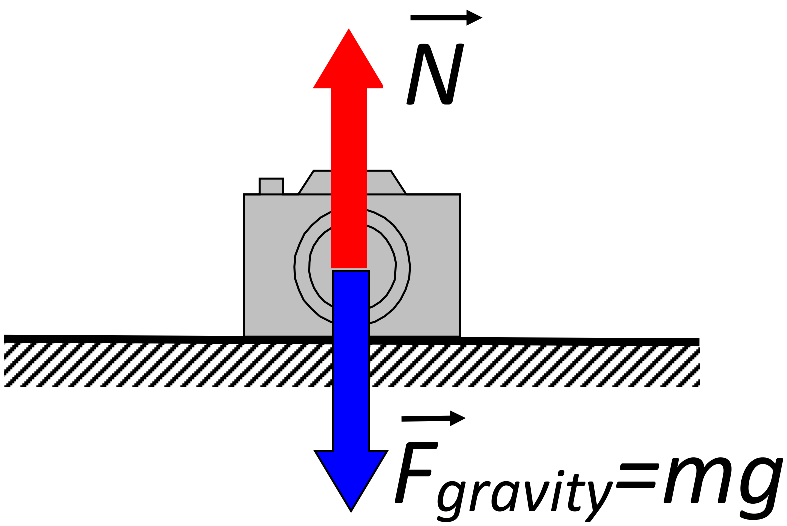
Homework 4.

Normal force.

Any time we put an object (a camera, for example) on a table, floor or any other surface this object apply force to this surface. The origin of this force may be just the gravity (the camera is attracted by Earth). You can also apply additional force to the camera by pressing it down with your hand. Since the camera is still not moving in vertical direction (in case you a not too strong☺) – the vertical acceleration of the camera is zero. This means that the gravity force is compensated by some other force. This force is applied to our object by the support and does not allow the camera to go down through the table. We will call this force as "normal force". Normal force is directed perpendicularly to the supporting surface. (Just to remind: two straight lines are called perpendicular if they cross at the right angle. A straight line is called perpendicular ("normal") to the plane if the line is perpendicular to any straight line belonging to the plane)



As we can see in the picture, if the camera just lies on the table, the magnitude of the normal force is equal to the magnitude of the gravity force.

$$ma = N - mg = 0$$

$$N = mg$$

Here our "positive" axis is directed up.

If we will press the camera down with a force F_{press} the normal force will increase to compensate both the gravity force and the pressure force.

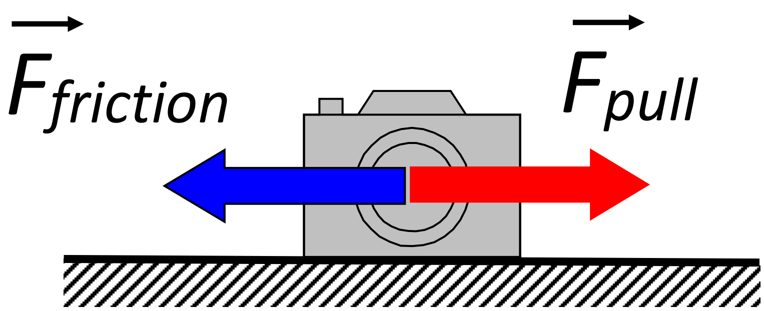
$$ma = N - mg - F_{press} = 0$$

$$N = mg + F_{press}$$

We will define the ***weight*** of an object as total force applied by the object to the support. The magnitude of the weight is equal to the magnitude of the normal force.

Friction force

When we try to push or pull a heavy box standing on the floor it may not move in spite of a considerable pulling of pushing force applied. Some force (or forces) applied to the box by the surface compensates the pushing force and the acceleration in the "pushing" direction is zero. If the magnitude of pushing (or pulling) force is less than certain magnitude which we will call *static friction force*, the box will not move and friction force magnitude is equal to this of the pushing force. If we increase the pushing force, the friction force increases as well until the static friction force is reached. After that, the friction force does not increase anymore and, if we increase the pushing force just a little bit, the box will start moving.



$$ma = F_{friction} - F_{pull} = 0$$

$$F_{friction} = F_{pull}$$

Here our positive direction is chosen from left to right.

How to calculate the static friction force F_{fs}? The magnitude of the static friction force is proportional to the magnitude of the normal force. Speaking "common sense language" the heavier the box the stronger we have to push to move it.

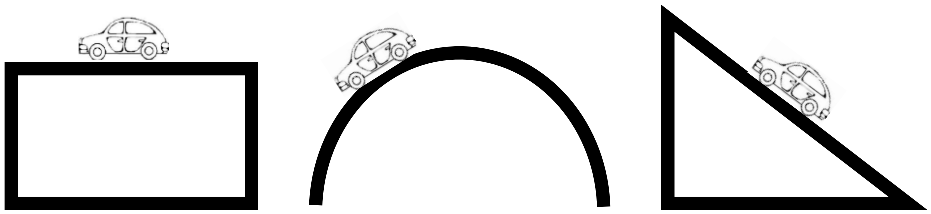
$$F_{fs} = \mu \cdot N$$

Here μ is the coefficient of friction. This is a number which depends of the object (box) and surface materials and the roughness of the surfaces. If the surfaces are rough, this number is large, so more force is required to move the object.

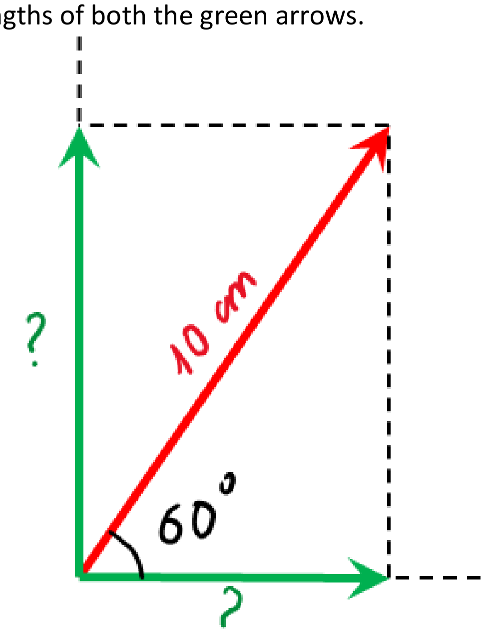
After the box started moving the friction force is equal to μN. Strictly speaking this is not always correct and, in some cases, the friction force applied to a moving object (dynamic friction force) is not equal to the static friction force. This time we will not discuss this effect in details and, for simplicity, assume that the static friction force is equal to the dynamic one.

Problems:

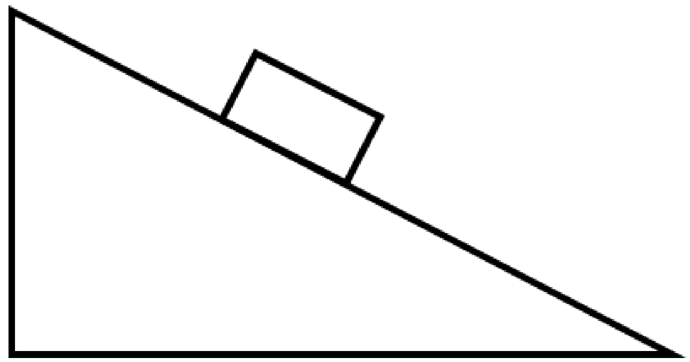
1. Mark the direction of the normal force applied to the car:



2. The red arrow forms an angle of 60° with the horizontal line (Figure 1). The length of the red arrow is 10 cm. Find the lengths of both the green arrows.



3. The friction force keeps brick on the incline plane without sliding down (Figure 2). Mark all the forces applied to the brick



4. A 2000kg car accelerates at $5m/s^2$. The friction coefficient is 1/10. Find the pulling force of the car's engine.