Friction

Suppose a crate has a mass of 100kg and you push on it with a force of 900N as it slides. You then measure the resulting acceleration and find it is only $4 m/s^2$. But you know that if your push was the only horizontal force, then the acceleration should be $9 m/s^2$ using $F = m \cdot a$. So there must be some other horizontal force and this is most likely kinetic friction.

It is called *kinetic* friction because the two surfaces involved (the floor and crate) are moving relative to each other.

From the mass and acceleration, the net force must be 400N and you know that you are pushing with a force of 900N. So the force of kinetic friction must be -500N.

Answer Webassign Question 1

It is found experimentally that in many situations, kinetic friction follows the equation: $F_{kf} = \pm\mu_k \cdot F_N$ where

F_{kf} is the force of kinetic friction
μ_k is the coefficient of kinetic friction
F_N is the normal force between the two sliding surfaces

Here, the Earth pulls down on the crate with a force of -980N, so the floor pushes back up with a normal force of +980N. Putting that into the equation above, the coefficient of kinetic friction can be solved-for:

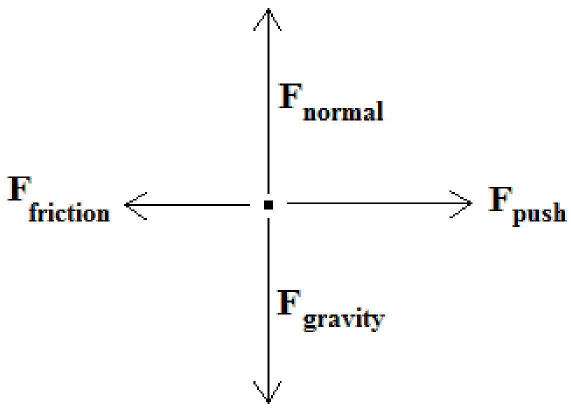
$-500N = -(\mu_k)(980N)$ or $\mu_k = 0.51$

The coefficient is a unitless value that essentially indicates how difficult it is to slide two surfaces relative to each other. The ± sign in the equation accounts for the fact that the force of kinetic friction could be left or right, depending upon which way you are pushing the crate.

Answer Webassign Question 2

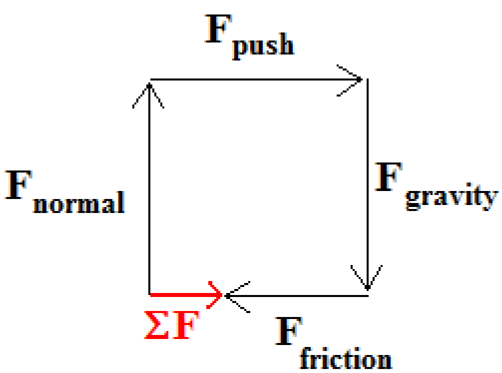
Answer Webassign Question 3

We can draw what is known as a *free body diagram* for the crate. This is a diagram where an object has been extracted from its environment and all forces *on* the object are drawn as vectors. The object itself is often collapsed to a single point. For the crate, it would look like this:



Again, the only forces in the diagram are forces *on* the object. While it's true, by Newton's third law, that there is a force vector of the crate pushing on the person, this vector would belong in the free body diagram of the person.

Also, because force is a vector concept, we can add all of these vectors tail-to-tip to find the net force vector:



You can see the net force is to the right, matching the acceleration.

Now suppose the crate is stationary and you push on it with a force of 100N and it doesn't move. You push with 200N and it doesn't move. You push harder and harder until it finally begins to accelerate when you push with a force greater than 700N.

When you pushed with a force of 100N and the crate was stationary, there must have been a force of -100N coming from somewhere and it is again coming from friction, but this is known as static friction, *static* because when the crate is stationary, the two surfaces of crate and floor are not moving relative to each other.

This situation would be written with the equation: $| F_{sf} | \leq 700N$. What this means is that static friction can apply a magnitude of force up to 700N, but no more. Once more than that is required, static friction fails and the two surfaces slide relative to each other.

More generally, it is often found that this force of static friction also depends upon a coefficient and the normal force. So, this is written as $| F_{sf} | \leq \mu_s \cdot F_N$ where

$| F_{sf} |$ is the magnitude of static friction, again the force itself could be positive or negative depending upon which way the crate is pushed
μ_s is the coefficient of static friction
F_N is the normal force between the two non-sliding surfaces

Generally speaking, the coefficient of static friction between two surfaces is greater than the coefficient of kinetic friction, meaning it is more difficult to begin something sliding than to keep it sliding.

When solving problems with static friction, you often replace the left-hand side of the equation with whatever force is attempting to make the surfaces slide relative to each other. For instance, if the question was, "What coefficient is necessary to keep a strongman from being able to move a 1200kg car with the brakes locked, assuming they can push with a maximum force of 10,000N?", the set-up would be:

$10{,}000N \leq (\mu_s)(11{,}760N)$ if the car is not sliding

Answer Webassign Question 4

The other possibility is the force of static friction actually causing acceleration. This may sound paradoxical, but it works in a situation like this: Suppose a 10kg crate is in the flatbed of a pick-up truck and the coefficient of static friction between the flatbed and crate is 0.5. How fast can the pick-up truck accelerate from a green light without the crate sliding off the back? Actually, it just seems as if it's sliding off the back; what's really happening is that the truck is accelerating out from underneath the crate.

Here, the force of static friction is actually *causing* the acceleration. If the truck begins to accelerate, the crate will go with it and only because of the force of friction. But, even though the crate is moving, it is not kinetic friction because the crate and flatbed surface are not moving relative to each other.

So here, because static friction is causing the acceleration, the left hand side is replaced with this responsibility, which, by Newton's second law equals $m \cdot a$.

$(10kg)(a) \leq (0.5)(98N)$ if the crate is not slipping

Solving for a yields a maximum acceleration of $4.9 m/s^2$ for the truck.

Answer Webassign Question 5