Today

• Announcements:
  – HW#1 is due Wednesday by 8:00 am
  – The first extra credit assignment is on the LONCAPA system. One short answer is all that is required. The due date is 23 January at 8:00 am.

• Review
• Units
• Motion
• Scalars, Vectors, Tensors
Review

- **Time is the thing that is measured by clocks**
- **What we know about the laws of nature say the speed of light is a constant**, independent of the speed of the source.
  - One of the implications is that moving clocks run slow
  - Time is relative
- **Position** – location relative to the center of a coordinate system (0,0)
- **Velocity** – rate of change of position
- **Acceleration** – rate of change of velocity
- **Distance** = speed x time (60 mi = 60 mph x 1 hr)
Time Travel

• Moving at high speed is a way to travel into the future. No problem here; this is correct.

• We can look into the past because, although the speed of light is fast, distances in space are large.
  – We see the Sun as it was 8 minutes ago
  – We see nearby stars as they were 4-10 years ago
  – The distance light travels in one year is called a light-year.
  – We see nearby galaxies as they were 1 million years ago
  – Looking out at the stars is like looking back in time.

• We can move forward in time. Can we move backward in time? Maybe
Scalors, Vectors, Tensors

- Physical quantities can have characteristics.
- **Scalars** – a quantity without direction
  - such as the mass of an object
  - the magnitude of a vector
- **Vectors** – a quantity that has a length and direction
- **Tensors** – generalized versions of vectors in multiple directions
  - The number of dimensions in a tensor is called the rank
  - Rank 0 tensor is a scalar
  - Rank 1 tensor is a vector
Examples of Scalars

- mass, electric charge
- speed (magnitude of velocity)
- amount of money in my wallet
- the volume of a container (gallons or liters)
Examples of Vectors

- Position – 2 miles East of Spartan Stadium
- Velocity – 60 mph toward Detroit
- Acceleration – 9.8 m/s² down
- Note: velocity and acceleration can have opposite directions. Example: a ball moving upward.
Vectors

Representation

1 meter East

A

A is the same vector no matter where it sits.

Addition

A + B

A

B

A_x

A_y

B_x

B_y

ISP209s8 Lecture 2

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Motion

- **Position** – location relative to the center of a coordinate system (0,0). 2 miles NE
- **Velocity** – rate of change of position. This means changing direction as well.
- **Acceleration** – rate of change of velocity. If either the magnitude of the velocity or its direction are changing, the object is accelerating.
Units

• Physical quantities always have a unit attached; for example 2 meters
• Some quantities are a combination of units; for example 1 liter = 1000 cm$^3$ (LONCAPA 1000 cm$^3$ or 1.0E3 cm$^3$ or 1.0E-3 m$^3$)
• How many liters are in a gallon?
LONCAPA Units

• We will use the System International (SI) system of units. Link

• Common units
  – Kilogram (mass) kg
  – Meter (length) m
  – Second (time) s
  – Newton (force) N – same as kg*m/s^2
  – Joule (energy) J – same as N*m
  – Moles (Amount of substance) - mol

• The LONCAPA system has help
An example of unit conversion

\[100 \text{ cm} = 1.00 \text{ m}\]

This means there are: \(\frac{1.00 \text{ m}}{100 \text{ cm}}\)

\[11.2 \text{ cm}^2 = 11.2 \text{ cm}^2 \times \left(\frac{1.00 \text{ m}}{100 \text{ cm}}\right)^2 = 1.12 \times 10^{-3} \text{ m}^2\]
# Prefixes

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<thead>
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<th>prefix</th>
<th>name</th>
<th>value</th>
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**Example:**

\[ 2.0 \text{My} = 2.0 \times 10^6 \text{y} \]

\[ 2.0 \text{My} = \frac{1 \text{Gy}}{1000 \text{My}} \times 2.0 \text{My} = 2.0 \times 10^{-3} \text{Gy} \]
Velocity – Rate of change of position

<table>
<thead>
<tr>
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<th>Time (s)</th>
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<tbody>
<tr>
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<tr>
<td>1.0</td>
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<td>1.0</td>
<td>3.0</td>
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<tr>
<td>0.5</td>
<td>4.0</td>
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Velocity is the rate of change of position
\[ \vec{v} = \frac{\text{change in position}}{\text{change in time}} \]

Speed is the magnitude of the velocity
\[ s = \frac{x_{\text{final}} - x_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}} \]

\[ \frac{1.0m - 0.0m}{2.0s - 1.0s} = 1.0 \frac{m}{s} \]
### Velocity – Rate of change of position

What is the velocity between 3.0 and 4.0 seconds?

\[
\vec{v} \text{ (between 3 and 4s)} = \frac{x_{\text{final}} - x_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}
\]

- A) 0.0 m/s
- B) 1.0 m/s
- C) -1.0 m/s
- D) -0.5 m/s
- E) 0.5 m/s

What is the speed between 3.0 and 4.0 seconds?

- A) 0.0 m/s
- B) 1.0 m/s
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Example: Motion of a car as a function of time.

Velocity is the rate of change of position:

\[ \vec{v} = \frac{\vec{x}_2 - \vec{x}_1}{t_2 - t_1} \]
What is the average speed at 2.5 min?

\[ v = \frac{x_f - x_i}{t_f - t_i} = \frac{0.75 \text{ miles} - 0.25 \text{ miles}}{2.7 \text{ min} - 1.8 \text{ min}} = 0.56 \frac{\text{miles}}{\text{min}} \times \frac{60 \text{ min}}{h} = 33.6 \frac{\text{miles}}{h} \]

We get 0.60 miles/min = 33.6 mph from the velocity graph.
Motion Problem

At what time is the acceleration negative?

A) 0.5 min  
B) 2.2 min  
C) 3.3 min  
D) 5.3 min  
E) 6.4 min

x direction $\rightarrow$  $+$ is to the right,  $-$ is to the left
Example 2: Stress Tensor

• Stress is defined as the force per unit area.

• In a solid object each point has three values of stress (up, left, right)

• The stress tensor describes the stress at all points in an object

Tensors (tensor fields)

Tensors are objects that have more than one value at each point in space.

- Example: Curvature of space-time: $R_{\mu\nu}$

Riemann curvature tensor

One number is not sufficient to describe each point in space.