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 cm^3 (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

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Unit Conversions

$$3.7854\,l = 1.000\,gallons$$

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

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

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

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Another example of unit conversion

$$100\,cm = m$$

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

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

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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:

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

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

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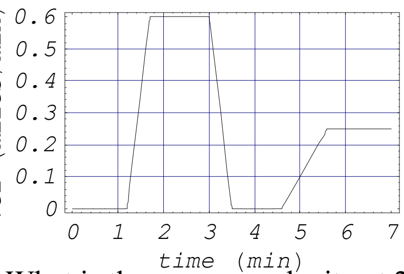
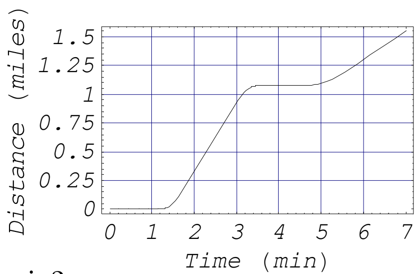
LONCAPA Units

- 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*m/s^2
  - Joules (energy) J – same as N*m
- The LONCAPA system has help
- Frequency is 1/s (Hz)

Motion

Motion of a car as a function of time.



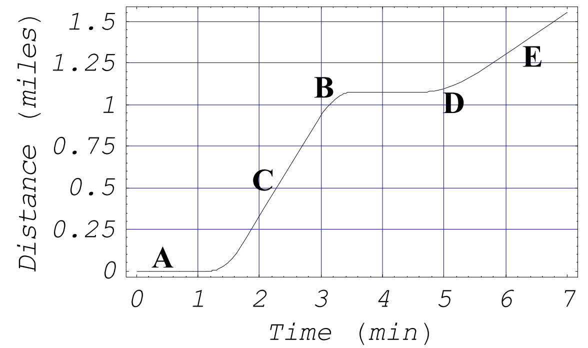


What is the average velocity at 2.5 min?

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

We get 0.60 miles/min = 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 a 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)

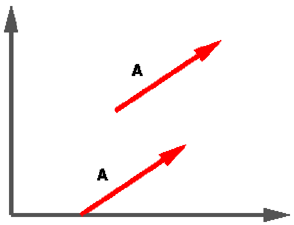
Examples of Vectors

- 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.

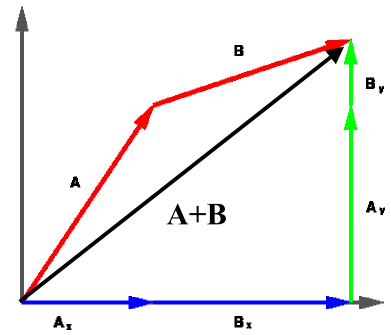
Vectors

- Representation

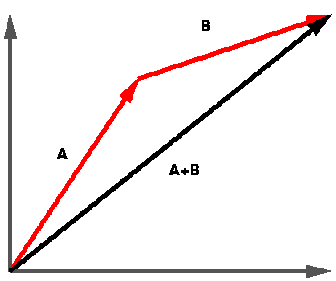
1 meter East



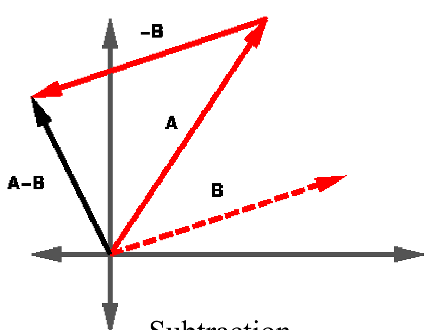
- Addition



Vector Addition and Subtraction



Addition

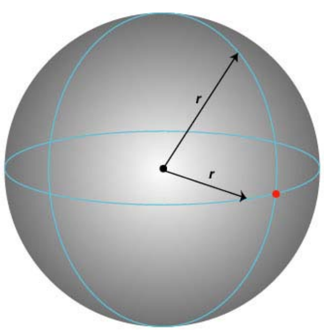


Subtraction

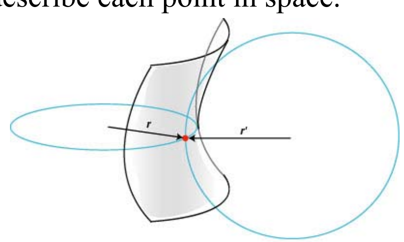
An example of a Tensor

- Curvature of space-time: Riemann curvature tensor

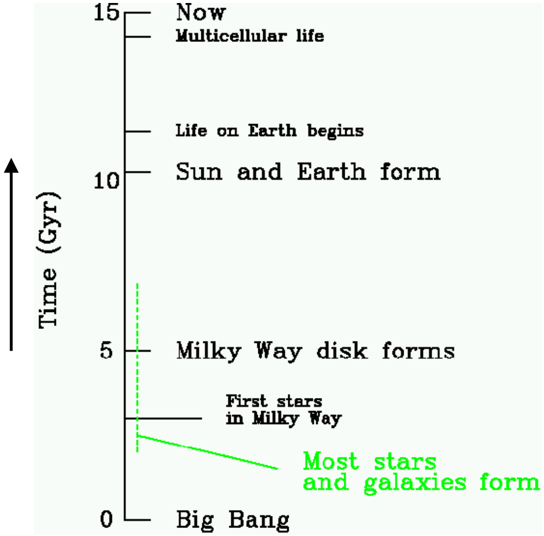
$$R_{\mu\upsilon}$$



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 in given in units where a particle moving at c will fall along a 45 degree line, e.g., y vs. ly .