4.5 – Friction

Carpet burn, anyone?

Be sure to find a Balloon Car Team!

1. Friction Demo

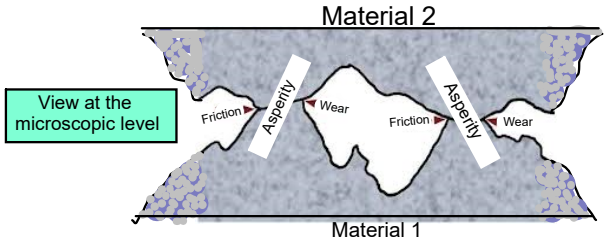
Can you gently pull the two interlinked phonebooks apart?

The spines are a bit loose - get a firm grip and pull them carefully.

Explain what is going on in the demonstration.

Force of Friction

Important – necessary to walk.
Opposes motion.
Happens when surface irregularities (called asperities) come into contact and weld together.
Somewhat due to mechanical interactions as well.

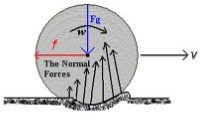


3 Types of Friction

Static – Force unable to move object.

Kinetic – Object slides.

Rolling – Object rotates as it moves over another, but doesn't slide. Internal friction occurs as materials deform and return to shape, making heat. We won't study this.



Rubber ball rolling.

The interface between two materials has a unique coefficient of friction(μ), which varies if objects are moving or stationary.

Frictional Force: F_f

$$\left|\vec{F}_f\right| \le \mu \left|\vec{F}_n\right|$$

AP Equation

μ - coefficient of friction:
μ_s - static: object not moving
μ_k - kinetic: object is moving
F_n - Normal Force (N)

The ≤ sign means if no force is applied, friction = 0. As more force is applied, static friction increases until the object moves, when it becomes kinetic friction.

It is customary to replace the≤ with an = sign when calculating kinetic friction.

YOU distinguish betweenstatic and kinetic friction.

2. Physics Democracy!

Which coefficient of friction do you think has greater values?

In other words, which force is greater, that to hold an object steady, or that required to keep it going, once it moves? Write down why do you think this then vote!

Vote!

Static	Kinetic

Friction Answer

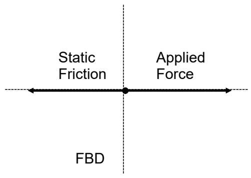
Once an object starts to move, it takes less force to keep it going. Static friction coefficients are greater than kinetic friction ones.

3. Friction Example

A 40.0 kg box is on a floor with a coefficient of $\mu_s = 0.650$. What is the minimum applied force needed to get it moving?

Answer: Equal and opposite to the force of static friction.

$$F_f = \mu_s F_n = \mu_s \bullet m \bullet g$$
$$= 0.650(40.0\,kg \bullet 9.81\,m/s^2)$$
$$= 255\,N$$



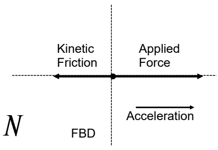
4. Acceleration Example

What's the acceleration if the same force (255 N) is applied after the 40.0 kg box starts moving? ($\mu_k = 0.500$)

Find the net force of the system first:

$$F_{f_k} = \mu_k F_n$$
$$= 0.500(4[\ldots]/s^2)$$
$$= 196\,N$$

F_{net}: Use FBD:



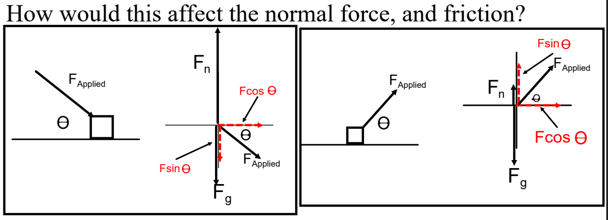
$$F_{net} = F - F_{f_k} = 255\,N - 196\,N = 59\,N$$

Acceleration:

$$a = \frac{F_{net}}{m} = \frac{59\,N}{40.0\,kg} = 1.5\,m/s^2$$

Angled Applied Force

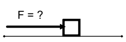
Suppose there's a non-horizontal force applied to the object. How would this affect the normal force, and friction?



Any downward force increases the normal force, so friction increases.
Any upward force reduces the normal force, so friction decreases.

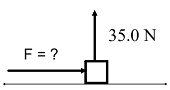
Minimum Force Examples

5. What is the minimum force necessary to move a 25.0 kg box on a surface with $\mu_s = 0.260$?



$$F_f = \mu_s \bullet F_n = \mu_s \bullet m \bullet g$$
$$= 0.260 \bullet 25.0\,kg \bullet 9.81\,m/s^2 = 63.8\,N$$

6. What if someone is pulling on the box with a force of 35.0 N straight upwards?

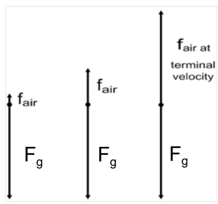


$$F_f = \mu_s(F_n - Applied\ Force)$$
$$= 0.260(25.0\,kg \bullet 9.81\,m/s^2 - 35.0\,N) = 54.7\,N$$

Air Resistance (f_{air})

Friction experienced by objects moving in air.

Terminal Velocity When $f_{air} = F_g$.



When $F_g = f_{air}$, $a = 0$.

7. Physics Democracy!

Which object will experience greater air friction at its terminal velocity, an ant or a person? Explain!

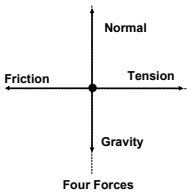
Ant	Person	The Same

Falling Ant!

The person: at terminal velocity, where $F_g = f_{air}$, the person experiences a much larger force of gravity, thus more air friction.

8. Car Example

A 1300 kg car with locked brakes ($\mu_s = 0.54$) must be pulled along a road by a horizontal cable that can handle 6100 Newtons before it snaps.
Make an FBD, then compare forces on the x-axis.



Look at forces in the x direction only and compare: Tension vs. Friction. If tension is larger than friction, the car will accelerate. If not, the cable will snap:

Tension = 6100 N.

$$f_s = \mu_s \cdot N = \mu_s \cdot m \cdot g$$
$$= 0.54 \cdot 1300\,kg \cdot 9.81\,m/s^2$$
$$= 6800\,N$$

The cable will break before motion.

Homework

4.5 Problems in your Booklet
Due: Next Class.

Finish Unit 4 Review Problems:
Scan ????

Test: ????