 Name: KEY

Momentum Review

1. What was Newton's Third Law? Why is it important?

"For every action, there is an equal and opposite reaction"

also: $F_{AB} = -F_{BA}$

important b/c it implies that MOMENTUM IS CONSERVED!

2. You are holding an apple that weighs 1 N in your hand. What is the reaction force to the weight of the apple?

Since the weight of the apple is the force of the earth pulling down on the apple, the reaction is the apple pulling up on the earth!

3. If action and reaction forces are equal and opposite, why don't they cancel out?

Because the forces are acting on different objects! In order for 2 forces to cancel out, they need to be acting on the same object.

4. Define the following terms:

Momentum

$p = mv$

Impulse

$J = Ft$

Inelastic Collision

a collision where the objects stick together

Elastic Collision

a "bouncy" collision (a much better definition depends on some energy ideas - which is the next unit.)

5. What are the units for momentum and impulse? Show that they are the same thing.

momentum: $kg \cdot m/s$

impulse: $N \cdot s$

$N \cdot s = (kg \cdot m/s^{\cancel{2}}) \cdot \cancel{s} = kg \cdot m/s$

because $1\ N = 1\ kg \cdot m/s^2$!

6. Imagine you are standing still in the hallway. Do you have any momentum? Then you decide to walk down the hall. Do you have any momentum now? If momentum is conserved, how did you suddenly gain momentum?

Standing still = NO momentum (because $v = 0$)

when you are walking you do have momentum (mv).

Since you pushed the ground backwards, so that the ground pushed you forwards, you took momentum from the earth! But the earth is so big, we don't notice its change in momentum.

Momentum Review

7. If you drop a glass onto a tile floor it will likely break, but if it fell the same distance onto a carpeted floor it might not. In terms of impulse and change in momentum, why is that? What does the cushioning of the carpet change? What doesn't it change?

Falling the same distance, the glass will have the same velocity, and so the same momentum whether it hits tile or carpet. So in both cases, the impulse on the glass is the same. But the carpet has "more give" - the cushioning makes the time of impact longer, which decreases the Force on the glass. $Ft = FT$

8. What impulse is needed to stop a 2000 kg car traveling at 30 m/s?

Impulse = Ft, so it would seem we can't do this...

BUT Impulse is how Momentum is changed so

$\Delta p = mv_f - mv_i = (2000)(0) - (2000)(30) = \boxed{-60{,}000 \text{ Ns}}$

9. A firecracker at rest explodes into two pieces. One piece has a momentum of 0.3 kg•m/s to the right. What is the momentum of the second piece?

$\Sigma p_i = \Sigma p_f$

$0 + 0 = (0.3) + p_2$ $\boxed{p_2 = -0.3 \text{ kg·m/s}}$ or, 0.3 kg·m/s to the left.

10. A ball of clay has a momentum of 2 kg•m/s when it collides and sticks to another ball of clay at rest. What is the momentum of the clay blob when they are stuck together?

$\Sigma p_i = \Sigma p_f$

$2 + 0 = \Sigma p_f = \boxed{2 \text{ kg·m/s}}$

11. A force of 12 N is exerted on a cart with a mass of 0.5 kg for a time of 2.5 seconds.

$F = 12$ N
$t = 2.5$ s
$m = 0.5$ kg
$v_i = 0$ m/s

a. If the cart was initially at rest, what is the final velocity of the cart?

$J = \Delta p$

$Ft = mv_f - mv_i$

$(12)(2.5) = (0.5)v_f - (0.5)(0)$

$30 = 0.5\, v_f$

$\boxed{v_f = 60 \text{ m/s}}$

b. If the cart had an initial velocity of 4 m/s in the same direction as the force, what is the final velocity of the cart?

Now $v_i = 4$ m/s

$J = \Delta p$

$Ft = mv_f - mv_i$

$(12)(2.5) = (0.5)v_f - (0.5)(4)$

$30 = (0.5)v_f - 2$

$32 = 0.5\, v_f$

$\boxed{v_f = 64 \text{ m/s}}$

c. If the cart had an initial velocity of 4 m/s in the opposite direction as the force, what is the final velocity of the cart?

$v_i = -4$ m/s

$J = \Delta p$

$Ft = mv_f - mv_i$

$(12)(2.5) = (0.5)v_f - (0.5)(-4)$

$30 = 0.5\, v_f + 2$

$28 = 0.5\, v_f$

$\boxed{v_f = 56 \text{ m/s}}$

Momentum Review

12. A 250 kg astronaut is floating next to a satellite. The astronaut pushes off the satellite, causing the two to fly apart. The speed of the astronaut is 1.2 m/s and the speed of the satellite is 0.3 m/s.
    a. What is the mass of the satellite?

$m_1 = 250$ kg $\quad m_2 = ?$

$v_{1i} = 0$ m/s $\quad v_{2i} = 0$ m/s

$v_{1f} = 1.2$ m/s $\quad v_{2f} = -0.3$ m/s

they go in opposite directions

$\Sigma p_i = \Sigma p_f$

$0 + 0 = (250)(1.2) + m_2(-0.3)$

$0 = 300 - 0.3 m_2$

$0.3 m_2 = 300$

$\boxed{m_2 = 1000 \text{ kg}}$

    b. Who experiences the greater change in momentum?

Same!

    c. Who experiences the greater impulse?

same!

    d. Who experiences the greater acceleration?

astronaut (b/c smaller mass)

    e. What is the total momentum of the astronaut and satellite before they fly apart? How about after they fly apart?

0! still 0!

13. A 1.5 kg cart traveling at 3 m/s collides and sticks to a cart with a mass of 2 kg initially at rest.
    a. What is the speed of the carts after the collision?

$m_1 = 1.5$ kg $\quad m_2 = 2$ kg

$v_{1i} = 3$ m/s $\quad v_{2i} = 0$ m/s

$v_{1f} = v_{2f}$! (They stick)

$\Sigma p_i = \Sigma p_f$

$(1.5)(3) + (2)(0) = (1.5)v + (2)v$

$4.5 = 3.5v$

$\boxed{v = 1.29 \text{ m/s}}$

    b. Which cart experienced a greater force during the collision?

Same!

    c. Which cart experienced a greater impulse during the collision?

same!

    d. Which cart experienced a greater change in momentum during the collision?

Same!

    e. Which cart experienced a greater change in velocity during the collision?

1.5 kg cart, b/c smaller mass.

Momentum Review

14. A 16 kg object traveling at 4 m/s East has a collision with a 9 kg object traveling at 3 m/s West. After the collision, the 16 kg object has a velocity of 1 m/s East.

a. What is the velocity of the 9 kg object after the collision?

$\Sigma p_i = \Sigma p_f$

$m_1 = 16$ kg
$v_{1i} = 4$ m/s
$v_{1f} = 1$ m/s

$m_2 = 9$ kg
$v_{2i} = -3$ m/s
$v_{2f} = ?$

$(16)(4) + (9)(-3) = (16)(1) + (9)v_{2f}$

$64 - 27 = 16 + 9v_{2f}$

$21 = 9v_{2f} \rightarrow \boxed{v_{2f} = 2.33 \text{ m/s}}$

b. To be clear, which direction is the 9 kg object going after the collision?

East! (it was +) Notice it reversed direction!

c. What was the change in velocity of the 16 kg object due to the collision?

$\Delta v = v_f - v_i = (1) - (4) = \boxed{-3 \text{ m/s}}$

d. What was the change in velocity of the 9 kg object due to the collision?

$\Delta v = v_f - v_i = (2.33) - (-3) = \boxed{5.33 \text{ m/s}}$

e. Why (hopefully) are your answers to c and d different?

because the masses were different!

Notice how smaller mass had a bigger change in velocity...

f. What was the change in momentum of the 16 kg object due to the collision?

$\Delta p = p_f - p_i = mv_f - mv_i = (16)(1) - (16)(4) = \boxed{-48 \text{ kg·m/s}}$

g. What was the change in momentum of the 9 kg object due to the collision?

$\Delta p = mv_f - mv_i = (9)(2.33) - (9)(-3) = \boxed{48 \text{ kg·m/s}}$

h. Why (hopefully) are your answers to f and g equal and opposite?

Momentum is conserved! So the changes in momentum are = and opposite; the momentum lost by the 16 kg was gained by the 9 kg.

i. If the collision lasted only 0.03 seconds, what was the average force on the 16 kg object?

Remember, Impulse = change in momentum $(J = \Delta p)$

and Impulse is (Force)(time) so

$J = Ft$ $\quad -48 = F(.03)$

$\boxed{F = -1600 \text{ N}}$

Momentum Review

Answers:

8) (–)60,000 Ns		*9) 0.3 kg•m/s to the left*		*10) 2 kg•m/s*
11. a) 60 m/s	*b) 64 m/s*	*c) 56 m/s*		
12. a) 1000 kg	*b) same*	*c) same*	*d) astronaut*	*e) both = 0*
13. a) 1.29 m/s	*b) same*	*c) same*	*d) same*	*e) the 1.5 kg cart*
14. a) 2.33 m/s	*b) East*	*c) –3 m/s*	*d) 5.33 m/s*	

e) because the masses were different; smaller mass affected more by collision

f) –48 kg•m/s *g) 48 kg•m/s*

h) because momentum is conserved; the momentum lost by one object was gained by the other

i) –1600 N