

UNIVERSITY OF ESWATINI
FACULTY OF SCIENCE AND ENGINEERING
DEPARTMENT OF PHYSICS
MAIN EXAMINATION: 2018/2019
TITLE OF PAPER: Research Methods for Physics
COURSE NUMBER: PHY351
TIME ALLOWED: TWO HOURS

INSTRUCTIONS:

- ANSWER QUESTIONS ONE AND ANY THREE OUT OF THE FOUR REMAINING QUESTIONS.
- POINTS FOR DIFFERENT SECTIONS ARE SHOWN IN THE RIGHT-HAND MARGIN.

THIS PAPER HAS 3 PAGES, INCLUDING THIS PAGE.

DO NOT OPEN THIS PAGE UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

Question 1: Compulsory Question

- (a) State whether each of the following statements is true or false. (14)
- i. The question, 'Why are leaves green?', is not a *testable* question.
 - ii. *Test a hypothesis: Hypothesis-driven research*, is a research method also known as the Scientific Method.
 - iii. The hypothesis '*Users of Macs and PCs like their computers equally well*' is an *alternative hypothesis*.
 - iv. Increasing the number of measurements in an experiment reduces the *standard error of the mean*.
 - v. Given a collection of numbers x_1, \dots, x_N , then the average of these numbers lies somewhere in the middle.
 - vi. For a given probability distribution $P(X)$, we have $\int P(X)dX = 1$.
 - vii. For a given set of data, $\{(x_1, y_1), \dots, (x_N, y_N)\}$, there is a unique polynomial of order $N - 1$ that passes through all of the points.
- (b) The number of bins in a histogram are important: if they are too few then the shape of the distribution is not obvious, and if they are too many the shape of the distribution is lost. Give an estimate of the number of bins that can be used to draw histograms in each case. Justify your answers
- i. If there 10 measurements; (3)
 - ii. If there are 20 measurements; (3)
 - iii. If there are 100 measurements. (4)

(c) In linear regression the correlation coefficient is given by

$$r = \frac{1}{N-1} \sum_{i=1}^N \frac{(x_i - \bar{x})(y_i - \bar{y})}{s_x s_y},$$

where \bar{x} and \bar{y} are the sample averages and s_x and s_y are the sample standard deviations.

- i. What does a $r \sim 1$ mean in terms of how the data relate to the linear fit? (2)
 - ii. What does a $r \sim -1$ mean in terms of how the data relate to the linear fit? (2)
 - iii. What does a $r \sim 0$ mean in terms of how the data relate to the linear fit? (2)
- (d) Briefly discuss two ways through which scientists communicate their work? (10)

Question 2: One of Four Optional Questions

The formulas for the sample mean and sample variance are $\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$ and $s^2 = \frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2$, respectively

- (a) Prove that if all x_i are the same, then the $\bar{x} = x_i$. (4)
- (b) Prove by contradiction that \bar{x} is larger than the smallest of the x_i . (6)

- (c) Prove by contradiction that \bar{x} is smaller than the largest of the x_i . (6)
- (d) Why do we divide by N-1 instead of N in the formula for the variance. (4)

Question 3: Two of Four Optional Questions.....

Imagine that the Eswatini Environment Authority regulates the amount of mercury that is allowed in drinking water, suggesting that more 1 ppm (parts per million) in water poses a health hazard. A student measures mercury concentration in water samples from 20 tap water sources in Mbabane and they obtain the following (in ppm)

1.1, 1.23, 1.07, 0.98, 0.94, 1.29, 1.04, 0.99, 1.34, 1.05
 1.18, 1.2, 1.08, 1.01, 0.94, 1.01, 0.85, 0.99, 1.05, 1.13

- (a) Calculate the sample mean. (2)
- (b) Calculate the sample standard deviation. (4)
- (c) Calculate the sample standard error. (2)
- (d) If the experiment were repeated many times
 - i. 68.2% of the time the sample mean would lie between what values? (2)
 - ii. 95.5% of the time the sample mean would lie between what values? (2)
 - iii. 99.7% of the time the sample mean would lie between what values? (2)
- (e) Based on the 95.5% confidence interval, is Mbabane water safe? (3)
- (f) Based on the 99.7% confidence interval, is Mbabane water safe? (3)

Question 4: Three of Four Optional Questions.....

Obtain an order of magnitude estimate for each of the problems. Note that you have to state all your assumptions and indicate how they affect the estimate.

- (a) The number of hair on a human head. (10)
- (b) The total annual sales of a typical supermarket in Manzini. (10)

Question 5: Four of Four Optional Questions.....

- (a) Briefly describe the general format of a scientific article. For each section, briefly indicate what type of information is relayed. (10)
- (b) List six things that should be avoided when preparing figures for scientific papers. (6)
- (c) Give an example of a good topic for a scientific paper and an example of a bad topic for a scientific paper. (4)