Conservation of Momentum

Quantities of motion:

momentum:	**$p = mv$**	**vector**
kinetic energy:	**$K = 1/2mv^2$**	**scalar**

Momentum has direction, kinetic energy does not.

Example: A 4-kg is moving to the *right* (positive direction) with a speed of 6 m/s.

K = 72 J
p = +24 kg·m/sec

A 4-kg is moving to the *left* with a speed of 6 m/s.

K = 72 J
p = -24 kg·m/sec

Conservation laws:

- The total kinetic energy of a closed system is <u>not</u> conserved. (But the total of all types of energy is conserved.)

- The total momentum of all objects in a closed system is conserved.

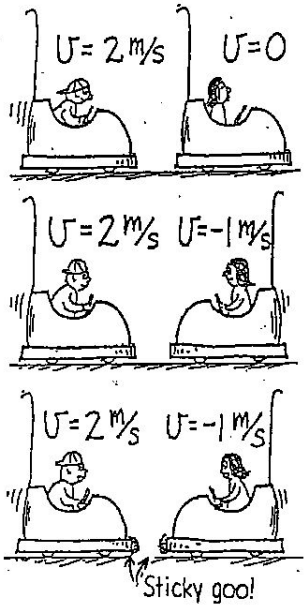
(Example: A collision between billiard balls.)

Momentum Conservation

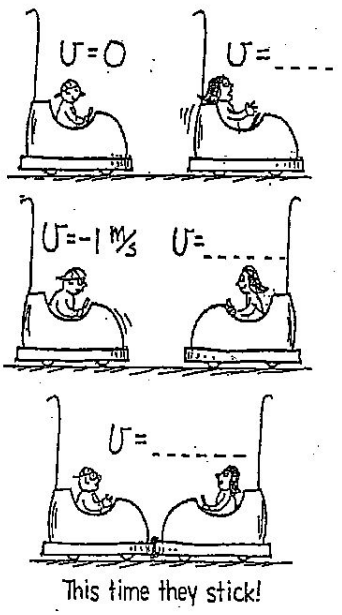
2

Momentum conservation for colliding balls, freight cars, and fish are worked out in the textbook. Here we consider more collisions. In the table below, fill in the numerical values for total momentum before and after the collisions of the two-body systems. Also fill in the blanks for velocity.

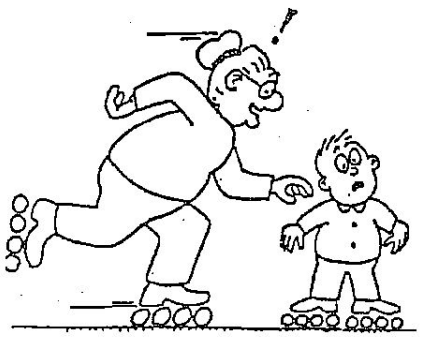
1. Bumper cars are fun. Assume each car with its occupant has a mass of 200 kg.



Momentum of Two-Car System	
BEFORE	AFTER



2. Granny whizzes around the rink and is suddenly confronted with Ambrose at rest directly in her path. Rather than knock him over, she picks him up and continues in motion without "braking."



DATA

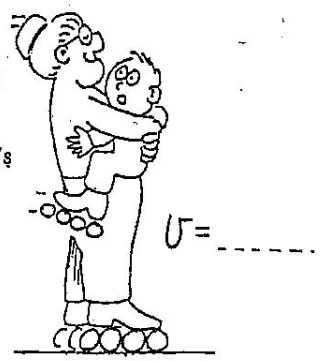
Granny's mass; 50 kg

Granny's initial speed; 3 m/s

Ambrose's mass; 25 kg

Ambrose's initial speed; 0 m/s

Momentum of Granny-Ambrose System	
BEFORE	AFTER



Determine the total kinetic energy of the system before the collision and after the collision.

PHY 111 **Recoiling gun**

A 50-g bullet is shot at a speed of 400 m/s from a 5-kg gun.
a) What is the recoil speed of the gun right after the bullet is fired?

b) In terms of Newton's third law, why does the gun recoil?

Energy
c) The gun and the bullet have equal (and opposite) momenta. Find the kinetic energy of each. Do they also have equal kinetic energies?

d) Does initial kinetic energy = final kinetic energy?

e) Does total initial energy = total final energy? Fill in an energy bar chart for this process.

$$K_o + U_{go} + U_{chem} + \text{Work} = K_f + U_{gf} + U_{chem} + \text{Heat}$$

f) How much energy was stored in the gun powder?

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PHY 111 Momentum of bullet, part 2

A 2-kg block of wood is sitting at rest on frictionless ice. A 50-gram bullet traveling at 400 m/s hits the block of wood is and is embedded in the wood.

a) What is the momentum of the bullet before it hits the block?

b) How fast does the wood (with the embedded bullet) move away after being hit?

c) How much heat is generated as the bullet embeds in the wood?

PHY 111 Momentum/Kinetic energy

1. A 1000 kg vehicle traveling east and an1800 kg vehicle traveling west hit head on in crash test. Each vehicle has a speed of 25 m/s. The vehicles stick together after the impact.
a) What is the speed and direction of the two vehicles immediately after impact?

b) How much heat is produced during the collision?

2. Person A (mass 70 kg) is sitting at rest in a lake in Boat A (50 kg). Person B (mass 50 kg) is sitting at rest in Boat B (50 kg). The two boats are sitting side by side. Person B shoves on Boat A giving is a speed of 5 m/s. How much chemical energy from person B is converted into kinetic energy? (First find the recoil speed of Boat B.)

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PHY 111 Initial and final momentum

1. Objects A and B collide and stick together. What is their final momentum (magnitude and direction)?

Initial:

$p_A = 5$ $p_B = 15$

Final:

$p_f = ?$

2. A hits B (initially at rest). A continues forward. What is the final momentum of A (magnitude and direction)?

Initial:

$p_A = 5$ $p_B = 0$

Final:

$p_{Af} = 2$ $p_{Bf} = ?$

3. A hits B (initially at rest). A bounces backward. What is the final momentum of A (magnitude and direction)?

Initial:

$p_A = 5$ $p_B = 0$

Final:

$p_{Af} = -2$ $p_{Bf} = ?$

PHY 111 **Recoiling bumper car**

A light weight bumper car (mass = 200 kg) traveling at 6 m/sec collides into a heavier bumper car (mass = 400 kg). The heavier bumper car is initially at rest. The lighter bumper car recoils backward after the collision at a speed of 1 m/sec.

a) What is the forward speed of the heavier bumper car after the collision?

b) How much heat was generated in the collision?

Be sure to draw diagrams for the motion before and after the collision.

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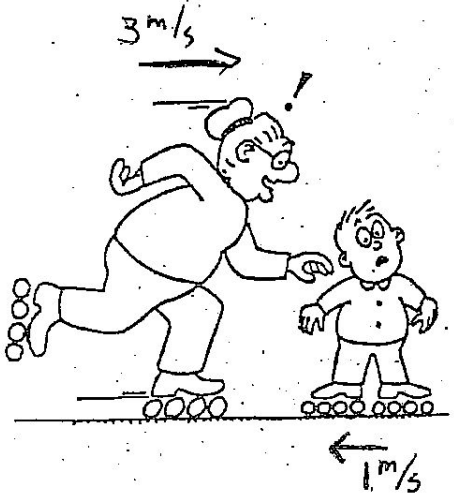
2. Granny whizzes around the rink and is suddenly confronted with Ambrose directly in her path. Rather than knock him over, she picks him up and continues in motion without "braking."



DATA

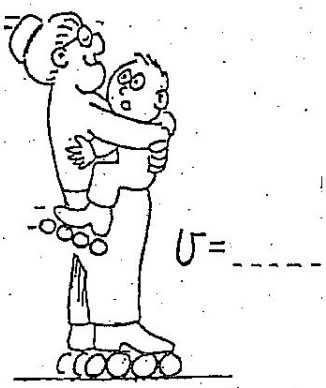
Granny's mass; 50 kg

Granny's initial speed; 3 m/s

Ambrose's mass; 25 kg

Ambrose's initial speed;

Momentum of Granny-Ambrose System	
BEFORE	AFTER



a) Find V_f.

b) Find heat from collision.

51. ‖ A spaceship of mass 2.0×10^6 kg is cruising at a speed of 5.0×10^6 m/s when the antimatter reactor fails, blowing the ship into three pieces. One section, having a mass of 5.0×10^5 kg, is blown straight backward with a speed of 2.0×10^6 m/s. A second piece, with mass 8.0×10^5 kg, continues forward at 1.0×10^6 m/s. What are the direction and speed of the third piece? d) ?

a) Find original momentum.

b) Find momenta of 1st and 2nd piece.

c) Find mass of 3rd piece.

d) Answer question above.

PHY 111 **Can the astronaut be saved?**

An astronaut whose jetpack is malfunctioning is drifting in space at a speed of .5 m/s away from his spaceship. His total mass, including the jetpack is 110 kg. In order to move back *toward* his spaceship, he needs to throw something *away* from his spaceship. The only thing he has that he can risk throwing is his 15-kg jetpack. He throws his jetpack away from the space ship with a velocity of 8 m/sec.
He is currently 120 m from his spaceship and he has 10 minutes of oxygen remaining. He is hoping to get back to his spaceship before his oxygen runs out.
a) What is the initial momentum of the astronaut/jetpack?

b) What is the momentum of his jetpack after he throws it?

c) What will the astronaut's momentum be after he throws the jetpack? What direction will his momentum be? What will his velocity be?

d) How many minutes will it take him to get back to the spaceship?

Energy considerations: Predict: By the astronaut pushing on the jetpack, did he add kinetic energy to the system or did he take it away?

Calculate: Find the initial and final kinetic energy of the system. Draw an appropriate bar chart for the system.

$$K_o + U_{go} + U_{chem} + \text{Work} = K_f + U_{gf} + U_{chem} + \text{Heat}$$

_____ _____

How much chemical potential energy was converted to kinetic energy in this process?

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PHY 111 Ballistics test: Determining the speed of a bullet (#1)

Enter "ballistics pendulum" on YouTube.
(For example http://www.youtube.com/watch?v=cVjxn4KjOb4)

1. Normally the unknown to solve for is the speed of the bullet. We will take the speed of the bullet as known and solve for the final height of the pendulum.

As in the video, a 20 g bullet is shot at 300 m/sec into a 4-kg piece of wood.

a) What is the velocity of the wood (with the bullet) immediately after the bullet is embedded in the wood?

b) What is the KE of the wood (with the bullet) immediately after the bullet is embedded in the wood?

c) How high will the pendulum swing (looking at the center of mass) at its highest point?

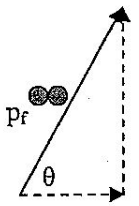
PHY 111 Initial and final momentum: 2 dimensional

In two or three dimensions, momentum is conserved in each dimension:

$\Sigma p_{x\ initial} = \Sigma p_{x\ final}$ $\Sigma p_{y\ initial} = \Sigma p_{y\ final}$

1. Objects A and B collide and stick together. What is their final momentum (magnitude and direction)?

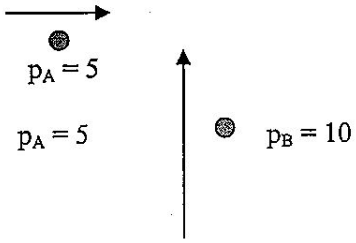
Final:



$p_f = ?$

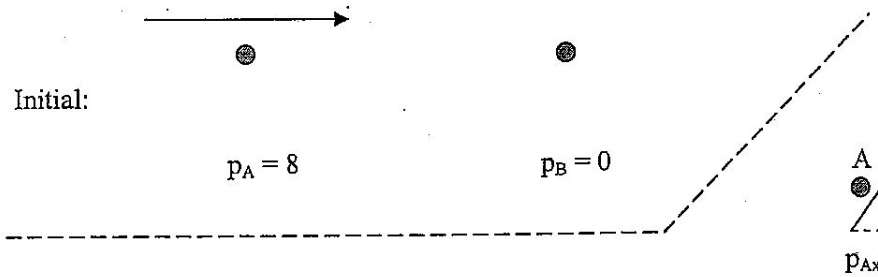
$\theta =$

Initial:

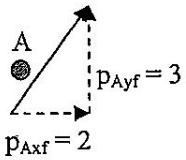


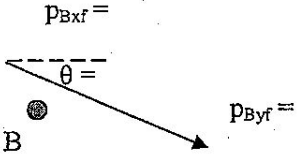
2. A hits B (initially at rest). A continues forward but also upward. What is the final momentum of B (magnitude and direction)?

Initial:



Final:





magnitude $p_{Bf} =$

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Hitting the eight ball

The cue (or white) ball is initially moving in the y direction at a speed of 4 m/sec. The eight (or black) ball is initially at rest. After the cue collides with the eight ball, the eight ball moves away with a speed of 3.2 m/sec at an angle of 30° to the left of the y axis. The mass of each ball is 500 g.

a) What is the speed and direction of the cue ball after the collision?