...nservation of Momentum Name________ Period________

WS5

1. What's the difference between a Ping-Pong ball moving at 30 mi./hr and a semi-trailer truck moving at the same speed?

truck has more momentum

2. What characterizes an elastic collision?

objects bounce off each other

3. Why is it better to hold a rifle tightly against your arm while firing it rather than holding it loosely away from your body?

Mass of whole torso > mass of arm: smaller recoil v

4. What is center of mass and how does it relate to momentum conservation?

linear momentum of system (cm) = sum of momenta of all objects in system

5. If you were floating freely outside a Space Shuttle and tossed a huge tool to another astronaut, what would happen to you? Why?

you move back conservation of momentum

6. Which of Newton's laws of motion is related to the idea of momentum?

1st: inertia is similar to momentum (mass x v) | 3rd: Equal + opposite forces similar to equal + opposite momentum (rocket, balloon lift)

7. Which of Newton's laws of motions is related to the idea of impulse?

2nd: $F = ma \rightarrow F = \frac{m\Delta v}{\Delta t} \rightarrow F\Delta t = m\Delta v$ ($F\Delta t$ = J, $m\Delta v$ = Δp)

8. What happens to the center of mass if a ball explodes?

same spot

9. What is meant by the term conservation of momentum?

total momentum of a system is the same before + after a collision (aka if no forces outside the system act on it)

10. In billiards, how is hitting a ball straight on different from hitting it at an angle? Describe what happens to the cue ball and the ball being hit. ∡: ball acquires x + y v
cue ball + ball being hit go off at different ∡s

11. How do high-jumpers and pole-vaulters use center of mass?

Keep CM below the bar, so can jump higher w/ same amt. of F

12. A watermelon is dropped and strikes the ground without bouncing. What becomes of its momentum?

goes into the ground (transferred to)

13. On a cold day a person is at rest in the middle of a frictionless ice pond. How can the person get to shore?

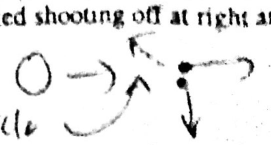
Throw something!

14. While driving, a bug splatters on your car windshield. Compared to the change in momentum of the bug, how much does your car's momentum change?

smaller Δv for car because very little change in speed. bug accelerates more, so greater Δv = Δp
The sum of the momentum for bug + car is same before + after collision. force of bug on car = force of car on bug

15. A certain object is at rest. It suddenly explodes. Two particles are detected shooting off at right angles to each other. Are these the only two particles given off? Explain.

No: conservation of momentum says there must be another particle



16. Release an inflated balloon. Explain the motion.

downward momentum of air = upward momentum of balloon
(out of balloon)

Sample Problem

Suppose a 1.5 kg brick is dropped on a glass table top from a height of 20 cm.

A) What is the magnitude and direction of the impulse necessary to stop the brick?

$mgh = \frac{1}{2}mv^2$

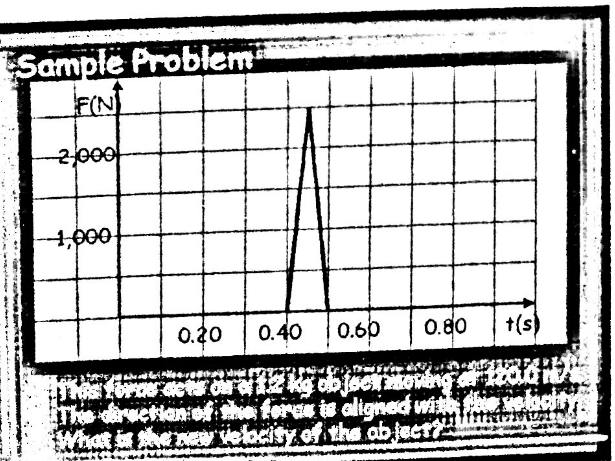
$v = \sqrt{2gh} = 2.0$ m/s ↓

$J = m\Delta v = 1.5 \times 2 = 3$ kg m/s or **3 Ns**

B) If the table top doesn't shatter, and stops the brick in 0.01 s, what is the average force it exerts on the brick? $F\Delta t = J$

$\frac{3}{0.01} =$ **300 N**

C) What is the average force that the brick exerts on the table top during this period? 300 N



$J = 125$ Ns $= m\Delta v$

$\Delta v = 104$ m/s

$v_f = 120 + 104 =$ **224 m/s**

Law of Conservation of Momentum

Definition:

Equation:

Sample problem

A 75-kg man sits in the back of a 120-kg canoe that is at rest in a still pond. If the man begins to move forward in the canoe at 0.50 m/s relative to the shore, what happens to the canoe?

$0 = (75)(0.5) + 120(v)$, $v = 0.31$ m/s

External versus internal forces

External forces are

Internal forces are

What can external forces do that internal forces cannot?

Δp

Explosions

What type of forces exist in an explosion (external or internal?)

What is conserved in an explosion?

What is not conserved in an explosion?

Recoil
Definition:

Which of Newton's three laws is most applicable to recoil? 3rd: equal & opposite F

Sample problem
Suppose a 5.0-kg projectile launcher shoots a 209 gram projectile at 350 m/s. What is the recoil velocity of the projectile launcher?

$0 = (5\,kg)v_1' + (0.209\,kg)(350)$

$v_1' = -14.6\,m/s$

Sample problem
An exploding object breaks into three fragments. A 2.0 kg fragment travels north at 200 m/s. A 4.0 kg fragment travels east at 100 m/s. The third fragment has mass 3.0 kg. What is the magnitude and direction of its velocity?

y: $0 = (200\,m/s)(2\,kg) + 3\,kg\,v_y'$

$v_y' = -133\,m/s$

x: $0 = (100\,m/s)(4\,kg) + 3\,kg\,v_x'$

$v_x' = -133\,m/s$

$v_{tot} = \sqrt{v_y^2 + v_x^2} = 189\,m/s$ @ 45° W of S / S of W

Collisions
Definiton:

What is conserved in all collisions?

Collision Types
Describe an elastic collision.

Describe a perfectly inelastic collision.
What is conserved in both elastic and inelastic collisions?
What is conserved in an elastic collision but not conserved in an inelastic collision?

Sample Problem
An 80-kg roller skating grandma collides inelastically with a 40-kg kid. What is their velocity after the collision? What is the change in kinetic energy?

$80\,kg\,v_1 = (80\,kg + 40\,kg)v'$

$v' = 2/3\,v_1$

$KE_i = \frac{1}{2}(80\,kg)v_1^2$

$KE_f = \frac{1}{2}(80\,kg + 40\,kg)v'^2 = \frac{1}{2}(120\,kg)(\frac{2}{3}v_1)^2$

$\Delta KE = 26.\bar{6}v_1^2 - 40v_1^2$

$= -13\frac{1}{3}v_1^2$

Sample Problem
A fish moving at 2 m/s swallows a stationary fish which is 1/3 its mass. What is the velocity of the big fish and after dinner?

$mv_1 = (m + \frac{1}{3}m)v' \Rightarrow mv_1 = m(1 + \frac{1}{3})v'$

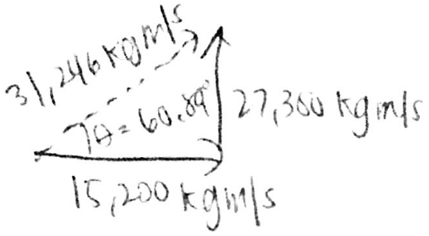
$v' = \frac{mv_1}{(m + \frac{1}{3}m)}$

$v' = \frac{2\,m/s}{1\frac{1}{3}} = 1.5\,m/s$

Sample Problem

A car with a mass of 950 kg and a speed of 16 m/s to the east approaches an intersection. A 1300-kg minivan traveling north at 21 m/s approaches the same intersection. The vehicles collide and stick together. What is the resulting velocity of the vehicles after the collision?

14 m/s @ 61° N of E



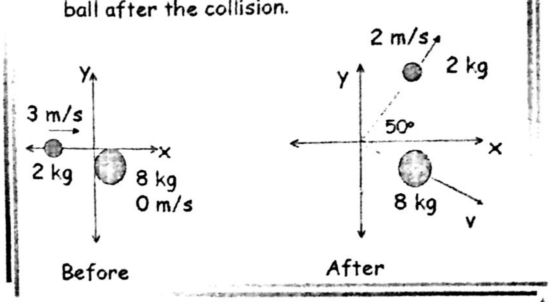
2-Dimensional Collisions

What key concept do you need to remember when you work 2-dimensional collisions problems, either elastic or inelastic?

Sample problem

Sample problem

- Calculate velocity of 8-kg ball after the collision.



$x: 2\times3 = 2\times2\cos50 + 8V_2'\cos\theta$ (V_{x2}')

$y: 0 = 2\times2\sin50 + 8V_{y2}'$

$V_{x2}' = 0.43$ m/s

$V_{y2}' = -0.38$ m/s

$V_{tot} = \sqrt{(V_{y2}')^2 + (V_{x2}')^2}$

$= 0.57$ m/s

$\theta = \tan^{-1}\left(\frac{0.38}{0.43}\right)$ 42° below x-axis

Sample Problem - elastic collision

A 500-g cart moving at 2.0 m/s on an air track elastically strikes a 1,000-g cart at rest. What are the resulting velocities of the two carts?

$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$

$v_1 - v_2 = v_2' - v_1'$ ← elastic collisions only: derived from cons. of KE

$(0.5)(2\text{m/s}) = (0.5\text{kg})v_1' + ([illegible]\text{kg})v_2'$

$2\text{m/s} = v_2' - v_1'$

$v_2' = v_1' + 2\text{m/s}$

$1\text{kgm/s} = 0.5\text{kg}\,v_1' + (1\text{kg})(v_1' + 2\text{m/s})$

$1 = 1.5v_1' + 2$

$v_1' = \frac{-1}{1.5} = -0.67$ m/s

$v_2' = -0.67 + 2$ m/s $= 1.3$ m/s

Sample Problem

Suppose three equally strong, equally massive astronauts decide to play a game as follows: The first astronaut throws the second astronaut towards the third astronaut and the game begins. Describe the motion of the astronauts as the game proceeds. Assume each toss results from the same-sized "push." How long will the game last?