ACCURACY AND PRECISION

Definitions:

Accuracy - how close a measurement is to ______________________________

Precision - how close a measurement is to ______________________________

Precision versus Accuracy:
Look at each target and decide whether the “hits” are accurate, precise, both accurate and precise, or neither accurate nor precise: (Note: An accurate “hit” is a bulls eye!)

<table>
<thead>
<tr>
<th>Accurate?</th>
<th>Precise?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes / No</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

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<thead>
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<th>Precise?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes / No</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

Precision Problems:

A group of students worked in separate teams to measure the length of an object. Here are their data:

<table>
<thead>
<tr>
<th>Team 1</th>
<th>Team 2</th>
<th>Team 3</th>
<th>Team 4</th>
<th>Team 5</th>
<th>Team 6</th>
<th>Team 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.65 cm</td>
<td>2.75 cm</td>
<td>2.80 cm</td>
<td>2.77 cm</td>
<td>2.60 cm</td>
<td>2.65 cm</td>
<td>2.68 cm</td>
</tr>
</tbody>
</table>

- The average length is ________ cm.
  This is the mean or average.

- Subtract the highest value from the lowest value: ________ cm.
  This is the range or spread.

- Divide this number by 2: ________ cm.
  This is the approximate ± range from the average.

- The precision of the measurement can be shown as average ± range.
  The precision of the measurement was ________±______ cm.
A second group of students obtained the following data:

<table>
<thead>
<tr>
<th>Team 8</th>
<th>Team 9</th>
<th>Team 10</th>
<th>Team 11</th>
<th>Team 12</th>
<th>Team 13</th>
<th>Team 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.60 cm</td>
<td>2.70 cm</td>
<td>2.80 cm</td>
<td>2.75 cm</td>
<td>2.65 cm</td>
<td>2.62 cm</td>
<td>2.78 cm</td>
</tr>
</tbody>
</table>

- The average length is ________ cm.
- The precision of the measurement was ________ ± ______ cm.

In comparing groups, the first or the second, which group was more precise or was the precision the same? **Justify your answer.**

**Expressing Errors in Measurement:**
Scientists often express their uncertainty and error in measurement by giving a percent error. The percent error is defined as:

\[
\% \text{ error} = \frac{\text{actual value} - \text{measured value}}{\text{actual value}} \times 100
\]

Answer the following four questions. Pay attention to significant figures, and **show your work**!

1. While doing a lab, a student found the density of a piece of pure aluminum to be 2.85 g/cm³. The accepted value for the density of aluminum is 2.70 g/cm³. What was the student’s percent error?
2. A student measured the specific heat of water to be 4.29 J/g · °C. The literature value of the specific heat of water is 4.18 J/g · °C. What was the student’s percent error?

3. A student took a calibrated 200.0 gram mass, weighed it on a laboratory balance, and found it read 196.5 g. What was the student’s percent error?

4. Accuracy is often expressed as an average of several measurements. Look at the target to the right. In your opinion, how well do the measurements on the target represent: (Justify your opinion.)

   a. Accuracy?

   b. Precision?
Ch2 Accuracy and Precision

Multiple Choice
Identify the choice that best completes the statement or answers the question.

1. The accepted value is 29.35. Which correctly describes this student’s experimental data?

<table>
<thead>
<tr>
<th>Trial</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.48</td>
</tr>
<tr>
<td>2</td>
<td>28.97</td>
</tr>
<tr>
<td>3</td>
<td>29.27</td>
</tr>
</tbody>
</table>

a. accurate but not precise  
b. precise but not accurate  
c. both accurate and precise  
d. neither accurate nor precise

2. The accepted value is 1.43. Which correctly describes this student’s experimental data?

<table>
<thead>
<tr>
<th>Trial</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.29</td>
</tr>
<tr>
<td>2</td>
<td>1.93</td>
</tr>
<tr>
<td>3</td>
<td>0.88</td>
</tr>
</tbody>
</table>

a. accurate but not precise  
b. precise but not accurate  
c. both accurate and precise  
d. neither accurate nor precise

3. The accepted value is 15.63. Which correctly describes this student’s experimental data?

<table>
<thead>
<tr>
<th>Trial</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.84</td>
</tr>
<tr>
<td>2</td>
<td>13.02</td>
</tr>
<tr>
<td>3</td>
<td>12.96</td>
</tr>
</tbody>
</table>

a. accurate but not precise  
b. precise but not accurate  
c. both accurate and precise  
d. neither accurate nor precise

4. Which is the term used for the measurement of the average kinetic energy of the particles of a substance?

a. density  
b. temperature  
c. length  
d. mass

5. The reason for organizing, analyzing, and classifying data is

a. so that computers can be used.  
b. to prove a law.  
c. to find relationships among the data.  
d. to separate qualitative and quantitative data.

6. Poor precision in scientific measurement may arise from

a. the standard being too strict.  
b. human error.  
c. limitations of the measuring instrument.  
d. both human error and the limitations of the measuring instrument.

7. Precision pertains to all of the following except

a. reproducibility of measurements.  
b. agreement among numerical values.  
c. sameness of measurements.  
d. closeness of a measurement to an accepted value.

8. Five darts strike near the center of the target. Whoever threw the darts is

a. accurate.  
b. precise.  
c. both accurate and precise.  
d. neither accurate nor precise.

9. A chemist who frequently carries out a complex experiment is likely to have high

a. accuracy, but low precision.  
b. accuracy.  
c. precision.  
d. precision, but low accuracy.

10. When applied to scientific measurements, the words accuracy and precision

a. are used interchangeably.  
b. have limitations.  
c. can cause uncertainty in experiments.  
d. have distinctly different meanings.
A student conducts an experiment to determine the effect of adding salt on the boiling temperature of water. The results are shown below.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Amount of Salt</th>
<th>Boiling Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>0 g</td>
<td>100.0° C</td>
</tr>
<tr>
<td>Sample 2</td>
<td>2 g</td>
<td>102.3° C</td>
</tr>
<tr>
<td>Sample 3</td>
<td>5 g</td>
<td>104.8° C</td>
</tr>
<tr>
<td>Sample 4</td>
<td>10 g</td>
<td>107.5° C</td>
</tr>
</tbody>
</table>

16. The student graphs this data using the axes shown. Is this graph correct? Explain your answer.

17. The mass of a 3.45-g piece of aluminum was measured several times. The measured masses were 2.67 g, 2.59 g, 2.60 g, and 2.64 g. Use these results to explain the difference between accuracy and precision.

Problem

18. Analyze the table and determine which student reported the most precise data.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Student A Data (Mass in grams)</th>
<th>Student B Data (Mass in grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.43</td>
<td>5.43</td>
</tr>
<tr>
<td>2</td>
<td>5.45</td>
<td>5.47</td>
</tr>
<tr>
<td>3</td>
<td>5.44</td>
<td>5.50</td>
</tr>
<tr>
<td>4</td>
<td>5.43</td>
<td>5.53</td>
</tr>
</tbody>
</table>

Essay

19. Student A says: “It is impossible to get a perfectly exact measurement because every measuring device is limited in how many decimal places it can measure accurately.”
   Student B says: “If I had better equipment I would be able to make accurate measurements.”
   Student C says: “You would be able to make accurate measurements if you knew how to do it properly. Let me do it.”

Who is right? Justify your answer.
11. Using the same balance, a chemist obtained the values 5.224 g, 5.235 g, and 5.25 g for the mass of a sample. These measurements have
a. good precision.
b. good accuracy.
c. poor precision.
d. poor accuracy.

<table>
<thead>
<tr>
<th>Mass Data of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Trial 1</td>
</tr>
<tr>
<td>__________</td>
</tr>
<tr>
<td>Student A</td>
</tr>
<tr>
<td>Student B</td>
</tr>
<tr>
<td>Student C</td>
</tr>
<tr>
<td>Student D</td>
</tr>
</tbody>
</table>

12. Four students each measured the mass of one 1.43 g sample four times. The results in the table above indicate that the data collected by ____ reflect the greatest accuracy and precision.

a. Student A
c. Student C
b. Student B
d. Student D

Completion
Complete each statement.

13. A laboratory balance is not adjusted correctly, and each mass measured is 0.54 g too high. A student finds the mass of a sample several times, and the masses are close to each other. The results are __________ but not __________.

14. A measurement that closely agrees with accepted values is said to be ________________.

Short Answer

15. The data for two different measurements are shown below. Which experiment was more accurate? Explain your answer.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Measured value</th>
<th>Accepted value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>54,700 m</td>
<td>57,900 m</td>
</tr>
<tr>
<td>Mass</td>
<td>61.3 g</td>
<td>65.7 g</td>
</tr>
</tbody>
</table>
Ch2 Accuracy and Precision
Answer Section

MULTIPLE CHOICE

1. ANS: C PTS: 1 DIF: Bloom's Level 4
   NAT: UCP.2 | A.1 | A.2 STA: 11.A.5d

2. ANS: D PTS: 1 DIF: Bloom's Level 4
   NAT: UCP.2 | A.1 | A.2 STA: 11.A.5d

3. ANS: B PTS: 1 DIF: Bloom's Level 4
   NAT: UCP.2 | A.1 | A.2 STA: 11.A.5d

4. ANS: B PTS: 1 DIF: Bloom's Level 2
   NAT: UCP.2 | UCP.3 STA: 11.A.4c

5. ANS: C PTS: 1 DIF: I OBJ: 2.2.1

6. ANS: D PTS: 1 DIF: II OBJ: 2.3.1

7. ANS: D PTS: 1 DIF: I OBJ: 2.3.1

8. ANS: C PTS: 1 DIF: II OBJ: 2.3.1

9. ANS: C PTS: 1 DIF: II OBJ: 2.3.1

10. ANS: D PTS: 1 DIF: I OBJ: 2.3.1

11. ANS: C PTS: 1 DIF: II OBJ: 2-3.1

12. ANS: B PTS: 1 DIF: II OBJ: 2-3.1

COMPLETION

13. ANS: precise, accurate
    PTS: 1 DIF: II OBJ: 2.3.1

14. ANS: accurate
    PTS: 1 DIF: I OBJ: 2.3.1

SHORT ANSWER

15. ANS:
The distance measurement has an error of 5.53%. The mass measurement has an error of 6.70%. Therefore, distance was measured more accurately.

   PTS: 1 DIF: Bloom's Level 6 NAT: UCP.2 | UCP.3 STA: 11.A.5d

16. ANS:
The independent variable should be placed on the X axis, and the dependent variable on the Y axis. This graph is correct as shown.

   PTS: 1 DIF: Bloom's Level 6 NAT: UCP.2 STA: 11.A.4c
17. ANS:
Because the masses were close to each other, they were precise. Because they were not close to the accepted value of the mass, they were not accurate.

PTS: 1   DIF: II   OBJ: 2.3.1

PROBLEM

18. ANS:
Student A reported the most precise data.

PTS: 1   DIF: 1   REF: Page 36
OBJ: 2.3.1 Define and compare accuracy and precision.   STA: 11.A.4d | 11.A.5d
TOP: Define and compare accuracy and precision.   KEY: Mass | Precision
MSC: 3   NOT: The measurements that are closest to each other are the most precise.

ESSAY

19. ANS:
All of the students display part of the truth. Student B is correct in saying that better equipment can result in a greater degree of accuracy. Student C brings up a good point that knowing how to use a measuring tool properly can increase accuracy. However, it is Student A who really seems to understand the limits of measurement. No tool can measure to an infinite number of places; this is why we record significant digits as the known values plus one estimated value. As measurement scales get smaller and smaller, there is still a way to estimate between the markings on any scale.

PTS: 1   DIF: Bloom's Level 6   NAT: UCP.3 | A.2
STA: 11.A.4c