Solutions to problems (Chapter I)

1.1) What is a structure?

Any physical artifact that carries loads other than self-weight is known as a structure.

1.2) What is the difference between a primary and a secondary structure?

The structure whose principal function is to carry loads is known as a primary structure. The structure for which load carrying is ancillary is known as a secondary structure.

1.3) Give examples for each of the following:

	Aerospace	**Civil**	**Marines**	**Mechanical**
Early structures	1. Balloon 2. Blimp	1. Tent 2. Stadium	1. Canoe 2. Schooner	1. Lever 2. Winch
Modern structures	1. Jet 2. Satellite	1. Airport 2. Parking garage	1. Speed boat 2. Ferry	1. Engine 2. Lathe

1.4) Is the "skin" of an airplane an example of an integral load-carrying monologue structure? Of a car? Of a human.

For an airplane the skin is an integral load-carrying structure. For a car the skin may be regarded as an integral load-carrying structure in case of a crash. Similarly in humans, skin can be considered as a load-carrying structure, e.g. hanging jewelry from an ear lobe.

1.5) Give a simple example how physics and chemistry provide different points of view of the same phenomenon.

Consider 'water freezing': physics considers coefficient of thermal expansion (which is negative) while chemistry considers polar molecules of water.

1.6) In the design of a paperclip, how does the requirement for being "reusable" relate to mechanics issues? Material issues?

From mechanics point of view we keep geometry as simple as possible and stress low. For materials we use ductile material for durability.

1.7) Give an example of a dynamic load whose magnitude remains constant but whose direction of applications changes with time.

A ball on the end of a string, being whirled around the head.

1.8) Through what mechanism do concentrated forces act? Gravity forces? Electromagnetic forces?

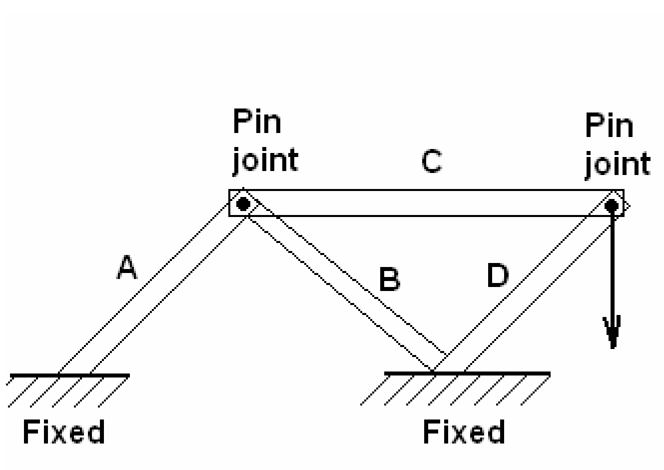
Concentrated forces act through contact. Gravity and electromagnetic forces act "at a distance" through "field interactions".
"In quantum mechanics, the forces or interactions between matter particles are all supposed to be carried by particles…"
"Force-carrying particles can be grouped into four categories, according to the strength of the force that they carry and particles with which they interact."
"The first category is the gravitational force. … The gravitational force between the sun and the earth is ascribed to the exchange of *gravitons* …"
"The next category is the electromagnetic force, …The electromagnetic attraction is pictured as being caused by the exchange of large numbers of virtually massless particles … called *photons*."

Stephen Hawking, <u>A Brief History of Time</u> (1998).

1.9) What are the different types of loads acting on the pole due to a steady wind blowing at point A, B and C.?

Point C: Negligible load
Point B: Bending moment, torsion, shear.
Point A: Bending, shear.

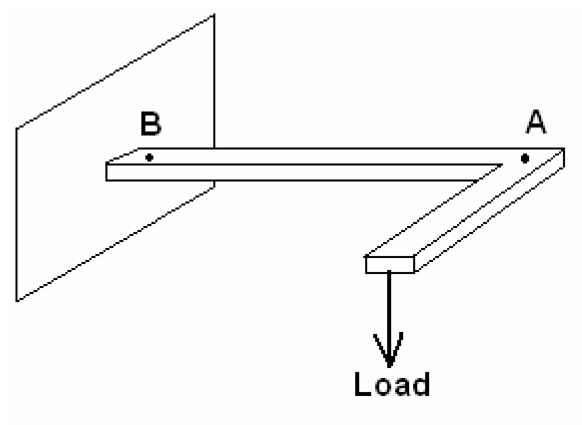
1.10) What is the type of loading in each of the members A to D in Figure P10?



Member	**Load**
A	Tension
B	Compression

C	Tension
D	Compression

1.11) What is the loading at points A and B in Figure P11?

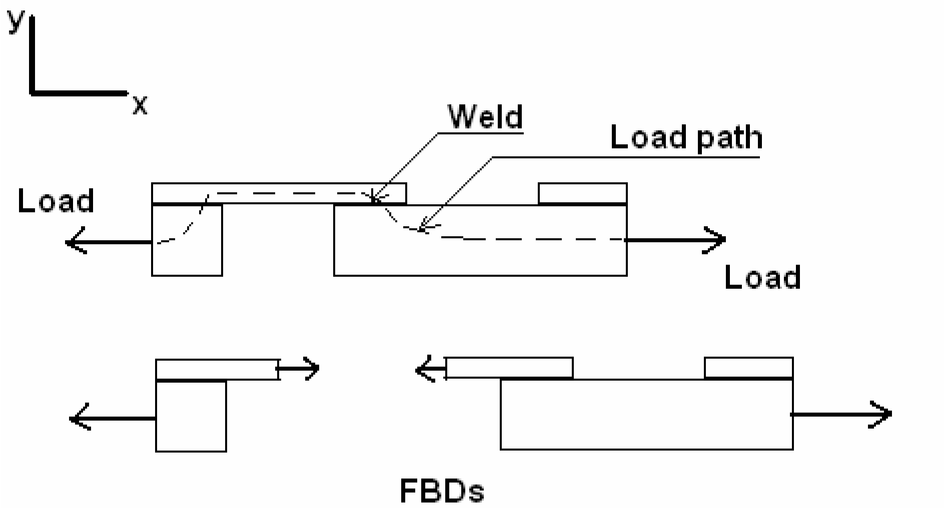


Point A: Bending and shear.
Point B: Bending, shear and torsion.

1.12) Give two examples of structural designs/products that were inspired by new or novel use of existing materials. (You may conduct a search on the internet or in the library)

Piezomaterials	→	Smart structures
Rubber	→	Tires

1.13) Draw the load path in the specimen, shown in the Figure P13, subjected to a tensile load. Will the specimen bend under the load or remain straight?



Due to moments that are apparent from FBD, bending is likely to occur.

1.14) Sketch the load paths for the following structure:

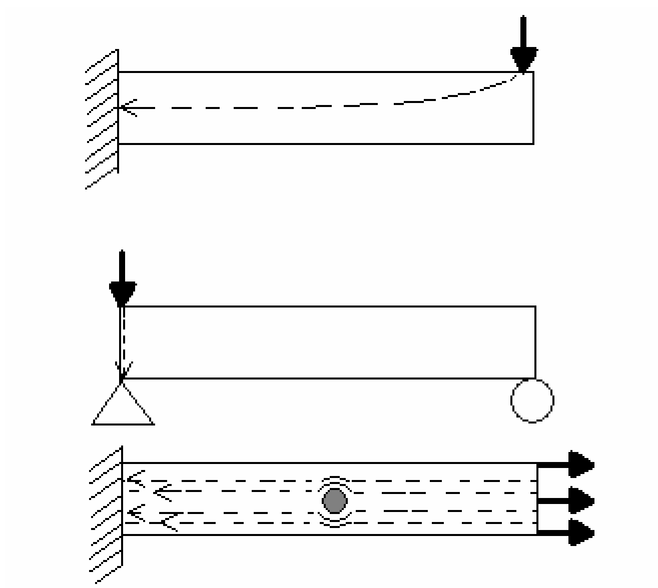


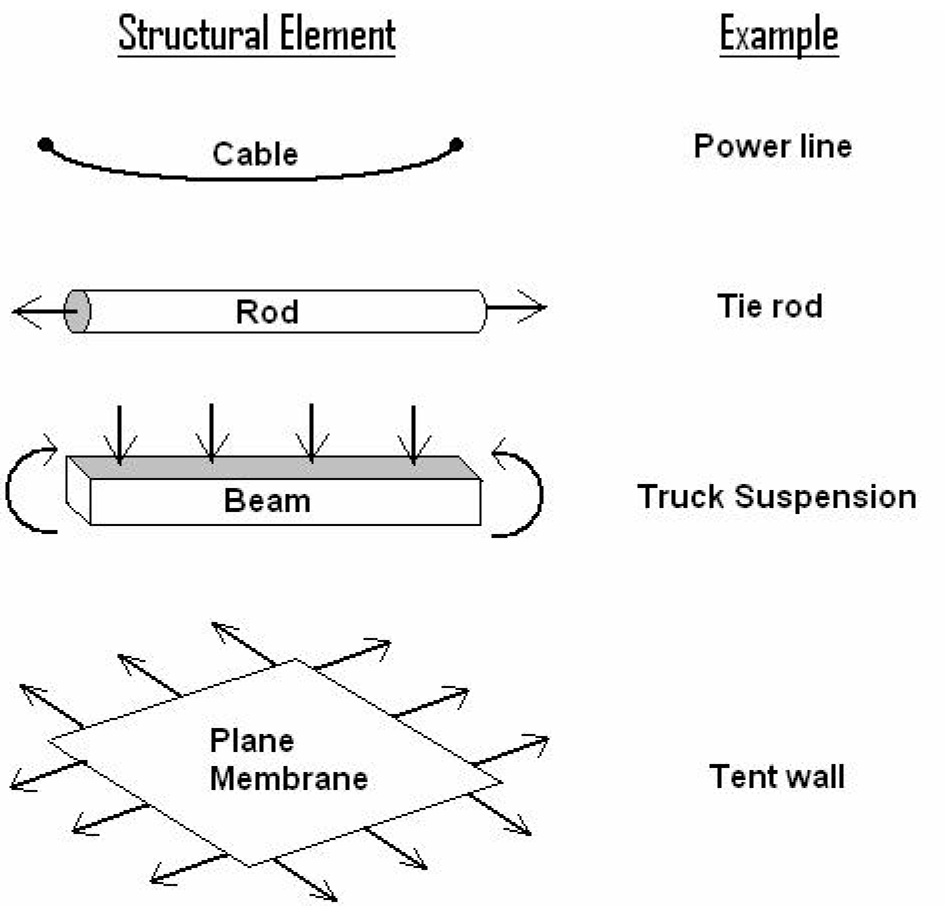
Figure P14

1.15) Give 2 examples each from everyday life of real structures undergoing:

- Tension — Guy wires, power lines
- Compression — Table legs, bridge piers
- Shear — Hinge pin, short bracket
- Torsion — Motor shaft, coil spring
- Bending — Street light arm, bridge deck

1.16) Give an example from everyday life for each of the structural elements listed in table 1.4.2/ Figure 1.4.3

FUNCTION	FORM						
	Line-forming			Surface-forming			
				Area-forming		Volume-forming	
Load carried:	**Cable**	**Rod**	**Beam**	**Plane membrane**	**Plate**	**Curved Membrane**	**Shell**
Tensile axial	P	P	P	P	P	P	P
Compressive axial	-	P	P	-	P	-	P
Shear	-	-	P	P	P	P	P
Torsion moment	-	P	P	-	P	-	P
Bending moment	-	-	P	-	P	-	P
Distributed force	P	-	P	P	P	P	P
Thermal	P	P	P	P	P	P	P



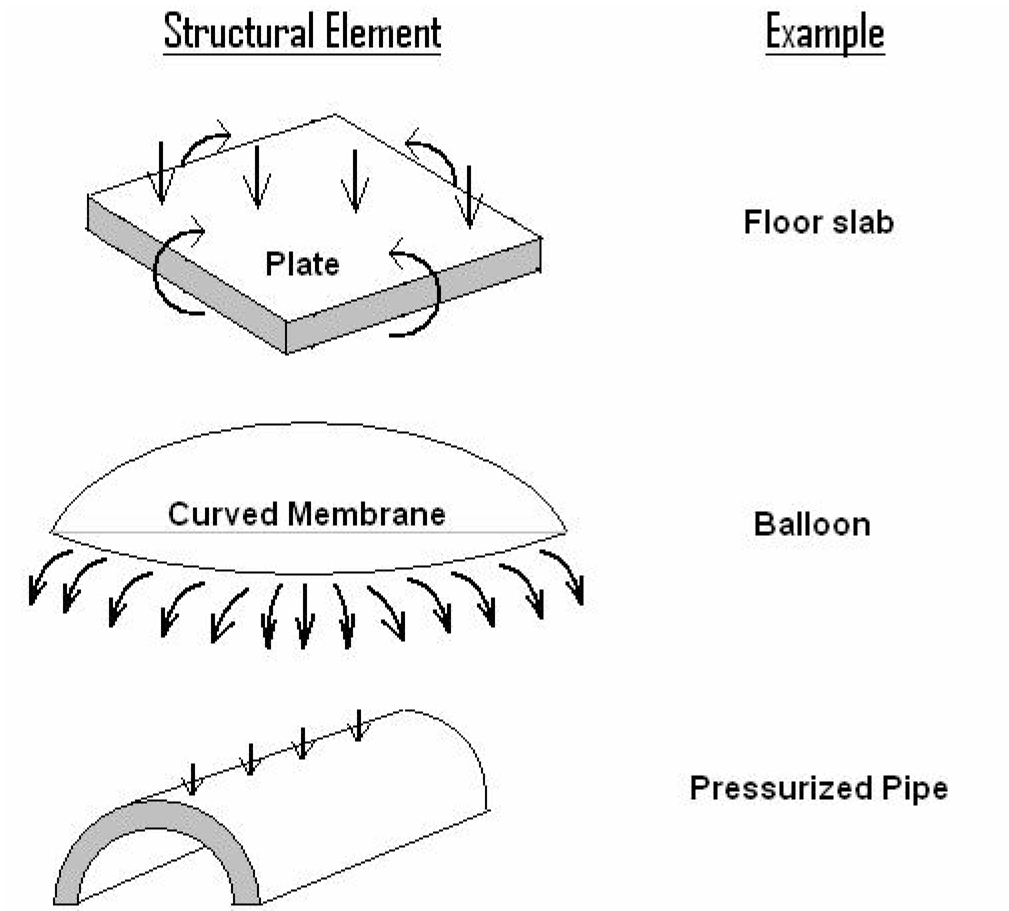
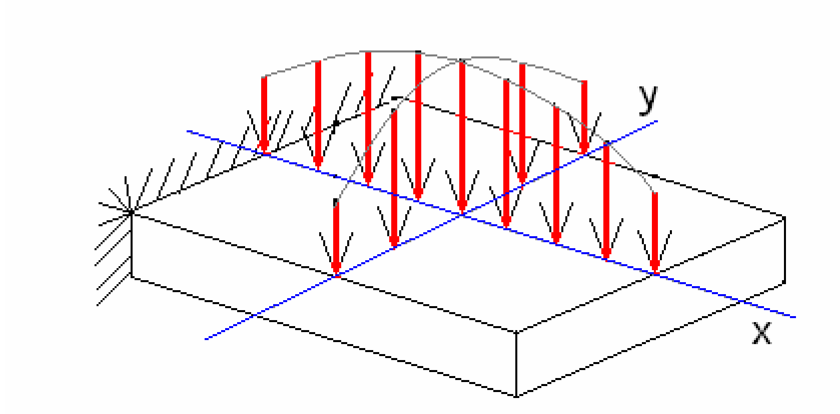


Figure 1.4.3

1.17) When does a beam become a plate and vice versa?

A beam becomes a plate when it becomes important to consider 2-D stress and displacement variations. For example, when the loading varies in 2 dimensions as in the cantilever "plate" shown below, it is no longer sufficient to consider only σ_x, but σ_y as well.



1.18) Give an example from everyday life for each of the boundary conditions shown in Figure 1-9.

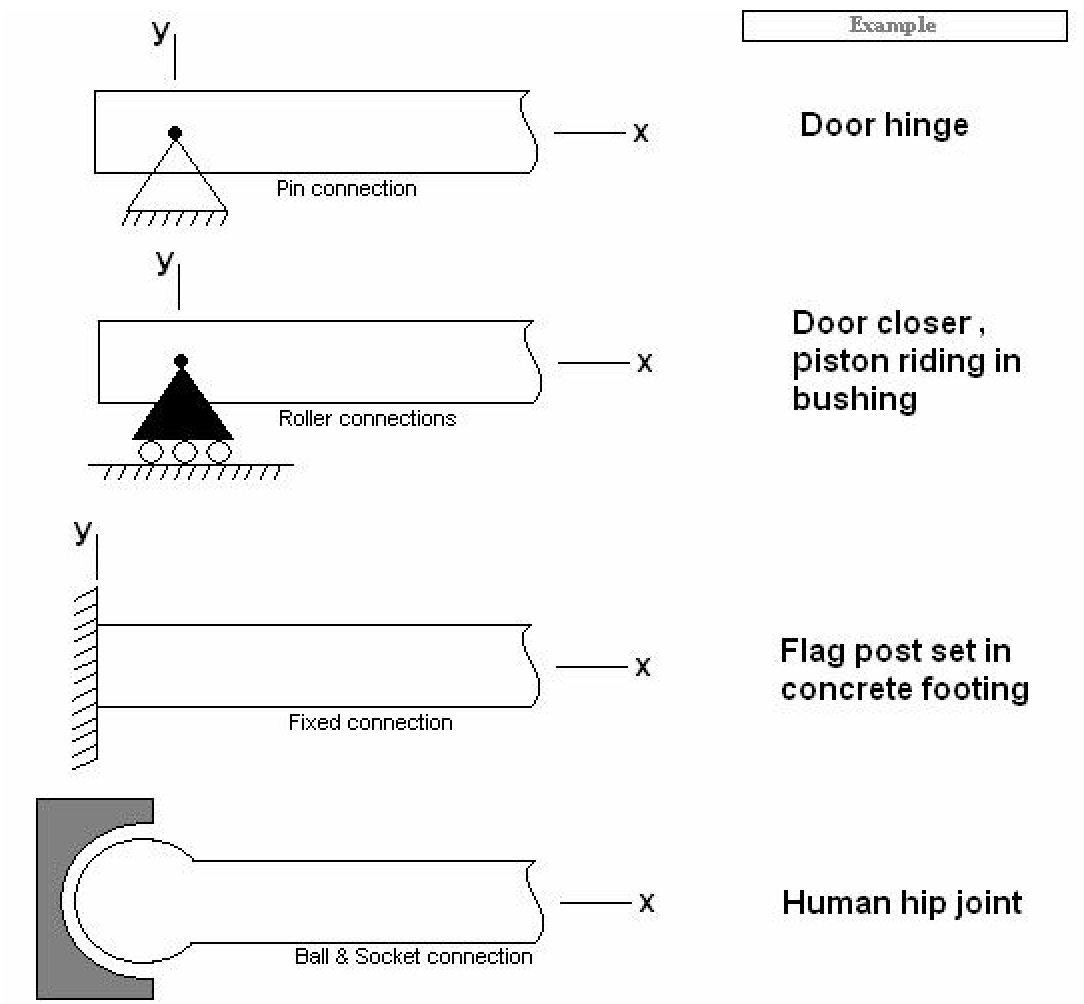
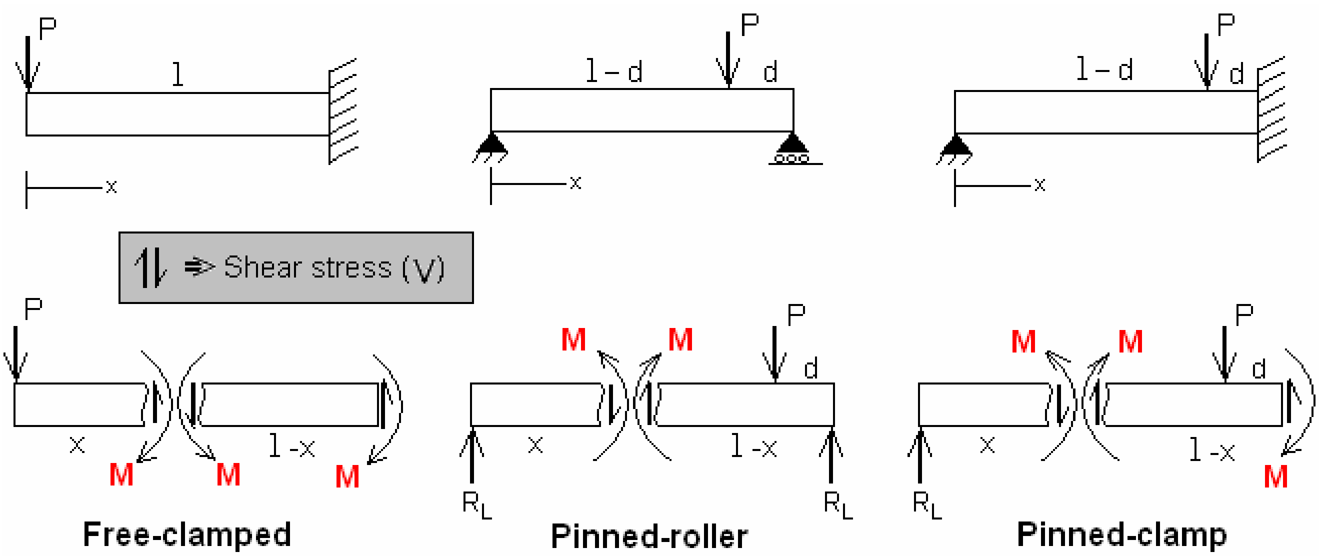


Figure 1.9

1.19) Sketch beams with following combinations of boundary conditions:



1.20) Which is more conservative, a FS of 2 or 3? Why?

'3' is <u>more</u> conservative than '2', since it accounts for a higher degree of uncertainty in load, material properties, etc.

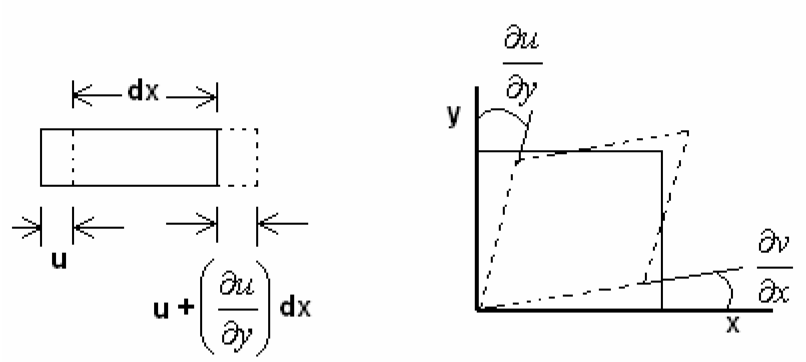
1.21)

A) Define longitudinal strain and shear strain.
Longitudinal strain can be defined as

$$\varepsilon_x = \frac{\partial u}{\partial x}$$

Shear strain can be defined as

$$\gamma_{xy} = \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)$$



B) Is stress a vector quantity or not?
No. It's a second order tensor.

C) In common engineering materials, what is the type of relationship between stress and strain?

They have a linear relationship, $\sigma = E\,\varepsilon$

1.23) Give the name of five elements that have BCC, FCC and HCP structure.

BCC	**FCC**	**HCP**
V	Co	Zn
Cr	Ni	Cd
Mo	Pt	Ti
W	Cu	Be
Zr	Ag	Mg

1.24) Which of the elements names in Problem 23 are ductile and which are brittle? What is their elastic modulus?

Look up material properties for ductility and elastic modulus. Generally BCC and FCC are ductile while HCP are more brittle.

1.25)

a) The negative term is attractive.

b) $$\frac{\partial E}{\partial r} = 0$$ at $r = r_0$

$$\frac{d}{dr}\left(-\frac{\alpha}{r}+\frac{\beta}{r^{8}}\right)=\alpha\times r_{0}^{-2}+\left(-8\beta r_{0}^{-9}\right)=0$$

$$\Rightarrow r_{0}^{7}=\frac{8\beta}{\alpha}$$

$$\Rightarrow r_{0}=\left(\frac{8\beta}{\alpha}\right)^{\frac{1}{7}}$$

c) Stable equilibrium at $r = r_0$

Ratio of energy = $-\frac{\alpha}{\beta}r_0^{7}$ at $r = r_0$

$$\Rightarrow -\frac{\alpha}{\beta}\left(\frac{8\beta}{\alpha}\right)=-8$$

Attractive energy = 8 × Repulsive energy