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

MICHIGAN STATE UNIVERSITY

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 a 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 dimension in a tensor is called the rank
  - Rank 0 tensor is a scalar
  - Rank 1 tensor is a vector

Examples of Scalars

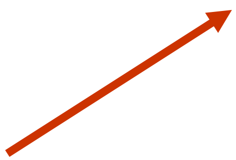
- mass, electric charge
- speed (magnitude of velocity)
- amount of money in my wallet
- the volume of a container (gallons or liters)

Examples of Vectors

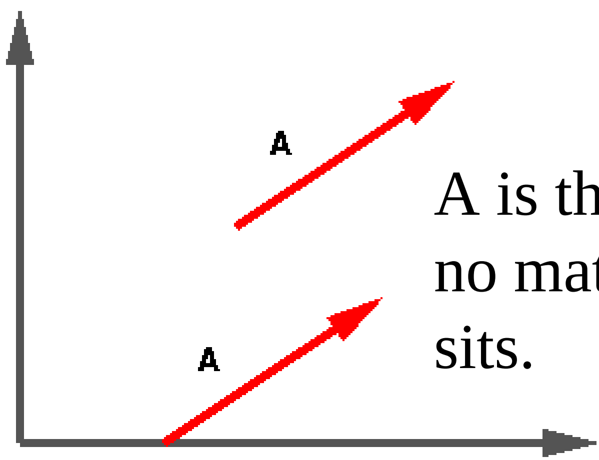
- Position – 2 miles East of Spartan Stadium
- Velocity – 60 mph toward Detroit
- Acceleration – 9.8 m/s^2 down
- Note: velocity and acceleration can have opposite directions. Example: a ball moving upward.

Vectors

Representation

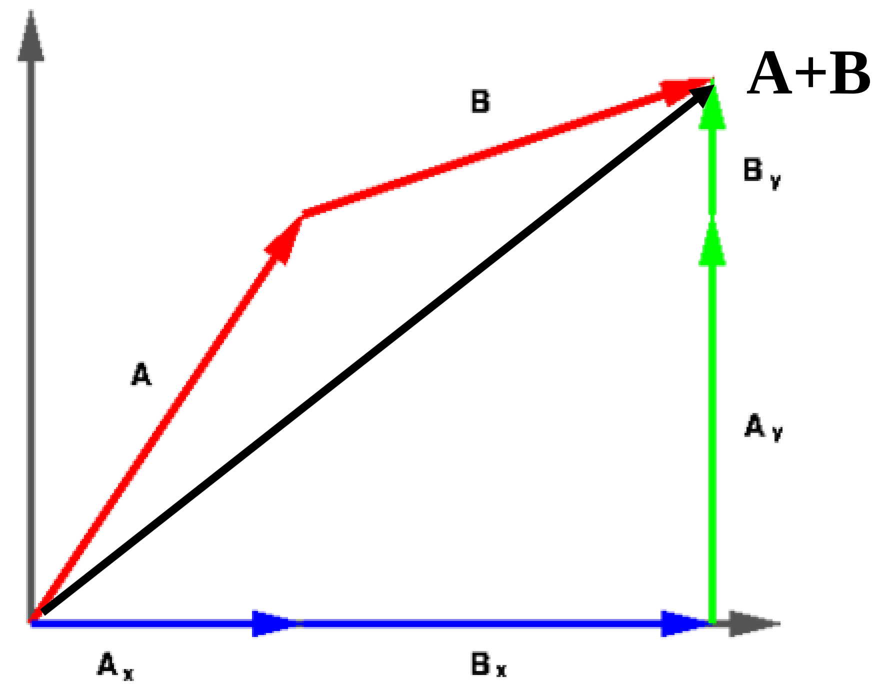


1 meter East



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: $\dfrac{1.00\text{ m}}{100.\text{ cm}}$

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

Prefixes

prefix	name	value
n	nano	10^{-9}
μ	micro	10^{-6}
m	milli	10^{-3}
c	centi	10^{-2}
d	deci	10^{-1}
		1
k	kilo	10^{3}
M	Mega	10^{6}
G	giga	10^{9}

<u>Example:</u>

$$2.0My = 2.0\times10^{6}\,y$$

$$2.0My = \frac{1Gy}{1000My}\times2.0My = 2.0\times10^{-3}Gy$$

Velocity – Rate of change of position

Position (m)	Time (s)
-1.0	0.0
0.0	1.0
1.0	2.0
1.0	3.0
0.5	4.0

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

$$s\ (\text{between 1 and 2s}) = \frac{x_{\text{final}} - x_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

$$\frac{1.0m - 0.0m}{2.0s - 1.0s} = 1.0\, {}^{m}\!/_{s}$$

Velocity – Rate of change of position

Position (m)	Time (s)
-1.0	0.0
0.0	1.0
1.0	2.0
1.0	3.0
0.5	4.0

What is the velocity between 3.0 and 4.0 seconds?

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

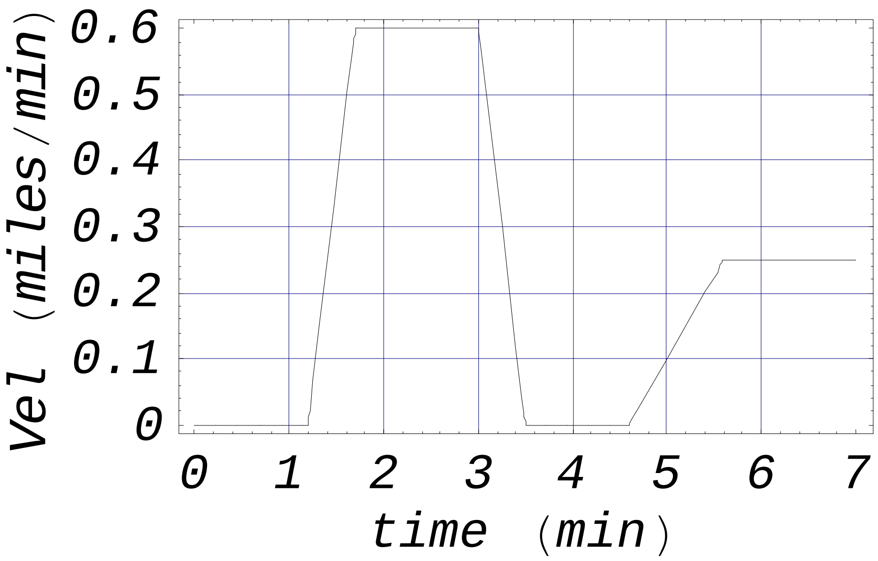
A) 0.0 m/s B) 1.0 m/s C) -1.0 m/s D) -0.5 m/s E) 0.5 m/s

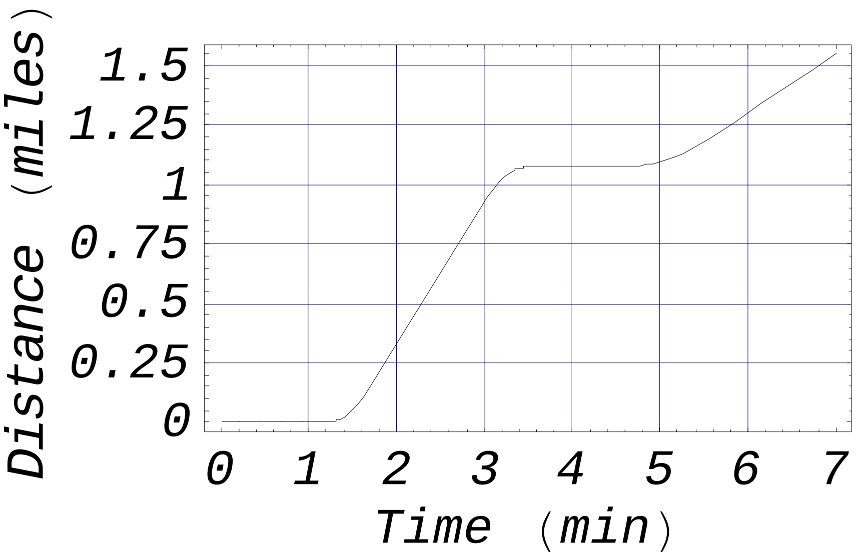
What is the speed between 3.0 and 4.0 seconds?

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

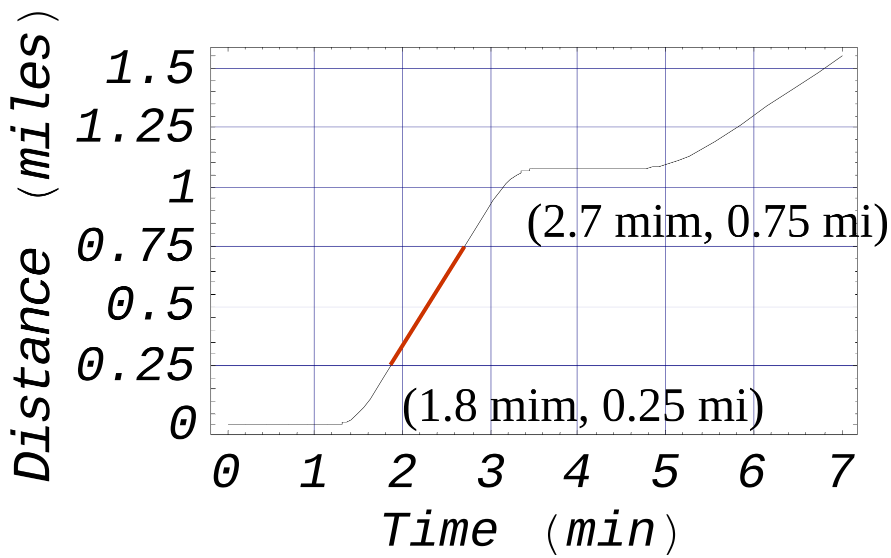
Example: Motion of a car as a function of time.





Velocity is the rate of change of position: $\vec{v} = \dfrac{\vec{x}_2 - \vec{x}_1}{t_2 - t_1}$

Calculation of Motion

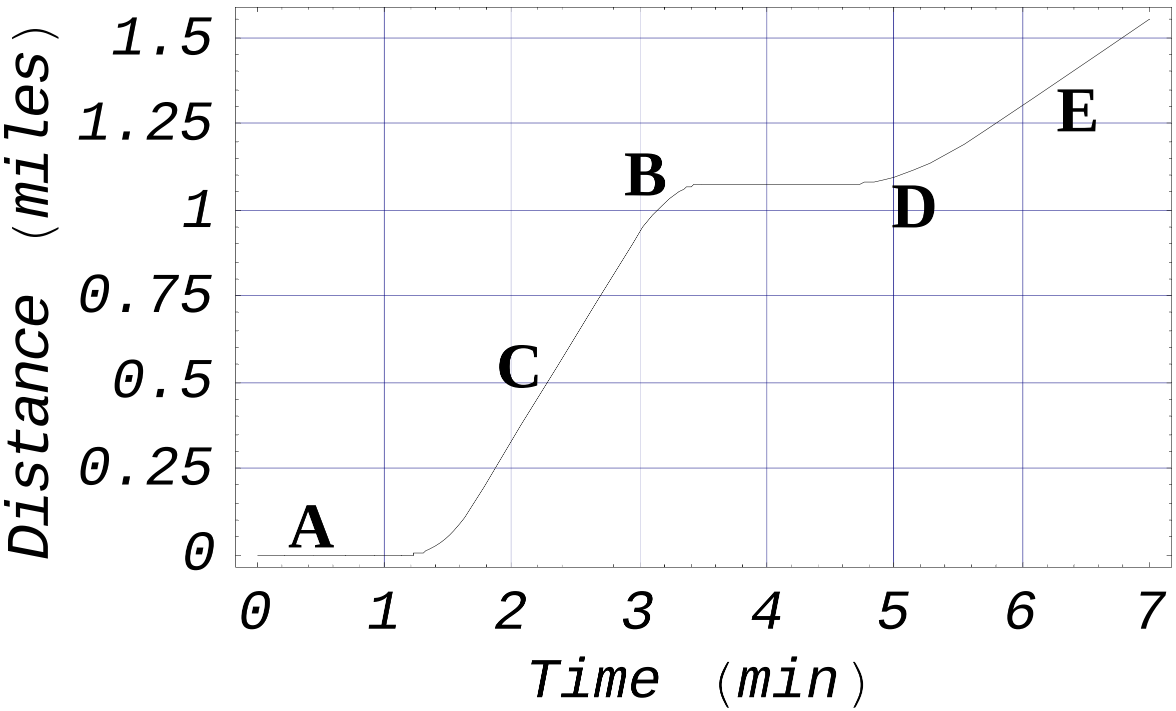


What is the average speed at 2.5 min?

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

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

Motion Problem



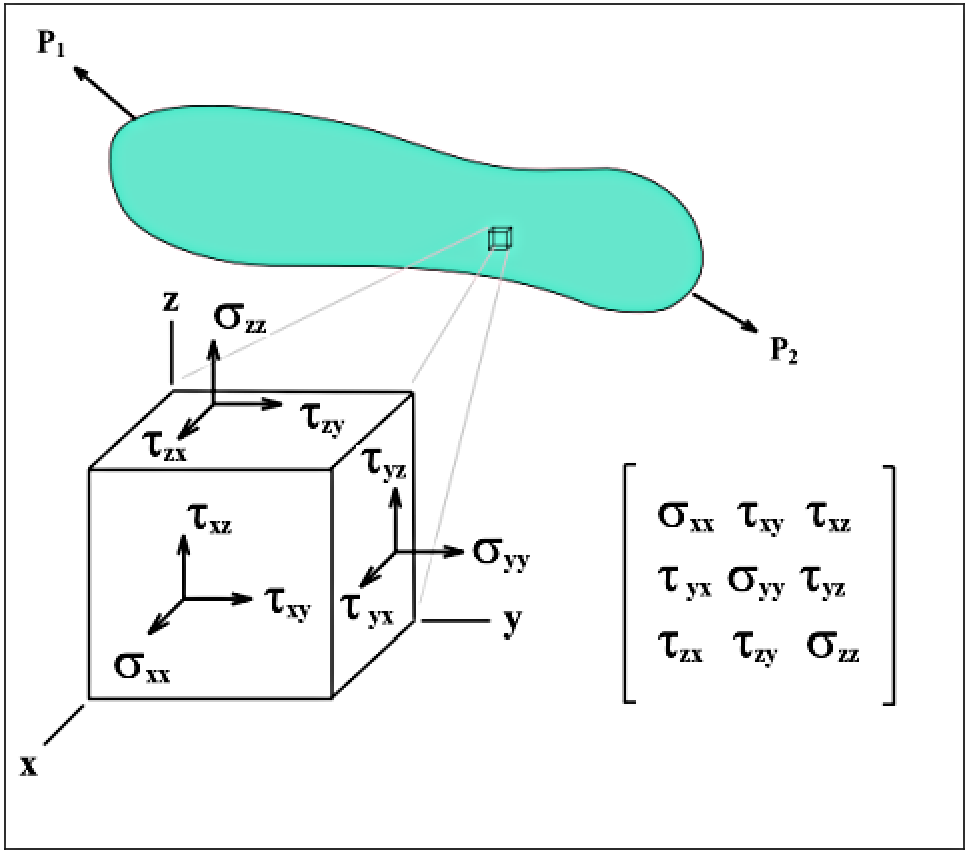
At what time is the acceleration negative?

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

x direction ⟶ + 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



http://en.wikipedia.org/wiki/Image:Stress_tensor.png

Tensors (tensor fields)

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

- Example: Curvature of space-time: Riemann curvature tensor $R_{\mu\upsilon}$

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