



**JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR**  
**Course Structure for Civil Engineering**  
**B. Tech Course**  
**(2015-16)**

**II B. Tech – I Sem**

S.No.	Course Code	Subject	L	Tu	Lab	C
1	15A54301	Mathematics - III	3	1	-	3
2	15A01301	Electrical and Mechanical Technology	3	1	-	3
3	15A01302	Building Materials and Construction	3	1	-	3
4	15A01303	Strength of Materials – I	3	1	-	3
5	15A01304	Surveying – I	3	1	-	3
6	15A01305	Fluid Mechanics	3	1	-	3
7	15A01306	Surveying Laboratory – I	-	-	4	2
8	15A01307	Strength of Materials Laboratory	-	-	4	2
		<b>Total</b>	<b>18</b>	<b>06</b>	<b>08</b>	<b>22</b>

# JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR

B. Tech II - I sem (C.E)

<b>T</b>	<b>Tu</b>	<b>C</b>
<b>3</b>	<b>1</b>	<b>3</b>

(15A54301) MATHEMATICS-III

(Common to All Branches)

## Objectives:

- This course aims at providing the student with the concepts of Matrices, Numerical Techniques and Curve fitting.

### UNIT – I

Elementary row transformations-Rank – Echelon form, normal form – Consistency of System of Linear equations. Linear transformations. Hermitian, Skew-Hermitian and Unitary matrices and their properties. Eigen Values, Eigen vectors for both real and complex matrices. Cayley – Hamilton Theorem and its applications – Diagonalization of matrix. Calculation of powers of matrix and inverse of a matrix. Quadratic forms – Reduction of quadratic form to canonical form and their nature.

### UNIT – II

Solution of Algebraic and Transcendental Equations: The Bisection Method – The Method of False Position– Newton-Raphson Method, Solution of linear simultaneous equation: Crout's triangularisation method, Gauss - Seidal iteration method.

### UNIT – III

**Interpolation:** Newton's forward and backward interpolation formulae – Lagrange's formulae. Gauss forward and backward formula, Stirling's formula, Bessel's formula.

### UNIT – IV

Curve fitting: Fitting of a straight line – Second degree curve – Exponential curve-Power curve by method of least squares. Numerical Differentiation for Newton's interpolation formula. Numerical Integration: Trapezoidal rule – Simpson's 1/3 Rule – Simpson's 3/8 Rule.

### UNIT – V

Numerical solution of Ordinary Differential equations: Solution by Taylor's series-Picard's Method of successive Approximations-Euler's Method-Runge-Kutta Methods. Numerical solutions of Laplace equation using finite difference approximation.

**TEXT BOOKS:**

1. Higher Engineering Mathematics, B.S.Grewal, Khanna publishers.
2. Introductory Methods of Numerical Analysis, S.S. Sastry, PHI publisher.

**REFERENCES:**

1. Engineering Mathematics, Volume - II, E. Rukmangadachari Pearson Publisher.
2. Mathematical Methods by T.K.V. Iyengar, B.Krishna Gandhi, S.Ranganatham and M.V.S.S.N.Prasad, S. Chand publication.
3. Higher Engineering Mathematics, by B.V.Ramana, Mc Graw Hill publishers.
4. Advanced Engineering Mathematics, by Erwin Kreyszig, Wiley India.

**Outcomes:**

The student will be able to analyze engineering problems using the concepts of Matrices and Numerical methods.

**PART – A**

**ELECTRICAL TECHNOLOGY**

**Objective:**

Electrical Technology contains basic Circuits, DC generators & motors, Transformers, Induction motors and their performance aspects will be studied.

**UNIT – I Introduction to DC & AC Circuits**

Ohm's Law, Basic Circuit Components, Kirchoff's Laws, Types of Sources, Resistive Networks, Series Parallel Circuits, Star Delta and Delta Star Transformation. Principle of AC Voltages, Waveforms and Basic Definitions, Root Mean Square and Average Values of Alternating Currents and Voltage, Form Factor and Peak Factor, Phasor Representation of Alternating Quantities, The J Operator and Phasor Algebra, Analysis of Ac Circuits With Single Basic Network Element, Single Phase Series.

**UNIT-II DC Machines**

**D.C Generators:** Principle of Operation of Dc Machines, Types of D.C Generators, E.M.F Equation in D.C Generator, O.C.C. of a D.C. Shunt Generator

**D.C Motors:** Principle of Operation of Dc Motors, Types of D.C Motors, Torque Equation, Losses and Efficiency Calculation in D.C Motor- Swinburne's Test

**UNIT-III AC Machines**

**Transformers:** Principles of Operation, Constructional Details, Losses and Efficiency, Regulation of Transformer, Testing: OC & SC Tests.

**Three Phase Induction Motors:** Principle of Operation, Slip and Rotor Frequency, Torque (Simple Problems).

**Alternators:** Principle of Operation-Constructional Details-EMF Equation-Voltage Regulation by Synchronous Impedance Method.

**OUTCOME:**

After going through this course the student gets a thorough knowledge on basics of Electrical Circuits, DC Machines, Transformers, Induction motors & Alternators with which he/she can able to apply the above conceptual things to real-world problems and applications.

**TEXT BOOKS:**

1. Basic Electrical Engineering, M.S.Naidu and S. Kamakshiah, Mc Graw Hill Education.
2. Basic Electrical Engineering, T.K.Nagasarkar and M.S. Sukhija, Oxford University Press.

**REFERENCES:**

1. Theory and Problems of Basic Electrical Engineering, D.P.Kothari & I.J. Nagrath, PHI.
2. Principles of Electrical Engineering, V.K Mehta, S.Chand Publications.
3. Fundamentals of Electrical Electronics Engineering 5<sup>th</sup> Edition, T.Thyagarajan, SCITECH Publications 2007
4. Electrical and Electronic Technology, Hughes, Pearson Education.

**PART – B**  
**MECHANICAL TECHNOLOGY**

**Objective:**

Mechanical Technology contains basic welding process, steam engines & turbines and their performance aspects will be studied.

**UNIT – I**

**WELDING PROCESSES:** Introduction to welding classification of welding processes, Oxyacetylene welding – equipment, welding fluxes and filler rods, Gas cutting, Introduction to arc welding – Manual metal arc welding. Submerged arc welding, TIG and MIG processes, soldering and brazing Importance, comparison and applications.

**UNIT - II**

Description and working of steam engines and steam turbines (Prime movers) – impulse and Reaction turbines. Description and working of I.C. Engines – 4 stroke and 2 stroke engines – comparison – Gas Turbines – Closed and open type gas turbines.

Reciprocating Air compressors – description and working of single stage and multistage reciprocating air compressors – inter cooling. Transmission of power; Belt, Rope, Chain and gear drive-simple problems.

**UNIT - III**

Block diagram of a vapour compression refrigeration system. Names of common refrigerates. Basic principles of air-conditioning. Room and General air conditioning systems Ducting – Different types of ventilation system. Earth moving machinery and Mechanical handling equipment – bull dozers – power shovels – Excavators – concrete mixer – Belt and bucket conveyers.

**TEXT BOOKS :**

1. Elements of Mechanical Engineering by S.N.Lal, Cengage Learning, 2013
2. Elements of Mechanical Engineering by S.Trymbaka Murthy, Universities Press, 2015
3. Manufacturing Technology, P.N. Rao, TMH

**REFERENCE BOOKS**

1. Pneumatics by Jagadeesha University Press,2015

**OUTCOME:**

After going through this course the student gets a thorough knowledge on basics of welding process, turbines, steam engines with which he/she can able to apply the above conceptual things to real-world problems and applications.

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**(15A01302) BUILDING MATERIALS & CONSTRUCTION**

**OBJECTIVES:** *To give the students a basic idea about the traditional and modern construction materials a brief knowledge on building components and its construction methodologies.*

**UNIT – I**

**INTRODUCTION TO BUILDING MATERIALS**

Traditional & Organic Building Materials – Stone – Dressing of Stones – Modern Building Materials – Bricks – Manufacturing process – Ceramic Products – Manufacturing Process – Building Materials for Low Cost Housing – Utilisation of Wastes for Alternative Building Materials – Sustainable Materials in Construction – National Standards.

**UNIT – II**

**GLASS:**

Introduction – Functions of Glass in Buildings – Constituents and Classification of Glass – Manufacturing Process – Properties of Glass – Common Types of Glass – Special Glass – Advantages and Disadvantages of Glass – National Standards.

**PLASTIC:**

Introduction – Polymerisation – Classification of Plastics – Commonly Used Plastics – Moulding and Fabricating for Plastic Products – Applications – Advantages – Disadvantages – Intelligent Use of Plastics in Buildings – National Standards.

**UNIT – III**

**INSULATING MATERIALS**

Thermal Insulating Materials: Introduction – Thermal Insulation – Heat Transfer Fundamentals – Thermal Properties of Insulating Materials – Selection of Insulating Materials – Classification of Insulation materials – Reflective Insulation Systems – Commonly Used Building Insulation Materials – National Standards.

Sound Insulating Materials: Introduction – Basics of Acoustics – Sound Absorption or Insulation – Green Insulation – National Standards.

**UNIT – IV**

**STRUCTURAL COMPONENTS:–**

Foundations – classification of Foundations – consideration in selection of foundation types – Masonry – Brick and block walls – Cavity walls – Damp-proof courses and membranes – Mortars – Arches and openings – Windows – Glass and glazing – Doors – Stairs – Types and Applications – Cladding to external walls – Flat roofs – Dormer windows – Formwork & Scaffolding – Precast concrete frames – Portal frames – Types – components – Framed structures – Components – Construction Procedure – Panel walls – National Standards.

**UNIT – V**

**INTERNAL CONSTRUCTION AND FINISHES**

Internal elements – Internal walls – Construction joints – Internal walls, fire protection – separating walls – Partitions – Plasters and plastering – Domestic floors and finishes – Sound insulation – Timber, concrete and metal stairs – Internal doors – Door sets – Fire resisting doors – Plasterboard ceilings – Suspended ceilings – Paints and painting – Components of Paints – Types of Paint – Considerations in Selecting Paints – Cement Paints – Oil Paints –

Emulsion Paints – Whitewash and Colourwash – Application of Paints –Distempers – Varnishes – Safety –Joinery production – Composite boarding – National Standards.

**TEXT BOOKS:**

1. Building Material by S K Duggal – New Age International Publishers; Second Edition
2. Building Construction by B.C.Punmia, Ashok Kumar Jain and Arun Kumar Jain - Laxmi Publications (P) ltd., New Delhi
3. Building Materials by M.L.Gambhir, TMH Pubilishers.
4. A Textbook on Building Construction by S.K.Sharma, S.Chand Pubilishers.

**REFERENCES:**

1. Building construction by W.B.Mckay, Vol.I, II, III & IV Pearson Publications, 2013 edition.
2. Building Construction by P.C. Varghese, Prentice-Hall of India private Ltd, New Delhi.
3. Building materials by P.C. Varghese, Prentice-Hall of India private Ltd, New Delhi
4. Building materials by S.C.Rangawala, Charotar Pubilishing House, Anand- INDIA.
5. Building Construction by S.C.Rangawala, Charotar Pubilishing House, Anand-INDIA

**Outcomes :**

On the completion of course, the students :

1. Will be able to understand the quality of various construction materials.
2. Will be able to prepare plan of staircase block.
3. Will be able to supervise the various construction activities at the time of actual execution.
4. Will be able to identify and select the materials for construction activities.

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**(15A01303) STRENGTH OF MATERIALS - I**

***OBJECTIVE:** The subject provide the knowledge of simple stresses and strains, flexural stresses in members, shear stresses and deflection in beams so that the concepts can be applied to the Engineering problems.*

**UNIT – I**

**SIMPLE STRESSES AND STRAINS :** – Deformable bodies - Elasticity and Plasticity – Types of stresses and strains – Hooke’s law – stress – strain diagram for mild steel – Working stress – Factor of safety – Lateral strain, Poisson’s ratio and volumetric strain – Elastic moduli and the relationship between them – Bars of varying section – composite bars – Temperature stresses.

Strain energy – Resilience – Gradual, sudden, impact and shock loadings – simple applications.

**UNIT – II**

**SHEAR FORCE AND BENDING MOMENT:** Definition of beam – Types of beams – Concept of shear force and bending moment – S.F and B.M diagrams for cantilever, simply supported and overhanging beams subjected to point loads, uniformly distributed load uniformly varying loads and combination of these loads – Point of contra flexure – Relation between S.F., B.M and rate of loading at a section of a beam.

**UNIT – III**

**FLEXURAL STRESSES :** Theory of simple bending – Assumptions – Derivation of bending equation:  $M/I = f/y = E/R$  – Neutral axis – Determination of bending stresses – Section modulus of rectangular and circular sections (Solid and Hollow), I, T, Angle and Channel sections – Design of simple beam sections.

**SHEAR STRESSES:** Derivation of formula – Shear stress distribution across various beam sections like rectangular, circular, triangular, I, T and angle sections.

**UNIT – IV**

**DEFLECTION OF BEAMS:** Bending into a circular arc – slope, deflection and radius of curvature – Differential equation for the elastic line of a beam – Double integration and Macaulay’s methods.

Determination of slope and deflection for cantilever and simply supported beams subjected to point loads, U.D.L. uniformly varying load-Mohr’s theorems – Moment area method – application to simple cases including overhanging beams-deflections of propped cantilevers for simple loading cases.

**UNIT – V**

**CONJUGATE BEAM METHOD:** Introduction – Concept of conjugate beam method. Difference between a real beam and a conjugate beam. Deflections of determinate beams with constant and different moments of inertia.

**DIRECT AND BENDING STRESSES :** Stresses under the combined action of direct loading and bending moment, core of a section – determination of stresses in the case of chimneys, retaining walls and dams – conditions for stability – stresses due to direct loading and bending moment about both axis.



**TEXT BOOKS :**

1. Mechanics of Materials – Dr.B.C.Punmia, Ashok Kumar Jain, Arun Kumar Jain, Lakshmi Publications.
2. Strength of Materials by R.K Rajput, S.Chand & Company Ltd.
3. Strength of Materials by B.S.Basavarajaiah, Universities Press, Hyderabad.

**REFERENCES:**

1. Strength of Materials by Ghosh & Datta, New Age Pubilishers
2. Strength of Materials by Dr.R.K.Bansal, Lakshmi Publications.
3. Strength of Materials by S.S.Rattan, TMH Publishers.

**Outcome :**

- (1) The students would be able to understand the behavior of materials under different stress and strain conditions.
- (2) The students would be able to draw bending moment, shear force diagram, bending stress and shear stress distribution for beams under the different conditions of loading.
- (3) The student would be able to apply knowledge to analyse concept of deflection, bending moment and shear force diagram in beams, and columns under various loading conditions using different analysis methods.

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**(15A01304) SURVEYING – I**

***OBJECTIVE:** To ensure that the student develops knowledge of the basic and conventional surveying instruments, principles behind them, working of the instruments, plotting of the area from the field measurements, determination of the area and the theory behind curves.*

**UNIT – I**

**BASIC CONCEPTS:** Surveying – History; Definition; primary divisions, Classification, Principles of surveying Plan and map; Basic Measurements; Instruments and Basic methods; Units of measurement, Scales used for Maps and plans, Duties of a surveyor. Errors: Accuracy and Precision Sources and types of errors, theory of Probability, Rounding of numbers.

**CHAIN SURVEYING:** Instruments for chaining, Ranging out, chaining a line on a flat ground; Chaining on an uneven or a sloping ground; Chain & Tape corrections; Degree of accuracy. Principles of chain surveying; Basic definitions; Well-Conditioned Triangle, Field book, Field work; Offsets, Cross Staff survey; obstacles in chain survey-problems, Conventional signs.

**UNIT-II**

**COMPASS SURVEY:** Introduction, Bearings and angles, Designation of bearings, Conversion of bearings from one system to the other, fore bearing and back bearing, Calculation of bearing from angles, Theory of Magnetic compass (i.e. Prismatic compass), Temporary adjustments of compass-Magnetic Declination, Local attraction-Related Problems-Errors in compass survey.

**PLANE TABLE SURVEYING:** Introduction, Accessories, Working operations, Methods of plane tabling, Three point problem-Mechanical method -Graphical method, Two point problem, Errors in plane tabling.

**UNIT-III**

**LEVELLING:** Introduction, basic definitions, methods of leveling, leveling instruments: dumpy level, levelling staff, Temporary adjustments of dumpy level, theory of simple and differential leveling, Level field book, Classification of direct leveling methods, Reciprocal leveling, Profile leveling and Cross sectioning, Curvature and Refraction, Difficulties in leveling, errors in leveling, Degree of Precision.

**CONTOURING:** Introduction, contour interval, Characteristics of contours Methods of locating contours - Direct and indirect methods; Interpolation and sketching of contours, Contour gradient-Uses of contour maps.

**UNIT-IV**

**THEODOLITE:** Vernier Theodolite: Basic definitions; Fundamental lines and desired relations; Temporary adjustments; Measurement of a horizontal angle; Repetition and Reiteration methods of horizontal angle measurement. Measurement of vertical angle; Sources of errors in Theodolite survey.

**TRAVERSE SURVEYING:** Introduction, Selection and marking of traverse stations, methods of traversing, traversing by free needle and fast needle method, traversing by direct

observation of angles, checks in closed traverse, closing error, methods of balancing the traverse, Gale's traverse table, Omitted measurements.

#### **UNIT-V**

**COMPUTATION OF AREAS AND VOLUMES:** methods of determining areas, areas by sub-division into triangles, areas from offsets to a base line: regular and irregular intervals, area by double meridian distances, area by co-ordinates. embankments and cutting for a level section, two level sections, three level section and multi level section, volume of earth work from contour plan, capacity of a reservoir , volume of barrow pits.

**MINOR INSTRUMENTS:** Uses and working of the minor instruments: hand level, line ranger, optical square, Abney level, clinometers, pantagraph, sextant and planimeter.

#### **TEXT BOOKS:**

1. Surveying (Vol – 1,2 &3), by B.C.Punmia, Ashok Kumar Jain and Arun Kumar Jain – Laxmi Publications (P) Ltd., New Delhi
2. Text book of surveying by C.Venkataramaiah, Universities Press.
3. Surveying (Vol – 1 & 2) by Duggal S.K, Tata McGraw Hill Publishing Co.Ltd. New Delhi, 2004.

#### **REFERENCES:**

1. Plane Surveying by Chandra AM, New age International PVt.Ltd., Publishers, New Delhi, 2002
2. Arora K R “Surveying (Vol-1 & 2), Standard Book House, Delhi, 2004
3. Advanced Surveying by Satheesh Gopi, R.Shanta Kumar and N.Madhu, Pearson education

#### **OUTCOMES:**

On completion of the course, the students will be able to:

- (1) carry out preliminary surveying in the field of civil engineering applications such as structural, highway engineering and geotechnical engineering
- (2) plan a survey, taking accurate measurements, field booking, plotting and adjustment of traverse
- (3) use various conventional instruments involved in surveying with respect to utility and precision
- (4) plan a survey for applications such as road alignment and height of the building
- (5) undertake measurement and plotting in civil engineering

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**(15A01305) FLUID MECHANICS**

***OBJECTIVE:** This subject introduces the basic concepts of fluids, their behavioural properties, analyzing the fluid flows using primary equations. This subject further deals with various flow measuring devices and concepts of boundary layer flows.*

**UNIT – I**

**INTRODUCTION:** Dimensions and units – physical properties of fluids, specific gravity, viscosity, surface tension and capillarity, vapor pressure and their influences on fluid motion. Newtonian and non-Newtonian fluids. Fluid Pressure at a Point; Pascal’s law, Hydrostatic law, Atmospheric, Absolute and gauge pressure; Hydrostatic paradox, Pressure measurement manometers; Simple, differential and Micro Manometers

**HYDROSTATIC FORCES ON SURFACES:** Total Pressure and Centre of Pressure on Horizontal Plane Surface; Vertical Plane Surface; Inclined Plane Surface and Curved Surfaces.

**UNIT-II**

**BUOYANCY:** Buoyancy; Buoyant Force and Centre of Buoyancy, Stability of submerged bodies and floating bodies; Metacentre and metacentric height, analytical method for metacentric height.

**KINEMATICS OF FLUID MOTION:** Methods of describing fluid motion; Classification of flow; Steady, unsteady, uniform and non-uniform flows; Laminar and turbulent flows; Three, two and one dimensional flows; Irrotational and rotational flows; Streamline; Pathline; Streakline; Equation for acceleration; Convective acceleration; Local acceleration; Continuity equation; Velocity potential and stream function; Flow net; Vortex flow – free vortex and forced vortex flow.

**UNIT-III**

**DYNAMICS OF FLUID FLOW:** Forces acting on a Fluid in Motion; Euler’s equation of motion; Bernoulli’s equation ; Energy correction factor; Momentum principle; Force exerted on a pipe bend.

**FLOW MEASUREMENTS IN PIPES:** Discharge through Venturi Meter; Discharge through Orifice Meter; Discharge through flow nozzle; Measurement of velocity by Pitot tube, pitot-static tube.

**UNIT-IV**

**FLOWTHROUGH ORIFICES AND MOUTHPIECES:** Flow through Orifices: Classification of Orifices; Determination of coefficients for an Orifice Flow through large rectangular Orifice; Flow through submerged Orifice – fully sub-merged and Partially sub-merged. Classification of Mouthpieces; Flow through external and internal cylindrical Mouthpiece

**FLOW OVER NOTCHES & WEIRS:** Classification of Notches and Weirs; Flow through rectangular, triangular and trapezoidal notches and weirs; End contractions; Velocity of approach; Cipolletti weir, Broad crested weir.

## **UNIT-V**

**ANALYSIS OF PIPE FLOW:** Energy losses in pipelines; Darcy – Weisbach equation; Minor losses in pipelines; Hydraulic Grade Line and Total Energy Line; Concept of equivalent length; Hydraulic power transmission through a pipe; Siphon; Pipes in series, parallel & branched pipes.

**LAMINAR & TURBULENT FLOW IN PIPES:** Reynolds's experiment; Characteristics of laminar flow; Steady laminar flow through a circular pipe (Hazen Poiseuille equation). Characteristics of turbulent flow, Prandtl's mixing length theory, Hydro dynamically smooth and rough boundaries, Velocity distribution, Friction factor for pipe flow.

### **TEXT BOOKS:**

- (1) Fluid Mechanics by Modi and Seth, Standard book house.
- (2) A Text of Fluid Mechanics and Hydraulic Machines by Dr.R.K.Bansal – Laxmi Publications (P) Ltd., New Delhi.
- (3) Fluid Mechanics and Machinery by D.Rama Durgaiiah, New Age International.

### **REFERENCES:**

- (1) Principles of Fluid Mechanics and Fluid Machines by M.Narayana Pillai, Universities Press.
- (2) Fluid Mechanics and Machinery, CSP Ojha, Oxford Higher Education
- (3) Fluid mechanics and machinery by Garde, New Age Pubilishers.
- (4) Introduction to Fluid Machines by S.K.Som & G.Biswas .Tata Mc.Grawhill publishers PVt.Ltd.

**OUTCOMES:** On completion of the course, the students will be able to:

- (1) determine the properties of fluid like pressure and their measurement
- (2) compute forces on immersed plane and curved plates
- (3) apply continuity equation and energy equation in solving problems on flow through conduits
- (4) compute the frictional loss in laminar and turbulent flows

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**(15A01306) SURVEYING LABORATORY -I**

***OBJECTIVE:** To impart the practical knowledge in the field, it is essential to introduce in curriculum. Drawing of Plans and Maps and determining the area are pre requisites before taking up any Civil Engineering works.*

**LIST OF EXERCISES:**

- (1) Survey of an area by chain survey (Closed traverse) & Plotting
- (2) Chaining across obstacles
- (3) Determination of distance between two inaccessible points with compass.
- (4) Surveying of a given area by prismatic compass (Closed traverse) and plotting after adjustment.
- (5) Radiation method, intersection methods by plane Table survey
- (6) Two point and three point problems in plane table survey.
- (7) Traversing by plane table survey
- (8) Fly leveling (differential leveling)
- (9) An exercise of L.S. and C.S. and plotting.
- (10) Two exercises on contouring.

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**(15A01307) STRENGTH OF MATERIALS LABORATORY**

**OBJECTIVE:** *The object of the course to make the student to understand the behavior of materials under different types of loading for different types structures.*

**LIST OF EXERCISES:**

1. Tension test.
2. Bending test on (Steel/Wood) Cantilever beam.
3. Bending test on simply supported beam.
4. Torsion test.
5. Hardness test.
6. Spring test.
7. Compression test on wood or concrete
8. Impact test
9. Shear test
10. Verification of Maxwell's Reciprocal theorem on beams.
11. Use of electrical resistance strain gauges.
12. Continuous beam – deflection test.