ME 218 – Solid Mechanics Lab – 2023

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Laboratory Course - Preamble

Goal(s): Experimentally measure and evaluate:

(a) Material properties
(b) Structural response
(c) Stress and Strain
to model or verify a model or discover new mechanics, etc.

Structured – Where we will teach and perform some experimental methods

- Some experiments in the lab will be conducted to study materials and structural testing
  - Constitutive response
  - Material properties
  - Stress and Strain measurement

Unstructured – Where you will will plan and execute and experiment with a goal

- Student Design Projects (SDP)
  - Students will design, perform and analyze the projects related to solid mechanics

Course Details

- When: Monday, Tuesday and Thursday

(S1 on L1,S2 on L2 and S3 on L3) from 2:00 PM to 5:00 PM

- Office Hours: 5-6 PM on Thursday
- Where: Solid Mechanics Lab, Ground Floor, ME Building
- Number of Experiments:
  - 6 (split into 2 sets)
  - Student designed experiment
- Experiments and Viva on alternate weeks in the first half of the semester. Time given to work on reports.

Lab Policies

- Report to the lab on or before 2 PM. *2 X Late = 1 Absent*
- Wearing shoes compulsory to enter the lab (Dept. rule)
- Use of safety gear wherever required as suggested by the TAs is compulsory
  - If you are found without safety gear during the lab session = absent
- It is important to follow the instructions of the TAs to ensure that the lab runs smoothly
- Read the manual before you come to lab. This way you are prepared to ask questions related to the experiment
- Pre-lab report compulsory.

Report Writing

- Reports should be written individually by every student, irrespective of whether they are done individually or in a group. Upload as PDF files on Moodle for grading.

- Report should contain
  - Objectives
  - Results from the experiments properly presented
  - Analysis, calculations, observations and conclusions from the experiment

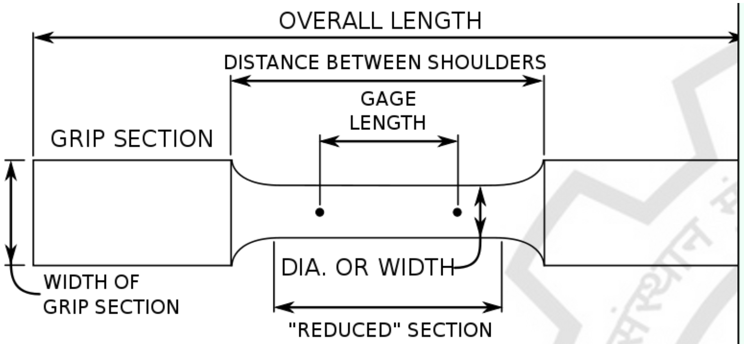
- Plagiarism
  - Do not copy data or reports.
  - It is in your own interest to analyze data and report them.
  - It is more important to learn analysis of data these days

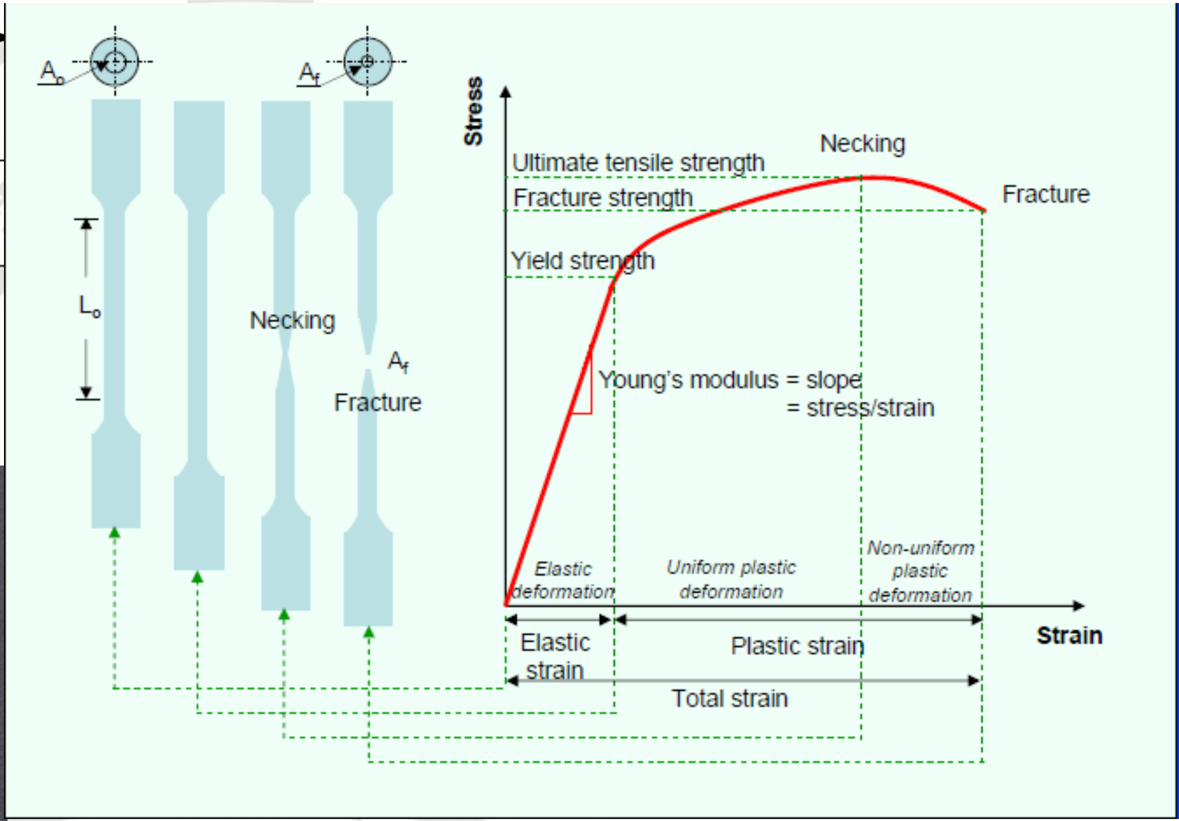
Uniaxial Tensile Experiment

- Objectives:
  - To extract stress vs. strain curves for two ductile materials, steel and aluminum, until fracture
  - To calculate
    - Elastic Modulus – Slope of linear portion of stress vs. strain curve,
    - Ultimate Tensile Strength (UTS) – maximum stress the material can withstand before failure
    - Ductility – strain to fracture and reduction in cross-sectional area

- This is a very important experiment conducted to measure mechanical properties (elastic and plastic) and extract constitutive behavior of almost all material

Uniaxial Tensile Experiment





Uniaxial Compression Experiment

- Objectives:
  - To extract stress vs. strain curves of an aluminum cylinder in compression
  - To calculate the machine compliance of the UTM
  - To calculate the elastic modulus from the corrected stress vs. strain curve
- This is a very important experiment conducted to measure mechanical properties and large deformation constitutive behavior in metals

Torsion of Cylindrical Rod

- Objectives: To find the torque vs. twist angle response of a material and to calculate the limiting torque.

The Torque (T) - twist (θ), for perfectly plastic material is given by,

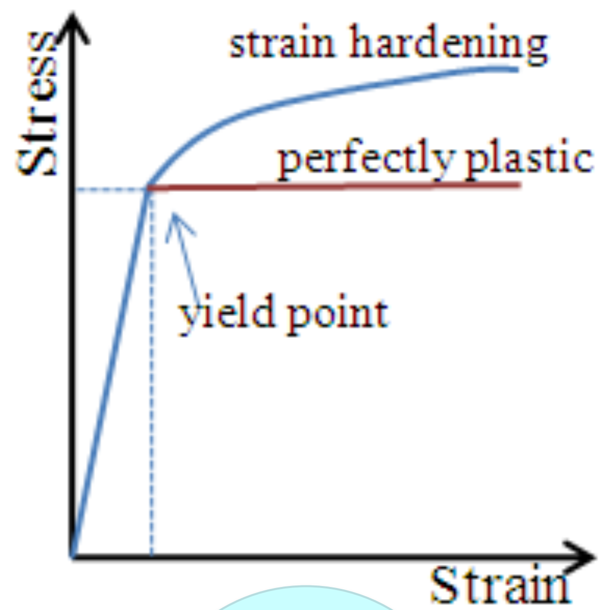
$$T = (4/3)\, T_Y \left(1 - 0.25(\theta_Y/\theta)^3\right)$$

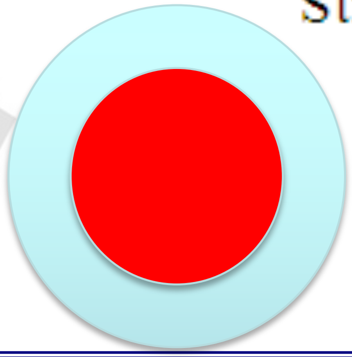
Limiting torque is given by:

$$T_Y = (J^* \tau_Y)/R \;;\quad T_L = (4/3)\, T_Y$$

Metals strain harden and this increases the limiting torque

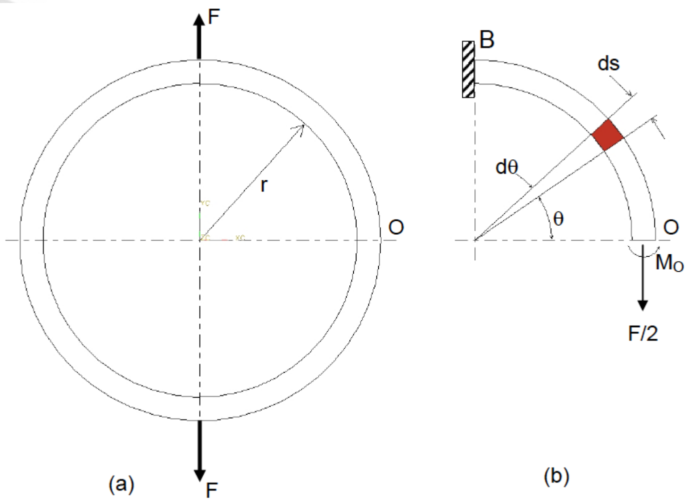
In this experiment we want to know how much deviation is caused.

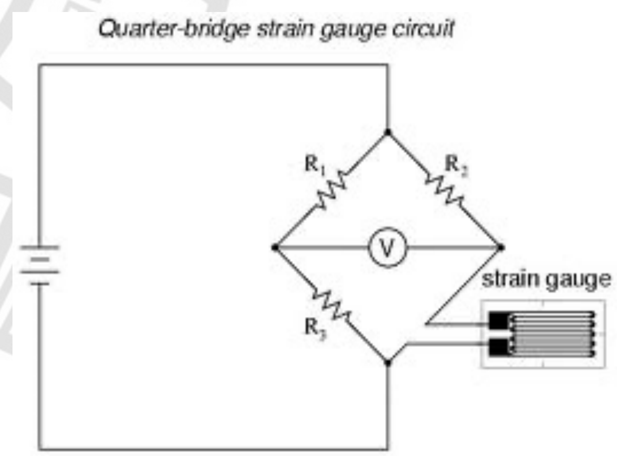




Curved Beam Bending and Strain Gage Experiment

- Objectives:
  - To understand the use of strain gages in measuring surface strains
  - To understand and measure the stains in a circular ring subjected to combined axial and bending loads
- The circular ring loaded at two points in tension will be combined loads
- Also, the neutral axis location is not the centroid of the cross-sectional area
- Strain gage are used widely in all industries to measure strain at a point in certain orientations
- The state of strain can be obtained using a rosette configuration



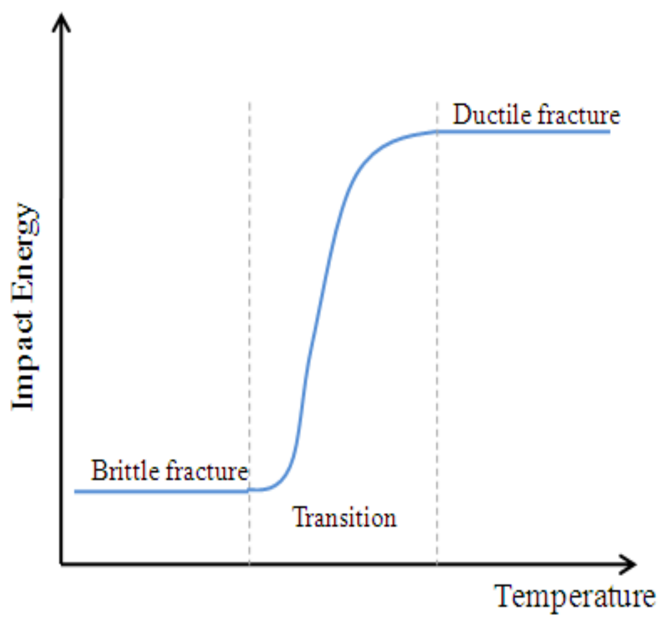


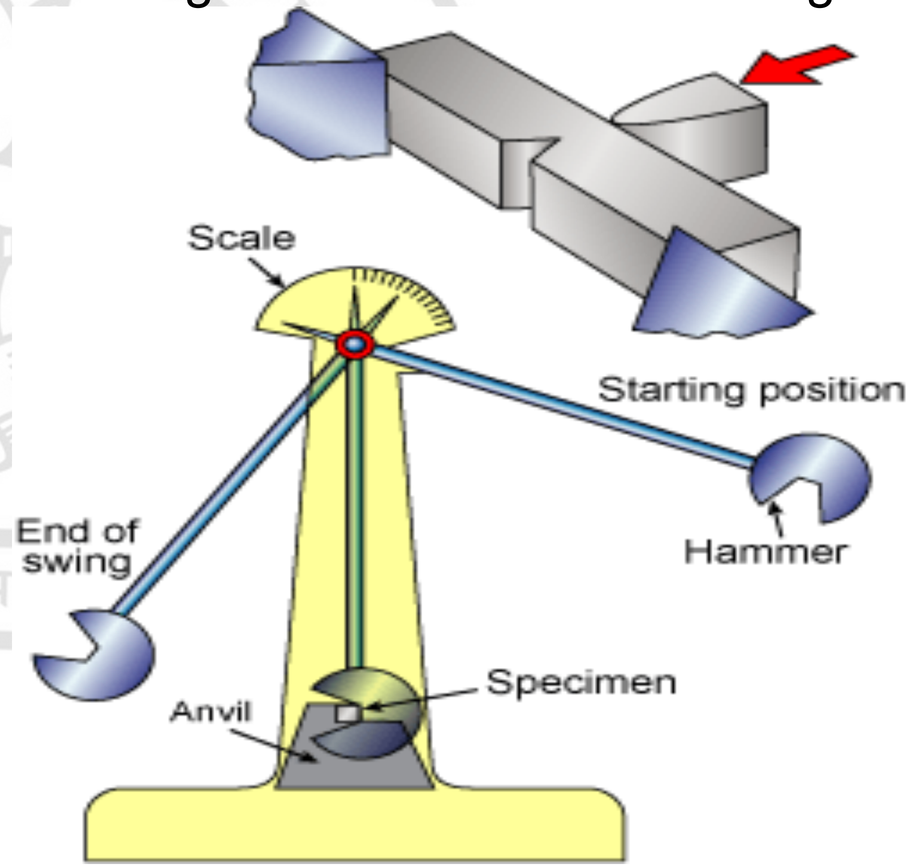
Rockwell Hardness Experiment

- Objectives:
  - To measure Rockwell Hardness numbers for various metals
- Rockwell Hardness number depends on the depth of penetration of an indenter for an applied load. Higher the penetration depth the smaller the number
- This is a simple and minimally invasive experiment to know the relative increase in the strength of a material
- Used in industry to quickly ascertain the effect of various thermo-mechanical and manufacturing processes on metals
- The hardness number is used to ascertain the resistance to plastic (permanent deformation).
- The hardness numbers are sometimes empirically related to yield strength of the material

Charpy Impact Experiment

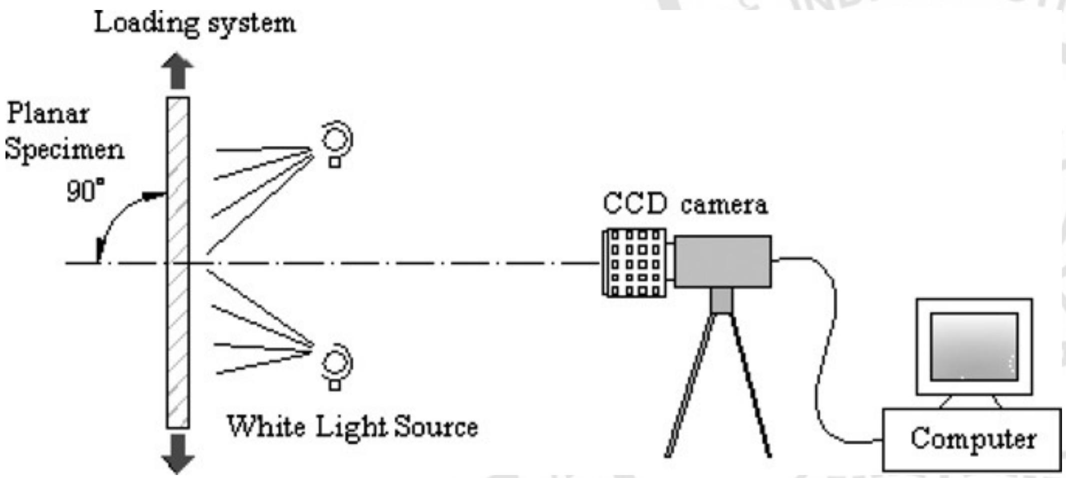
- Objectives:
  - To study the impact resistance of metals using Charpy type specimens
  - To determine the variation of impact strength of a material with change in temperature.

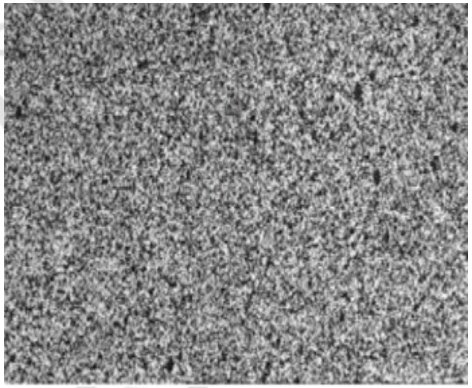




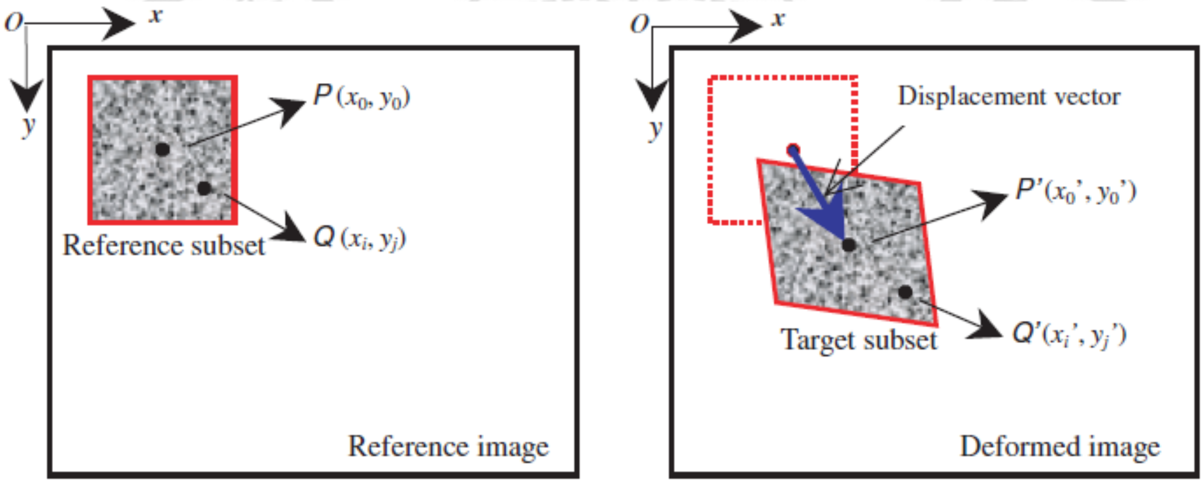
Digital Image Correlation

- Objectives: Non-contact strain measurement in 2D using a speckle pattern on the sample and image processing





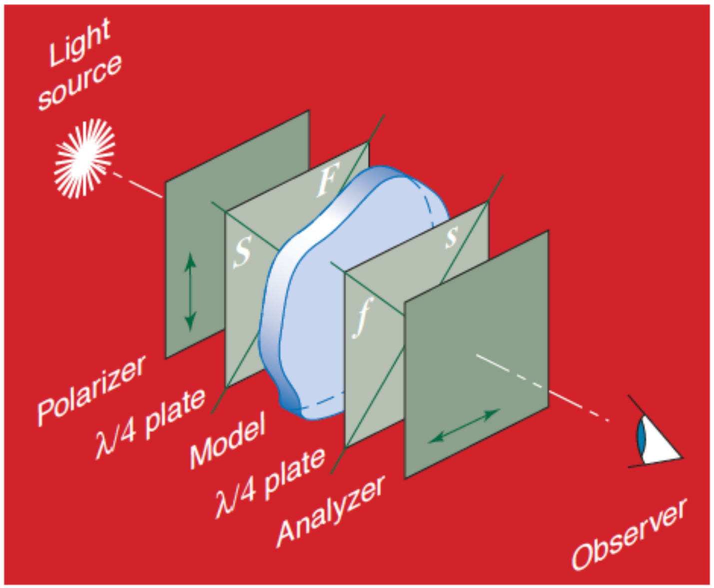
Speckle Pattern

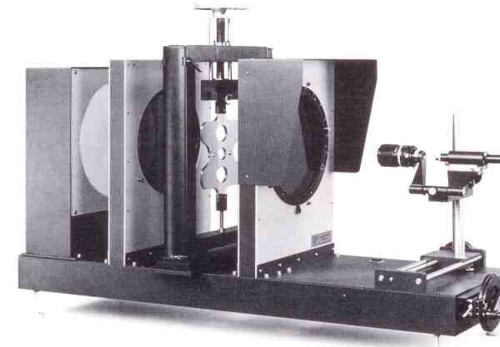


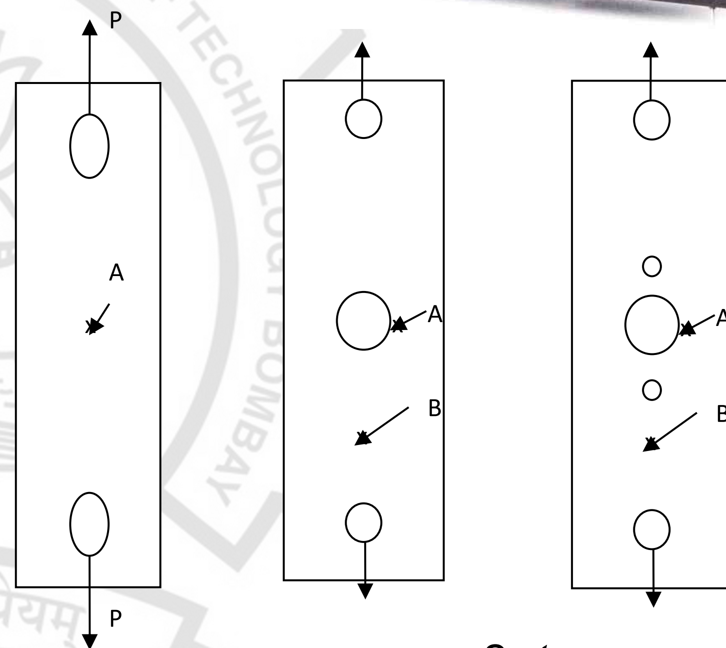
Photoelasticity Experiment

Objectives:

- To measure the stress concentration around a circular hole in a plate subjected to tensile loading







- Δ is phase difference
- λ is wavelength of the light
- t is thickness of the specimen
- N is fringe order
- F_σ is model fringe constant
- C stress optic coefficient

$$\Delta \propto \sigma_1 - \sigma_2$$

$$\Delta \propto 1/\lambda$$

$$\Delta \propto t$$

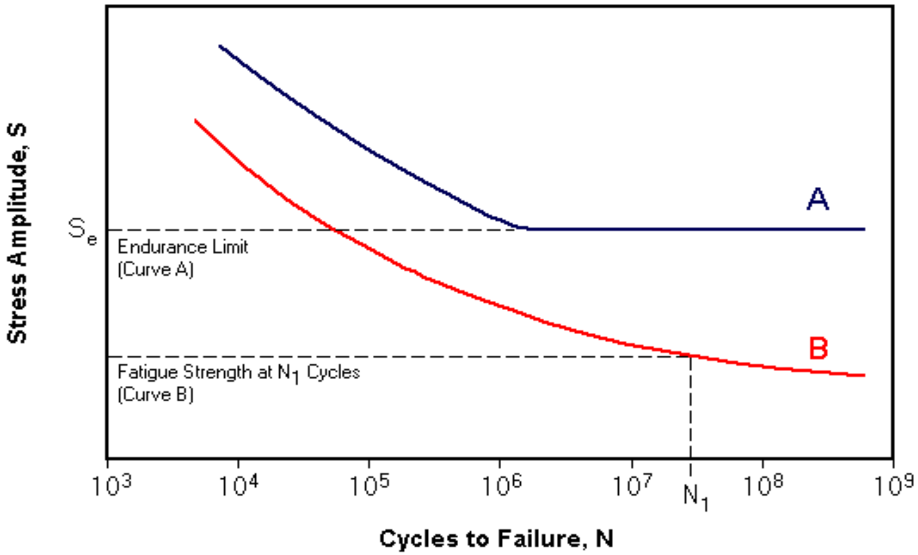
$$\Delta = C\frac{2\pi t}{\lambda}\left(\sigma_1 - \sigma_2\right)$$

$$\frac{\Delta}{2\pi} = \frac{Ct}{\lambda}\left(\sigma_1 - \sigma_2\right) = N$$

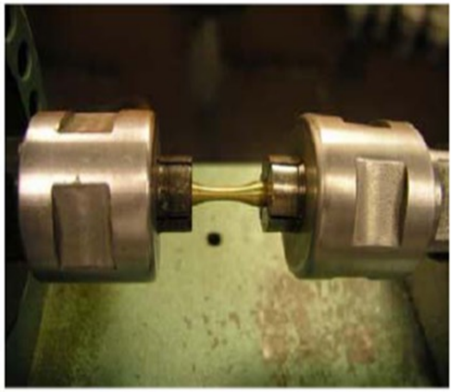
$$\left(\sigma_1 - \sigma_2\right) = Nf_\sigma$$

Rotating Beam Bending Experiment

- Objectives:
  - To measure the endurance strength of a material subjected fully reversed cyclic loading
- A cantilever type specimen is used with a transverse load at one end
- The cantilever is rotated about its axis under transverse loading causing fully reversed tension-compression state of stress at a material point



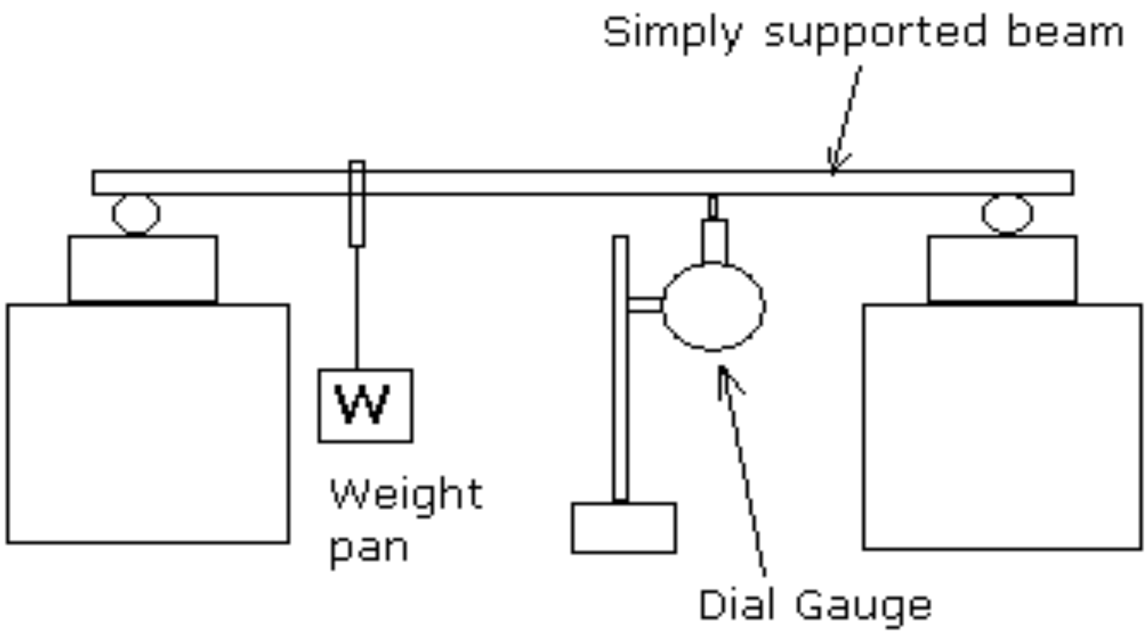
Rotating Bending



Test Specimen

Reciprocal Theorem and Superposition Principle

- Objectives:
  - To verify Reciprocal Theorem and Superposition Principle for simply supported beam
- Based on the principle of minimum potential energy



Large Deflection of a Cantilever Beam

- Objectives:
  - To study large deflection of cantilever beams
  - To measure load vs. deflection (vertical and horizontal curves
  - To compare the results with elementary beam theory and large deflection beam theory

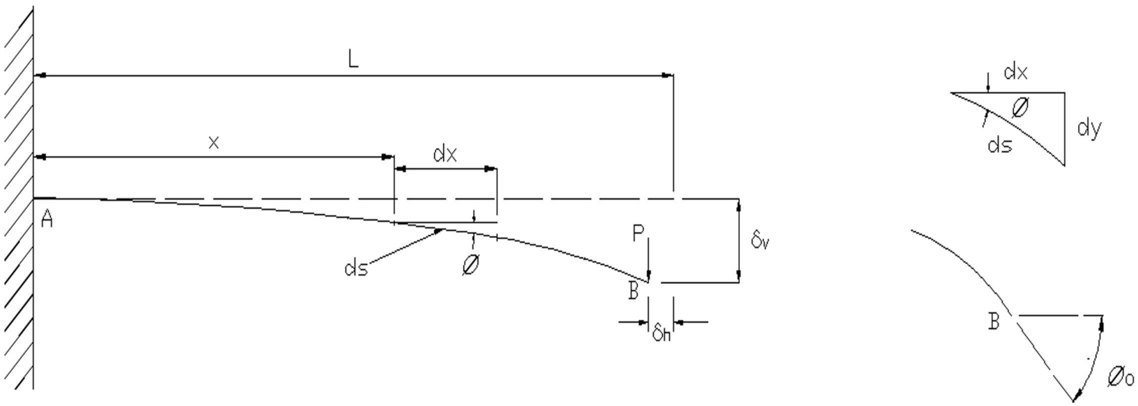
Small Deflection Theory (EB):

$$\delta_v = \frac{Pl^3}{3EI}$$

Large Deflection Theory (EB):

$$\frac{\delta_v}{L} = 1 - \frac{2}{\alpha}\left[E(K,\pi/2) - E(K,\theta_1)\right]$$

$$\frac{L-\delta_h}{L} = \sqrt{\frac{2\sin\phi_o}{\alpha^2}}$$



Student Design Experiment

Objective: Design, plan and execute a solid mechanics related experiment using instruments available in the lab (or institute with permission) to:

a. Material property, e.g., modulus, Poisson's ratio, etc.

b. Stress or strain distribution in a specimen geometry, e.g., stress or strain concentration.

c. Structural behavior validating a theoretical result, e.g., beam bending.

SDE – Proposal Stage 1

Stage 1

- Propose a project addressing one **or more** of (a), (b) or (c) with,

i. Objective

ii. Experimental plan

iii. Analysis to be performed, and

iv. expected outcomes.

Submissions required:

- A 1-page summary of your proposal to be submitted on Moodle
- A 5-minute presentation with 1-slide on each of the above aspects, with the title slide containing your title and group member names

SDE – Proposal Stage 2

Stage 2

- Details of the project plan and execution

i. Method

ii. Materials and their availability

iii. Instruments, including their access

iv. Data collection and analysis.

Submissions required:

- A 1-page summary of your plan to be submitted on Moodle
- A 5-minute presentation with 1-slide on each of the above aspects, with the title slide containing your title and group member names

SDE – Review(s)

Review(s) of your project

- All projects will be reviewed at least twice before the final presentation.

i. Progress in the stated objectives

ii. Execution of the plan

iii. Analysis done

iv. Changes if any, due to unforeseen circumstances

Submissions required:

- A 1-page summary of your progress to be submitted on Moodle
- A 5-minute presentation with 1-slide on each of the above aspects, with the title slide containing your title and group member names

SDE – Final Presentation

Final Presentation – In the last week of instruction

- Propose a project addressing one **or more** of (a), (b) or (c) with,

i. Objective

ii. Experimental Method

iii. Results and analysis

iv. Summary and conclusion

Submissions required:

- A 3-page report of project to be submitted on Moodle
- A 5-minute presentation with 1-slide on each of the above aspects, with the title slide containing your title and group member names

Assessment

- Lab Reports + Viva + Quiz = 40%
- SDE Project = 40%
- Attendance = 20%

Relative or Scale Score = Your Marks x 100 / Class highest

Relative Score	Grade
>=90	AA
>82	AB
>74	BB
>65	BC
>56	CC
>48	CD
>=40	DD
<40	FR