PHY 121 Mechanics *S.G. Rajeev*

Lecture 8

Friction

• We have so far ignored a basic aspect of everyday life: *friction*. There are two kinds of friction: *static* and *kinetic*.

• If you push a body sitting on this table with a small force it won't move, because *static* friction is acting to cancel the force you are applying . As you increase the magnitude of the force above a value f_s the table is no longer able to hold on to the body and suddenly it will start to move.

Kinetic Friction

• But even then, part of the force you apply is cancelled by a new kind of friction, *kinetic* (or moving) friction.

• How big is *friction*? The larger the weight of the body , the more the friction is. In fact, the force of friction is proportional to the force N perpendicular to the table. The static friction is

$$f_s = \mu_s N$$

where μ_s is a constant called the *coefficient of static friction*. Similarly the kinetic friction is

$$f_k = \mu_k N$$

where μ_k is another constant called the *coefficient of kinetic friction*.

• The coefficients of friction are properties of the surface of the bodies. Usually μ_s is larger than μ_k : to get something to move takes more force than to keep it moving.

Braking a Car

Exercise

A car was moving at $210\ km/hr$ when the brakes are slammed on causing the wheels to lock up. The coefficient of kinetic friction is $\mu_k = .6$. What is the distance it will take to stop the car?

Solution

Let M be the mass of the car. The Normal force is the weight Mg ; kinetic friction is $\mu_k Mg$. The acceleration due to this force is $a = -\mu_k g$, the negative sign indicating that the velocity is in fact decreasing.

Now, we have, for motion at

constant acceleration,

$$v_2^2 - v_1^2 = 2aD.$$

Here, the initial velocity is v_1 and the final velocity v_2 , and D is the distance moved. For us $v_2 = 0, a = -\mu_k g$ so that

$$v_1^2 = 2\mu_k g D.$$

In other words

$$D = \frac{v_1^2}{2\mu_k g}.$$

We are given

$v_1 = 210\ km/hr = 210/3.6\ ms^{-1} = 58.3\ ms^{-1}$

so that

$$D = 290\ m.$$

What Causes Friction?

•No surface is perfectly smooth. As we press down on a pair of objects, the surface bends a bit so that more of the bodies are in contact with each other. The force is roughly proportional to the area of the surface in contact, which in turn is proportional to the normal force with which we press them together.

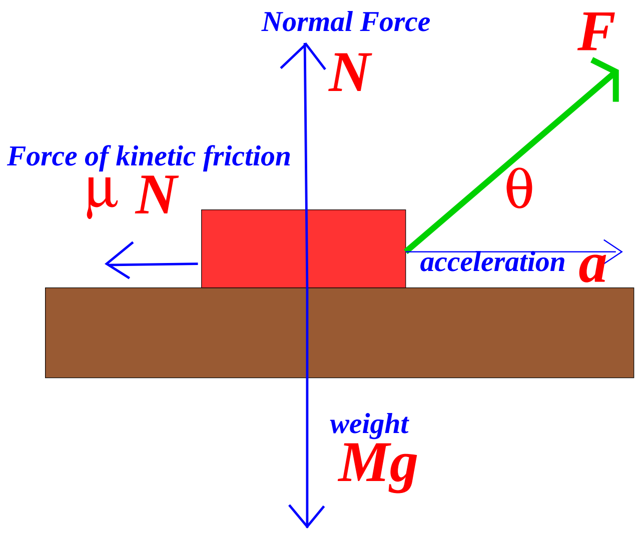
•Ultimately what causes friction is the electromagnetic force between the atoms at the surface of the bodies. The force is proportional to the number of atoms in close contact which in turn is proportional to the area.

A Block Moving With Friction

Exercise

A block of mass $m = 7.2\ kg$ is moving because it is pulled by a rope at an angle $\theta = 8°$ to the horizontal, by a force of magnitude $F = 81\ N$. The coefficient of kinetic friction is $\mu = 0.6$. What is the acceleration of the block?

Block Pulled by a Rope



Solution
This is the same problem we saw in lecture 7 except that now we allow for friction. (See the accompanying diagram.)
The force N with with which the block presses down on the table is vertical and is the sum of the weight and the component of the force F in the vertical direction.

$$N = Mg - F\sin\theta.$$

So the friction force is horizontal and

$$F_{fr} = \mu N.$$

The total horizontal force is the horizontal component of the pulling force minus the frictional

force. Hence,

$$Ma = F\cos\theta - F_{fr}$$

In other words,

$$Ma = F\cos\theta - \mu Mg + \mu F\sin\theta$$

which gives

$$Ma = F(\cos\theta + \mu\sin\theta) - \mu Mg$$

or,

$$a = \frac{F}{M}(\cos\theta + \mu\sin\theta) - \mu g$$

If $F = 81\ N$, $M = 7.2\ kg, \mu = 0.6, \theta = 8^\circ$, we have

$$a = \frac{81}{7.2}(\cos 8^\circ + 0.6\sin 8^\circ) - 0.6 \times 9.8$$

or,

$$a = 6.3\ ms^{-2}.$$

We have of course assumed that the force is not large enough to lift the bock off the table; that is, that the vertical component of F is smaller than the weight.