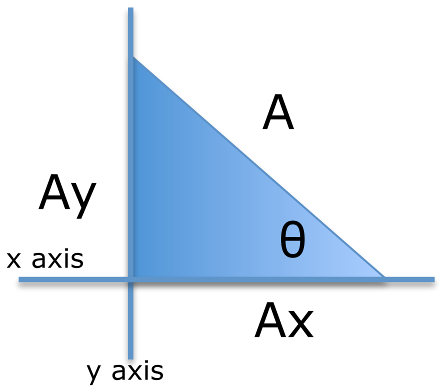
Review and Remember from Exam 1

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

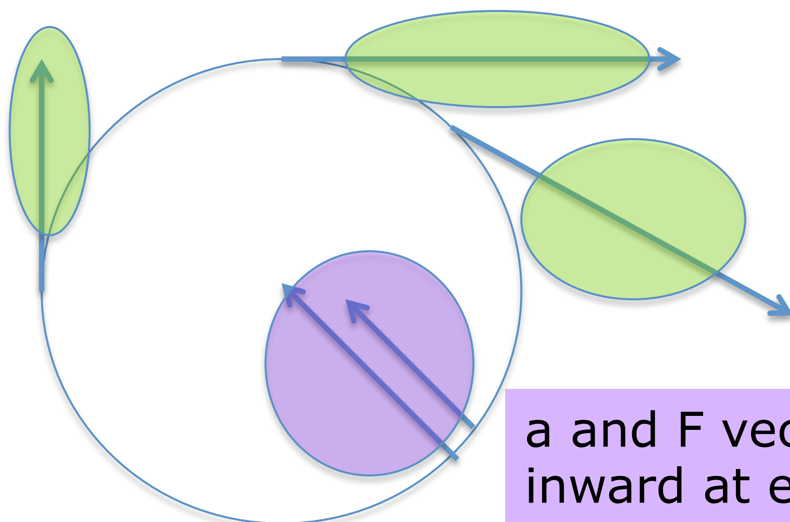
Vectors

- 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



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, $F = m * v^2 / r$**

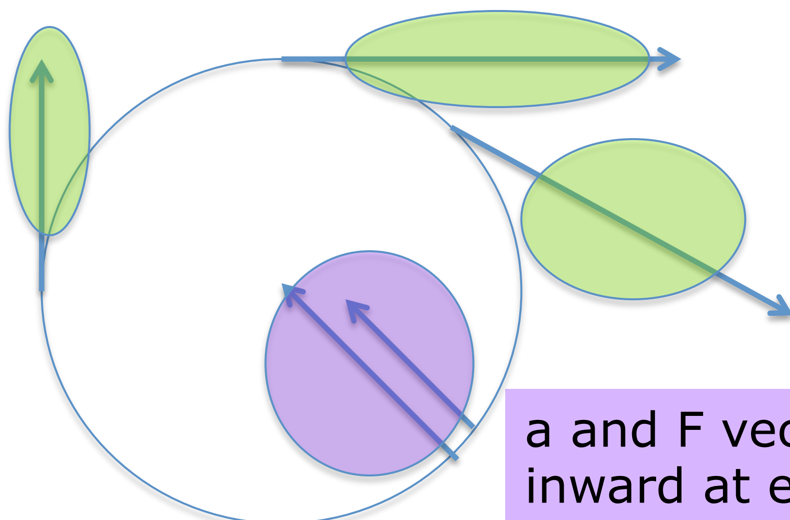


These 3 lines are the velocity vector's direction at that particular point along the path of motion

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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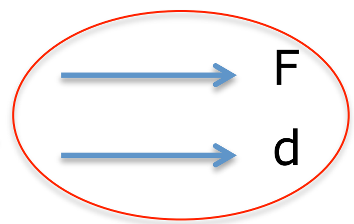
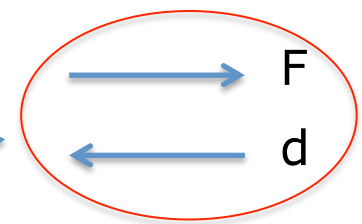
New Material for Exam 2

Work

- When an applied force moves an object over a distance d, work is done
- $W = F * d * \cos\theta$
  - θ is the angle between the force and displacement vectors





- $\theta = 0°$, maximum work done
- $\theta = 180°$, maximum negative work done
  - remember, for vectors a negative sign = opposite direction. Maximum negative work means work acts to slow motion

Potential Energy: scalar

- stored energy as a result of the object's position

- Gravitational (E stored as result of vertical position of object)
  - $PE_{grav} = m * g * h$, units = Joules

- Elastic (E stored in elastic materials as a result of their stretching or compressing)

Kinetic Energy: scalar

- Energy of motion
- Can be vibrational, rotational, etc.
- $KE_{linear} = ½ * m * v^2$, units = Joules

Conservation of Energy

- E can be transformed from PE to KE
- Can transfer E from one object to another
  - ex: slingshot and rock

- Total Energy Conservation: Energy is never created or destroyed, only transformed from one type to another
  - Total E initial = Total E final
  - $(\text{all KE} + \text{all PE})_{\text{initial}} = (\text{all KE} + \text{all PE})_{\text{final}}$

Relating Work and Energy

- Net work done on a body is the change in kinetic energy of that body

- $W_{NET} = KE_{final} - Ke_{initial}$

- Power: rate work is done or energy is transformed
  - Power = Work / time = (F * d) / t = F * v

Systems of Bodies

- Before had looked at the motion of single objects
- Now need to look at systems of objects, or groups of objects

- A system of objects is one where conservation of energy holds
  - ex: slingshot and rock. If we consider only the slingshot before it's fired and after it's fired, energy conservation does not hold. If we consider the system of the slingshot plus rock, energy conservation does hold

Linear Momentum: vector

- p = m * v
- Useful quantity when talking about collisions

- Force is required to change momentum of an object
  - F = change in momentum / t
  - = change in (m * v) / t
  - = m * a

- Impulse is the change in momentum, or F * t

Conservation of Momentum

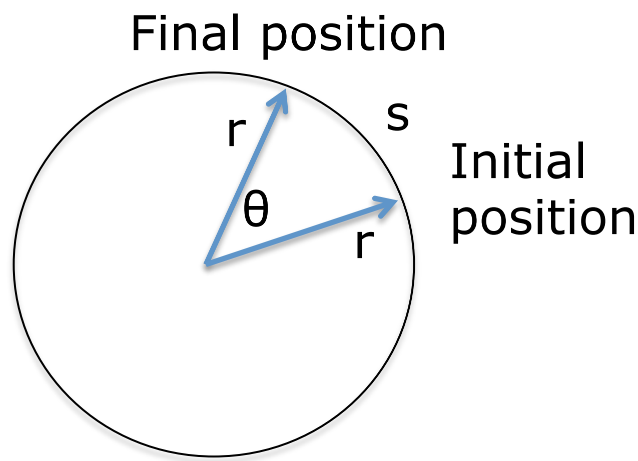
- Total momentum of a group of objects is the same before and after they interact, if no external forces act upon them
  - $p_{final} = p_{initial}$
- Momentum is a vector, so conservation law holds for magnitude AND direction
- Conservation of momentum means the momentum in the x direction and in y direction are separately conserved
  - $p_{x,\ initial} = p_{x,\ final}$
  - $p_{y,\ initial} = p_{y,\ final}$

Types of Collisions

- Elastic: E, p, and KE are each conserved
  - Objects bounce off of each other, billiard balls

- Inelastic: E and p are conserved, KE is NOT
  - Objects stick together

Circular Motion



- Angular position
  - $s = \theta * r$
  - θ = angular distance in RADIANS
  - s = arc length, r = radius

- 1 complete circle = 360° = 2π radians
- Convert degrees to radians
  - X in degrees * $(2 \pi / 360)$ = X in radians

Circular Motion

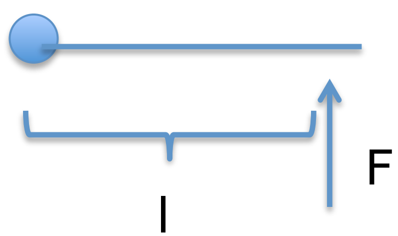
- Angular velocity (vector) , units radians / s
  - $w = \theta / t$
- Relate circular motion to linear motion
  - $v = r * w$
- Angular acceleration, units radians / s^2
  - α = change in w / t
  - $= (w_{final} – w_{initial}) / t$
- Relate circular motion to linear motion
  - $a = r * \alpha$

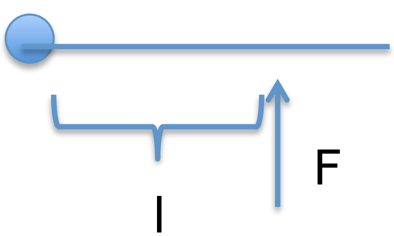
Circular Motion

- Frequency of rotation
  - $w = 2 \pi f$
  - $f = w / 2 \pi$

Circular Motion

- For rotational/circular motion, need new way to express the concept of force
- Torque: force equivalent for rotational motion
  - Force applied across the distance between the point of rotation and the point where force is applied
  - $\tau = F * l * \sin\theta$ (l as in lamp)





Circular Motion

- The l in torque is NOT the distance an object moves but the distance from the pivot point to where the force is applied

- Torque causes motion

- Newton's 2nd law for rotation
  - $\tau = I * \alpha$ (I as in interesting)
  - I = moment of inertia or angular mass, describes a measure of an objects resistance to change in rotation

Circular Motion

- Inertia differs based on geometry of object:
  - Cylinder of radius r, axis of rotation in center
    - $I = \frac{1}{2} m r^2$
  - Sphere of radius r, axis of rotation in center
    - $I = 2/5\ m r^2$
  - Rod of length l, axis of rotation in center
    - $I = 1/12\ m l^2$
  - Rod of length l, axis of rotation at one end
    - $I = 1/3\ m l^2$

Circular Motion

- Rotational KE
  - $KE_{rot} = ½ I w^2$
- Rotational/angular momentum
  - $L = I * w$

- Law of conservation of angular momentum: the angular momentum of an object remains constant, if no external torque acts upon it

Circular Motion

- Objects move as if all of their mass is located at the Center of Mass

Equilibrium

- Sum of all forces acting on a body must be 0 (no linear motion)

- Sum of all torques acting on a body must be 0 (no rotational motion)

Equilibrium

- 3 types, when at rest and slightly displaced
  - Stable: return to original position
  - Unstable: move further away from original position
  - Neutral: remains in new position

- An object whose center of mass is above it's base of support will be in stable equilibrium

Examples From Class

- Calculate linear KE = ½ m v^2
- Work done by a force to move a box, stop a moving object
- Conservation of E to calculate v and total E at each point on a roller coaster
- Two cars collide head on, come to rest, what E is converted into heat
- Use conservation of momentum to fully calculate elastic collision
  - moving ball hits a stationary ball, both rebound
  - figure out initial and final velocities
  - Conservation in x and y directions separately

Examples From Class

- Use conservation of momentum to fully calculate inelastic collision
  - figure out initial and final velocities/momentum
- Convert degrees to radians
- Angle subtended/arc length
- Number of revolutions of an object
- Torque meterstick balance
- Conservation of E using angular KE and linear KE

Examples From Class

- Conservation of angular momentum – spinning in chair
- Calculate torque, balance torque
- Equilibrium
- Rotational KE and Work
- Hookes Law for deformation of an object