2.75 PSet 1

Due Tuesday, September 11, 2012

Name: Solutions Major/Course: 

This first problem set is meant to gauge your understanding as a class. Please attempt this problem set on your own. We are aware that there will be problems in a discipline outside your own for which you have little or no understanding.

Problem 1:

A. For the cantilever beam shown below (length L, square cross section with edge length b) with an applied load P, what is the vertical deflection \( w \) of the tip of the beam? The beam has Young’s modulus \( E \) and yield strength \( \sigma_y \).

\[
W = \frac{PL^3}{3EI} \quad \text{where} \quad I = \frac{b^4}{12}
\]

B. As load \( P \) is increased, where on the beam will first failure most likely occur?

Top edge, closest to wall → Where moment is greatest (in tension)

C. At what load \( P \) will the beam fail?

\[
\sigma = \frac{My}{I} = \frac{PLb}{\frac{4b^4}{12}} = \frac{6PL}{b^3}
\]

\[
\sigma_y = \frac{6PL}{b^3}
\]

\[
\frac{P_{\text{max}}}{b} = \frac{\sigma_y b^3}{6L}
\]
Problem 2:

Identify each of the following components and briefly describe their function in an electronic circuit.

A. - Resistor
   - Creates a potential difference within a circuit.

B. - Rectifier (Diode)
   - Only allows current to flow in one direction. Used to convert AC into DC.

C. - Piezo Transducer
   - Converts electric potential into mechanical stress (in this case to generate sound waves)
- Inductor
  - Opposes changes in current flowing through them.

- Transistor
  - A small signal can be used to control or switch a much larger signal.

- Vacuum Tubes
  - Used as a rectifier or amplifier in old electronic circuits.
Problem 3:

In a variety of systems, mechanical, electrical, or other, the term "efficiency" is often used.

A. In your own words, briefly define the "efficiency" of a system.

\[ \eta = \frac{\text{Useful Power or energy out}}{\text{Power or energy in}} \]  
(or) \[ \frac{\text{Actual Performance}}{\text{Ideal Performance}} \]

B. Estimate a typical value for the efficiency of the following. If you feel you cannot do this, attempt to put them in order of highest to lowest efficiency:

a. Automobile internal combustion engine  
\( \sim 20\% \)

b. Diesel engine  
\( \sim 40\% \)

c. Incandescent lightbulb  
\( \sim 2\% \)

d. Standard ACME leadscrew  
\( \sim 40\% \)

e. 12V Electric motor  
\( \sim 80\% \)

f. Rocket Engine  
\( \sim 70\% \)

g. Electric water kettle  
\( \sim 90\% \)

h. Solar panel  
\( \sim 15\% \)

i. Electric battery  
\( 90\% \)

j. Fuel Cell  
\( 50\% \)
Problem 4:

Precision Machine Design, Inc. has hired you as a design consultant to develop a new device to track the time each of its employees spends at work. Each day at 7AM, the assistant to the regional manager of each PMD Inc. office needs to record the amount of time spent at work in the past 24 hours by each employee for payroll purposes. Employees are at work any time between 8AM and 12AM.

The device needs to be deployable at office locations around the world – many of which are in remote areas without grid power. Maintenance and cost should be kept to a minimum. In addition, the device should be “foolproof”; although employees sign an honor code, this system will be the only way to officially keep track of time. It is best if the employees themselves can access a “receipt” or record of their time as they use the device. In addition, make sure that the device can be used and easily understood by any employee.

A. List a set of functional requirements for this device.

B. Come up with three strategies to solving the problem. Choose your top strategy. Briefly describe your reasoning.

C. Come up with three specific device concepts, and choose your top concept (again give reasoning).

D. Convince us your top concept satisfies your set of functional requirements and will function as intended, using appropriate analysis, reference to existing devices, or other methods.

A. – Low cost
 – Low maintenance = Robust
 – Secure = Accurately records time with little chance of cheating/inaccuracies
 – Employees receive receipt/carbon copy
 – Easy to use for employees
 – Accessible (various heights, disabilities)
 – Off-grid
 – Easy to use for cost manager.