



Today

- Announcements:
 - HW#1 is due Wednesday by 8:00 am
 - The first extra credit assignment is on the LONCAPA system. The due date is 16-Sept.
- Review
- Time Travel
- Units
- Motion
- Scalars, Vectors, Tensors



Review

- **The speed of light is a constant**, independent of the speed of the source.
 - this is one of the two postulates of Special Relativity (Einstein)
 - One of the implications is that moving clocks run slow.
- **Position** – location relative to an origin
- **Velocity** – rate of change of position
- **Acceleration** – rate of change of velocity



Time Travel

- Moving at high speed is a way to travel into the future. No problem here; this is correct.
- Twin Paradox (stated in class)– resolved by general relativity
- The speed of light is fast, but 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 the nearby Andromeda Galaxy as it was 3 My ago
 - Looking out at the stars is like looking back in time.
- Can we move backward in time? Maybe



Units

- Physical quantities always have a unit attached; for example *2 meters*
- Some quantities are a combination of units; for example 1 liter = 1000 cm³ (LONCAPA 1000 cm^{^3} or 1.0E3 cm^{^3} or 1.0E-3 m^{^3})
- How many liters are in a gallon?
- What is the density of materials:
density = mass/volume



Unit Conversions

$$3.7854l = 1.000 \text{ gallons}$$

$$1.000 = \frac{3.7854l}{\text{gallon}}$$

Let's take an example. Suppose we have 16.4 gallons. How many liters is that?

$$16.4g = 16.4 \text{ gal} \times \frac{3.7854l}{\text{gal}} = 62.1l$$



Another example of unit conversion

$$100cm = m$$

$$1.000 = \frac{100cm}{m}$$

$$11.2cm^2 = 11.2cm^2 \times \left(\frac{1.000m}{100cm}\right)^2 = 1.12 \times 10^{-3} m^2$$



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

Example:

$$2.0My = 2.0 \times 10^6 y$$

$$2.0My = \frac{Gy}{1000My} \times 2My = 2 \times 10^{-3} Gy$$



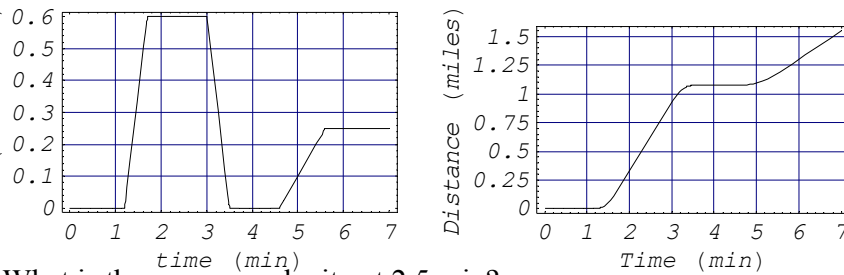
LONCAPA Units

- We will use the SI system of units. [Link](#)
- Common units
 - Kilogram (mass) kg
 - Meter (length) m
 - Seconds (time) s
 - Newtons (force) N – same as $kg \cdot m/s^2$
 - Joules (energy) J – same as $N \cdot m$
- The LONCAPA system has help
- Frequency is 1/s (Hz)



Motion

Motion of a car as a function of time.



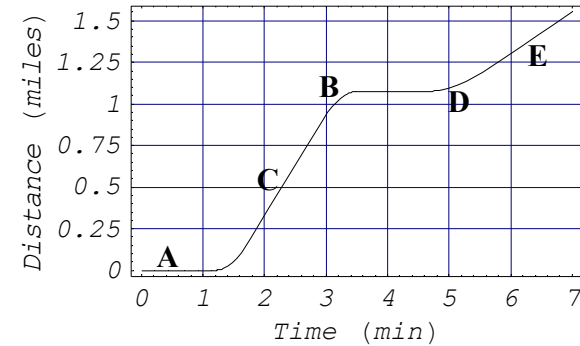
What is the average velocity at 2.5 min?

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

We get 0.60 miles/min = 36 mph from the velocity graph.



Motion Problem



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 more than one direction
 - 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, charge
- Speed (magnitude of velocity)
- Amount of money in my wallet
- The volume of a container (gallons or liters)



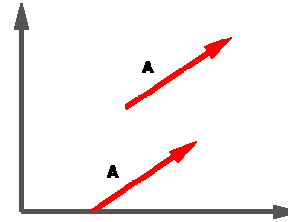
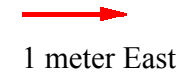
Examples of Vectors

- 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.

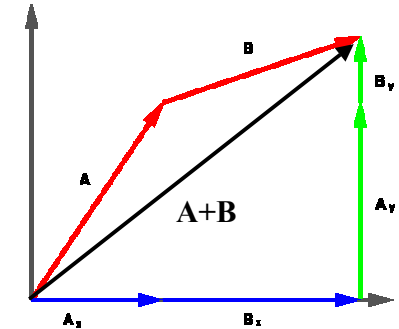


Vectors

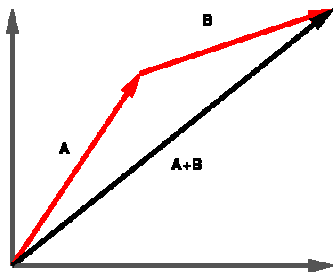
- Representation



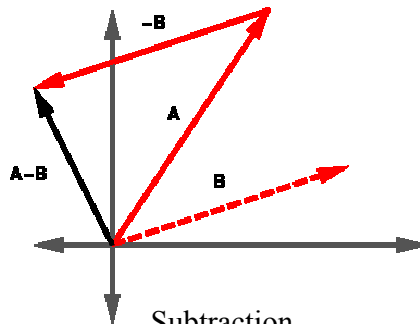
- Addition



Vector Addition and Subtraction



Addition



Subtraction

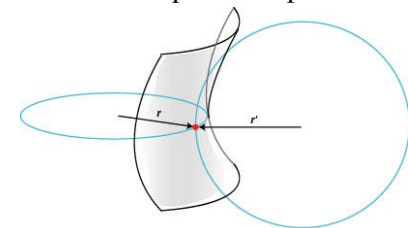
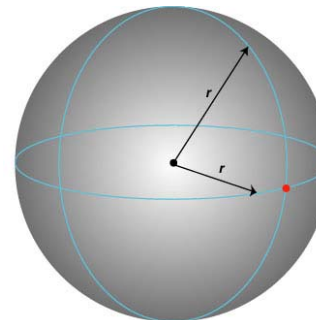


An example of a Tensor

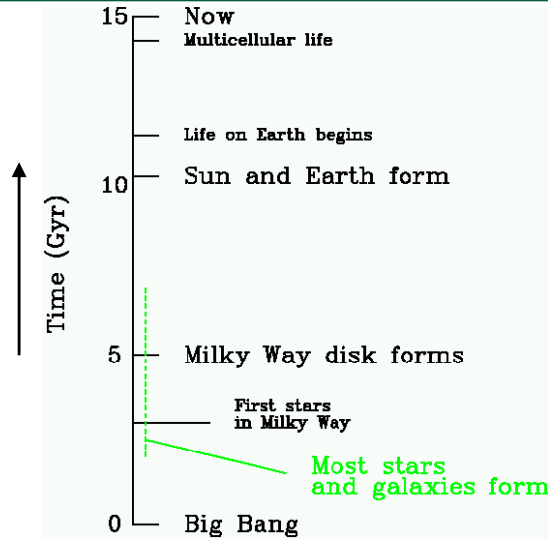
- Curvature of space-time: Riemann curvature tensor

$$R_{\mu\nu}$$

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



Time-lines



Time-Lines and World Diagrams

- A world diagram is a plot of time vs. position.
- Nothing can go faster than the speed of light, hence all events must fall within a “light cone”
- The path of an object is called the world line
- Usually the time axis is given in units where a particle moving at c will fall along a 45 degree line, e.g., y vs. ly .

