Key concepts this week:

- Definition of momentum ($\vec{p} = m\vec{v}$)
- Conservation of momentum
  - Total momentum does not change so long as the next external force is zero (i.e. $\vec{F}_{\text{net, external}} = 0 \;\Rightarrow\; \vec{P}_{\text{total}} = \sum_i \vec{p}_i = \text{constant}$)
  - Particularly easy to use in the center of mass frame where $\vec{P}_{\text{total}} = 0$
  - In general, kinetic energy is NOT conserved in a collision (i.e. most collisions are "inelastic")

Along Came a Spider...

A man and a woman are sitting in a sleigh that is at rest on frictionless ice. The mass of the man is 80 kg, that of the woman is 60 kg, and that of the sleigh is 120 kg. The people suddenly see a poisonous spider on the floor of the sleigh and jump out. The man jumps to the left with a velocity of 5.0 m/s relative to the ground at 30^{o} above the horizontal. The woman jumps to the right at 9.0 m/s relative to the ground at 37^{o} above the horizontal. What is the velocity (magnitude and direction) of the sleigh after they have both jumped out?

Run the Plank

In frozen Minnesota the Winter Sports Carnival includes some unusual events. Since it is dangerous to run on ice, each runner runs on a heavy (240 kg) and long (40 m) wooden plank, which itself rests on the smooth and horizontal ice. One of the competitors is a 60 kg woman who runs the length of the plank in 4.4 seconds, quite an impressive time. Her performance is viewed by a crowd huddled on the ice. The performance that they see is less impressive. With what speed do they see her moving?

Space Shuttle Emergency

You have been hired to check the technical correctness of an upcoming made-for-TV murder mystery. The mystery takes place in the space shuttle. In one scene, an astronaut's safety line is sabotaged while she is on a space walk, so she is no longer connected to the space shuttle. She checks and finds that her thruster pack has also been damaged and no longer works. She is 200 m from the shuttle and moving with it (i.e., she is not moving with respect to the shuttle). She is drifting in space with only 4 minutes of air remaining. To get back to the shuttle, she decides to unstrap her 10-kg tool kit and throw it away with all her strength, so that it has a speed of 8 m/s *relative to her*. In the script, she survives, but is this correct? Her mass, including her space suit but not her tool kit, is 80 kg.

Review: Bungee Jumpin'

In order to raise money for a scholarship fund, you convince the Physics 211 lecturer to bungee jump from a crane. To add some interest, the jump will be made from 44 m above a 2.5 m deep pool of Jello. A 30 m long bungee cord would be attached to his ankle. First you must convince him that your plan is safe for a person of his mass, roughly 70 kg. He knows that as the bungee cord begins to stretch, it will exert a force that has the same properties as the force exerted by a spring. Your plan has your lecturer stepping off a platform and being in free fall for the 30 m before the cord begins to stretch. You must determine the elastic constant of the bungee cord so that it stretches exactly 12 m, which will just keep his head out of the Jello.

Review: Speeding Ticket?

You are driving your car uphill along a straight road. Suddenly you see a car run a red light and enter the intersection just ahead of you. You slam on your brakes and skid in a straight line to a stop, leaving skid marks 100 feet long. A policeman observes the whole incident and, much to your shock, gives *you* a ticket for exceeding the speed limit of 30 mph. When you get home, you consult your Physics 211 notes and estimate that the coefficient of kinetic friction between your tires and the road was 0.60 and the coefficient of static friction was 0.80. You estimate that the hill made an angle of 10^o with the horizontal. You look up in your owner's manual and find that your car weighs 2050 lbs. Will you fight the traffic ticket in court?

Kinematics

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$

$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + at^2/2$

$v^2 = v_0^2 + 2a(x-x_0)$

$g = 9.81\ m/s^2 = 32.2\ ft/s^2$

$\mathbf{v}_{A,B} = \mathbf{v}_{A,C} + \mathbf{v}_{C,B}$

Uniform Circular Motion

$a = v^2/r = \omega^2 r$

$v = \omega r$

$\omega = 2\pi/T = 2\pi f$

Dynamics

$\mathbf{F}_{net} = m\mathbf{a} = d\mathbf{p}/dt$

$\mathbf{F}_{A,B} = -\mathbf{F}_{B,A}$

$F = mg$ (near earth's surface)

$F_{12} = -Gm_1m_2/r^2$ (in general)

(where $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$)

$\mathbf{F}_{spring} = -k\, \mathbf{\Delta x}$

Friction

$f = \mu_k N$ (kinetic)

$f \leq \mu_S N$ (static)

Work & Kinetic energy

$W = \int \mathbf{F \cdot dl}$

$W = \mathbf{F \cdot \Delta r} = F\, \Delta r\, cos\theta$

(constant force)

$W_{grav} = -mg\Delta y$

$W_{spring} = -k(x_2^2 - x_1^2)/2$

$K = mv^2/2 = p^2/2m$

$W_{NET} = \Delta K$

Potential Energy

$U_{grav} = mgy$ (near earth surface)

$U_{grav} = -GMm/r$ (in general)

$U_{spring} = kx^2/2$

$\Delta E = \Delta K + \Delta U = W_{nc}$

Power

$P = dW/dt$

$P = \mathbf{F \cdot v}$ (for constant force)

System of Particles

$\mathbf{R}_{CM} = \Sigma m_i \mathbf{r}_i / \Sigma m_i$

$\mathbf{V}_{CM} = \Sigma m_i \mathbf{v}_i / \Sigma m_i$

$\mathbf{A}_{CM} = \Sigma m_i \mathbf{a}_i / \Sigma m_i$

$\mathbf{P} = \Sigma m_i \mathbf{v}_i$

$\Sigma \mathbf{F}_{EXT} = M\mathbf{A}_{CM} = d\mathbf{P}/dt$

Impulse

$\mathbf{I} = \int \mathbf{F}\, dt$

$\Delta \mathbf{P} = \mathbf{F}_{av} \Delta t$