Types of Forces

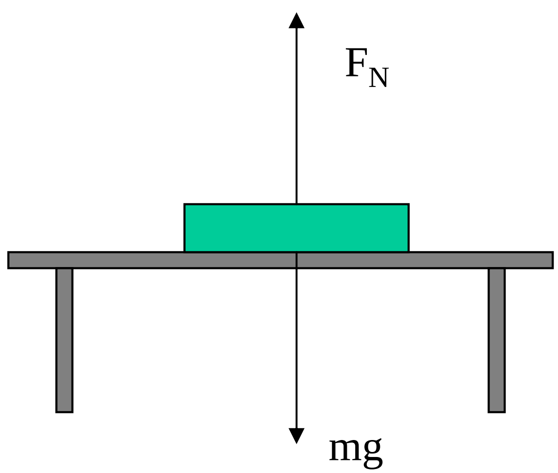
1. Force of Gravity:

This is often referred to as the weight of an object. It is the attractive force of the earth. And is always directed toward the center of the earth. It has a magnitude equal to the mass of the object times the acceleration due to gravity, or mg.

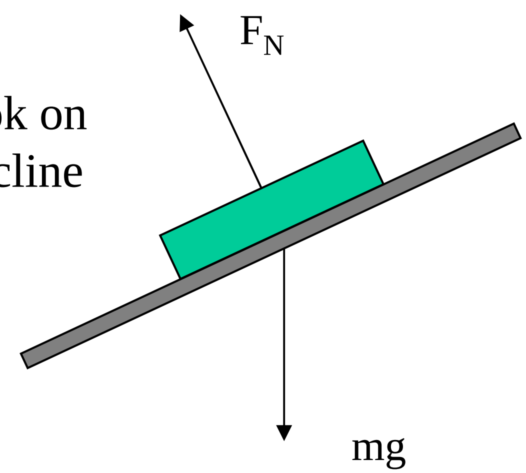
2. Normal Force:

When an object rests on another surface (which could be another object in a problem), the surface exerts a force on the object which is perpendicular (or normal) to the surface of contact.

Example: Book on table



Example: Book on smooth incline



Types of Forces

3. Friction Force:

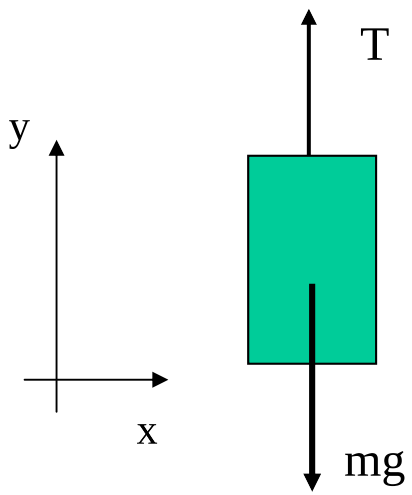
When an object slides over a surface, there is usually some resistance to this sliding. This is due to a friction force, and is always directed opposite the intended direction of motion along the surface. The size of this force is dependent on the particular object and surface - for example, it is harder to push a hockey puck along an asphalt driveway than it is along an ice rink. Often, we will refer to some surfaces as **smooth,** and in this case we will assume that the friction force (which is really always present) is small enough that we can ignore it altogether.

4. Tension force:

This is the force exerted by a rope, cable, or string, when it is attached to an object and pulled taut. It is directed away from the object and along the rope at the point of attachment. We will assume (unless otherwise stated) that the ropes are massless and unstretchable. Ropes and cables are sometimes used in conjunction with pulleys, which we will assume (unless otherwise stated) are massless and frictionless. In this case the pulley does not change the magnitude of the tension in the rope, it just changes its direction.

Example: (Ch 5, Prob 43) An elevator of mass 1.60×10^3 N moving downward at 12.0m/s is brought to rest with constant acceleration in a distance of 42.0m. Find the tension in the supporting cable during this time.

I) Draw a picture of the object, showing the forces which are acting on it:



Cable exerts a tension T on the elevator.

Gravity exerts a force equal to mg on the elevator.

II) Now apply Newton's 2nd Law to the elevator:

$$\sum F = ma$$
$$T - mg = ma$$
$$T = mg + ma$$
$$T = m(g + a)$$

But what is a?

Example: (Ch 5, Prob 43) Continued.

To find the acceleration of the cable, we can treat the motion of the elevator as motion under constant acceleration. We know the initial velocity of the elevator, its final velocity (zero), and its initial and final position.

$$
\begin{aligned}
y_0 &= 0 \\
y &= -42.0\text{m} \\
v_{y0} &= -12.0\text{m/s} \\
v_y &= 0 \\
a_y &= ? \\
t &= ?
\end{aligned}
$$

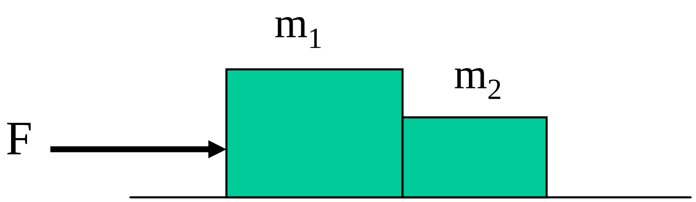
$$
\begin{aligned}
v_y^2 &= v_{y0}^2 + 2a_y(y - y_0) \\
0 &= 144 + 2a_y(-42 - 0) \\
a_y &= \frac{144}{82} = +1.71\text{m/s}^2
\end{aligned}
$$

Why is the acceleration +?

Now substitute this value of a back into the earlier equation to find T:

$$
\begin{aligned}
T &= mg + ma \\
T &= 1600(9.80 + 1.71) \\
T &= 18416\text{N} \\
T &= 18.4 \times 10^3\,\text{N}
\end{aligned}
$$

Example: Two blocks lie in contact on a frictionless table as shown below.
A force F=3.2N is applied to one of the blocks.
What is the normal force between the two blocks?



$m_1 = 2.3\text{kg}$

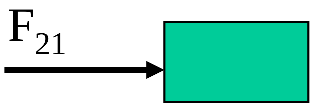
$m_2 = 1.2\text{kg}$

I) Draw the forces which act on each block.

Block #1:

F_{21} is the normal force (or contact force) of block 2 on block 1.

Block #2:



F_{21} is the normal force (or contact force) of block 1 on block 2. It is the Newton's 3rd Law equal and opposite force of the normal force of block 2 on block 1.

Example: Two blocks continued

II) Now apply Newton's 2nd Law to each block:

Block #1:

$$\sum_{\text{block 1}} F = m_1 a$$

$$F - F_{21} = m_1 a$$

Block #2:

$$\sum_{\text{block 2}} F = m_2 a$$

$$+F_{21} = m_2 a$$

substitute

NOTE: The acceleration of block 2 is equal to the acceleration of block 1.

$$F - F_{21} = m_1 a$$
$$F - m_2 a = m_1 a$$
$$F = (m_1 + m_2) a$$
$$a = \frac{F}{m_1 + m_2}$$
$$a = \frac{3.2\text{N}}{3.5\text{kg}} = 0.91\text{m/s}^2$$

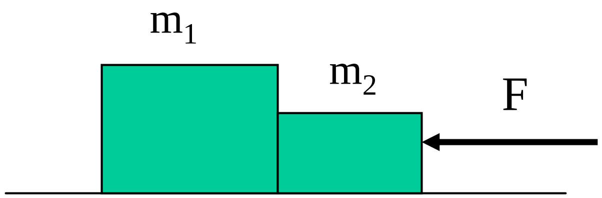
and then $F_{21} = m_2 a = 1.1\text{N}$

Example (Continued):

What is the interpretation of the force F_{21}?

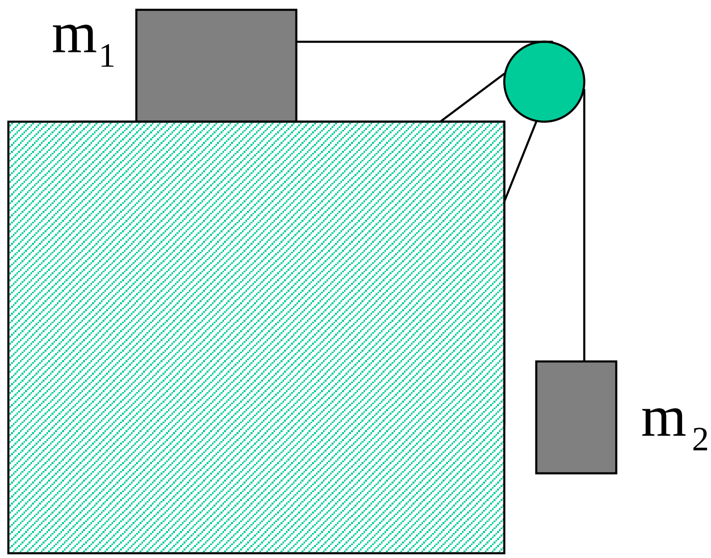
This is the force needed to accelerate block m_2 at $0.91 m/s^2$.

What happens to the force F_{21} if the force F is applied instead to block 1?



- Will the acceleration be the same?
- What about the interpretation of the force F_{21}?

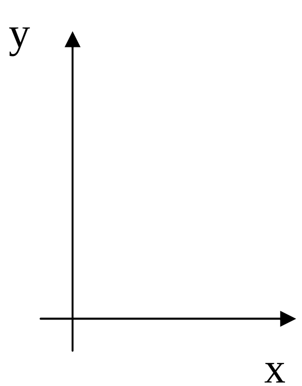
Example: Two blocks are connected by a string. Block 1 is on a frictionless surface, while block 2 hangs freely. The string passes over a massless frictionless pulley. Find the acceleration of block 1, the acceleration of block 2, and the tension in the string.



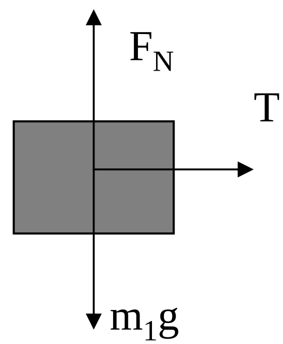
$m_1 = 3.3\text{kg}$

$m_2 = 2.1\text{kg}$

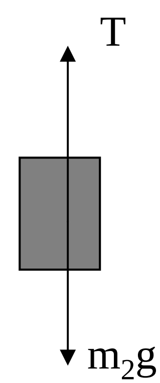
1) Draw the forces on the two blocks



Block 1:



Block 2:



Example (Continued):

2) Apply Newton's 2nd Law, separately, to both blocks:

$$\sum_{\text{block 1}} \vec{F} = m_1 \vec{a}_1$$

$$\sum F_x = m_1 a_{1x}$$

$$+T = m_1 a_{1x}$$

$$\sum F_y = m_1 a_y = 0$$

$$F_N - mg = 0$$

$$F_N = mg$$

$$\sum_{\text{block 2}} \vec{F} = m_2 \vec{a}_2$$

$$\sum F_y = m_2 a_{2y}$$

$$T - m_2 g = m_2 a_{2y}$$

Example (Continued):

3) IMPORTANT: Since the string does not stretch, the magnitude of the accelerations of the two blocks are the same!

We defined to the right as positive x and upward as positive y.

If block 1 accelerates to the right, then block 2 must accelerate downward, so the accelerations must have opposite sign (even though they have the same magnitude).

Call this common acceleration a:

$$a = a_{1x} = -a_{2y}$$

Put this “a” into the equations for the two blocks:

$$\sum F_x = m_1 a_{1x}$$

$$+T = m_1 a_{1x}$$

$$T = m_1 a$$

$$\sum F_y = m_2 a_{2y}$$

$$T - m_2 g = m_2 a_{2y}$$

$$T - m_2 g = -m_2 a$$

Example (Continued):

4) Now substitute: $T = m_1 a$ into: $T - m_2 g = -m_2 a$

$$T - m_2 g = -m_2 a$$
$$m_1 a - m_2 g = -m_2 a$$
$$m_1 a + m_2 a = m_2 g$$
$$a = \frac{m_2 g}{m_1 + m_2} = \frac{(2.1)(9.80)}{3.3 + 2.1} = 3.8\text{m/s}^2$$

$$T = m_1 a$$
$$T = (3.3)(3.8)$$
$$T = 13\text{N}$$

5) Checks of answer:

$$a = \frac{m_2 g}{m_1 + m_2}$$

If $m_2 >>> m_1$ then $a \approx \frac{m_2 g}{m_2} = g = 9.80\text{m/s}^2$

If $m_1 >>> m_2$ then $a \approx 0$