Next hour exam is Friday Nov 9 Same rules as last time. One side of a sheet for notes, calculators w/o text storage. Etc…

Homework is due today, and is posted on Tycho.

Office hours

Today: 4:40+ - 6:00 or more as needed.
Tomorrow (4-5:30pm) not Friday.

CLUE exam review Today, Wednesday, November 7 at 7pm.
The review is in Mary Gates Hall 231.

Review Chapter 5.2 -- 8

Applications of Newton's laws, work, energy, and linear momentum.

Center of Mass (*M* is total mass)

$M\vec{r}_{cm} = \sum_i m_i \vec{r}_i = m_1\vec{r}_1 + m_2\vec{r}_2$ **illustrating special case of a system with 2 elements.**

Thus, differentiating to get velocities:

$M\vec{v}_{cm} = \sum_i m_i \vec{v}_i = m_1\vec{v}_1 + m_2\vec{v}_2$ **which means**

$$\vec{P}_{cm} = \sum_i \vec{p}_i = \vec{p}_1 + \vec{p}_2$$

Differentiating again to get accelerations, use Newton's 2nd and 3rd (3rd says internal forces cancel)

$$M\vec{a}_{cm} = \sum_i m_i \vec{a}_i = m_1\vec{a}_1 + m_2\vec{a}_2 = \vec{F}_{\text{net,ext}} = \vec{F}_1 + \vec{F}_2$$

$\dfrac{d\vec{P}}{dt} = \vec{F}_{\text{net,ext}}$ **note if** $\vec{F}_{\text{net,ext}} = 0$ **then** $\vec{F}_1 = -\vec{F}_2$

Conservation of momentum:

$\vec{P}_{cm}$ **is conserved if net external force = 0. In CM system, i.e. moving along with** $\vec{V}_{cm}$**, note** $\vec{P}_{cm}$ **is 0.**

Internal forces (between the m_i) are responsible for collisions.

For forces of short duration,

$$\int d\vec{p} = \int \vec{F}dt \rightarrow \Delta\vec{p} = \int \vec{F}dt = \vec{F}_{\text{ave}}\Delta t \quad \textbf{Impulse.}$$

Work, kinetic, potential, and other energy

Work is defined $dW = \vec{F}\bullet d\vec{\ell}$ **and for some displacement** $W = \vec{F}\bullet\Delta\vec{s}$ **if** $\vec{F}$ **is constant.**

Power is work per unit time: $P = dW/dt$

consequently $P = \vec{F}\bullet\vec{v}$ **also.**

(Units W, ft-lb/s, or hp)

The amount of work needed to change a speed gives us $K = \frac{1}{2}mv^2$ **and the amount of *W* is equal to the change in *K*. (unit Joule)**

For conservative (not-dissipative) forces, there is a potential energy, and $\Delta U = -W = -\int_{\vec{r}_1}^{\vec{r}_2} \vec{F}(\vec{r})\bullet d\vec{\ell}$

For gravity near surface of earth, *U=mgh*

For a spring, *U=½kx*^{2}

Mechanical Energy $E_{mech}=U+K$ for a system is conserved if there is no dissipation (or other non-conservative forces) and no external work. (for a system, but the members of the system can exchange E_{mech})

If we have dissipation, $E_{mech} \rightarrow E_{thermal}$
$E_{chemical} \rightarrow E_{mech}$ sometimes. (explosions, e.g.)

Collisions can be elastic (K is conserved) or inelastic (K turns into $E_{thermal}$) often in collisions or explosions external forces are negligible and $\vec{P}_{cm}$ is conserved. Then we use $\vec{P}_{tot,initial} = \vec{P}_{tot,final}$ to pin down various things.

Repeat: Mechanical Energy $E_{mech}=U+K$ for a system is conserved if there is no dissipation (or other non-conservative forces) and no external work.

Examples where *U* and *K* turn into each other but E_{mech} is conserved:

- **frictionless sliding on ramps, tracks, etc**
- **perfect springs**
- **elastic collisions**
- **perfect pendulums**

Examples where E_{mech} is not conserved

- **Sliding with friction**
- **actual springs (a good spring has little dissipation)**
- **inelastic collisions**
- **completely inelastic collisions, where the colliding partners stick together**
- **actual pendulums (a little dissipation)**

Final example: Rockets
considering the system of
the rocket and as yet unburned fuel (mass M)
plus a bit of fuel being exhausted in a short Δt
at a speed u_{exh} (relative to the rocket)

Momentum conservation gives us (after some fiddling) $M\vec{a}_{\text{rocket}} = \vec{F}_{\text{thrust}} + \vec{F}_{ext}$ **with**

$$\vec{F}_{\text{thrust}} = -\frac{dM}{dt} u_{\text{exh}} = +Ru_{\text{exh}}$$

in the direction the rocket points. (think of impulse)

This equation is integrated in the text to give *v*(*t*) for a rocket going straight up. You should not try to memorize it, but maybe understand it.

The main point is M is decreasing as long as the rocket burns, and the acceleration grows with constant force but shrinking mass.

Chemical energy (or who knows what kind) is turned into kinetic and potential energy as the rocket lifts up and speeds up.