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Vision of the Institute	Mission of the Institute
"To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values."	⇨ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence. ⇨ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges. ⇨ To impart human values and ethics in students, to make them socially and Eco-friendly responsible.

LAB MANUAL
OF
SOLID MECHANICS LAB

[BCE 452]

B. TECH, 2nd Year, 4TH Sem

Dr. A.P.J. Abdul Kalam Tech. University
Uttar Pradesh

2025-26

Department of Civil Engineering

Faculty Name: Mr. Abhay yadav
Assistant Professor

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MANUAL CONTENTS

The manual is designed to provide students with practical knowledge of the behavior of engineering materials and structural members under different loading conditions. It includes experiments related to tension, bending, torsion, beam deflection, flexural rigidity, and impact testing. The objective of this manual is to help students understand the relationship between theoretical concepts and practical applications in Strength of Materials. The experiments included in this manual will develop analytical skills, observation techniques, and engineering understanding required for structural and material analysis.

Students are advised to perform experiments carefully, record observations accurately, and follow all laboratory safety instructions during practical sessions.

Good Luck for your Enjoyable Laboratory Sessions.

PREFACE

Engineering education is incomplete without practical exposure and experimental verification of theoretical concepts. The Strength of Materials Laboratory plays an important role in helping students understand the behavior of engineering materials and structural members under different loading conditions. The purpose of this manual is to provide students with a clear and systematic procedure for conducting laboratory experiments and understanding the practical applications of Strength of Materials. Each experiment has been presented with objectives, theory, apparatus required, procedures, observation tables, formulas, diagrams, results, and precautions for better understanding and effective learning.

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VISION OF THE DEPARTMENT

To impart academic excellence in Civil Engineering field with emphasis on holistic development of the professional, while inculcating ethics, socially and professionally responsive technocrats.

MISSION OF THE DEPARTMENT

Mission-1. To provide a comprehensive platform for the academic expertise and proficiency.

Mission-2. To develop Civil Engineering professionals with creative skills and leadership qualities in order to face regional and global challenges.

Mission-3. To develop ethics in students in order to promote socially responsible environmental awareness with innovative thinking.

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Program Educational Objectives (PEOs) of Department

The following are PEOs of the department:

PEO 1: To enhance skill and expertise in field of Civil Engineering with aim of boosting employability and entrepreneurship.

PEO 2: To develop multidisciplinary approach of Civil Engineering system with lifelong learning solutions.

PEO 3: To develop the potential to pursue higher education and research in field of Civil Engineering.

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Program Outcomes:(PO)

Graduates will be able to achieve

PO 1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering Fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes (PSOs) of the Department

PSO 1: Graduates shall be able to apply critical thinking in research, design, analysis and implementation of Civil Engineering problems.

PSO 2: Graduates shall be able to inculcate the idea of sustainability in engineering solution to meet real world challenges.

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Course Evaluation Scheme

Sr No	Subject Code	Subject Name	Periods			Evaluation Scheme				Total	Credit
						Sessional Assessment			PE		
			L	T	P	CT	TA	PS			
1.	**BCE452**	**Solid Mechanics lab**	0	0	2	-	-	50	50	100	1

Course Objectives:

The main objectives of this lab course are:

1. To understand the mechanical behavior of engineering materials.
2. To study bending, torsion, and deflection characteristics of beams.
3. To determine elastic properties and flexural rigidity.
4. To perform experimental verification of theoretical concepts.
5. To study impact strength and deformation behavior of materials..

Pre- requisite:

I. Concepts of stress and strain.
II. Elastic properties of materials.
III. Hooke's Law and Young's Modulus.
IV. Shear stress and torsional behaviour.
V. Bending moment and shear force in beams.
VI. Beam deflection and slope equations.

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Course Outcomes (COs)

Course Outcomes: The students should be able to:		**Bloom's Level**
CO1	Conduct standard laboratory tests on structural members and materials following prescribed procedures.	L4
CO2	Determine stress–strain behavior, strength parameters, deflections, and critical loads experimentally.	L4
CO3	Verify fundamental theories of solid mechanics through laboratory experiments.	L4
CO4	Analyze and interpret experimental data to evaluate structural response under different loading conditions.	L5
CO5	Integrate results from multiple experiments to assess structural performance and relate experimental findings with theoretical concepts.	L4

CO-PO-PSO Mapping

	PO 1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	**3**	**1**	–	**2**	**2**	–	–	–	–	–	–	–	**2**	–
CO2	**3**	**2**	–	**2**	**1**	–	–	–	–	–	–	–	**3**	–
CO3	**3**	**2**	–	**3**	–	–	–	–	–	–	–	–	**3**	–
CO4	**2**	**3**	–	**3**	–	–	–	–	–	–	–	–	**3**	–
CO5	**2**	**2**	–	**2**	–	–	**1**	–	–	**1**	–	–	**3**	**1**
Avg.	**2.6**	**2**	–	**2.4**	**1.50**	**-**	**1**	**-**	–	**1**	**-**	–	**2.8**	**1**

The extent of mapping is as follows: 1 for low, 2 for moderate, 3 for high &"-" for No correlation between CO & PO.

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List of Experiments

S. No	Experiment Name
1	Tension test on Mild Steel
2	Bending tests on simply supported beam
3	Bending tests on Cantilever beam.
4	Determination of torsion in Beam.
5	Determination of deflection, in Beam.
6	Determination of bending moments in beams,
7	Measurement of deflections in statically determinate beam.
8	To determine Flexural Rigidity (EI) of a given beam
9	To find deflection of curved members.
10	Impact test (Charpy and IZOD)

Beyond the Syllabus

1	To Verify Maxwell Reciprocal theorem.
2	To study two hinged arch for the horizontal displacement of the roller end for a given system of loading.

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INDEX

S.No.	Name of the Experiment	CO	BTL	Lab Conduction Date	Remark/ Grade/ Marks	Faculty Signature with Date
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

Do's (What You Should Do)

1. Wear proper laboratory uniform and safety shoes during practical sessions.
2. Read the experiment and procedure carefully before starting the experiment.
3. Ensure that all instruments and apparatus are properly connected and calibrated.
4. Check the specimen dimensions accurately before testing.
5. Apply loads gradually and uniformly.
6. Record observations neatly and systematically in the observation table.
7. Maintain cleanliness and discipline inside the laboratory.
8. Handle measuring instruments and machines carefully.
9. Follow the instructions given by the laboratory instructor.
10. Switch off the equipment after completion of the experiment.

Dont's (What You Should Avoid)

1. Do not operate any machine without permission from the instructor.
2. Do not apply sudden or excessive load on specimens or equipment.
3. Do not touch moving or rotating parts of machines during operation.
4. Do not use damaged instruments or apparatus.
5. Do not disturb other students during experimentation.
6. Do not leave the experiment unattended while equipment is running.
7. Do not make false entries or overwrite observations in the record book.
8. Do not bring food or drinks inside the laboratory.
9. Do not handle electrical connections with wet hands.
10. Do not remove safety guards or protective covers from machines.

EXPERIMENT – 1

Aim:

To determine the mechanical properties of mild steel under tensile loading.

Apparatus Required:

- Universal Testing Machine (UTM)
- Mild Steel Specimen
- Vernier Caliper
- Scale

Theory:

The tensile test is performed to determine the strength and ductility of mild steel. During loading, the specimen undergoes elastic deformation, yielding, strain hardening and finally fracture.

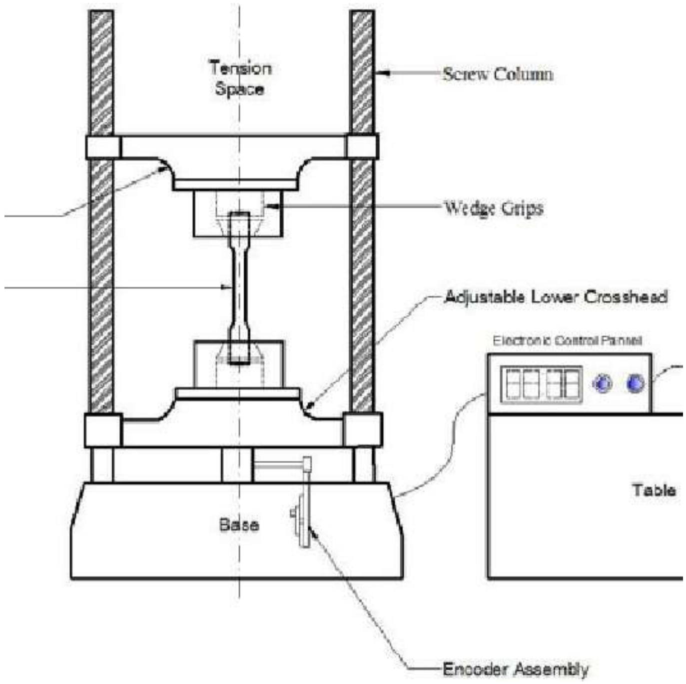

Figure 1: Tension Test Setup on UTM

Procedure:

1. Measure initial diameter and gauge length of specimen.
2. Fix specimen in UTM grips.
3. Apply tensile load gradually.
4. Record load and elongation.
5. Continue till fracture.
6. Note breaking load and final dimensions.

Observation Table:

S.No.	Load (kN)	Extension (mm)
1		
2		
3		
4		
5		

Calculations

- Stress = Load / Area = ……………………………………

- Strain = Extension / Original Length = ………………………………

- Young's Modulus = Stress / Strain= ……………………………

Result

The mechanical properties of mild steel were determined successfully.

Precautions

1. Apply load gradually.
2. Ensure proper alignment of specimen.
3. Take readings carefully.

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EXPERIMENT – 2

Aim:

To study the bending behavior of a simply supported beam.

Apparatus Required:

- Beam setup
- Dial gauge
- Loading arrangement
- Weights

Theory

When load acts on a simply supported beam, bending stress and deflection are produced.

Figure 2: Simply Supported Beam Setup

Procedure

1. Mount beam on supports.
2. Measure dimensions.
3. Apply load gradually at center.
4. Record corresponding deflection.
5. Remove load carefully.

Observation Table

S.No.	Load (N)	Deflection (mm)
1		
2		
3		
4		
5		

Formula:

[y =]

Result:

The bending behavior of simply supported beam was studied successfully.

Precautions

1. Supports should be level.
2. Avoid sudden loading.

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EXPERIMENT – 3

Aim:

To determine deflection in a cantilever beam.

Apparatus Required:

- Cantilever beam setup
- Dial gauge
- Weights

Theory:

A cantilever beam fixed at one end deflects when load is applied at free end.

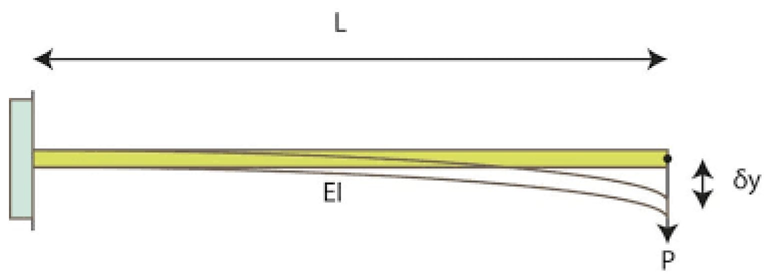

Figure 3: Cantilever Beam Setup

Procedure:

1. Fix beam rigidly at one end.
2. Apply load gradually at free end.
3. Measure deflection.
4. Record observations.

Observation Table:

S.No.	Load (N)	Deflection (mm)
1		
2		
3		
4		
5		

Formula:

[y =]

Result:

Deflection of cantilever beam was determined successfully.

Precautions:

1. Ensure rigid fixing.
2. Apply load gradually.

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EXPERIMENT – 4

Aim:

To determine torsional behavior of shaft/beam.

Apparatus Required:

- Torsion Testing Machine
- Circular Specimen
- Measuring Instruments

Theory:

When torque acts on a shaft, shear stress and angle of twist are produced.

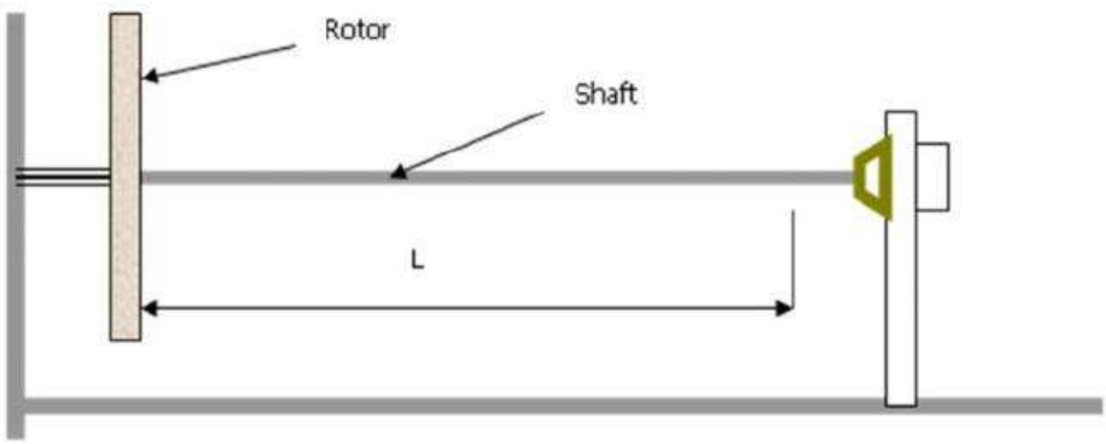

Figure 4: Torsion Test Setup

Procedure:

1. Fix specimen in machine.
2. Apply torque gradually.
3. Record angle of twist.
4. Continue loading within limit.

Observation Table:

S.No.	Torque (N-m)	Angle of Twist (Degree)
1		
2		
3		
4		
5		

Result:

By plotting Graph, Relationship between torque and angle of twist was verified.

Precautions:

1. Avoid sudden loading.
2. Ensure proper alignment.

EXPERIMENT – 5

Aim:

To determine beam deflection under loading.

Apparatus Required:

- Beam apparatus
- Dial gauge
- Loading arrangement

Figure:

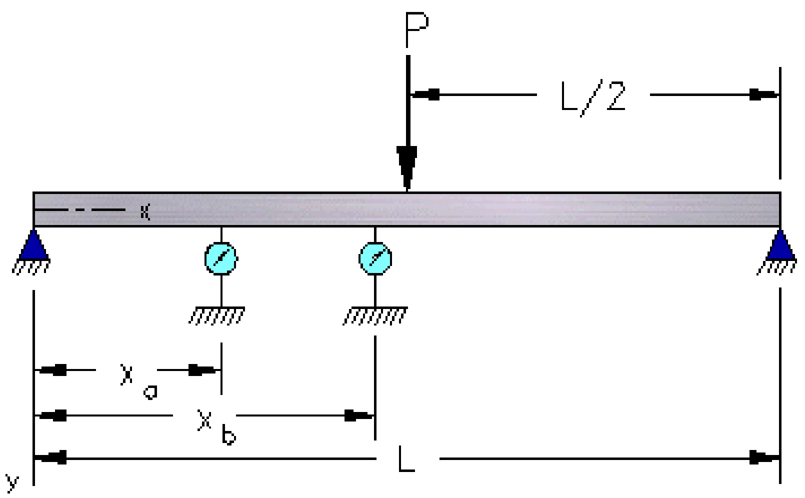

Figure 1 Simply Supported Beam

Beam Deflection Setup

Procedure:

1. Place beam on supports.
2. Apply load gradually.
3. Measure corresponding deflections.
4. Compare theoretical and experimental values.

Observation Table:

S.No.	Applied Load (N)	Deflection (mm)
1		
2		
3		
4		
5		

Result

Beam deflection was measured successfully.

Precautions

4. Dial gauge should be calibrated.
5. Avoid eccentric loading.

EXPERIMENT – 6

Aim:

To determine bending moments experimentally.

Apparatus Required:

- Beam setup
- Loading arrangement
- Measuring instruments

Figure:

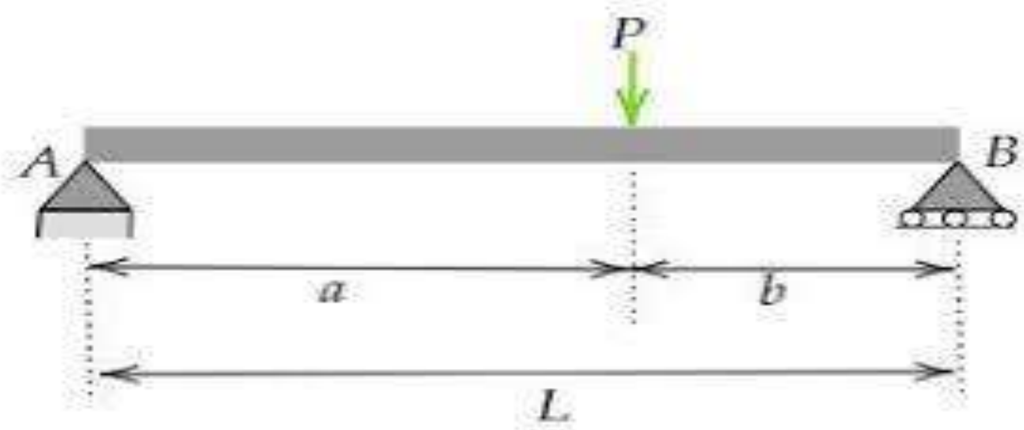

Figure 6: Beam for Bending Moment Study

Procedure:

1. Setup beam properly.
2. Apply load at specified positions.
3. Measure reactions.
4. Calculate bending moments.

Observation Table:

S.No.	Load (N)	Distance (m)	Bending Moment (N-m)
1			
2			
3			
4			
5			

Formula

[M = W L]

Result

Bending moments in beam were determined successfully.

Precautions

6. Load positions should be accurate.
7. Readings should be taken carefully.

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EXPERIMENT – 7

Aim

To measure deflections in statically determinate beam.

Apparatus Required

- Beam apparatus
- Dial gauges
- Weights

Figure

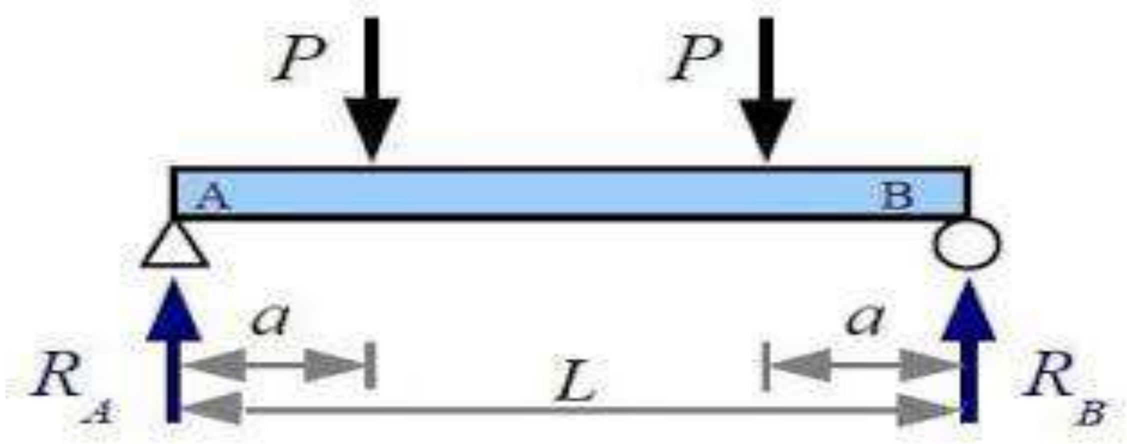


Figure 7: Deflection Measurement Setup

Procedure

1. Mount beam properly.
2. Apply load incrementally.
3. Measure deflection at different points.
4. Plot load-deflection graph.

Observation Table

S.No.	Load (N)	Deflection at Point A (mm)	Deflection at Point B (mm)
1			
2			
3			
4			
5			

Result

Deflections in statically determinate beam were measured.

Precautions:

1. Ensure proper support conditions.
2. Avoid vibrations during readings.

EXPERIMENT – 8

Aim:

To find the value of flexural rigidity (EI) for a given beam and compare it with theoretical value

Apparatus:

- Elastic Properties of deflected beam,
- weight's, hanger,
- dial gauge,
- scale,
- Verniar caliper.

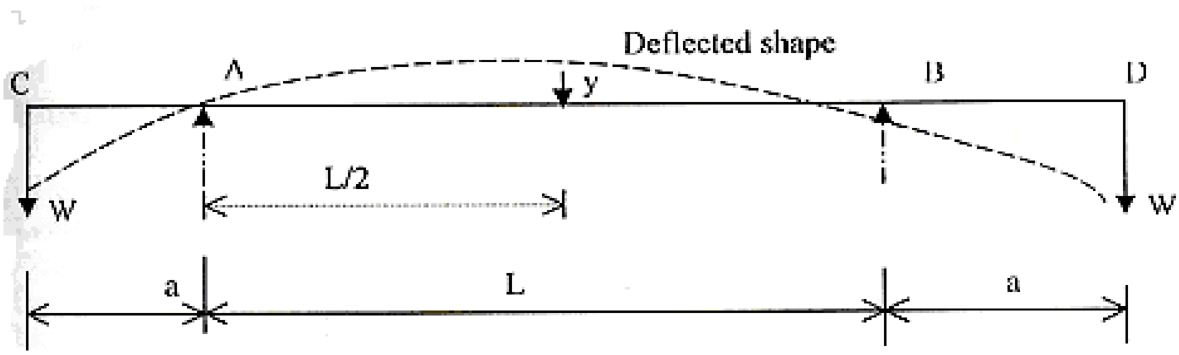
Formula:

(1) Central upward deflection, $y = W.a.L^2 / 8y$ .... (1)

(2) $EI = W.\ a.\ L^2 / 8y$............................ (2)

(3) Also it is known that EI for beam = $E \times bd^3 /12$.............(3)

Figure:-



Theory: -

For the beam with two equal overhangs and subjected to two concentrated loads W each at free ends, maximum deflection y at the centre is given by central upward deflection.Central upward deflection, $y = W.a.L^2 / 8EI$

Where,

a = length of overhang on each side

W = load applied at the free ends

L = main span

E = modulus of elasticity of the material of the beam

I = moment of inertia of cross section of the beam

$EI = W.a.L^2 / 8y$

It is known that, EI for beam = $E \times bd^3 /12$

Where, b = width of beam

d = depth of beam

Procedure: -

i) Find b and d of the beam and calculate the theoretical value of EI by Eq. (3).

ii) Measure the main span and overhang span of the beam with a scale.

iii) By applying equal loads at the free end of the overhang beam, find the central deflection y.

iv) Repeat the above steps for different loads.

Observation: -

1) Length of main span, L (cm) =

2) Length of overhang on each side, a (cm) =

3) Width of beam, b (cm) =

4) Depth of beam, d (cm) =

5) Modulus of elasticity, E (kg/cm2) = 2×10^6

Observation Table:-

Sr. No	. Equal loads at the two ends (kg)	Dial gauge reading at the mid span of beam(cm)	EI from Eq. (3)	EI from Eq (2)
.				

Calculation: -

Average values of EI from observation = ……cm4 Average values of EI from calculation = …….cm^4

Result: -

Flexural rigidity (EI) is found same theoretically and experimentally.

Precaution:-

1. Measure the center deflection y very accurately.
2. Ensure that the beam is devoid of initial curvature.
3. Loading should be within the elastic limit of the materials.

EXPERIMENT – 9

Aim

To study deflection behavior of curved members.

Apparatus Required

- Curved beam setup
- Dial gauge
- Weights

Figure

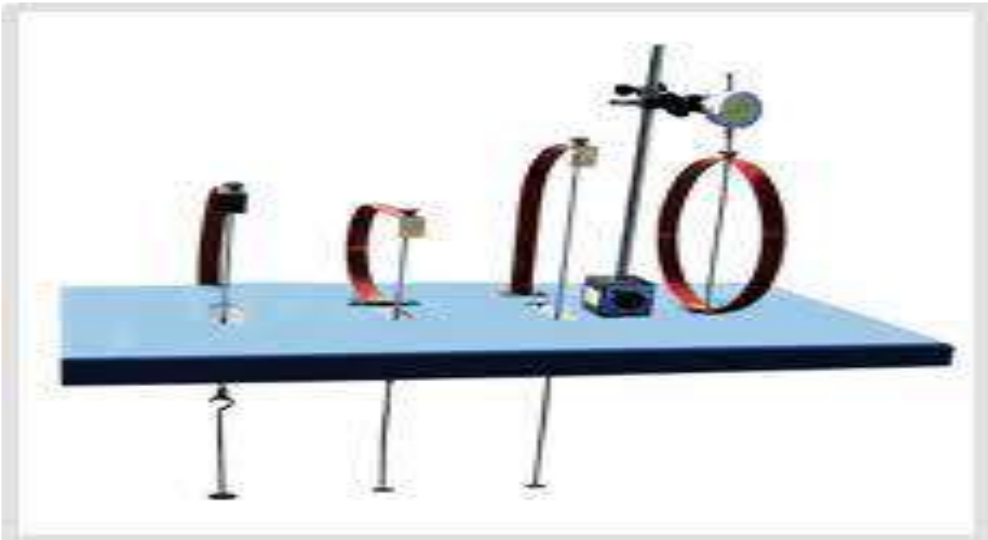


Figure 9: Curved Beam Deflection Setup

Procedure

1. Fix curved member properly.
2. Apply load gradually.
3. Measure deflection.
4. Compare theoretical and practical results.

Observation Table:

S.No.	Load (N)	Deflection (mm)
1		
2		
3		
4		
5		

Result:

Deflection characteristics of curved members were studied.

Precautions

8. Ensure proper fixing.
9. Avoid shock loading.

EXPERIMENT – 10

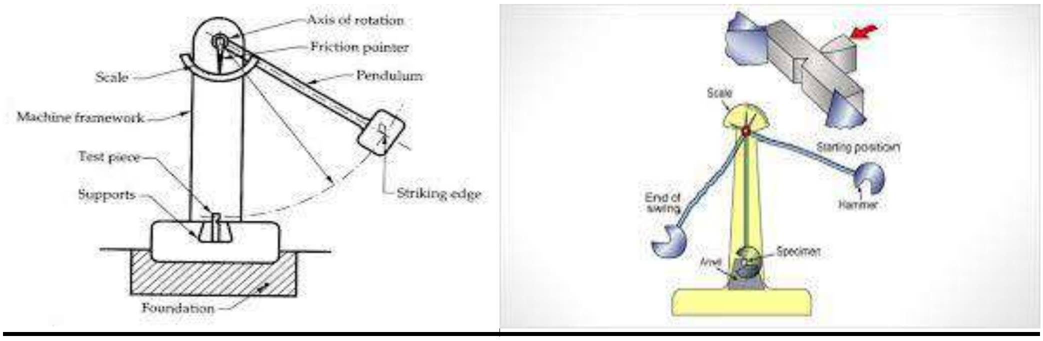
Aim

To determine impact strength of material using Charpy and Izod tests.

Apparatus Required

- Impact Testing Machine
- Notched Specimens

Figure:



(a) Izod Impact Test Setup (b) Charpy Impact Test Setup

Figure 10: Charpy and Izod Impact Test Setup

Theory:

Impact test determines the energy absorbed by a material during sudden loading.

Figure 10: Charpy and Izod Impact Test Setup

Procedure

Charpy Test:

1. Place specimen horizontally.
2. Release pendulum hammer.
3. Note absorbed energy.

Izod Test:

1. Fix specimen vertically.
2. Release pendulum hammer.
3. Record impact energy.

Observation Table:

S.No.	Specimen	Initial Energy (J)	Final Energy (J)	Energy Absorbed (J)
1				
2				
3				

Result:

Impact strength of material was determined successfully.

Precautions:

1. Specimen should be properly notched.
2. Ensure safety during pendulum motion.

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Experiment No.1 (Beyond Syllabus)

Aim: - To verify clerk Maxwell's reciprocal theorem

Apparatus: - Clerk Maxwell's Reciprocal Theorem apparatus, Weight's, Hanger, Dial Gauge, Scale Vernier caliper.

Diagram:-

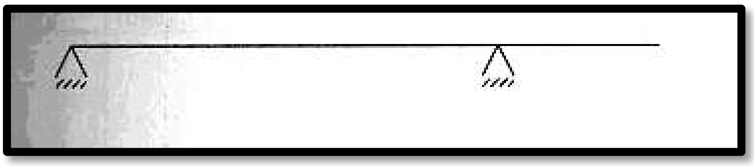


Fig.-Beam of Maxwell Reciprocal Apparatus.

Theory: -

Maxwell theorem in its simplest form states that deflection of any point A of any elastic structure due to load P at any point B is same as the deflection of beam due to same load applied at A. It is, therefore easily derived that the deflection curve for a point in a structure is the same as the deflected curve of the structure when unit load is applied at the point for which the influence curve was obtained.

Procedure: -

i) Apply a load either at the center of the simply supported span or at the free end of the beam, the deflected form can be obtained.

ii) Measure the height of the beam at certain distance by means of a dial gauge before and after loading and determine the deflection before and after at each point separately.

iii) Now move a load along the beam at certain distance and for each positions of the load, the deflection of the point was noted where the load was applied in step1.This deflection should be measured at each such point before and after the loading, separately. Plot the graph between deflection as ordinate and position of point on abssica the plot for graph drawn in step2 and 3.These are the influence line ordinates for deflection of the beam.

Observation Table:-

Distance from the pinned end	Load at central point/ cantilever end		Deflection of various points (mm) 2-3	Load moving along beam		Deflection of various points (mm) 5-6
	Beam unloaded Dial gauge reading (mm)^2	Beam loaded Dial gauge reading (mm)^3	Beam unloaded Dial gauge reading (mm)^5	Beam unloaded Dial gauge reading (mm)^5	Beam loaded Dial gauge reading (mm)^6	

Result: - The Maxwell reciprocal theorem is verified experimentally and analytically.

Precaution: -

(i) Apply the loads without any jerk.

(ii) Perform the experiment at a location, which is away from any

(iii) Avoid external disturbance.

(iv) Ensure that the supports are rigid.

Experiment No.2 (Beyond Syllabus)

Aim: - To study two hinged arch for the horizontal displacement of the roller end for a given system of loading and to compare the same with those obtained analytically.

Apparatus: - Two Hinged Arch Apparatus, Weight's, Hanger, Dial Gauge, Scale, Verniar Caliper.

Formula: - $H = 5WL\,(a - 2a^3 + a^4)/8r$

Where,

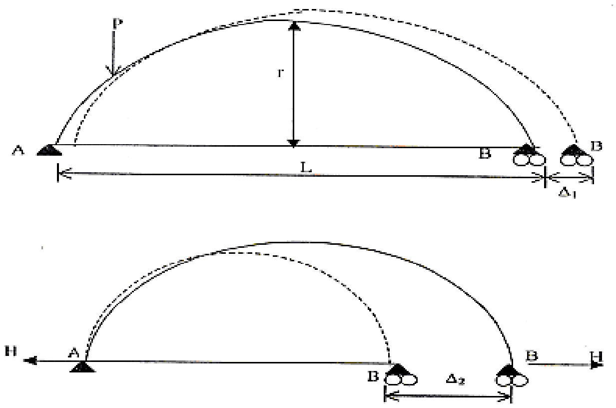
W= Weight applied at end support.

L= Span of two hinged arch.

r= rise of two hinged arch.

a = dial gauge reading.

Diagram:-



Theory: - The two hinged arch is a statically indeterminate structure of the first degree.The horizontal thrust is the redundant reaction and is obtained y the use of strain energy methods. Two hinged arch is made determinate by treating it as a simply supported curved beam and horizontal thrust as a redundant reaction. The arch spreads

out under external load. Horizontal thrust is the redundant reaction is obtained by the use of strain energy method.

Procedure: -

i) Fix the dial gauge to measure the movement of the roller end of the model and keep the lever out of contact.

ii) Place a load of 0.5kg on the central hanger of the arch to remove any slackness and taking this as the initial position, set the reading on the dial gauge to zero.

iii) Now add 1 kg weights to the hanger and tabulated the horizontal movement of the roller end with increase in the load in steps of 1 kg. Take the reading up to 5 kg load. Dial gauge reading should be noted at the time of unloading also.

iv) Plot a graph between the load and displacement (Theoretical and Experimental) compare. Theoretical values should be computed by using horizontal displacement formula.

v) Now move the lever in contact with 200gm hanger on ratio 4/1 position with a 1kg load on the first hanger. Set the initial reading of the dial gauge to zero.

vi) Place additional 5 kg load on the first hanger without shock and observe the dial gauge reading.

vii) Restore the dial gauge reading to zero by adding loads to the lever hanger, say the load is w kg.

viii) The experimental values of the influence line ordinate at the first hanger position shall be 4w.

ix) Repeat the steps 5 to 8 for all other hanger loading positions and tabulate. Plot the influence line ordinates.

x) Compare the experimental values with those obtained theoretically by using equation (5).

Observation Table: - Horizontal displacement

Sr. No.	Central load (kg)	0.0	1.0	2.0	3.0	4.0	5.0	6.0
	Observed horizontal Displacement (mm)							
	Calculated horizontal Displacement Eq. (4)							

Sample Calculation: - Central load (kg) =……….

Observed horizontal Displacement (mm) =

Calculated horizontal Displacement = H = 5WL (a – 2a³ + a4)/8r=…………..

Result:-The observed and horizontal displacement is nearly same.

Precaution: -

1.Apply the loads without jerk.

2. Perform the experiment away from vibration and other disturbances.