Some Useful Conversions for Linear Measurements

- British vs. SI

The Size of Things

- Always a good idea to have a physical feel for the size of things
  - The thickness of this paper = __________
  - The diameter of a human hair = __________
  - Computer disk track spacing = __________
  - Visible light wavelength (mid-spectrum) = __________
  - Size of a typical virus = __________
  - Atomic diameter = __________
Angular dimensions

- Dividing the circle
  - \( C = 2\pi R \)
  - 360 degrees (sexagesimal system - Babylonian?)
  - 60 minutes/degree = 21,600 arc-min
    - 1 min = about 0.0167 deg.
  - 60 seconds/minute = 1,296,000 arc-sec
    - 1 sec = about 2.78E-4 deg.
  - 2\pi radians
    - 1 microradian = about 57.3E-6 deg
    - = about 206.3E-3 arc-sec

The Size of Things, cont.

- Angular displacements
  - The distance at which a baseball (3 in. diameter) will subtend a given angle: \( R = 3 \text{ in.} \)

<table>
<thead>
<tr>
<th>Angle, deg</th>
<th>R, feet</th>
<th>R, miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>859.4</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1432.4</td>
<td></td>
</tr>
<tr>
<td>1 arc min</td>
<td>51566.2</td>
<td>9.8</td>
</tr>
<tr>
<td>1 arc sec</td>
<td>250000.0</td>
<td>47</td>
</tr>
<tr>
<td>1 micro rad</td>
<td>100 arc sec/year</td>
<td></td>
</tr>
</tbody>
</table>

Accuracy and Precision (Repeatability)

- The Target Analogy:
### Accuracy and Precision, cont.

- **Accuracy**
  - Has to do with the comparison of results with a standard or with desired results.
  - The deviation of the measured value from the ‘true’ value
  - (‘How close did we get to the target?’)
  - Ex: Difference between commanded move and actual move

- **Precision (repeatability)**
  - Has to do with the dispersement of the results.
  - The scatter of results obtained when attempts to repeat a given operation.
  - (‘How scattered are the results?’)
  - Ex: Scatter in results from repeated moves in a translation stage.

### Repeatability, cont.

- Where does the scatter come from?
  - Influences inherent in the design and effects that have not been controlled by the designer.
  - Ex: backlash, hysteresis, frictional effects, temperature, vibration.
  - Can quantify the repeatability for normally distributed phenomena:

  "The basic idea is that machine tools obey cause and effect relationships that are within our ability to understand and control and that there is nothing random or probabilistic about their behavior. Everything happens for a reason and the list of reasons is small enough to manage." J. Bryan, “The Power of Deterministic Thinking in Machine Tool Accuracy,” First Int. Mach. Tool Eng. Conf. Tokyo, Nov., 1984

### Resolution

- The smallest discernible change in the parameter of interest that can be detected by the instrument, or
- The smallest positional increment that can be commanded of a motion control system.