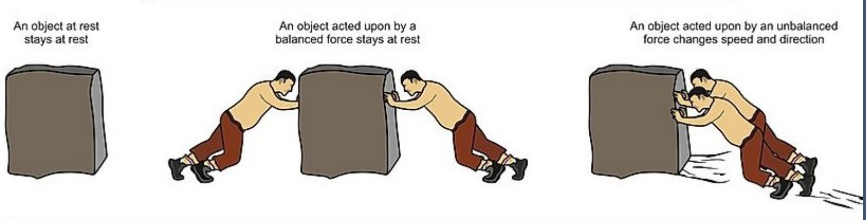
NEWTON'S FIRST LAW

Newton's First Law

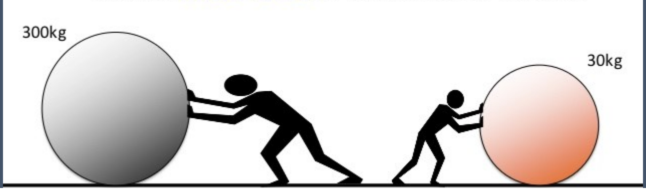
- An object in motion tends to stay in motion; an object at rest tends to stay at rest
- **An object with *no net force acting on it* remains at rest or moves with constant velocity**
- If an object is not moving, an unbalanced force is required to make it move
- If an object is moving, it will continue with a constant velocity unless an unbalanced force causes a **change**



NEWTON'S FIRST LAW (LAW OF INERTIA)

Inertia – is the resistance an object has to a change in its state of motion

- The amount of inertia an object has depends on its **mass**
  - Mass is the amount of material in a body (Kg)
  - Weight is a measure of the gravitational force on an object (N)


Objects with a **greater mass** have **more inertia**. It takes **more force** to change their motion.

NEWTON'S SECOND LAW (F = MA)

The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

*Σ **F** represents the vector **sum** of all external forces acting on the object, or the net force.*

$$\mathbf{a} = \sum \mathbf{F}/m$$

We usually rewrite this as: **Force = mass x acceleration**

$\sum F = ma$

Like any of our other vector equations, we can split this into equations for x- and y-components:

$$\sum F_x = ma_x$$

$$\sum F_y = ma_y$$

NEWTON'S LAWS: FIRST & SECOND

The key is to ask yourself: Does the object have acceleration?

If NO – the object is either at rest or moving with a constant velocity, so the forces on the object must be balanced (the net force on the object is zero).

If YES – the object has acceleration, and therefore the forces are unbalanced.

The direction of the net force is the same as the direction of acceleration.

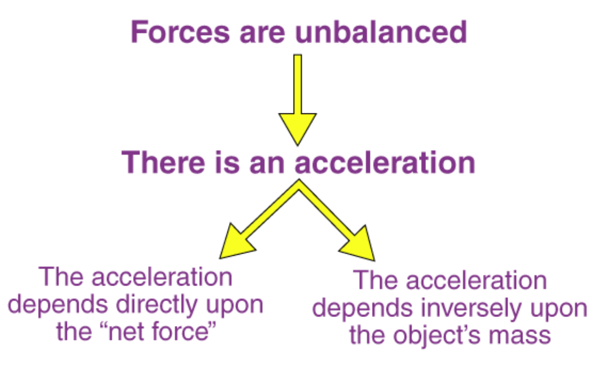
Do not make the mistake of asking yourself: Is the object moving?

NEWTON'S 2ND LAW

An object will only accelerate if there is an unbalanced force

- The acceleration of an object is directly proportional to the **net force** acting on the object and inversely proportional to the object's mass.

$$a = \frac{\sum F}{m}$$



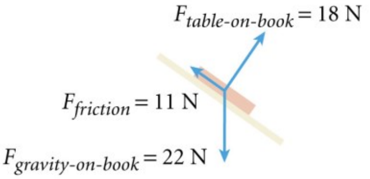
Forces are unbalanced

There is an acceleration

The acceleration depends directly upon the "net force"

The acceleration depends inversely upon the object's mass

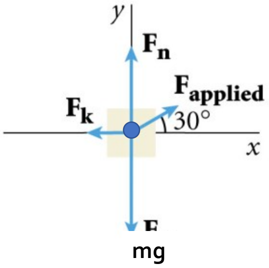
FREE BODY DIAGRAMS



Free-body diagrams – shows all the forces acting on a **single** object.

- Only shows the forces acting **on** the object. DO NOT INCLUDE COMPONENTS (F_{Ty} and F_{Tx})
- Choose a coordinate axis system, one that puts the most forces on the axis's
- The effect of a force depends on both **magnitude** and **direction.** Thus, force is a **vector** quantity
- Represented by arrows away from the object appropriate direction

DRAWING FBD



Steps to draw free-body diagrams

- Draw a "**super dot**" of the object
  - In same position – if on inclined plane, so should dot
- **Draw & label vector** arrows (not components)
  - Use Standard labels: F_T F_f F_N F_w etc
- Each force must be represented by a distant arrow, starting on and pointing away from the dot
    - You cannot draw one force vector on top of another one. Each force vector must also start on and point away from the dot.
- Make an attempt to indicate the relative of the force with the length of the vector

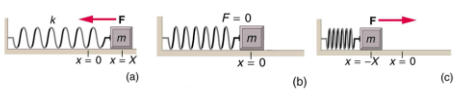
TYPES OF FORCES

Tension F_T:

- The force of a rope/string/etc. attached to an object and pulling on it.
- The tension in a rope pulls on the object(s) at both ends of the rope, in the direction of the rope.

Spring Force F_s:

- Similar to tension, but a spring can push or pull an object depending on how Spring is compressed or stretched from its original length (Δx)
- The direction of the force is always opposite the direction in the springs length has changed



TYPES OF FORCES

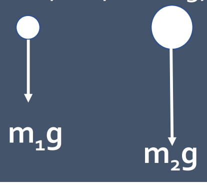
Normal Force F_N:

- Contact force that acts **perpendicular** (normal) to the surface
- Measures how firmly the objects are in contact with each other
- F_N =0 when surface NOT in contact with object

Normal forces are always directed perpendicular to the surface.

Force of Gravity F_w:

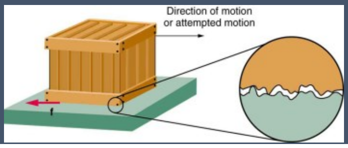
- Only Field Force – No physical contact between the object and Earth necessary
- Labels of G, g and "gravity" are NOT allowed for gravitational force, use Fw or mg
- If there are 2 distinct objects, must distinguish the gravitational force. (W1, W2, or m1g, m2g)



TYPES OF FORCES

Friction F_f:

- Contact force that opposes relative motion between two objects
- F_f always acts parallel to surface
- The amount of frictional force **depends on the normal force** and the microscopic properties of the objects



- If the problem refers to "negligible friction" or a "smooth surface" then there NO friction force
- **Friction is always less than or equal to Normal Force**

EXAMPLE 1

- A book is at rest on a table top. Diagram the forces acting on the book.
- In this diagram, there are normal and gravitational forces on the book
- Note: Vectors are same length
- Eqns: Sum of forces

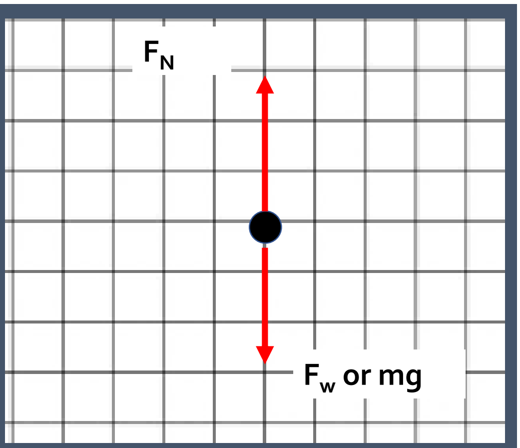
$\sum F_x = ma_x$

$\sum F_x = 0$

$\sum F_y = ma_y$

$\sum F_y = F_N - F_w = \cancelto{0}{ma}$

$F_N = F_w$

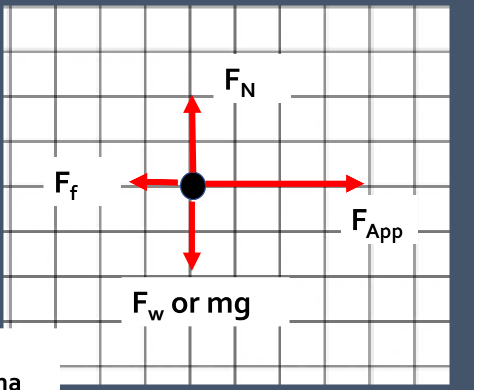


EXAMPLE 2

A rightward force is applied to a book in order to move it across a desk. Consider frictional forces. Neglect air resistance. Construct a free-body diagram.

- Note the larger applied force arrow pointing to the right since the book is accelerating to the right.
- Friction force opposes the direction of motion.
- The force due to gravity and normal forces are balanced.

Write the Eqns for the sum of forces



$\sum F_x = ma_x$

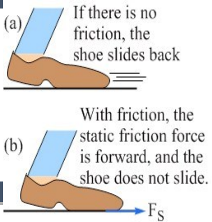
$\sum F_x = F_{app} - F_f = ma$

$\sum F_y = ma_y$

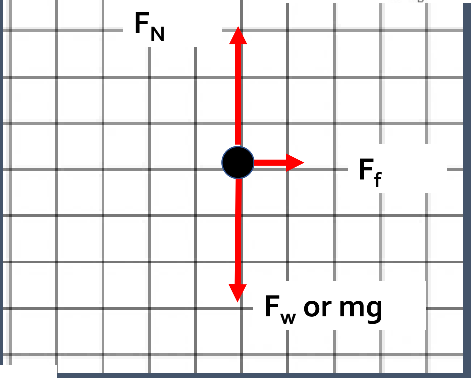
$\sum F_y = F_N - F_w = ma$

$F_N = F_w$

EXAMPLE 3



- Your shoe is in contact with the ground as you walk , the shoe does not slip on the ground.
- Because there is no relative motion between the shoe and the ground, the friction force is static friction F_f
- With friction ,the F_f is forward, and the shoe does not slide
- If there is no friction, the shoe would slide back. So F_{fs} opposes this motion (traction)



$\sum F_x = ma_x$

$\sum F_x = F_f = ma$

$\sum F_y = ma_y$
$\sum F_y = F_N - F_w = ma$
$F_N = F_w$

SAMPLE PROBLEM - COMPLEX

Determining Net Force

Derek leaves his physics book on top of a drafting table that is inclined at a 35° angle. The book has a force of 22N, the force of friction is 11N, and the normal force is 18N. Find the net force acting on the book.

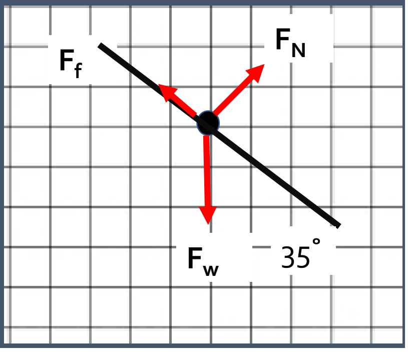
1. **Draw the free-body diagram and identify the variables.**

Given:

$F_{gravity} = F_w = 22$ N
$F_{friction} = F_f = 11$ N
$F_N = 18$ N

Unknown:

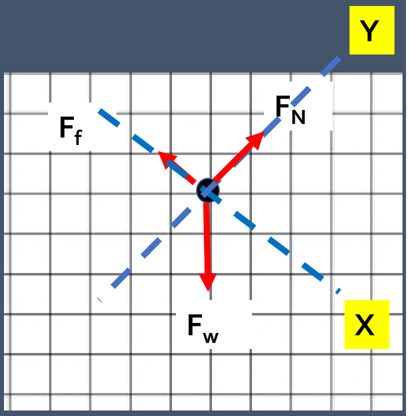
$F_{net} = ?$



SAMPLE PROBLEM (CONTINUED)

2**. Select a coordinate system & apply it to the free-body diagram.**

- Choose the *x*-axis parallel to and the *y*-axis perpendicular to the incline of the table
- This coordinate system is the most convenient
- only one force needs to be resolved into *x* and *y* components.



Tip: *To simplify the problem, always choose the coordinate system in which as many forces as possible lie on the x- and y-axes.*