Activity 6.2b – Engineering Problem Solving

Purpose

Engineers are technical problem solvers. The way in which they solve problems varies. In general, engineers implement a logical approach, or method, in solving the problems they encounter. Mathematically based science and engineering courses attempt to prepare future engineers for such problem-solving by stepping them through a methodological approach in solving both word problems and more authentic design problems. The method shown here has been used for years with students in physics and engineering classes and will help in solving more complex problems later on.

Materials

Paper and Pencil
Calculator
MDSolids Program

Procedure

1. Study the five steps below.

Five Steps to Textbook Problem-Solving:

I. Identify "**Knowns**" (what you're given) and "Unknowns" (what you want to find out). Assign variable names to the knowns and unknowns and specify each using the correct number and unit name. For example: diameter = d = 3m.

II. **Draw a picture. Be sure to label all parts shown.**

III. Find an **Equation** (or series of equations) that will get to the answer. Write it down. Manipulate it using algebraic principles, if necessary.

IV. Substitute **numbers and units into the equation, and** solve**. Write your answer in terms of the variable name you previously chosen. Be sure to specify not only the numeric answer but the units as well. For example: F = 4N.**

V. Convert**, if necessary. Use the conversion method.**

2. Memorize the phrase below. Remember what the letters stand for.

THIN**K**:	**Knowns and unknowns**
DON'T	**D**rawing
EVER	**E**quation(s)
SAY	**S**ubstitute and solve
"**C**AN'T"	**C**onvert

3. Study this example problem.

   Example 1: A force of 150 lbs. pushes on a round plate with an area of 30 in^2. How much pressure does the plate apply to the ground?

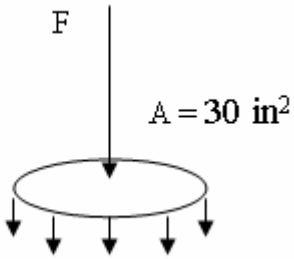
4. Step one: Identify the Knowns and the Unknowns.

Step 1

KN	UNK
$F = 150\ lb$	$P = ?$
$A = 30\ in^2$	

5. Step two: Draw a picture.

Step 2



6. Step three: Write an equation.

Step 3 EQN: $P = \frac{F}{A}$

7. Step 4: Substitute Knowns into the equation.

Step 4 $P = \frac{150lb}{30in^2} = 5\frac{lb}{in^2} = P$

8. Step 5: Convert if necessary. In this problem, the $5lbs/in^2$ is in the form we desire, so no conversion is necessary.

Now apply the method on the following problems. Be sure to show your work. Make a list of the Knowns and Unknowns. Create a diagram. Write the formulas down even if you are using a calculator or the MDSolids program to help you solve the problems. Months later, it is important to be able to follow your thought process. Substitute the numbers into the equation and convert, if necessary. Complete each of the problems below.

Common Variable Names:

Δ = the change in

δ = total deformation

σ = stress (force per unit area)

$\in$ = strain

E = modulus of elasticity, Young's Modulus

P = axial force

A = cross section area

L = length

r = radius of a circle

d = diameter of a circle

Press = Pressure

Formulae you might use are:

$\sigma = P/A$

$\in = \delta/L$

$\delta = PL/AE$

$E = \sigma/\in$

$A = \Pi r^2$ (area of circle when using the radius)

$A = .7854d^2$ (area of circle when using the diameter)

Press = P/A

1. A force of 200 lbs pushes against a rectangular plate that is 1 ft. by 2 ft. Determine the pressure in $\frac{lb}{ft^2}$ and $\frac{lb}{in^2}$ that the plate exerts on the ground due to this force.

2. A piece of steel wire 100 feet long, with a cross-sectional area of 0.004 sq. in., must be stretched with a pull of 16 pounds when in use. If the modulus of elasticity of steel is 30,000,000 psi:

   a) What is the total elongation δ in the entire length of the wire?

   b) What tensile stress is produced by the pull?

3. A 2” by 4” rectangular piece of steel, that is 20 feet long between centers of the pins at its ends, is used as the diagonal member in a bridge. If the total tensile load in the steel is 80, 000 pounds and the modulus of elasticity is 30, 000,000 psi, calculate:

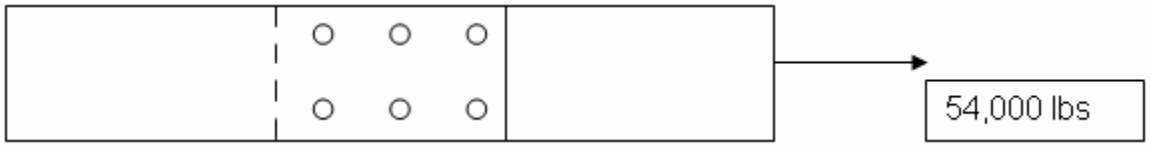
   a) The tensile stress-

b) The total elongation caused by the load-

c) The unit elongation-

4. A sample of material is ¼ “diameter and must be turned to a smaller diameter to be able to be used in a tensile machine. The target breaking point for the material is 925 pounds. The tensile strength of the material is 63,750 psi. What diameter would the sample have to be turned to in order to meet the specified requirements?

5. Two pieces of steel are held together with six bolts. One end of the first piece of steel is welded to a beam and the second piece of steel is bolted to the first. There is a load of 54,000 pounds applied to the end of the second piece of steel. The tensile strength of steel is 74,000 psi, the shear strength is 48,000 psi.



a) Calculate the diameter of the bolts needed to support the load.

b) Find the width of the steel if the thickness of the steel is ¼". The bolt holes are 1/16" larger than the bolt.

6. Determine the required nominal diameter of a threaded steel rod to carry an axial load of 16,000 pounds in tension if the tensile stress of 20,000 psi is permitted.

7. A piece of wire 1200 feet long, with a cross-sectional area of 2.25 sq. in., must be stretched with a pull of 1600 pounds when in use. If the modulus of elasticity of this steel is 30,000,000 psi:

   a) What is the total elongation δ in the entire length of the wire?

   b) What tensile stress is produced by the pull?

8. A 2" circular piece of steel, that is 20 feet long between centers of the pins at its ends, is used as the diagonal member in a bridge. If the total tensile load in the steel is 180,000 pounds and the modulus of elasticity is 30,000,000 psi, calculate:

a) The tensile stress-

b) The total elongation caused by the load-

c) The unit elongation-

9. A round, steel 1-1/8” diameter rod, is 85 feet 6 inches in length, and supports an axial load (P) in tension. Calculate:

   a) The maximum unit tensile stress in the rod, if the axial load (P) is 12,000 lb.

   b) The maximum allowed load (P) on this rod, if the unit tensile stress must not exceed 25,000 psi.

c) The total elongation of the rod, if E= 30,000,000 psi using the maximum allowed load from part B.

10. A sleigh is supported and held off the ground with four vertical ½" diameter rods. If the modulus of Elasticity is 10,000,000 psi and the length of each rod is 1 ft., how much weight in toys can be put into this sleigh without compressing the rods more than .01" and ultimately destroying the sleigh?

11. A piece of wire is subjected to a load of 8000 lb. and is 60 ft. in length. The wire deforms a total of 1” in length due to this weight. If the Modulus of Elasticity is 30,000,000 psi, what is the diameter of the wire?

12. A piece of circular aluminum with a diameter of ¼ ft. and 13 ft. in length is used as a structural component of a robot. If the tensile load applied to the component is equivalent to 84 tons and the Modulus of Elasticity is 10,000,000 psi, what is the total elongation in the entire length of the rod?

13. Calculate the stress created in a 3” diameter piece of steel that is 21 feet long between the centers of pins at its ends, and is used as a diagonal member in a

bridge. The load applied to this member is 181,000 pounds and the modulus of Elasticity is 30,000,000 psi.

14. A strand of wire 1,000 ft. long with a cross-sectional area of 3.5 sq. inches must be stretched with a load of 2000 lb. The modulus of Elasticity of this metal is 29,000,000 psi. What is the unit deformation of this material?

Conclusion

1. You have been asked to design a machine to punch circular holes into a sheet of metal. Create a sketch of the problem and set up the equations to calculate shear stress in the metal sheet. Make sure to include applied force, hole diameter, modulus of elasticity and sheet thickness.

2. A community in a mountainous area has developed a playground in a park by a stream. The time it takes for children who live on the other side of the stream to walk to the playground is an hour. The stream is 60 feet across. You have been asked to come up with a design for a cable bridge for foot traffic only. What size cables will need to be obtained so 10 average-sized children can walk on the bridge at once?