

Free Body Diagrams

- What is a Free Body Diagram
- Demonstrations
- Static Equilibrium
- Unbalanced Forces
- Apparent Weight

Free Body Diagrams

- This is where the physics gets done, the rest is just algebra and calculus
- An important tool for understanding motion
- The following steps will help you get it right every time

Identifying forces

- **Identify “the system” and “the environment.”** The system is the object whose motion you wish to study; the environment is everything else.
- **Draw a picture of the situation.** Show the object—the system—and everything in the environment that touches the system. Ropes, springs, and surfaces are all parts of the environment.
- **Draw a closed curve around the system.** Only the object is inside the curve; everything else is outside.
- **Locate every point on the boundary of this curve where the environment touches the system.** These are the points where the environment exerts *contact forces* on the object.
- **Name and label each contact force acting on the object.** There is at least one force at each point of contact; there may be more than one. When necessary, use subscripts to distinguish forces of the same type.
- **Name and label each long-range force acting on the object.**

Drawing a free-body diagram

- **Draw a coordinate system.** Use the axes defined in your pictorial representation. If those axes are tilted, for motion along an incline, then the axes of the free-body diagram should be similarly tilted.
- **Represent the object as a dot at the origin of the coordinate axes.** This is the particle model.
- **Draw vectors representing each of the identified forces.** Be sure to label each force vector.
- **Draw and label the *net force* vector** Draw this vector beside the diagram, not on the particle. Then check that it points in the same direction as the acceleration vector on your motion diagram.

Demo

Draw the free body diagram of an object resting on a table which is tilted.

Demo

Draw the free body diagram for a bouncing ball:

1. At the very top of its path
2. At the very bottom of its path

Demo

Draw the free body diagram for a ball on a loop-the-loop:

1. At the top of the loop-the-loop
2. At the bottom of the loop-the-loop

Demo

Draw the free body diagram for a mass that is being lifted by:

1. One string
2. Two strings
3. One string which goes through a pulley that is connected to the top of the mass

Quick Quiz

A person is sitting on a swing. The rope that holds the swing up goes over a pulley that is attached to a tree. The other end of the rope is pulled so that the person sitting on the swing is lifted upward.

Does the tension in the rope increase, decrease, or stay the same if the person sitting on the swing pulls herself up?

- A) Increases
- B) Decreases
- C) Stays the Same



Demo

Draw the free body diagram for the water in the spinning pail when:

- it is as low as it goes
- it is above my head

Demo

Draw the free body diagram for the ball bearing when it:

- is in the middle of the loop
- has just gotten to the missing part of the loop

Demo

A piece of wood is balanced, and is free to rotate on top of a piece of curved glass. Draw the free body diagram for the wood when I exert a tangential force on one of its ends.

Static Equilibrium

$$\sum \vec{F} = m\vec{a} = 0$$

- This is the simple case where the acceleration of an object is exactly zero
- In such a situation, an object is said to be in equilibrium
- If the object is not moving, and has no acceleration, it is said to be in static equilibrium
- Since there is no physical difference between being at rest, and moving at a constant velocity, a moving object can be in static equilibrium

Quick Quiz:

Which of the following situations describe objects in static equilibrium?

- (A) An air conditioning unit is lifted at constant speed by a crane
- (B) A jet plane once it has reached cruising speed and altitude
- (C) A penny dropped off of the top of a building
- (D) both A and B
- (E) both A, B and possibly C

Quick Quiz:

If you know all of the forces acting on a moving object, can you tell which direction the object is moving?

- A) Yes
- B) No

Quick Quiz:

Draw the free body diagram for an 2.5 kg object on a table which is tilted at 30 degrees to the horizontal.

What is the magnitude of the force of friction if the object is in static equilibrium?

(A) 12.5 N

(B) 22.5 N

(C) 25 N

(D) You need more information about the surfaces

Non-Equilibrium

$$\sum \vec{F} = m\vec{a} \neq 0$$

- An object acted on by unbalanced forces will accelerate
- Newton's second law allows us to predict this acceleration

Quick Quiz:

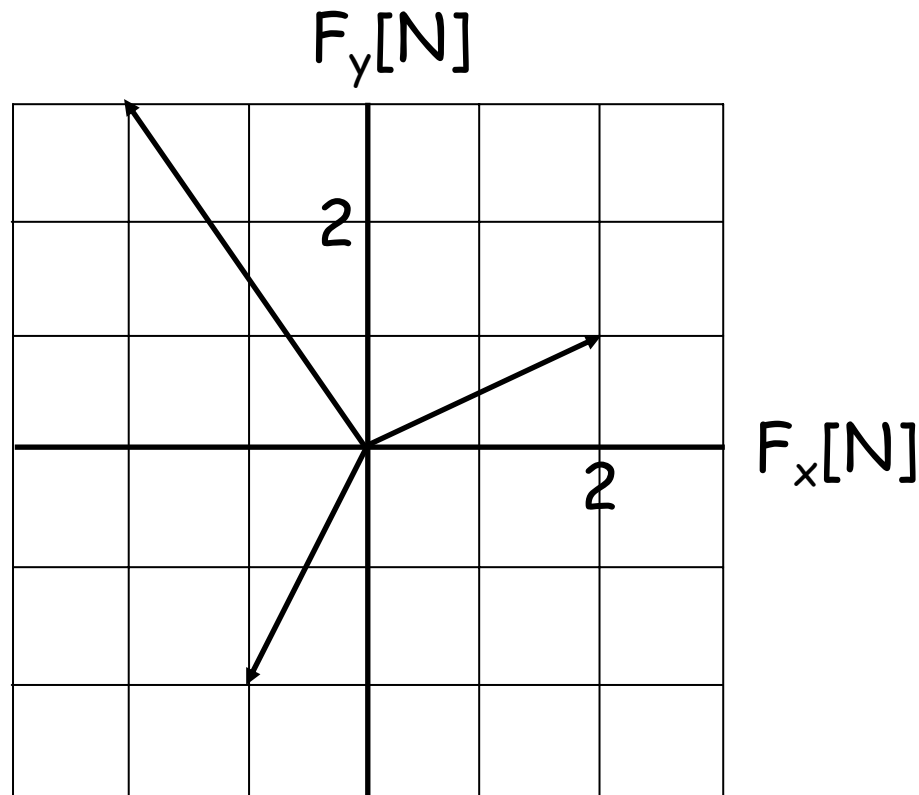
Draw the free body diagram for an 2.5 kg object on a table which is tilted at 30 degrees to the horizontal.

If the force of friction on the object is 10 N, what is the magnitude of the acceleration for the object?

- (A) 0 m/s^2
- (B) 1 m/s^2
- (C) 2 m/s^2
- (D) 3 m/s^2

Example:

The free-body diagram below shows three forces acting on an 10 kg object. Calculate the x and y components of its acceleration.



Quick Quiz:

The 10 kg object is acted on by the following forces:

$$\vec{F}_1 = 3\hat{i} + 2\hat{j}$$

$$\vec{F}_2 = -2\hat{i} + 2\hat{j}$$

$$\vec{F}_3 = 1\hat{i} - 5\hat{j}$$

What is the magnitude of this object's acceleration?

- (A) 1.08 m/s²
- (B) 0.76 m/s²
- (C) 0.3 m/s²
- (D) 0.22 m/s²
- (E) 0.1 m/s²

Weight versus Apparent Weight

- Weight is just the force due to gravity on an object
- Apparent weight is the weight that is measured by a contact force (such as a spring force in a bathroom scale)
- Your weight changes when you change your mass, or your planet
- Your apparent weight changes whenever the contact force between you and the measuring device changes

Quick Quiz:

An astronaut of mass 100 kg is accelerated upwards at 50 m/s^2 . What is the astronaut's weight during this ascent?

- A) 1000 N
- B) 2000 N
- C) 4000 N
- D) 5000 N
- E) 6000 N

Example:

If the astronaut were to stand on a bathroom scale during the ascent, such that the normal force exerted by the scale on the astronaut pointed in the same direction as the astronaut's acceleration, how many kg would the bathroom scale read?