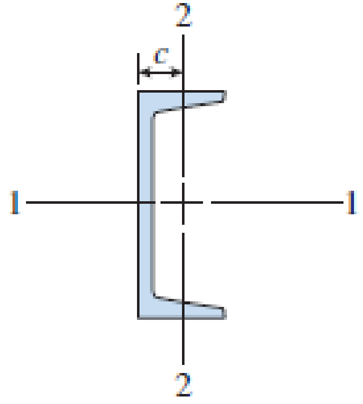
Chapter 1. Tension, Compression, and Shear

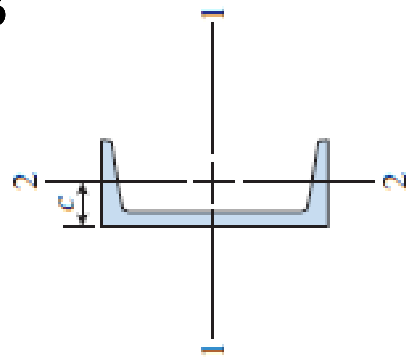
- Course overview
  - normal stress ( ), Normal strain ( )
  - Modulus of Elasticity ( )
  - Yield ( ) and ultimate ( ) stresses
  - Shear stress ( ), shear strain ( )
  - Shearing modulus of elasticity ( )
  - Poisson's ratio ( )
  - Factor of safety
  - Strength and Stiffness

Kahoot review

Case A



Case B

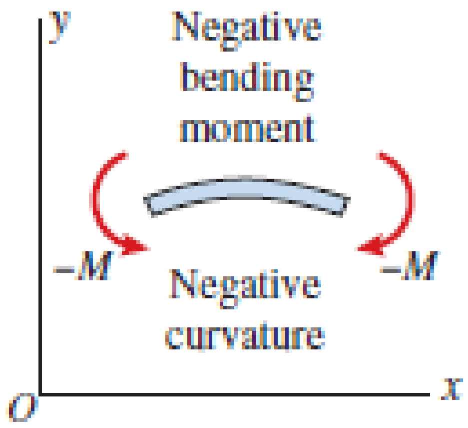


$$I = \int_A y^2\, dA$$

$$\kappa = \frac{1}{\rho} = \frac{M}{EI}$$

TABLE E-3(a) PROPERTIES OF CHANNEL SECTIONS (C SHAPES) – USCS UNITS (ABRIDGED LIST)

Designation	Weight per foot	Area	Depth	Web thickness	Flange		Axis 1-1			Axis 2-2			
					Width	Average thickness	I	S	r	I	S	r	c
	lb	in.^{2}	in.	in.	in.	in.	in.^{4}	in.^{3}	in.	in.^{4}	in.^{3}	in.	in.
C 15 × 50	50.0	14.7	15.0	0.716	3.72	0.650	404	53.8	5.24	11.0	3.77	0.865	0.799
C 15 × 40	40.0	11.8	15.0	0.520	3.52	0.650	348	46.5	5.45	9.17	3.34	0.883	0.778
C 15 × 33.9	33.9	10.0	15.0	0.400	3.40	0.650	315	42.0	5.62	8.07	3.09	0.901	0.788



Kahoot result

Steel section				
Final Scores				
Rank	Players	Total Score (points)	Correct Answers	Incorrect Answers
1	15 Fossil	2077	2	0
2	hsjd	2067	2	0
3	보이루	2043	2	0
4	malong	2026	2	0
5	나는유리안드레예비치지바고!!	2010	2	0
6	민큐쓰짱짱맨	2010	2	0
7	Yakooja	1995	2	0
8	sjk	1980	2	0
9	kdh	1976	2	0
10	치킨먹고싶다	1970	2	0
11	참치심리학과	1931	2	0
12	Blacknut	1904	2	0
13	닉닉	1903	2	0
14	sw	1877	2	0
15	jh	1872	2	0
16	Cee	1851	2	0
17	^^@	1848	2	0
18	asdf	1836	2	0
19	블러드트레일^^7	1798	2	0
20	—	1709	2	0
21	sb	1672	2	0
22	AA	1591	2	0
23	v수현짱짱맨v	991	1	1

Syllabus

- Evaluation
  - Attendance: 10% (call or Kahoot)
  - HW: 30%
    - Lab report (1~3)
    - Problem solving (5-10 questions will be uploaded)
  - Midterm: 20% (10th May)
  - Final: 40% (14th June)
  - Kahoot extra point: additional 5% (class participation)
  - **-> from now on, please use your own name in Kahoot**

Chapter 1.

How to represent material behavior under various loading conditions

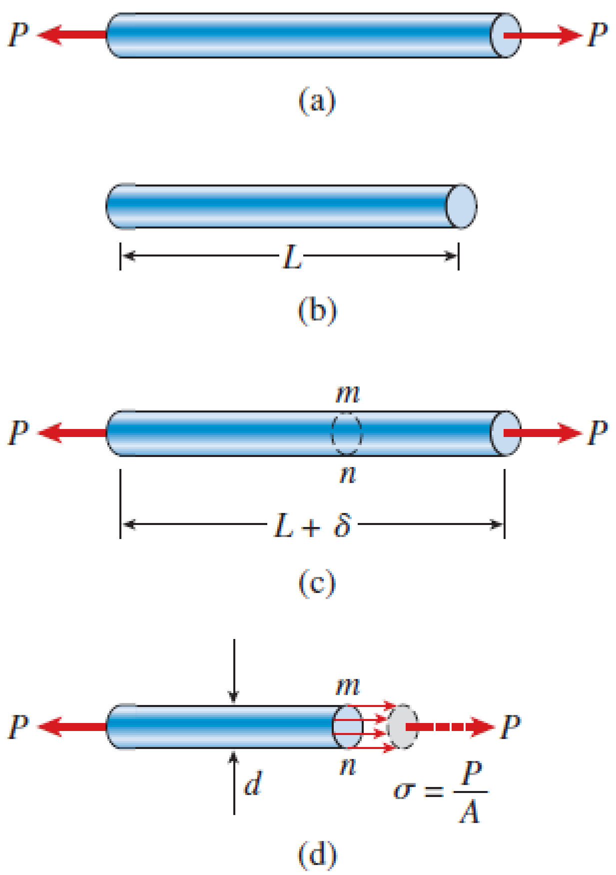
Compression / Tension

Shear

Bending / Torsion

-> Will examine the stresses, strains, and displacements in bars of various materials acted on by axial loads applied at the centroids of their cross sections.

Tension/Compression



Cross section *mn* are *uniformly distributed* over the area

Sign convention: tensile (positive) compressive (negative)

Unit:

Normal stress:

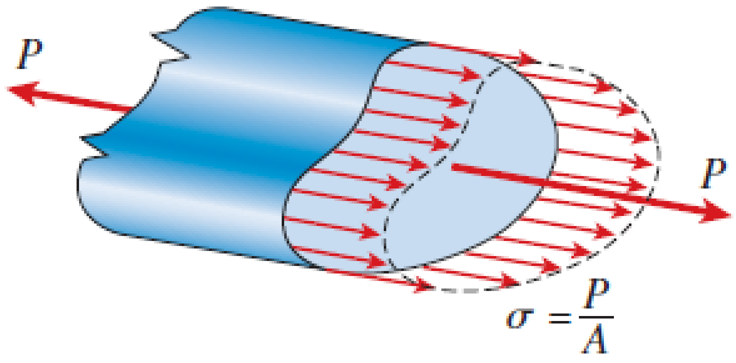
$$\sigma = \frac{P}{A}$$

Normal strain:

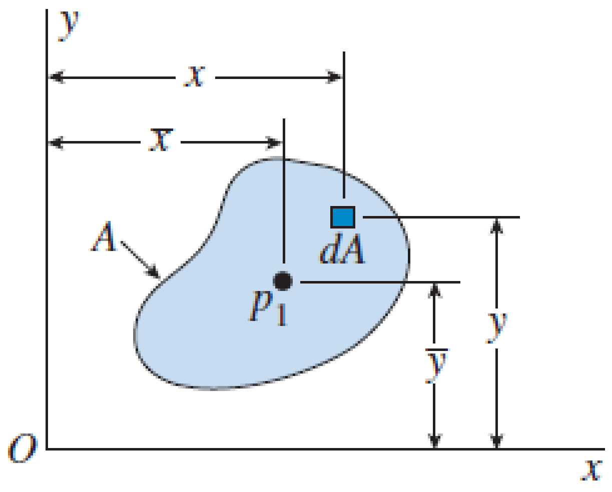
$$\epsilon = \frac{\delta}{L}$$

Axial forces for a uniform stress distribution

- Centroid of the cross-sectional area
- Line of action of the axial forces for a uniform stress distribution



(a)



(b)

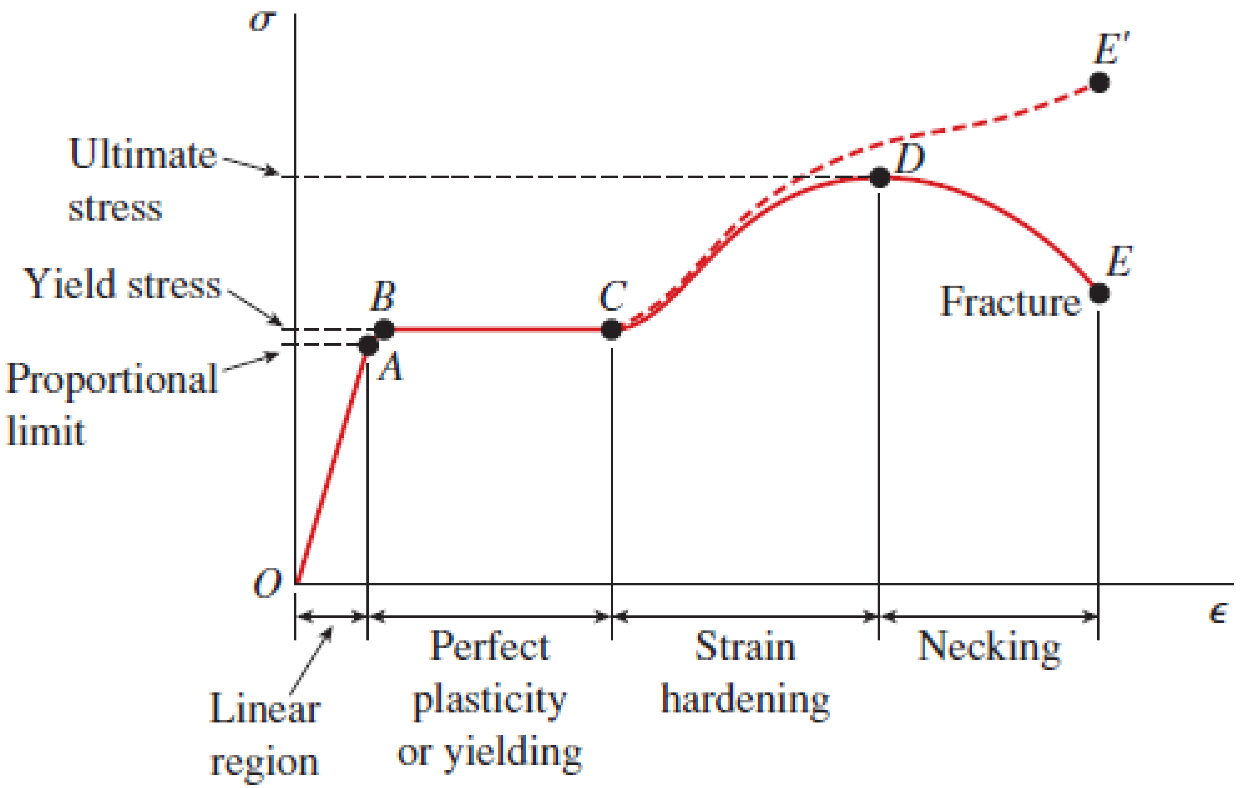
$$M_x = \int \sigma y \, dA \qquad M_y = -\int \sigma x \, dA$$

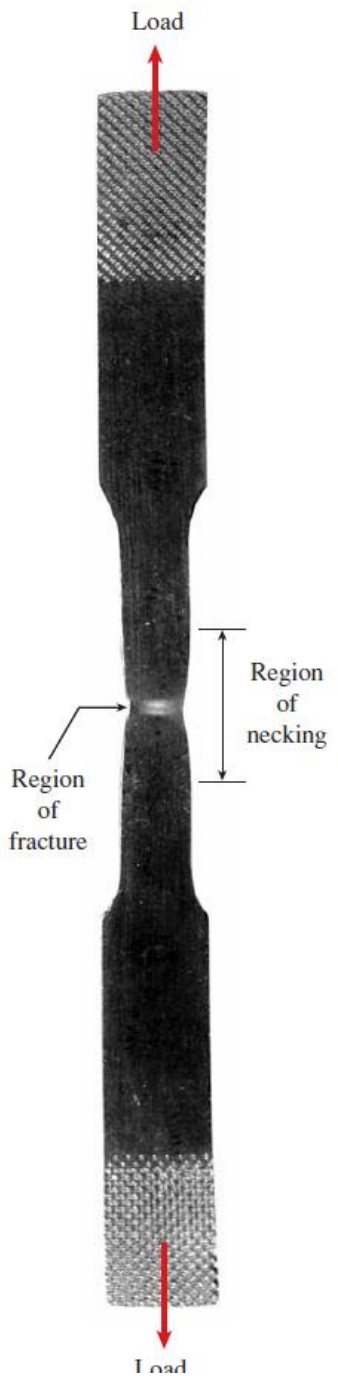
$$P\bar{y} = \int \sigma y \, dA \qquad P\bar{x} = \int \sigma x \, dA$$

$$\bar{y} = \frac{\int y \, dA}{A} \qquad \bar{x} = \frac{\int x \, dA}{A}$$

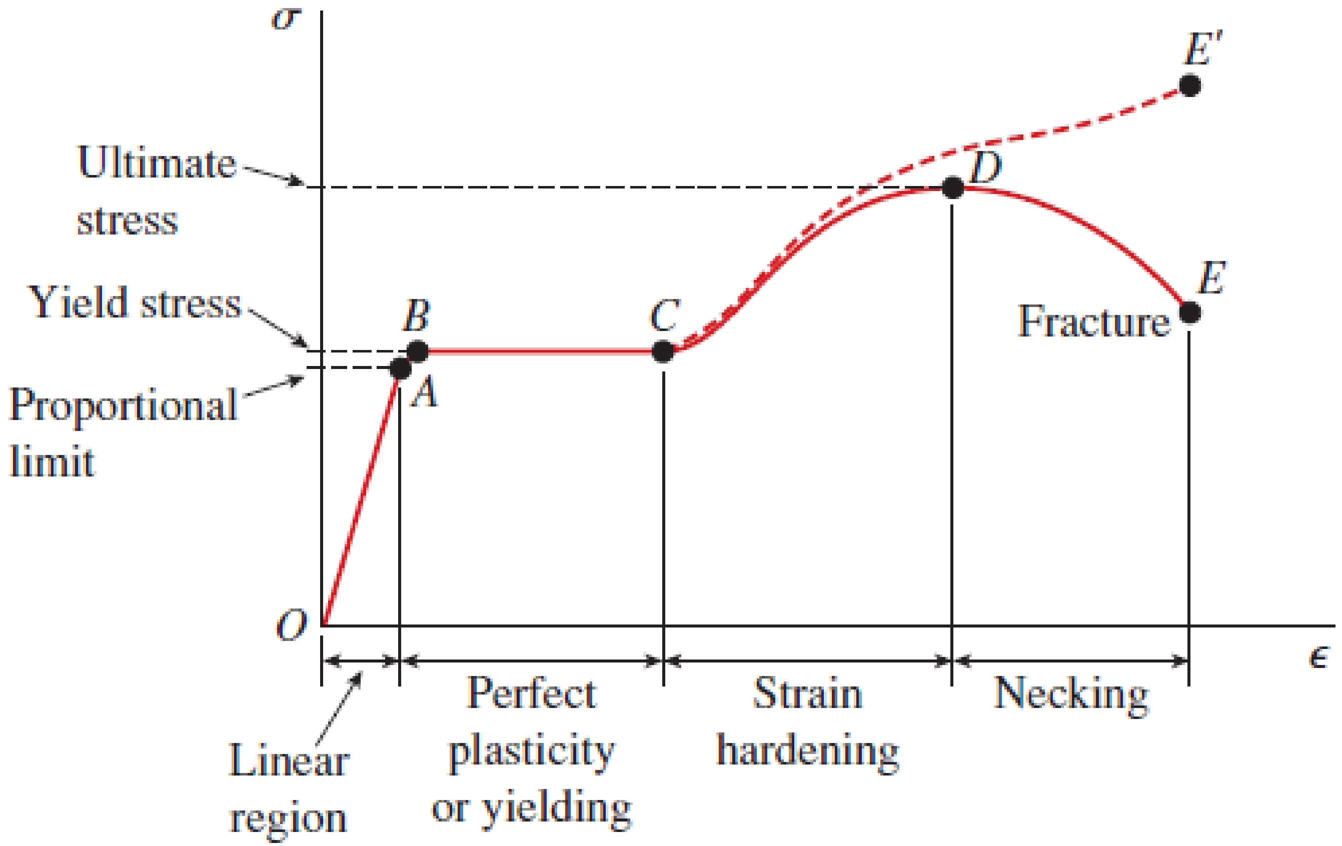
Stress-strain diagram

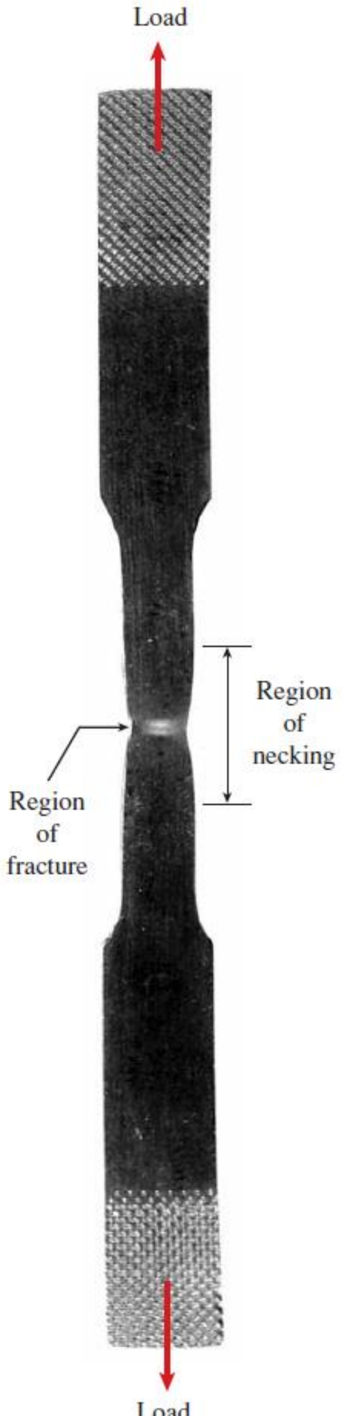
Stress-strain diagram





True strain vs Engineering strain





Stress-strain diagram

- Unit

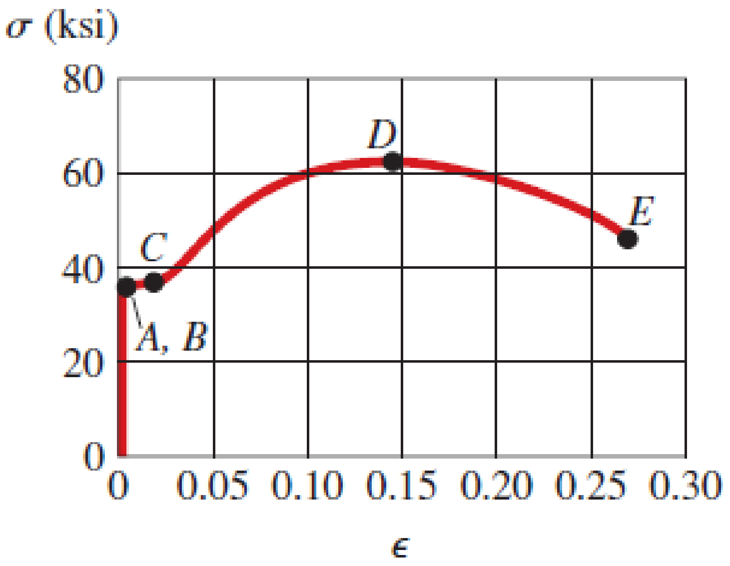


FIG. 1-12 Stress-strain diagram for a typical structural steel in tension (drawn to scale)

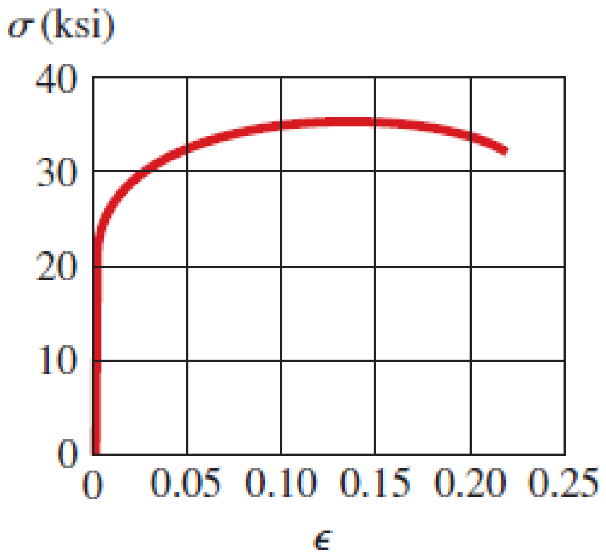


FIG. 1-13 Typical stress-strain diagram for an aluminum alloy

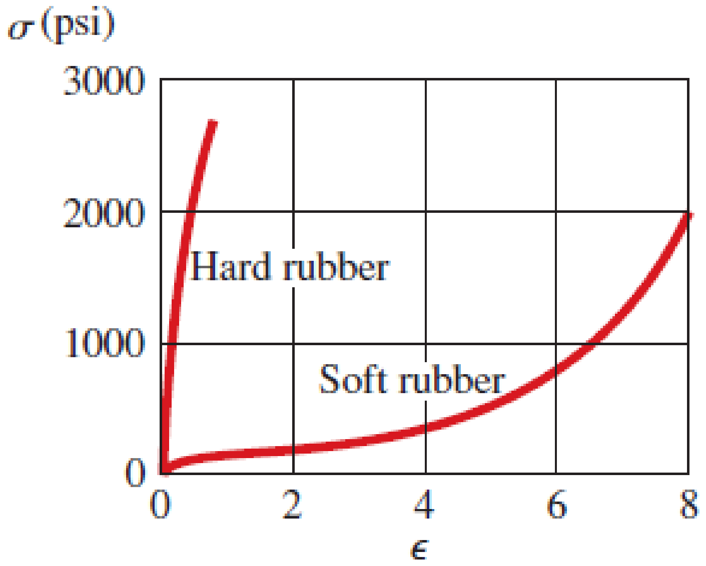
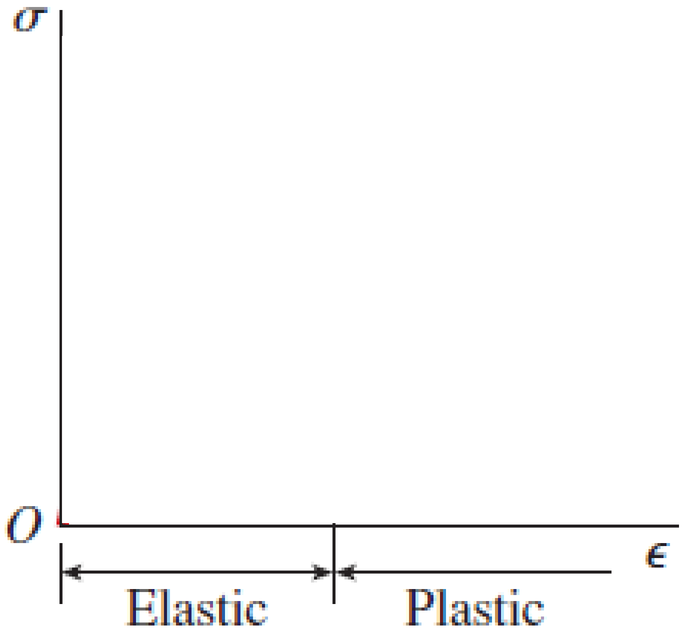


FIG. 1-15 Stress-strain curves for two kinds of rubber in tension

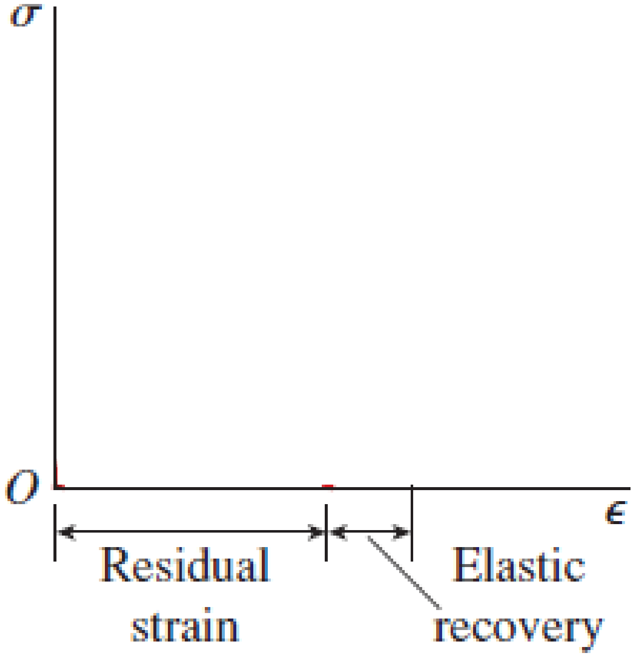
Elasticity

- Elastic / Plastic / Perfect Plastic



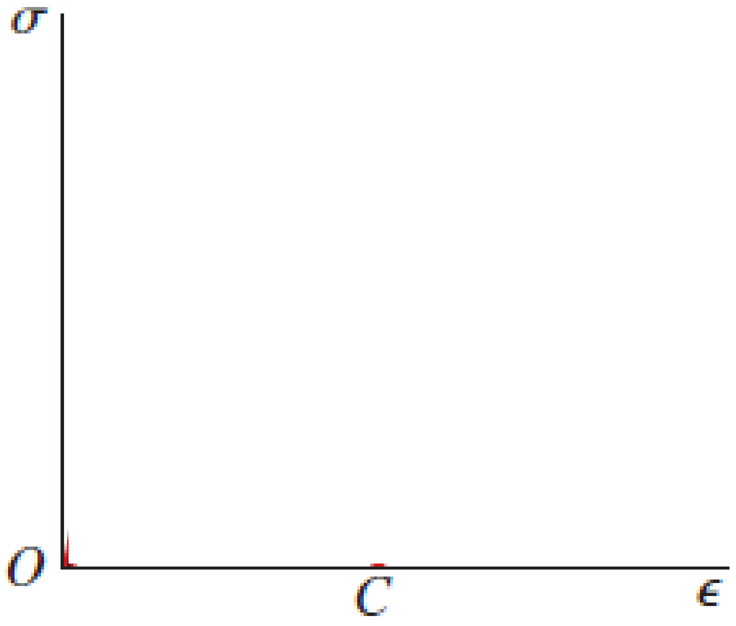
Plasticity

- Loading, Unloading, and Reloading



Hooke's law

- In "Elastic" region (either in tension or compression)

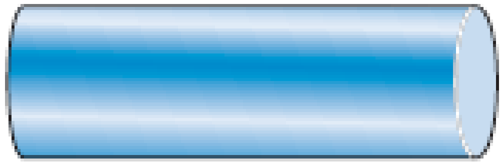


Material constants:

$$\sigma = E\epsilon$$

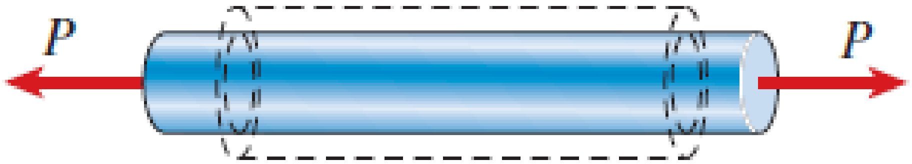
Poisson's ratio

- In "Elastic" region (either in tension or compression)


(a)

$$\nu = -\frac{\text{lateral strain}}{\text{axial strain}} = -\frac{\epsilon'}{\epsilon}$$

Material constants
Or Intrinsic properties of materials

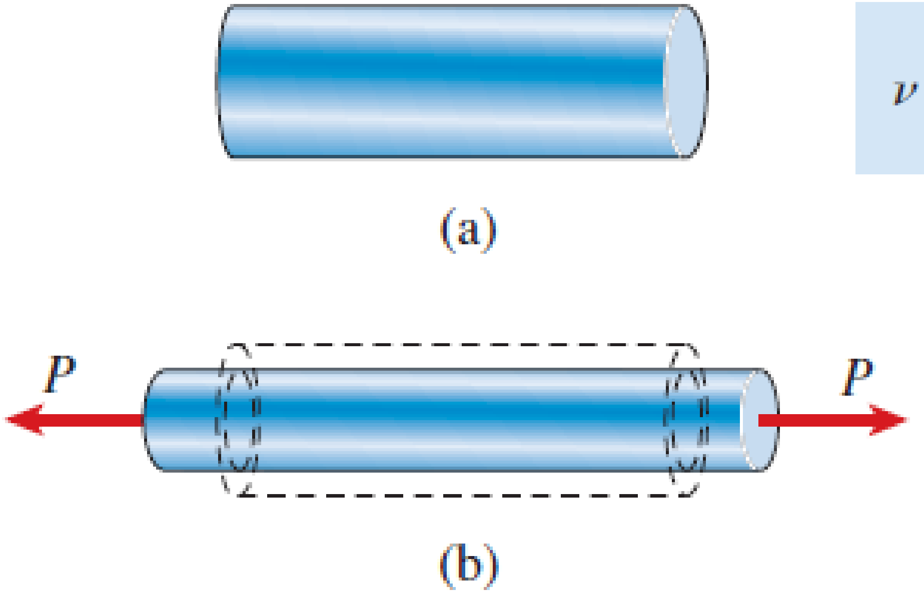


(b)

$$\epsilon' = -\nu\epsilon$$

Negative Poisson's ratio?

- https://www.youtube.com/watch?v=wu-i3XC2OS0

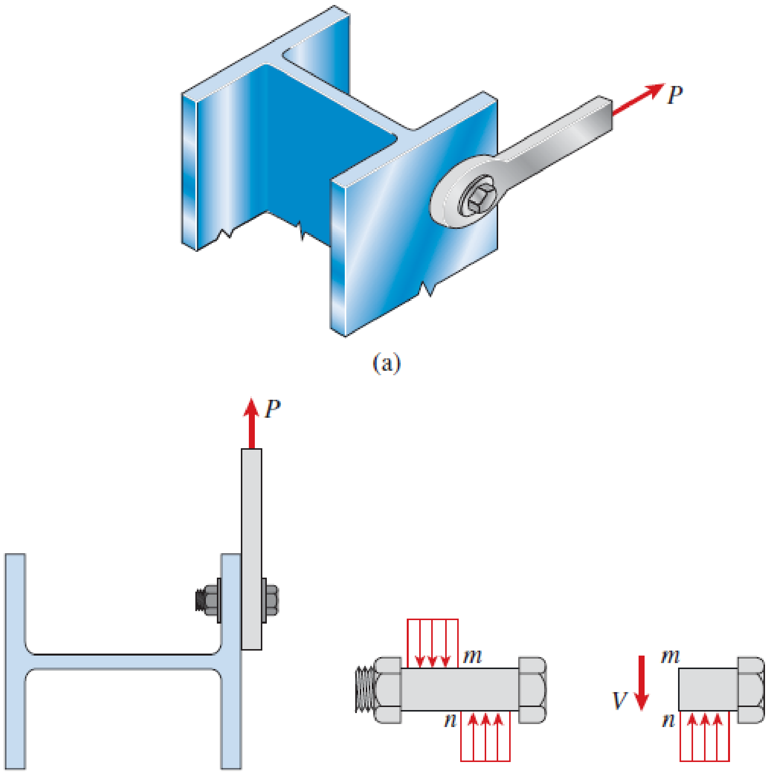


$$\nu = -\frac{\text{lateral strain}}{\text{axial strain}} = -\frac{\epsilon'}{\epsilon}$$

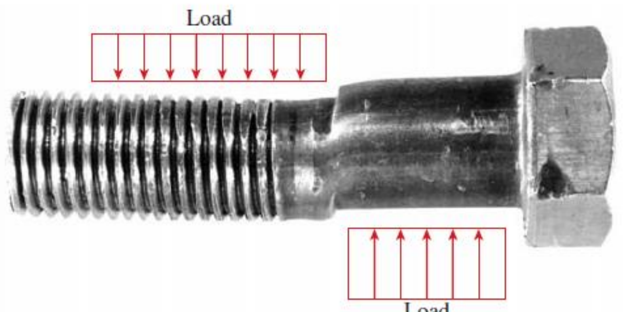
$$\epsilon' = -\nu\epsilon$$

Shear stress

- Single shear

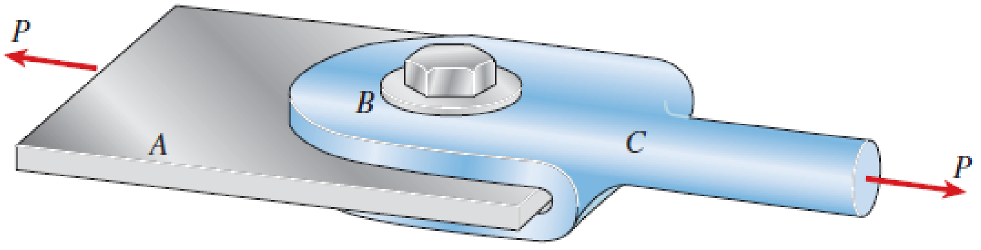


$$\tau_{\text{aver}} = \frac{V}{A}$$



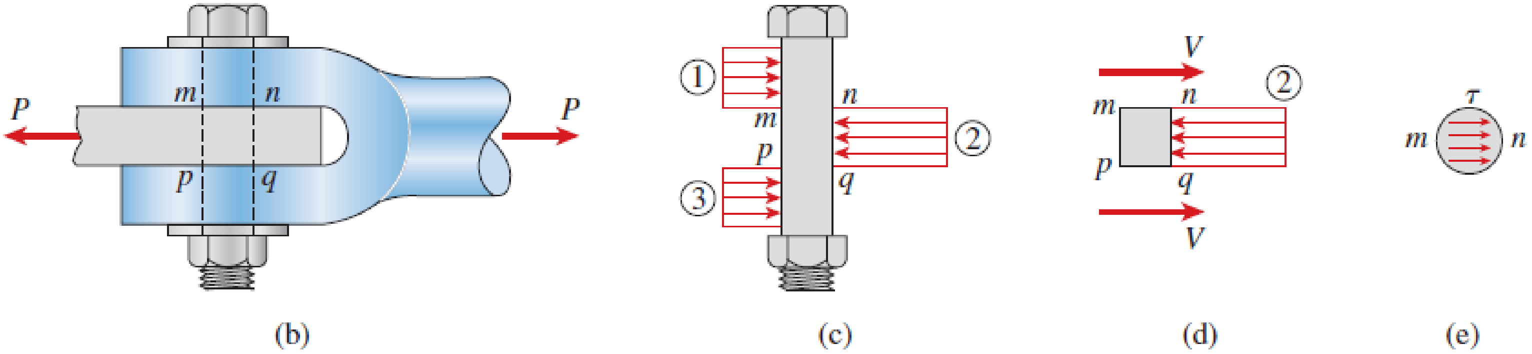
Shear stress

- Double shear



(a)

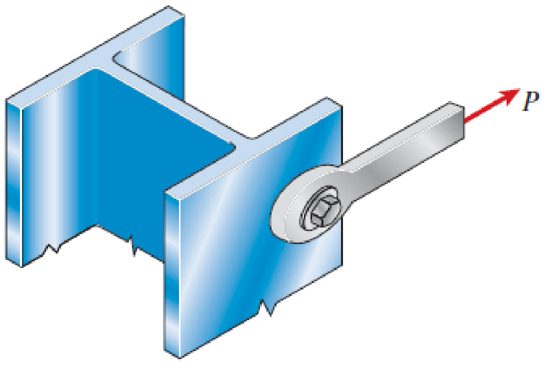
$$\tau_{aver} = \frac{V}{A}$$



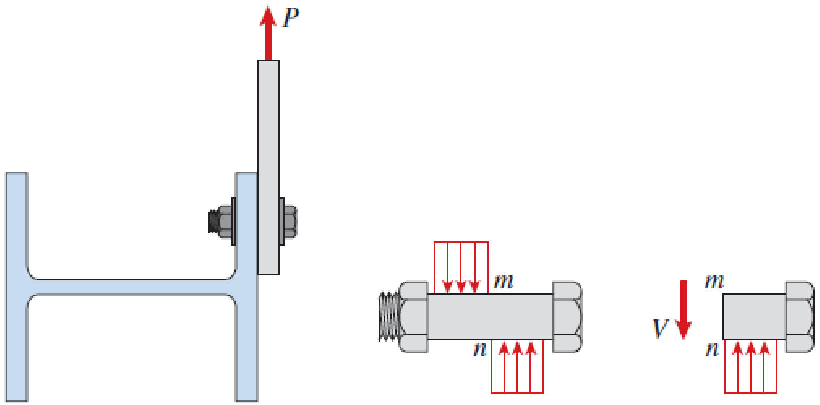
Shear strain

- Single shear

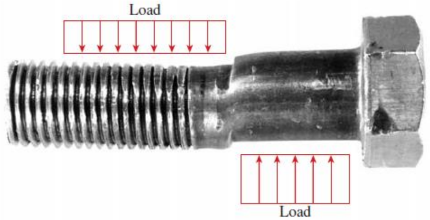
What is the deformation induced from shear stress?

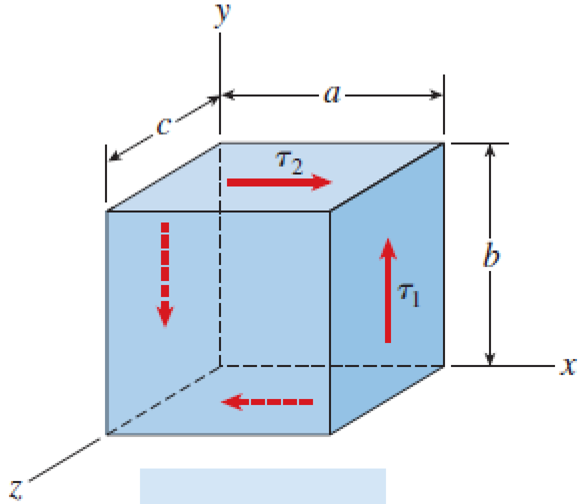


(a)

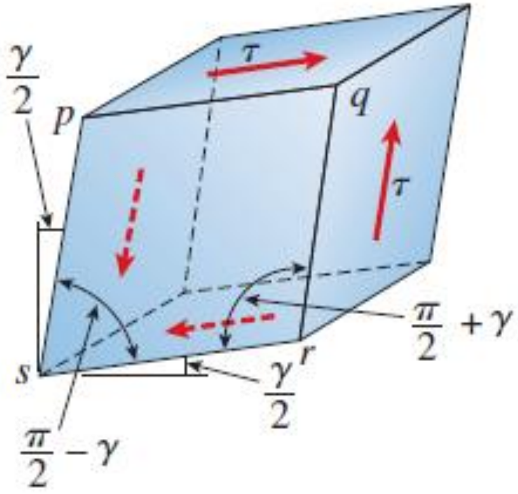


(b) (c) (d)



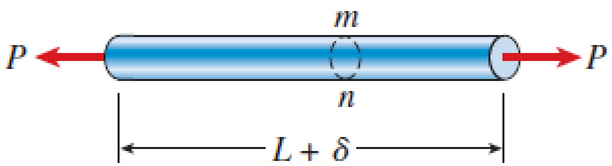


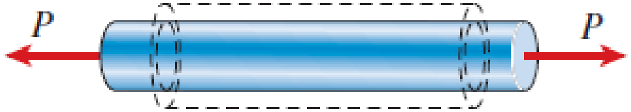
$$\tau_1 = \tau_2$$

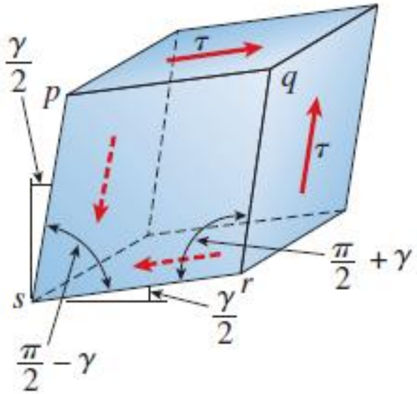


Shear stress and strain

- Material Properties, E, v, G (only in the linear region)







$$\sigma = E\epsilon$$

$$\nu = -\frac{\epsilon'}{\epsilon}$$

$$G = \frac{E}{2(1+\nu)}$$

$$\tau = G\gamma$$

Factors of safety

- Factor of safety, allowable stress, yielding stress, ultimate stress
- n of cable in elevator ?
- n of cables in bridges ?

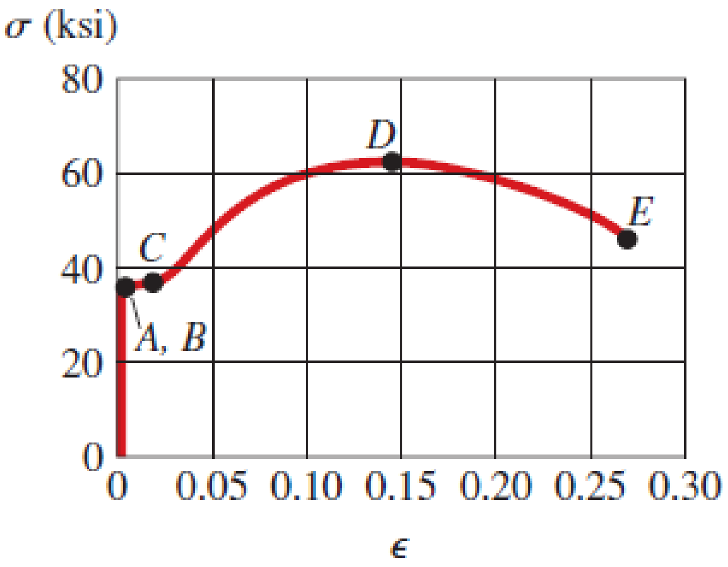
$$\text{Factor of safety } n = \frac{\text{Actual strength}}{\text{Required strength}}$$

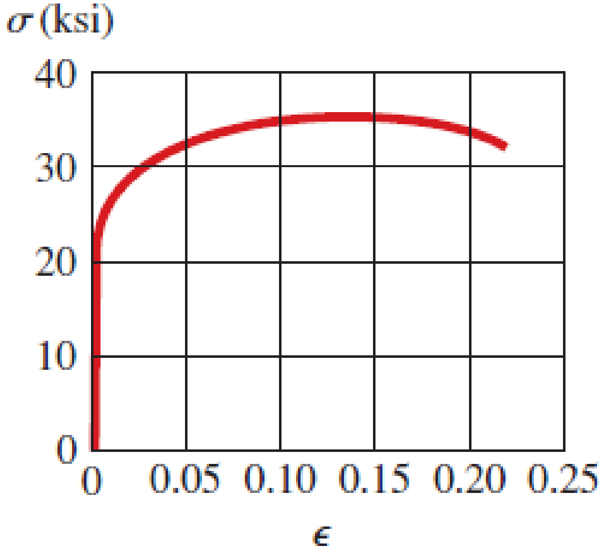
Golden gate bridge, CA USA

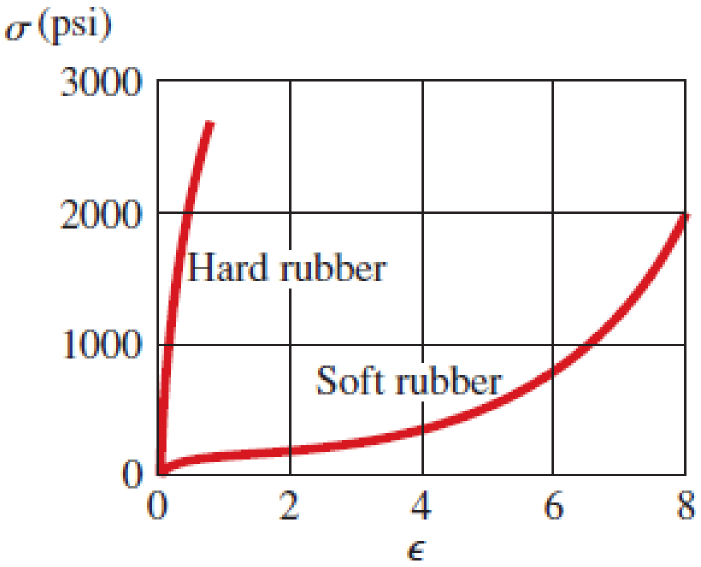
$$\sigma_{\text{allow}} = \frac{\sigma_Y}{n_1} \quad \text{and} \quad \tau_{\text{allow}} = \frac{\tau_Y}{n_2}$$

$$\sigma_{\text{allow}} = \frac{\sigma_U}{n_3} \quad \text{and} \quad \tau_{\text{allow}} = \frac{\tau_U}{n_4}$$

Kahoot







	Case A	Case B	Case C	Case D
	Structural Steel	**Aluminum Alloy**	**Hard rubber**	**Soft rubber**
E =	**200 GPa**	**400 GPa**	**10 GPa**	**2 GPa**