

JSS MAHAVIDYAPEETHA
JSS SCIENCE & TECHNOLOGY UNIVERSITY
(JSS&TU)
FORMERLY SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING
MYSURU-570006

DEPARTMENT OF MECHANICAL ENGINEERING

Basic Material Testing Laboratory Manual
IV Semester B.E. Mechanical Engineering



USN : _____
Name: _____
Roll No: _____ Sem _____ Sec _____
Course Name _____
Course Code _____

DEPARTMENT OF MECHANICAL ENGINEERING

VISION OF THE DEPARTMENT

Department of mechanical engineering is committed to prepare graduates, post graduates and research scholars by providing them the best outcome based teaching-learning experience and scholarship enriched with professional ethics.

MISSION OF THE DEPARTMENT

- M-1:** Prepare globally acceptable graduates, post graduates and research scholars for their lifelong learning in Mechanical Engineering, Maintenance Engineering and Engineering Management.
- M-2:** Develop futuristic perspective in Research towards Science, Mechanical Engineering Maintenance Engineering and Engineering Management.
- M-3:** Establish collaborations with Industrial and Research organizations to form strategic and meaningful partnerships.

PROGRAM SPECIFIC OUTCOMES (PSOs)

- PSO1** Apply modern tools and skills in design and manufacturing to solve real world problems.
- PSO2** Apply managerial concepts and principles of management and drive global economic growth.
- PSO3** Apply thermal, fluid and materials fundamental knowledge and solve problem concerning environmental issues.

PROGRAM EDUCATIONAL OBJECTIVES (PEOS)

- PEO1:** To apply industrial manufacturing design system tools and necessary skills in the field of mechanical engineering in solving problems of the society.
- PEO2:** To apply principles of management and managerial concepts to enhance global economic growth.
- PEO3:** To apply thermal, fluid and materials engineering concepts in solving problems concerning environmental pollution and fossil fuel depletion and work towards alternatives.

PROGRAM OUTCOMES (POS)

- PO1 Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- PO2 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.
- PO3 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.
- PO4 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.
- PO5 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.
- PO6 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.
- PO7 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.
- PO8 Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- PO9 Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- PO10 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 instructions.
- PO11 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.
- PO12 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.

BASIC MATERIALS TESTING LABORATORY

Subject Code	: ME47L	No. of Credits	: 0 - 0 - 1.5
No. of Practical Hours / Week	: 03	CIE Marks	: 50
Total No. of Practical Hours	: 39		

COURSE OBJECTIVES:

1. To conduct Tension, Compression, Bending & Shear tests on UTM and evaluate material properties.
2. To carry out Torsion, Hardness & Impact tests and determine various moduli, hardness numbers and impact energy.

COURSE CONTENT

1. **Hardness Test:** Estimating the Hardness of different Engineering materials using Brinell's & Rockwell Hardness Testers.
2. **Impact Test:** Determining the impact strength of a given material using Charpy & IZOD tests.
3. **Tension Tests using Universal Testing Machine:** Tension test on the given specimens (at least 2 materials for comparison) and to plot the stress strain graphs.
4. **Compression Tests using Universal Testing Machine :** Compression test on the given specimens and to plot the stress strain graphs
5. **Bending and Double Shear Tests using Universal Testing Machine:** Bending test, Double Shear test on the given specimens and to plot the stress strain graphs.

COURSE OUTCOMES

Upon completion of this course, students should be able to:

- CO1** Conduct Tension, Compression, Bending & Shear tests on UTM and evaluate material properties.
- CO2** Conduct Torsion, Hardness & Impact tests and determine various moduli, hardness numbers and impact energy

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1. ROCKWELL HARDNESS TESTS

Aim: To determine the Rockwell hardness number on B and C scales for a given metallic specimen.

Test Setup:

- Rockwell Hardness Testing Machine.
- Indenters:
 - i) For Rockwell – B Test: Steel ball indenter of diameter $(1/16)^{\text{th}}$ inch.
 - ii) For Rockwell – C Test: Rockwell diamond cone of vertex angle 120° and tip radius 0.2 mm.

Standard Loads:

Sl. No.	Material	For Rockwell – B Test Load, kgf	For Rockwell – C Test Load, kgf
1.	Cast Iron	–	150
2.	Mild Steel	–	150
3.	Brass	100	–
4.	Gun Metal	100	–
5.	Aluminum	100	–

Procedure:

- Smoothen the surface of the specimen to be tested, and clean it to remove dirt and oil, if any.
- Fix the appropriate indenter to the thrust member or penetrator.
- Depending upon the material of the specimen and type of the indenter, select and set the required load stage, and see that the load lever is in position “A”.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction to have contact between specimen and the penetrator. Continue turning until the small pointer of the dial gauge reaches the red spot and the long pointer comes to “0” mark on the dial gauge. This also indicates the application of a preload of 10 kg.
- Turn the load lever from position “A” to position “B” to apply the main load on the specimen.
- Wait for the long needle of the dial gauge to reach a steady position.
- Release the main load by bringing back the load lever from position “B” to position “A” slowly.

- Record the reading shown by the long pointer
 - on red scale for Rockwell – B Test
 - on black scale for Rockwell – C Test.
- Turn the main nut in the counter clock wise direction and remove the specimen.

Note:

- One division of Rockwell B or C scale is equal to a depth of indentation of 2 micron.
- Rockwell hardness should be designated by HR, preceded by the hardness value and supplemented by a letter indicating the scale.

Ex: 60 HRC indicates Rockwell hardness of 60 on C scale.

Observations and Calculations:

I. Rockwell – B Test

Type of indenter. Steel ball of diameter $(1/16)^{\text{th}}$ inch.

Specimen	Load P, kg	Load P, N	Red scale reading 'n'	Hardness value, n	Depth of indentation = $(130-n) \times 2$, microns
Brass					
Gun Metal					
Aluminum					

II. Rockwell – C Test

Type of indenter. Rockwall diamond cone of vertex angle 120°

Specimen	Load P, kg	Load P, N	Black scale reading 'n'	Hardness value, n	Depth of indentation $(100-n) \times 2$, microns
Cast Iron					
Mild Steel					

Results and Conclusion:

2. BRINELL HARDNESS TEST

Aim: To determine the hardness number for a given metallic specimen by Brinell Test (HB).

Theory: Definitions: Hardness, Static Indentation, Dynamic Indentation.

Test Set Up:

- Brinell Hardness Testing machine, hereafter called as HTM-1.
- Brinell and Vickers Hardness Testing Machine, hereafter called as HTM-2.
- Indenters. Steel ball indenters of diameters 5 mm and 2.5 mm.
- Test specimens of different materials: Mild steel, Cast iron, Brass, Gun metal and Aluminum.
- Travelling microscope.

Some Important Tables:

Load range for Brinell hardness test:

The load to be applied can be obtained by the

$$\text{formula } P = KD^2 \text{ kgf.}$$

where K = Constant for a given metal (listed in Table-1)

D = Diameter of the ball indenter in mm.

Table 1: Values of 'K' and range of hardness for different metals (for Brinell Hardness Test)

Sl. No.	Metal	Value of K	Range of Brinell hardness number (HB)
1.	Mild steel	30	67-500 kgf/mm ²
2.	Cast Iron	30	67-500 kgf/mm ²
3.	Brass	10	22-315 kgf/mm ²
4.	Gun Metal	10	22-315 kgf/mm ²
5.	Aluminum	5	11-158 kgf/mm ²

Example:

Material \ Ball Indenter diameter, mm	5	2.5
Mild steel	750 kgf	187.5 kgf
Cast Iron	750 kgf	187.5 kgf
Brass	250 kgf	62.5 kgf
Gun Metal	250 kgf	62.5 kgf
Aluminum	125 kgf	31.25 kgf

Procedure:*I. For HTM-1*

- Clean the smooth surface of the specimen to be tested to remove dirt and oil, if any. Polish the test spot, which is flat, by Emory sheet. The top and bottom surfaces of the specimen should be parallel to each other.
- Fix the required ball indenter along with its holder to the thrust member or penetrator.
- Depending upon the material of the specimen and the indenter diameter, arrange the designed loads on the weight shaft (The combined weight of the lever, hanger bracket, weight shaft and the bottom weight is equivalent to 500 kg. Additional weights can be placed on the bottom weight using loose weights 250 kg each).
- Actuate the toggle switch.
- Actuate the hydraulic loading system by pressing the green button provided on the side of the machine.
- Switch on the indicator lamp.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction until a sharp display of the surface of the specimen is obtained on the focusing screen of the measuring device.
- Apply the load by turning the load lever to the “Load” position.
- Wait for the red indicator present near the optical device at the top to activate.
- Release the load by turning the load lever to the “Unload” position. At the same instant, the objective (of magnification 14) comes just above the indentation, and a sharp image of the indentation is seen on the focusing screen.
- Measure the diameter of the indentation using the scale with micrometer present on the screen itself.

Procedure for using the scale present on the screen for measuring the dimension of the indentation.

The scales of the focusing screen and clear screen have long and short division marks. In addition, the focusing screen is equipped with a vernier scale. The long centre division mark on the clear screen (marked ‘O’) should be within the vernier scale. If it is not so, turn the micrometer to bring the long centre division mark within the vernier scale. The distance between a long and a short division mark of the scale is equal to 1 mm.

- The inner edge of the nearer long or short division mark on the left of the scale is made to coincide with the left outer edge of the impression of the indentation using the turning knob provided for that purpose.
- The inner edge of the nearer long or short division mark on the right side of the scale is made to coincide with the right outer edge of the impression of the indentation using the micrometer. If the long center division is not within the vernier scale, adjust the micrometer once again so that the outer edge of the impression contacts with another long or short mark.
- Count the number of divisions between the long and short marks enclosing the impression (exclude the small strip 0 – 0) to get the diameter of the indentation before the decimal point.
- Count the number of vernier scale divisions within the small strip 0 – 0. This indicates the 1st decimal value of the diameter of the indentation.
- Read the coinciding head scale division of micrometer, which is the value of the 2nd decimal place of the diameter of the indentation.
- Turn the screw through 90° and determine the diameter of the indentation once again. Consider the mean of the two values so determined as the diameter of the indentation.
- If no further tests are to be conducted, switch off the lamp indicator, hydraulic loading system (by pressing the red button provided on the side of the machine) and finally the main switch.

II. . For HTM-2

- Clean the smooth surface of the specimen to be tested to remove dirt and oil, if any. Polish the test spot, which is flat, by Emory sheet. The top and bottom surfaces of the specimen should be parallel to each other.
- Fix the required ball indenter along with its holder to the thrust member or penetrator.
- Depending upon the material of the specimen and the indenter diameter select the required load stage and adjust it through corresponding push button provided on the side of the machine.
- Actuate the switch to switch on the lamp of light source.
- Place the standard specimen on the test table, and turn the main nut (hand wheel) in the clockwise direction until a sharp display of the surface of the specimen is obtained on the focusing screen of the measuring device.
- Push the button provided at the front bottom of the instrument, and hold it until the hand

lever moves upwards. Then, release the push button and wait until the hand lever stops. Further, wait for 10 seconds.

- Press down the hand lever without any jerks, which indicates the release of the load. At the same instant, the object (of magnification 70) comes just above the indentation, and a sharp image of the indentation is seen on the focusing screen.
- Measured the diameter of the indentation using the scale with micrometer present on the screen itself.

Procedure for using the scale present on the screen for measuring the dimension of the indentation.

The scales of the focusing screen and clear screen have long and short division marks. In addition, the focusing screen is equipped with a vernier scale. The long centre division mark on the clear screen (marked 'O') should be within the vernier scale. If it is not so turn the micrometer to bring the long centre division mark within the vernier scale. The distance between a long and a short division mark of the scale is equal to 0.1 mm.

- The inner edge of the nearer long or short division mark on the left of the scale is made to coincide with the left outer edge of the impression of the indentation using the turning knob provided for that purpose.
- The inner edge of the nearer long or short division mark on the right side of the scale is made to coincide with the right outer edge of the impression of the indentation using the micrometer. If the long center division is not within the vernier scale, adjust the micrometer once again so that the outer edge of the impression contacts with another long or short mark.
- Count the number of divisions between the long and short marks enclosing the impression (exclude the small strip 0 – 0). Multiply that by 0.1 to get the diameter of the indentation up to first decimal value.
- Count the number of vernier scale divisions within the small strip 0 – 0. This indicates the 2nd decimal value of the diameter of the indentation.
- Read the coinciding head scale division of micrometer, which is the value of the 3rd decimal place of the diameter of the indentation.
- Turn the screw through 90° and determine the diameter of the indentation once again. Consider the mean of the two values so determined as the diameter of the indentation.
- If no further tests are to be conducted, switch off the machine.

Note:

1. The thickness of the test piece should not be less than 10 times the depth of indentation.
2. The distance of the centre of the indentation from the edge of the test piece are from the circumference of the adjacent indentation should not be less than 3 times the diameter of the indentation.
3. The Brinell hardness number is calculated using the formula

$$HB = \frac{2P}{\pi D (D - \sqrt{D^2 - d^2})} \quad \text{N/mm}^2$$

where P is the applied load in kg, D is the diameter of the indenter in mm and d is the diameter of the indentation in mm.

The Brinell hardness number is expressed as: (value in N/mm²)

HB (D in mm) / (P in N) / (time in s).

Observations and Calculations:

I. H.T.M.-1

Material of the specimen	Diameter of the indenter D, mm	Load P, kg	Load P, N	Diameter of the indentation			Brinell hardness value
				d ₁ , mm	d ₂ , mm	d = (d ₁ + d ₂)/2, mm	
Cast Iron							
Mild Steel							

II. H.T.M.-2

Material of the specimen	Diameter of the indenter D, mm	Load P, kgf	Diameter of the indentation			Brinell hardness value
			d ₁ , mm	d ₂ , mm	d = (d ₁ + d ₂)/2, mm	
Brass						
Gun Metal						
Aluminum						

Specimen calculation:

For the given _____ specimen,

$$HB = \frac{2P}{\pi D (D - \sqrt{D^2 - d^2})} \quad \text{N/mm}^2$$

Result and discussion:

3. IMPACT TEST

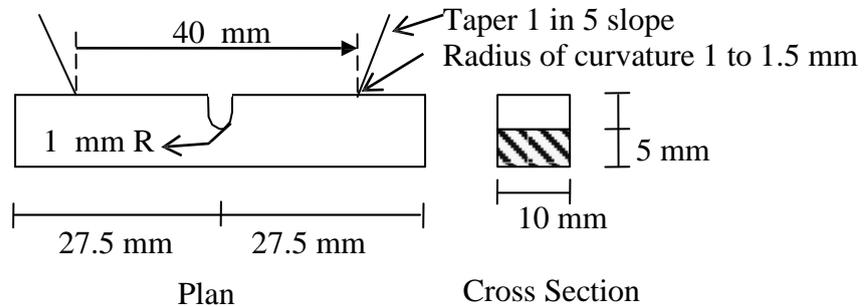
Aim: To determine the impact energy/Impact strength of a given test specimen by

- (a) Izod test (b) Charpy test

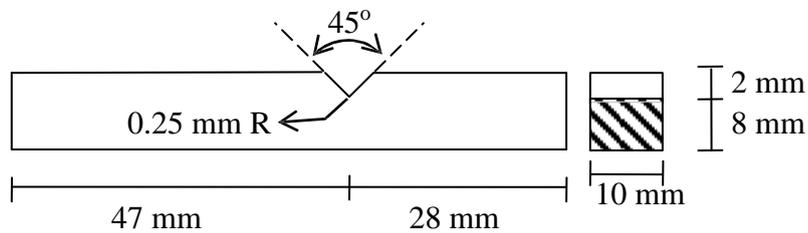
Theory: Definitions: Impact load, Impact energy, Impact strength, Toughness.

Test Set Up:

- Pendulum type impact testing machine. The machine consists of:
 - A pendulum of mass 18.748 kg, length = 825 mm with an angle of swing of 160°.
 - Specimen holder (different for Izod and Charpy tests)
 - Striking edge (different for Izod and Charpy tests)
 - Lock lever and pendulum releaser.
 - Pendulum brake.
 - A calibrated dial to measure the Impact energy, with red and black indicators.
 - Slide Calipers and Scale
- Standard Specimen for Charpy test:



- Standard specimen for IZOD test



Procedure:

- Check the specimen for the its standard dimensions.
- Depending upon the type of test, fix the corresponding striking edge to the hammer.
- To find the frictional loss:
 - Raise the pendulum to its highest position where it gets locked. At this position, the potential energy stored in the pendulum is 30 Nm.
 - Set the dial to read 30 Nm with the indicator showing black colour.
 - Press the lock lever first and then the pendulum releaser to release the pendulum.
 - Stop the oscillations of the pendulum using the damper plate / brake.
 - Record the reading on the dial which indicates the frictional loss directly.

Note: Read the black or red scale according as the indicator is black or red respectively.

- i) Fix the specimen in its holder.
 - a) For Izod Test: The specimen should be placed vertically as a cantilever with the shorter end of the specimen projecting above the holder and V-Notch on the tension side.
 - b) For Charpy Test: The specimen should be placed horizontally as a simple beam and the U-notch on the tension side.

Note: Use the appropriate centraliser to keep the specimen in its proper position.

- ii) Raise the pendulum to its highest position where it gets locked. Set the dial to read 30 Nm with the indicator showing black colour.
- iii) Release the pendulum by pressing down the lock lever first and then the pendulum releaser to strike the specimen.
- iv) Use the damper plate / brake to stop the oscillations of the pendulum.
- v) Record the dial reading on the red or black scale depending upon whether the indicator is red or black respectively.
- vi) Observe whether the specimen has broken completely or not.

Note:

1. Utmost care must be taken to see that no person is present in the line of oscillation of the pendulum.
2. During the test, if the test piece is not completely broken, the impact value obtained is indefinite. Then the test report should state that the test piece was unbroken by _____ joules, in case of Izod test, and the test report should state that the test piece was not broken by the striking energy of the testing machine, in case of Charpy test.

Observations and Calculations:

1. Material of the specimen : _____
2. Mass of the pendulum : 18.748 kg
3. Length of the pendulum : 825 mm
4. Angle of swing : 160°
5. Frictional loss = $U_f =$ _____ Nm

I. Izod Impact Test:

Specimen No.	Specimen dimensions	Observed reading U_0 , Nm	Impact energy or Impact value $U_I = U_0 - U_f$		Remarks
			Nm	joules	

II. Charpy Impact Test

Specimen No.	Specimen dimensions	Cross sectional dimensions of the specimen below the	Area of cross section below the notch, A	Observed reading U_0 Nm	Impact energy $U_I = U_0 - U_f$ Nm	Impact strength $KU = U_I / A$ $\frac{\text{kg-m}}{\text{mm}^2}$	Remarks

Results and Conclusions:

4. TORSION TEST

Aim: To study the behaviour of Mild steel when subjected to a gradually increasing torsional load and to determine the rigidity modulus & modulus of rupture (torsion):

Theory: Definitions: Shear stress, Shear strain, Rigidity modulus; Torsion, Torsion equation; Modulus of rupture (torsion).

Test set up:

- Torsion machine

It has the following parts:

- Arrangement to twist the specimen – It consists of end blocks, specimen holder, a worm gear arrangement and a heavy weight pendulum.
- A circular scale with a vernier to record the angle of twist.
- A calibrated scale mounted on a rack and pinion arrangement to record the torque in Nm. The capacity of the machine is 50 Nm.

The machine can be operated either manually by means of a crank or mechanically with the help of an electric motor.

- Slide calipers/micrometer, scale.

Procedure:

- Observe the specimen. Measure its diameter and initial length.
- Mark a straight line parallel to the longitudinal axis of the specimen with a piece of chalk to observe the twisting of the specimen and to measure the percentage elongation.
- Place the two enlarged ends of the specimen inside the two end blocks and place the whole assembly in the specimen holder. See that the specimen is fixed with no slack.
- Adjust the circular scale and the torque scale to read zero. See that the screw provided in the torque scale arrangement is in contact with the main scale and that the vernier of the circular scale is in contact with the pendulum frame, initially.
- To begin with, operate the machine manually. Record the torque scale readings at regular intervals of 1° twist up to 10° and at every 2° intervals up to 30° .
- Now, remove the crank used for manual operation and connect the machine to an electric motor through a clutch arrangement.
- Note down the torque scale readings at 60° and afterwards at an interval of 60° up to the

failure of the specimen.

- At the instant of failure, disengage the clutch. Record the angle of twist as well as the torque at the instant of failure.
- Remove the tested specimen. Observe the type of fracture.
- With the help of a thread, measure the length of the chalk mark on the specimen.

Observations and calculations before the test:

1. Material of the specimen : _____
2. Diameter of the specimen = $D =$ _____ mm
3. Length of the specimen = $L =$ _____ mm
4. Polar moment of inertia of the cross section of the specimen
= $I_p = \frac{\pi D^4}{32}$ _____ mm⁴
5. Least count of circular scale = _____
6. Least count of torque scale = _____ Nm
7. Capacity of the torque scale = _____ Nm

Data Sheet for Torsion Test:

Angle of twist θ°	Torque T, Nm	Remarks

Observations and calculations after the test:

- 1 Type of fracture : _____
- 2 Length of the chalk mark on the specimen = $L' =$ _____ mm
- 3 Modulus of rigidity of the material of the specimen

$$G = \left(\frac{dT}{d\theta} \right) \frac{L}{I_p} = \text{_____ kg/cm}^2 = \text{_____ N/mm}^2$$

Where $\left(\frac{dT}{d\theta} \right)$ = Slope of the initial straight line portion of torque-angle of twist curve

(dT in kg-cm and dθ in radians).

L= length of the specimen in mm.

I_p = Polar moment of inertia.

- 4 Modulus of rupture (Torsion) = $\frac{16 T_{\max}}{\pi D^3} = \text{_____ kg/cm}^2$
= _____ N/mm²

- 5 Percentage elongation = $\left[\frac{L' - L}{L} \right] 100 = \text{_____}$

Result and Conclusions:

5. TENSION TEST

Aim: To study the stress-strain behaviour of mild steel test specimen under a gradually increasing tensile load and to determine the Young's modulus of elasticity, yield stress, tensile strength, percentage elongation & percentage reduction in cross sectional area.

Theory: Definitions: Stress, Strain; Statement of Hooke's law; Definitions: Ductility, Brittleness, Young's modulus of elasticity, Limit of proportionality, Elastic limit, Yield stress, Proof stress, Ultimate strength, Breaking stress, Gauge length, Percentage elongation, Percentage reduction in area; Typical stress-strain diagrams for mild steel and cast iron under axial tension with explanation.

Test Set Up:

- Universal Testing Machine (UTM)

The machine is so called as it can be used to conduct various tests like tension test, compression test, bending test, shear test etc. The loading is done hydraulically. Three ranges of loading are available (i) 0 to 4 tonnes (ii) 0 to 20 tonnes (iii) 0 to 40 tonnes. UTM is equipped with a provision for getting load – deformation diagram automatically.

The loading unit of UTM consists of (i) Lower cross head (ii) Middle cross head (iii) Upper cross head and (iv) Linear scale. Lower and upper cross heads are connected rigidly with each other and with the hydraulic piston. During loading condition, middle cross head is fixed and the remaining two cross heads move as one unit. However, during no load condition, the position of the middle cross head is adjustable.

The control unit of UTM consists of ON and OFF switches, load indicating dial with live and dummy needles, switches to position the middle cross head and also a graph plotter.

- Extensometer:

This is a device which is used to measure the elongation of the test specimen over certain length. It consists of two dials. The average of their readings is taken as the extensometer reading.

- Slide Calipers and Scale

Procedure:

- Observe the specimen. Measure the total length and parallel length of the specimen. Also measure the diameter of the specimen. Calculate the gauge length. Mark the gauge length on the central portion of the specimen.

- Fix the specimen in-between the upper and middle cross heads using the gripping devices. Take precautions to fix the test specimen in such a way as to ensure that the load is applied axially.
- Fix the extensometer in its position over the gauge points. Adjust the extensometer and the linear scale to read zero initially.
- Select proper range of loading (i.e. 0 to 40 tonnes).
- Switch on the machine. Apply the axial tensile load on the specimen gradually. Record the extensometer readings at a constant load increment of 400 kg.
- The yield point can be observed either:
 - by the kickback of the live needle of the load indicating dial.

OR

- by the rapid movement of extensometer dial needle at constant load reading. Record the yield load(s), and remove the extensometer.
- Continue the axial loading.
- At one stage, the live needle begins to return, leaving the dummy needle there itself. Note down the load at that point as the ultimate load. Also, observe the neck formation on the specimen.
- Note down the load at the point of failure of the specimen.
- Switch off the machine; Remove the failed specimen; Observe the type of fracture.
- Measure the final gauge length on the tested specimen, if the failure has occurred within the gauge length portion and also, the diameter at the neck.

Note:

- a) The above procedure is valid for steel bar of diameter equal to or greater than 4 mm, or of thickness equal to or greater than 3 mm.
- b) For test pieces of rectangular section, a ratio of width to thickness of 8 : 1 should not be exceeded.
- c) The gauge length can be calculated from the equation $L_0 \sqrt{A} = 5.65 \approx 5D$

where A is the initial cross sectional area of the test specimen. It is rounded off to nearest multiple of 5 mm. However, test pieces with other gauge lengths may be used, for technical or economical reasons.

- d) Some specimens exhibit both upper and lower yield points, and some specimens exhibit only one yield point.
- e) Some materials may not exhibit any yield point at all. For such materials, 0.2% proof stress is to be determined.
- f) If the failure occurs outside the gauge length, the value of the percentage of elongation can not be calculated.

Observations and Calculations after the test:

1. Type of fracture : _____
2. Diameter of the specimen at the neck after failure = $d =$ _____ mm
3. Final parallel length = $L_f =$ _____ mm
4. Final gauge length = $L_U =$ _____ mm
5. Final cross sectional area of the specimen at the neck = $a =$ _____ mm²
6. Percentage elongation = $(L_U - L_0) \times 100 / L_0 =$ _____
7. Percentage reduction in cross sectional area = $(A - a) \times 100 / A =$ _____
8. Young's modulus of elasticity of Mild Steel in tension = Slope of the straight line portion of the stress vs. strain curve = $E_t =$ _____ N/mm²

$$(a) \text{ Upper yield stress } = \sigma_{yu} = \frac{\text{load at upper yield point}}{A} = \text{_____ N/mm}^2$$

$$(b) \text{ Lower yield stress } (\sigma_{yl}) = \frac{\text{load at lower yieldpoint}}{A} = \text{_____ N/mm}^2.$$

OR

$$9. \text{ Yield stress } (\sigma_y) = \frac{\text{load at yieldpoint}}{A} = \text{_____ N/mm}^2.$$

$$10. \text{ Tensile strength (Ultimate strength) } (\sigma_{ult}) = \frac{\text{Ultimate load}}{A} = \text{_____ N/mm}^2.$$

$$11. \text{ Failure or breaking stress } (\sigma_f) = \frac{\text{Load at failure}}{A} = \text{_____ N/mm}^2.$$

Results and conclusions:

6. COMPRESSION TEST

Aim: To study the stress-strain behaviour of the given mild steel specimen under a gradually increasing axial compressive load and to determine the compressive strength characteristics of the given material.

Theory: Definitions: Ductility, Malleability; Stress-strain diagram of mild steel specimen under axial compressive load with explanation.

Test Set Up:

- Universal Testing Machine (UTM)
- Dial gauge to measure the axial compression of the specimen.
- Slide calipers / Micrometer, Scale.

Procedure:

- Observe the specimen. Measure its diameter and length.
- Place the specimen in between the middle and lower cross heads of the UTM.
- Fix the dial gauge in its proper position. Adjust the dial reading to zero initially or note down the dial gauge reading corresponding to zero load.
- Select proper range of loading (i.e. 0 to 40 tonnes).
- Switch on the machine. Apply the axial compressive load on the specimen gradually. Note down the dial gauge readings at a constant load increment of 400 kg.
- The yield point can be observed either
 - by the kickback of the live needle of the load indicating dial

OR

- by the rapid movement of dial gauge needle at constant load reading.
- Record the yield load(s), and remove the dial gauge.

- Loading is continued and can be stopped at any stage after this. The specimen will not fail under compression in the case of highly ductile materials.
- Release the load. Switch off the machine. Remove the tested specimen and observe its shape.

Note:

1. It is preferable to have a length to diameter ratio of 2 to 3 for the compression test specimen of either ductile or brittle material.
2. Utmost care should be taken to apply the load axially.

Observations and calculations before the test:

1. Material of the specimen : _____
2. Diameter of the specimen = D = _____ mm
3. Length of the specimen = L = _____ mm
4. Initial Cross sectional area of the specimen = A = _____
5. Least count of the dial gauge = _____ mm
6. Capacity of the dial gauge = _____ mm

Data Sheet for Compression Test:

Load P, kg	Stress = $\sigma =$ P/A, N/mm ²	Dial gauge reading, div.	Deformation dl, mm	Strain e = dl/L	Remarks

Observations and calculations after the test:

1. Nature of the specimen after the test : _____
2. Young's modulus of Elasticity of Mild Steel under compression = slope of the straight line portion of the stress vs. strain curve = $E_c =$ _____ N/mm²

3. (a) Upper yield stress (σ_{yu}) = $\frac{\text{load at upper yield point}}{A} =$ _____ N/mm².

(b) Lower yield stress (σ_{yl}) = $\frac{\text{load at lower yield point}}{A} =$ _____ N/mm².

OR

Yield stress (σ_y) = $\frac{\text{load at yield point}}{A} =$ _____ N/mm².

Results and conclusions:

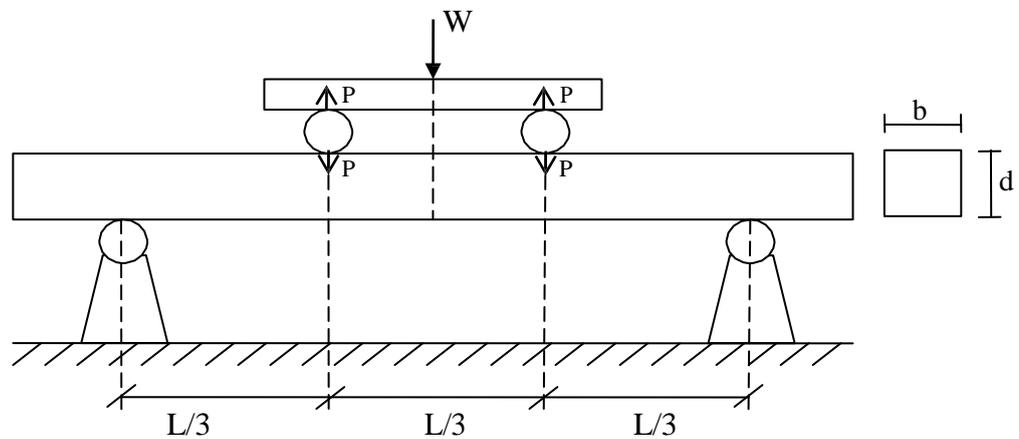
7. BENDING TEST

Aim: To study the behaviour of given specimen subjected to pure bending and to determine the Young's modulus of elasticity and modulus of rupture (bending).

Theory: Definitions: Bending moment, Pure bending, Neutral axis, Bending equation, Section modulus, Modulus of rupture (bending).

Test set up:

- Universal Testing Machine (UTM)
- Roller supports mounted on a rigid base. The distance between the roller supports can be adjusted with the help of adjustable blocks.
- Dial gauge.
- Trisquare.
- Arrangements to apply two-point loading. This consists of two rollers, one M.S. Plate, and a loading element fixed to the middle cross head.
- Scale.



Procedure:

- Observe the specimen and measure its cross sectional dimensions.
- Select a suitable span.
- Mark the mid span point and two-point loading locations at 1/3 span distances. Mark the cross section lines at these locations.
- Select a proper range of loading (i.e. 0 to 4 tonnes).
- Move the adjustable blocks and fix them at positions corresponding to selected span.
- Place the specimen over the roller supports. Place two more rollers at two-point loading positions and M.S. plate over them.
- Move the middle cross head to suitable position close to M.S. plate.
- Move the lower cross head and establish a slight contact between M.S. plate and the loading element fixed to the middle cross head.
- Start applying the load gradually. Note down the dial gauge readings at regular load intervals of 40 kg. Remove the dial gauge after about 10 readings.
- Continue loading up to failure and record the load at failure.
- Switch off the machine and release the load. Remove the specimen and observe the type of failure.

Observations and Calculations before the test:

1. Type of material : _____
2. Cross sectional dimensions = $b \times d =$ _____ mm^2 .
3. Span = $L =$ _____ mm .
4. Moment of inertia of the beam
cross section about the neutral axis = $I = \frac{bd^3}{12} =$ _____ mm^4 .
5. Section modulus = $Z = \frac{bd^2}{6} =$ _____ mm^3 .

6. Least count of the dial gauge = _____ mm
7. Capacity of the dial gauge = _____ mm

Data Sheet for Bending Test:

Total Load W, kg	Load $P = \frac{W}{2}$, N	Dial gauge readings, Divisions	Central deflection δ , mm	Remarks

Observations and Calculations after the test:

1. Type of failure : _____
2. Young's modulus of elasticity

$$E = \frac{23}{648} \left(\frac{dP}{d\delta} \right)^3 \frac{L}{I} = \text{_____ N/mm}^2$$

$$= \text{_____ GPa}$$

3. Maximum bending moment $M_f = \left(\frac{P_f L}{3} \right) = \text{_____ N - mm}$

Where P_f is the load at failure.

4. Modulus of rupture (bending) $= I_f = \frac{M_f}{z} = \text{_____ N/mm}^2$

$$= \text{_____ MPa}$$

Results and Discussions:

8. DOUBLE SHEAR TEST ON MILD STEEL

Aim: To determine the average and maximum shear strengths of the given mild steel specimen when subjected to double shear:

Theory: Definition of shear force; Difference between single and double shear; Relationship between maximum and average shear stresses for different cross sections.

Test set up:

- Universal testing machine (UTM)
- Double shear box: This consists of
 - (a) a load centraliser
 - (b) a central bush
 - (c) two end bushes
 - (d) two end screws
 - (e) a main block to house the above elements
- Slide calipers/Micrometer.

Procedure:

- Observe the specimen. Measure its diameter.
- Place the load centraliser along with the central bush, inside the main block.
- Insert the specimen inside the block such that it passes through the central bush.
- Place the end bushes in their positions such that their grooved surfaces face outwards.
- Tighten the end screws moderately.
- Place the whole assembly on the lower cross head of UTM such that the compression plate of the middle cross head touches the load centraliser.
- Select a proper load range (i.e. 0 to 20 tonnes)
- Apply the axial compressive load gradually on the load centraliser which transforms the axial load into shear load along two parallel planes.
- Record the load at which the specimen fails.
- Switch off the machine; Remove the tested specimen and observe the nature of failure.

Observations and calculations:

2. Material of the specimen : _____
3. Diameter of the specimen = $D =$ _____ mm
4. Initial cross sectional area
of the specimen = $A =$ _____ mm²

5. Load at failure = $P_f =$ _____ kg

6. Type of failure : _____

7. Average shear stress at failure = $\tau_{av.} = \frac{P_f}{2A} =$ _____ N/mm².

8. Maximum shear stress at failure = $\tau_{max.} = \frac{4}{3}\tau_{av.} =$ _____ N/mm².

Results and conclusion:

VIVA-VOCE QUESTIONS

1. Define (a) Hardness (b) Static indentation and (c) Dynamic indentation.
2. Differentiate between Hardness and Toughness.
3. Why do the Brinell hardness numbers obtained from the depth of indentation usually differ from those computed from the diameter of indentation.?
4. How long should the load be maintained in the Brinell test for hardness of steel and why is a definite loading period essential?
5. Explain how hardness is a relative term.
6. Why should the surface of the specimen be flat and well polished?
7. What is the need to perform the hardness test?
8. How is Rockwell hardness test different from Brinell's hardness test?
9. How do the following affect the reading
 - a) Pitted surface
 - b) Oiled surface
 - c) Curved surface
 - d) Presence of a compressible material between specimen and indenter.
10. How do you define the word 'Engineering Material'?
11. What are the objectives of testing of materials?
12. Write brief classification of materials.
13. List out the properties of materials.
14. What is purpose of doing the following tests: Tensile Test, Compression Test, Shear Test, Impact Test, Hardness Test
15. In Tensile test, what is the nature of failure for brittle and ductile material?
16. Define stress and strain. In what unit is each one measured?
17. State Hook's law. Is this applicable to all materials?
18. Define the following terms: elastic limit, proportional limit, yield point, yield strength, resilience and toughness. Do all materials have yield point? Give examples.
19. What is the use of tensile test? What factor should be considered in selecting the gauge length?
20. Which property in a tension test is an indication of stiffness of a material?
21. What is the difference between the proportional limit and the elastic limit?
22. Distinguish between yield point and yield strength?
23. What are the uses of hardness test?
24. What are the types of hardness measurement?
25. What are the types of hardness test, with brief explanation?
26. What are the advantages of Rockwell test over Brinell's Test?

27. How do you define single shear and double shear?
28. How do you place the specimens in impact test?
29. What is metallography?
30. What are the types of metallurgical microscopes?
31. What are the steps involved for preparation of metallographic specimen?
32. What is the purpose of conducting the wear test?
33. What are the types of wear?
34. What are the factors affecting wear?
35. What is the importance of fatigue test?
36. Describe the events that occur when a specimen undergoes a tension test.
37. How is stress calculated? What additional measurement must be made to determine the true stress?
38. Explain why the difference between engineering strain and true strain becomes larger as strain increases in tension?
39. What is breaking stress? How does it differ from the maximum stress?
40. If a brittle material and a ductile material have same tensile strength. Which one will require the greater energy for fracture? Explain.
41. Describe the difference between brittle and ductile fracture?
42. What is universal testing machine? Describe briefly the mechanism for applying load, and for measuring force in testing machine.
43. What is the effect of rate of loading on tensile properties?
44. What are the limits of ratio of the height to the diameter of the compression specimen?
45. Explain compression fracture of the following materials: (a) cast iron and (b) mild steel
46. How failure in bending occurs in the following materials? (a) Cast iron and (b) mild steel.
47. What physical property of the material is determined by means of an impact test?
48. Discuss the significance and advantages of impact test compared with static tests.
49. In what units are the results of an impact test usually given?
50. For impact tests why are notch specimens used?
51. What is difference between Charpy tests and Izod tests?
52. What is meant by velocity sensitivity and notch sensitivity?
53. What is the effect of temperature on impact toughness? What is a transition temperature?
54. Explain the impact fracture as in the case of ductile material.
55. Define hardness. Why is hardness test conducted instead of tension test?
56. What physical properties of a material can be estimated from a hardness test?

57. What is the unit for Brinell hardness number?
58. Where are the Vickers and Rockwell hardness test employed?
59. Why is a minor load applied before setting the Rockwell measuring dial?
60. What is stress concentration? What is stress raiser?
61. What is meant by the term fatigue of metals?
62. Define the following terms in discussing fatigue tests: Stress cycle, maximum stress, range of stress, minimum stress, normal stress, alternating stress, amplitude, mean stress, fatigue life, fatigue limit, stress ratio, cycle ratio, fatigue strength and fatigue ratio.
63. Explain why there is difference between a theoretical stress concentration factor and the actual-strength reduction factor found in actual tests?
64. What are the types of fatigue loading? Give examples of machine parts and structures subjected to fatigue loading.
65. If a material does not have an endurance limit, how would you estimate its fatigue life?
66. What type of fracture would you expect in the case of steel member fractured by repeatedly applied loads? Explain the mechanism of such fracture.
67. What is creep? Name two structural or machine members in which creep strength is an important property.
68. State the resemblance and the difference between creep and slip?
69. Define wear of the material. Name different types of wear.
70. Define micrography.
71. What are the general objectives of the macro examination of a metallic component as compared with the micro examination of a metal?
72. Describe the various steps involved in preparation of specimen for micrographic examination.
73. What is the difference between eutectic and eutectoid?
74. Explain the Curie point in iron, iron-carbide equilibrium diagram.
75. What is annealing? What are the purposes for annealing steel?
76. How does normalizing differ from annealing as applied to steels?
77. What are the advantages of the normalizing process in respect of final properties?
78. Describe the hardening process. Where does the defect occur after hardening the steel?