GENERAL PHYSICS I: PHYS 10

Schedule - Fall 2007
(lecture schedule is approximate)

8	M	22	19	Chapter 7	Impulse and momentum	No lab or tutorial
	Tue	23	MID-TERM TEST, Ch 1-5, Tuesday, October 23, 7-9 pm			
	W	24	20	Chapter 7	Impulse and momentum	
	F	26	21	Chapter 8, sections 1-3 only	Rotational kinematics	
9	M	29	22			Experiment 3: Forces in Equilibrium
	W	31	23	Chapter 9 sections 1 - 3, 6	Rotational dynamics	
	F	Nov 2	24			
10	M	5	25	Chapter 10 exclude 10.7 and 10.8	Simple harmonic motion, sections 10.5 and 10.6, for self study only	Tutorial and Test 3 (chapters 7, 8)
	W	7	26			
	F	9	27	Chapter 11 exclude 11.11	Fluids	

Week of October 29

Experiment 3: Forces in Equilibrium

Mastering Physics Assignment 3

Is due Friday, October 26 at 11 pm

Covers material from chapters 4 and 5

There are 8 questions for practice and 6 for credit

Assignment 4 arrives on Monday

Chapters 6, 7

Due November 12 at 11 pm

Newton's Second Law in Various Forms

$$\vec{F} = m\vec{a}, \text{ or, } \vec{F} = m\frac{\Delta\vec{v}}{\Delta t}$$

$$\text{Define momentum } \vec{p} = m\vec{v}, \text{ so,}$$

$$\text{impulse } \vec{F}\Delta t = m\Delta\vec{v} = \Delta\vec{p}$$

(impulse-momentum theorem,
the change in momentum is equal to the impulse imparted)

$$\text{and, } \vec{F} = \frac{\Delta\vec{p}}{\Delta t}$$

$$\text{If } \vec{F} = 0, \text{ then momentum is constant}$$

Clickers!

You are standing on the edge of a dock and jump straight down. If you land on sand your stopping time is much shorter than if you land on water. Using the impulse-momentum theorem as a guide, $F\Delta t = \Delta p$, determine which one of the following statements is correct.

A) In bringing you to a halt, the sand exerts a greater impulse on you than does the water.

B) In bringing you to a halt, the sand and the water exert the same impulse on you, but the sand exerts a greater average force.

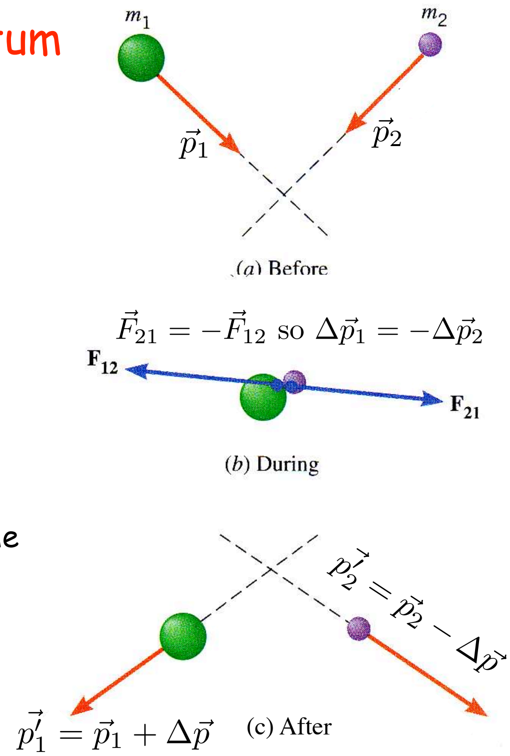
C) In bringing you to a halt, the sand and the water exert the same impulse on you, but the sand exerts a smaller average force.

Conservation of Momentum

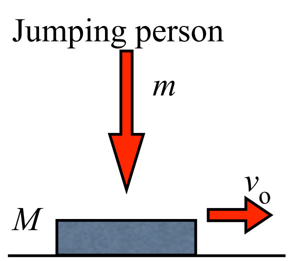
In a collision between two isolated masses (no applied or friction forces) the total momentum is conserved:

$$\vec{p}_1 + \vec{p}_2 = \vec{p}_1' + \vec{p}_2'$$

This is because the action and reaction forces that act between the masses while they're in contact are equal in magnitude, but opposite in direction, so what one mass gains in momentum the other loses...



7.C13: An ice boat slides without friction horizontally across the ice. Someone jumps vertically down from a bridge onto the boat.
Does the momentum of the boat change?



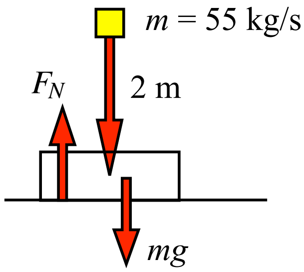
As the momentum of the person is downward, not sideways, the horizontal momentum of the boat is unchanged.

As the mass of the boat is increased by the mass of the person, the boat moves more slowly, so that the momentum is unchanged –

before $\quad Mv_0 = (M+m)v \quad$ after

$$v = \frac{Mv_0}{M+m}$$

7.14: A dump truck is being filled with sand at a rate of 55 kg/s. The sand falls straight down from rest from a height of 2 m above the truck bed.



The truck stands on a weigh scale.

By how much does the reading of the scale exceed the weight of the truck?

The truck and scale absorb the momentum of the falling sand.

The force exerted by the truck and scale to bring the sand to rest is equal to the rate at which they absorb momentum.

That is, $F = \dfrac{\Delta p}{\Delta t}$

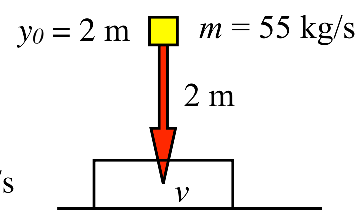
Work out speed and momentum of the sand at impact.

Conservation of mechanical energy:

$PE_0 + KE_0 = PE + KE$

$mgy_0 + 0 = 0 + mv^2/2$

So $v = \sqrt{2gy_0} = \sqrt{2g \times (2\ \text{m})} = 6.261$ m/s



The momentum carried by the sand is then,

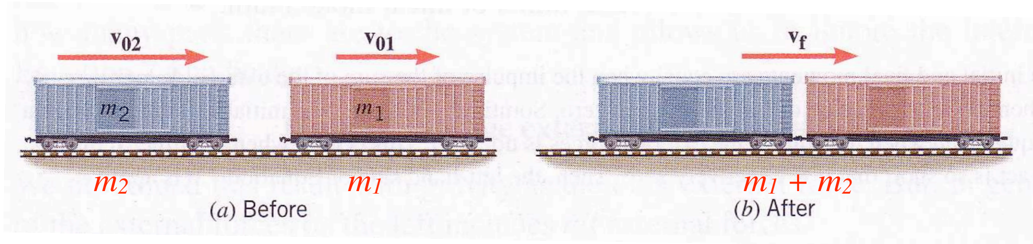
mv = (55 kg) × (6.261 m/s) = 344.4 kg.m/s, each second

This is the rate at which the momentum of the sand is changed by impact with the truck and scale, i.e. $\Delta p/\Delta t$.

Then, $F = \dfrac{\Delta p}{\Delta t}$

So the force exerted by the truck and scale is 344.4 N.

Conservation of Momentum



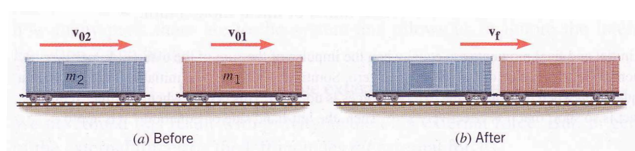
The freight car on the left catches up with the one on the right and connects up with it. They travel on with the same speed v_f.

Conservation of momentum:

$$m_2 v_{02} + m_1 v_{01} = (m_1 + m_2) v_f$$

So $v_f = \dfrac{m_2 v_{02} + m_1 v_{01}}{m_1 + m_2}$

$$\boxed{v_f = \frac{m_2 v_{02} + m_1 v_{01}}{m_1 + m_2}}$$



Example: $m_1 = 65{,}000$ kg, $m_2 = 92{,}000$ kg
$v_{01} = 0.8$ m/s, $v_{02} = 1.3$ m/s

$$v_f = \frac{92{,}000 \times 1.3 + 65{,}000 \times 0.8}{92{,}000 + 65{,}000} = 1.09 \text{ m/s}$$

Kinetic energy: $KE_i = \dfrac{m_1 v_{01}^2}{2} + \dfrac{m_2 v_{02}^2}{2} = 98,540 \text{ J}$

$KE_f = \dfrac{(m_1 + m_2) v_f^2}{2} = 93,266 \text{ J}$

Missing 5,274 J

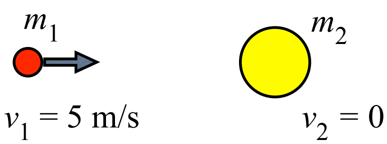
What happened to the missing kinetic energy?

The collision was **inelastic**, some KE got turned into heat.

- **Elastic collision**: the total kinetic energy after collision is equal to the total before collision.

- **Inelastic collision**: the total kinetic energy is not conserved. If objects stick together after collision, the collision is "perfectly inelastic" – there is no bounce.

Example: A ball of mass $m_1 = 0.25$ kg makes a perfectly elastic collision with a ball of mass $m_2 = 0.8$ kg.

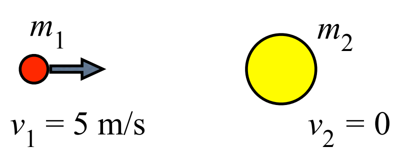


Initial momentum = $m_1 v_1 + 0$

Momentum after impact = $m_1 v_{f1} + m_2 v_{f2}$

Momentum conserved: $m_1 v_1 = m_1 v_{f1} + m_2 v_{f2}$

$\boxed{\text{Momentum conserved: } m_1 v_1 = m_1 v_{f1} + m_2 v_{f2}}$



So, $v_{f2} = \dfrac{m_1 v_1 - m_1 v_{f1}}{m_2}$

substitute for v_{f2}

The collision is elastic, so:

$$\text{KE:} \quad \frac{m_1 v_1^2}{2} + 0 = \frac{m_1 v_{f1}^2}{2} + \frac{m_2 v_{f2}^2}{2}$$

Solution, after some algebra, is:

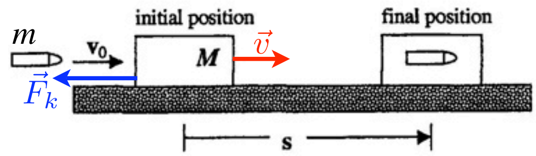
$$v_{f1} = v_1 \left[\frac{m_1 - m_2}{m_1 + m_2}\right]$$

$$v_{f2} = v_1 \left[\frac{2m_1}{m_1 + m_2}\right]$$

If $m_1 = m_2$, then $v_{f1} = 0$, $v_{f2} = v_1$

If $m_1 = 0.25$ kg, $m_2 = 0.8$ kg, then $v_{f1} = -2.62$ m/s, $v_{f2} = 2.38$ m/s

Dec 2003 Final, Q26: A bullet of mass m is fired with speed v_0 into a block of wood of mass M. The bullet comes to rest in the block. The block with the bullet inside slides along a horizontal surface with coefficient of kinetic friction μ_k. How far does the block slide before it comes to rest?



For the impact -

bullet

Conservation of momentum: $mv_0 = (m+M)v$

right after impact

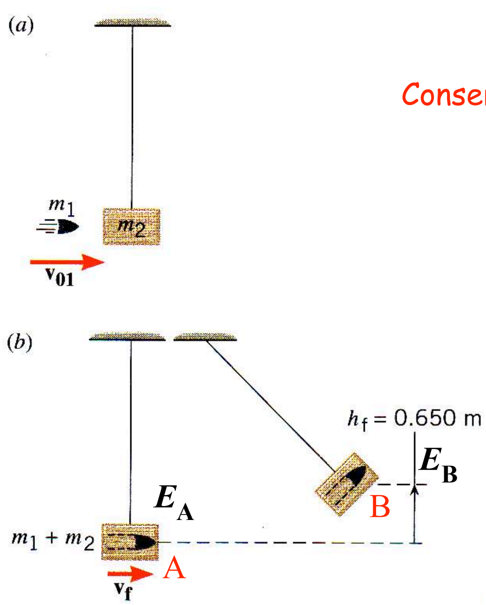
So, speed of block + bullet immediately after impact is: $v = \dfrac{mv_0}{m+M}$

Work-energy theorem, block coming to rest: $W_{nc} = F_k s = \Delta KE + \Delta PE$

That is: $-\mu_k(m+M)g \times s = -(m+M)v^2/2 + 0$

So, $s = \dfrac{v^2/2}{\mu_k g} = \dfrac{1}{2\mu_k g}\left[\dfrac{mv_0}{m+M}\right]^2$

Ballistic pendulum
Measure the speed of a bullet



Conservation of momentum for initial impact:

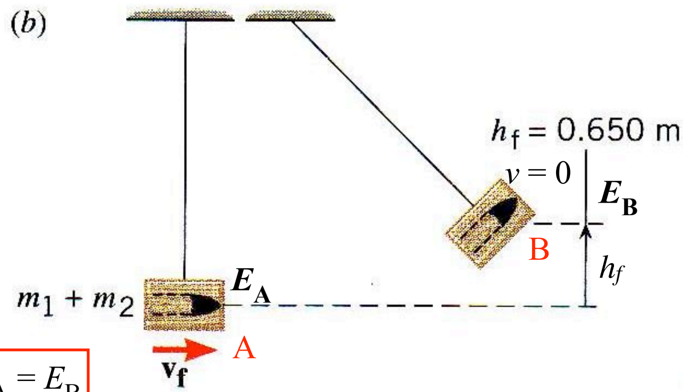
$$\boxed{m_1 v_{01} = (m_1 + m_2) v_f}$$

The collision is inelastic – the bullet drills into the block, generating a lot of heat.

BUT, after the collision, the block + bullet swing up to a highest point and conserve mechanical energy.

E_A(**after** impact) $= E_B$

$$\boxed{m_1 v_{01} = (m_1 + m_2) v_f \ \rightarrow\ v_f = \frac{m_1 v_{01}}{(m_1 + m_2)}}$$

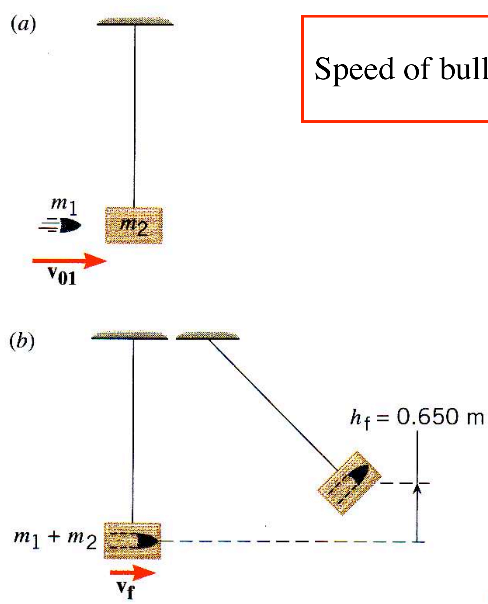


$$\boxed{E_A = E_B}$$

That is, $\frac{1}{2}\cancel{(m_1 + m_2)} v_f^2 = 0 + \cancel{(m_1 + m_2)} g h_f$

$$v_f = \sqrt{2 g h_f} = \frac{m_1 v_{01}}{m_1 + m_2}$$

Speed of bullet, $v_{01} = \frac{(m_1 + m_2)}{m_1}\sqrt{2 g h_f}$

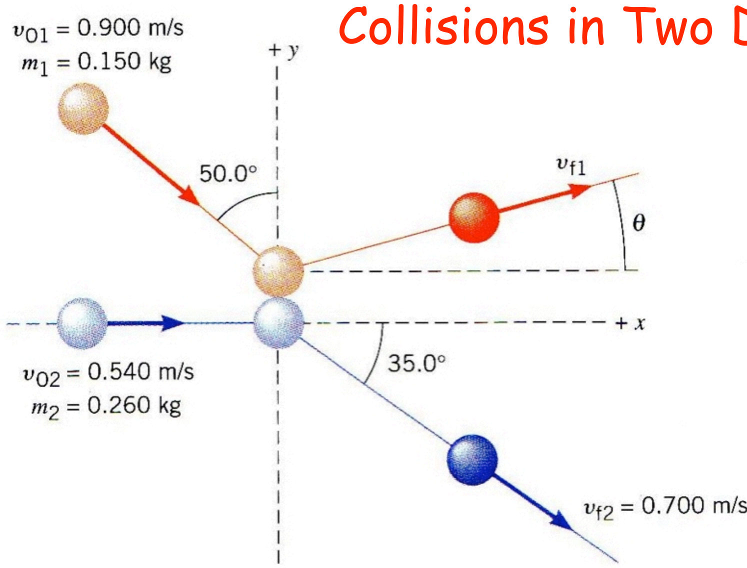


$$\boxed{\text{Speed of bullet, } v_{01} = \frac{(m_1 + m_2)}{m_1}\sqrt{2 g h_f}}$$

$$\begin{aligned} \text{Bullet, } m_1 &= 0.01 \text{ kg}, \\ \text{block, } m_2 &= 2.5 \text{ kg}, \\ h_f &= 0.65 \text{ m} \end{aligned}$$

Speed of bullet, $v_{01} = \frac{(0.01 + 2.5)}{0.01}\sqrt{2g \times 0.65} = 896$ m/s

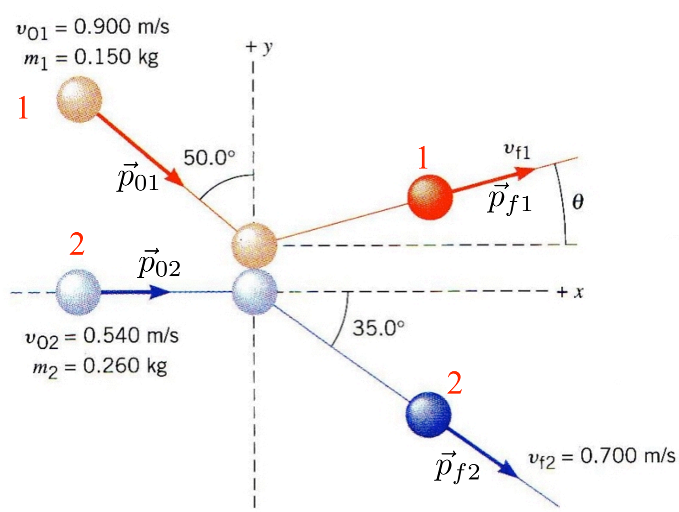
Collisions in Two Dimensions



Conservation of momentum: $\vec{p}_0 = \vec{p}_f$

x and y components: $p_{0x} = p_{fx}$

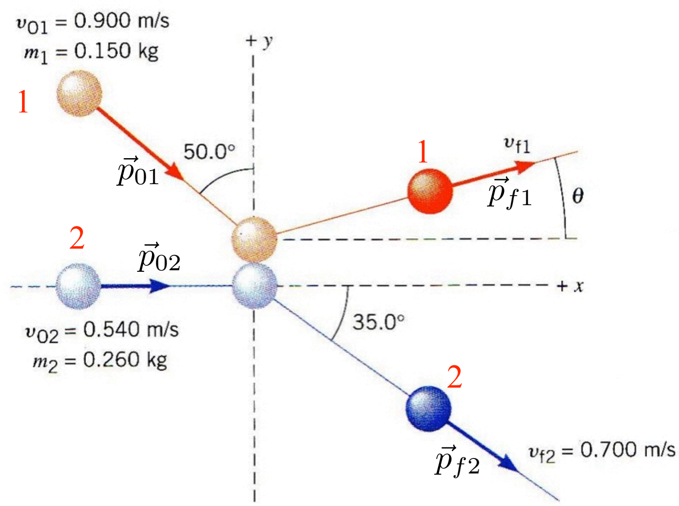
$$p_{0y} = p_{fy}$$



x: $p_{01} \sin 50^\circ + p_{02} = p_{f1x} + p_{2f} \cos 35^\circ$

That is, $p_{f1x} = 0.9 \times 0.15 \sin 50^\circ + 0.26 \times 0.54 - 0.26 \times 0.7 \cos 35^\circ$

$$\boxed{p_{f1x} = 0.0947 \text{ kg.m/s}}$$

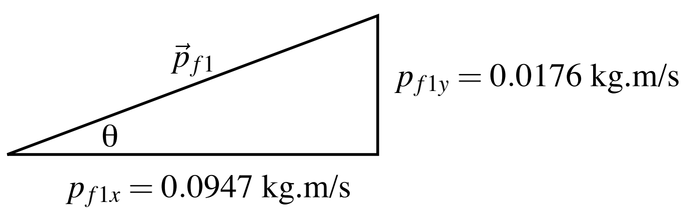


y: $-p_{01}\cos 50^\circ + 0 = p_{f1y} - p_{f2}\sin 35^\circ$

So, $p_{f1y} = p_{f2}\sin 35^\circ - p_{01}\cos 50^\circ$

$$= 0.26 \times 0.7 \sin 35 - 0.15 \times 0.9 \cos 50^\circ$$

$$\boxed{p_{f1y} = 0.0176 \text{ kg.m/s}}$$



$$p_{f1} = \sqrt{0.0947^2 + 0.0176^2} = 0.0963 \text{ kg.m/s}$$

$$v_{f1} = p_{f1}/m_1 = 0.64 \text{ m/s}$$

$$\tan\theta = \frac{0.0176}{0.0947} = 0.1859$$

$$\theta = 10.5^\circ$$