DYNAMICS

Forces and Newton's Laws

What is a force?

Symbol: $\vec{F}$

Force is a vector; it has magnitude and direction

Unit of Force: Newtons (N)

Note: 1 N = $\frac{kg \times m}{s^2}$

To represent a force:

Types of Forces:

1) **Gravitational Force**

Symbol

Formula

G: gravitational constant $6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

m_1: one body's mass

m_2: other body's mass

r: distance between the 2 bodies

2) **Simplified Force of Gravity (aka weight)**

Symbol

Formula

3) Normal force

Symbol

4) Force of friction

Symbol

Formula

There are 2 types of friction:

Static Friction

Kinetic Friction

5) Tension

Symbol

6) Force in a spring

Symbol

Formula

7) Centripital Force

Symbol

Formula

8) Applied Force

Symbol

9) Net Force

Symbol

Free Body Diagrams

Free Body Diagrams (FBD) are used to show the forces acting on an object. You should always start a problem by drawing a FBD.

In a FBD, objects are represented by •

Arrows starting from this dot are used to show the forces acting on the objects

Examples: Draw the FBD for the situations below

1) A box rests on a table

2) A sign is supported by 2 vertical cables

3) A sign is supported by 2 angled cables

4) A box slides down a frictionless ramp

5) A box is resting on a spring

6) A girl is pushing a box along a rough floor

7) A car is turning a sharp corner (there is friction on the road)

Finding the net force

To find F_{net} we find the vector sum of all forces exerted on one object

Examples: find the net force for each situation below

1) A 2.0 kg brick gets detached from a wall of a building. The brick falls to the ground (ignore air resistance)

2) A car's engine provides 5500 N of force. Friction slows the car down with 2200 N. of force.

3) The engine of a 2000 kg rocket provides 85 700 N of force. Air resistance provides 12 400 N.

Equilibrium of Forces

A system is said to be in equilibrium when $F_{net} = 0$

When a system is in equilibrium,

- The object is not moving (at rest)
  OR
- The object is moving at a constant velocity.

When $F_{net} = 0$, it means that

- All forces pushing the object up are equal to all the forces pushing the object down
- All forces pushing the object left are equal to all forces pushing the object right
  i.e. the vector sum of all forces is zero.

  Knowing that a system is in equilibrium allows us to solve some problems

Examples

1) A 50 kg box rests on a table. What is the normal force applied by the table?

2) When you hang a 4.0 kg mass from a spring, the spring stretches by 10 cm. What is the spring constant of this spring?

3) A 45 kg box is being pushed along a rough floor. The coefficient of friction between the box and the floor is 0.20. What is the force of friction?

4) A 5.0 kg light fixture is suspended from the ceiling using a cable. What is the tension in the cable?

Newton's Laws

1st Law: Law of Inertia

When no net force acts on an object the object remains at rest or continues to move at a constant velocity.

Examples:

1) When you hit the brakes in a car, all objects that are not strapped down go flying forward. The objects continue moving forward at the same velocity because no net force is acting on them.

2) Ketchup in a glass bottle

2nd Law: Law of Acceleration

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

$$F_{net} = ma$$

1) A 2.0 kg rock falls from the edge of a cliff. Air resistance exerts 12 N. What is the acceleration of the rock?

2) A 70.0 kg box is pushed along a rough surface with a force of 452 N. The box accelerates at a rate of 0.500 m/s^2. What is the force of friction acting on the box?

3rd Law: Action- Reaction

For every force applied to an object the object applies a force of equal magnitude but opposite direction.

Examples:

1) You push the wall with 50 N; the wall pushed you back with 50N

2) Jet engines

Solving problems using Newton's Second Law

Basic idea:

There are 2 ways of finding the net force

- $F_{net} = ma$
- F_{net} = the vector sum of all forces

So to solve problems

- Find F_{net} using both methods (you may get a number or an algebraic expression)
- Make both F_{net}'s equal to each other
- Solve for what you are looking for

Examples:

1) A boy pushed a 10 kg box along a rough surface. He applies a force of 125 N. The coefficient of friction between the floor and the box is 0.4. What is the acceleration of the box?

2) A 2500 kg car's engine provides a force of 8500 N. The car accelerates at a rate of 2.6 m/s^2. What is the magnitude of force that slows down the car (air resistance combined with friction between parts)?

Some classics

Rocket problems

- Don't forget that gravity is involved
- Acceleration and velocity don't always have to be in the same direction.

1) A 4.00 kg toy rocket is being propelled by its engine using a force of 50.0 N. What is the acceleration of the rocket?

2) The engine of a rocket applies a force of 3.0×10^3 N. As a result the rocket experiences an upward acceleration of 5.2 m/s^2. What is the mass of the rocket?

Elevator Problems (standing on a scale in the elevator of course)

- When the elevator has an upward acceleration

- When the elevator has a downward acceleration

- We use F_N as the force shown by the scale (assuming it is in Newtons)

3) As she often does Carrie is standing on a scale in an elevator. Carrie has a mass of 62 kg. The elevator has an upward acceleration of 1.5 m/s^2. What is Carrie's weight, according to the scale (which is in Newton's)?

4) Tony who has a mass of 75 kg also likes to stand on scales in elevators. The elevator is moving and he sees that scale indicated 585 N. What is the acceleration of the elevator ? (don't forget to specify the direction).

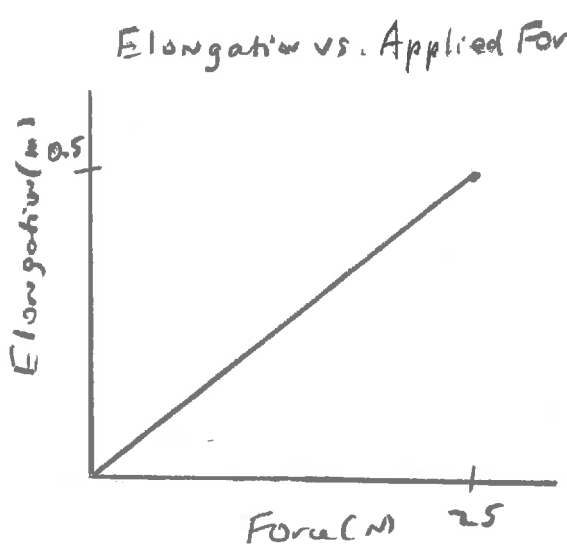
Using a graph to determine a coefficient

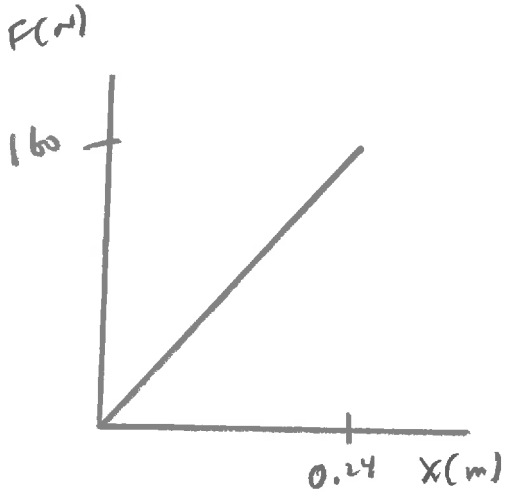
Sometimes we get graphs that allow us to determine either the coefficient of friction or the spring constant

We find the rate of change (slope) or the inverse of the slope to determine the value of the coefficient of friction or the spring constant.

Example:

Find the spring constant for each spring below





What now?

We will now look at situations where forces are being applied in various directions (not just parallel and perpendicular to the motion).

We will look at horizontal and vertical forces separately.

We will split forces into components that are either

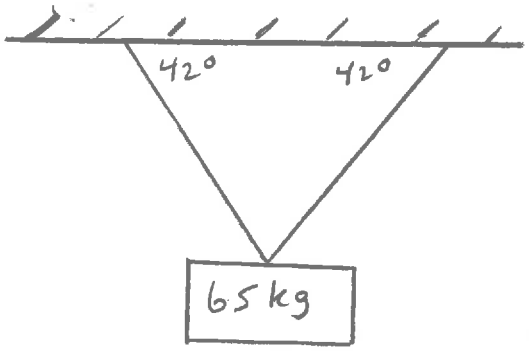
- Parallel to motion
- Perpendicular to motion

Note: when an object is rest $F_{net} = 0$ horizontally and vertically.

Case 1: hanging objects and tension

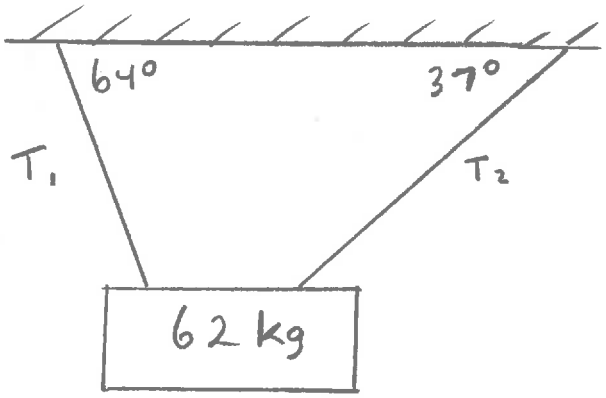
Symmetrical Situations

Example: a sign is supported by 2 strings, as illustrated below. What is the tension in the springs?



Non-symmetrical situations:

Example: a sign is supported by 2 strings as illustrated below. What is the tension in each string?



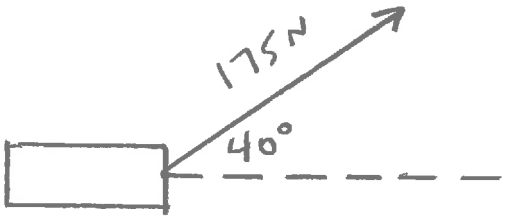
Case 2: pulling at an angle

An object is being pulled or pushed, but the force is being applied at an angle.

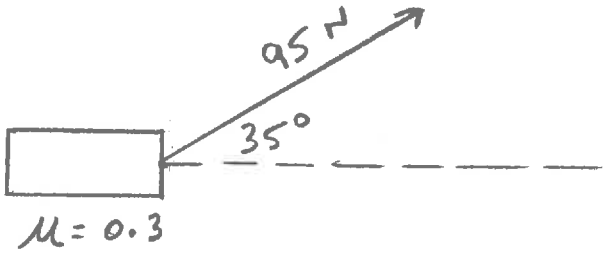
Look at the horizontal (usually parallel to motion) and vertical (usually perpendicular to motion) components separately.

Remember in this case, $F_N \neq F_g$

Example 1: a 25 kg sled is being pulled with a force of 175 N at an angle of 40° to the horizontal. What is the acceleration of the sled?



Example 2: a 15 kg sled is being pulled with a force of 95 N at an angle of 35° to the horizontal. What is the acceleration of the sled?



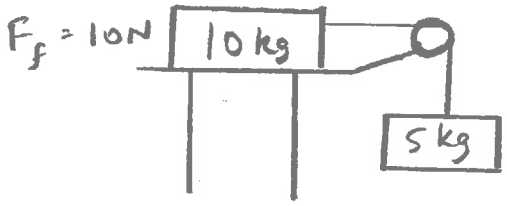
Case 3: mass hanging off edge of table

Remember:

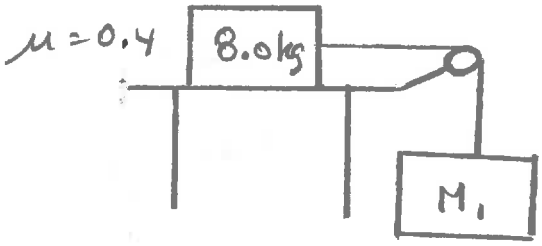
- Both masses (or more) accelerate together because they are tied together.
- We added the masses to find the acceleration of the system.

Examples:

1. A 10 kg mass is tied to a 5 kg mass, as illustrated below. Friction exerts a force of 10 N. What is the acceleration of the 10 kg mass?



2. The system below accelerates at 1.6 m/s^2. The coefficient of kinetic friction between the table and the 8.0 kg box is 0.4. What is the mass of M_1?



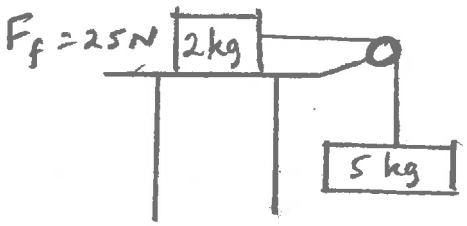
Tension in between

To find the tension in the string that connects two objects together

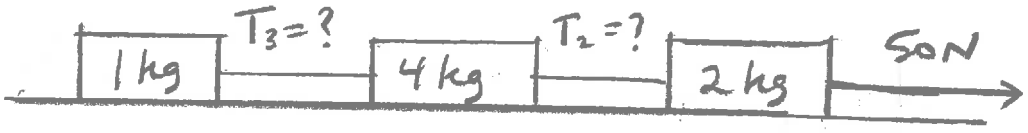
- First we find the acceleration of the system
- Then we isolate one of the masses and apply Newton's second law

Examples:

3. Consider the system below. What is the tension in the string?



4. A series of masses are pulled along a frictionless surface, using a force of 50 N. What is the tension in strings 2 and 3?



Case 4: inclined plane

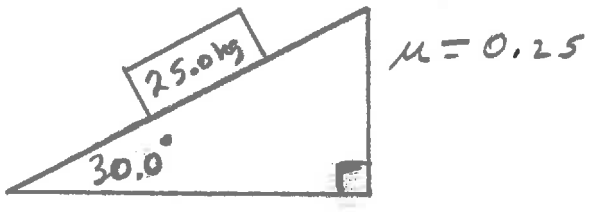
When dealing with an inclined plane, we will call

- Direction parallel to motion x
- Direction perpendicular to motion y

Note when splitting F_g remember that it is always the hypotenuse

Examples:

1. What is the acceleration of the block down the incline?



2. A girl pushes a 50.0 kg box up a ramp set at 25°. Friction exerts a force of 75 N. What is the magnitude of the force she must apply in order to slide the box at a constant velocity?