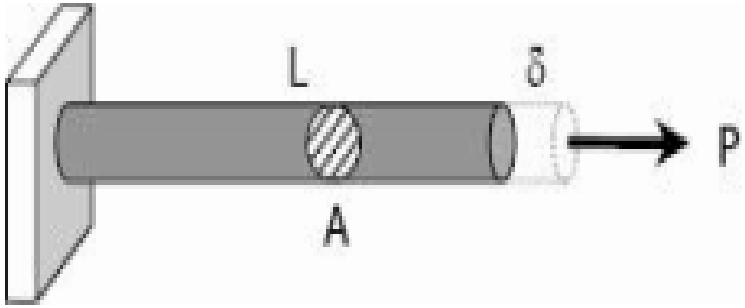
Strength of Material

Strain

Strain

Simple Strain

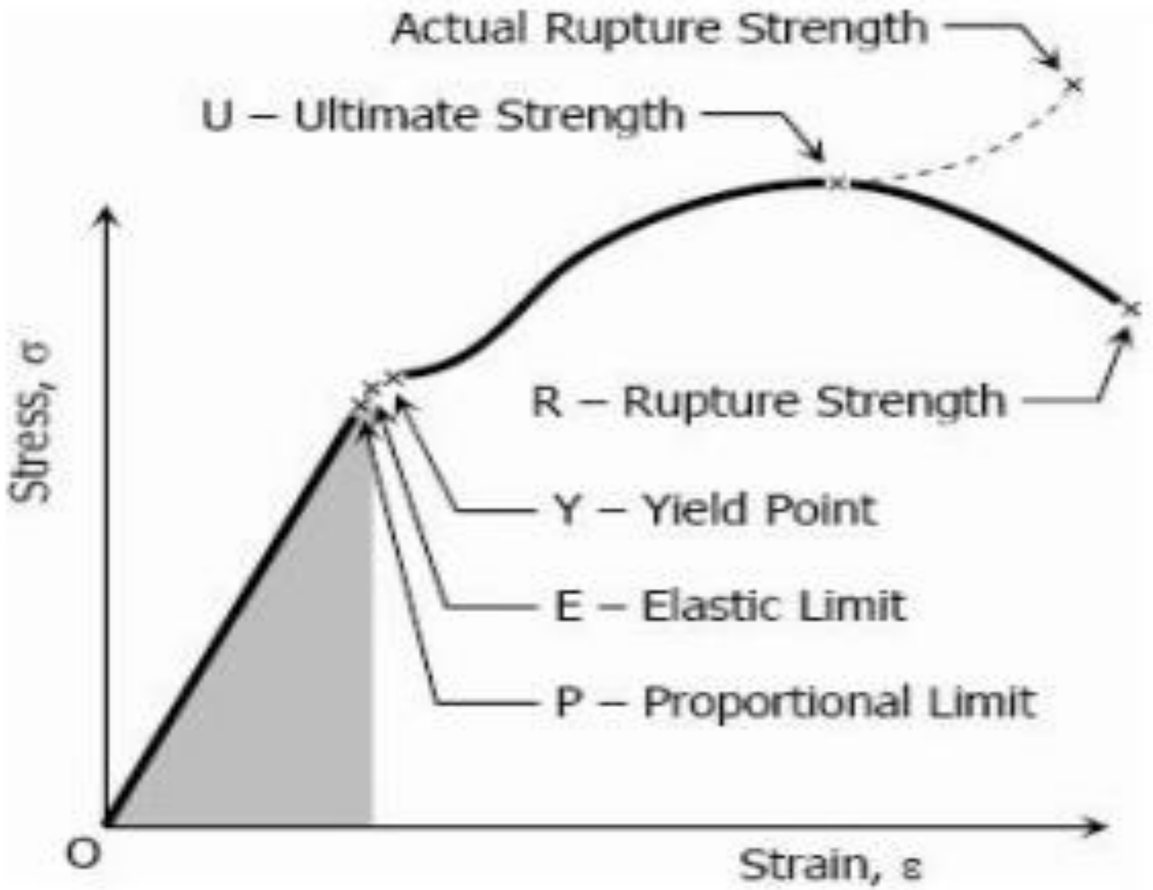
Also known as unit deformation, **strain** is the ratio of the change in length caused by the applied force, to the original length.



$$\varepsilon = \frac{\delta}{L}$$

where δ is the deformation and L is the original length, thus ε is dimensionless.

Stress-strain Diagram



Stress-strain diagram of a medium-carbon structural steel

Hooke's Law

From the origin O to the point called proportional limit, the stress-strain curve is a straight line. This linear relation between elongation and the axial force causing was first noticed by Sir Robert Hooke in 1678 and is called Hooke's Law that within the proportional limit, the stress is directly proportional to strain or

$$\sigma \propto \varepsilon \quad \text{or} \quad \sigma = k\varepsilon$$

The constant of proportionality k is called the Modulus of Elasticity E or Young's Modulus and is equal to the slope of the stress-strain diagram from O to P. Then

$$\sigma = E\varepsilon$$

since $\sigma = P/A$ and $\sigma = E.\ \varepsilon$ $(\varepsilon = \delta/L)$, then $P/A = E(\delta/L)$
or

$$\delta = \frac{PL}{AE} = \frac{\sigma L}{E}$$

Example 1

The following data were recorded during the tensile test of a 14-mm-diameter mild steel rod. The gage length was 50 mm.

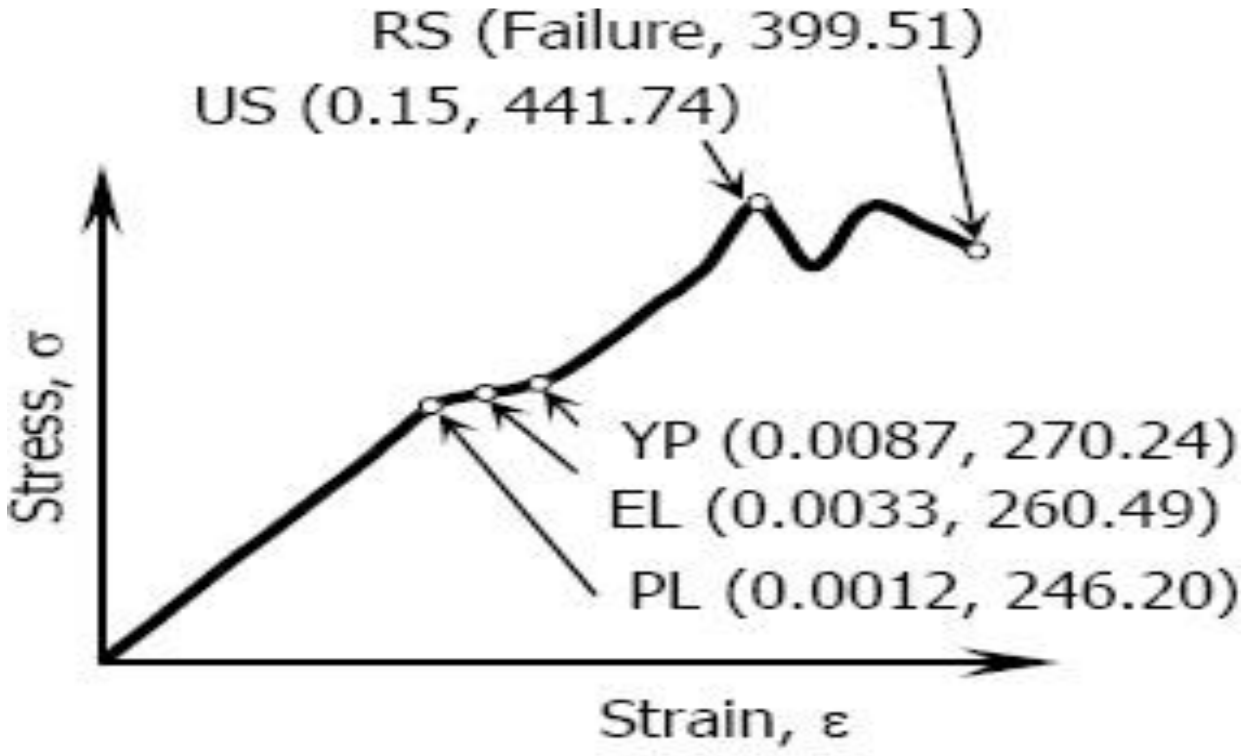
Load (N)	Elongation (mm)	Load (N)	Elongation (mm)
0	0	46 200	1.25
6 310	0.010	52 400	2.50
12 600	0.020	58 500	4.50
18 800	0.030	68 000	7.50
25 100	0.040	59 000	12.5
31 300	0.050	67 800	15.5
37 900	0.060	65 000	20.0
40 100	0.163	65 500	Fracture
41 600	0.433		

Plot the stress-strain diagram and determine the following mechanical properties: (a) proportional limits; (b) modulus of elasticity; (c) yield point; (d) ultimate strength; and (e) rupture strength.

Solution 1

Area, $A = 0.25\pi(14^2) = 49\pi\ mm^2$
Length, $L = 50$ mm
Strain = Elongation/Length
Stress = Load/Area

Load (N)	Elongation (mm)	Strain (mm/mm)	Stress (MPa)
0	0	0	0
6 310	0.010	0.0002	40.99
12 600	0.020	0.0004	81.85
18 800	0.030	0.0006	122.13
25 100	0.040	0.0008	163.05
31 300	0.050	0.001	203.33
37 900	0.060	0.0012	246.20
40 100	0.163	0.0033	260.49
41 600	0.433	0.0087	270.24
46 200	1.250	0.025	300.12
52 400	2.500	0.05	340.40
58 500	4.500	0.09	380.02
68 000	7.500	0.15	441.74
59 000	12.500	0.25	383.27
67 800	15.500	0.31	440.44
65 000	20.000	0.4	422.25
61 500	Failure		399.51



Stress-Strain Diagram
(not drawn to scale)

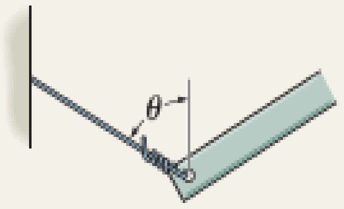
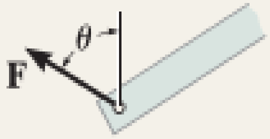
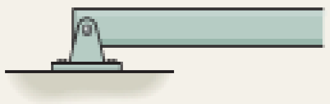
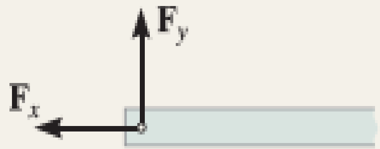
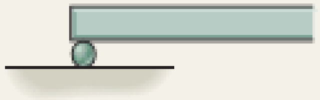
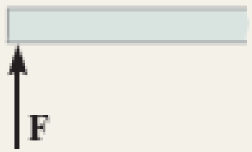
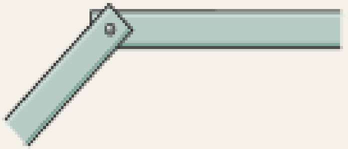
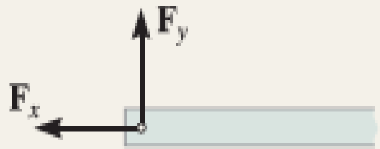
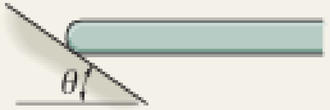
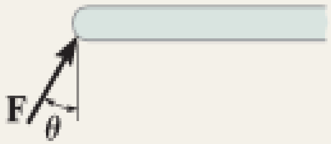
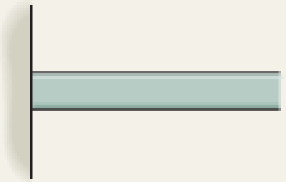
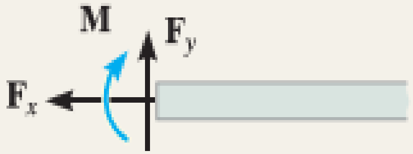
PL = Proportional Limit
EL = Elastic Limit
YP = Yield Point
US = Ultimate Strength
RS = Rupture Strength

From stress-strain diagram:

a. Proportional Limit = **246.20 MPa**
b. Modulus of Elasticity

   E = slope of stress-strain diagram within proportional limit

   E = 246.20/0.0012 = 205 166.67 MPa = **205.2 GPa**
c. Yield Point = **270.24 MPa**
d. Ultimate Strength = **441.74 MPa**
e. Rupture Strength = **399.51 MPa**

Type of connection	Reaction	Type of connection	Reaction
 Cable	 One unknown: F	 External pin	 Two unknowns: F_x, F_y
 Roller	 One unknown: F	 Internal pin	 Two unknowns: F_x, F_y
 Smooth support	 One unknown: F	 Fixed support	 Three unknowns: F_x, F_y, M