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

Scalars, 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 is the same vector no matter where it sits.

Addition

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

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

Prefixes

<table>
<thead>
<tr>
<th>prefix</th>
<th>name</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>nano</td>
<td>10^-9</td>
</tr>
<tr>
<td>μ</td>
<td>micro</td>
<td>10^-6</td>
</tr>
<tr>
<td>m</td>
<td>milli</td>
<td>10^-3</td>
</tr>
<tr>
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<td>centi</td>
<td>10^-2</td>
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<tr>
<td>d</td>
<td>deci</td>
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</tr>
<tr>
<td>k</td>
<td>kilo</td>
<td>10^3</td>
</tr>
<tr>
<td>M</td>
<td>Mega</td>
<td>10^6</td>
</tr>
<tr>
<td>G</td>
<td>giga</td>
<td>10^9</td>
</tr>
</tbody>
</table>

Example:

2.0 M\(\text{y}\) = 2.0 \times 10^6 \text{ y}
2.0 M\(\text{y}\) = \frac{1 \text{ Gy}}{1000 \text{ M}\(\text{y}\)} \times 2.0 M\(\text{y}\) = 2.0 \times 10^{-3} \text{ Gy}
Velocity – Rate of change of position

<table>
<thead>
<tr>
<th>Position (m)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.0</td>
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</tr>
<tr>
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<td>1.0</td>
</tr>
<tr>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>0.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

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:
\[
s = \frac{x_{\text{final}} - x_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}
\]

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 C) -1.0 m/s D) -0.5 m/s E) 0.5 m/s

Back to Motion

Example: Motion of a car as a function of time.

Velocity is the rate of change of position:
\[
\vec{v} = \frac{x_2 - x_1}{t_2 - t_1}
\]

Calculation of Motion

What is the average speed at 2.5 min?
\[
v = \frac{x_f - x_i}{t_f - t_i} = \frac{0.75 \text{ miles} - 0.25 \text{ miles}}{2.7 \text{ min} - 1.8 \text{ min}} = \frac{0.5 \text{ miles}}{0.9 \text{ min}} = \frac{0.56 \text{ miles}}{60 \text{ min}} = 0.00933 \text{ miles/min}
\]

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

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.