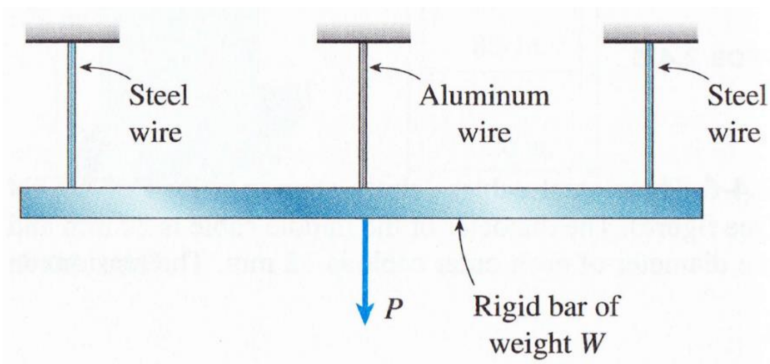
PLEASE NOTE:

You need to correctly answer only 3 out of the 4 problems to receive full credit. In case you attempt all 4 problems, clearly state which 3 problems you want to be graded. If you do not explicitly so indicate, the 3 lowest scores will be used.

Problem #1

A rigid bar of weight W = 300 N hangs from three equally spaced vertical wires, two of steel and one of aluminum. The wires also support a load P acting at the midpoint of the bar. The diameter of the steel wires is 3 mm and the diameter of the aluminum wire is 5 mm. Assume the following properties for the steel and aluminum wires and that the stress-strain curve for each can be approximated as **elastic-perfectly plastic**:

Material	Young's modulus, E	Yield strength, σ_y
Steel wire	200 GPa	800 MPa
Aluminum wire	70 GPa	100 MPa

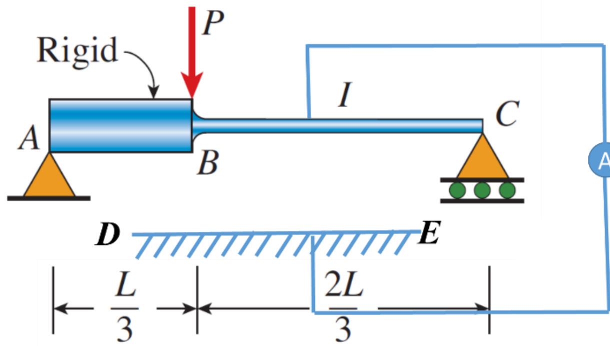


(a) What is the maximum load P that can be supported if all of the wires need to remain elastic?

(b) If the load P is increased by 500 N above the load computed in part (a) and then the load P is removed, what is the load carried by each of the wires?

Problem #2

A device has an alarming mechanism as shown in the figure below. A metal (with a Young's modulus ***E***) beam *ABC* with a total length of ***L*** has a rigid segment from *A* to *B* and a flexible segment with moment of inertia ***I*** from *B* to *C*. The work load is a concentrated load ***P*** acting at point *B*. If any part of the beam *ABC* touches the conductive flat surface *DE*, the circuit will connect and the alarm will sound.



(a) Draw the necessary free-body diagram(s).

(b) Determine the angle of rotation θ_A of the rigid segment.

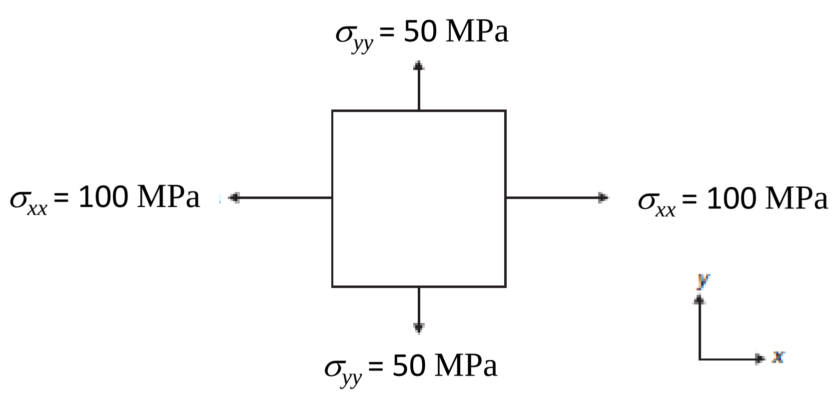
(c) Determine the deflection at point *B*.

(d) If the initial distance from the axis of *ABC* to the surface of *DE* is $\mathbf{0.00136}QL^3/EI$**,** where *Q* is a constant force, at what load *P*, will the alarm sound?

Problem #3

A thin plate is subjected to a biaxial stress field at room temperature (T_R = 20 °C) as shown in the schematic below. The plate is made of either aluminum or boron fiber epoxy composite. The aluminum plate is made by pouring melted aluminum into a mold at room temperature. The melting point of aluminum is 660 °C. The composite plate is cured at 200 °C. The following data are available:

Properties of aluminum	Properties of boron fiber epoxy composite
E_{Al} = 69 GPa ν_{Al} = 0.33 α_{Al} = 23.5×10^{-6}	E_{11} = 207 GPa E_{22} = 19 GPa ν_{12} = 0.21 G_{12} = 6.4 GPa α_{11} = 1.5×10^{-6} α_{22} = 30×10^{-6}



(a) Calculate the total strains (mechanical and thermal) in the *xy* directions if the plate is made of aluminum.

(b) Calculate the total strains (mechanical and thermal) in the *xy* directions if the plate is made of 90° degree unidirectional boron fiber epoxy composite.

(c) Calculate the total strains (mechanical and thermal) in the principal material directions (parallel and normal to the fibers) if the plate is made of 30° degree unidirectional boron fiber epoxy composite.

Clearly list all of your assumptions and explain the thought process.

Problem #4

Figure 1 shows a materials selection map (an Ashby map) in the space of fracture toughness and strength. The dashed trendlines of fracture toughness vs strength can be viewed as the manifestation of fracture vs yielding at the level of small intrinsic flaws or cracks.

(a) Comment briefly on the general trend(s) in how different failure mechanisms influence material behaviors and therefore the choice of materials for specific applications.

(b) If you are designing a pressure vessel (e.g., the tank in Fig. 2) and the two candidate materials are: (a) a maraging steel with $K_{IC} = 82\ \text{MPa}\sqrt{m}$ and σ_y = 1900 MPa and (b) a medium strength steel with $K_{IC} = 50\ \text{MPa}\sqrt{m}$ and σ_y = 1000 MPa. Determine which of these materials is more tolerant of inherent microscopic defects or microcracks. Point out one way to improve the less defect-tolerant material and by how much so both are equally useful for this design.

Figure 1

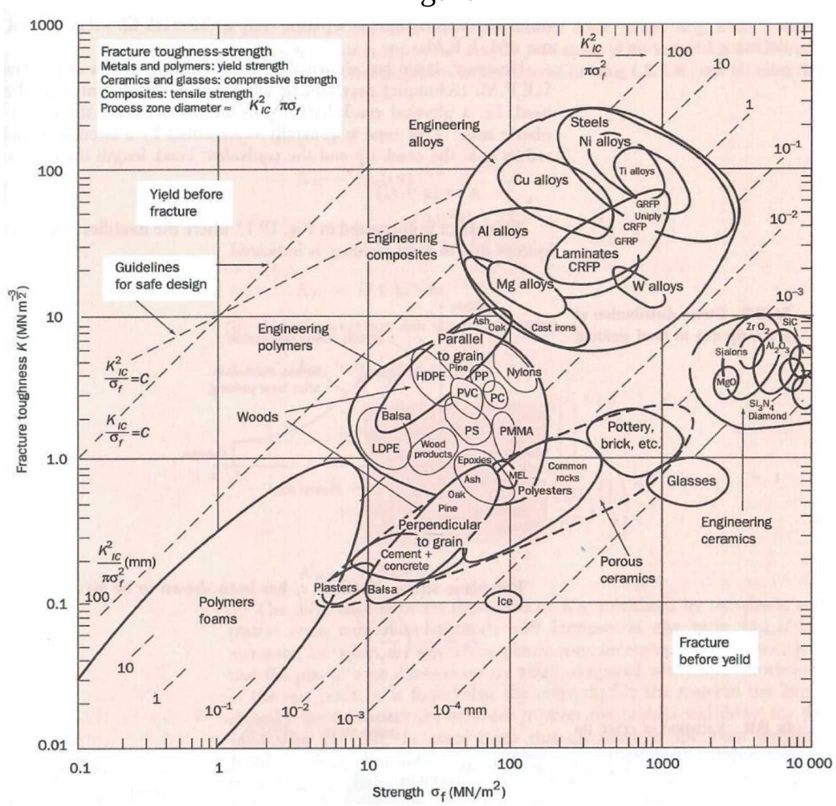


Figure 2