Lesson 2

Newton's Laws:

- **Law of Inertia**
- **F=ma**
- **Action-Reaction**

Newton's First Law:
Objects at rest tend to stay at rest (and objects in constant motion will stay in motion) unless acted upon by an external unbalanced force.

Inertia: the property of an object to maintain its state of motion. The more massive an object, the more inertia it has.

**Note that if an object is at rest, the net force acting on it is 0. This is also true if an object is moving at a constant velocity. As soon as $F_{net} \neq 0$, the object will accelerate.

Inertial Frame of Reference:
One in which Newton's first law of motion is valid (i.e. any frame of reference that is not accelerating).
Consider a bus travelling in a straight line at a constant speed. The bus frame of reference is an inertial frame of reference. If you lay a ball at your feet it will stay there; if you push it, it will roll up the aisle. But if you lay the ball on the floor and the driver hits the brakes slightly, the ball will roll forward. To you, it looks like it is rolling forward for no reason – objects at rest should remain at rest. The frame of reference of the accelerating bus is no longer an inertial frame of reference.

Newton's Second Law:

Recall that if $F_{net} = 0$, an object will either move at a constant velocity or it will remain at rest.

If $F_{net} \neq 0$ the object is accelerating according to Newton's Second Law.

$$F_{net} = ma$$

where F_{net} is the net force in Newtons
m is the mass in kg
a is the acceleration in m/s^2

Example 1:
What is the acceleration of a 12 kg object that has a net force of 36 N (E)?

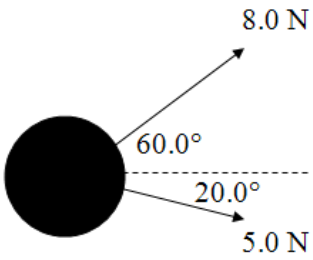
Example 2:
What is the mass of an object if an unbalanced force of 36 N gives it an acceleration of 3.0 m/s^2?

Example 3:
What force is necessary to accelerate a 1200 kg car along a horizontal surface from rest to 130 km/h in 8.0 s?

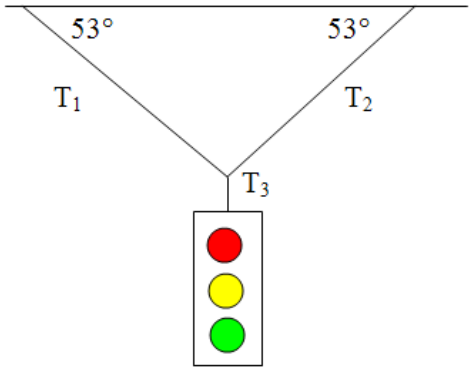
Example 4:
What mass would a sled on ice have if it requires a horizontal force of 100.0 N to change its velocity from 30.0 km/h to 120.0 km/h in 5.0 s?

Example 5:
What is the acceleration of a block having a mass of 0.50 kg that is being pulled in opposite directions by two children? Sean is pulling with a force of 3.0 N (W) and Diane is pulling 5.0 N (E). How far will it move in 3.0 s when these forces are exerted?

Example 6:
A hockey puck with a mass of 0.30 kg slides on the horizontal frictionless surface of an ice rink. Two forces act on the puck as shown. Determine the acceleration of the puck.



Example 7:
A traffic light weighing 100.0 N hangs from a cable tied to two other cables as shown. Find the tension in all three cables.



Example 8:
A person weighs a fish on a spring scale attached to the ceiling of an elevator.

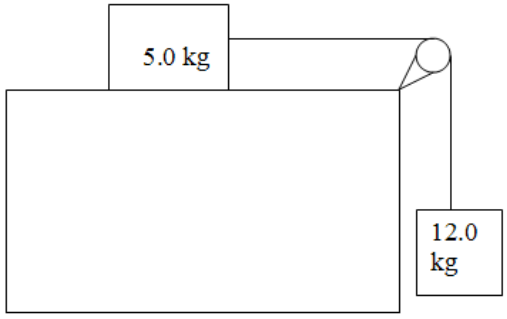
a) elevator at rest
b) accelerating upward
c) accelerating downward
d) elevator cable breaks

Try:
What would the tension be in a cable lifting an elevator and a person having a combined mass of 575 kg, moving at:

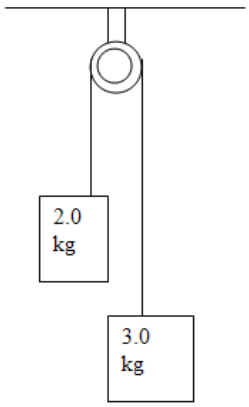
a) 5.0 m/s^2 (up)
b) 5.0 m/s^2 (down)

Example 9
For the blocks shown, calculate,

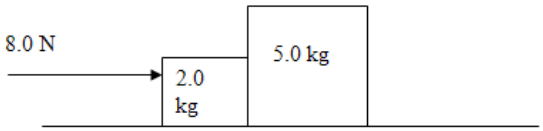
a) the acceleration of the blocks
b) the tension in the string



Example 10: Atwood's Machine
Determine the acceleration and the tension for the system of blocks shown below.



Example 11:
Calculate the acceleration of the system shown.



Newton's Third Law

If object A exerts a force on object B, then object B exerts an equal but opposite force on object A.

$$F_{AonB} = F_{BonA}$$

Consider holding a book in your hand.

If the hand exerts a 5 N force upward on the book, then the book exerts a 5 N force downward on the hand.

Note: Action-reaction forces always act on different objects.

Example:
Draw a free body diagram to show all the action-reaction pairs when a father pulls his daughter on a sled.

If these action-reaction pairs are opposite and equal, then how does the sled move forward?
Even though action-reaction pairs are equal, all forces in this situation are not equal. In this case the father can push harder on the ground than the ground can push on the sled.

Example:
If two people pull in opposite directions on the same object, is this an action-reaction pair?

No, these forces are acting on the same object and are not an action-reaction pair.