Physics 207 – Lecture 2

Agenda for Today

- Chapter 1, Chapter 2.1, 2.2
- Units and length scales
- Order of magnitude calculations
- Significant Digits
- Position, Displacement
- Velocity, Speed

Assignment: Finish reading Ch. 2, begin Chapter 3 (3.1 and 3.2)
- Acceleration, Direction (vectors)
- WebAssign Problem Set 1

Distance____ Length:
Radius of Visible Universe 1 x 10^26
To Andromeda Galaxy 2 x 10^12
To nearest star 4 x 10^16
Earth to Sun 1.5 x 10^11
Radius of Earth 6.4 x 10^6
Skys Tower 4.5 x 10^3
Football Field 1.0 x 10^2
Tail person 2 x 10^1
Thickness of paper 1 x 10^-2
Wavelength of blue light 4 x 10^-7
Diameter of hydrogen atom 1 x 10^-10
Diameter of proton 1 x 10^-15

Length:
Distance
Length (m)
Radius of Visible Universe 1 x 10^26
To Andromeda Galaxy 2 x 10^12
To nearest star 4 x 10^16
Earth to Sun 1.5 x 10^11
Radius of Earth 6.4 x 10^6
Skys Tower 4.5 x 10^3
Football Field 1.0 x 10^2
Tail person 2 x 10^1
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Order of Magnitude Calculations / Estimates

Questions: What is the earth’s radius in meters?

- Need to know something from your experience:
  - Flying from NYC to SF one accumulates ~ 3,000 miles
  - NYC to SF spans about 1/8 of the Earth’s circumference
  - Since circumference of a circle is: \( L = 2\pi r \)
  - Estimate of Earth radius:

\[
 r = \frac{L}{2\pi} = \frac{24,000 \text{ mi}}{6} = 4,000 \text{ mi}
\]

4 x 10^3 mi = 4 x 10^3 mi x 1.6 km/mi x 10 m/km = 6.4 x 10^6 m

Time:

<table>
<thead>
<tr>
<th>Interval</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of Universe</td>
<td>5 x 10^17</td>
</tr>
<tr>
<td>Age of Grand Canyon</td>
<td>3 x 10^10</td>
</tr>
<tr>
<td>Avg age of college student</td>
<td>6.3 x 10^9</td>
</tr>
<tr>
<td>One year</td>
<td>3.2 x 10^7</td>
</tr>
<tr>
<td>One hour</td>
<td>3.6 x 10^4</td>
</tr>
<tr>
<td>Light travel from Earth to Moon</td>
<td>1.3 x 10^9</td>
</tr>
<tr>
<td>One cycle of guitar A string</td>
<td>2 x 10^3</td>
</tr>
<tr>
<td>One cycle of FM radio wave</td>
<td>6 x 10^-4</td>
</tr>
<tr>
<td>One cycle of visible light</td>
<td>1 x 10^-10</td>
</tr>
<tr>
<td>Time for light to cross a proton</td>
<td>1 x 10^-15</td>
</tr>
</tbody>
</table>

Mass:

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible universe</td>
<td>~ 10^31</td>
</tr>
<tr>
<td>Milky Way galaxy</td>
<td>7 x 10^41</td>
</tr>
<tr>
<td>Sun</td>
<td>2 x 10^30</td>
</tr>
<tr>
<td>Earth</td>
<td>6 x 10^24</td>
</tr>
<tr>
<td>Boeing 747</td>
<td>4 x 10^5</td>
</tr>
<tr>
<td>Car</td>
<td>1 x 10^3</td>
</tr>
<tr>
<td>Student</td>
<td>7 x 10^2</td>
</tr>
<tr>
<td>Dust particle</td>
<td>1 x 10^-1</td>
</tr>
<tr>
<td>Bacterium</td>
<td>1 x 10^-14</td>
</tr>
<tr>
<td>Proton</td>
<td>2 x 10^-17</td>
</tr>
<tr>
<td>Electron</td>
<td>9 x 10^-19</td>
</tr>
</tbody>
</table>

Some Prefixes for Power of Ten

<table>
<thead>
<tr>
<th>Power</th>
<th>Prefix</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^-15</td>
<td>femto</td>
<td>f</td>
</tr>
<tr>
<td>10^-12</td>
<td>pico</td>
<td>p</td>
</tr>
<tr>
<td>10^-9</td>
<td>nano</td>
<td>n</td>
</tr>
<tr>
<td>10^-6</td>
<td>micro</td>
<td>( \mu )</td>
</tr>
<tr>
<td>10^-3</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>10^3</td>
<td>kilo</td>
<td>k</td>
</tr>
<tr>
<td>10^6</td>
<td>mega</td>
<td>M</td>
</tr>
<tr>
<td>10^9</td>
<td>giga</td>
<td>G</td>
</tr>
<tr>
<td>10^12</td>
<td>tera</td>
<td>T</td>
</tr>
<tr>
<td>10^15</td>
<td>peta</td>
<td>P</td>
</tr>
<tr>
<td>10^18</td>
<td>exa</td>
<td>E</td>
</tr>
</tbody>
</table>
Density

- Every substance has a density, designated \( \rho = \frac{M}{V} \)
- Dimensions of density are, \( \text{units (kg/m}^3 \) \)
- Some examples:

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \rho ) (10^3 kg/m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>19.3</td>
</tr>
<tr>
<td>Lead</td>
<td>11.3</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.70</td>
</tr>
<tr>
<td>Water</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Atomic Density

- In dealing with macroscopic numbers of atoms (and similar small particles) we often use a convenient quantity called Avogadro’s Number, \( N_A = 6.023 \times 10^{23} \text{ atoms per mole} \)
- Commonly used mass units in regards to elements
  1. Molar Mass = mass in grams of one mole of the substance (averaging over natural isotope occurrences)
  2. Atomic Mass = mass in u (a.m.u.) of one atom of a substance.

\[ 1u = 1.6605387 \times 10^{-27} \text{ kg} \]

\[ \text{atom/mol} \times 6.023 \times 10^{23} \times 1.2 \times 10^{-3} \text{ (carbon)} = 2 \times 10^{-23} \text{ g/atom} \]

Dimensional Analysis

- This is a very important tool to check your work
- Provides a reality check (if dimensional analysis fails then no sense in putting in the numbers; this leads to the GIGO paradigm)
- Example
  - When working a problem you get the answer for distance \( d = vt^2 \) (velocity \( \times \) time \(^2\))
  - Quantity on left side = \( L \)
  - Quantity on right side = \( L \times T \times T = L \times T \times T \)
- Left units and right units don’t match, so answer is nonsense

Lecture 2, Exercise 1

- The force (F) to keep an object moving in a circle can be described in terms of:
  - velocity \( v \) (dimension \( L/T \)) of the object
  - mass \( m \) (dimension \( M \))
  - radius of the circle \( R \) (dimension \( L \)).

Which of the following formulas for \( F \) could be correct?

\[ (a) \quad F = mvR \quad \quad (b) \quad F = m\left(\frac{v}{R}\right)^2 \quad \quad (c) \quad F = \frac{mv^2}{R} \]

Note: Force has dimensions of \( ML/T^2 \)

Lecture 2, Exercise 2

- When on travel in Europe you rent a small car which consumes 6 liters of gasoline per 100 km. What is the MPG of the car? (There are 3.8 liters per gallon.)

\[ 100 \text{ km} = \frac{100 \text{ km}}{6 \text{ L}} \times \frac{1 \text{ mi}}{1.6 \text{ km/gal}} = 39.6 \text{ mi/gal} = 40 \text{ mi/gal} \]

Converting between different systems of units

- Useful Conversion factors:
  - 1 inch = 2.54 cm
  - 1 m = 3.28 ft
  - 1 mile = 5280 ft
  - 1 mile = 1.61 km

- Example: Convert miles per hour to meters per second:

\[ \text{mi/hr} = \frac{5280 \text{ ft}}{3600 \text{ s}} \times \frac{1 \text{ m}}{3.28 \text{ ft}} = \frac{1 \text{ m}}{2 \text{ s}} \]
**Significant Figures**

- The number of digits that have merit in a measurement or calculation.
- When writing a number, all non-zero digits are significant.
- Zeros may or may not be significant.
  - Those used to position the decimal point are not significant (unless followed by a decimal point).
  - Those used to position powers of ten ordinals may or may not be significant.
- In scientific notation all digits are significant.

**Examples:**
- 2: 1 sig fig
- 40: ambiguous, could be 1 or 2 sig figs (use scientific notations)
- $4.0 \times 10^1$: 2 significant figures
- 0.0031: 2 significant figures
- 3.03: 3 significant figures

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**Significant Figures**

- When multiplying or dividing, the answer should have the same number of significant figures as the least accurate of the quantities in the calculation.
- When adding or subtracting, the number of digits to the right of the decimal point should equal that of the term in the sum or difference that has the smallest number of digits to the right of the decimal point.

**Examples:**
- $2 \times 3.1 = 6$
- $4.0 \times 10^1 / 2.04 \times 10^0 = 1.6 \times 10^{-1}$
- $2.4 - 0.0023 = 2.4$

End of Chapter 1

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**Motion in One-Dimension (Kinematics)**

**Position / Displacement**

- Position is measured and referenced to an origin:
  - Joe is 10 feet to the right of the lamp
  - origin = lamp
  - direction = to the right
  - position vector:

**Examples:**
- $10 \text{ meters}$
- Joe

**Position / Displacement**

- Displacement is just change in position.

**Examples:**
- $10 \text{ meters}$
- Joe

**Average speed and velocity**

**Changes in position vs Changes in time**

- Average velocity = total distance covered per total time,
  $$\bar{v}(\text{average velocity}) = \frac{\Delta x (\text{total displacement})}{\Delta t (\text{total time})}$$
- Speed is just the magnitude of velocity.
  - The “how fast” without the direction.

**Examples:**
- Active Figure 1: http://www.phy.ntnu.edu.tw/ntnujava/main.php?lang=282
- Active Figure 2: http://www.phy.ntnu.edu.tw/ntnujava/main.php?lang=230

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**Recap**

- If the position $x$ is known as a function of time, then we can find both velocity $v$ and acceleration $a$.

**Examples:**
- $x(t)$
- $v = \frac{dx}{dt}$

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**See text: 1-7**
Recap of today’s lecture

- Measurement and units (chapter 1)
  - Systems of units (Text: 1.1)
  - Density (Text: 1.3)
  - Converting between systems of units (Text: 1.5)
  - Dimensional Analysis (Text: 1.4)
  - Position and displacement
  - Velocity and speed

- Reading for Wednesday’s class 9/13/06:
  - All of Chapter 2
  - Chapter 3.1, 3.2
  - Begin WebAssign Homework #1: