Today

• Announcements:
  – HW#2 is due Wednesday by 8:00 am
  – Extra Credit project #1 in on the LONCAPA website is also due next Wednesday at 8:00 am
• Review
• What is Force? Introduction

Scalors, Vectors, and Tensors (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


Motion

• **Position** – location relative to the center of a coordinate system (0,0). 2 miles NE
• **Displacement** – the difference between two positions
• **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.

Find the speed at 5.1 s.

Steps in calculating rates of change:
• Draw a line tangent to the curve at the time you want. The line can be any length.
• Mark two points on the line and record the values.
• Calculate the slope

\[
m = \text{speed} = \frac{d_2 - d_1}{t_2 - t_1} = \frac{6 - 2}{9.3 - 2.5} = 0.59 \text{ m/s}
\]
Homework Problem Traveling Car

**Speed increasing** – acceleration and velocity in the same direction

**Speed decreasing** – opposite direction (deceleration)

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**History of our effort to understand motion**

- **Aristotle (384 BC – 322 BC)**
  - Natural motions: items seek their natural locations
  - Violet motions like moving across the room require an agent
- **Galileo (1564-1642)**
  - Tried to deduce the laws of motion from experiments
  - Introduced the concept of inertia. (Inertia is not a well defined concept.)
  - He spent a great deal of effort trying to understand acceleration
- **Isaac Newton (1643-1727)**

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**What is a Force?**

- A force is a push or pull.
- Force is a vector, it has a magnitude and a direction.
- A better definition is given by Newton’s Three Laws of Force (my versions)
  - If the net force on an object is zero the object will not accelerate.
  - The amount of acceleration depends on the mass of the object and the amount of the applied force: \( F = ma \).
  - For every force, there is an equal and opposite force.
- Improved definition: Force is the rate of change of momentum.

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**How much force?**

Neglecting friction from the air, a 80.0 kg professor falls off a bench and accelerates toward the ground at 9.81 m/s².

What is the magnitude of the force of gravity on the professor?

\[ F = \text{mass} \times \text{acceleration} = 80.0 \text{ kg} \times 9.81 \text{ m/s}^2 = 785 \text{ N} \]
What is momentum?

• Momentum is mass times velocity.
• Momentum is a vector. Often we write it as a “p”.
• \( p = \text{mass} \cdot \text{velocity} \)
• Momentum is the modern analog to Galileo's idea of inertia.

Momentum Problem Picture

Momentum Problems

Hint: Force is the rate of change of momentum.

\[
\vec{F} = \frac{\Delta \vec{p}}{\Delta t} = \frac{\vec{p}_2 - \vec{p}_1}{t_2 - t_1}
\]

magnitude of \( F \) for motion in one dimension = \( \frac{p_2 - p_1}{t_2 - t_1} \)

Note: A negative slope means the direction of the force is toward \(-x\). Force is a vector, and direction matters.

What is a force (continued)?

• These laws let us recognize a force, but what causes a force?
  – The modern view is related to field theory.
  – Forces are the result of an exchange of particles.
• To understand field theory, we have to talk about energy and quantum mechanics (later in the term).