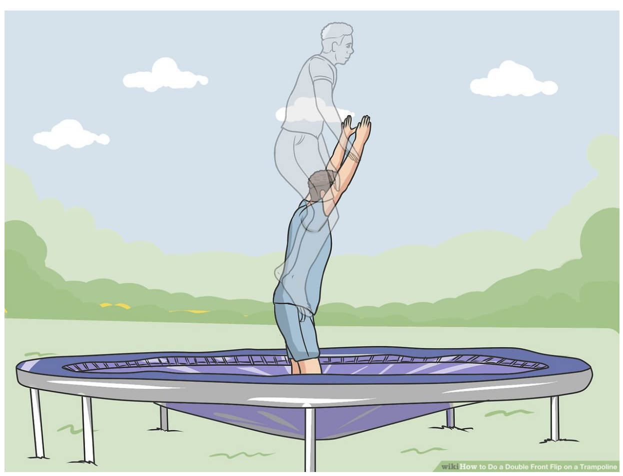
NORMAL FORCE.

NOVEMBER 19, 2023

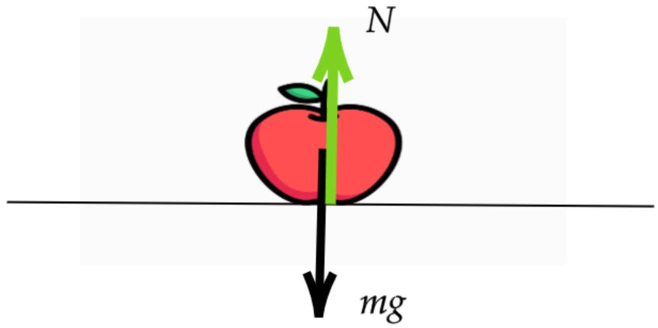
Theory recap

Today we discussed another example of force - normal force. When you stand on the floor gravity pulls you down but you don't fall through the floor. What does not let you fall? Of course it is the floor, you can feel that it pushes you feet up supporting the whole weight of your body.

Where does this force come from? To understand this, let us take a look at a trampoline. When you stand on a trampoline, it bends under your weight in order to support it. The force with which the trampoline acts on you is due to its elastic properties. Now if you imagine trampoline being stiffer, it will bend less. You can think of a trampoline so stiff, that with a naked eye you can not see its deformation under your weight. But you know it is still there - elastic forces are supporting your weight even if you don't see the deformation.



For the floor the situation is the same as for a very stiff trampoline. Floor bends very slightly under your weight and the resulting elastic force supports your weight and does not let you fall through the floor. For the same reason an apple doesn't fall through a plate, the plate does not fall through a table, the table does not fall through the floor and a house does not fall through the ground. In all these cases the normal force counteracts against gravity force and as a result an object rests.



The fact that normal force plays against gravity allows us to calculate it in many situations. Assume an apple of mass m rests on a table. There are two forces acting on the apple - gravitational force(weight) $W = mg$ and normal force from the table N. Since the apple is at rest, its' acceleration is zero. So net force must be zero. Gravitational force is directed down while normal force is directed up. Thus to find the net force down we subtract normal force from gravitational force and find

$$mg - N = 0 \;\Rightarrow\; N = mg$$

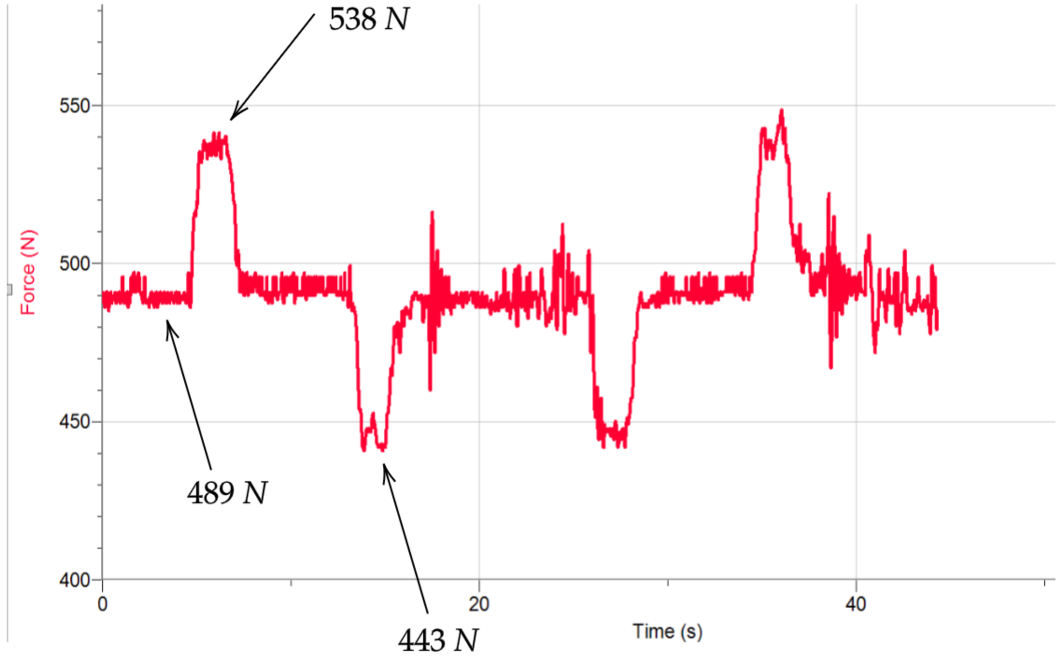
If an object is moving with acceleration, normal force changes compared to when it is at rest. Let us assume that the same apple is in an elevator which is moving with acceleration a directed up. The net force up in terms of normal and gravitational forces is $F_{net} = N - mg$, and by Newton's second law for the apple:

$$F_{net} = N - mg = ma \Longrightarrow \boxed{N = mg + ma}$$

We see that for positive a (acceleration up) normal force is increased (compared to normal force at rest) and for negative a (acceleration down) normal force is decreased.

Homework

1. In this problem using the data obtained in our elevator experiment you will need to calculate the upwards and downwards acceleration of the elevator. On the next page there is the plot (which is the result of our experiment) of how normal force acting on a person riding an elevator changes with time. It has the relevant data points provided. In order to find the person's mass, use the fact that when there is no acceleration, normal force measured by the scales is equal to the gravitational force acting on the person. Knowing the mass and normal force during upward acceleration you will **find the upward acceleration**. Then similarly **find the downward acceleration**. You can use $10\,\frac{\text{m}}{\text{s}^2}$ for the free fall acceleration.



2. A tiger has mass 200 kg. It jumps vertically upwards so that normal force acting on it is 3500 N. Find acceleration of the tiger at this moment.

The problem below is a bonus problem.

***3.** Find the force with which a 1 kg block attracts the Earth due to gravity. What is Earth's acceleration due to this force (assuming this was the one and only force acting on the Earth)? Earth's mass is approximately $6 \cdot 10^{24}$ kg.