

Homework #3

The Context of Robust Design and the Principles of Quality Engineering

Due Date: Monday, June 15, 1:05-2:55 (the first meeting of 16.881)

Objectives:

- Reinforce material from Phadke chapters 1 and 2
- Tie that material back to fundamental principles from session #1
- Apply concepts on the context of robust design in system development

Assignment

1. Consider an experiment in which two, six-sided fair dice are rolled. One die is green, the other is red. Let's model the outcome on the green die as a discrete random variable G and the outcome on the red die as a discrete random variable R and the sum of the two outcomes as a discrete random variable $T=G+R$
 - a) Sketch the probability mass functions for G and R .
 - b) Compute the expected value and variance of G and R .
 - c) Sketch the joint density function for G and R .
 - d) What is the covariance of G and R ?
 - e) Sketch the probability mass function of T .
 - f) Compute the expected value and standard deviation T .

Note: Recall that the variance is a measure of the dispersion of a random variable and is defined as $\text{VAR}(X)=E((X-E(X))^2)$. Similarly, the covariance is a measure of the degree of association between two random variables and is defined as $\text{COV}(X,Y)=E((X-E(X))(Y-E(Y)))$.

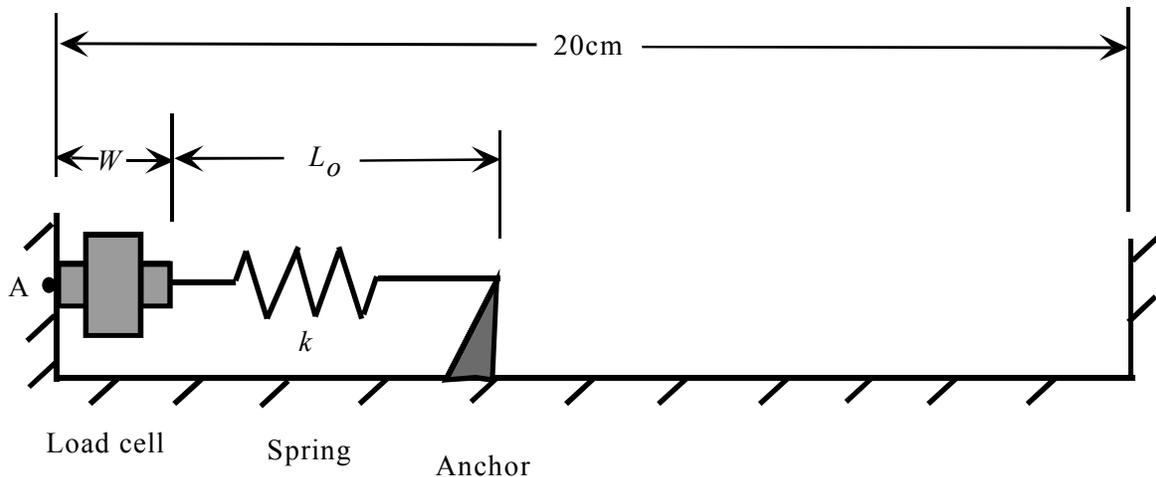
2. Repeat all of the steps in problem 1 for a slightly different experiment. Two, six-sided fair dice are rolled. Again, one die is green, the other is red. But this time, after the dice are rolled, a smurf magically appears and changes the outcome of the red die to match that of the green die.

3. Anstron Corporation uses a spring to calibrate the load cells it manufactures. The function of the calibration system is to apply 10 Newtons of tensile force to the load cell while an instrument measures the voltage across a Wheatstone bridge of strain gauges within the load cell. This voltage is recorded and included in the documentation provided to the customer. The records suggest that if the recorded voltage varies from the proper value by more than 0.1%, the load cell will be returned costing Anstron Corporation \$20.

Both the widths of the load cells and the natural lengths of the springs tend to vary about their nominal values of 2cm and 6cm respectively. A sample of data suggests that the width of the load cell (W) has a standard deviation of $2\mu\text{m}$, the natural length of the spring (L_o) has a standard deviation of $10\mu\text{m}$, and the spring constants have a standard deviation of $1 \times 10^{-3} \text{N/cm}$.

Your job is to design the calibration fixture so as to minimize the quadratic loss due to variation in the applied force F . You may anchor the calibration spring at any point within 20 cm from the point of attachment of the load cell to the fixture (point A). You may choose from among springs with spring constants of 1N/cm, 2N/cm, and 3N/cm (all have a nominal natural length of 6cm).

- Which spring will you choose?
- Where will you place the anchor point?
- What is the expected value of the quality loss due to variation (assuming these three noise variables dominate)?



4) Integration – Referring to the figure below, compare two cases:

Case 1

NT and A–G are all new technologies and are not robust when they are integrated.

Case 2

NT and A–G are all robust when they are integrated.

Compare the two cases:

1. Problems encountered
2. Fundamental phenomena that underlie the difference in problems encountered. Use a little mathematics to make your points more clear.

Two computer-generated pages should be sufficient

