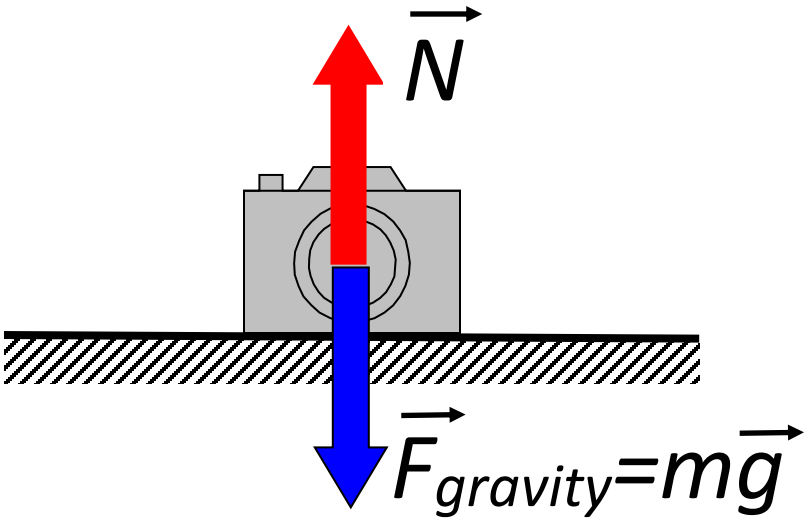
Homework 4

Normal force and friction force

Last time we discussed normal force and friction force.

a) Normal force.

Any time we put an object (say, a pen) 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 pen is attracted by Earth). We can also apply additional pressure to the pen. We observe that the pen does not move in vertical direction – it just lies on the table. This means that in spite of the gravity force applied to the pen, the acceleration of the pen in vertical direction is zero. This, in turn, means that the gravity force is compensated by some other force or forces. According to the third Newton's law the surface applies the force of equal magnitude and opposite direction to the object. This force does not allow the pen to go down through the table. We will call this force as "normal force". Normal force is directed perpendicularly to the 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 lays on the table, the magnitude of the normal force is equal to the magnitude of the gravity force. Choosing "up" as positive direction we have:

$$ma = N - mg = 0$$

$$N = mg$$

Here our "positive" axis is directed up.

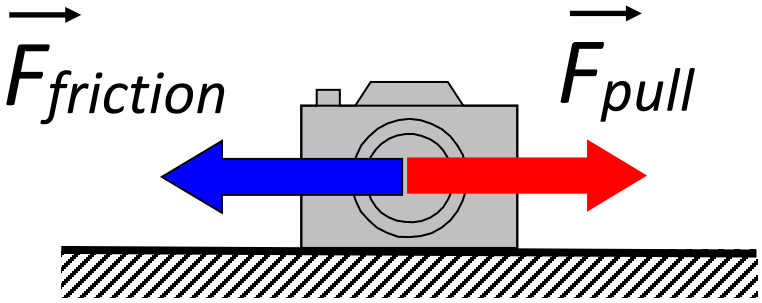
If we will press the camera down with a force F_{press} the normal force will increase to compensate both the gravity force and the pressure force.

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

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

b) Friction force *(we will discuss it in detail during next class)*

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. Why there is tread on the surface of a tire?
2. We have learned that any object which is set to motion tends to stay in motion. What about a car? Why cannot we just let the car go after the acceleration? Why we have to keep the gas pedal pressed?
3. A 2000kg car accelerates at $5m/s^2$. The friction coefficient is 1/10. Find the pulling force of the car's engine.
4. The car from the problem 3 accelerated to 100km/h and moves at a constant velocity. Find total net force applied to the car. :)
5. The driver of a car moving at a velocity of 100km/h presses the brake so a friction force of 500N is applied to the car. How long will it take for the car to stop?