : 25 marks
Oral examination : 25 marks

Term work:

Term work consists of minimum eight experiments and a written test. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal) :10 marks
Test (at least one) :10 marks
Attendance (Practical and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

List of Laboratory Experiments:

1. Implementing study of Gates and Logic Operations like, NOT, AND , OR, NR, XOR & XNOR using (i)all NAND Gates (ii)all NOR Gates.
2. Implementing a binary to gray, gray to binary or binary to XS3 code converter using gate ICs.
3. Simplifying 3, 4 variable logic functions and implementing them using gate ICs AND/OR, OR/AND, ALL NAND & ALL NOR.
4. Implementation of Half & Full Adder Circuit.
5. Study of Multiplexer & Demultiplexer.
6. Constructing flip flops like SR, D, JK and T using all NAND gates and a de-bounce switch.
7. Designing a mod N counter where N<14 using JK F/F and D F/F.
8. Design a ripple counter/or a two bit comparator using gate ICs.
9. Building a ring counter and a twisted ring counter using D f/f ICs.
10. Any one of the following:
    i. Full Adder using Gates and using Decoder or a multiplexer.
    ii. Using a counter ICs like 7490 or 7492 or 7493 as a BCD counter.
    iii. Using a shift register as a sequence generator.

Text Books:

1. Jain R.P., *Modern Digital Electronics,* Tata McGraw Hill, 1984.
2. Malvino Leach, *Digital Principles and Applications,* Tata McGraw Hill, 1991.

Reference Books:

1. Floyd Thomas L., *Digital Fundamentals,* 3rd ed., Belland Howell Company-1993.
2. Morris Mano M., *Digital Design,* Prentice Hall International-1984.
3. Almaini A.E., *Electronic Logic Systems,* 2nd ed., PHI-1986.
4. Malvino, *Digital Electronics,* Tata McGraw Hill, 1997.
5. Tocci, *Digital Systems,* PHI, 2000.
6. Dr. Jog Nandini K., *Logic Circuits,* 2nd ed., Nandu Publishers and printers Pvt, Ltd, 1998.
7. Floyd & Jain, *Digital Fundamentals,* Pearson Education.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** III	
Subject: Engineering Mathematics-III (abbreviated as EM-III)			
Periods per Week (60 min. each)	Lecture	05	
	Practical	---	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	05	100
	Practical & Oral	---	---
	Oral	---	---
	Term Work	---	---
	Total	05	100

Module	Contents	Hours
1	**Laplace Transform** Functions of bounded variations. Laplace Transforms of 1, t^n, e^{at}, sin at, cos at, sinh at, cosh at, erf(t) Linear property of L.T .First shifting theorem Second shifting theorem $L\{t^n f(t)\}$, $L\{f(t)/t\}$, $L\{\int f(u)du\}$, $L\{d^n/dt^n f(t)\}$.Change of scale property of L.T. Unit step function , Heavyside, Dirac delta functions, Periodic functions and their Laplace Transforms. **a) Inverse Laplace Transforms** Evaluation of inverse L.T., partial fractions method, convolution theorem. **b) Applications** to solve initial and boundary value problems involving ordinary diff. Equation with one dependant variable.	20
2	**Complex Variables** Functions of complex variables, continuity and derivability of a function, analytic functions, necessary condition for f(z) to be analytic, sufficient condition (without proof), Cauchy – Riemann conditions in polar forms. Analytical and Milne – Thomson method to find analytic functions f(z) = u + iv where (i) u is given (ii) v is given (iii) u+v (iv) u-v is given. Harmonic functions and orthogonal trajectories. **a) Mapping** Conformal mapping, Bilinear mapping, fixed points and standard transformation, inversion, reflection, rotation and magnification. **b)Line Integral** of function of complex variable, Cauchy's theorem for analytical function (with proof), Cauchy's Goursat theorem (without proof), properties of line integral, Cauchy's Integral formula and deduction. **c) Singularities and poles**: Taylor's and Laurent's	30

	development (without proof), residue at isolated singularity and it's evaluation. **d) Residue theorem** application to evaluate real integrals of type $\int_0^{2\pi} f(\cos\theta, \sin\theta)d\theta$ *and* $\int_{-\infty}^{+\infty} f(x)dx$	
3	**Fourier series** Orthogonality & orthogonal functions, Expression for the function in a series of orthogonal functions, Dirichlet's conditions, Fourier series of periodic functions with period 2pi or 2*l*. (Derivation of Fourier coefficients a0, an, bn is not expected) Dirichlet's theorem Even & Odd functions. Half range sine & cosine expressions Parsaval's identities (without proof) **a) Complex form of Fourier Series**: Fourier transform & Fourier integral in detail	25

Theory Examination:

11. Question paper will consist of total 7 questions carrying 20 marks each.
12. Only 5 questions need to be attempted.
13. Q.1 will be compulsory and based on the entire syllabus.
14. Remaining questions will be mixed in nature.
15. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Wartikar P.N. / Wartikar J. N., *Textbook of Applied Mathematics*, Pune Vidyarthi Griha Prakashan, 1981.
2. Kreyszig Erwin, Advanced Engineering Mathematics, 8th ed., Wiley Student Edition, New Delhi, 2006.

Reference Books:

1. Churchil, *Coplex variables*, Mc Graw Hill.
2. Shantinarayan, *Theory of function Complex Variable*, S. Chand & co.
3. Shastri S.S., *Engineering Mathematics*, Prentice Hall.
4. Glyn James, Advanced Modern Engineering Mathematics, 3rd ed., Pearson Education Ltd., 2004.
5. Potter Merle C., Goldberg J. L., Aboufadel Edward F., 3rd ed., Oxford University Press, New Delhi, 2005.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** III	
Subject: Transducers-I			
Periods per Week (60 min. each)	Lecture	04	
	Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	03	100
	Practical & Oral	02	50
	Oral	---	*25
	Term Work	---	25
	Total	05	200

*-Oral examination will be based on object-oriented industrial visit.

Module	Contents	Hours
1	**Instrumentation System** Units & standards of measurement. Introduction, block diagram, functional elements of measurement system, static & dynamic characteristics or performance characteristics of transducer. Error: definition, classification, statistical analysis of errors.	06
2	**Transducer** Definition, classification (active, passive, primary, secondary, mechanical, electrical, analog, digital), selection criteria, sources of error for parameter under measurement, transducer specifications, test condition & operating conditions.	03
3	**Displacement** **a) Resistance potentiometer:** (linear & logarithmic), piezo-resistive effect, ultrasonic transducer. LVDT, RVDT (transfer function, linearity, sensitivity, source frequency dependence, phase null, & signal conditioning). Selection & properties of materials for LVDT, and general electromagnetic sensors. **b) Capacitance type transducers:** with applications, materials for capacitive, ultrasonic and elastic transducers. **c) Digital transducer:** translational & rotary encoders (absolute position & incremental position encoders), Optical & magnetic pickups. **d) Pneumatic transducer**: flapper- nozzle transducer.	12
4	**Temperature transducers** Modes of heat transfer, laws of conduction convection and radiation, engineering materials for Temperature and conductive, resistive sensors, properties of materials for RTD, thermister, thermocouple. Temperature scales (standard scale), glass thermometers, liquid expansion thermometer, gas	12

	thermometer (filled system thermometer), bimetallic thermometer, solid state temperature sensor. **a) Resistance temperature detector (RTD**): types, construction, errors associated with RTD & its solutions (3 wire & 4 wire method, null balance, power supply stability), self heating effect, sensitivity, response time, dissipation constant, range advantages, disadvantages and limitations. **b) Thermistors**: principle, types (NTC, PTC) , characteristics, construction, sensitivity, range, response time, signal conditioning measuring circuit, calibration & applications. **c) Thermocouple:** Principle, thermoelectric effect, Seebeck effect, Peltier effect, laws of thermocouple, types of thermocouple with characteristic curve, thermocouple table, sensitivity, construction, range, signal conditioning, electrical noise & noise reduction techniques, cold junction compensation method, thermowell, thermopile, thermocouple emf measurement method. **d) Pyrometers:** Radiation & optical.	
5	**Level Transducers** Dipsticks, displacers, float system, bubbler, diaphragm bore type, capacitive devices for level measurement, ultrasonic level gauge, DP cell, load cell, vibrating type, microwave, radar, radioactive type level gauges, LASER type transducers, fiber optic level sensors, solid level detectors, Intelligent level measuring instruments.	07
6	**Metrology** Elements of Engineering measurement: Abbas & Taylorr's principle, theory of limits and fits and their selection, screw thread measurement, gear profile measurement, absolute & comparative measurement & measuring principle, alignment testing, use of auto collimators and design & use of limit gauges, screw & slip gauges.	08

Theory Examination:

16. Question paper will consist of total 7 questions carrying 20 marks each.
17. Only 5 questions need to be attempted.
18. Q.1 will be compulsory and based on the entire syllabus.
19. Remaining questions will be mixed in nature.
20. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Practical & Oral Examination:

Practical examination will be based on one experiment performed from the list of experiments given in the syllabus and the oral will be based on entire subject. The distribution of the marks shall be as follows,

Practical examination : 25 marks
Oral examination : 25 marks

Term work:

Term work consists of minimum eight experiments, a written test and industrial visit report. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal) :10 marks
Test (at least one) :10 marks
Attendance (Practical and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

*Oral Examination Based on Object-Oriented Industrial Visit

Visit to transducer manufacturing industry to study the manufacturing of the transducer from raw material to finished product. The student should submit the detailed report depending on the observations made. The concerned teachers of subject Transducer-I will co-ordinate the visit. Oral examination will be based on object oriented industrial visit.

List of Laboratory Experiments:

1. To plot & study the characteristics of- RTD.
2. To plot & study the characteristics of Thermistor (NTC, PTC).
3. To plot & study the characteristics of- Thermocouple J, K, R, S, T (any three).
4. To plot & study the characteristic of LVDT.
5. To plot & study the characteristic of capacitive transducers.
6. Measurement of angular and linear displacement by using digital encoder.
7. Level measurement by using capacitive, air purge method.
8. Study of Flapper nozzle transducer.
9. Application of ultrasonic transmitter receiver for any one parameter.

Text Books:

1. B.C Nakra, K.K. Cahudhary, *Instrumentation Measurement and Analysis*, Tata Mc Graw Hill.
2. Sawney A.K., *Electrical and Electronic Measurement and Instrumentation*, Dhanpatrai And Co.

Reference Books:

1. Doeblin E.D., *Measurement system*, 4th ed..
2. Liptak B.G., *Process measurement and analysis*.
3. Neubert Hermann K. P., *Instrument Transducer*, 2nd ed., Oxford University Press, New Delhi, 2003.
4. Johnson Curtis D., *Process Control Instrumentation Technology*, 5th ed..
5. Jain R.K., *Engineering Metrology*, Khana Publishers.
6. Rangan, Mani, Sarma., *Instrumentation Systems and Devices*, 2nd ed., Tata Mc Graw Hill.
7. S.P. Sukhatme, *Heat Transfer*, 3rd edition, University Press.
8. B.E. Jones, *Instrument Technology*.
9. Cheatle Keith R., *Fundamentals of Test Measurement Instrument Instrumentation*, ISA Publication.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** III	
Subject: Electrical Networks (abbreviated as EN)			
Periods per Week (60 min. each)	Lecture	04	
	*Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	03	100
	Practical and Oral	---	---
	Oral	---	25
	Term Work	---	25
	Total	03	150

* Only tutorials should be conducted.

Module	Contents	Hours
1.	**Networks Theorems** Analysis of networks with dependent & independent sources, mesh analysis, nodal analysis, source transformation technique, superposition theorem, Thevenin's theorem, Norton's theorem, maximum power transfer theorem, solution of networks with AC sources. Analysis of coupled circuits (self inductance, mutual inductance, and dot convention)	12
2.	**Graph Theory** Introductory definition – Graph of a network, trees, co-trees, loops. Incidence matrix, loop matrix and cutest matrix. Network equilibrium equations, Duality.	06
3.	**Time and Frequency response of circuits** Voltage/current relations for R, L, C & their equations in time domain. Initial and final conditions, first and second order differential equations, steady state and transient response. Analysis of transient and steady state responses using Classical technique as well as by Laplace transforms. Steady state response to step, ramp, impulse & sinusoidal input functions.	10
4.	**Network Functions & Two-Port Network** Network functions- driving point and transfer functions. Poles and zeros, time domain behavior from pole zero plot. Concept of two port network. Open circuit impedance (Z) parameters, Short circuit admittance(Y) parameters, transmission (ABCD) parameters, inverse transmission parameters, hybrid parameters. Interrelation of different parameters. Interconnection of two port networks, T and π representation. Terminated two-port networks.	10

5.	**Fundamentals of Network Synthesis.** Casuality and stability, Hurwitz polynomials, positive real functions, synthesis of one port networks with two kinds of elements. Properties & synthesis of L-C, R-C, R-L driving point impedances, synthesis of R-L-C functions. Properties of transfer functions, zeros of transmission, synthesis of Y_{21} and Z_{21} with a 1-Ohm termination, synthesis of constant – resistance networks.	10

Theory Examination:

1. Question paper will consist of total 7 questions carrying 20 marks each.
2. Only 5 questions need to be attempted.
3. Q.1 will be compulsory and based on the entire syllabus.
4. Remaining questions will be mixed in nature.
5. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Oral Examination:

The oral will be based on the entire subject.

Term work:

Term work consists of minimum ten tutorials properly recorded and graded as well as assessed test paper(s). The distribution of the term work shall be as follows,

Laboratory work (Tutorials) :10 marks
Test (at least one) :10 marks
Attendance (Tutorials and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

List of Tutorials:

1. Examples indicating concept of super loop and super node.
2. Examples of indicating the application of thevenin,s and Norton,s theorem in presence of dependent sources.
3. The incidence, Cut-set, Tieset, F-Cutest and F-Tie-Set Matrices should be written for given graph.
4. Examples on evaluating the transient and steady-state conditions for a R-L-C series or parallel connections for different values of resistance. The concept of overdamped, critically damped, underdamped, oscillatory and unbounded response should become clear from this problems.
5. Examples on evaluating the transient and steady-state conditions for a R-L, R-C circuits for DC conditions.
6. Evaluating the above examples using Laplace Transform.
7. Examples on Hurwitz Polynomial. Necessary and sufficient condition for Positive real function.
8. Examples on realization of R-L, R-C, L-C functions.
9. Examples on synthesis of R-L-C function.
10. Examples on the synthesis of Y_{21} and Z_{21} with a 1 ohm termination.

Text Books:

1. Kuo Franklin F., *Network analysis & synthesis*, 1st ed., Wiley International, 1962.
2. Van Valkenburg M.E., *Network analysis*, 3rd ed., Eastern Economy Edition, 1983.

Referance Books:

1. Roy Chaudhary D., *Network & systems*, Wiley Eastern Limited, 1991.
2. Hayt William, Kemmerly Jr.Jack E., *Engineering circuit Analysis*, 6th ed., Tata McGraw Hill, New Delhi 2002.
3. Edminister Joseph A., Nahvi Mohmood, *Electric Circuits*, 3rd ed., Tata McGraw Hill New Delhi 1999.
4. Shyammohan Sudhakar, *Circuits & Networks Analysis & Synthesis*, 13th reprint, Tata McGraw Hill, 2000
5. Bruce Carsion A., *Circuits*, Brooks/Cole Thomson Learning, 2000.
6. Dav Artice M., *Linear Circuits Analysis*, PWS Publishing company, 1998.
7. Alexander Charlesk, Mathew N.O., Sadlku, *Fundamentals of Electric Circuits*, McGraw Hill, 2000.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** IV	
Subject: Analytical Instrumentation (abbreviated as AI)			
Periods per Week (60 min. each)	Lecture	04	
	Practical	02	
	Tutorial	--	
		Hours	Marks
Evaluation System	Theory	3	100
	Practical & Oral	---	---
	Oral	---	25
	Term Work	--	25
	Total	3	150

Module	Contents	Hours
1	**Overview & Introduction** Introduction to the analytical process & Electromagnetic Spectrum.	02
2	**Basics of Spectroscopy** Laws of photometry- Light and its interaction with matter Introduction to Spectroscopic Methods. Components of Optical Systems (viz. Radiation sources & detectors, filters & mono-chromators, signal processors & readouts.)	06
3	**Atomic Spectroscopy** Atomic absorption spectroscopy Atomic Emission Spectroscopy	05
4	**Molecular Spectroscopy** **a) Electronic transitions** Introduction to UV-Visible molecular spectroscopy Applications of UV-Visible spectroscopy Fluorescence, phosphorescence and chemiluminescence Raman scattering & Raman spectrophotometer **b) Nuclear transitions** Nuclear Magnetic Resonance (NMR) **c) Vibrational excitation** IR absorption spectroscopy Applications of Infrared Spectrometry	11
5	**Additional Instrumental Methods for Organic Structural Analysis** Mass Spectrometry	04
6	**Separation Science** Fundamentals of chromatographic separations	06

	Gas chromatography- Gas chromatograph & its components High performance liquid chromatography	
7	**Industrial Gas Analyzers** Oxygen, Carbon dioxide, NOx analyzers, Online Gas Analyzers, Nephalometer, Densitometer, etc.	07
8	**Radio Chemical Instrumentation** Radio Chemical methods, radiation detectors- ionization chamber, Giger Muller counter, proportional counter, scintillation counter, semiconductor detectors, pulse height analyzer, X-ray spectrometry, X-ray spectrum, X-ray spectrometry, X-ray diffractometers, X-ray absorption meter.	07

Theory Examination:

6. Question paper will consist of total 7 questions carrying 20 marks each.
7. Only 5 questions need to be attempted.
8. Q.1 will be compulsory and based on the entire syllabus.
9. Remaining questions will be mixed in nature.
10. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Oral Examination:

The oral will be based on entire subject.

Term work:

Term work consists of minimum eight experiments and a written test. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal) :10 marks
Test (at least one) :10 marks
Attendance (Practical and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

List of Laboratory Experiments:

1. Photoelectric Colorimeter
2. Nephalo-turbidity meter
3. Densitometer
4. Refractometer
5. Single beam Spectrometer for UV/VIS range.
6. Double beam Spectrometer for UV/VIS range.
7. Gas Chromatograph
8. Atomic absorption spectrometer
9. Balance Cell Calorimeter
10. Spectroflourimeter

Text Books:

1. Willard, Merritt, Dean, Settle, *Instrumental Methods of Analysis,* CBS Publishers & Distributors, New Delhi, 7^{th} ed..

2. Khandpur R. S., *Handbook of Analytical Instruments*, Tata McGraw–Hill Publications, 3rd ed..

Reference Books:

1. Skoog, Holler, Nieman, *Thomson Principles of Instrumental Analysis*, Books-cole publications, 5th ed..
2. Ewing Galen W., *Instrumental Methods of Chemical Analysis*, McGraw-Hill Book Company, 5^{th} ed..
3. Braun Robert D., *Introduction to Instrumental Analysis*, McGraw-Hill Book Company.
4. Sherman R.E., *Analytical Instrumentation*, ISA Publication.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** IV	
Subject: Application Software Practices-I (abbreviated as ASP-I)			
Periods per Week (60 min. each)	Lecture	---	
	Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	---	---
	Practical and Oral	2	50
	Oral	---	---
	Term Work	---	25
	Total	2	75

Module	Contents	Hours
1	Study of Visual Basic/VB6.0 as a tool for developing real time HMI (Human Machine Interface) for instrumentation applications. 1) Configuring and using Hyper Terminal. 2) Developing a Login form with password. 3) Developing a Dynamic Linked Library (DLL) for parallel port using VC++ 6.0. 4) Using parallel port DLL for On-Off system. 5) Using MSCOMM.OCX for Serial communication. 6) Developing a real-time database using serial port and parallel port programs. 7) Developing different types of graphs for trend display, historical display. 8) Developing an ActiveX component for a) Tank System. b) Control Valve c) Pipe d) Any other system/component	

Practical & Oral Examination:

Practical & oral examination will be based on the various experiments mentioned as above. The distribution of the marks shall be as follows,

Practical examination : 25 marks
Oral examination : 25 marks

Term work:

Term work consists of programs on the above contents. The distribution of the term work marks shall be as follows,

Laboratory work (Journal) : 10 Marks

Laboratory Test : 10 Marks
Attendance (Practical) : 05 Marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

Books Recommended:

1. Soma Dasgupta, *Visual Basic Projects*, BPB Publications.
2. Christopher, *Visual Basic*.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** IV	
Subject: Electrical Technology & Instruments (abbreviated as ETI)			
Periods per Week (60 min. each)	Lecture	05	
	Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	03	100
	Practical & Oral	---	---
	Oral	---	25
	Term Work	---	25
	Total	03	150

Module	Contents	Hours
1	**D.C. Machines** Constructional details, types (shunt, series & compound), generator action. emf equation, motoring action, significance of back emf, torque and speed equations, torque-armature current, speed-armature current and torque-speed characteristics of different types of motors, speed control, starter, applications. General specifications of D.C. Machine & their significance.	10
2	**Induction Motor** Rotating magnetic field, construction and principle of operation, slip, rotor frequency, torque-slip characteristic, relationship between slip and rotor copper loss, speed control, starting methods, motor ratings. General specifications of induction motor & their significance.	08
3	**Fractional Horse Power Motors** Construction and principle of operation of single phase induction motor, types of single phase induction motor (resistance split phase, capacitance split phase) and their applications. Shaded pole induction motor.	06
4	**Analog Meters** Construction & working principle of: ammeters, voltmeters, ohmmeters, power factor meter, energy meter, Q meters, D'Arsonaval galvanometers-PMMC & PMMI instruments. Shunts & multipliers-Measurement of phase & frequency, analog multimeters.	08
5	**Measurement of R, L, C** Measurement of medium, low and high resistance, megger. A.C. and D.C. potentiometers: A.C. Bridges, measurement of self and mutual inductances. Measurement of capacitance.	10

	Derivations and numericals related to all bridges.	
6	**Electronic Measuring Instruments** Electronic voltmeters, DVM and DMM, automation in voltmeters (ranging, zeroing, polarity indication).	05
7	**Input/Output devices** **a) Digital I/O devices**: punched card, paper tape, bar codes, line printer, ink-jet printer, digital tape recording, floppy disk. **b) Display devices**: LED, LCD, seven segment display driver, alpha numeric displays and recorders.	08
8	**Cathode Ray Oscilloscope** CRT, Types of CRO: Single beam, double beam, digital storage (DSO) and sampling. Brief comparison between CROs. Application in instrumentation and measurement.	05

Theory Examination:

11. Question paper will consist of total 7 questions carrying 20 marks each.
12. Only 5 questions need to be attempted.
13. Q.1 will be compulsory and based on the entire syllabus.
14. Remaining questions will be mixed in nature.
15. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Oral Examination:

The oral examination will be based on the entire subject.

Term work:

Term work consists of minimum eight experiments and a written test. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal) :10 marks
Test (at least one) :10 marks
Attendance (Practical and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

List of Laboratory Experiments:

1. Speed control of DC shunt motor by armature voltage and flux control method.
2. Load test on DC shunt motor.
3. Load test on DC series motor.
4. Speed control of 3 phase slip ring induction motor by adding the external resistance in the rotor circuit.
5. Starting of induction motor by D.O.L., autotransformer, star/delta and rotor resistance starter.
6. Study of different types of fractional horse power motors.
7. Study of D.C. machine starter.
8. Study of Multi-meter& CRO: front panel controls & specifications.
9. Introduction, identification & testing of various components like resistors, capacitors, inductor, transistor, diode, various ICs.

10. Measurement of medium value resistance using bridge.
11. Measurement of small value resistance using bridge.
12. Measurement of Inductance by using bridge.
13. Study of D.C. Potentiometer.
14. Study of Megger.
15. Measurement of Capacitance using A.C. Bridges.
16. Measurement of phase & frequency using frequency meters & Synchroscope.
17. Applications of CRO (Measurements of phase & frequency & component testing).
18. Study of DVM.
19. Study of Recorders.
20. Study of Display Devices.
21. Study of spectrum/wave analyzer.

Text Books:

1. Sawhney A. K., *Electrical & Electronics Measurement & Instrumentation,* Dhanpat Rai & Co.Pvt Ltd.
2. Nagrath I. J., Kothari D. P., *Electrical Machines*, 2nd ed., Tata McGraw Hill, New Delhi 1997.

Reference Books:

1. Guru Bhag S., Hiziroglu Huseyin R., Electric Machinery & Transformers, 3rd ed., Oxford University Press, New Delhi 2007.
2. Say M. G., *The performance and Design of Alternating Current Machines*, 3rd ed., CBS Publisher and Distributor, Delhi, 1983.
3. Taylor Openshaw, *FHP Motors,* Addison Wesley 1976.
4. Kalsi H. S., *Electronics Instrumentation,* Tata McGraw Hill, New Delhi 1997.
5. Khandpur R. S., *Preventive Maintenance & Troubleshooting*, Tata McGraw Hill, New Delhi 1997.
6. Cooper W.D., Helfrick A.D., *Electronic Instrumentation and Measurement Techniques,* Prentice Hall of India Limited, New Delhi.
7. Rangan C. S., Sharma G. R., Mani V. S., *Instrumentation Devices & Systems,* 2nd ed., Tata McGraw Hill, New Delhi 1997.
8. Rathore-Narosa T. S., *Digital Measurement Techniques*.
9. Oliver & Cage, *Modern Electronic Measurements & Instrumentation,* MGH.
10. Bouwens A. J., *Digital Instrumentation,* MGH.
11. Technical Manuals of DSO: APLAB, Scientific, HP etc.
12. Technical Manuals for Virtual CRO.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** IV	
Subject: Feedback Control System (abbreviated as FCS)			
Periods per Week (60 min. each)	Lecture	04	
	Practical	02	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	03	100
	Practical & Oral	02	50
	Oral	---	---
	Term Work	---	25
	Total	05	175

Module	Contents	Hours
1	**Introduction** Definition of control system and related terms, open loop and closed loop system, examples. Development of automatic control systems, classification of control system, examples.	02
2	**Servomechanism** Definition of servomechanism, block diagram of servo systems- AC servo system , DC servo system, servo components- potentiometer, synchros, AC servomotor, DC servomotor, AC/DC Tachometer, servo amplifiers.	05
3	**Mathematical Models of Physical Systems** Definition of physical systems, principle of superposition and homogeneity, linear non-linear, time varying, time invariant systems. Types of dynamic model, linear elements of electrical and mechanical systems, differential equations of physical systems-mechanical systems, electrical systems, thermal systems, fluid systems, pneumatic systems. Analogous systems.	07
4	**Transfer Function and Feedback Characteristics** Definition of transfer function, sinusoidal transfer function, transfer functions of physical systems, block diagram algebra, reduction rules, signal flow graphs-definition, construction, properties, and Mason's gain formula ,sensitivity of closed loop and open loop system, effect of feedback, effect of disturbances signals, regenerative feedback with examples	12
5	**Time Response Analysis** Standard test signal - pulse and impulse function, step function, ramp function, parabolic function, sinusoidal function, dynamic response, time response of first order system, time response of second order system, specifications, steady - state error, system types and error constants, effect of adding zeros	07

	and poles to a system, design specifications of second order system- desired close loop pole location and the dominant condition.	
6	**Stability Analysis and Root Locus** Concept of stability, definitions, bounded input-bounded output stability, relative stability, necessary and sufficient conditions for stability, Routh stability criterion, relative stability analysis, root locus technique, applications, concept, construction of root loci, root loci of different systems.	08
7	**Frequency Response and Stability Analysis** Correlation between time and frequency response, polar plots, Bode plots, log magnitude versus phase plots, Nyquist stability criterion, frequency response specifications, stability analysis using-bode, polar, log-magnitude versus phase plots, definitions and significance of gain margin and phase margin, sensitivity analysis in frequency domain	07

Theory Examination:

16. Question paper will consist of total 7 questions carrying 20 marks each.
17. Only 5 questions need to be attempted.
18. Q.1 will be compulsory and based on the entire syllabus.
19. Remaining questions will be mixed in nature.
20. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Practical & Oral Examination:

Practical examination will be based on one experiment performed from the list of experiments given in the syllabus and the oral will be based on entire subject. The distribution of the marks shall be as follows,

Practical examination : 25 marks
Oral examination : 25 marks

Term work:

Term work consists of minimum eight experiments and a written test. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal) :10 marks
Test (at least one) :10 marks
Attendance (Practical and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

List of Laboratory Experiments:

1. To study the characteristics of:
    a. Synchros Transmitter and Receiver.

b. Synchro as an error detector.

2. To study DC position control system.
3. To find characteristics of AC servo motor.
4. To study the operation of stepper motor.
5. To study time response of Type 0, 1, 2 systems.
6. To study the frequency response of First and Second order systems.
7. To study the effect of damping factor on the performance of second order system.
8. To study the effect of time constant on performance of 1^{st} order system.

Note: For Experiment No. 5 to 8 the hardware results must be verified using simulation software like MATH CAD/MATLAB/SCILAB/OCTAVE or equivalent.

Text Books:

1. Nagrath I. G., Gopal M., *Control System Engineering*, New Age International (P) Ltd. Publishers 2000.
2. Kuo Benjamin C., *Automatic Control Systems*, 6^{th} ed., Prentice Hall of India, New Delhi, 1993.

Books Recommended:

1. Gopal M., *Control Systems Principles and Design*, Tata McGraw Hill Publishing Co. Ltd. New Delhi, 1998.
2. Nise Norman S., *Control Systems Engineering*, 3^{rd} ed., John Wiley and Sons, Inc. -2000.
3. Lewis Paul H., Chang Yang, *Basic Control Systems Engineering*, Prentice Hall International, Inc. 1997.
4. Raymond T. Stefani, Bahram Shahian, late Clement J. Savant and late Gene H. Hostetter, *Design of Feedback Control Systems*, 4^{th} ed., Oxford University Press, New Delhi, 2001.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** IV	
Subject: Engineering Mathematics-IV (abbreviated as EM-IV)			
Periods per Week (60 min. each)	Lecture	05	
	Practical	---	
	Tutorial	---	
		Hours	Marks
Evaluation System	Theory	05	100
	Practical and Oral	---	---
	Oral	---	---
	Term Work	---	---
	Total	05	100

Module	Contents	Hours
1	**Vector Analysis:** Scalar and vector point functions, curl, gradient and divergence, conservative, irrotational and Solenoidal fields. **a) Line Integral**, Greens thoerem for plane regions and properties of line integral, Stoke's theorem, Gauss's Divergence theorem (without proof) related identities and deductions.	22
2	**Matrices** **a) Types of matrices**, adjoint of a matrix inverse of a matrix, rank of a matrix, linear dependence and independence of rows and columns of a matrix over a real field, reduction to normal form and partitioning of a matrix. **b) Systems of homogeneous** and non-homogeneous equations, their consistency and solutions. **c) Brief revision** of vectors over real fields, inner product, norm, linear independence and orthogonality of vectors. **d) Characteristic Polynomial**, characteristic equation, characteristic roots, and characteristic vectors of square matrix, properties of characteristic roots and vectors of different types of matrices such as orthogonal matrix, Hermitian matrix, Skew-Hermitian matrix, Diagonal matrix, Cayley-Hamilton theorem (without proof), functions of square matrix , minimal polynomial and derogatory matrix. **e) Quadratic forms**, Congruent and orthogonal reduction of quadratic form, rank, index, signature and class value of quadratic form.	30
3.	**Probability and Statistics :** Concept of probability, conditional probability. Baye's theorem (without proof). **a) Random variable**	23

	Probability distribution for discrete and continuous random variables. Density function and distribution function. Expected value, variance, moments, moment generating function, binomial, Poission, normal distributions for detailed study with proof, **b) Curve fitting** Correlation, Karl Pearson coefficient & Spearman's rank correlation coefficient (without proof), regression, lines of regression.	

Theory Examination:

21. Question paper will consist of total 7 questions carrying 20 marks each.
22. Only 5 questions need to be attempted.
23. Q.1 will be compulsory and based on the entire syllabus.
24. Remaining questions will be mixed in nature.
25. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Text Books:

1. Wartikar P.N. / Wartikar J. N., *Textbook of Applied Mathematics*, Pune Vidyarthi Griha Prakashan, 1981.
2. Kreyszig Erwin, Advanced Engineering Mathematics, 8th ed., Wiley Student Edition, New Delhi, 2006.

Reference Books:

1. Shastri S.S., *Engineering Mathematics*, Prentice Hall.
2. Shantinarayan, *Matrices*, S. Chand & co.
3. Gupta Kapoor, *Mathematical Statistics*.
4. Glyn James, Advanced Modern Engineering Mathematics, 3rd ed., Pearson Education Ltd., 2004.
5. Potter Merle C., Goldberg J. L., Aboufadel Edward F., 3rd ed., Oxford University Press, New Delhi, 2005.

University of Mumbai			
Class: S.E.	**Branch:** Instrumentation	**Semester:** IV	
Subject: Transducers-II			
Periods per Week (60 min. each)	Lecture	04	
	Practical	02	
	Tutorial	-	
		Hours	Marks
Evaluation System	Theory	3	100
	Practical & Oral	2	50
	Oral	---	*25
	Term Work	---	25
	Total	5	200

*-Oral examination will be based on object-oriented industrial visit.

Module	Contents	Hours
1	**Flow Measurement** **a) Introduction to fluid flow:** properties of fluids, type of fluid, dimensionless numbers, type of fluid flow, fluid pressure measurement using manometer (U tube-types, well type, inclined type, micro-manometer), continuity equation, Bernoulli's equation, hydrostatic law, Pascal's law, flow through pipes- major & minor losses, flow measurement through open channel-weirs & notches. Materials used for flow sensors, performance of materials, corrosion resistors, erosion, effect of vapour pressure, cavitation and flashing. **b) Head type**: orifice, venturi, nozzle, pitot tube, characteristics of head type flow meters. Variable Area type: Rotameter. **c) Other flow meters**: Turbine, electromagnetic, ultrasonic, positive displacement, anemometers, hot wire, mass flow meter, solid flow meter.	15
2	**Strain Measurement** Introduction, types of strain gauges, gauge factor calculation, materials for strain gauge, resistance strain gauge bridges, temperature compensation and applications of strain gauges**.**	05
3	**Pressure Measurement** Pressure scales, units & relations, classification, elastic elements- bourdon tube, diaphragm, bellows. Calibration using dead weight tester. **a) Elastic materials**: Properties and selection of elastic materials for elastic transducers like spring, diaphragm, bourdon tube, bellows, piezo-electric and magneto-strictive	08

	materials. **b) Electronic**: Capacitive, piezo-electric, variable reluctance. **c) Conversion methods**: LVDT, strain gauge. **d) High Pressure measurement**: Bulk modulus cell, Bridgeman type. **e) Differential pressure measurement**: Force balance, motion balance, DP Cell, semiconductor strain gauges.	
4	**Vacuum Measurement** Units & relations, Mc-leod gauge, Pirani gauge, Pirani thermocouple, hot cathode ionization gauge, Knudsen gauge. Calibration using dead weight tester.	04
5	**Electro-chemical Sensors** Terminology, equations, units. PH measurement-electrodes, measuring circuits, maintenance, temperature compensation, calibration. Conductivity measurement- probes and measuring circuits. ORP (Oxidation Reduction Potential) Measurement.	05
6	**Force, Torque and Power Measurement** **a) Force measurement**: strain gauge, LVDT, piezoelectric. **b) Torque**: Tortion bar, strain gauge. **c) Power**: Dynamometer, instantaneous power measurement, alternator power measurement.	06
7	**Miscellaneous Transducers** Position, speed, velocity, acceleration, vibration, sound, viscosity, density, humidity & moisture measurement, nanosensors.	05

Theory Examination:

26. Question paper will comprise of total 7 questions, each of 20 marks.
27. Only 5 questions need to be solved.
28. Q.1 will be compulsory and based on the entire syllabus.
29. Remaining questions will be mixed in nature.
30. In question paper weightage of each module will be proportional to the number of respective lecture hours as mentioned in the syllabus.

Practical & Oral Examination:

Practical examination will be based on one experiment performed from the list of experiments given in the syllabus and the oral will be based on entire subject. The distribution of the marks shall be as follows,

Practical examination : 25 marks
Oral examination : 25 marks

Term work:

Term work consists of minimum eight experiments, industrial visit report and a written test. The distribution of the term work shall be as follows,

Laboratory work (Experiments and Journal) :10 marks
Test (at least one) :10 marks

Attendance (Practical and Theory) :05 marks

The final certification and acceptance of term-work ensures the satisfactory performance of laboratory work and minimum passing in the term-work.

*Oral Examination Based on Object-Oriented Industrial Visit

Visit to a process industry & calibration institute to study transducer specification & calibration procedures. The student should submit the detailed report containing the list of seen transducers with their specifications & calibration procedures.

The transducer specification should be studied with respect to following points

i) Interpreting manufacturer specification sheets.
ii) Transducer type
iii) Operating principle
iv) Accuracy
v) Linearity
vi) Hysteresis
vii) Environmental operating limits

The student should submit the detailed report depending on the observations made. The concerned teachers of subject Transducer-II will co-ordinate the visit. Oral examination will be based on the visit report.

List of Laboratory Experiments:

1. Strain gauge characteristics and weight measurement.
2. Measurement of pressure using bellows, diaphragm, bourdon tube.
3. Test & calibration of pressure gauges using dead weight tester.
4. Measurement of flow using orifice/venturi tube/pitot tube.
5. Measurement of flow using rotameter.
6. Study and characterization of PH meter.
7. Study and characterization of conductivity meter.
8. Humidity measurement.
9. Viscosity measurement.

Text Books:

3. Nakra B.C., Cahudhary K.K., *Instrumentation Measurement and Analysis*, Tata Mc Graw Hill.
4. Sawney A.K., *Electrical and Electronic Measurement and Instrumentation*, Dhanpatrai And Co.

Reference Books:

1. Doeblin E.D., *Measurement system*, 4th ed..
2. Liptak B.G., *Instrument engineer's handbook- Process measurement and analysis*.
3. Douglas M. Considine, *Process Instruments & controls Handbook*, Mc Graw Hill.
4. Curtis Johnson, *Process Control Instrumentation Technology*, 5th ed..
5. Rangan, Mani, Sarma, *Instrumentation Systems and Devices*, 2nd ed., Tata Mc Graw Hill.

6. Andrew Williams, *Applied Instrumentation in process industry*, vol-I, Gulf publishing company.
7. Bansal R.K., *Fluid Mechanics & Hydraulic Machines*, Laxmi publications.
8. David W. Spitzer, *Industrial Flow Measurement*, ISA Publication.