Chi-Squared Tests  
Student Saturday Session  

Student Notes – Prep Session Topic: Chi-square Tests  

Content and Formula  
The AP Statistics topic outline contains the following item under  
IV. Statistical Inference  
B. Tests of Significance  
6. Chi-square test for goodness of fit, homogeneity of proportions, and independence (one- and two- way tables)  

The following formula is provided (it is the last formula on the formula sheet):  

\[ \text{Chi-square test statistic} = \sum \frac{(\text{observed-expected})^2}{\text{expected}} \]  

The following formula is not provided:  

\[ \text{expected count} = \frac{\text{(column total)(row total)}}{\text{table total}} \]  

Calculator Use  
You need to know how to use your calculator to do two-way tests (it consumes too much time to perform two-way tests by hand). Make sure you know how to enter the observed counts in a matrix and how to display the expected counts that are calculated and stored in a different matrix when the calculator test is performed.  

Your calculator may have a test option for performing a chi-square goodness of fit test. If so, you must enter both the observed and expected counts in lists (the calculator does not calculate the expected counts). If you do not have a chi-square goodness of fit test option on your calculator, you can enter the observed and expected counts in two lists, then create the list of components of (or contributions to) the chi-square statistic in a third list. You will need to find the sum of these contributions and use \( X^2 \text{cdf} \) to find the \( P \)-value The command is \( X^2 \text{cdf} (X^2, \text{infinity}, \text{df}) \) (or use the \( X^2 \) table provided with the exam to approximate the \( P \)-value).  

Reminders about concepts and communication---  
- Degrees of freedom for a chi-square goodness of fit test are: number of categories \(- 1\)  
- Degrees of freedom for a chi-square two-way test are: \( (r - 1)(c - 1) \)  
- Conditions for a chi-square test are:  
  1. Observed counts are based on random samples or observations are independent  
  2. Expected counts are at least 5 – note that some textbooks state a less conservative condition that all expected counts are at least 1 and no more than 20% of the expected counts are less than 5. Either of these is acceptable for checking the conditions  
- To verify that conditions are met, you must show all expected counts in your solution.  

- The chi-square test for homogeneity of proportions and the chi square test for independence are performed exactly the same way. However, they differ in the way the hypotheses are stated and in the way the data are collected.  
- Chi-square test for homogeneity of proportions …  
  1. Null hypothesis states that population proportions are equal while the alternative states that not all population proportions are equal.  
  2. The data are collected by taking independent samples from each population. So before the observed counts are recorded, marginal totals representing the sample sizes are known.  
  3. Rejecting the null hypothesis leads to the conclusion that not all population proportions are equal; this is different from concluding that all population proportions are different.
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• Chi-square test for independence (or association) …
  1. Null hypothesis states that there is no association between two categorical variables or that two
categorical variables are independent. The alternative hypothesis states that there is an association
between the variables or that the two variables are not independent.
  2. The data are collected by taking one sample from one population. Before the observed counts are
recorded, no marginal totals are known.
• The \( P \)-value for a chi-square test is the area under the chi-square density curve to the right of the test statistic
value. You never need to multiply this value by 2.
• If you reject the null hypothesis, you may need to do a follow-up analysis to determine which categories had
the largest contributions to the \( X^2 \)-value. Comparing observed and expected counts and examining the
values of the individual components enables you to see where the observed counts were most different than
what you would have expected if the null hypothesis were true.

Multiple Choice Questions from 2002 AP Exam

11. The following two-way table resulted from classifying each individual in a random sample of residents of a
small city according to level of education (with categories "earned at least a high school diploma" and "did
not earn a high school diploma") and employment status (with categories "employed full time" and "not
employed full time").

<table>
<thead>
<tr>
<th></th>
<th>Employed full time</th>
<th>Not employed full time</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earned at least a high school diploma</td>
<td>52</td>
<td>40</td>
<td>92</td>
</tr>
<tr>
<td>Did not earn a high school diploma</td>
<td>30</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>75</td>
<td>157</td>
</tr>
</tbody>
</table>

If the null hypothesis of no association between level of education and employment status is true, which of
the following expressions gives the expected number who earned at least a high school diploma and who are
employed full time?

A. \( \frac{92 \cdot 52}{157} \)

B. \( \frac{92 \cdot 82}{157} \)

C. \( \frac{82 \cdot 52}{92} \)

D. \( \frac{65 \cdot 52}{92} \)

E. \( \frac{92 \cdot 52}{82} \)
19. A geneticist hypothesizes that half of a given population will have brown eyes and the remaining half will be split evenly between blue- and green-eyed people. In a random sample of 60 people from this population, the individuals are distributed as shown in the table above. What is the value of the $X^2$ statistic for the goodness of fit test on these data?

<table>
<thead>
<tr>
<th></th>
<th>Brown Eyes</th>
<th>Green Eyes</th>
<th>Blue Eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>34</td>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>

A. Less than 1  
B. At least 1, but less than 10  
C. At least 10, but less than 20  
D. At least 20, but less than 50  
E. At least 50
5. Contestants on a game show spin a wheel like the one shown in the figure above. Each of the four outcomes on this wheel is equally likely and outcomes are independent from one spin to the next.
   - The contestant spins the wheel.
   - If the result is a skunk, no money is won and the contestant’s turn is finished.
   - If the result is a number, the corresponding amount in dollars is won. The contestant can then stop with those winnings or can choose to spin again, and his or her turn continues.
   - If the contestant spins again and the result is a skunk, all of the money earned on that turn is lost and the turn ends.
   - The contestant may continue adding to his or her winnings until he or she chooses to stop or until a spin results in a skunk.

A. What is the probability that the result will be a number on all of the first three spins of the wheel?

B. Suppose a contestant has earned $800 on his or her first three spins and chooses to spin the wheel again. What is the expected value of his or her total winnings for the four spins?
C. A contestant who lost at this game alleges that the wheel is not fair. In order to check on the fairness of the wheel, the data in the table below were collected for 100 spins of this wheel.

<table>
<thead>
<tr>
<th>Result</th>
<th>Skunk</th>
<th>$100</th>
<th>$200</th>
<th>$300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>33</td>
<td>21</td>
<td>20</td>
<td>26</td>
</tr>
</tbody>
</table>

Based on these data, can you conclude that the four outcomes on this wheel are not equally likely? Give appropriate statistical evidence to support your answer.
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AP® STATISTICS  
2003 SCORING GUIDELINES (Form B)

Question 5

Solution

Part (a):
P(a number on all 3 spins) = \((P(a \text{ number}))^3\) since the outcomes are independent from spin to spin
\[ = \left(\frac{3}{4}\right)^3 = 0.4219\]

Part (b):

<table>
<thead>
<tr>
<th>Winnings</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.25</td>
</tr>
<tr>
<td>900</td>
<td>0.25</td>
</tr>
<tr>
<td>1000</td>
<td>0.25</td>
</tr>
<tr>
<td>1300</td>
<td>0.25</td>
</tr>
</tbody>
</table>

\[E(\text{winnings}) = \sum x_i p_i = 0(0.25) + 900(0.25) + 1000(0.25) + 1300(0.25) = 800\]

Or

\[E(\text{winnings on 4th spin}) = \sum x_i p_i = -800(0.25) + 900(0.25) + 1000(0.25) + 500(0.25) = 0\]

So \(E(\text{winnings}) = \text{initial amount} + E(\text{winnings on 4th spin}) = 800 + 0 = 800\)

Part (c):

Element 1:
States a correct pair of hypotheses
\[H_0 : \text{The four outcomes are equally (} p_1 = p_2 = p_3 = p_4 = 0.25\)\]
\[H_A : \text{The four outcomes are not equally likely (or at least one proportions differs from } 0.25)\]

Element 2:
Identifies a correct test (by name or by formula) and checks appropriate conditions.

Chi Square Goodness of Fit Test OR \[\sum \frac{(\text{observed-expected})^2}{\text{expected}}\]

Conditions: Outcomes of spins of the wheel are independent and large sample size. The problem states that successive spins of the wheel are independent. The expected counts are all equal to 25, which is greater than 5 (or 10), so the sample size is large enough to proceed.

Element 3:
Correct mechanics, including the value of the test statistic, df, and p-value (or rejection region)
Expected counts: 25 for each of the 4 cells

\[X^2 = \sum \frac{(\text{observed-expected})^2}{\text{expected}} = \frac{(33-25)^2}{25} + \frac{(21-25)^2}{25} + \frac{(20-25)^2}{25} + \frac{(26-25)^2}{25} = 4.24\]

df = 3, p-value = .2367
(from tables p-value > 0.10, from Graphing Calculator: p-value = 0.23669, from table rejection region for \(\alpha = 0.05\) is 7.81, \(\alpha = 0.01\) is 11.34)
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Element 4:
Using the results of the statistical test, states a correct conclusion in the context of the problem.
Because the \( p \)-value is greater than the stated \( \alpha \) (or because the \( p \)-value is large, or because the test statistic does not fall in the rejection region), fail to reject \( H_0 \). There is not convincing evidence that the four outcomes on the wheel are not equally likely. That is, we don’t have convincing evidence against the conjecture that the four outcomes on the wheel are equally likely.

Scoring

Part (a): 1 for correct answer (including Binomial calculation) = 0.4219

\[
\frac{1}{2} \text{ if answer is } \frac{3}{4} \text{ or } \left( \frac{1}{2} \right)^3 = 0.0156 \text{ or } \left( \frac{1}{4} \right)^3 = 0.047 \text{ or } 0.4219 \text{ with no work shown.}
\]

Part (b): 1 if the expected value, 800, is correct (except for minor computational errors)

\[
\frac{1}{2} \text{ if expected value is computed as}
\]

\[800 + \text{expected winnings on one spin, or } 800 + 200 = 1000\]
\[E(\text{outcome on one spin}) = 200 \text{ but then solution breaks down}\]
\[E(\text{winnings on 4th spin}) = 0 \text{ but then solution breaks down}\]

\[\text{With fairly major computational errors (e.g., } \frac{3200}{3}\]

0 if
\[\text{answer of 800 is given but no work is shown or bad logic, e.g., } 4(200)\]
\[\text{expected value formula is given but no calculations are done}\]
\[\text{outcomes are set up correctly but no expected value is calculated}\]

Part (c): \( \frac{1}{2} \) for each element of the test that is correct

1. statement of hypotheses
2. identification of test and check of sample size condition
3. correct mechanics \( X^2 = 4.24, \text{df}=3, p\text{-value}=0.2367, \text{and/or } X^3_3,0.05 = 7.81\)
4. statement of conclusion (fail to reject)

If both an \( \alpha \) and a \( p \)-value are given, the linkage is implied. If no \( \alpha \) is given, the solution must be explicit about the linkage by giving a correct interpretation of the \( p \)-value or explaining how the conclusion follows from the \( p \)-value.

NOTE: If the \( p \)-value in element 3 is incorrect but the conclusion is consistent with the computed \( p \)-value, element 4 can be considered as correct.

4 Complete Response
Score of 4 from parts (a) through (c)

3 Substantial Response
Score of 3 from parts (a) through (c)

2 Developing Response
Score of 2 from parts (a) through (c)

1 Minimal Response
Score of 1 from parts (a) through (c)

IF A PAPER IS BETWEEN TWO SCORES (FOR EXAMPLE, 2 1/2 PARTS) USE A HOLISTIC APPROACH TO DETERMINE WHETHER TO SCORE UP OR DOWN DEPENDING ON THE STRENGTH OF THE RESPONSE AND COMMUNICATION.
(a) What is the probability that the result will be a number on all of the first three spins of the wheel?

$$\frac{3}{4} \times \frac{3}{4} \times \frac{3}{4} = .422$$

(b) Suppose a contestant has earned $800 on his or her first three spins and chooses to spin the wheel again. What is the expected value of his or her total winnings for the four spins?

$$800$$

$$\frac{1300 + 1000 + 900 + 0}{4} = 800$$

Based on these data, can you conclude that the four outcomes on this wheel are not equally likely? Give appropriate statistical evidence to support your answer.

$$H_0: P_1 = P_2 = P_3 = P_4 = .25$$

$$H_a:$$ at least one of the population proportions differ from its hypothesized value.

Test Statistic

$$X^2 = \sum \frac{(n_i - E(n_i))^2}{E(n_i)}$$

(where $P_i$ is probability of getting a skull, $P_2 = \text{probability of getting }$ $100$, $P_3 = \text{probability of getting }$ $200$, and $P_4 = \text{probability of getting }$ $500$)

Rejection Region

Set $\alpha = .05$. 7.81.

Reject $H_0$ if $X^2 > 7.81$.
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Assumptions

The samples are independent and randomly selected, and therefore a multinomial experiment.

Expected value test: (at least 5)

\[ 100 \times .25 = 25 \quad E(n_1) = E(n_2) = E(n_3) = E(n_4) = 25 \]

All expected values are greater than 5, so assumption is satisfied.

Calculations

\[ \chi^2 = \sum \frac{(n_i - E(n_i))^2}{E(n_i)} = 4.24 \quad \text{Ho not rejected} \]

Conclusions

Since the critical value of the test statistic does not fall in the rejection region, we don’t have enough evidence at a significance level of \( \alpha = .05 \) to claim that the four outcomes on the spin wheel (skunk, $100, $200, + $300) are not equally likely.

Sample A – Score 4

In part (a), the student performed the correct calculation and in part (b), the student found the correct outcomes and then averaged them. It could be clearer that this is an expected value calculation. In part (c), the student stated the correct hypotheses for a goodness of fit test (not only that the four probabilities are equal but also that they must equal 0.25) and gave excellent definitions of the parameters. The student stated that the expected values must be at least 5 and clearly calculated the expected counts to check this condition. The test statistic calculations are correct, though no work is shown, and the student has specified the rejection region. The conclusion compares the test statistic to the rejection region, comes to a correct decision, and is stated in context.
2003 #5

A random sample of 200 students was selected from a large college in the United States. Each selected student was asked to give his or her opinion about the following statement.

“The most important quality of a person who aspires to be the President of the United States is a knowledge of foreign affairs.”

Each response was recorded in one of five categories. The gender of each selected student was noted. The data are summarized in the table below.

<table>
<thead>
<tr>
<th>Response Category</th>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>

Is there sufficient evidence to indicate that the response is dependent on gender? Provide statistical evidence to support your conclusion.
Solution

Part 1: States a correct pair of hypotheses
$H_0$: Response and gender are independent
$H_A$: Response and gender are not independent

OR

$H_0$: There is no association between response and gender
$H_A$: There is an association between response and gender

Part 2: Identifies a correct test (by name or by formula) and checks appropriate conditions.
Chi-Square test (for independence)

$$X^2 = \sum \frac{(\text{observed-expected})^2}{\text{expected}}$$

Conditions: Random sample and large sample size. Expected counts are

<table>
<thead>
<tr>
<th>Response Category</th>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>13.5</td>
<td>18</td>
<td>18</td>
<td>22.5</td>
<td>18</td>
</tr>
<tr>
<td>Female</td>
<td>16.5</td>
<td>22</td>
<td>22</td>
<td>27.5</td>
<td>22</td>
</tr>
</tbody>
</table>

All expected counts are greater than 5 (or 10), so the sample size is large enough for the Chi-Square test to be appropriate. (Or, all expected counts are $\geq 1$, and no more than 20% of expected counts $< 5$.)

Part 3: Correct mechanics, including the value of the test statistic, df, and $P$-value (or rejection region)

$$X^2 = \sum \frac{(\text{observed-expected})^2}{\text{expected}} = \frac{(10-13.5)^2}{13.5} + \frac{(15-18)^2}{18} + \cdots + \frac{(15-22)^2}{22} = 8.921$$

$$\text{df} = 4, \quad P\text{-val} = 0.063$$

(Or, using tables, $0.05 < P\text{-value} < 0.10$, or rejection regions: $\alpha = 0.05$ is 9.48, $\alpha = 0.01$ is 13.27)

Part 4: Stating a correct conclusion in the context of the problem, using the result of the statistical test.

Because $P$-value $> \alpha$ (or because $X^2$ is not in the rejection region, or because the $P$-value is large), fail to reject the null hypothesis. There is not sufficient evidence to conclude that response is dependent on gender (or that response and gender are not independent, or that response and gender are associated)

OR

Because results this extreme would occur about 6 times in 100 by chance alone, there is marginal evidence to reject the null hypothesis and conclude that there is an association between response and gender.

Scoring

Note that the solution has 4 parts and each part is either correct or incorrect. No partial credit is given for individual parts.

4 Complete Response
Four parts are correct.

3 Substantial Response
Three parts are correct.

2 Developing Response
Two parts are correct.

1 Minimal Response
Only one part is correct.
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<table>
<thead>
<tr>
<th>Response Category</th>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Somewhat Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>

Is there sufficient evidence to indicate that the response is dependent on gender? Provide statistical evidence to support your conclusion.

**H₀:** There is no relationship between the response and gender

**H₁:** There is a relationship between the response and gender

\[
\chi^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}
\]

\[
\chi^2 = \frac{(10-13.5)^2}{13.5} + \frac{(15-18)^2}{18} + \frac{(15-18)^2}{18} + \frac{(25-22.5)^2}{22.5} + \frac{(25-18)^2}{18} + \frac{(20-16.5)^2}{16.5} + \frac{(25-22)^2}{22} + \frac{(25-22)^2}{22} + \frac{(25-27.5)^2}{27.5} + \frac{(15-22)^2}{22}
\]

\[
\chi^2 = 8.92
\]

**p-value = .063**

**Conclusions**

- 6.3% of the time the observed values would occur by chance alone if there was no relationship between response and gender.
- Moderate evidence supporting the claim that there is a relationship between gender and response.

**Assumptions**

- Simple Random Sample from population of interest
  - Yes - it says the sample was random.
- All individual expected counts are ≥ 5
  - Yes - the smallest expected count was 13.5.

---

**Sample B – Score 4**

The statement of the hypotheses is correct, although the use of the word “association” is preferred over the use of the word “relationship.” The assumptions for the test are given at the bottom of the response, and it is clear that the student inspected all 10 of the expected cell counts because these are displayed in the calculation of the Chi-square statistic. A complete interpretation in context of the p-value is given; not specifying the number of degrees of freedom was considered only a minor error.
2. The Colorado Rocky Mountain Rescue Service wishes to study the behavior of lost hikers. If more were known about the direction in which lost hikers tend to walk, then more effective search strategies could be devised. Two hundred hikers selected at random from those applying for hiking permits are asked whether they would head uphill, downhill, or remain in the same place if they became lost while hiking. Each hiker in the sample was also classified according to whether he or she was an experienced or novice hiker. The resulting data are summarized in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Uphill</th>
<th>Downhill</th>
<th>Remain in Same Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>20</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Experienced</td>
<td>10</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

Do these data provide convincing evidence of an association between the level of hiking expertise and the direction the hiker would head if lost? Give appropriate statistical evidence to support your conclusion.
Solution:
States a correct pair of hypotheses
\( H_0 : \) There is no association between level of hiking experience and direction
\( H_A : \) There is an association between level of hiking experience and direction

OR
\( H_0 : \) Level of hiking experience and direction are independent
\( H_A : \) Level of hiking experience and direction are not independent

Identifies a correct test (by name or by formula) and checks appropriate conditions.
Chi-Square test (for independence)
\[ X^2 = \sum \frac{(\text{observed}-\text{expected})^2}{\text{expected}} \]

Requirements: Need to check expected counts using some accepted rule (textbooks differ).
Table of Observed and (Expected Counts):

<table>
<thead>
<tr>
<th></th>
<th>Direction</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uphill</td>
<td>Downhill</td>
<td>Remain in Same Place</td>
</tr>
<tr>
<td>Novice</td>
<td>18</td>
<td>48</td>
<td>54</td>
</tr>
<tr>
<td>Experienced</td>
<td>12</td>
<td>32</td>
<td>36</td>
</tr>
</tbody>
</table>

\[ X^2 = \left( \frac{20-18}{18} \right)^2 + \left( \frac{50-48}{48} \right)^2 + \cdots + \left( \frac{40-36}{36} \right)^2 = 1.5046 \]

\[ df = 2, \ P\text{-value} = 0.471 \text{ OR (using tables) } P\text{-value} > 0.25 \]

Since the P-value is large for any reasonable level of significance, we fail to reject \( H_0 \). (A picture showing an appropriate rejection region and the test statistic value is acceptable). There is not convincing evidence that an association exists between level of hiking expertise and direction.

Note:
For rejection region approach, rejection regions are
\( X^2 > 9.21 \) or significance level 0.01,
\( X^2 > 5.99 \) for significance level 0.05,
\( X^2 > 4.61 \) for significance level 0.10

A complete response constitutes
a. Stating a correct set of hypotheses,
b. Identifying appropriate test & checking appropriate assumptions,
c. Providing correct mechanics, and
d. Stating correct conclusion in the context of the problem using results of the statistical test.

Part (a) Stating a correct set of hypotheses,
- States null and alternative hypothesis correctly defining any notations used.
- Both hypotheses are stated in the context of problem.

Note: If a student switches the null and alternative hypotheses, then no credit will be given for part (a).
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Part (b) Identifying appropriate test & checking appropriate requirements,
- Gives some indication of using a correct statistical test by naming the test, by giving correct symbol or formula for the test statistic.
- Checks requirements. In this case, expected counts are greater than or equal to 5. Some indication of use of expected counts in checking requirements is needed.

Note: If a wrong statistical test is performed, then no credit is given for section (b).

Part (c) Providing correct mechanics,
- Gives the computed test statistic value correctly.
- Gives the associated P-value correctly (the rejection region approach is acceptable)

Note: One minor computational error will not necessarily drop the score to a 3.

Part (d) Stating correct conclusion in the context of the problem using results of the statistical test.
- Uses test results correctly to arrive at the conclusion (either p-value approach or the rejection region approach). Linkage between the conclusion and the test result must be stated clearly. Correct interpretation of a P-value is acceptable as a statistical linkage.
- Writes conclusion in the context of the problem consistent with the defined hypotheses.

Note: If a student applies rejection rule incorrectly, then no credit will be given for part (d).

Points:
4 Complete Response
Essentially correct responses on all 4 parts.

3 Substantial Response
Essentially correct responses on any 3 of the 4 parts.
OR
Essentially correct responses on any 2 of the 4 parts and partially correct responses on the remaining 2 parts.

2 Developing Response
Essentially correct responses on any 2 of the 4 parts.
OR
Essentially correct response on any 1 of the 4 parts and partially correct responses on any 2 of the remaining 3 responses.
OR
Partially correct responses on all 4 parts.

1 Minimal Response
Essentially correct response on 1 of the 4 parts.
OR
Partially correct responses on 2 or 3 of the 4 parts.

Notes:
1. Maximum score of 2 if the student does a Chi-square on the proportions rather than the counts.
2. Some students may attempt to do the problem using two-proportion tests. Bring these solutions to the table leaders.
3. Score is 0 if there is no statistical test used (e.g. conclusion based on the comparison of proportions only).