Announcements

1. HW6 due March 4.
2. Prof. Reitze office hour this week:

   Friday 3 – 5 pm

3. Midterm1:

   grades posted in e-learning

   solutions and grade distribution posted on website

   if you want to look at your scantron, see Prof. Chan before March 3.

4. Make-up exam: April 21, 7:30 pm

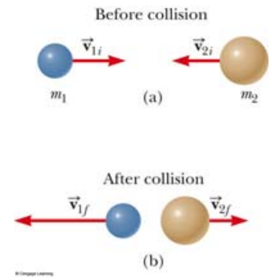
   covers all material in the course.

   need to let Prof. Chan and Prof. Reitze know in advance if you need to miss the midterms or final.

   location TBA

Recap: conservation of Momentum

- In a collision, the momentum of each object will change.
- The total momentum of the system remains constant



airplanes need Air

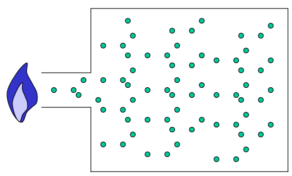
Rocket Propulsion

- The operation of a rocket depends on the law of conservation of momentum as applied to a system, where the system is the rocket plus its ejected fuel
  - This is different than propulsion on the earth where two objects exert forces on each other
    - Road on car
    - Train on track

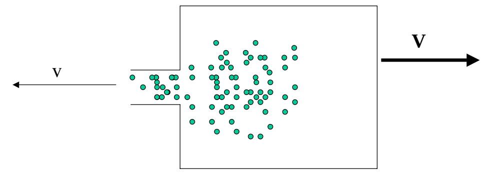
Rocket Propulsion, 2

- The rocket is accelerated as a result of the thrust of the exhaust gases
- This represents the inverse of an inelastic collision
  - Momentum is conserved
  - Kinetic Energy is increased (at the expense of the stored energy of the rocket fuel)

Milk jug rocket



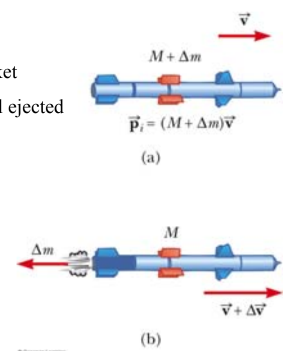
Milk jug rocket



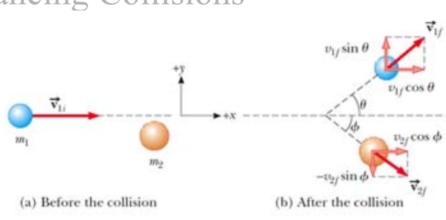
Rocket Propulsion

M = rocket

Δm = fuel ejected

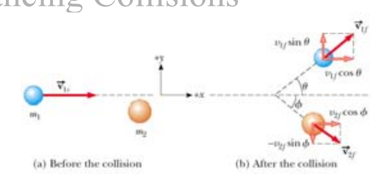


Glancing Collisions



- $\vec{p}_i = \vec{p}_f \Rightarrow p_{ix} = p_{fx}$ and $p_{iy} = p_{fy}$
- Momentum is conserved in the x direction and in the y direction
- Apply conservation of momentum separately to each direction

Glancing Collisions



- the *total momentum of the system in each direction is conserved*
  - $m_1 v_{1ix} + m_2 v_{2ix} = m_1 v_{1fx} + m_2 v_{2fx}$ and
    $m_1 v_{1iy} + m_2 v_{2iy} = m_1 v_{1fy} + m_2 v_{2fy}$

For the figure above:

$m_1 v_{1i} = m_1 v_{1f} \cos\theta + m_2 v_{2f} \cos\phi$ (x-component)

$0 = m_1 v_{1f} \sin\theta - m_2 v_{2f} \sin\phi$ (y-component)

Kinetic energy is conserved for glancing elastic collisions too. Remember kinetic energy is a scalar so the KE conservation equation is the same for glancing and head-on collisions.

$$\frac{1}{2}m_1v_{1i}^2 + \frac{1}{2}m_2v_{2i}^2 = \frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2v_{2f}^2$$

~~$v_{1i} + v_{1f} = v_{2i} + v_{2f}$~~

Chapter 7

Rotational Motion

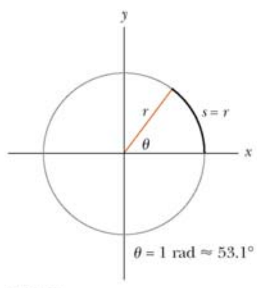
and

The Law of Gravity

The Radian

- The radian is a unit of angular measure
- The radian can be defined as the arc length s along a circle divided by the radius r
-

$$\theta = \frac{s}{r}$$



More About Radians

- Comparing degrees and radians

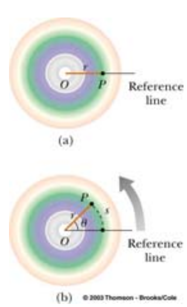
$$1\,\text{rad} = \frac{360°}{2\pi} = 57.3°$$

- Converting from degrees to radians

$$\theta\,[rad] = \frac{\pi}{180°}\,\theta\,[\deg rees] = \frac{1}{57.3°}\theta[\deg rees]$$

Angular Displacement

- Axis of rotation is the center of the disk
- Need a fixed reference line
- During time t, the reference line moves through angle θ

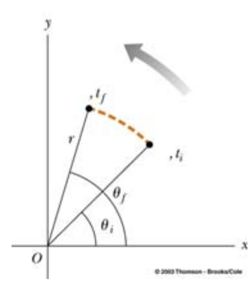


Average Angular Speed

- The average angular speed, ω, of a rotating rigid object is the ratio of the angular displacement to the time interval

$$\omega_{av} = \frac{\theta_f - \theta_i}{t_f - t_i} = \frac{\Delta\theta}{\Delta t}$$

Unit: rad/s



Average Angular Acceleration

- The average angular acceleration α of an object is defined as the ratio of the change in the angular speed to the time it takes for the object to undergo the change:

$$\alpha_{av} = \frac{\omega_f - \omega_i}{t_f - t_i} = \frac{\Delta\omega}{\Delta t}$$

Unit: rad/s^2

Relationship Between Angular and Linear Quantities

- Displacements
  $\Delta s = \Delta\theta r$
- Speeds
  $v_t = \omega r$
- Accelerations
  $a_t = \alpha r$

- Every point on the rotating object has the same angular motion
- Not every point on the rotating object has the same linear motion

Rotational kinematic equations

$$\frac{v_t}{r} = \frac{v_{ti}}{r} + \frac{a_t t}{r}$$

$$\Rightarrow \omega = \omega_i + \alpha t$$

Similarly:

$$\omega^2 = \omega_i^2 + 2\alpha\,\Delta\theta$$

$$\Delta\theta = \omega_i t + (1/2)\,\alpha t^2$$

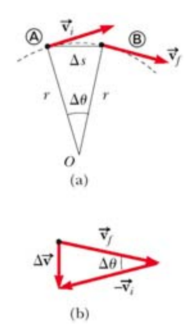
Analogies Between Linear and Rotational Motion

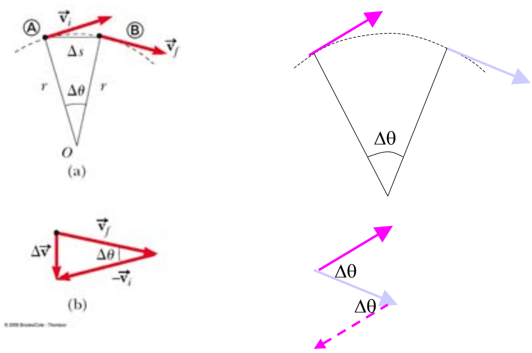
Linear Motion with a Constant (Variables: x and v)	Rotational Motion about a Fixed Axis with α Constant (Variables: θ and ω)	
$v = v_i + at$	$\omega = \omega_i + \alpha t$	[7.7]
$\Delta x = v_i t + \frac{1}{2}at^2$	$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$	[7.8]
$v^2 = v_i^2 + 2a\Delta x$	$\omega^2 = \omega_i^2 + 2\alpha\Delta\theta$	[7.9]

A coin with a diameter of 2.40 cm is dropped on edge onto a horizontal surface. The coin starts out with an initial angular speed of 18.0 rad/s and rolls in a straight line without slipping. If the rotation slows with an angular acceleration of magnitude 1.90 rad/s^2, how far does the coin roll before coming to rest?

Centripetal Acceleration

- Centripetal refers to "center-seeking"
- The direction of the velocity changes
- The acceleration is directed toward the center of the circle of motion





Centripetal Acceleration, final

- The magnitude of the centripetal acceleration is given by

$$a_c = \frac{v_t^2}{r}$$

  – This direction is toward the center of the circle

Centripetal Acceleration and Angular Velocity

- The angular velocity and the linear velocity are related ($v_t = \omega r$)
- The centripetal acceleration can also be related to the angular velocity

$$a_C = \omega^2 r$$