Graded exams that were not yet picked up can be obtained from Helen in C136.

Average: 66 and standard dev: 18.

If you (still) feel a grading error has been made on your exam, you may submit a request (to Helen Gribble in PAB C136) for regrading. (Form on class website.) If you plan this, do not write anything more on your exam. If you request regrading, your entire exam will be regraded. DEADLINE: End of business today.

HW #5 is due by midnight.
It is relatively short.

Office hours this afternoon: 4:00 – 5:30pm…

Exam grades posted on Tycho.

Sections 8.1 Conservation of (linear) Momentum

(Linear) Momentum:

Newton's "quantity of motion"

$\vec{p} = m\vec{v}$ **is definition so can write Newton's 2nd**

$$\vec{F} = m\vec{a} = m\frac{d\vec{v}}{dt} = \frac{d\vec{p}}{dt}$$ **this for a particle.**

For a system, $\vec{P}_{\text{sys}} = \sum_i \vec{p}_i = \sum_i m_i\vec{v}_i = M\vec{v}_{\text{cm}}$

So $\frac{d}{dt}\vec{P}_{\text{sys}} = M\vec{a}_{\text{cm}} = \vec{F}_{\text{net,ext}} = \sum_i \vec{F}_{\text{i,ext}}$

If no net external force $\vec{P}_{\text{sys}}$ **is constant.**

Law of conservation of (linear) momentum. Follows from Newton's 2nd and vector addition.

Note different rules for conservation of momentum and of mechanical energy:

1. **You can have internal dissipation and E_{mech} will change, but $\vec{P}_{\text{sys}}$ need not change.**
2. **You can have a net external force perpendicular to the displacement, and $\vec{P}_{\text{sys}}$ will change (direction) but E_{mech} need not change**

A 40-kg girl, standing at rest on the ice, gives a 60-kg boy, who is also standing at rest on the ice, a shove.

After the shove, the boy is moving backward at 2 m/s. Ignore friction.

The girl's speed is

A. zero
B. 1.3 m/s
C. 2 m/s
D. 3 m/s
E. 6 m/s

Clicker

Section 8.2 ***K* for a system**

Considering sum of individual *K* for elements of a system, find $K = \frac{1}{2}Mv_{\text{cm}}^2 + K_{\text{rel}}$

where $K_{\text{rel}} = \sum_i \frac{1}{2} m_i u_i^2$

and $\vec{v}_i = \vec{V}_{\text{cm}} + \vec{u}_i$ **gives** $\vec{u}_i$

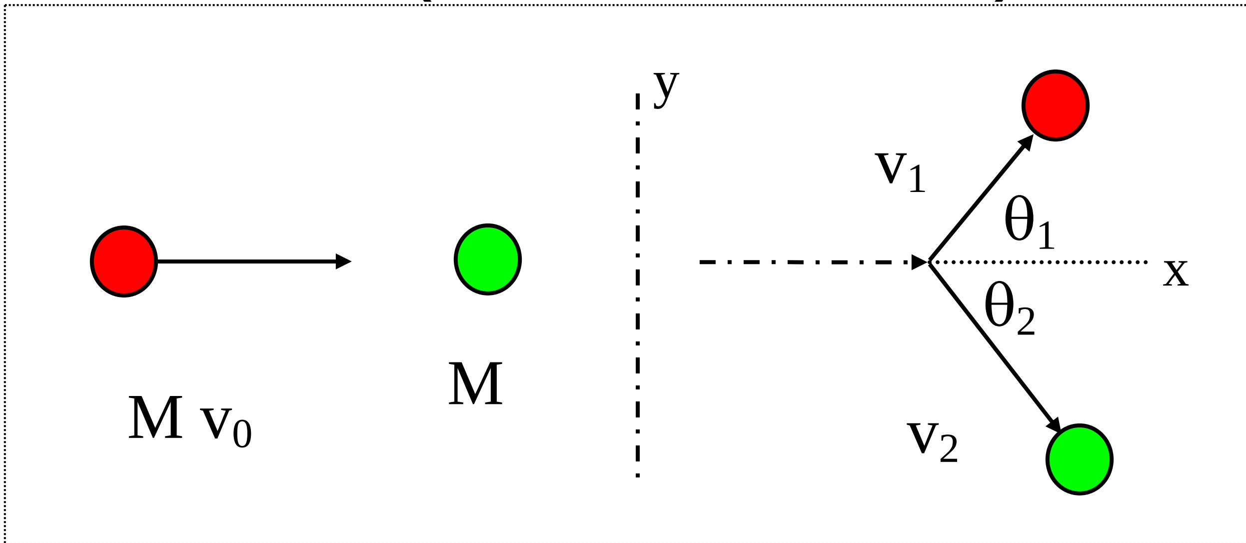
If $\vec{P}_{\text{sys}}$ **is constant, so is** $\frac{1}{2}Mv_{\text{cm}}^2$ **but** K_{rel} **may change from internal forces. Examples:**

Section 8.3 Impulse, collisions

$\int \vec{F} dt = \int \frac{d\vec{p}}{dt} dt = \Delta \vec{p}$ **"Impulse" usually F is applied over a short time, e.g. hit a ball. If you know (or estimate)** Δt**, you can get** $\vec{F}_{\text{ave}} = \frac{\Delta \vec{p}}{\Delta t}$

Demo.

Billiard Balls (ignore rotation for now)
elastic collision (means K is conserved):



θ_1 can be a range of angles. What about θ_2?
What about v_1 and v_2?

Conservation of momentum: 2 equations
Conservation of energy: 1 equation.
3 equations → three unknowns, v_1, v_2 and θ_2

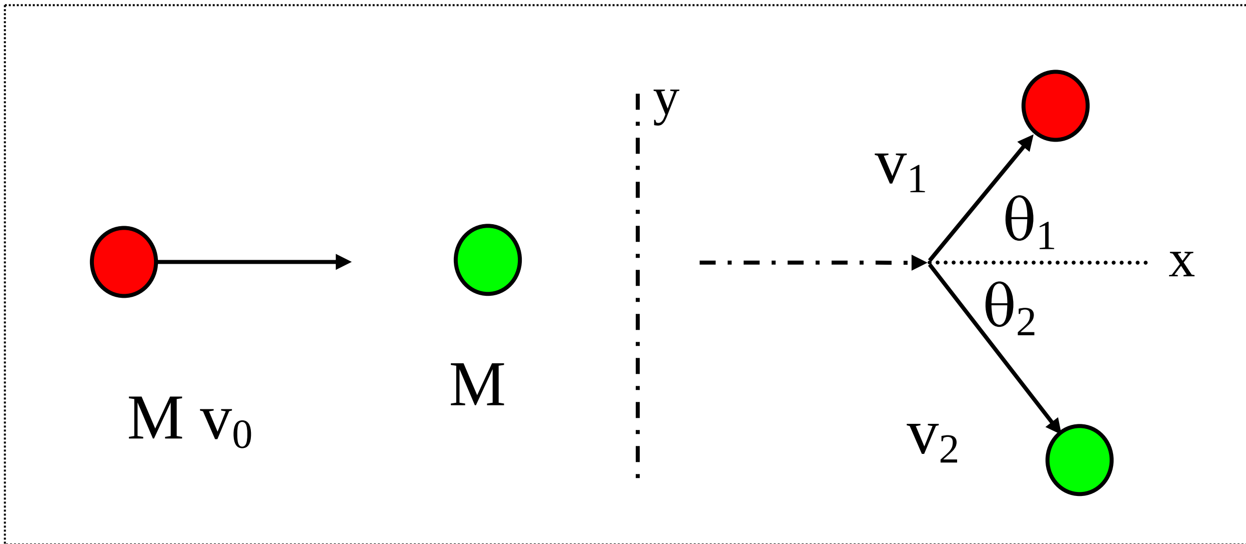
Challenging algebra.
(special trick when both have same M.)

Special case:
$\theta_2 = 0$ (head on collision)
then v_{1y}, and v_{2y} are 0.
$v_{2x} = v_2 = v_0$

What if M's are not equal?

Demo

inelastic collision:



If you don't know how much energy is lost you have only 2 equations

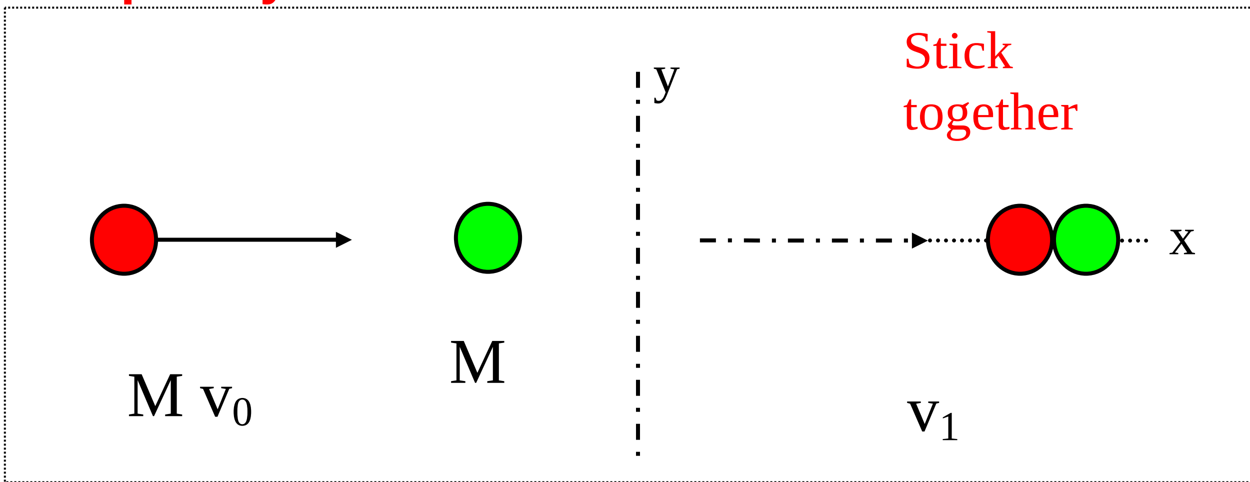
Conservation of momentum: (M's cancel)

$$v_1 \sin(\theta_1) - v_2 \sin(\theta_2) = 0 \qquad \textbf{y – momentum}$$

$$v_1 \cos(\theta_1) + v_2 \cos(\theta_2) = v_0 \qquad \textbf{x – momentum}$$

Given both angles, you can solve for v_1 and v_2, or given *v*'s you can get angles, etc.

Completely inelastic collision:



Now conservation of momentum tells you v_1 is in same direction as v_0 (i.e. y-component stays 0)

One equation, one unknown – you can get v_1 from M and v_0 (what is it?)
and then you get initial and final K.
(Do it).