What is the length of this line?

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**US Customary System (USC)**

- Based on things that made sense to people
- Previously known as English (or British)
- 1 inch = 3 dry, round, barleycorns end-to-end
- 1 foot = length of King Edward I’s foot
- 1 mile = 1000 double paces of Roman soldier
- 12 in/ft; 4 in/hand; 3 ft/yd; 5280 ft/mile
Systeme Internationale (SI)

- Commonly called metric system, although different
- Attempted to be less arbitrary
- Example: 1 meter
  - original: one ten-millionth of the distance from the equator to either pole
  - current: based on wavelength of light
- Based on powers of 10

Prefixes

<table>
<thead>
<tr>
<th>$10^{-1}$</th>
<th>Deci-</th>
<th>$10^1$</th>
<th>Deca-</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-2}$</td>
<td>Centi-</td>
<td>$10^2$</td>
<td>Hecto-</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>Milli-</td>
<td>$10^3$</td>
<td>Kilo-</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>Micro-</td>
<td>$10^6$</td>
<td>Mega-</td>
</tr>
<tr>
<td>$10^{-9}$</td>
<td>Nano-</td>
<td>$10^9$</td>
<td>Giga-</td>
</tr>
<tr>
<td>$10^{-12}$</td>
<td>Pico-</td>
<td>$10^{12}$</td>
<td>Tera-</td>
</tr>
</tbody>
</table>

Only prefixes with powers of three are officially part of SI system. We will use centimeter, as it is the same order of magnitude as an inch.
SI Units

■ Fundamental (Base)
- Time second sec
- Length meter m
- Mass kilogram kg
- Temperature kelvin K
- Amount of substance mole mol
- Electric current ampere A
- Intensity of light candela cd

■ Some Derived Units
- Hertz Hz frequency /s
- Newton N force kg·(m/s²)
- Pascal Pa pressure N/m²
- Joule J energy or work N·m
- Watt W power J/s
- °Celsius °C temperature K - 273.15
- Radian rad plane angle m/m
- Steradian sr solid angle m²/m²
SI Units

- Units of Some Physical Quantities
  - Speed $v$ m/s
  - Acceleration $a$ m/s$^2$
  - Angular speed $\omega$ rad/s
  - Angular acceleration $\alpha$ rad/s$^2$
  - Torque $\tau$ N-m
  - Heat flow $Q$ J
  - Entropy $S$ J/K
  - Thermal conductivity $k$ W/(m·K)

US Customary Units

- Fundamental (Base)
  - Time second sec
  - Length foot ft
  - Force pound lb
  - Temperature °Fahrenheit °F
US Customary Units

- **Some Derived Units**
  - Hertz (Hz) frequency /s
  - Slug mass (lb·s²)/ft
  - psi pressure lb/in²
  - Foot-Pound energy or work ft·lb
  - Horsepower (hp) power 550 ft-lb/s
  - Degree ° plane angle
  - Steradian (sr) solid angle ft²/ft²

US Customary Units

- **Units of Some Physical Quantities**
  - Speed v ft/s
  - Acceleration a ft/s²
  - Angular speed ω rad/s
  - Angular acceleration α rad/s²
  - Torque τ ft-lb
  - Heat Q BTU
  - Entropy S BTU/°F
  - Thermal conductivity k (BTU/hr) ft °F
Conversion Factors

- \(2.54 \text{ cm} = 1 \text{ in} \) (exact)
- \(1 \text{ lb} = 4.448222 \text{ N}\)
- \(\ ^\circ\text{F} = K \times 1.8 - 459.67\)
- Example:
Units: Angles

- Common unit: degree
- Why are there 360 degrees in a circle?
  - convenience
  - divisible by 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 16, 18
- Degrees are sub-divided into 60 minutes
  - minute subdivided into 60 seconds.
  - Notation 43°18′37″ = 43 degrees, 18 minutes, 37 seconds
- Radians are often required to measure angles
  - angle defines an arc on the circle’s circumference
  - ratio of arc length to circle radius is angle in radians
  - dimensionless

\[
\theta = \frac{s}{r}
\]

Significant Figures

Significant figures: communicate level of uncertainty.

If we say the length of a line is 12.7”, what does that mean?

How is it different if we say the length of a line is 12.70”?

The numbers you put down communicate the level of precision, or how sure you are of the number.
Significant Figures: Illustrations

1. Locator 0’s to the right of the decimal don’t count.
   
   Example: 0.0032 has 2 significant figures.
   
   Illustration: Expressing a distance of 3.2 meters as 0.0032 km does not change the precision.

2. Definitions are exact

   Example: Conversion between inches and cm is exactly 2.54 cm / inch

   *Using this conversion in a calculation will have NO impact on the number of significant figures in the result.*

Significant Figures: Rounding

Round off **after calculations**
(prevents accumulation of error)

Example:

\[(3.24)(1.96) - (2.56)(2.48) = 6.3504 - 6.3488 = 0.0016\]

If you round each product to three significant figures, you get zero when you subtract.

If you round each product to two significant figures, you get 0.1 as the answer.
Significant Figures: Multiplication

Round to number of significant figures in the least precise term in multiplication or division

Example: $0.1742 \times 0.216 \times 0.0013 = 0.000048915 = 0.000049$ round to 2 significant figures.

Illustration: We measure a chair to be 19" wide.
- $19" = 482.6 \text{ mm}$
- Can we really measure chair to 0.1 mm?
- How big is 0.1 mm? Express width as 480 mm.

Illustration: Consider the volume of a cube, which is $s^3$.
- If $s=4.36 \text{ cm}$, $V = 82.881856 \text{ cm}^3$
- $s$ could be as small as $4.355 \text{ cm}$, $V = 82.597 \text{ cm}^3$
- $s$ could be as great as $4.365 \text{ cm}$, $V = 83.167 \text{ cm}^3$
- There is uncertainty even in the 2nd significant figure!

Significant Figures: Addition

Keep the least number of places to the right of the decimal in addition and subtraction

Example: $1725.463 + 189.2 + 16.73 = 1931.393 = 1931.4$
- Least number of places to right of decimal is one place.

Illustration: Distance from Nashville to point A is 189 miles.
Consider a point B which is 4.00 inches (0.0000631 miles) further from Nashville than point A.
- Is the distance from Nashville to point B 189.0000631 miles?
  - A  B
Significant Figures: Confusion

Illustration: Distance from Knoxville to Atlanta is 200 miles.

Do we know the distance to 1, 2, of 3 SF?

We could use words to clarify.
Distance from Knoxville to Atlanta is about 200 miles.
Distance from Knoxville to Atlanta is exactly 200 miles.

Better way – Scientific Notation

Significant Figures: Summary

- Use all available significant figures in calculations
- Be realistic about the number of significant figures you report
  - How precisely do you know the reported value?
- Full credit on exams requires appropriate use of significant figures
**Accuracy vs. Precision**

**Accuracy**, in science, engineering, industry and statistics, is the degree of conformity of a measured/calculated quantity to its actual (true) value.

**Precision** (also called reproducibility or repeatability) is the degree that further measurements or calculations will show the same or similar results.

<table>
<thead>
<tr>
<th></th>
<th>Inaccurate</th>
<th>Accurate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imprecise</td>
<td>The shots are not clustered (not precise) nor near the center (not accurate).</td>
<td>The shots are not clustered (not precise) but near the center (accurate).</td>
</tr>
<tr>
<td>Precise</td>
<td>The shots are clustered (precise) but not near the center (not accurate).</td>
<td>The shots are clustered (precise) and near the center (accurate).</td>
</tr>
</tbody>
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**Central Tendency**

- For a given data set, we can characterize or measure the “center” in a variety of ways:
  - **Mode**: the most common (frequent) value.
  - **Median**: the “middle value.” The smallest number such that at least half the numbers in the list are no greater than it. If the list has an odd number of entries, the median is the middle entry in the list after sorting the list into increasing order. If the list has an even number of entries, the median is equal to the sum of the two middle (after sorting) numbers divided by two.

The Shodor Education Foundation, Inc.: [http://www.shodor.org/interactivate/dictionary/m.html](http://www.shodor.org/interactivate/dictionary/m.html)
Central Tendency

- For a given data set, we can characterize or measure the “center” in a variety of ways:
  - **Mean (arithmetic):** The sum of a list of numbers, divided by the total number of numbers in the list. Usually referred to as the average.

\[
\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]

Data Variation

- For a given data set, we can characterize the “variation” in the data in a variety of ways:
  - **Variance and Standard Deviation:** measures the “spread” in the data.

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance</td>
<td>( \sigma^2 = \frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2 )</td>
<td>( s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2 )</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>( \sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2} )</td>
<td>( s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2} )</td>
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</tbody>
</table>

Data Variation

For a given data set, we can characterize the “variation” in the data in a variety of ways:

- **Coefficient of Variation**: unit independent. It “normalizes” the variation measurement.

\[
CV = \frac{\sigma}{\bar{x}} \quad \text{Population} \\
CV = \frac{s}{\bar{x}} \quad \text{Sample}
\]

Example