Suffolk County Community College

**Michael J. Grant Campus**

# Department of Mathematics

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# MAT 103
# Statistics I

## Final Exam: Solutions and Answers

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**Problem 1.** University of California, Berkeley graduate division admitted 44% of male and 35% of female applicants in the Fall of 1973.

Noticing this apparent discrepancy, Eugene A. Hammel, then the Associate Dean of the Graduate Division,[1] asked Peter Bickel, then a professor of statistics at Berkeley, to analyze the data. The results of that analysis [2] became one of the most widely cited examples of the statistical phenomenon called *Simpson's Paradox*. In this problem, we explore this phenomenon and its ramifications.

The original paper by Bickel at al. does not contain the raw data on the individual departments, but the Data Science Discovery platform [3] has a data set covering all the $12,763$ applicants from the original study. It obscures the specific department names, but identifies the six most popular departments by the department codes A, B, C, D, E and F. In this problem, we will focus only on those six departments, and — in the interest of time — we will further group them into two groups. The departments A and B will form the "easy-to-get-into" group, and departments C, D, E and F will make up the "hard-to-get-into" group. The effect of the Simpson's paradox becomes even more pronounced when only those six departments are considered.

**(1).** Based on the aggregated six-department data:

| | **Male** | **Female** |
|---|---|---|
| **Accepted** | $1,511$ | $557$ |
| **Rejected** | $1,493$ | $1,278$ |

compute and compare the conditional probabilities:

$$P(\text{Accepted}|\text{Male}) =$$

$$P(\text{Accepted}|\text{Female}) =$$

and determine if there has been a bias against women in graduate admissions.

*Space for your solution:*

$$P(\text{Accepted}|\text{Male}) = \frac{1,511}{1,511 + 1,493} = \frac{1,511}{3,004} \approx 50\%$$
$$P(\text{Accepted}|\text{Female}) = \frac{557}{557 + 1,278} = \frac{557}{1,835} \approx 30\%$$

These probabilities seem to suggest a bias against women.

[1]see Cari Tuna (2009) "When Combined Data Reveal the Flaw of Averages", A Wall Street Journal interview with Peter Bickel, https://www.wsj.com/articles/SB125970744553071829,

[2]Bickel, P. J., Hammel, E. A., and O'Connell, J. W. (1975) "Sex bias in graduate admissions: Data from Berkeley", Science, 187, 398–403, http://brenocon.com/science_1975_sex_bias_graduate_admissions_data_berkeley.pdf

[3]Berkeley's 1973 Graduate Admissions Dataset, Data Science Discovery, University of Illinois at Urbana-Champaign, https://discovery.cs.illinois.edu/dataset/berkeley/

**(2).** Graduate admission decisions are made by individual departments. In the attempt to "look for the responsible parties", Professor Bickel and his colleagues analyzed data for each of the 101 departments separately. We will use a much more coarse analysis, grouping the six most popular departments into two groups and analyzing the admissions data for those two groups.

Here is the statistics for the easy-to-get-into departments (those labelled as "A" and "B" in the Data Science Discovery dataset):

| **Easy** | **Male** | **Female** |
|---|---|---|
| **Accepted** | 1,178 | 106 |
| **Rejected** | 520 | 27 |

and for the hard-to-get-into departments (labelled "C", "D", "E" and "F" in the same dataset):

| **Hard** | **Male** | **Female** |
|---|---|---|
| **Accepted** | 333 | 451 |
| **Rejected** | 973 | 1,251 |

Compute and compare the conditional probabilities:

$$P(\text{Accepted}|\text{Male}) =$$

$$P(\text{Accepted}|\text{Female}) =$$

separately for the easy-to-get-into and hard-to-get-into departments.

*Space for your solution:*

For the easy-to-get-into departments:

$$P(\text{Accepted}|\text{Male}) = \frac{1,178}{1,178+520} = \frac{1,178}{1,698} \approx 69\%$$

$$P(\text{Accepted}|\text{Female}) = \frac{106}{106+27} = \frac{106}{133} \approx 80\%.$$

For the hard-to-get-into departments:

$$P(\text{Accepted}|\text{Male}) = \frac{333}{333+973} = \frac{333}{1,306} \approx 25\%$$

$$P(\text{Accepted}|\text{Female}) = \frac{451}{451+1,251} = \frac{451}{1,702} \approx 26\%.$$

**(3).** What overall conclusion can you draw from this analysis of admissions data? Did Berkeley discriminate against women in their fall 1973 graduate admissions?

*Space for your solution:*

The department type was a stronger predictor of admission than the sex of the applicant. Women were more likely to apply to the hard-to-get-into departments, while men disproportionately applied to the easy-to-get-into departments, thus the aggregation of the data from all six departments obscured the effect of the department choice on the admission outcomes, creating an illusion of a bias against women.

When the two department groups are analyzed separately, the effect of the department choice is separated from the effect of sex (and the bias *in favor of* women in the easy-to-get-into departments becomes apparent).

Department choice is the decision made by the applicant, not by the school. While it is entirely possible that women suffered from bias against them on the way leading them to their department selection, graduate admission statistics does not indicate any bias against women on the part of the school.

**Problem 2.** A grain mill manufactures 100-pound bags of flour for sale in restaurant-supply warehouses. Historically, the weights of bags of flour manufactured at the mill were normally distributed with a mean $\mu = 100$ pounds and a standard deviation $\sigma = 15$ pounds.

**(1).** What is the probability that the weight of a randomly selected bag of flour falls between 94 and 106 pounds? Use the table of Standard Normal Distribution included at the end of this exam.

*Space for your solution:*

The $z$-score $\frac{x-\mu}{\sigma}$ becomes $\frac{94-100}{15} = -0.4$ for $x = 94$ and $\frac{106-100}{15} = 0.4$ for $x = 106$. Using the table of standard normal distribution, we get:

$$P(94 < x < 106) = P(-0.4 < z < 0.4) = 2 \cdot P(0 < z < 0.4) = 2 \cdot 0.1554 = 0.3108.$$

**(2).** If samples of 36 bags are taken, what is the $\sigma_{\bar{X}}$, the standard error of the mean?

*Space for your solution:*

$$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{n}} = \frac{15}{\sqrt{36}} = 2.5.$$

**(3).** What is the probability that a sample of 36 bags of flour has a mean weight between 94 and 106 pounds?

*Space for your solution:*

In the manner analogous to finding the $z$-score for the single bag of flour, the $z$-score for the sample $\frac{\bar{X}-\mu}{\left(\frac{\sigma}{\sqrt{n}}\right)}$ becomes $\frac{94-100}{2.5} = -2.4$ for $x = 94$ and $\frac{106-100}{2.5} = 2.4$ for $x = 106$. Using the table of standard normal distribution, we get:

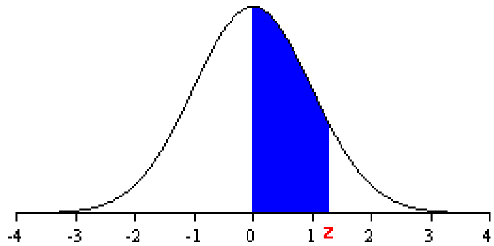
$$P(94 < x < 106) = P(-2.4 < z < 2.4) = 2 \cdot P(0 < z < 2.4) = 2 \cdot 0.4918 = 0.9836.$$

**(4).** Suppose the mill wants to determine if the equipment used for automatic measurement and packing of the flour bags needs readjustment. The mill engineers take a sample of 36 bags of flour and determine that its mean is 106 pounds. If they decide to readjust the equipment, how confident can they be about their decision?

*Space for your solution:*

Based on the result of the previous sub-problem, if the equipment is working nominally, the probability of observing sample mean outside of the $94 - -106$ range is less than 2%. Thus with confidence level 98% the equipment needs re-adjustment.

# Standard Normal Distribution




| z | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.00** | 0.0000 | 0.0040 | 0.0080 | 0.0120 | 0.0160 | 0.0199 | 0.0239 | 0.0279 | 0.0319 | 0.0359 |
| **0.10** | 0.0398 | 0.0438 | 0.0478 | 0.0517 | 0.0557 | 0.0596 | 0.0636 | 0.0675 | 0.0714 | 0.0753 |
| **0.20** | 0.0793 | 0.0832 | 0.0871 | 0.0910 | 0.0948 | 0.0987 | 0.1026 | 0.1064 | 0.1103 | 0.1141 |
| **0.30** | 0.1179 | 0.1217 | 0.1255 | 0.1293 | 0.1331 | 0.1368 | 0.1406 | 0.1443 | 0.1480 | 0.1517 |
| **0.40** | 0.1554 | 0.1591 | 0.1628 | 0.1664 | 0.1700 | 0.1736 | 0.1772 | 0.1808 | 0.1844 | 0.1879 |
| **0.50** | 0.1915 | 0.1950 | 0.1985 | 0.2019 | 0.2054 | 0.2088 | 0.2123 | 0.2157 | 0.2190 | 0.2224 |
| **0.60** | 0.2257 | 0.2291 | 0.2324 | 0.2357 | 0.2389 | 0.2422 | 0.2454 | 0.2486 | 0.2517 | 0.2549 |
| **0.70** | 0.2580 | 0.2611 | 0.2642 | 0.2673 | 0.2704 | 0.2734 | 0.2764 | 0.2794 | 0.2823 | 0.2852 |
| **0.80** | 0.2881 | 0.2910 | 0.2939 | 0.2967 | 0.2995 | 0.3023 | 0.3051 | 0.3078 | 0.3106 | 0.3133 |
| **0.90** | 0.3159 | 0.3186 | 0.3212 | 0.3238 | 0.3264 | 0.3289 | 0.3315 | 0.3340 | 0.3365 | 0.3389 |
| **1.00** | 0.3413 | 0.3438 | 0.3461 | 0.3485 | 0.3508 | 0.3531 | 0.3554 | 0.3577 | 0.3599 | 0.3621 |
| **1.10** | 0.3643 | 0.3665 | 0.3686 | 0.3708 | 0.3729 | 0.3749 | 0.3770 | 0.3790 | 0.3810 | 0.3830 |
| **1.20** | 0.3849 | 0.3869 | 0.3888 | 0.3907 | 0.3925 | 0.3944 | 0.3962 | 0.3980 | 0.3997 | 0.4015 |
| **1.30** | 0.4032 | 0.4049 | 0.4066 | 0.4082 | 0.4099 | 0.4115 | 0.4131 | 0.4147 | 0.4162 | 0.4177 |
| **1.40** | 0.4192 | 0.4207 | 0.4222 | 0.4236 | 0.4251 | 0.4265 | 0.4279 | 0.4292 | 0.4306 | 0.4319 |
| **1.50** | 0.4332 | 0.4345 | 0.4357 | 0.4370 | 0.4382 | 0.4394 | 0.4406 | 0.4418 | 0.4429 | 0.4441 |
| **1.60** | 0.4452 | 0.4463 | 0.4474 | 0.4484 | 0.4495 | 0.4505 | 0.4515 | 0.4525 | 0.4535 | 0.4545 |
| **1.70** | 0.4554 | 0.4564 | 0.4573 | 0.4582 | 0.4591 | 0.4599 | 0.4608 | 0.4616 | 0.4625 | 0.4633 |
| **1.80** | 0.4641 | 0.4649 | 0.4656 | 0.4664 | 0.4671 | 0.4678 | 0.4686 | 0.4693 | 0.4699 | 0.4706 |
| **1.90** | 0.4713 | 0.4719 | 0.4726 | 0.4732 | 0.4738 | 0.4744 | 0.4750 | 0.4756 | 0.4761 | 0.4767 |
| **2.00** | 0.4772 | 0.4778 | 0.4783 | 0.4788 | 0.4793 | 0.4798 | 0.4803 | 0.4808 | 0.4812 | 0.4817 |
| **2.10** | 0.4821 | 0.4826 | 0.4830 | 0.4834 | 0.4838 | 0.4842 | 0.4846 | 0.4850 | 0.4854 | 0.4857 |
| **2.20** | 0.4861 | 0.4864 | 0.4868 | 0.4871 | 0.4875 | 0.4878 | 0.4881 | 0.4884 | 0.4887 | 0.4890 |
| **2.30** | 0.4893 | 0.4896 | 0.4898 | 0.4901 | 0.4904 | 0.4906 | 0.4909 | 0.4911 | 0.4913 | 0.4916 |
| **2.40** | 0.4918 | 0.4920 | 0.4922 | 0.4925 | 0.4927 | 0.4929 | 0.4931 | 0.4932 | 0.4934 | 0.4936 |
| **2.50** | 0.4938 | 0.4940 | 0.4941 | 0.4943 | 0.4945 | 0.4946 | 0.4948 | 0.4949 | 0.4951 | 0.4952 |
| **2.60** | 0.4953 | 0.4955 | 0.4956 | 0.4957 | 0.4959 | 0.4960 | 0.4961 | 0.4962 | 0.4963 | 0.4964 |
| **2.70** | 0.4965 | 0.4966 | 0.4967 | 0.4968 | 0.4969 | 0.4970 | 0.4971 | 0.4972 | 0.4973 | 0.4974 |
| **2.80** | 0.4974 | 0.4975 | 0.4976 | 0.4977 | 0.4977 | 0.4978 | 0.4979 | 0.4979 | 0.4980 | 0.4981 |
| **2.90** | 0.4981 | 0.4982 | 0.4982 | 0.4983 | 0.4984 | 0.4984 | 0.4985 | 0.4985 | 0.4986 | 0.4986 |
| **3.00** | 0.4987 | 0.4987 | 0.4987 | 0.4988 | 0.4988 | 0.4989 | 0.4989 | 0.4989 | 0.4990 | 0.4990 |