Avanti Learning Centre

2014 - 2016

# P8. Mechanical Properties of Solids

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## Elasticity -I Introduction

#### Learning objectives

1. Define a rigid body, an elastic body and a plastic body.
2. Understand the phenomenon of elasticity at the molecular level.
3. Define Stress and Strain.
4. Define Longitudinal, Shearing and Volume Strain.
5. Establish the mathematical relation between stress and strain. (Hooke's law)
6. Define Young’s Modulus.
7. Differentiate between pressure and stress.
8. Describe various regions on the stress-strain curve.

#### Pre-test (5 mins)

1. If a rope is tied to a wall and you are pulling it with force, what is the direction and the magnitude of the tension in the rope?

1. A rectangular rod of length L and cross-sectional area A, is pulled such that the new length is 4L. What would be the new area of cross section

(Answers at the end of this topic)

|  |  |
| --- | --- |
| SCORE |  |

Score 2 point per correct answer. If you score less than 2 – please take some time to revise the following topics.

#### Pre-reading (60 mins)

You may refer to one of the following sources:

|  |  |  |  |
| --- | --- | --- | --- |
| Category | Book Name (Edition) | Chapter | Section |
| REQUIRED | NCERT, Class 11 (Compulsory) | 9–Mechanical Properties of Solids | 9.1 to 9.5 and 9.6.1 |
| ADDITIONAL | Concepts of Physics – H. C. Varma, Part-1  (2013- Second reprint) (Optional) | 14-Some Mechanical Properties of Matter | 14.1 to 14.6 |
| ADDITIONAL | Fundamentals of Physics – Halliday, Resnick, Walker (6th Edition) | 13-Equilibrium and Elasticity | 13.6 |
| ADDITIONAL | Maharashtra State Board Physics textbook Class 12. (2012) | 5 – Elasticity | 5.1, 5.2, 5.3, 5.4(Only Definitions) 5.5 |

#### Pre-reading Exercise (10 mins + 5 mins GD)

Attempt each problem individually without discussion. Parts of some questions have been solved as illustrations. After the allotted time please fill in the self-assessment below for individual attempts.

1. A body which completely regains its original dimensions when the deforming forces are removed is called said to be
2. Perfectly plastic b. Perfectly elastic c. Rigid d. elastic body

1. A 4.0m long steel cable having cross sectional area of, is hung with 500kg load. Find the stress developed in the cable.

##### C:\Users\Pritesh-PC\Desktop\P8 Module Version 4\Images-prabhakar\14.jpg

1. A graph is shown between stress and strain for a metal. The part in which Hooke’s law holds good is
2. OA b. AB

c. BC d. CD

1. In the above graph, point B is referred to as the
2. Breaking point b. limiting point
3. Yield point d. None of the above
4. In the above graph, point D indicates
5. Limiting point b. Yield point
6. Breaking point d. None of the above
7. A steel wire of length 10m and diameter 5mm is stretched by 10 kg wt force. Find the increase in its length, if the Young’s modulus of steel is .

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Qs. |  | Correctly solved | Attempted | Not Attempted |
| 6 | Individually |  |  |  |
| After GD |  |  |  |

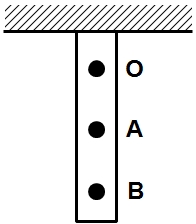
#### In-class Exercise (60 mins + 20 mins GD)

**Level 1**

1. A copper wire of length 5m is suspended from ceiling. When a mass is hung from its lower end, its length increased by 2cm. Find the longitudinal strain in the wire.
2. A solid cylindrical steel column is 4m long and 9 cm diameter. What will be its decrease in length when carrying a load of 80000 kg? .
3. The radius of a copper wire is 4 mm. What force is required to stretch the wire by 20% of its length, assuming that the elastic limit is not exceeded?
4. b. c. d.

**Level 2**

1. A wire of length and radius r has a weight and the Young’s modulus. It is suspended vertically from a fixed point. Calculate the increase in length of wire produced due to its own weight.



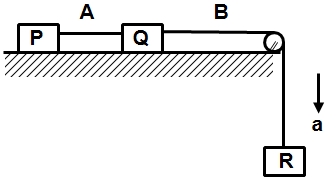
1. A wire has density of and breaking stress and the diameter of wire is 1 mm. What is the length of wire such that it breaks under its own weight when suspended vertically? What will happen if the diameter of the wire is doubled?
2. A light rod of length 200 cm is suspended from the ceiling horizontally by means of two vertical wires of equal length tied to its end. One of the wires in made of steel and is of cross-section 0.1 and the other of brass of cross-section 0.2. Along the rod at which distance a weight should be hung to produce

a. Equal stresses in both the wires

b. Equal strains in both the wires?

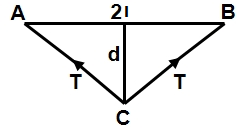
Y for brass and steel are and respectively.

1. The stress applied to the wire having mass per unit length and density 7 , when 10 gm weight is attached to its free end is......
2. b. c. d.
3. A copper wire of negligible mass 1 m length and cross-sectional area is kept on a smooth horizontal table with one end fixed. A ball of mass 1 kg is attached to the other end. The wire and the ball are rotating with an angular velocity of 20 rad/sec. If the elongation in the wire is , obtain the Young’s modulus. If on increasing the angular velocity to 100 rad/sec, the wire breaks down, obtain the breaking stress
4. The length of a metal wire is when the tension in it is and is when the tension is . The natural length of the wire is:
5. b. c. d.



1. Each of three blocks P,Q and R show in figure has a mass of 3 kg. Each of the wire A and B has cross-sectional area 0.005 and young’s modulus. Neglect friction. Find the longitudinal strain developed in each of the wires. Take g=10
2. Two similar wires under the same load yield elongations of 0.1mm and 0.05 mm respectively. If the area of cross-section of the first wire is 4m, then the area of cross-section of the second wire is \_\_\_\_\_\_\_
3. b. c. d.

**LEVEL 3**

1. A wire of radius r stretched without tension along a straight line is lightly fixed at A and B (figure). What is the tension in the wire when it is pulled into the shape ACB. Assume Young’s modulus of the material of wire to be Y.(Given )
2. A bar of cross section is subjected two equal and opposite tensile forces at its ends. Consider a plane through the bar making an angle with a plane at right angle to the bar.
3. What is the tensile stress at this plane, in terms of and?
4. What is the shearing stress at this plane, in terms of and?
5. For what value of is the tensile stress a maximum?
6. For what value of is the shearing stress a maximum?

##### self assessment

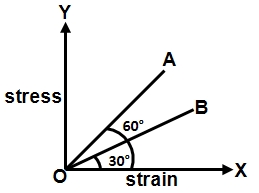
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Qs. |  | Correctly solved | Attempted | Not Attempted |
| 13 | Individually |  |  |  |
| After GD |  |  |  |

#### Homework (60 mins + 20 MINS GD)

##### LEVEL 1

1. A metal wire 75 cm long and 0.13 cm in diameter stretches 0.035 cm, when a load of 8 kg is hung on its ends. Find the stress, strain and Young’s modulus.
2. A copper wire of length 5m is suspended from ceiling. When a mass is hung from its lower end, its length increased by 2cm. Find the strain in the wire.
3. A metallic wire is subjected to a tension of 400 gm weight. If its diameter is 0.5 mm, what is the value of stress exerted upon it?
4. b.
5. d.

##### LEVEL 2

1. The stress versus strain graphs for wires of two materials A and B are as shown in the figure. If are the Young’s moduli of the materials, then
2. b.

c. d.

1. A metal wire of length L, area of cross section A and Young modulus Y behaves as a spring of spring constant K then K is \_\_\_\_\_
2. b. c. d.
3. A student plots a graph from his readings on the determination of Young’s modulus of a metal wire but forgets to put the labels. The quantities on X and Y-axis may be respectively:
4. weight hung and length increased
5. stress applied and length increased
6. stress applied and strain developed
7. length increased and the weight hung
8. A rod 1.05 m long, whose weight is negligible, is supported at its ends by wire A and B of equal lengths. The cross-section of A is 1 and that of B is . The Young’s modulus for wire A is and for B is . At what point along the rod should a weight be suspended in order to produce
9. equal stress in A and B
10. equal strain in A and B

##### LEVEL 3

1. A body of mass 3.14 kg is suspended from one end of a wire of length . The radius of the wire is changing uniformly form m at one end to m at the other end. Find the change in length of the wire when is suspended form narrower end. What will be the change in length if the ends are interchanged given that the Young’s modulus of the material of the wire is .
2. A brass wire 4m long is loaded with 4 kg. If the diameter of the wire is 1mm. Calculate extension produced by the load. Young‘s modulus of elasticity of brass=dynes/ and
3. A rod AD of uniform cross-section 0.1, consists of three segments AB, BC and CD joined together is hanging vertically from a fixed support at A. The lengths of the segments are respectively 0.1 m , 0.2 m and 0.15 m. A weight of 10 kg m is hung from D. Calculate the displacement of a point B, C and D using the data on young’s moduli given below (neglect the weight of the rod)

,

##### self assessment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Qs. |  | Correctly solved | Attempted | Not Attempted |
| 10 | Individually |  |  |  |
| After GD |  |  |  |

PRE-TEST SOLUTIONS

##### Notes/Doubts:

##### PRE-TEST ANSWERS

1. The magnitude is equal to the magnitude of force and the direction will be in the direction the opposite of the direction of force.

## Elasticity - II

#### Learning objectives

1. Define Young’s Modulus, Modulus of Rigidity and Bulk Modulus and compressibility
2. Determine the elastic potential energy of a strained body.
3. Define Torsion.
4. Relate Torsion to modulus of rigidity.
5. Study the laboratory experiment to measure Young’s Modulus.
6. Study applications of elastic behavior of solids.

#### Pre-test (10 mins)

* + - 1. If Young’s Modulus (Y) and Y , then what are the dimensions of Young’s Modulus(proportionality constant is 1)?
      2. A mass m is attached to an unstretched spring (of spring constant), suspended from a fixed support. It is now released. What is the potential energy stored in the spring when the extension in the spring

* + - 1. In the previous question what will be the kinetic energy when the extension is .

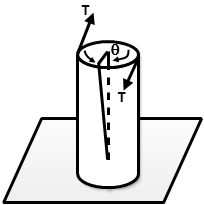
#### Pre-reading (30 mins)

You may refer to one of the following sources:

|  |  |  |  |
| --- | --- | --- | --- |
| Category | Book Name (Edition) | Chapter | Section |
| REQUIRED | NCERT, Class 11 (Compulsory) | 9 – Mechanical Properties of Solids | 9.6 and 9.7 |
| ADDITIONAL | Concepts of Physics – H. C. Verma, Part - 1  (2013- Second reprint) (Optional) | 14 - Some Mechanical Properties of Matter | 14.7 and 14.8 |
| ADDITIONAL | Fundamentals of Physics – Halliday, Resnick, Walker (6th Edition) (Optional) | 13- Equilibrium and Elasticity | 13.6 |
| ADDITIONAL | Maharashtra State Board Physics textbook Class 12. (2012) (Optional) | 5 – Elasticity | 5.4 and 5.6 to 5.10 |

#### Pre-Reading (TORSION)

Torsion is a variation of pure shear, wherein a structure is twisted in the manner as shown in the figure below; torsional forces produce a rotational motion about the longitudinal axis of one end relative to the other end. Examples of torsion are found for machine axles and drive shafts. A shear stress is a function of the applied torque T, whereas shear strain is related to the angle of twist, see figure.

For a bar fixed at one end the restoring torque is given as, 

Where,

#### Pre - reading EXERCISE (10 mins + 5 mins GD)

1. On stretching a wire. the elastic energy stored per unit volume is
2. b. FA/2L c. FL/2A d. FL/2
3. The compressibility of water is per unit atmospheric pressure. The decrease in volume of of water under a pressure of 100 atmospheres will be :
4. b. c. d.

##### self assessment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Qs. |  | Correctly solved | Attempted | Not Attempted |
| 2 | Individually |  |  |  |
| After GD |  |  |  |

#### In-class Exercise (60 mins + 20 mins GD)

**LEVEL 1**

1. Compute the bulk modulus of water from the following data: Initial volume litre, Pressure increase atm, Final volume litre.
2. b.
3. d.
4. A wire of length L and cross-sectional area A is made of a material of Young’s modulus Y. The work done in stretching the wire by an amount x is given by
5. b. c. d.
6. A box shaped piece of jelly has a top area of and a height of 3 cm. When a shearing force of 0.5 N is applied to the upper surface, the upper surface is displaced 4.0 mm relative to the bottom surface. What are the values of the shearing stress, shearing strain and shear modulus?
7. Compute the volume change of a solid copper cube, 40 mm on each edge, when subjected to a pressure of . The bulk modulus of copper is.

**LEVEL 2**

1. When a force is applied at one end of an elastic wire, it produces a strain 𝜀 in the wire. If Y is the Young’s modulus of the material of the wire, the amount of energy stored per unit volume of the wire is given by:
2. b. c. d.
3. Two cylinders A and B are made of the same material. The length and radii of the two cylinders are in the ratio of Both are twisted by the same external torque. What is the ratio of the angle of twist of A and B?
4. Calculate the increase in energy of a brass bat 0.2 metre long and of cross-sectional area when compressed with a load of 5 kg weight along its length. (Young’s modulus of brass=
5. A metallic wire is stretched by suspended weight to it. If is longitudinal strain and Y its young’s modulus of elasticity, show that elastic potential energy per unit volume is given by
6. Calculate the work done in stretching a uniform metal wire of area of cross-section and length 1.5m through The Young’s modulus for the wire is

**LEVEL 3**

1. A balloon ascends vertically slowly unreeling a long copper wire. Estimate the amount by which the wire has stretched when 1 km of initially unstretched wire has been unreeled. The density of copper is and its Young’s Modulus

1. Find the density of water near the ocean bed where the pressure is about 700 atm. Given density of water at the surface, for water.

##### self assessment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Qs. |  | Correctly solved | Attempted | Not Attempted |
| 11 | Individually |  |  |  |
| After GD |  |  |  |

#### 

#### Homework (60 mins)

##### LEVEL 1

1. If shearing stress is, what is the minimum force required to punch a hole of radius 1mm, and thickness 2mm ?
2. The work required to be done in producing an extension of 1.0 mm in a wire of length 50 cm and area of cross-section will be)
3. b. c. d.
4. The following four wires (length L and diameter D) are made of the same material. Which of these will have the largest extension when the same tension is applied?
5. cm, mm b. cm, mm
6. cm, mm d. cm, mm

##### LEVEL 2

1. In Searle’s experiment, which is used to find Young’s modulus of elasticity, the diameter of experimental wire is (measured by a scale of least count 0.001 cm) and length is (measured by a scale of least count 0.1 cm). A weight of 50 causes an extension of cm (measured by a micrometer of least count . Find maximum possible error in the values of Young’s modulus. Screw gauge and meter scale are free from error.
   1. b.

c. d.

1. A cylinder of length 1.5 m and diameter 4 cm is fixed at one end. A tangential force of is applied at the other end. Calculate the twist produced in the cylinder if the modulus of rigidity is .
2. A brass wire 4m long is loaded with 5 kg. If the diameter of the wire is 1mm. Calculate Work done in producing 0.4m extension, given that the modulus of elasticity of brass=N/ and .

##### LEVEL 3

1. A steel cylindrical rod of length and radius is suspended by its end from the ceiling.

a. Find the elastic deformation energy of the rod.

b. Define in terms of tensile strain of the rod.

1. A mass 2 kg is attached to one end of an elastic string of natural length 1.5m, whose other end is fixed at a point A. The elastic modulus of the string is such that the 2 kg mass hanging vertically would stretch the string by the 3 cm. The mass is held at A and allowed to fall vertically. How far below A will it come to rest?
2. A rod 1m long is in area for a portion of its length and in area for the remainder. The strain energy of this stepped bar is of that a bar in area and 1 m long under the same stress in part. What is the length of the portion in area?
   * + - 1. 40cm b. 20cm c. 30cm d. None of these

##### self assessment

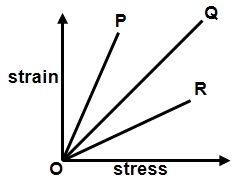
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Total Qs. |  | Correctly solved | Attempted | Not Attempted |
| 9 | Individually |  |  |  |
| After GD |  |  |  |

##### Notes/Doubts:

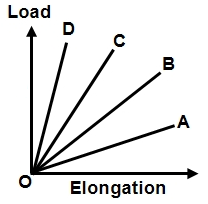
##### Pre-test answers

Objective Questions

1. A wire is loaded by 6 kg at its one end; the increase in length is 12 mm. If the radius of the wire is doubled then the increase in length will be.
2. 6 mm b. 3 mm c. 24 mm d. 48 mm
3. If the density of the material increases, the value of Young’s modulus
4. Increases  b. Decreases
5. First increases than decreases d. First decreases than increases

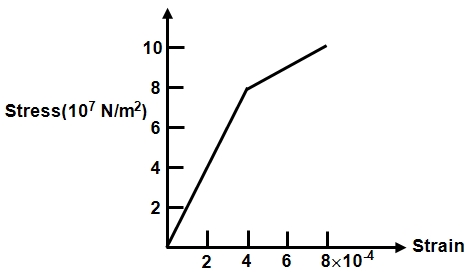


1. The strain –stress curves of three wires of different materials are shown in the figure. P, Q and R are the elastic limits of the wire. The figure shows that
2. Elasticity of wire P is maximum
3. Elasticity of wire Q is maximum
4. Elasticity of wire R is maximum
5. None of the above is true

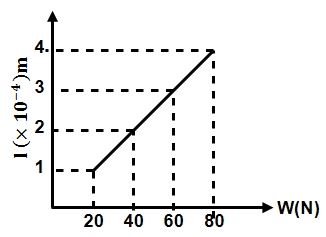


1. The load versus elongation graph for four wires of the same material and same length is shown in the figure. The thickest wire is represented by the line
2. OD b. OC

c. OB d. OA

1. Which one of the following is the Young’s modulus (in for the wire having the stress-strain curve shown in the figure
2. b.

c. d.

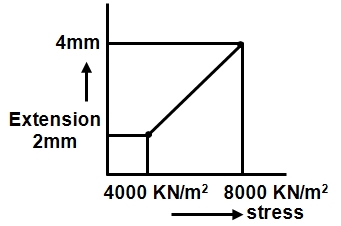


1. The adjacent graph shows the extension of a wire of length 1 m suspended from the top of a roof at one end and with a load connected to the other end. If the cross-sectional area of the wire is , calculate from the graph the Young’s modulus of the material of the wire.
2. b.

c. d.

1. A wire of length cross-sectional area is made of a material of Young’s modulus If the wire is stretched by an amount what is the work done in the process?
   1. b.

c. d.



1. In determination of young modulus of elasticity of wire, a force is applied and extension is recorded. Initial length of wire is ‘1m’. The curve between extension and stress is depicted besides ,the young modulus of wire will be:

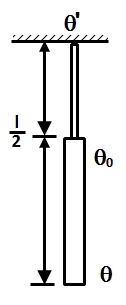
b.

c. d.

1. If x longitudinal strain is produced in a wire of Young’s modulus Y, then the energy stored in the material of the wire per unit volume is.
2. b. c. d.

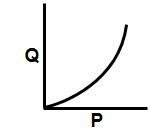
1. A rubber cord catapult has cross-sectional area and initial length of rubber cord is 10 cm. It is stretched to 5cm and then released to project a missile of mass 5 gm. Taking velocity of projected missile is
2. b. c. d.
3. If a rubber ball is taken at the depth of 200 m in a pool, its volume decreases by 0.1%. If the density of the water is and then the volume elasticity in will be
4. b. c. d.

1. A uniform cube is subjected to volume compression. If each side is decreased by 1%, then bulk strain is,
2. 0.01 b. 0.06 c. 0.02 d. 0.03
3. The pressure of a medium is changed from Pa to Pa and change in volume is 10% keeping temperature constant. The bulk modulus of the medium is
4. b.
5. d.

1. Two wires A and B same length and of the same material have the respective radii and . Their one end is fixed with a rigid support, and at the other end equal twisting couple is applied. Then the ratio of the angle of twist at the end of A and the angle of twist at the end of B will be.
   1. b. c.  d.
2. A cube of aluminum of sides 0.1 m is subjected to a shearing force of 100 N. The top face of the cube is displaced through 0.02 cm with respect to the bottom face. The shearing strain would be
3. 0.02 b. 0.1 c. 0.005 d. 0.002
4. A rod length l and radius r is joined to a rod of length l/2 and radius r/2 of the same material. The free end of small rod is fixed to a rigid base and the free end of larger rod is given a twist of the twist angle at the joint will be
5. /4 b. /2

c. 56 d.

1. Wires A and B are made from the same material. A has twice the diameter and three times the length of B. If the elastic limits are not reached, when each is stretched by the same tension, the ratio of energy stored in A to that in B is
2. 2:3 b. 3:4 c. 3:2 d. 6:1

1. The ratio of Young’s modulus of the material of two wires is 2:3. If the same stress is applied on both, then the ratio of elastic energy per unit volume will be
2. 3:2 b. 2:3 c. 3:4 d. 4:3
3. The graph shows the behavior of a length of wire in the region for which the substance obeys Hooke’s law. P and Q represent
4. P=applied force ,Q= extension
5. P=extension Q= applied force
6. P= extension Q= stored elastic energy
7. P=stored elastic energy ,Q=extension
8. A solid sphere of radius made of a material of bulk modulus is surrounded by a liquid in a cylindrical container. A massless piston of area floats on the surface of the liquid. When a mass is placed on the piston to compress the liquid, the fractional change in the radius of the sphere.
   * + - 1. b. c. d. None of these

##### Answers

## Elasticity I - Introduction

#### Pre-reading Exercise

1. Perfectly elastic
2. OA
3. Yield Point
4. Breaking Point

#### In-class Exercise (60 mins + 20 mins GD)

**Level 1**

1. Longitudinal strain

**Level 2**

1. 68 km, and stress does not depend on its diameter.
2. a. and b.
4. d (

b

**LEVEL 3**

1. a. b. c. d.

#### Homework (60 mins + 20 MINS GD)

##### LEVEL 1

1. Stress = , Strain , Young’s Modulus
2. Longitudinal strain
3. a

##### LEVEL 2

1. d.
2. a.
3. All are correct.
4. a. and b.

##### LEVEL 3

1. On interchanging the ends, the change in length remains the same
3. Displacement of B

Displacement of C

Displacement of D

## Elasticity - II

#### Pre - reading EXERCISE (10 mins + 5 mins GD)

1. )

#### In-class Exercise (60 mins + 20 mins GD)

**LEVEL 1**

1. c.
2. b.
3. Shear stress ; Shear strain (Shear modulus)

**LEVEL 2**

2. Increase in energy =
3. elastic energy per unit volume

**LEVEL 3**

1. Increase in length = 0.3675m
2. . Water gets compressed by about at the ocean bed due to very high pressure.

#### Homework (60 mins)

##### LEVEL 1

1. c
2. d ( cm, mm)

##### LEVEL 2

2. Radians

##### LEVEL 3

1. a. The elastic deformation energy = and b.
2. 1.83m below A
3. a.

Objective Questions

1. b (3mm)
2. a (Increases)
3. c (Elasticity of wire R is maximum)
4. d (OD)
5. d ()
6. a ()
7. b ()
8. a
9. d
10. c
11. d
12. d (0.03)
13. d (Pa)
14. c
15. d (0.002)
16. d (
17. b (3:4)
18. a (3:2)
19. c (P= extension Q= stored elastic energy)
20. a