Name: ____________________

Period: ____________________

Momentum and Conservation of Momentum

Momentum

Momentum is how hard it is to stop a moving object. Momentum depends on both mass and velocity. An object gains momentum as it gains velocity. A heavy object will have more momentum than a light object, if at the same velocity.

Momentum (in kgm/sec) → $p = mv$ ← Mass (in kg), Velocity (in m/sec)

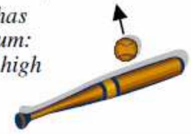
Momentum equals mass times velocity.

Ex. How much momentum does a 30 kg object going 4 m/s have?

Variables:	*Solve*:
$m = 30$ kg $v = 4$ m/s $p =$ _____	$p = mv = (30\text{kg})(4\text{m/s})$ $= 120$ kgm/s

A house has no momentum because it is not moving ($v = 0$ m/s).

A fast baseball has a lot of momentum: small mass, but high velocity.



A slow bowling ball has little momentum: a lot of mass, but low velocity.

Momentum is a Vector

As a vector, direction matters. So, momentum can be positive or negative and can be added or subtracted.

Negative momentum: ← -10 m/s [20 kg] → **-200 kgm/s**

Positive momentum: [20 kg] 10 m/s → **200 kgm/s**

Net Momentum

To find the net momentum, add up all of the individual momentums. Net momentum can add up to zero, if the objects are moving different directions.

Net Momentum → $p_{net} = \Sigma p$ ← Sum of all Momentum

$$\Sigma p = p_1 + p_2 + \ldots$$

Add up all of the momentums

Ex. Calculate the net momentum of the two objects.

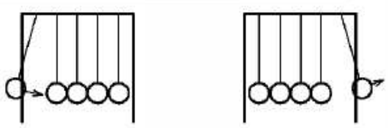
[10 kg] → 5 m/s   ← -5 m/s [10 kg]

$p_1 = 50$ **kgm/s** $p_2 = -50$ **kgm/s**

$p_{net} = \Sigma p = p_1 + p_2 =$
$50 + -50 = \mathbf{0}$ **kgm/s**

Momentum Can Be Transferred

When two objects collide momentum is transferred from one object to the other.



The ball on the left transfers its momentum thru the three middle balls to the ball on the right.

Momentum is transferred in collisions.

Before collision: [M_1] fast → [M_2] slow →

After collision: [M_1] slow → [M_2] fast →

M_2 speeds up after the collision because it gained momentum from M_1.

Momentum is Conserved

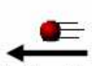
In any interaction (when objects collide or push off from each other) momentum is conserved, meaning that the net momentum before (Σp_{before}) equals the net momentum after (Σp_{after}).

Law of Conservation of Momentum:
If there are no outside forces, momentum is <u>always</u> conserved OR $\Sigma p_{before} = \Sigma p_{after}$.

Thrown, Shot or Launched Objects:

Thrown objects are initially rest, so $v = 0$ and $\Sigma p_{before} = 0$. Afterwards, Σp_{after} must still $= 0$. How? Only if the momentums of the two objects are equal and opposite: $p_{Left} = p_{Right}$ and $p_R - p_L = 0$.

Ex. A 40 kg boy on a skateboard throws a 1 kg ball 20 m/s to the left. If both were at rest beforehand, find how fast the boy is going afterward.



ball = 1 kg
$v_L = -20$ m/s

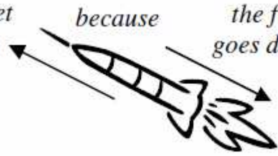
skater = 40 kg
$v_R = ?$

Momentum is conserved:

$\Sigma p_{before} = \Sigma p_{after}$
$0 = 1(-20) + 40(v)$
$0 = -20 + 40v$
$20 = 40v$
$v = 0.5$ m/s
(to the right)

Conservation of momentum is how rockets move. Gases are expelled at a very fast velocity, pushing the rocket in the opposite direction.

The rocket goes up ← *because* *the fuel goes down.*



Momentum is conserved:

$\Sigma p_{before} = \Sigma p_{after}$
$0 = p_{rocket} - p_{fuel}$
$\mathbf{p_{rocket} = p_{fuel}}$

Collisions

When objects collide, momentum is transferred, but ***the total momentum <u>does not change</u>***. The Law of Conservation of Momentum can tell us unknown velocities and directions.

BEFORE: 4 m/s → [2 kg]   ← 6 m/s [5 kg]

$p_{1b} = 2(4)$ $p_{2b} = 5(-6)$

AFTER: ?← v = ? →? [2 kg]   ← 2 m/s [5 kg]

$p_{1a} = 3(v)$ $p_{2a} = 5(-2)$

"b" means "before"   *"a" means "after"*

$\Sigma p_{before} = \Sigma p_{after}$
$p_{1b} + p_{2b} = p_{1a} + p_{2a}$
$2(4) + 5(-6) = 2v + 5(-2)$
$8 - 30 = 2v + 5(-2)$
$-22 = 2v - 10$
$-12 = 2v$
$v = -6$ **m/s**

Keep directions straight! (left is negative)

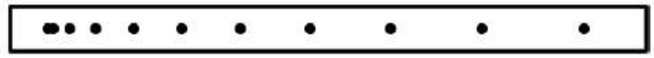
The negative means the object ends up going to the left.

1. Momentum	A. The total momentum will stay the same when objects interact.
2. kgm/sec	B. Units for momentum.
3. Law of Conservation of Momentum	C. Product of an object's mass and velocity.
4. Net momentum	D. Means to add together all of the individual momentums ($p_1 + p_2 \ldots$).
5. Σp	E. The total of all the momentums.

How is it possible that two objects have a net momentum equal to zero? *(There are two ways.)*

Number these from least (1) to most (5) momentum.

A bullet	A fast car	A slow baseball	A house	A fast train



If the tapetimer above shows the position of an object every second, how does the momentum of the object change?

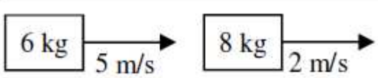
Find the momentum of a 25 kg object going 4 m/s to the right.

A 3 kg object is going 22 m/s *to the left*. Find its momentum.

A ball has 2 kgm/s of momentum when thrown 8 m/s to the right. Find the mass of the ball.

A 25 kg cart has -125 kgm/s of momentum. How fast is the cart going?

Two objects are at rest. Find the net momentum of the two.



Calculate the net momentum of these two objects.

How can an object have negative momentum?

If a fast object hits a slower object, why does the slower object speed up?

If two objects have 24 kgm/s of momentum before they collide. How much momentum do the two objects have afterwards?

How does a rocket fly in space if it has nothing to push on?

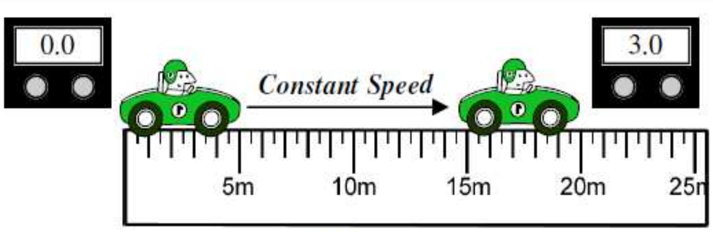
A 50 kg girl on ice skates throws a 5 kg ball to the left. If the ball ends up going 20 m/s, .

A) If the girl and ball are initially at rest, what was their velocities? $v_{1i} = v_{2i} =$

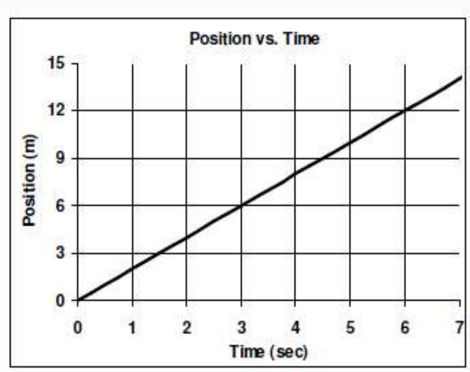
B) What is the net momentum of the girl and ball before $\Sigma p_{before} =$

B) How much momentum do the girl and ball have to have afterwards? $\Sigma p_{after} =$

C) Use the Law of Conservation of Momentum to find how fast the girl is going afterwards.



Calculate the momentum of the 100 kg car.



If the object has 6 kg of mass, find its momentum from the graph.