DYNAMICS

CHAPTER 3

PPP0101

CONTENTS

AT THE END OF THIS CHAPTER YOU SHOULD BE ABLE TO :

- Relate force and motion and explain what is meant by a net or unbalanced force.
- State and explain Newton's first law of motion, and describe inertia and its relationship to mass.
- State and explain Newton's second law of motion and apply it to physical situations.
- Apply Newton's second law, including the component form, to various situations.
- State and explain Newton's third law of motion and identify action-reaction pairs.
- Compute linear momentum.

AT THE END OF THIS CHAPTER YOU SHOULD BE ABLE TO :

- Explain the condition for the conservation of linear momentum and apply it to physical situations.
- Relate impulse and momentum, and kinetic energy and momentum.
- Describe the conditions on kinetic energy and momentum in elastic and inelastic collisions.
- Explain collision.
- Explain the meaning of apparent weight and weightlessness.
- Explain the causes of friction and how it is described using coefficient of friction.
- Explain the different between static and kinetic friction force.

BEFORE START ......

Mechanics

Kinematics

- the description of **how** objects move

Dynamic

- deals with **force** and **why** objects move

BEFORE START ……

- **Dynamics** : deals with **force** and **why** objects move as they do.
  - In this part we will solve the following questions:
    - What makes an object at rest begin to move ?
    - What causes a body to accelerate or decelerate ?
    - What is involved when an object moves in a circle ?

BEFORE START ......

Force

Translations

$$ma = m\frac{dv}{dt}$$

$$ma = m\left(\frac{v_f - v_i}{t_f - t_i}\right)$$

Rotations

$$m a_c = m\left(\frac{v^2}{r}\right)$$

In the chapter of gravitation force

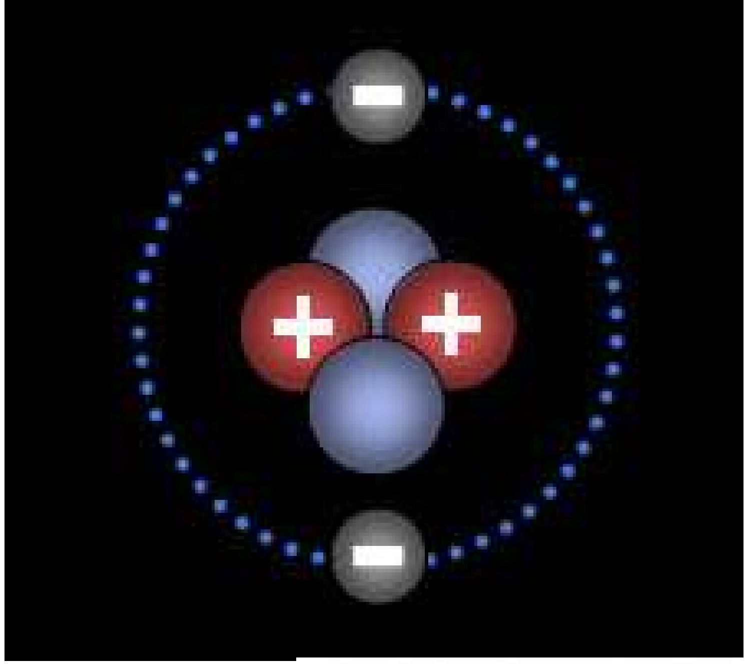
Vibrations

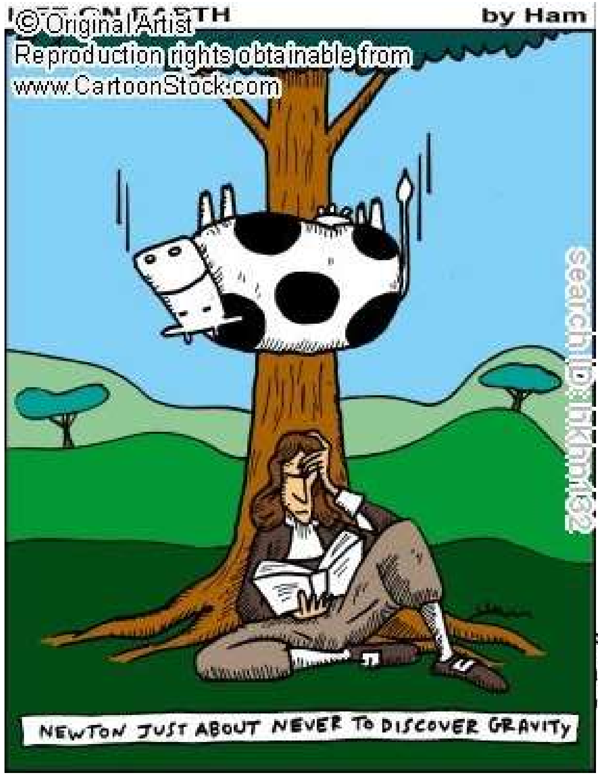
$$ma = -m\omega^2 x$$

Will be discussed in the chapter of Oscillatory motions

BEFORE START ......

- Type of Force
  - Strong nuclear force
    - subatomic particles
  - Electromagnetic force
    - electric charges
  - Weak nuclear force
    - radioactive decay processes
  - Gravity
    - attraction between objects





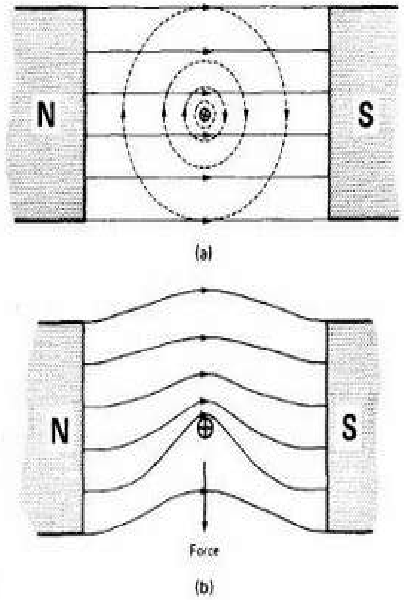
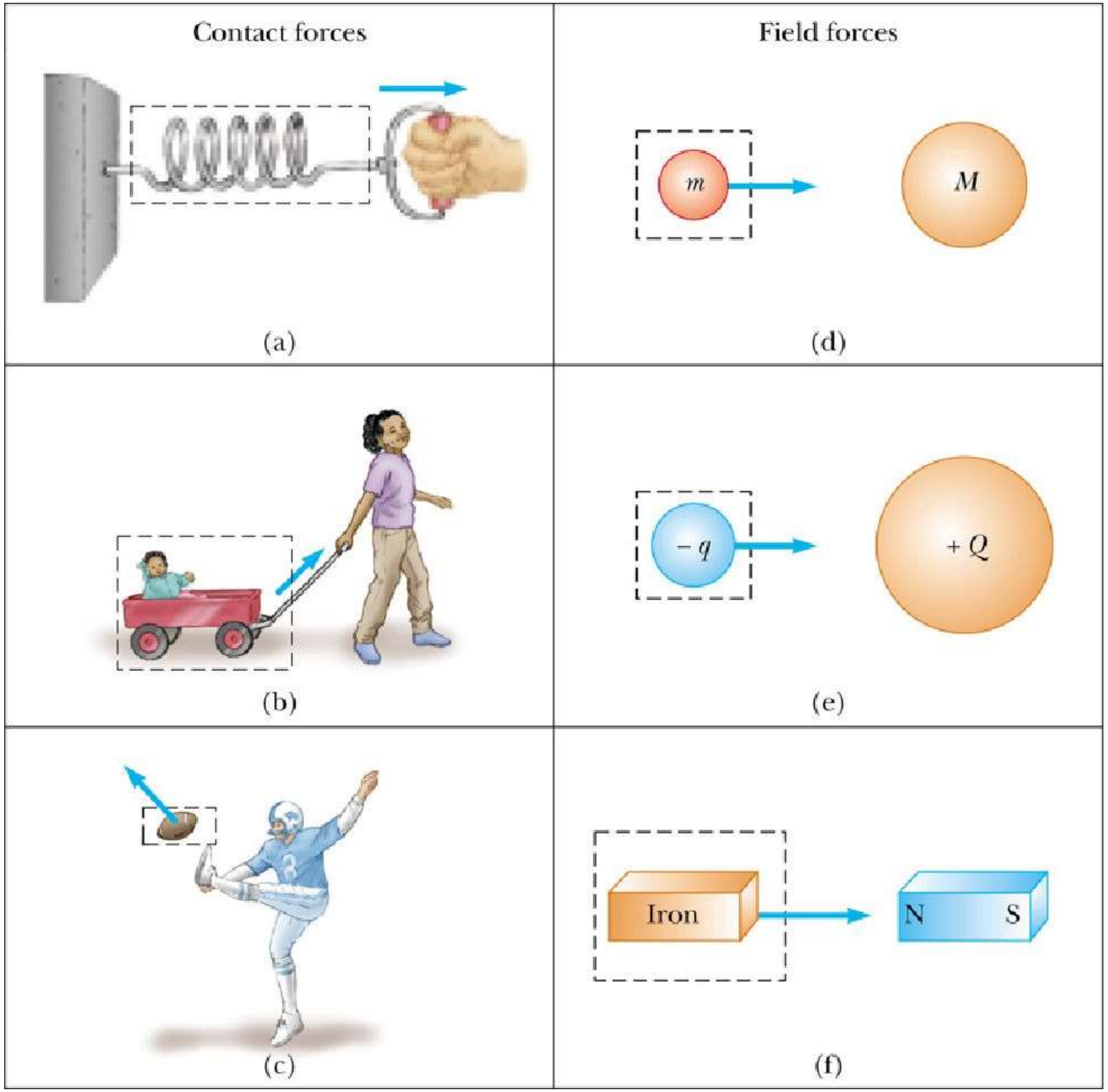


Figure 2.32
a. Magnetic field due to magnet and conductor.
b. Resulting magnetic field pushes the conductor downward.



Examples of forces applied to various objects . In each case a force acts
on the objects surrounded by the dashed lines. Something in the environment external to the boxed area exerts this force

3.1 FORCE AND NET FORCE

- Definition of Force

❖In other word, force is applied to cause of acceleration of an object.

❖It is a vector quantity.

❖There must be a net force on an object for the object to changes its velocity or to accelerate.

❖Symbol : F

3.1 FORCE AND NET FORCE

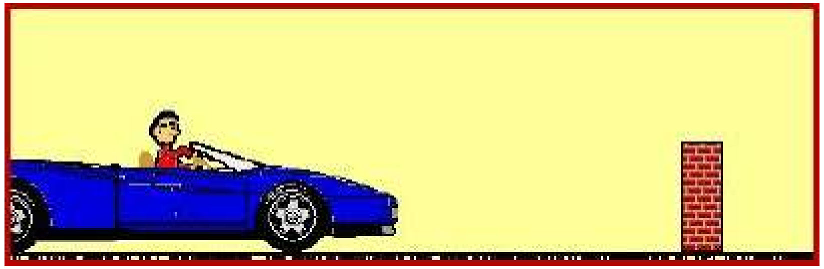
- Step to draw a net force diagram of a book sitting on desk.
  - We isolate the book and then we analyze the force acting on the book.
  - There are 2 forces acting on the book.
    - Gravitational force (Weight)
    - Supporting force on the book by desk.
  - Gravitational force always present if we dealing with object on the earth.
  - Whenever an object make a physical contact with another object, a force results.
    - Here the book makes a contact with desk and so there is a supporting force.
  - Normally the contact forces are perpendicular to the contact surface and therefore called normal forces

3.2 NEWTON'S LAW OF MOTION

Newton Force

3.2 NEWTON'S LAW OF MOTION

- 3.2.1 Newton's First Law



"Every body continues in its state of rest or of uniform speed in a straight line unless acted on by a nonzero net force." by Newton

3.2 NEWTON'S LAW OF MOTION

- According to Newton's first law
  - If Net force is zero
    - An object at rest will remain at rest.
      - There is no change in velocity
      - Acceleration is 0.
    - Object in motion (Same speed and direction) will keep with constant velocity.
      - There is no change in velocity
      - Acceleration is 0
- Mathematic representation

$$\sum F = 0 \text{ then } a = 0$$

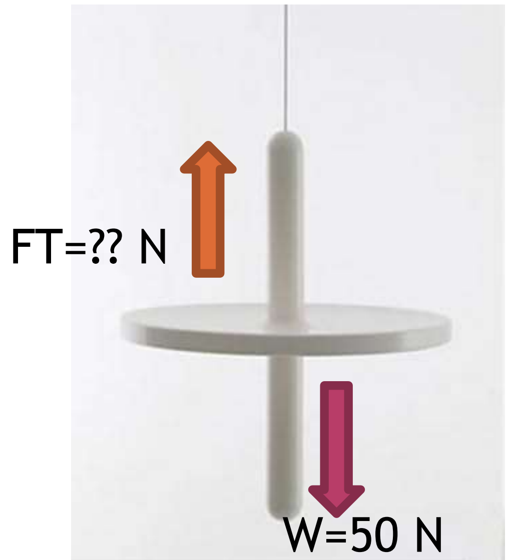
Object is in equilibrium

3.2 NEWTON'S LAW OF MOTION

- Law of inertia
  - The tendency of a body to maintain its state of rest or uniform motion in a straight line.

- Example

The object in the figure weighs is 50N and is supported by a cord. Find the tension in the cord.



Since the object is in rest condition, therefore, there are 2 forces act on it in order to achieve equilibrium condition.

Mathematic representation:

$$\sum F_y = 0$$

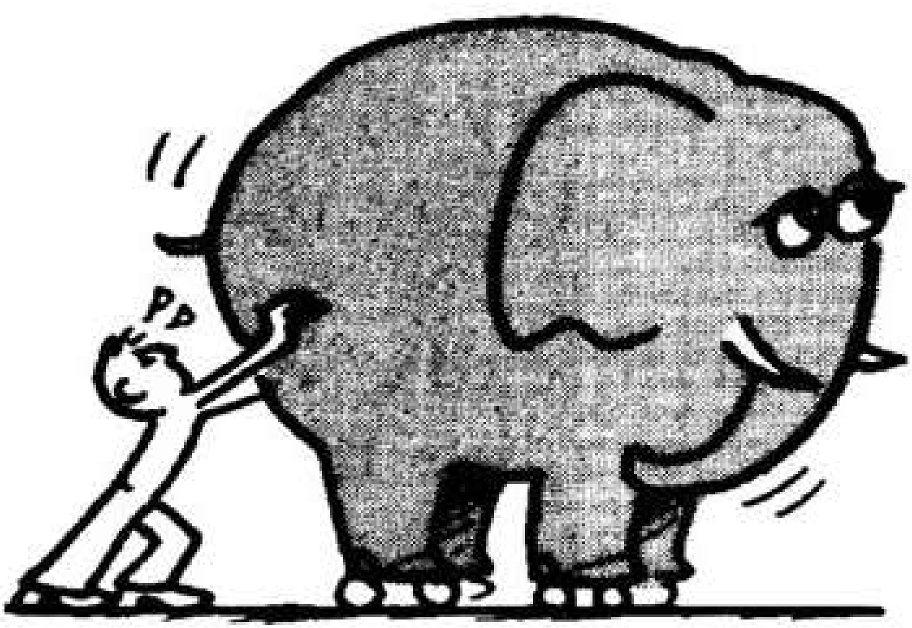
$$\sum F_y = FT - W$$

$$0 = FT - 50$$

$$FT = 50N$$

3.2 NEWTON'S LAW OF MOTION

- 3.2.2 Newton's Second Law



$$F \propto a$$

3.2 NEWTON'S LAW OF MOTION

- 3.2.2 Newton's Second Law

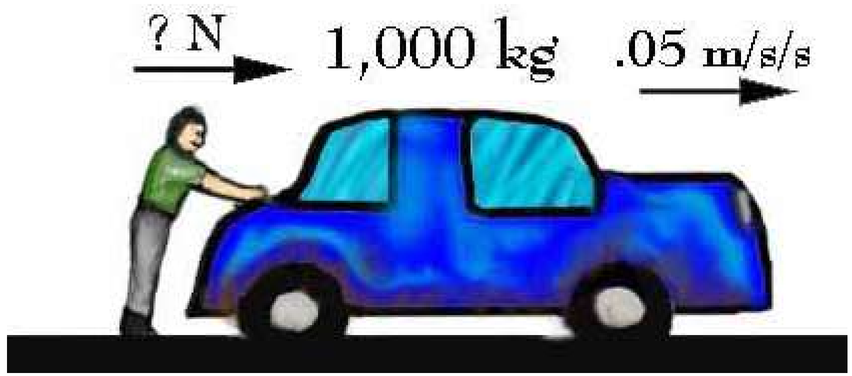
"The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object." by Newton

$$F \propto a$$

$$\sum F = ma$$

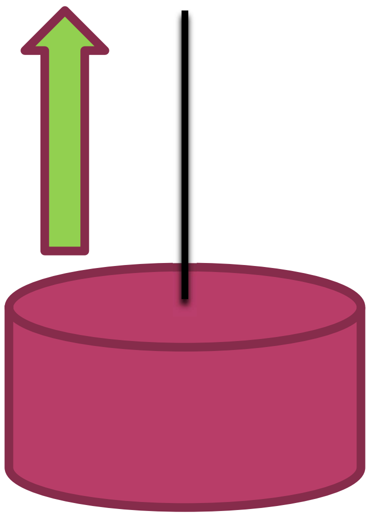
3.2 NEWTON'S LAW OF MOTION

- Example



Jimmy's car, which weighs 1,000 kg, is out of gas. Jimmy is trying to push the car to a gas station, and he makes the car go 0.05 ms^{-2}. How much force does Jimmy apply on his car ?

- Example



This 8.8 kg cylinder is to be given an upward acceleration of 0.66 ms^{-2} by a role pulling straight upward on it. What must be the tension force in the rope ?

3.2 NEWTON'S LAW OF MOTION

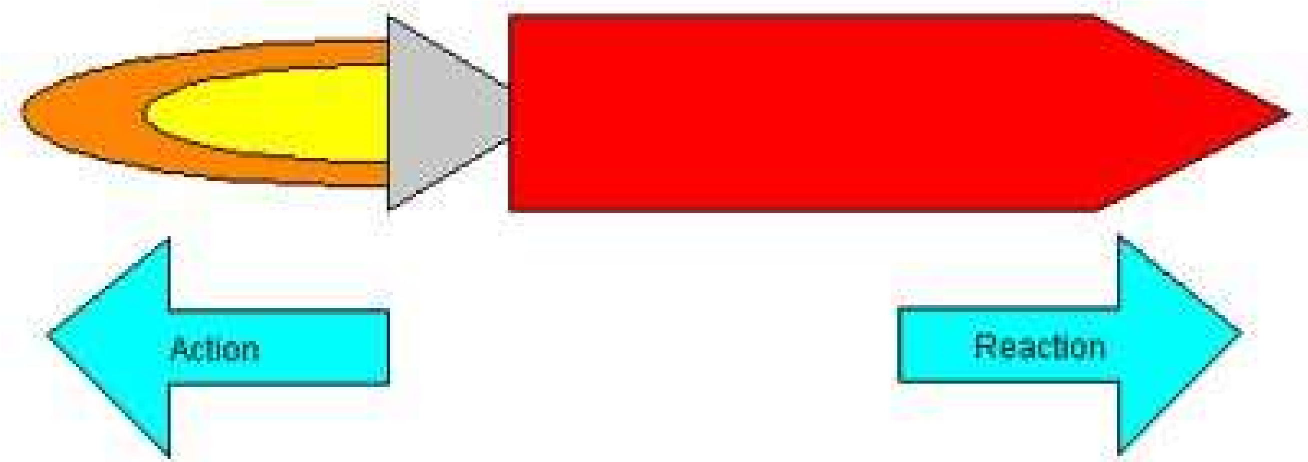
- 3.2.3 Newton's Third Law

"Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first." by Newton

This means that for every force there is a reaction force that is equal in size, but opposite in direction

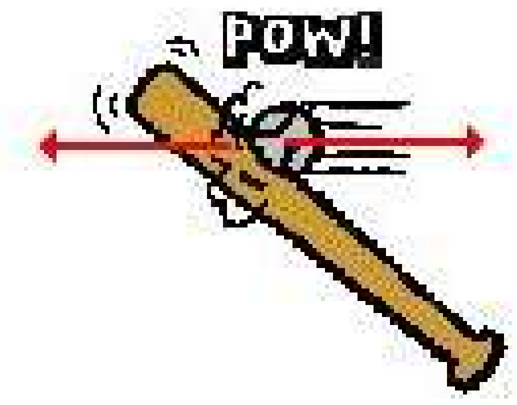
3.2 NEWTON'S LAW OF MOTION

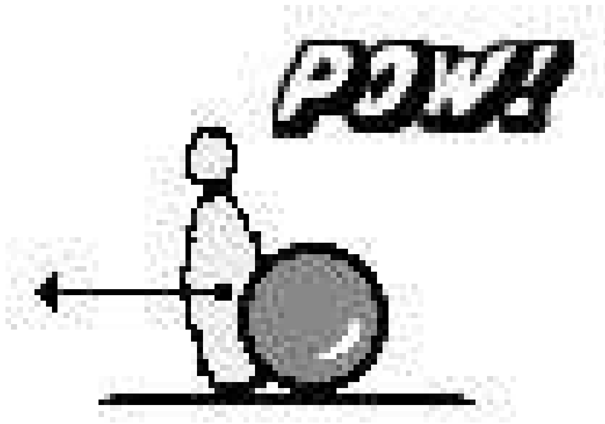
- 3.2.3 Newton's Third Law



Action: a rocket pushes out exhaust…
Reaction: the exhaust pushes the rocket forward.

3.2 NEWTON'S LAW OF MOTION





Action: The baseball forces the bat to the left

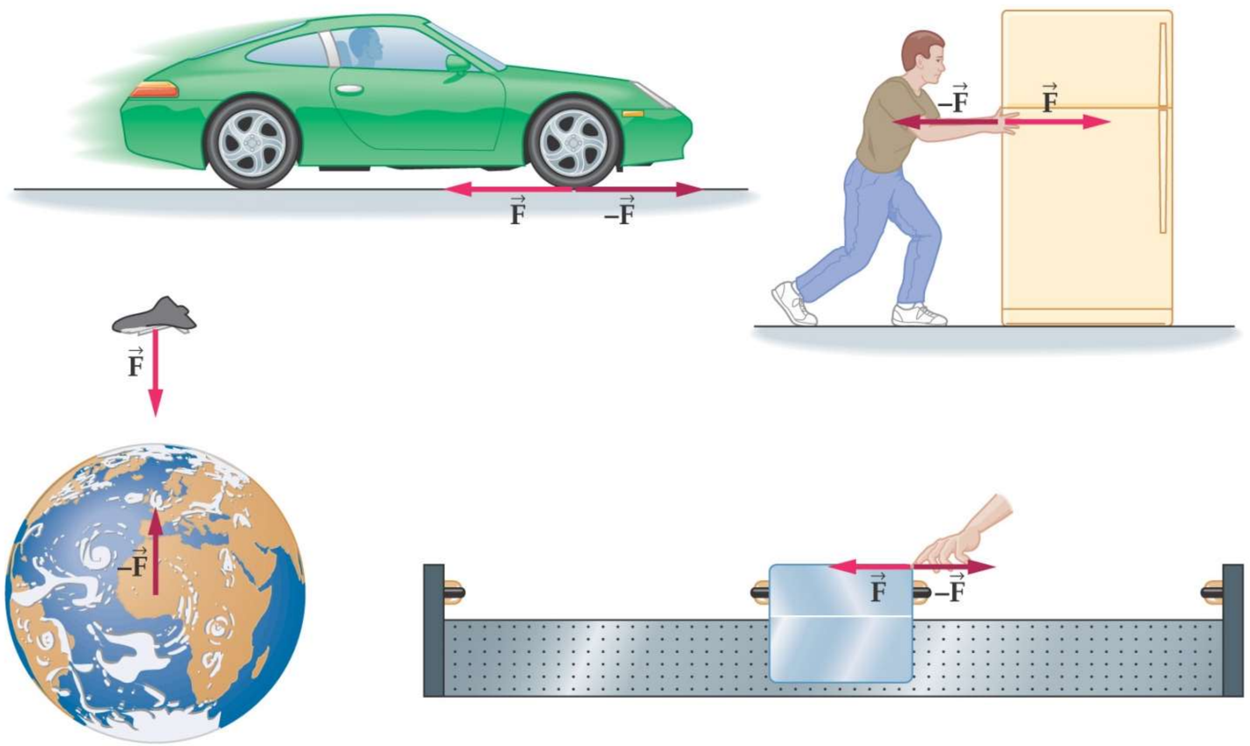
Reaction : the bat forces the ball to the right.

Action: Bowling ball pushes pin leftwards.

Reaction : Pin pushes bowling ball rightward.

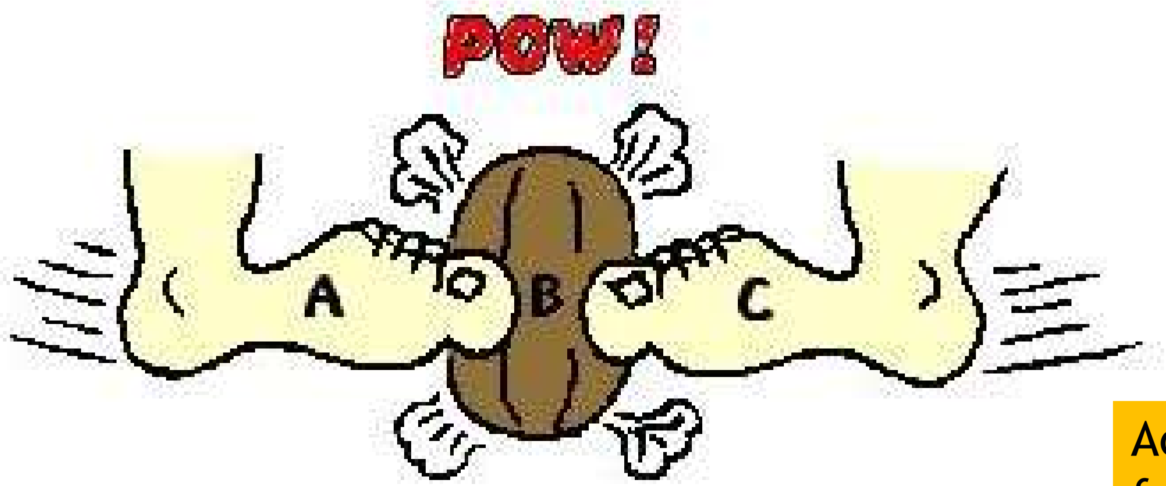
3.2 NEWTON'S LAW OF MOTION

- 3.2.3 Newton's Third Law



3.2 NEWTON'S LAW OF MOTION

Exercise



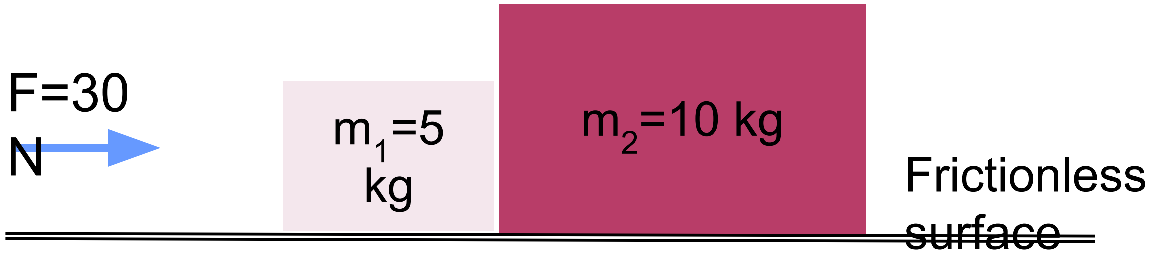
Consider the interaction depicted below between foot A, ball B, and foot C. The three objects interact simultaneously (at the same time). Identify the <u>two pairs</u> of action-reaction forces. Use the notation "foot A", "foot C", and "ball B" in your statements.

Action :
foot A pushes ball B to the right
Reaction:
ball B pushes foot A to the left

Action:
foot C pushes ball B to the left
Reaction:
ball B pushes foot C to the right

3.2 NEWTON'S LAW OF MOTION

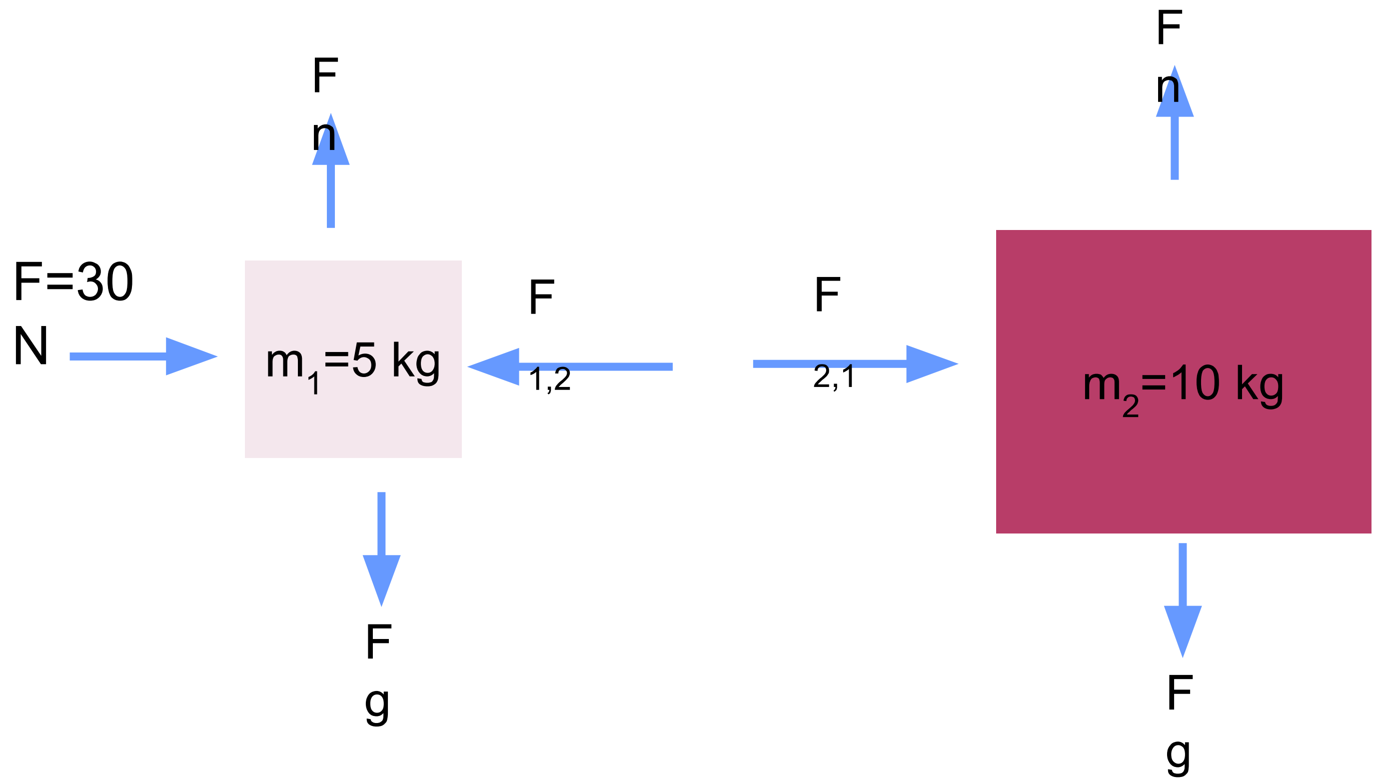
- Example



a) Draw the free body diagram for each block.
b) Determine the acceleration of the system
c) Determine the net force on each block
d) Determine the force exerts on m_2

3.2 NEWTON'S LAW OF MOTION

a.) Draw the free body diagram for each block.



3.2 NEWTON'S LAW OF MOTION

b.) Determine the acceleration of the system

$$\sum F_x = ma$$

$$30 = (5+10)a$$

$$a = \frac{30}{15}$$

$$= 2ms^{-2}$$

c.) Determine the net force on each block

Net force of Block m_1

$$
\begin{aligned}
F_{net} &= F - F_{12} \\
&= m_1 a \\
&= (5kg)(2ms^{-2}) \\
&= 10N
\end{aligned}
$$

Net force of Block m_2

$$
\begin{aligned}
F_{net} &= m_2 a \\
&= (10kg)(2ms^{-2}) \\
&= 20N
\end{aligned}
$$

3.2 NEWTON'S LAW OF MOTION

- Determine the force exerts on m_2

$$\begin{aligned} F - F_{12} &= m_1 a \\ 30 - F_{12} &= 5kg(2ms^{-2}) \\ F_{12} &= 30 - 10 \\ &= 20N \end{aligned}$$

$$F_{12} = F_{21}$$

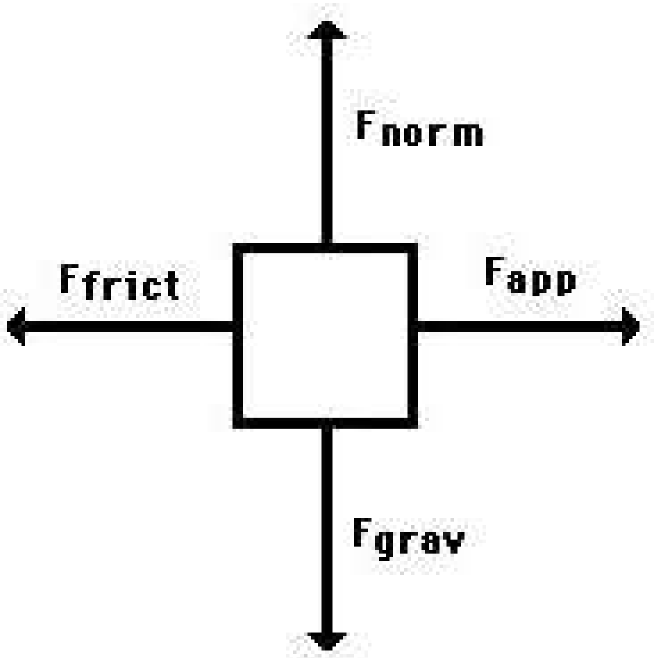
$$\therefore F_{21} = 20N$$

3.2 NEWTON'S LAW OF MOTION

- More exercise will be discussed in the tutorial section.

** FREE BODY DIAGRAM

- Diagrams used to show the relative magnitude and direction of all forces acting upon an object in a given situation.



F_{App}
An applied force is a force which is applied to an object by a person or another object.

F_{grav}
Force with which the earth, moon, or other massively large object attracts another object towards itself. The weight of the object.

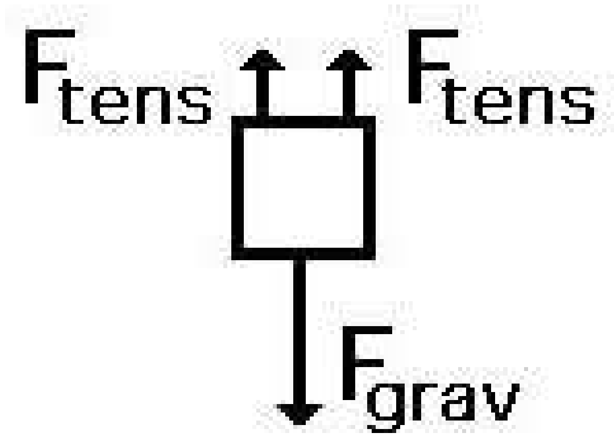
F_{norm}
Support force exerted upon an object which is in contact with another stable object.

F_{frict}
force exerted by a surface as an object moves across it or makes an effort to move across it.

** FREE BODY DIAGRAM

- Example

A girl is suspended motionless from the ceiling by two ropes. Diagram the forces acting on the combination of girl and bar.



3.3 WEIGHT - THE FORCE OF GRAVITY

- **Weight**
  - Force that pulls the body directly toward the earth.
  - Force of gravity acting on body

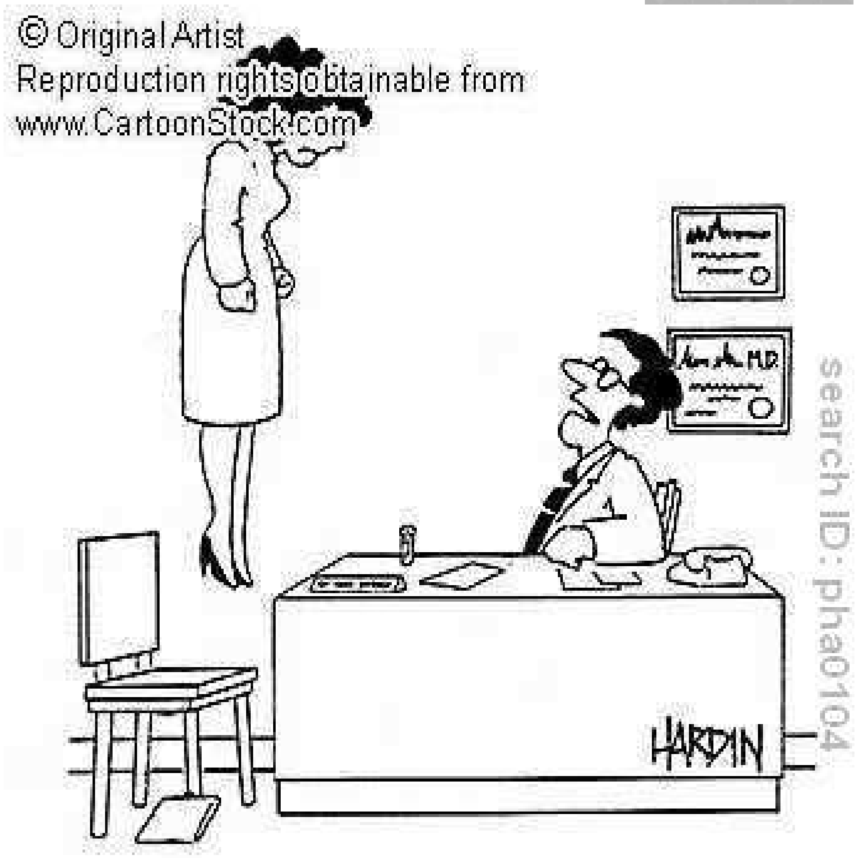
$$F_G = mg$$

Unit : Newton, $g = 9.8ms^{-2}$

3.3 WEIGHT - THE FORCE OF GRAVITY

- Weightlessness
  - When the acceleration of the person and the enclosure are equal, the person is said to be apparently weightless

    - Even though the weight is not zero



"Has the medication had any other side effects?"

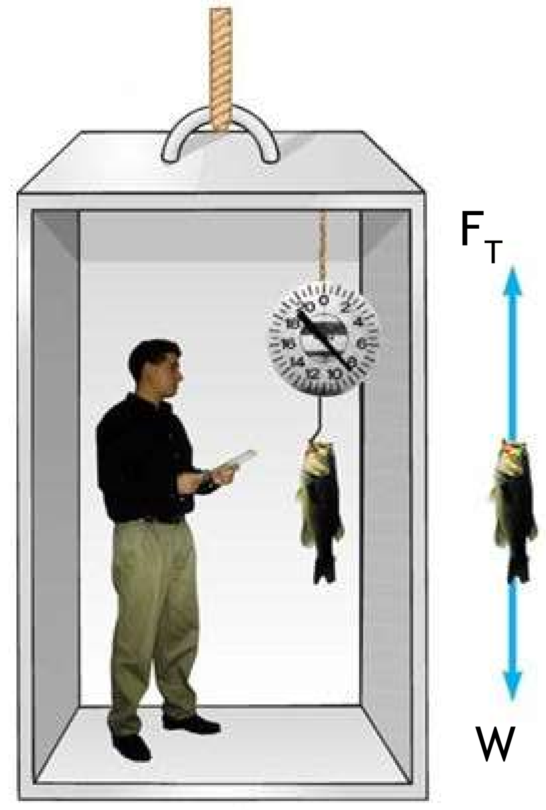
3.3 WEIGHT - THE FORCE OF GRAVITY

- Weightlessness – lift case

Case 1

Non-accelerating lift (a=0)

$$\sum F = 0$$
$$\sum F = F_T - W$$
$$= 0$$
$$F_T = W$$



3.3 WEIGHT - THE FORCE OF GRAVITY

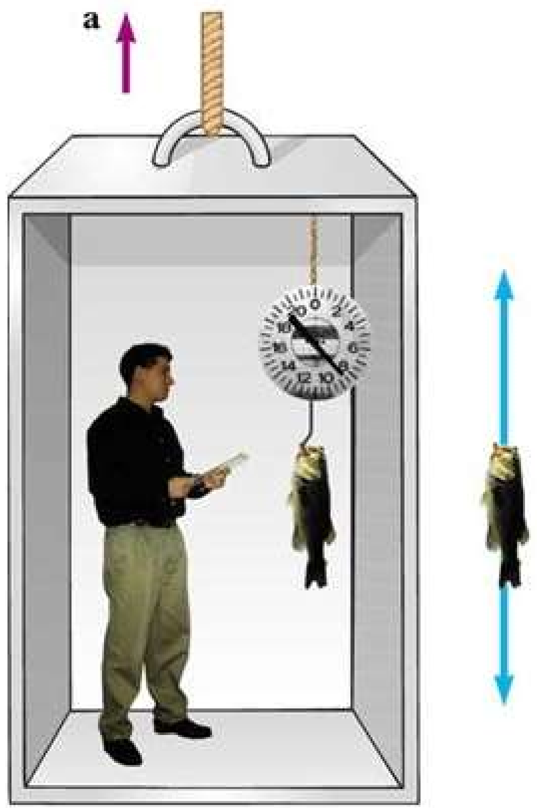
- Weightlessness – lift case

Case 2

Ascending lift

$$\sum F = ma$$
$$F_T + (-W) = ma$$
$$F_T - W = ma$$
$$F_T = ma + W$$
$$= ma + mg$$
$$= m(a+g)$$
$$\therefore F_T > mg$$

- With an upward acceleration a, we see that F_T is more than mg
- The scale indicates that the fish weights more than the true weight.



3.3 WEIGHT - THE FORCE OF GRAVITY

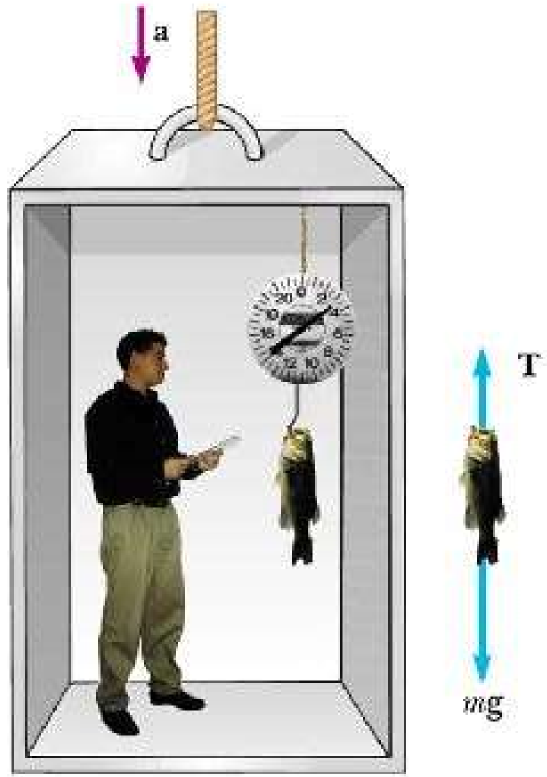
- Weightlessness – lift case

Case 3

Descending lift (a<g)

$$\sum F = ma$$
$$-F_T + W = ma$$
$$W - F_T = ma$$
$$F_T = W - ma$$
$$= mg - ma$$
$$= m(g-a)$$
$$\therefore F_T < mg$$

- With an downward acceleration a, we see that F_T is less than mg
- The scale indicates that the fish weights less than the true weight.



3.3 WEIGHT - THE FORCE OF GRAVITY

- Weightlessness – lift case

Case 3

Free fall lift (a=g)

$$\sum F = ma$$

$$\sum F = mg$$

$$W - F_T = mg$$

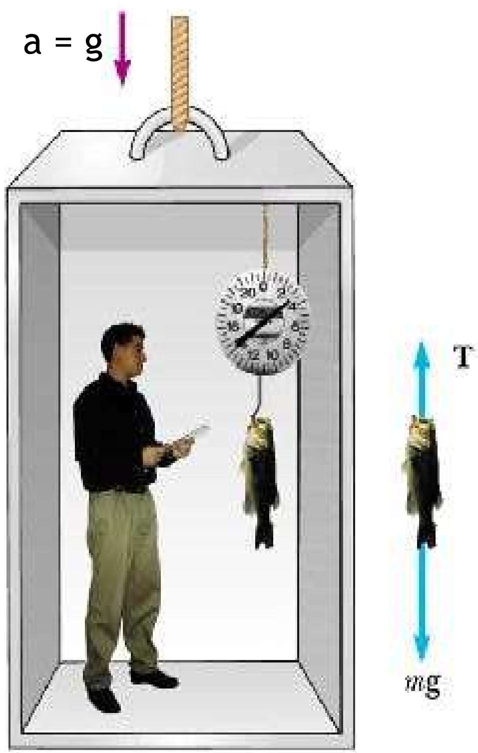
$$F_T = W - mg$$

$$= mg - mg$$

$$= m(g - g)$$

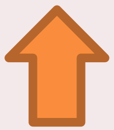
$$\therefore F_T = 0$$

- With an downward acceleration a, and a = g, free fall (weightless) condition occurs.
- The scale indicates that the fish weights is 0 N.



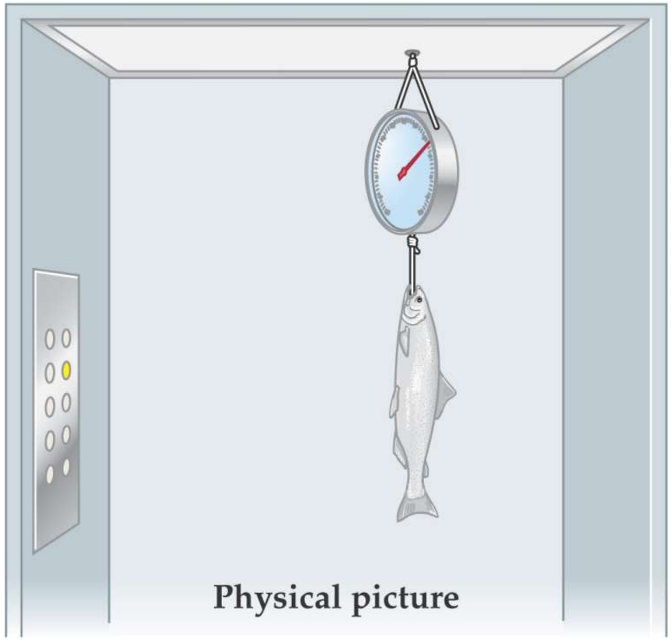
3.3 WEIGHT - THE FORCE OF GRAVITY

Summary

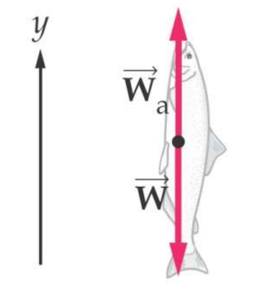
Acceleration, a (ms^{-2})	Lift movement Direction	Formula
a=0	None	$F_T=mg$
a>0		$F_T=m(g+a)$
0<a<g		$F_T=m(g-a)$
a=g		$F_T=m(g-g)=0$

3.3 WEIGHT - THE FORCE OF GRAVITY

- Exercise



Physical picture



Free-body diagram

A 5.0-kg salmon is weighed by hanging it from a fish scale attached to the ceiling of an elevator. Let $g=9.8ms^{-2}$What is the apparent weight of the salmon if the elevator

(a) is at rest,

(b) moves with an upward acceleration of 2.5 m/s/s, or

(c) moves with a downward acceleration of 3.2 m/s/s?

3.3 WEIGHT - THE FORCE OF GRAVITY

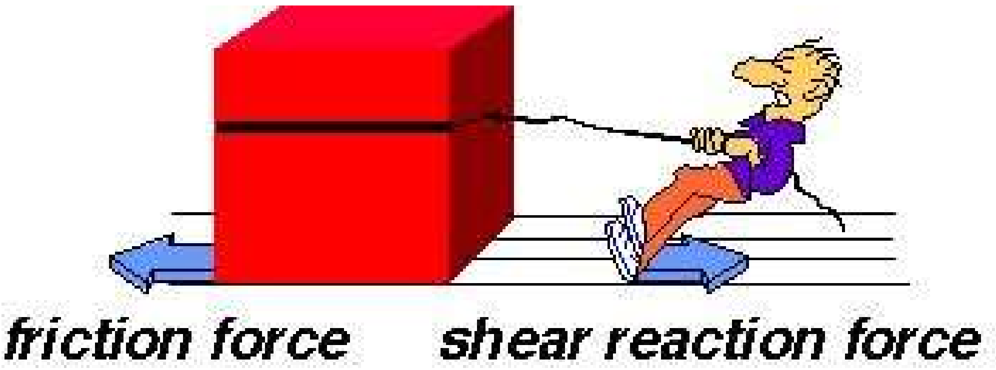
- Solution

a.)
$$\begin{aligned} F_T &= W \\ &= mg \\ &= 5(9.8) \\ &= 49N \end{aligned}$$

b.)
$$\begin{aligned} F_T &= m(g+a) \\ &= 5(9.8+2.5) \\ &= 61.5N \end{aligned}$$

c.)
$$\begin{aligned} F_T &= m(g-a) \\ &= 5(9.8+3.2) \\ &= 33N \end{aligned}$$

3.4 FRICTION FORCE



- When a body is in motion and the motion is taken in place on a surface, air or water, there is resistance to the motion because the body interacts with its surroundings.

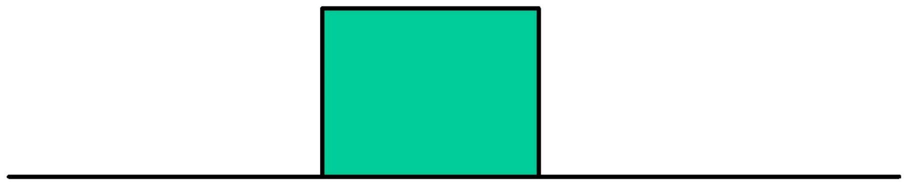
3.4 FRICTION FORCE

- Friction is a force that is created whenever two surfaces move or try to move across each other.
  - Friction always opposes the motion or attempted motion of one surface across another surface.
  - Friction is dependant on the texture of both surfaces.
  - Friction is also dependant on the amount of contact force pushing the two surfaces together

3.4 FRICTION FORCE - IN DETAIL

- There are 2 kinds of friction forces:
  - Static friction force (f_s)
  - Kinetic friction force (f_k)

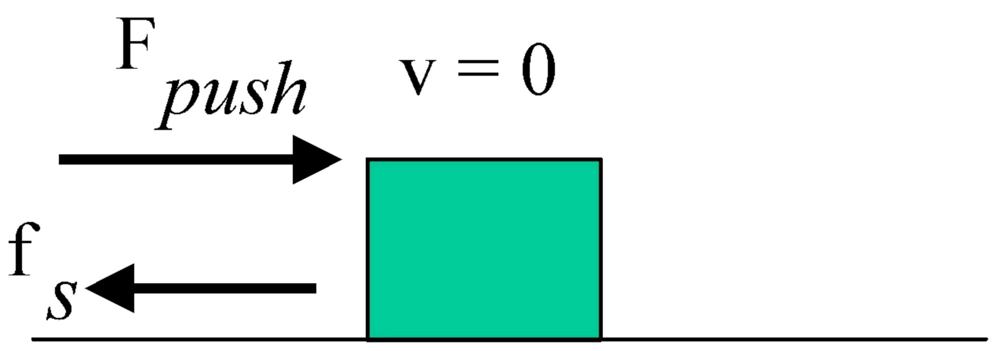
No horizontal forces



At rest

If a block is at rest (Not Movement) , no forces with horizontal components are applied to the block, then there is no static friction force.

3.4 FRICTION FORCE



$F_{push} = f_s$ At rest

Apply an external horizontal force, F_{push} to the block, the block remains stationary(not moving).

Conclude that an equal and opposite force acts on the block to prevent it from moving . This is the static friction force, f_s.

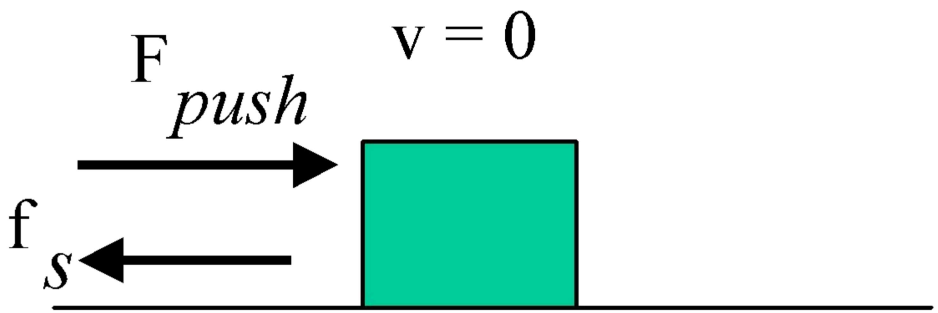
3.4 FRICTION FORCE

The static friction force is not a fixed value but it always equal to the applied force.

As long as the block is not moving,

$$F_{push} = f_s$$

3.4 FRICTION FORCE



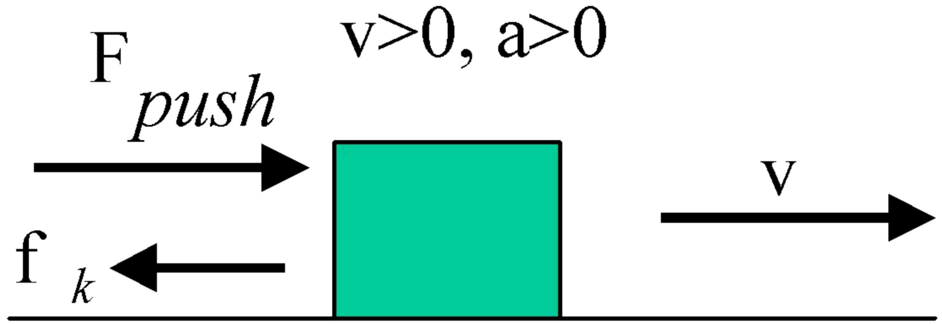
$F_{push} = f_{s_{max}}$ At rest

Static friction at its maximum

If we increased the horizontal applied force, F_{push} the static friction force will increase by the same amount until it reached its maximum value, f_{smax}

$$f_{s_{max}} = \mu_s F_N$$ F_N = Weight

3.4 FRICTION FORCE

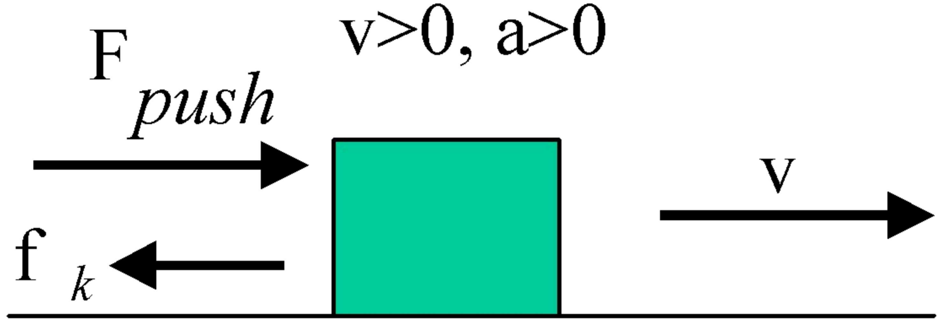


$$F_{push} > f_{s_{max}}$$

kinetic friction sets in

- If we Increase the magnitude of F_{push}, the block eventually slips, $\Rightarrow f_{smax}$.
- When F_{push} exceeds f_{smax} the block moves and accelerate.

3.4 FRICTION FORCE

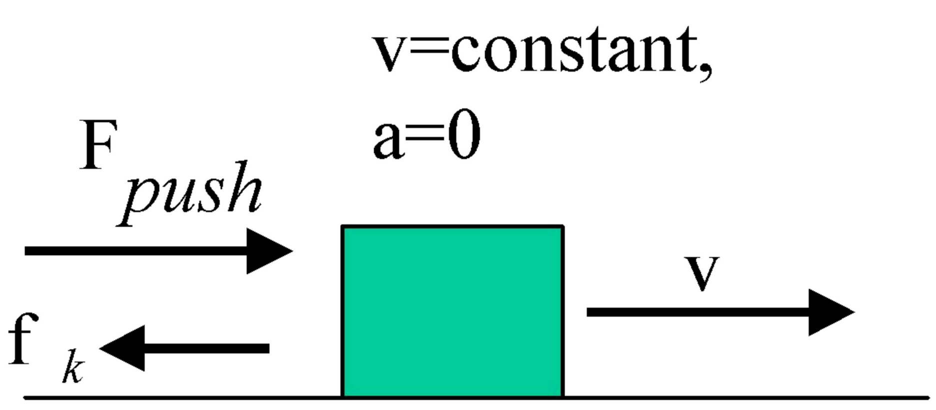


$F_{push} > f_{s_{max}}$

kinetic friction sets in

- The retarding force ⇒ kinetic friction force, f_k
- The value of f_k is smaller than the maximum value of f_s .

3.4 FRICTION FORCE



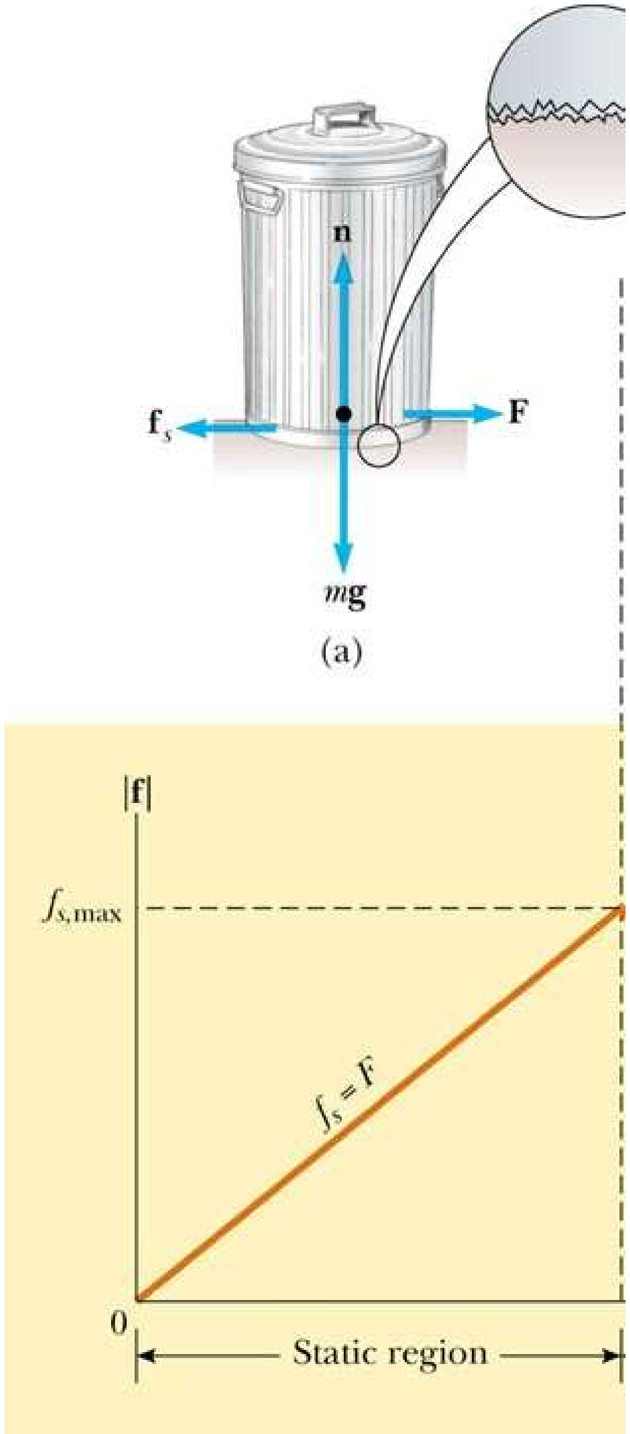
$F_{push} = f_k$

pushing force reduced

- If F is removed, the friction force acting to the left, accelerate the block in the negative x direction and eventually bring it to rest !

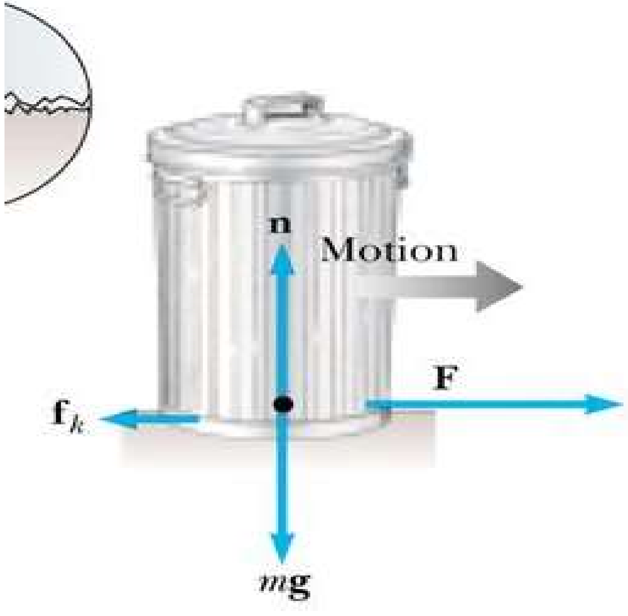
3.4 FRICTION FORCE

- Characteristics of Static Friction Force
  - Static friction acts to keep the object from moving
  - If F increases, so does f_s
  - If F decreases, so does f_s
  - $f_s \leq \mu F_N$

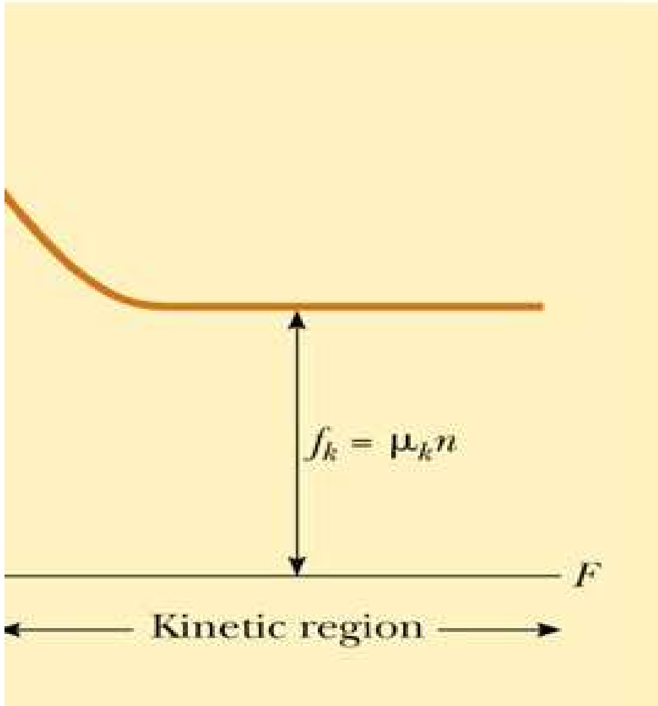


3.4 FRICTION FORCE

- Characteristic of Kinematic Friction Force
  - The force of kinetic friction acts when the object is in motion
  - $f_k = \mu F_N$

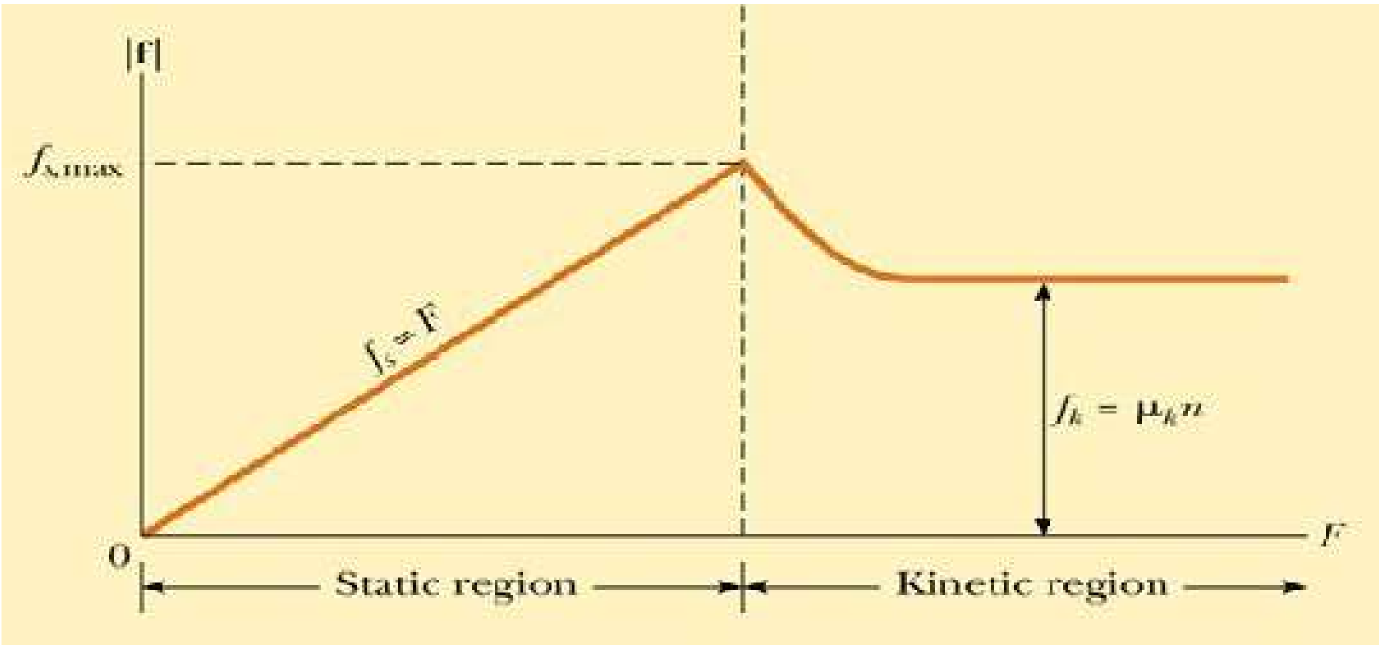


(b)



3.4 FRICTION FORCE

- Overall of Static friction force and kinematic friction force
  - Friction is proportional to the normal force
  - The force of static friction is generally greater than the force of kinetic friction



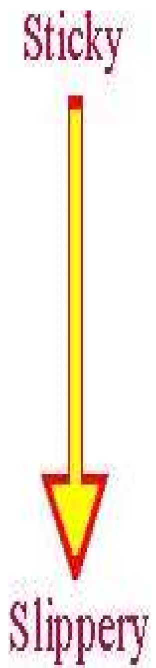
3.4 FRICTION FORCE

- The coefficient of friction
  - depends on the surfaces in contact
  - The direction of the frictional force is opposite the direction of motion (direction of applied force)
  - The coefficients of friction are nearly independent of the area of contact
  - The coefficient of friction is dimensionless and determined experimentally

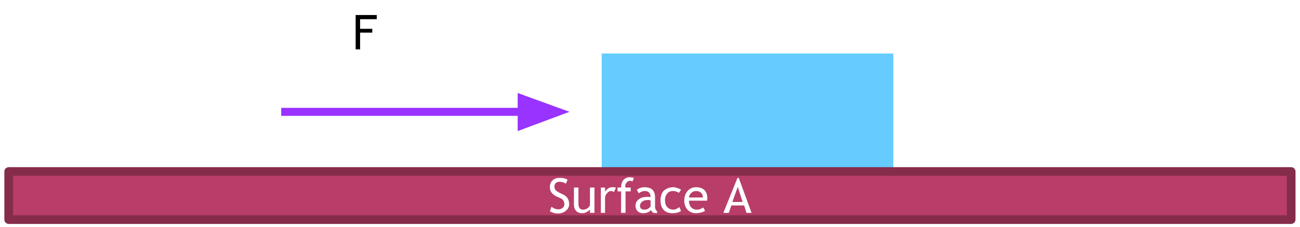
μ_s - Coefficient of Static Friction

μ_k - Coefficient of Kinematic Friction

3.4 FRICTION FORCE

surface-on-surface	μ_s	μ_k	
hook velcro-on-fuzzy velcro	>6.0	>5.9	
avg tire-on-dry pavement	0.9	0.8	
grooved tire-on-wet pavement	0.8	0.7	
glass-on-glass	0.9	0.4	
metal-on-metal (dry)	0.6	0.4	
smooth tire-on-wet pavement	0.5	0.4	
metal-on-metal (lubricated)	0.1	0.05	
steel-on-ice	0.1	0.05	
steel-on-Teflon	0.05	0.05	

3.4 FRICTION FORCE



- Example

The coefficient of static and kinetic friction between a 3.0 kg box and Surface A are 0.40 and 0.30 respectively. What is the net force on the box when each of the following horizontal force is applied to the box?

a.) 5.0N

b.) 15.0 N

3.4 FRICTION FORCE

- Solution

a.) $\mu_s = 0.40, \mu_k = 0.30, F_{push} = 5.0N, m = 3kg$

$\sum F_y = 0$

y-axis force is equilibrium

The maximum static friction force,

$$f_s = \mu_s F_N$$
$$= \mu_s mg$$
$$= 0.4(3)(9.8)$$
$$= 11.76N$$

Since the applied force is smaller than the maximum static friction force ($F_{push} < f_s$)
So, the object remains at rest .

3.4 FRICTION FORCE

- Solution

b.) $\mu_s = 0.40, \mu_k = 0.30, F_{push} = 15.0N, m = 3kg$

$$\sum F_y = 0$$

y-axis force is equilibrium

The maximum static friction force,

$$\begin{aligned} f_s &= \mu_s N \\ &= \mu_s mg \\ &= 0.4(3)(9.8) \\ &= 11.76N \end{aligned}$$

Since the applied force is more than the maximum static friction force ($F_{push} > f_s$)
So, the object is in motion with a acceleration.

3.4 FRICTION FORCE

Kinematic friction force, f_k

$$\begin{aligned} f_k &= \mu_k mg \\ &= 0.3(3)(9.8) \\ &= 8.82N \end{aligned}$$

$$\begin{aligned} \sum F_x &= F_{push} - f_k \\ &= 15 - 8.82 \\ &= 6.18N \end{aligned}$$

the box will accelerate at a rate of

$$\begin{aligned} \sum F_x &= ma \\ ma &= F_{push} - f_k \\ (3)a &= 6.18N \\ a &= 2.06ms^{-2} \end{aligned}$$

3.4 FRICTION FORCE

- Example

A person exerts a horizontal force of 267 N in attempting to push a freezer across a room, but the freezer does not move. What is the static friction force that the floor exerts on the freezer?

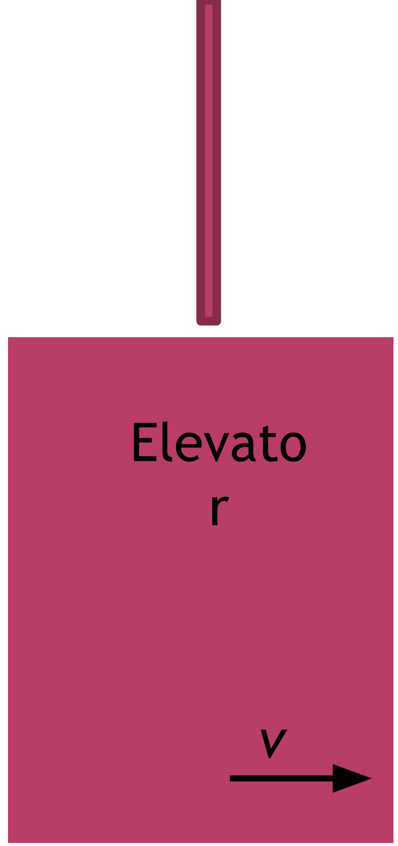
Solution

267 N, since the freezer does not move, so the applied force is equal to the static friction force.

3.4 FRICTION FORCE

- Example

A 6.0 kg box is sliding across the horizontal floor of an elevator. The coefficient of kinetic friction between the box and the floor is 0.360. Determine the kinetic frictional force that acts on the box when the elevator is,



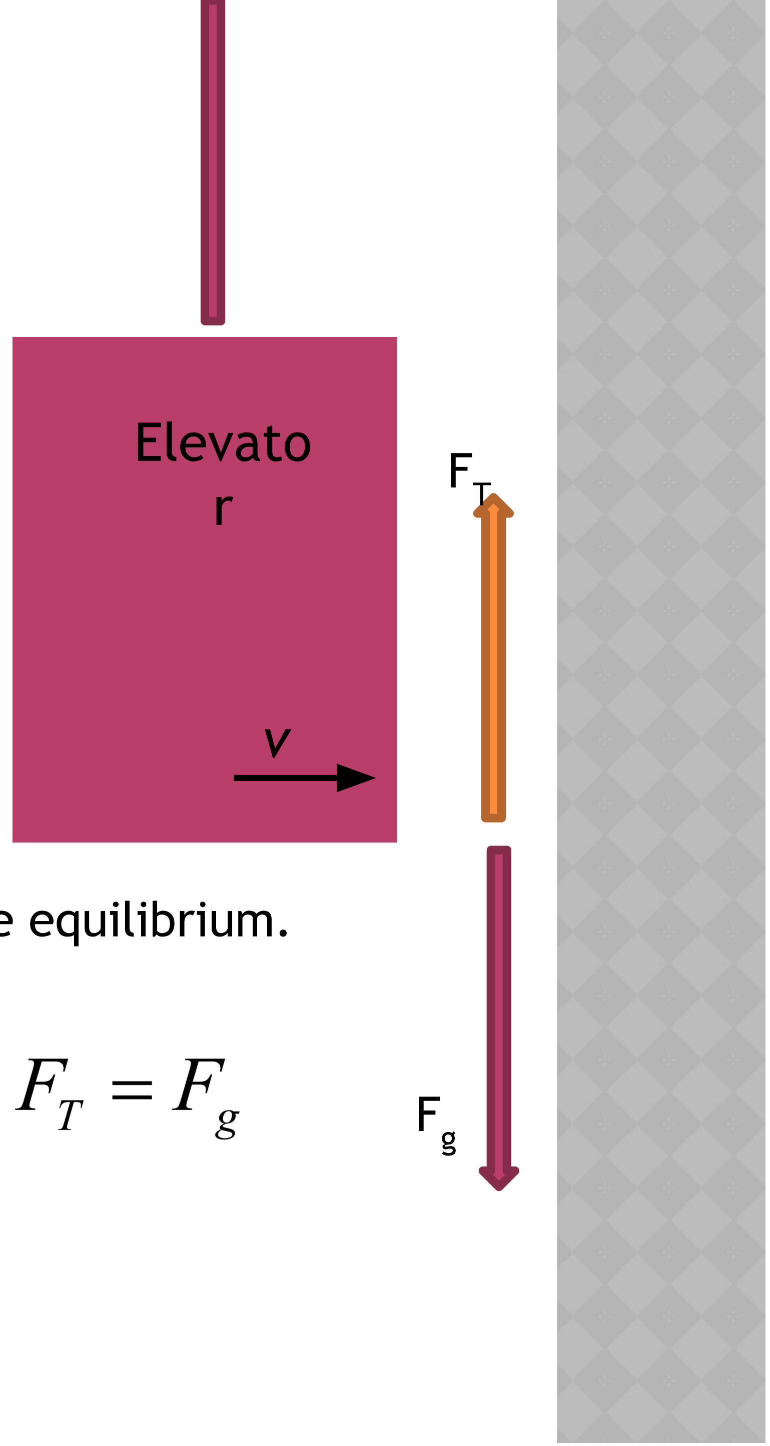
a.) stationary

b.) accelerating upward with an acceleration whose magnitude is 1.2 ms^{-2} .

c.) accelerating downward with an acceleration whose magnitude is 1.2 ms^{-2}.

a.) kinetic frictional force,

$$f_k = \mu_k N$$
$$= \mu_k (mg)$$
$$= 0.36(6)(9.8)$$
$$= 21.2N$$



F_T and F_g are equilibrium.
So ,

$$\sum F_x = F_T = F_g$$

3.4 FRICTION FORCE

b.) $f_k = \mu_k N$

Elevator move upward

$$F_T = m(a+g)$$
$$= 6(1.2+9.8)$$
$$= 66.0N$$
$$= N$$

Kinetic frictional force,

$$f_k = \mu_k N$$
$$= (0.36)(66.0)$$
$$= 23.8N$$

3.4 FRICTION FORCE

b.) $f_k = \mu_k N$

Elevator move upward

$$F_T = m(g-a)$$
$$= 6(9.8-1.2)$$
$$= 51.6N$$
$$= N$$

Kinetic frictional force,

$$f_k = \mu_k N$$
$$= (0.36)(51.6)$$
$$= 18.6N$$

3.5 LINEAR MOMENTUM & COLLISION

- Linear Momentum
  - a quantity associated with how a mass moves along a straight path.
  - A force can change the linear momentum of a mass.

- If you hit a hockey puck with a stick, the puck will move forward
  - there is a linear momentum associated with it
- If no forces are acting on the puck
  - it keeps moving in the same path with the same velocity forever

3.5 LINEAR MOMENTUM & COLLISION

- The linear momentum of an object of mass *m* moving with a velocity *v* is defined as the product of the mass and the velocity

  - $p = mv$
  - SI units: $kgms^{-1}$
  - A vector quantity and same direction with velocity

3.5 LINEAR MOMENTUM & COLLISION

- Truck and bicycle, which vehicle is much easier to stop off ?

m = 10 000 kg
$v = 2ms^{-1}$

m = 60 kg
$v = 2ms^{-1}$

The truck has a much larger linear momentum even though both are moving at the same velocity. It is easier to bring the bicyclist to a stop than it is to bring the truck to a stop. Similarly, it is easier to stop a bicyclist moving at 2 m/s than a bicyclist moving at 5 m/s.

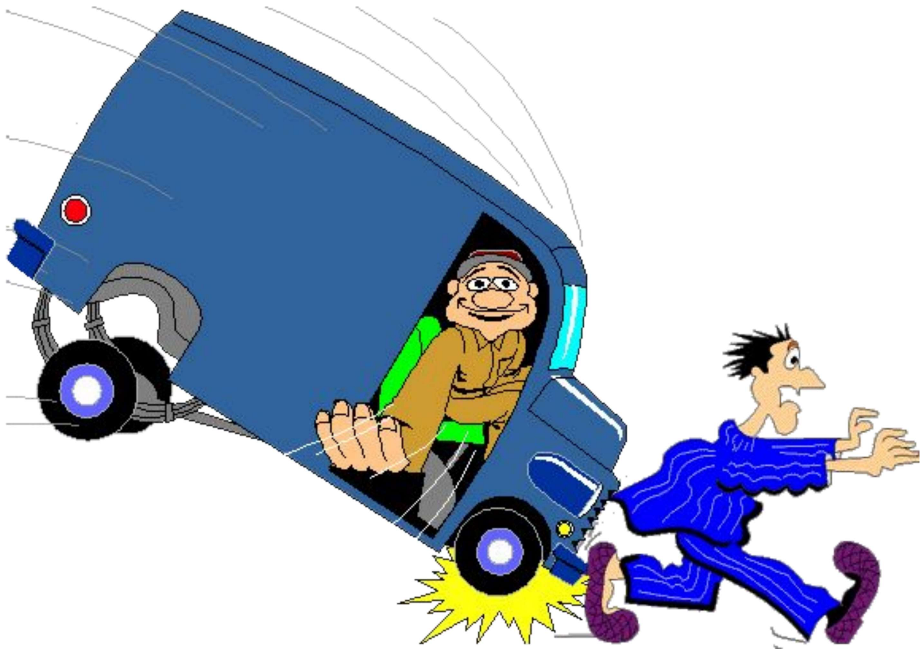
3.5 LINEAR MOMENTUM & COLLISION

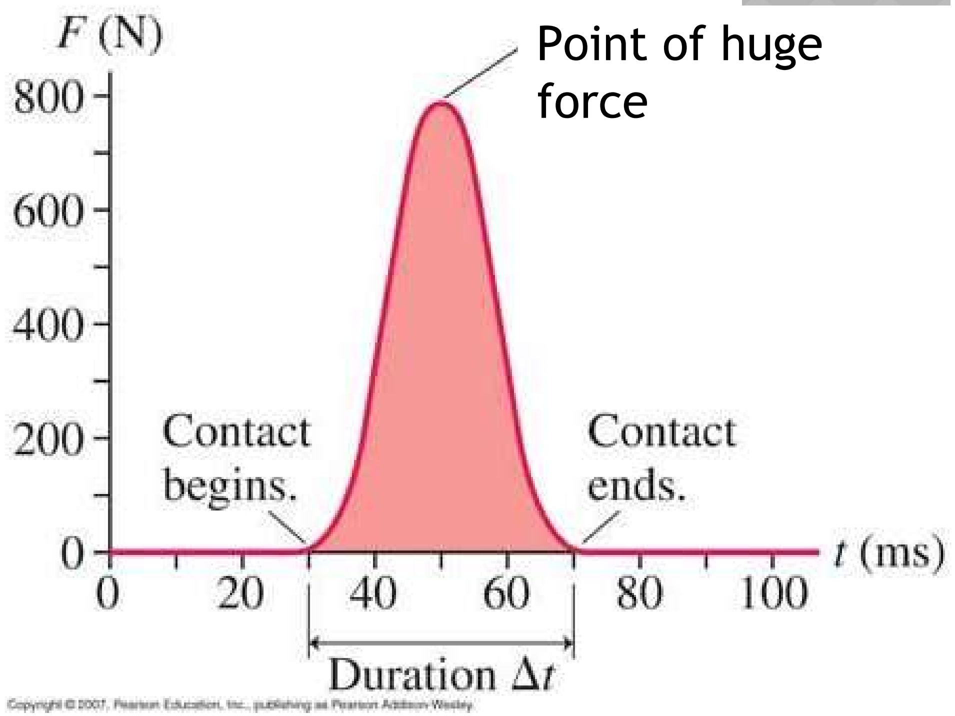
- Newton law that related to momentum
  - “The rate of change of the momentum of particle is equal to the net force applied to it”

$$\begin{aligned}\sum F &= \frac{\Delta p}{\Delta t} \\ &= \frac{mv - mv_0}{\Delta t} \\ &= \frac{m(v - v_0)}{\Delta t} \\ &= \frac{m\Delta v}{\Delta t} \\ &= ma\end{aligned}$$

3.5 LINEAR MOMENTUM & COLLISION

- Impulse





❖ When collision happen on this truck and human, both parties are deformed because of large force involved

  ❖The force usually jumps from zero at the moment of contact to a very huge value within a short time, and then abruptly return to zero

3.5 LINEAR MOMENTUM & COLLISION

- Impulse
  - Product of average force and the time interval (very short normally) during which the force acts
    - Vector quantity

According to Newton's second law:

$$\sum F = \frac{\Delta p}{\Delta t}$$

$$\Delta p = \sum F \times \Delta t$$

- Units: Ns

3.5 LINEAR MOMENTUM & COLLISION

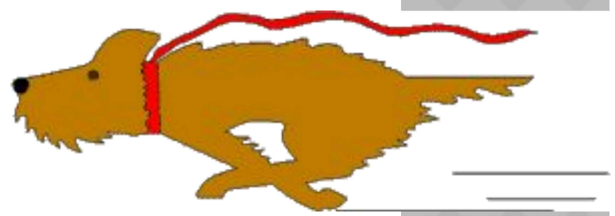
- Impulse force
  - It is a very strong force compare with other forces on the system
  - Act in very short time
  - Example
    - When a baseball struck with a bat
      - The collision time is 0.01 s
      - The average force typically is several thousand Newton's

3.6 CONSERVATION OF LINEAR MOMENTUM

- "The Total momentum of an isolated system of bodies remains constant"

Let's take an example

You are standing still when your dog runs up and jumps on you. Together, you and the dog fall backwards. Your mass is 40 kg and the dog is 20 kg. The dog is coming at you at 2 m/s. Since linear momentum is conserved in this situation, the total linear momentum before the collision must equal the total linear momentum afterwards.



$$\textit{total linear momentum}_{before} = \textit{total linear momentum}_{after}$$

3.6 CONSERVATION OF LINEAR MOMENTUM

The linear momentum before the collision is

$$
\begin{aligned}
(\textit{mass of dog}) * (\textit{velocity of dog}) + (\textit{your mass}) * (\textit{your velocity}) \\
&= 20*2 + 40*0 \\
&= 40
\end{aligned}
$$

You and the dog are basically stuck together as you are falling. The two of you are moving with the same velocity backwards. The linear momentum after the collisions is then

$$
\begin{aligned}
(\textit{mass of dog}) * (\textit{velocity backwards}) + (\textit{your mass}) * (\textit{velocity backwards}) \\
&= (\textit{mass of dog} + \textit{your mass}) * (\textit{velocity backwards}) \\
&= (20 + 40) * (\textit{velocity backwards}) \\
&= 60 * (\textit{velocity backwards})
\end{aligned}
$$

3.6 CONSERVATION OF LINEAR MOMENTUM

- Summary in one equation

$$\begin{aligned} \textit{total linear momentum}_{before} &= \textit{total linear momentum}_{after} \\ 40 &= 60 * (\textit{velocity backwards}) \\ 40/60 &= \textit{velocity backwards} \\ 2/3\ \text{m/s} &= \textit{velocity backwards} \end{aligned}$$

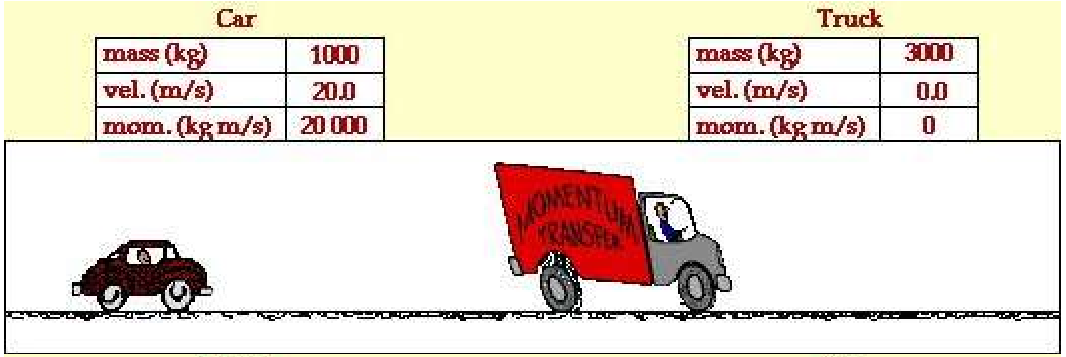
After the collision, you and the dog will be moving at 2/3 m/s backwards.

3.6 CONSERVATION OF LINEAR MOMENTUM

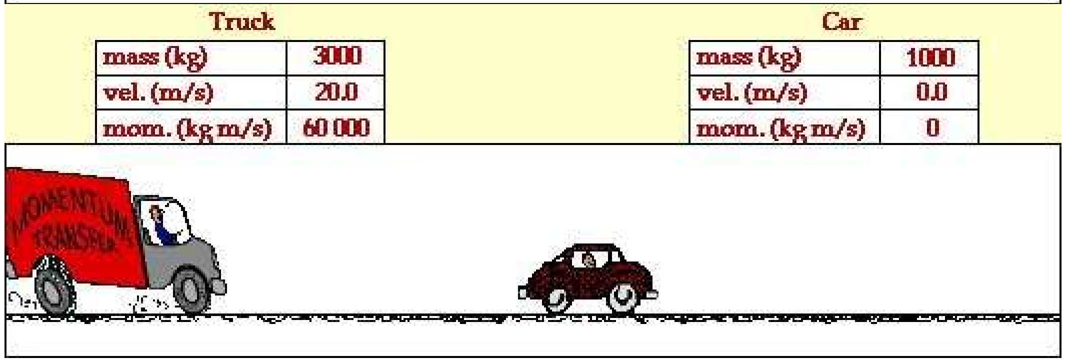
- There is an interaction between you and the dog during the collision that causes you to start moving and the dog to slow down. When the dog hits you, he pushes on you and exerts a force on you. You start moving and gain some linear momentum. At the same time, you are exerting a force on the dog to slow him down. The force the dog exerts on you is exactly equal and opposite to the force you exert on the dog. Nothing influences you or the dog from the outside so linear momentum is said to be conserved.

3.6 CONSERVATION OF LINEAR MOMENTUM

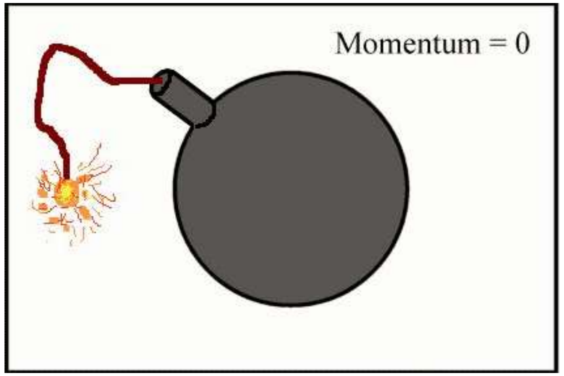
- In physics, there are 3 types of collision



Elastic Collision



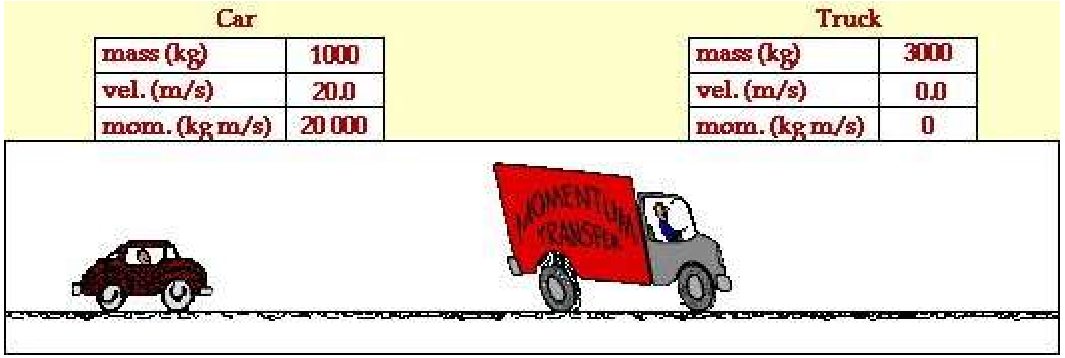
Inelastic Collision



Explosion

3.6 CONSERVATION OF LINEAR MOMENTUM

- Elastic Collision



Total momentum before impact = total momentum after impact

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

where u_1 and u_2 are the velocity before impact
and v_1 and v_2 are the velocity after impact

3.6 CONSERVATION OF LINEAR MOMENTUM

Kinetic energy is conserved during elastic collision

Therefore:

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2u_2^2$$

3.6 CONSERVATION OF LINEAR MOMENTUM

- Since we have 2 equation, let analysis it

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$
$$m_1(u_1 - v_1) = m_2(v_2 - u_2) \text{ --------------- } (1)$$

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$
$$m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$$
$$m_1(u_1 - v_1)(u_1 + v_1) = m_2(v_2 - u_2)(v_2 + u_2) \text{ ----------}(2)$$

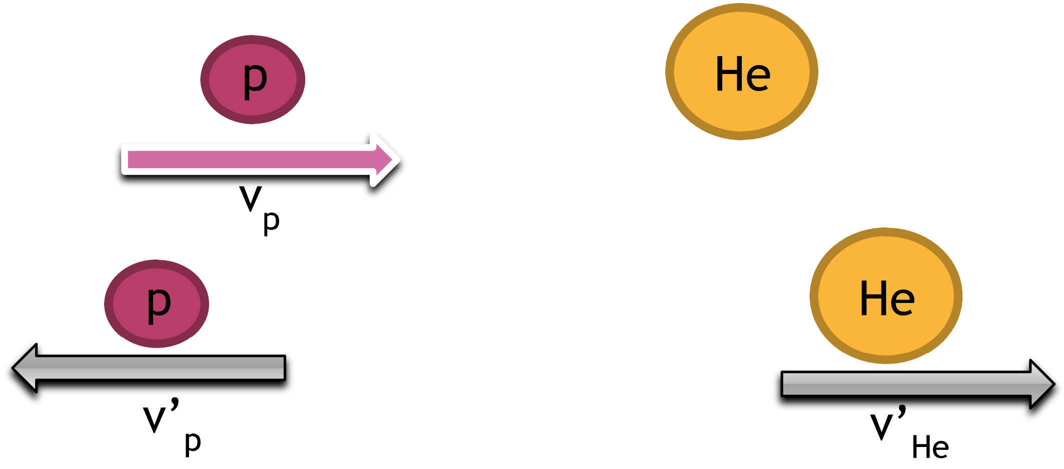
divide equation (1) and (2)

$$u_1 + v_1 = v_2 + u_2$$
$$u_1 - u_2 = v_2 - v_1$$

3.6 CONSERVATION OF LINEAR MOMENTUM

- Example

A proton (p) of mass 1.01u (unified atomic mass units) traveling with a speed of $3.60 \times 10^4\ ms^{-1}$ has an elastic head on collision with a helium (He)nucleus (m_{He}=4.00u) initially at rest. What are the velocities of the proton and helium nucleus after the collision ? Given that 1 u = 1.66×1^{-27} kg



3.6 CONSERVATION OF LINEAR MOMENTUM

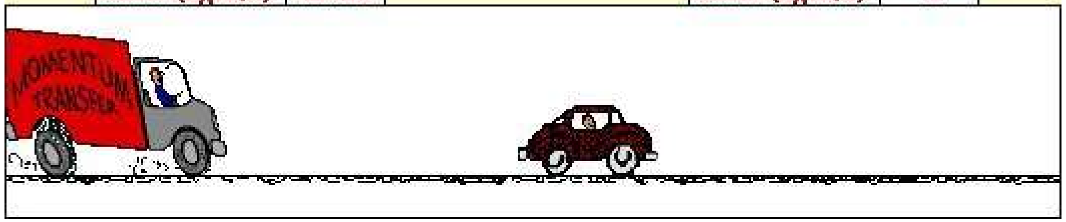
- Inelastic Collision

Truck

mass (kg)	3000
vel. (m/s)	20.0
mom. (kg m/s)	60 000

Car

mass (kg)	1000
vel. (m/s)	0.0
mom. (kg m/s)	0



$$\text{Total momentum before impact} = \text{total momentum afterimpact}$$

$$m_1u_1 + m_2u_2 = m_1v_f + m_2v_f$$

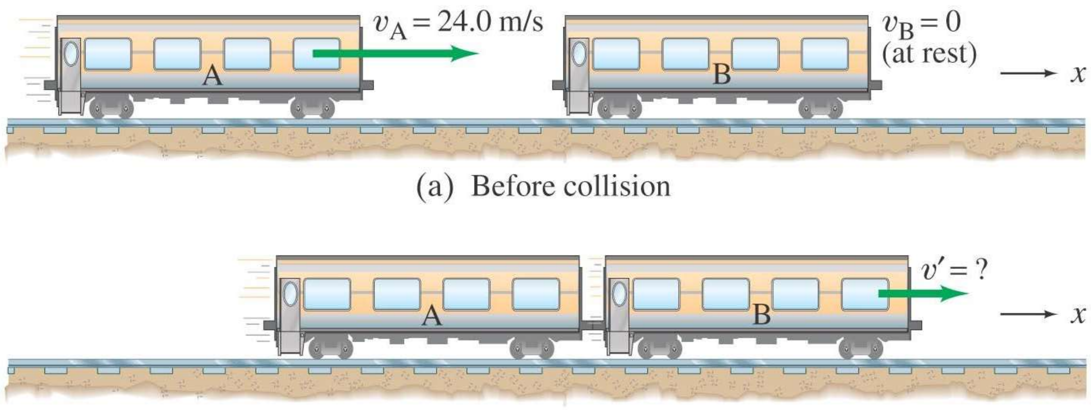
$$m_1u_1 + m_2u_2 = (m_1 + m_2)v_f$$

3.6 CONSERVATION OF LINEAR MOMENTUM

- Inelastic Collision - Kinetic energy
  - Not conserved
  - May transform into other types of energy
    - Thermal energy.
  - Total final kinetic energy is less than the total initial energy.

$$KE = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_1 v_2^2$$

3.6 CONSERVATION OF LINEAR MOMENTUM



(a) Before collision

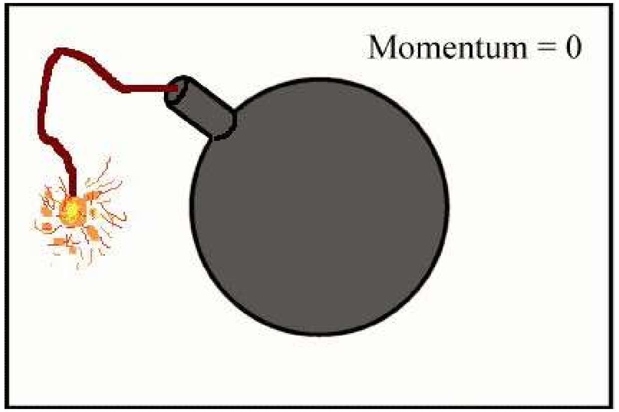
(b) After collision

- Example

A 10000kg railroad car, A, travelling at a speed of 24 ms^{-1} strikes an identical car, B, at rest. If the cars lock together as a result of collision, what is their common speed immediately after the collision.

3.6 CONSERVATION OF LINEAR MOMENTUM

- Explosion



Let say, when an explosion happen, an object will broken up into 2 pieces and moving with a velocity such that the momentum still Zero.

$$\text{Total momentum before impact} = \text{total momentum afterimpact}$$

$$0 = m_1 v_1 + m_2 v_2$$

3.6 CONSERVATION OF LINEAR MOMENTUM

- Explosion – Kinetic Energy
  - The energy is possible to be conserved as long as there is an initial potential energy.

$$PE = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$


THANK YOU
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