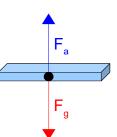# Lesson 21: Free Body Diagrams

We will need a way to organize forces that are acting on a particular object. The easiest way to do this is by using a **free body diagram**.

- A free body diagram is just a *simple* sketch of the object showing all the forces that are acting on it.
- To draw a proper free body diagram, you must follow these steps:
    1. Draw a quick **sketch** of the object. Often a simple box will do.
    2. Place a **dot** in the centre of the object. We basically treat this as the spot that all the forces are thought to act upon.
    3. For every force acting on *that* object (we don't care about forces acting on any other objects), draw a **vector** that shows the size and direction of the force. Each vector must start from the dot and point outwards.
    4. **Label** each vector based on the type of force it is. *Do **not** include numbers or calculations!*

Example 1: **Sketch** a free body diagram for a book being held up by a person.

We draw a quick sketch of the book, and then put a dot in the centre.

Next, we identify that there are two forces acting on this book; the force of gravity pulling it down, and the applied force of a person pushing it up. Since the book is just being held up (not accelerating up or down), we can assume that the two forces are equal, so we will draw the vectors the same size.

F_a

F_g

Drawing 1: Free body diagram of forces on a book.

Free body diagrams must show a wide variety of forces acting on an object.
- These are the common forces acting on objects that you need to memorize:

F_g = force due to gravity
F_a = applied force
F_f = force due to friction
F_T = force of tension
F_N = normal force
$\mathbf{F_{NET}}$ = **net force** *Not drawn on free body diagrams*
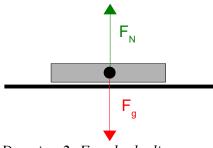
Warning!
It is critical that you label the forces on your diagrams using exactly the symbols shown here. The use of capitals and lower case letters does matter!

Any of the forces listed here that have not been mentioned yet will be discussed in detail as they are introduced in the following examples.

Example 2: **Sketch** a free body diagram of a laptop sitting on a table.
- We know that there will be a force due to gravity (F_g) pulling the laptop down, but if that was the only force it should be dropping down towards the ground.
- There must be a force acting against the force of gravity that is holding the laptop up. This is happening because the table top is strong enough to hold up the laptop.
    - We call this upwards force the **normal force**

F_N

F_g

Drawing 2: Free body diagram for example 2.
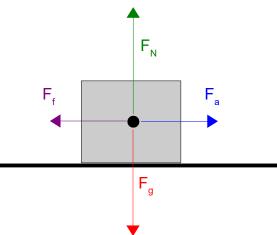
(F_N). *A normal force is exerted upwards by a surface (like a table or a floor) and is **perpendicular** to the surface.*

- As long as the object is not breaking through the table top or flying up into the air, the force due to gravity and the normal force must be equal. That way they just cancel out and the object stays where it is.

Example 3: You are trying to push a heavy box across the floor. It's causing you some trouble because the floor is not very smooth. **Sketch** a free body diagram of the box.

- We still have force due to gravity and normal force, since it is still an object on a surface.
- You are trying to push it sideways, so that will be an applied force that you are exerting.
- It's tough to push because of friction between the box and the floor, so we'll also need to draw a force due to friction.
    - **Force due to friction** (F_f) *always opposes the motion of an object. It is parallel to the surface the object is on.*
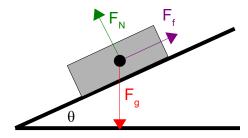- Notice the normal force and force due to gravity are still equal. The applied force and force due to friction are also equal to each other. This would mean that the object is moving at a constant velocity which includes not moving at all $v = 0$ m/s (more on this in later sections).

Drawing 3: Free body diagram for example 3.

Example 4: You are riding a toboggan down a sloped hill. Sketch the free body diagram of the toboggan.

We will have a situation similar to the one above, except that it is on a slope and there is no applied force (you don't usually push yourself down a hill on a toboggan).
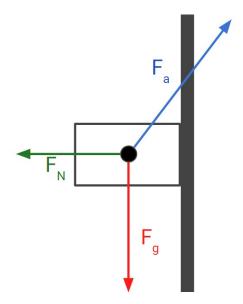
Drawing 4: Free body diagram for example 4.

Notice that...
- F_g still points straight down.
- F_N points upwards at an angle, since it has to be perpendicular to the surface of the slope.
- F_f points back up the hill, since friction will try to slow down the sled.

Example 5: Watch the video of a SWAT team member going up the side of a wall using only a pole held by people on the ground. When they get the person part ways up the wall, let's imagine he stops for a moment in one spot and we **sketch** the free body diagram of the person.
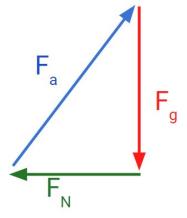
We would build a free body diagram following all the regular rules, with the following forces...
- There must be a force of gravity (F_g) acting on the person, since that's why they could still fall!
- There is a normal force (F_N) pushing perpendicular to the wall.
- There is an applied force (F_a) coming from the pole pushing on the person.

We should also consider what would happen if we followed our vector rules by taking these vectors and touching them head-to-tail. Notice that *all* the vectors touch head-to-tail.
- There is no resultant in this diagram.
- Instead, we would say that the forces are in **equilibrium**.
  - Since we would start and finish at the same spot after tracing around the diagram, these forces all cancel each other out.
  - This is an important concept in the next section on **Net Force**.

Homework

p.131 #1,2