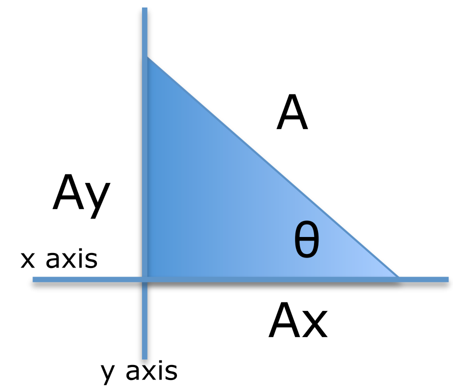
Units

- How to convert units (Get the 1 the right way up)
- Always carry units around in problems!
- **Your answer to a question should always include units!**
- **Use dimensional analysis to make sure you've solved a problem correctly – do the units make sense?**
- **Distance = meters (m), Time = seconds (s), Mass = kilograms (kg) ALWAYS!!!**
- Know multipliers: kilo = 10^3, milli = 10^{-3}, etc. See lecture 2nd day of class for more multipliers

Vectors

- Have magnitude (numerical value) and direction
- Add by graphical method: put tail of B at head of A, draw sum from tail of A to head of B
- **Component method**
  - YOU MUST REMEMBER YOUR TRIG!!
    - **sin θ = Ay / A, cos θ = Ax / A**
    - **$A^2 = Ax^2 + Ay^2$**



  - **Choose your coordinate system wisely, helps to draw your problem with coordinate system**
  - Vital for figuring out how things move using Newton's laws

How objects move

- **Speed = distance / time, is a scalar (no direction), m/s**
- **Velocity = distance / time, is a vector (has direction), m/s**
- **Acceleration = change in velocity / time, is a vector**
  - **= (final v – initial v) / time, m/s^2**
  - **Have acceleration when the magnitude OR the direction of velocity changes**

- These quantities are considered averages, because they tell you the overall motion, not the motion at each single instant of time (think of an everyday example: you say you went 60 mph to drive to Tampa, but that doesn't mean at every single minute you were driving 60 mph. Sometimes you went 65, sometimes 55)

Special case of motion: **constant acceleration**

- Equations you can use to solve problems:
  - **a = (final v – initial v) / time**
  - distance = v * time, where v is AVERAGE
    - $= \dfrac{(\text{ initial v + final v})}{2} * t$
  - Can make 2 other equations:
    - a in terms of velocity and distance
    - distance in terms of velocity, time, and a

Special case of motion: **constant acceleration**

- a in terms of velocity and distance
  - Solve d = $\frac{(\text{initial v} + \text{final v})}{2} * t$ for time
  - substitute into a = (final v – initial v) / time
  - Get **a = $\frac{(\text{final v}^2 - \text{initial v}^2)}{2 * d}$**

- distance in terms of velocity, time, and a
  - Solve a = (final v – initial v) / time for final velocity
  - Substitute into d = $\frac{(\text{initial v} + \text{final v})}{2} * t$
  - Get **d = (initial v * t) + (½ * a * t^2)**

Special case of motion: **constant acceleration** (ex: Falling Bodies)

- Galileo: **In the absence of air resistance, all bodies fall with the same acceleration, a**
  - ex: drop a sheet of paper vs crumpled sheet of paper, which falls faster?
  - This constant acceleration is due to gravity
  - **a due to gravity = g, g = 9.8 m/s^2 towards the Earth's surface**

Why objects move

- Forces: push or pull, vectors with direction
- **Newton's 3 Laws**
  1. **Law of inertia: every object in UNIFORM motion (at rest or moving) tends to remain in that state unless an external force is applied to it**
  2. **F = m * a, where F = NET force, a = TOTAL acceleration of object, units of Newtons (kg m/s^2)**
     - Forces cause objects to accelerate!
  3. **For every action there is an equal and opposite reaction**
     - **Must involve 2 bodies acting on each other! These action/reactions are 2 forces of same magnitude but opposite direction, acting on 2 different bodies**

Other properties of matter

- Mass: amount of stuff or material in an object
- Weight: gravitational force acting on the mass of an object
- Weight = F due to gravity = m * g

Special case of motion: **projectile motion** (2D motion)

- Has some initial velocity!
- Curved path of motion, or trajectory
- Understand motion by splitting it into 2 independent parts, one for the x direction and one for the y direction
- x direction: no acceleration because v_x always points in same direction and is constant because we assume a lack of air resistance.
  - **$x = x_0 + v_{0x} * t$**
  - **x = final position in x, x_0 = starting position in x, v_{0x} = starting velocity in x direction, t = total time of travel**

Special case of motion: **projectile motion** (2D motion)

- y direction: constant acceleration downward due to gravity!
  - **$v_y = v_{0y} + a * t$ ➔ $v_y = v_{0y} - g * t$**
  - **v_y = final velocity in y, v_{0x} = starting velocity in y direction, a = acceleration DOWNWARD due to gravity, t = total time of travel**
  - **$y = y_0 + (v_{0y} * t) – (½ * g * t^2)$**
  - **y = final position in y, y_0 = starting position in y**

Special case of motion: **projectile motion** (2D motion)

- Max range in x when object starts and returns to the same y position:
  - **$x = x_0 + ((v_{0x} * 2 v_{0y}) / g)$**
- Max distance traveled in x is when starting angle is 45°

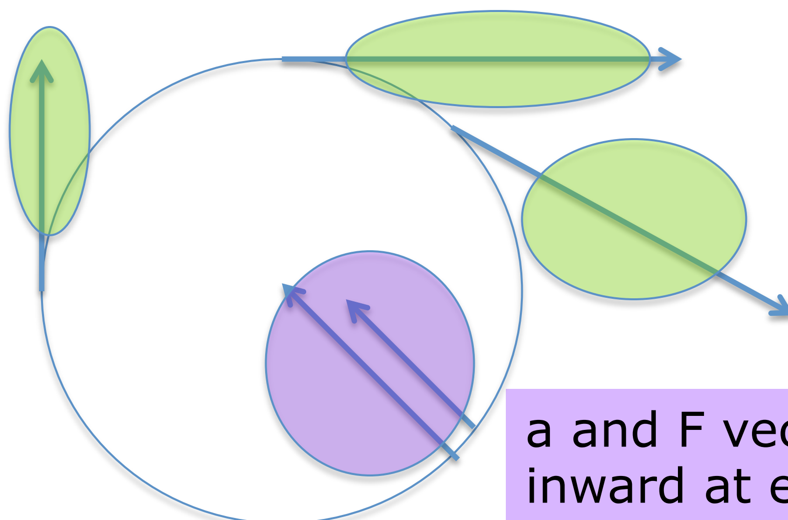
- Max height in y occurs when $v_y = 0$ (at top of trajectory)
  - **$y = y_0 + (½ * (v_{0Y}^2 / g))$**

- Your ability to hit a target a certain x and y distance away from where you fire your object depends on BOTH the firing angle and the initial velocity

Special case of motion: **uniform circular motion** (2D motion)

- **Speed is constant but velocity changes direction**
  - **Therefore there is acceleration, $a = v^2 / r$**
- **Direction of velocity vector is in direction of motion, tangential to the path of motion**
- **Acceleration points inward only, called centripetal acceleration**
- **Thus the Force must also point inward, $F = m * v^2 / r$**

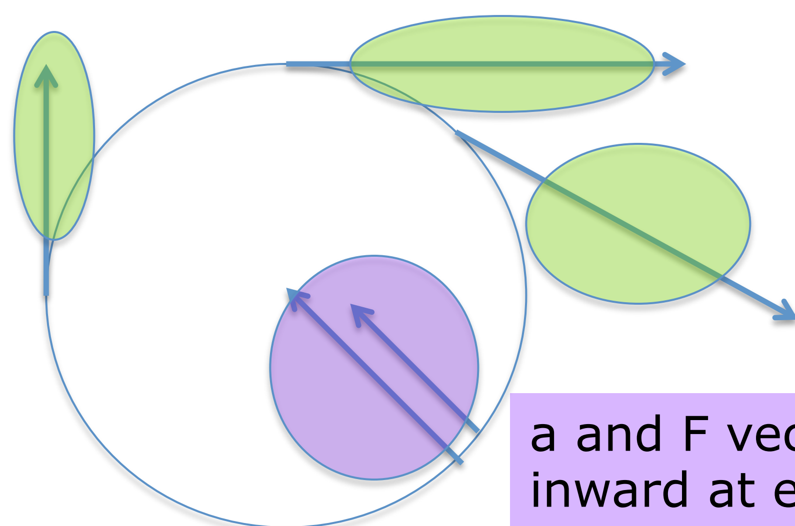
These 3 lines are the velocity vector's direction at that particular point along the path of motion



a and F vectors points inward at each point along the path of motion

Special case of motion: **uniform circular motion** (orbits!)

- Length around outside of circle is $2 * \pi * r$, time to make one complete trip around circle = period, T. Velocity = $2 * \pi * r / T$
- Substitute this in to $a = v^2 / r$, to get **$F = (4 * m * r * \pi^2) / T^2$**



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a and F vectors points inward at each point along the path of motion

Newton's Law of Universal Gravity

- **$F_{grav} = (G * m_1 * m_2) / d^2$**
  - **Where G is the universal gravity constant, $6.67 * 10^{-11}$, units of $N\ m^2/kg^2$**
  - **m_1 is the mass of the first object, m_2 is the mass of the second object, and d is the distance between the CENTERS of both objects**

- **This works for ANY TWO OBJECTS**
  - you and a pencil, the Earth and Moon, etc.
  - Can use for objects falling to the surface of the Earth, but **if the object is close to the Earth's surface (skydiver, on top of skyscraper and closer to surface) you can use $F = m * 9.8\ m/s^2$ instead. BOTH WILL GIVE YOU THE SAME ANSWER! One is just easier to use.**