Name: KEY

Recitation Section: ____________

Student Number: ______________________________

1. Check that your exam includes all 7 pages (cover, 6 problems). Additionally, there are two formula sheets.
2. Read all instructions and problems carefully. Points will be deducted for failure to follow instructions.
3. Complete the information requested in the spaces above.
4. PRINT your name and student number in the spaces at the top of all remaining pages of this exam.
5. **Show ALL of your work on these pages.** The pages in this exam may be separated for grading; therefore, if you need extra space for a particular problem, write on the back of the page for that problem. The instructions for a specific question may limit the amount of space allowed for an answer. For all multiple choice questions, select the closest, or most appropriate, answer.
6. You are permitted one sheet (8 1/2 x 11, double-sided) of **handwritten** notes. Use of any other notes, books, or other resources is prohibited.
7. Calculators are permitted; however, you are not allowed to use the calculator memory to store notes, etc.
8. Cell phones are prohibited and must be turned off and stored during the exam.
9. This exam lasts for 65 minutes. Point values are listed for each problem to assist you in best using your time.

______	Problem 1.	(20 points possible)
______	Problem 2.	(20 points possible)
______	Problem 3.	(15 points possible)
______	Problem 4.	(15 points possible)
______	Problem 5	(15 points possible)
______	Problem 6	(15 points possible)
______	**TOTAL.**	(100 points possible)

Problem 1. (20 points)

Following are 10 statements. For each of the following statements, circle the appropriate response in the right-hand column. This problem is scored by # of points = 2 (number circled correctly) – 1 (number circled incorrectly). In other words, incorrect guesses hurt worse than no guesses.

A.	In the video on engineering disasters the point was made that most disasters are related to a fundamental lack of knowledge of engineering or scientific principles.	TRUE FALSE
B.	The afternoon portion of the Fundamentals of Engineering Exam may be either general or discipline specific.	TRUE FALSE
C.	In benefit-cost analysis, sometimes the same item may be classified as either a disbenefit or a cost.	TRUE FALSE
D.	In designs where safety is a concern, the value of Cp should be approximately equal to unity.	TRUE FALSE
E.	A system composed of a highly reliable subsystem in parallel with a weakly reliable subsystem is more reliable than the highly reliable subsystem alone.	TRUE FALSE
F.	Tort law is the branch of statutory law that deals with contract disputes.	TRUE FALSE
G.	Engineering design patents fall under the category of "utility patents" and they are issued for 20 years.	TRUE FALSE
H.	When considering the sum of two of random variables, the standard deviation of the sum is equal to the sum of the individual standard deviations.	TRUE FALSE
I.	A duty-based theory of morality is based on motives, attitudes, aspirations and ideals.	TRUE FALSE
J.	Copyrights are valid for 50 years past the first public use of a book or document.	TRUE FALSE

Problem 2. (20 points)

A square notch is fabricated in 1,000,000 machined parts. Assume that the area of the notch is A = W x L, where the notch dimensions are width = W and length = L.

Measurement of notch dimensions have established the following statistics:

Mean value of W = 0.525 inches
Mean value of L = 0.375 inches

Standard deviation of W = 0.007 inches
Standard deviation of L = 0.012 inches

Compute the expected mean and standard deviation for the area of the notch. $A = WL$

$$\mu_A = \mu_W \mu_L = 0.525(.375) = 0.1969 \text{ sq. in.}$$

Expected mean value of notch area A (5 pts) = 0.1969 sq. in.

$$\sigma_A = \sqrt{\mu_L^2 \sigma_W^2 + \mu_W^2 \sigma_L^2} = \sqrt{(0.375)^2(0.007)^2 + (0.525)^2(0.012)^2}$$

Expected standard deviation of notch area A (5 pts) = 0.0068 sq. in.

$$C_p = \frac{USL - LSL}{6\sigma} \Rightarrow USL - LSL = C_p(6\sigma)$$

then $USL - \mu_A = C_p(3\sigma) \Rightarrow USL = \mu_A + 3\sigma C_p$

Notches either too large, or too small, in area are deemed to be defective. Assuming a Cp value of 1.5, specify the upper and lower specification limits for the area A of the notch.

then $LSL = \mu_A - 3\sigma C_p$ $\quad 3\sigma C_p = 3(0.0068)1.5 = 0.0306$

$USL = 0.1969 + 0.0306$
$LSL = 0.1969 - 0.0306$

USL (3 pts) 0.2275 sq. in. **LSL (3 pts)** 0.1663 sq. in.

For $C_p = 1.5$, z values are $\pm 3C_p\sigma = \pm 4.5\sigma$

How many parts out of the batch of 1,000,000 are expected to be defective?

$Z(4.5) = Z(-4.5) = 3.4 \times 10^{-6}$
$Z(4.5) + Z(-4.5) = 6.8 \times 10^{-6}$

Number of parts defective (4 pts) 6.8

Problem 3. (15 points)

A process is being evaluated to decide which choice of the three possible branches (A, B, or C) is preferred based upon a decision tree analysis with conditional uncertainties. Probabilities and expected payoff amounts are given, and the least expensive option should be chosen.

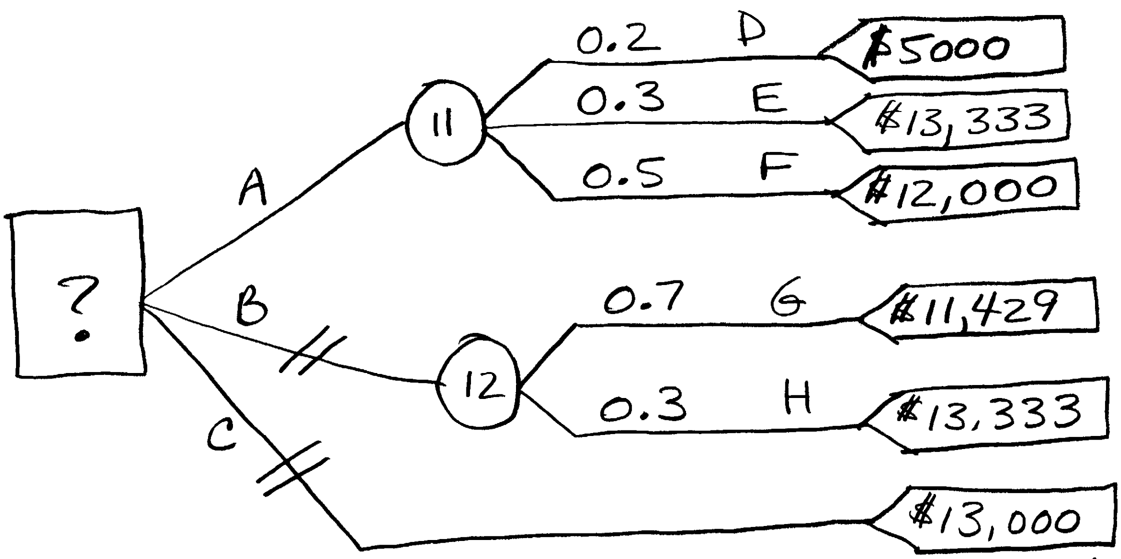
Branch A leads to a chance node with three output branches. Label these output branches as D, E, and F. The uncertainties for D, E, and F are as follows: Pr(D)=0.2, Pr(E)=0.3, and Pr(F)=0.5 Each output branch terminates at a separate payoff node.

Branch B leads to a chance node with two output branches. Label these output branches as G and H. The uncertainties for G and H are as follows: Pr(G)=0.7 and Pr(H)=0.3 Each output branch terminates at a separate payoff node.

Branch C leads directly to a payoff node with an expected value of $13,000

The expected values of the remaining payoff nodes are as follows: Value(D)=$5000, Value(E)=$13,333, Value(F)=$12,000, Value(G)=$11,429, and Value(H)=$13,333

Draw the decision tree for the above problem, and fill in the expected costs for each of the nodes (10 pts)



$EC_A = 0.2(5000) + 0.3(13,333) + 0.5(12,000) = \$11,000$

$EC_B = 0.7(11,429) + 0.3(13,333) = \$12,000$

$EC_C = \$13,000$

List the preferred process (A, B, or C) (2 pts) A

Expected cost of the preferred process (A, B, or C) (3 pts) $11,000

Problem 4. (15 points) ALSO SEE ALTERNATE SOLUTION

A city is planning the construction of a golf course, and is considering two configurations with different expected payoffs and operating expenses. Determine which of the two options is most cost effective for the city. For 10 years of operation, and using an equivalent present value viewpoint, determine the benefit to cost ratio for each of the options. Assume an interest rate of 8%. Show all calculations to receive full credit.

Option 1: 18 hole golf course at a construction cost of \$10,000,000

The expected yearly revenue is:

A fee of \$35 is charged to each player with the following course usage probabilities (a) 100,000 players per year at a probability of 0.3, (b) 125,000 players per year at a probability of 0.5, and (c) 150,000 players per year at a probability of 0.2

The expected yearly operating costs for option #1 are:

\$2,500,000 per year

Option 2: Professional Quality 18 hole golf course at a construction cost of \$15,000,000

The expected yearly revenue is:

A fee of \$95 is charged to each player with the following course usage probabilities (a) 25,000 players per year at a probability of 0.1, (b) 50,000 players per year at a probability of 0.3, (c) 75,000 players per year at a probability of 0.4, and (d) 100,000 players per year at a probability of 0.2

The expected yearly operating costs for option #1 are:

\$4,000,000 per year

Annual Rev #1 = \$35[.3(100,000) + .5(125,000) + .2(150,000)]
= \$4,287,500

Annual Net #1 = \$4,287,500 − \$2,500,000 = \$1,787,500

Present Val of Net = Benefits = \$1,787,500 [P/A, 8%, 10]
= \$1,787,500 (6.7101) = \$11,994,304

$B/C = \frac{\$11,994,304}{\$10,000,000}$

Benefit to cost ratio for option #1 (5 pts) 1.199

Annual Rev #2 = \$95[.1(25,000) + .3(50,000) + .4(75,000) + .2(100,000)]
= \$6,412,500

Annual Net #2 = \$6,412,500 − \$4,000,000 = \$2,412,500

Present Val of Net = Benefits = \$2,412,500 [P/A, 8%, 10]
= \$2,412,500 (6.7101) = \$16,188,116

$B/C = \frac{\$16,188,116}{\$15,000,000}$

Benefit to cost ratio for option #2 (5 pts) 1.079

Result: Choose best option (5 pts) A

Problem 4. (15 points) ALTERNATE SOLUTION

A city is planning the construction of a golf course, and is considering two configurations with different expected payoffs and operating expenses. Determine which of the two options is most cost effective for the city. For 10 years of operation, and using an equivalent present value viewpoint, determine the benefit to cost ratio for each of the options. Assume an interest rate of 8%. Show all calculations to receive full credit.

Option 1: 18 hole golf course at a construction cost of $10,000,000
The expected yearly revenue is:

A fee of $35 is charged to each player with the following course usage probabilities (a) 100,000 players per year at a probability of 0.3, (b) 125,000 players per year at a probability of 0.5, and (c) 150,000 players per year at a probability of 0.2

The expected yearly operating costs for option #1 are:

$2,500,000 per year

Option 2: Professional Quality 18 hole golf course at a construction cost of $15,000,000
The expected yearly revenue is:

A fee of $95 is charged to each player with the following course usage probabilities (a) 25,000 players per year at a probability of 0.1, (b) 50,000 players per year at a probability of 0.3, (c) 75,000 players per year at a probability of 0.4, and (d) 100,000 players per year at a probability of 0.2

The expected yearly operating costs for option #1 are:

$4,000,000 per year

Benefits #1 (annual) = $35[.3(100,000) + 0.5(125,000) + .2(150,000)]
= $4,287,500

Benefits #1 (present) = $4,287,500 $\overbrace{[P/A, 8\%, 10]}^{6.7101}$
= $4,287,500(6.7101) = $28,769,554

Costs #1 (PRESENT) = $10,000,000 + $2,500,000 (6.7101)
= $26,775,250

Benefit to cost ratio for option #1 (5 pts) 1.0745

$B/C = \frac{28,769,554}{26,775,250} = 1.0745$

Benefits #2 (annual) = $95[.1(25,000) + 0.3(50,000) + 0.4(75,000)]
= $6,412,500

Benefits #2 (present) = $6,412,500 (6.7101) = $43,028,516

Cost Present = $15,000,000 + $4,000,000 (6.7101)
= $41,840,400

Benefit to cost ratio for option #2 (5 pts) 1.0284

$B/C = \frac{43,028,516}{41,840,400} = 1.0284$

Result: Choose best option (5 pts) A

Problem 5. (15 points)

A manufacturing design for capacitors is characterized by the following values:

Lower Specification Limit = 0.085 microfarads
Upper Specification Limit = 0.115 microfarads
Target Mean = 0.1 microfarads
Actual Mean = 0.098 microfarads
Standard Deviation = 0.01 microfarads

Assume that the characteristics of the manufactured item are distributed according to a normal (Gaussian) distribution. Compute the values specified below. Show all calculations to receive full credit.

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{0.115 - 0.085}{6(0.01)} = 0.5$$

Cp (~~5~~ 3 pts) 0.5

$$K = \frac{|(\text{target mean}) - (\text{actual mean})|}{3\sigma C_p} = \frac{0.1 - 0.098}{3(0.01)0.5} = 0.133$$

$$C_{pK} = C_p(1-K) = 0.5(1 - 0.133) = 0.433$$

Cpk (~~5~~ 3 pts) 0.433

Defects below LSL: $z\left(\frac{\mu - LSL}{\sigma}\right) = z\left(\frac{0.098 - 0.085}{0.01}\right) = z(1.3)$

$z(1.3) \simeq 0.097$

% **Defects below LSL (~~5~~ 3 pts)** 9.7%

Defects above USL: $z\left(\frac{USL - \mu}{\sigma}\right) = z\left(\frac{0.115 - 0.098}{0.01}\right) = z(1.7)$

$z(1.7) \simeq 0.045$

% **Defects above USL (~~5~~ 3 pts)** 4.5%

Which one of the three descriptions would be most likely used to describe the above process? Circle the letter of the correct response below. (~~5~~ 3 pts)

(a) The process is capable

(b) The process is incapable SINCE $C_p < 1$

(c) The process and the design agree at the 3 sigma points

Problem 6. (15 points)

For each of the following questions, circle the letter in the right-hand column that corresponds to the best answer. Show all calculations to get full credit.

A. 15,000 devices are being tested for 300 hours. The process is characterized by a per unit failure rate of $4 \times 10^{-3}\ hr^{-1}$. How many devices fail between 200 and 250 hours of their life. a b c d

(a) 851
(b) 1222
(c) 1563
(d) 2368

Number surviving $= N_o e^{-\lambda t}$

Number failing between 200 and 500 hours equals the difference in the number surviving

Number failing $= 15{,}000 \{ e^{-200(.004)} - e^{-250(.004)} \}$

$= 15{,}000 (0.081) \simeq 1222$

B. A manufacturing process has an average defect rate of 1.3 defects per unit. What is the probability that a particular unit will have 4 defects? a b c d

(a) 3.2%
(b) 9.7%
(c) 14.8%
(d) 18.2%

$$P(4\ \text{defects}) = \frac{(dpu)^4 e^{-dpu}}{4!}$$

$$= \frac{(1.3)^4 e^{-1.3}}{4!} = 0.0324$$

C. A part is assembled by one of two employees. The percentage of the parts assembled by employee #1 is 40%, and the percentage by employee #2 is 60%. Employee #1 has an assembly defect rate of 5%, and employee #2 has a defect rate of 8%. One part is found to be defective, and may have been assembled by either employee. What is the probability that it was assembled by employee #1. a b c d

(a) 18.5%
(b) 29.4%
(c) 32.1%
(d) 38.7%

USE BAYES THEOREM

$$P(1 \mid \text{defective}) = \frac{P(1)\,P(\text{defect} \mid 1)}{P(1)\,P(\text{defect} \mid 1) + P(2)\,P(\text{defect} \mid 2)}$$

$$= \frac{.4(0.05)}{.4(0.05) + .6(0.08)} = 0.294$$