March 10

Momentum and Impulse

MOMENTUM

Newton combined the ideas of an object's mass with its velocity to get its "Quantity of Motion". This "Quantity of Motion" is now called "Momentum".

Momentum - the quantity of motion.

To bring a moving object to a stop, we must decrease the object's momentum to zero. If we were to calculate momentum, we would multiply the mass of the object by the velocity of the object.

The mathematical relationship for **momentum** is:

$$P = mv$$

P - momentum (N•s or kg•m/s)
m - mass of an object (kg)
v - velocity (m/s)

From this equation we know that the more mass an object has, the more momentum it has. In the same thinking, we know that the more velocity an object has the more momentum it has.

Example:

What is the momentum of a 100 000kg train moving at 5.0 m/s?

$p = mv$
$= (100000\,kg)(5\,m/s)$
$= 500000\,kg \cdot m/s$

What is the momentum of a 10g toy car moving at 5.0m/s?

$g \rightarrow kg$

$\frac{10g}{0.01\,kg} = \frac{1000g}{1kg}$

$p = mv$
$= (0.01\,kg)(5\,m/s)$
$= 0.05\,kg \cdot m/s$

Which one has the greatest amount of momentum?

Train, because it has more mass.

IMPULSE

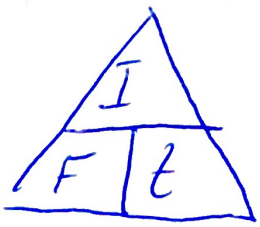
How can we reduce an object's momentum to zero? In order to do this, we must apply an impulse.

Impulse - product of force and time

- how you stop an object's momentum

The mathematical relationship for **impulse** is:

$I = Ft$



I - impulse (N•s or kg•m/s)
F - force of an object (N)
t - time (s)

From this equation we know that the greater the force being applied to an object, the greater the impulse. In the same thinking we know that the more time a force is being applied, the greater the impulse.

Example:

An object has a momentum of 1000kg•m/s.

What impulse is required to bring it to a stop?

1000 kg•m/s or 1000 N•s acting on the object in the opposite direction.

* How much force is required if it stops in 2 seconds? In 4 seconds? In 10 seconds?

$F = \frac{I}{t}$

2 sec	4 sec	10 sec.
$F = \frac{1000}{2}$	$F = \frac{1000}{4}$	$F = \frac{1000}{10}$
$F = 500N$	$F = 250N$	$F = 100N$

$P = mv$ | $I = Ft$ | $F = ma$ | $a = \frac{\Delta v}{\Delta t}$ Key

Force, Impulse and Momentum (practice)

1. What is the momentum of a 23 kg cannon shell going 530 m/s? $P = 12190\ N \cdot s$
2. What speed must a 5 kg object go to have 24 kg•m/s of momentum? $v = 4.8\ m/s$
3. A bullet going 640 m/s has 42 kg•m/s of momentum. What is its mass? $m = 0.0656\ kg$ or $65.6\ g$
4. What is the impulse imparted by a rocket that exerts 4.8 N for 1.63 seconds? $I = 7.8\ N \cdot s$
5. For what time must you exert a force of 45 N to get an impulse of 16 Ns? $t = 0.356\ s$
6. What force exerted over 6 seconds gives you an impulse of 64 Ns? $F = 10.67\ N$
7. What is the change in velocity of a 0.35 kg air track cart if you exert a force of 1.2 N on it for 3 seconds? $a = 3.4285\ m/s$ $\Delta v = 10.24\ m/s$
8. A rocket engine exerts a force of 500 N on a space probe (in outer space!) for 5 seconds. The probe speeds up from rest to a speed of 21 m/s. What is its mass? $m = 119\ kg$
9. What force exerted for 0.12 seconds will make a 0.54 Kg baseball change its velocity 80 m/s? $F = 360\ N$
10. Determine the momentum of:
    a) a bullet (m = 0.162 kg) leaving the muzzle of a gun at 860 m/s. $139.32\ N \cdot s$
    b) a 110-kg professional fullback running across the line at 9.2 m/s. $1012\ N \cdot s$
    c) a 36000-kg passenger plane taxiing down a runway at 1.5 m/s $54000\ N \cdot s$
11. A compact car, with mass 725 kg, is moving at 115 m/s toward the east.
    a) Find the momentum $83375\ N \cdot s$
    b) A second car, with a mass of 2175 kg, has the same momentum. What is its velocity?
    $v = 38.33\ m/s$
12. A 300 kg snowmobile is traveling at 30 m/s. How fast would a 200 kg snowmobile need to travel to have the same momentum? $45\ m/s$
13. A force of 4 N is applied to a ball for 0.75 s. What is the impulse? $I = 3\ N \cdot s$
14. A car pulls a trailer with a force of 250 N. If the total impulse is 900 000 N*s, for how long is the force applied? $t = 3600\ s$ or $1\ hr$
15. A model jet rocket applies an impulse of 20 N*s over 3 s interval of time. What is the force applied? $F = 6.67\ N$

KEY

Impulse and Momentum Practice Questions

1. Impulse depends on both force and time. Give an example for each case:
   a. a large force for a short time hitting a bag
   b. a small force for a long time pushing a grocery cart
   c. a large force for a long time stopping a train
   d. a small force for a short time snapping a rubber band

2. Analyze each of the following situations in terms of impulse and momentum changes. Discuss possible ways to improve performance.
   a. A professional golfer needs a larger impulse on his drives and a much smaller impulse for his putting. Increase force for drives ($I \uparrow = F \uparrow t$)
      Decrease Force for putting ($I \downarrow = F \downarrow t$)
   b. A volleyball player "sets up" a spike shot.
   c. A baseball player hits a home run. Large force, short time
   d. A car brakes for a yellow light. Lots time, Force Lots!
   e. A back catcher catches a fastball. small time, large force

3. If both the boulder and the boy have the same momentum, will the boulder crush the boy? Explain using the principles of impulse and momentum.
   No... larger mass means slower velocity
   ... smaller mass means greater velocity
   $P = m \downarrow v \uparrow$

4. How can a spacecraft change direction when it is in deep space?
   Impulse with enough force to over come its momentum