SPH3U
UNIVERSITY PHYSICS

FORCES

☞ Newton's Second Law of Motion (P.130-136)

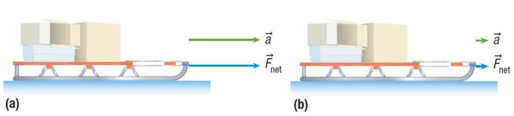
Newton's Second Law of Motion

When a constant unbalanced force acts on an object, it seems reasonable that the object will not have a constant velocity but will accelerate. But this raises a couple of questions.

1. *How does the acceleration of the object depend on the resultant force acting?*
2. *Can this relationship be expressed in a single equation?*

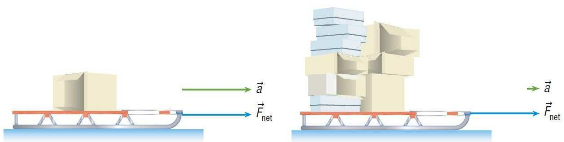
The Variables Involved in Newton's Second Law

Imagine pushing a large sled with a few small boxes on top across a nearly frictionless icy surface. In scenario (a) you push as hard as you can and the sled starts from rest and attains a high velocity in very little time. In scenario (b) you push with less force on the sled and the velocity increases more gradually. These two scenario imply that <u>*the acceleration increases as the net force increases*</u>*. In other words,* ***a*** α ***F****.*



The Variables Involved in Newton's Second Law

In scenario (c) you remove some of the boxes, push with a force and the lighter sled easily speeds up from rest. In scenario (d) you put more boxes on the sled and push with the same force. The heavier sled does not speed up at the same rate. These two scenario imply that <u>the acceleration decreases as the mass increases</u>. In other words, ***a α 1/m***.



(c) (d)

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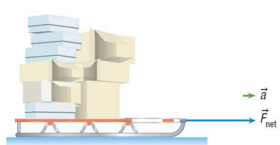
Newton's Second Law of Motion

Newton's ***second law of motion*** *is summarized as follows.*

If the net external force on an object is not zero, the object will accelerate in the direction of this net force. The magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass of the object.



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Newton's Second Law of Motion

From this we can derive an equation:

$$\because \quad \vec{a} \propto \vec{F}_{net} \quad \text{when m is constant and}$$

$$\because \quad \vec{a} \propto \frac{1}{m} \quad \text{when } \vec{F}_{net} \text{ is constant}$$

$$\therefore \quad \vec{a} \propto \frac{\vec{F}_{net}}{m}$$

and with some more math $\Rightarrow \vec{F}_{net} = m\vec{a}$

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Newton's Second Law of Motion

NEWTON'S SECOND LAW OF MOTION

$$\vec{F}_{net} = m\vec{a}$$

where F_{net} is the net force acting on the object (N)
m is the mass of the object (kg)
a is the acceleration of the object (m/s^2)

NOTE!

- $\mathbf{F_{net}}$ and **a** are always in the same direction.
- If $F_{net} = 0$ the object is experiencing uniform motion.
- If $F_{net} \neq 0$ the object is experiencing non-uniform motion.

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Newton's Second Law of Motion

PRACTICE

1. For each of the following, determine the net force and then state whether the object is experiencing uniform or non-uniform motion.
   (a) 5.0 N[N], 3.0 N[S]
   (b) 4.0 N[N], 2.0 N[E], 1.0 N[E], 1.0 N[S], 3.0 N[S], 3.0 N[W]
   (c) 2.0 N[E], 4.0 N[W]

   (a) F_{net} = 2.0 N[N] ☜ non-uniform motion
   (b) F_{net} = 0.0 N ☜ uniform motion
   (c) F_{net} = 2.0 N[W] ☜ non-uniform motion

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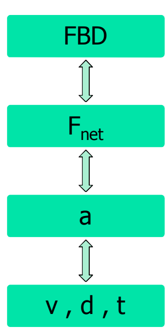
Newton's Second Law of Motion

NOTE!

When analyzing motion, the solution will typically require more than one step. For example, you might have information about the forces acting on an object which you would use to draw a FBD. You would then use the FBD to find the net force and subsequently the acceleration of the object. In the final step, you would use the acceleration to calculate other properties of the object's motion, such as velocity or displacement. Still, in other cases, you might need to analyze the motion of an object in order to find the acceleration which would then be used to calculate a force acting on the object.



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Newton's Second Law of Motion

PRACTICE

2. A worker applies a force of 360 N[E] on a trunk of mass 50 kg. Frictional resistance amounts to 340 N.
   (a) Draw a FBD of the situation.
   (b) What is the acceleration of the trunk?

   (b) $a = 0.40\ m/s^2$[E]

Newton's Second Law of Motion

PRACTICE

3. A boy pushes horizontally on a 10 kg wagon and the wagon accelerates along at 2.5 m/s^2. If frictional forces total 50 N, what force must he be exerting on it?

   F = 75 N[fwd]

Newton's Second Law of Motion

PRACTICE

4. An object with a mass of 15 kg rests on a frictionless horizontal plane and is acted upon by a horizontal force of 30 N. What will be its velocity after 10 s?

   $v_2 = 20$ m/s

Newton's Second Law of Motion

PRACTICE

5. A sports car, travelling at 28 m/s, applies it brakes and the car comes to a stop in 3.5 s. The mass of the car with the driver is 1.20 x 10^3 kg. What is the magnitude of the force of friction being applied by the brakes?

   F_f = 9600 N

✔ Check Your Learning

TEXTBOOK

P.136 Q.4-8

P.150 INV.3.3.1 (Investigating Newton's Second Law)

- Steps 1-9
- Analysis (a)-(i)
- $F_{net} = F_g = mg$

WIKI (FORCES)

✎.... 3U2 - WS#1 (2nd Law - Horizontal)