Last Name:

First Name:

SCIPER:

Sample Test 1 – Microengineering 110

Spring 2024

Prof. Vivek Subramanian

- **During the actual test, you would be entering your answers on moodle and on the paper. For this sample test, only the paper version is being provided. During the actual test you MUST enter your answers BOTH on this paper version and on the moodle. The paper version will be used as a backup in case your moodle version is corrupted, etc.**
- **No communications are allowed with others. Therefore, YOU MUST EXIT ALL COMMUNICATION PROGRAMS (Chat windows, etc.). Should a proctor notice that you have an open communication program, it will be considered to be a violation of academic integrity standards.**
- **In the real test, the moodle will allow you to enter information for exactly 45 minutes, at which point it will lock you out. This practice test is much longer than the real test (>2X in length), to give you more practice opportunities.**

1. Cerium Oxide (CeO2) is an important particle used as a catalyst in many electrochemical reactions. The accompanying summary data on CeO2 particle sizes (nm) under certain experimental conditions was read from a graph in the article "Nanoceria— Energetics of Surfaces, Interfaces and Water Adsorption" (J. of the Amer. Ceramic Soc., 2011, 3992–3999):

Diameter	3.0–<3.5	3.5–<4.0	4.0–<4.5	4.5–<5.0	5.0–<5.5	5.5–<6.0	6.0–<6.5	6.5–<7.0	7.0–<7.5	7.5–<8.0
Frequency	5	15	27	34	22	14	7	2	4	1

   a. What fraction of the observations are less than 5nm in diameter ? Give your answer as a decimal number.

   b. What fraction of the observations are at least 6nm in diameter? Give your answer as a decimal number.

c. Construct a histogram with relative frequency on the vertical axis and comment on interesting features.

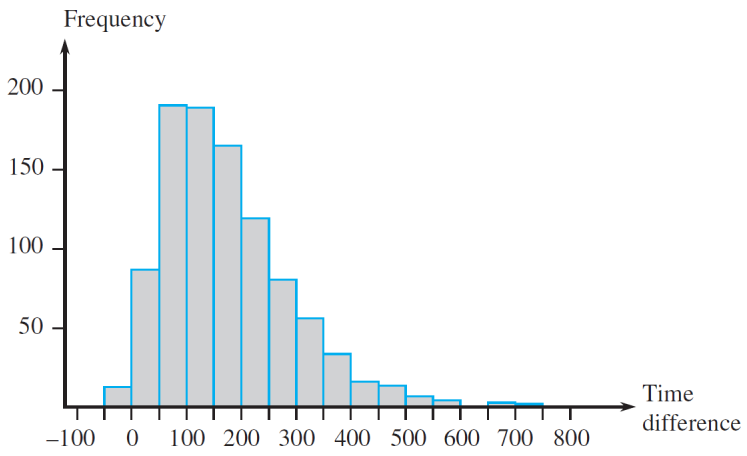
In the moodle test, you would be given a few distributions and would have to pick the correct one. For this practice test, you should generate the histogram yourself, for example using python.

d. Does the distribution of particle sizes appear to be reasonably symmetric or somewhat skewed?

e. Construct a histogram with density on the vertical axis and compare to the histogram in (c).

In the moodle test, you would be given a few distributions and would have to pick the correct one. For this practice test, you should generate the histogram yourself, for example using python.

2. How does the speed of a runner vary over the course of a marathon (a distance of 42.195 km)? To examine this, we calculate the difference in time (in seconds) taken to run the first 5km and the 5km starting at the 35th km. A positive value of this difference corresponds to a runner slowing down toward the end of the race. The accompanying histogram is based on times of runners who participated in several different Japanese marathons ("Factors Affecting Runners' Marathon Performance," Chance, Fall, 1993: 24–30).



3. Based on this data, do most runners slow down or speed up over the course?

4. Which of the following is a typical difference value?

    - -50 seconds
    - 10 seconds
    - 200 seconds
    - 400 seconds

5. Roughly what fraction (give your answer as a decimal) of the runners ran the late distance more quickly than the early distance?

6. Prof. Subramanian is from California, where there are major wildfires every year. Californians always worry bout the possibility of their homes catching fire. Fire load (MJ/m2) is the heat energy that could be released per square meter of floor area by combustion of contents and the house structure itself. The article "Fire Loads in Office Buildings" (J. of Structural Engr., 1997: 365–368) gave the following cumulative percentages (read from a graph) for fire loads in a sample of 388 rooms:

Value	0	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950
Cumulative%	0	19.3	37.6	62.7	77.5	87.2	93.8	95.7	98.6	99.1	99.5	99.6	99.8	1000

    a. Construct a relative frequency histogram from the above data

        In the actual test, you would be given a few options to choose from. For this sample test, you should practice generating one in python.

    b. What fraction (give your answer as a decimal) of fire loads are less than 600?

    c. What fraction (give your answer as a decimal) of fire loads are at least 1200?

    d. What fraction (give your answer as a decimal) of the loads are between 600 and 1200?

7. Exposure to microbial products, especially endotoxin, may have an impact on vulnerability to allergic diseases. The article “Dust Sampling Methods for Endotoxin— An Essential, But Underestimated Issue” (Indoor Air, 2006: 20–27) considered various issues associated with determining endotoxin concentration. The following data on concentration (EU/mg) in settled dust for one sample of urban homes (U) and another of farm homes (F) was obtained.

   U: 6.0, 5.0, 11.0, 33.0, 4.0, 5.0, 80.0, 18.0, 35.0, 17.0, 23.0
   F: 4.0, 14.0, 11.0, 9.0, 9.0, 8.0, 4.0, 20.0, 5.0, 8.9, 21.0, 9.2, 3.0, 2.0, 0.3

   a. Determine the sample mean for each sample. Which one is larger, i.e., E(U) or E(F)?

   b. Determine the sample median for each sample. Which one is larger? Why is the median for the urban sample so different from the mean for that sample?

   c. Calculate the trimmed mean for each sample by deleting the smallest and largest observation. What are the corresponding trimming percentages?

   d. Determine the value of the sample standard deviation for each sample, interpret these values, and then compare the variability in the two samples.

   e. The authors of the cited article also provided endotoxin concentrations in dust bag dust, taken from vacuum cleaners used to clean homes in these environments:

      UB: 34.0, 49.0, 13.0, 33.0, 24.0, 24.0, 35.0, 104.0, 34.0, 40.0, 38.0, 1.0

   f. FB: 2.0, 64.0, 6.0, 17.0, 35.0, 11.0, 17.0, 13.0, 5.0, 27.0, 23.0, 28.0, 10.0, 13.0, 0.2

g. Construct a comparative boxplot to compare and contrast the four samples.

In the real test ,you would be given options to choose from in moodle. Here, you should generate box plots using python.

8.

9. Poly(3-hydroxybutyrate) (PHB), a semicrystalline polymer that is fully biodegradable and biocompatible, is obtained from renewable resources. From a sustainability perspective, PHB offers many attractive propertie though it is more expensive to produce than standard plastics. The accompanying data on melting point (°C) for each of 12 specimens of the polymer using a differential scanning calorimeter appeared in the article "The Melting Behaviour of Poly(3-Hydroxybutyrate) by DSC. Reproducibility Study" (Polymer Testing, 2013: 215–220).

   180.5, 181.7, 180.9, 181.6, 182.6, 181.6, 181.3, 182.1, 182.1, 180.3, 181.7, 180.5

   Compute the following:

   a. The sample range

   b. The sample variance s^2

   c. The sample standard deviation

10. Four hocket teams —1, 2, 3, and 4—are participating in a hockey tournament. In the first round, 1 will play 2 and 3 will play 4. Then the two winners will play for the championship, and the two losers will also play. The outcome of the tournament is a final ranking. One possible outcome can be denoted by 1324 (1 beats 2 and 3 beats 4 in first-round games, and then 1 beats 3 and 2 beats 4).

a. List all outcomes in S

In the moodle, this would be a multiple choice question.

b. What is the size of the sample space in terms of number of outcomes?

c. Let A denote the event that team 1 wins the tournament. List outcomes in A.

d. Let B denote the event that 2 gets into the championship game. List outcomes in B.

e. What are the outcomes in $A \cup B$ and in $A \cap B$?

f. What are the outcomes in A'?

11. Suppose that 55% of all adults regularly consume coffee, 45% regularly consume carbonated soda, and 70% regularly consume at least one of these two products.

    a. What is the probability that a randomly selected adult regularly consumes both coffee and soda?

    b. What is the probability that a randomly selected adult doesn't regularly consume at least one of these two products?

12. A certain system can experience three different types of defects. Let A_i (i = 1,2,3) denote the event that the system has a defect of type i. Suppose that:

    $P(A_1) = .12$ $P(A_2) = .07$ $P(A_3) = .05$
    $P(A_1 \cup A_2) = .13$ $P(A_1 \cup A_3) = .14$
    $P(A_2 \cup A_3) = .10$ $P(A_1 \cap A_2 \cap A_3) = .01$

    a. What is the probability that the system does not have a type 1 defect?

    b. What is the probability that the system has both type 1 and type 2 defects?

    c. What is the probability that the system has both type 1 and type 2 defects but not a type 3 defect?

    d. What is the probability that the system has at most two of these defects?

    e. Given that the system has a type 1 defect, what is the probability that it has a type 2 defect?

    f. Given that the system has a type 1 defect, what is the probability that it has all three types of defects?

g. Given that the system has at least one type of defect, what is the probability that it has exactly one type of defect?

h. Given that the system has both of the first two types of defects, what is the probability that it does not have the third type of defect?

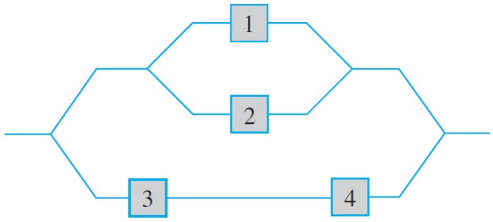
13. An experimenter is studying the effects of temperature, pressure, and type of catalyst on yield from a certain chemical reaction. Three different temperatures, four different pressures, and five different catalysts are under consideration.

    a. If any particular experimental run involves the use of a single temperature, pressure, and catalyst, how many experimental runs are possible?

    b. How many experimental runs are there that involve use of the lowest temperature and two lowest pressures?

    c. Suppose that five different experimental runs are to be made on the first day of experimentation. If the five are randomly selected from among all the possibilities, so that any group of five has the same probability of selection, what is the probability that a different catalyst is used on each run?

14. Consider the system of components connected as in the accompanying picture. Components 1 and 2 are connected in parallel, so that subsystem works iff (as a reminder, this means if *and only* if) either 1 or 2 works; since 3 and 4 are connected in series, that subsystem works iff both 3 and 4 work. If components work independently of one another and P(component i works) = .9 for i = 1,2 and = .8 for i = 3,4, calculate P(system works)



15. A company that produces fine crystal knows from experience that 10% of its goblets have cosmetic flaws and must be classified as “seconds.”

    a. Among six randomly selected goblets, how likely is it that only one is a second?

    b. Among six randomly selected goblets, what is the probability that at least two are seconds?

    c. If goblets are examined one by one, what is the probability that at most five must be selected to find four that are not seconds?

16. Let X denote the amount of space occupied by an article placed in a $1m^3$ box. The pdf of X is

$$f(x) = \begin{cases} 90x^8(1-x) & 0 < x < 1 \\ 0 & \text{otherwise} \end{cases}$$

a. Graph the pdf. Then obtain the cdf of X and graph it.

In the real test, you would be given a few options to choose from… in this practice test, you should generate the graphs yourself using python.

b. What is P(X <= .5) [i.e., F(.5)]?

c. Using the cdf from (a), what is P(.25 < X <= .5)?

d. What is P(.25 < X < .5)?

e. What is the 75th percentile of the distribution?

f. Compute E(X) and σ_X.

g. What is the probability that X is more than 1 standard deviation from its mean value?