Nelson p 96-107

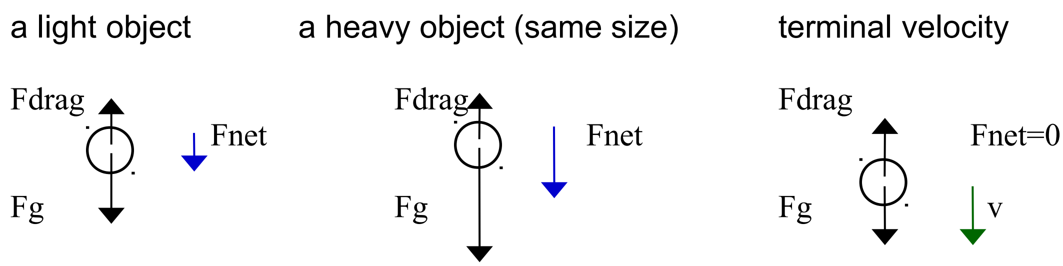
Updated: May 2020
Course: SPH 3U1
Unit: Mechanics

Lesson 5: Friction

There are three types of friction

I. Fluid friction – an object moving through a fluid (air, water, ...);
The frictional force in fluids is called air resistance (in air) or drag (in any fluid)
It depends on: the cross sectional area, the viscosity of the fluid, the square of the speed of the object, and the shape or streamlining of the object. *Most of the time, calculus is needed to calculate the effect of drag. This is because the force of friction will change the acceleration of an object, which then changes the speed, but drag is based on speed^2, so changing the speed changes drag, which then changes the acceleration, which changes the speed, which changed drag, etc. etc.*

What are the forces on an object that is falling?



If we work out Fnet for a falling object we get:

$\vec{F}_{net} = \vec{F}_g + \vec{F}_f$ or $ma = mg - F_f$

$a = g - F_f/m$

What happens when the force of friction is negligible or the mass is large? Acceleration increases and approaches g --- just like we saw yesterday.

What happens as the mass decreases? Ff/m will increase until it equals g. At this point a = 0 . The object has reached terminal velocity.

II. Rolling friction

This is what makes a round object roll when pushed on a flat surface, instead of just sliding. Rolling friction is very small. If you push a ball it will roll much further than if you cut it in half and try and slide it.
It only seems to be considered when one is trying to increase fuel efficiencies in cars. I've never used it.

The previous stuff is general information that's good to know,
but not something that you would be tested on in high school or expected to know.
What follows now is the material that you are expected to learn and understand.

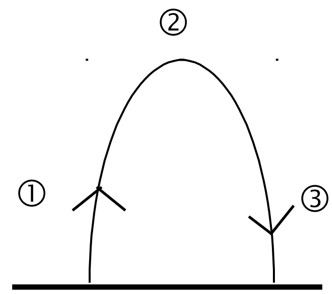
Friction always acts in a way to oppose the direction of motion (or intended motion).

(What is meant by "intended motion" is that if you're pushing something and it doesn't move, then there's no motion, but there is still friction opposing the direction of motion that would occur if there was no friction. By motion we mean speed or velocity, NOT acceleration. Friction can be in the same direction of acceleration. *Examples?*)

Use arrows to indicate the direction of a, v, Ff
at points ①, ②, ③ for a projectile thrown in the air.

(This is very useful in tying together
a number of concepts that they have learned.)

at ① v↑, a↓, Ff↓
at ② v=0, a↓, Ff = 0
at ③ v↓, a↓, Ff↑
(put on diagram)



III. Friction between two surfaces: sliding friction.

EXTRA INFO

What causes sliding friction? the jaggy surfaces of the two objects in contact, as well as electrons being attracted to both surfaces at the same time.
Molecular bonding between the surfaces occurs if the surfaces are really smooth – that's why it is so hard to scrape ice off the windshield in winter.
* What increases friction? more mass, rougher surface?
* What decreases friction? Lubrication. How does lubrication work? It fills in the jaggy bits and separates the two surfaces. Also the liquid between them allows them to slide.
Are there any solid lubricants? Yes (molybdenum, graphite, talc), but they are all powdered.

Theoretically, sliding friction only depends on the nature of the two surfaces and the force pushing them together.
Speed, surface area, and pressure do not affect it. Does mass? Yes, but indirectly.

DEMO: test this. Get a large slope, have three different objects and then raise the slope slowly until things start to slide. Does the same one sliding all the time? Have a block that you can flip over to change the surface area. Also add on weights to see if the mass makes a difference.

Formula: $F_f = \mu\ F_N$

- Note that this is a scalar equation.
  (The directions of the forces F_N and F_f are not specified, in fact, they are $\perp$).
- The normal force is what pushed the surfaces together.
- μ is called "the coefficient of friction". It describes the nature of the two surfaces in contact .
- μ has no units and is always positive (like the index of refraction)
  High μ means more friction. $\mu = 0$ means $Ff = 0$
- Unlike the other equations that we have looked at, this equation is an empirical equation. There is no theoretical basis for the equation. It is determined by repeated experiments.
- μ is also determined experimentally. It normally only has one or two sig. digits and is highly dependent on things like humidity, temperature, how clean the surface is.
- As we've already discussed in a separate document, F_N is not necessarily equal to Fg in either direction or magnitude.

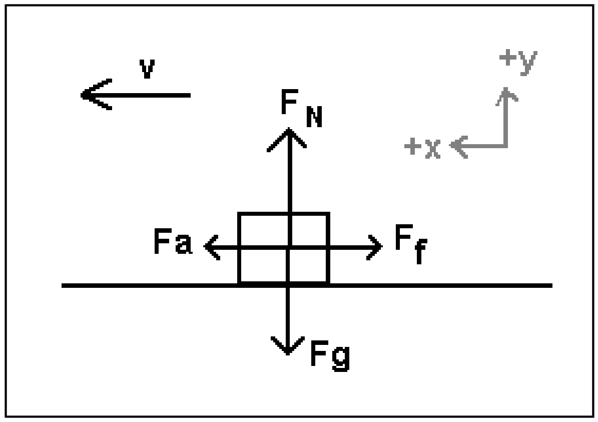
Typical values of μ might be:

Material	Coefficient of kinetic friction	Coefficient of static friction
Steel on steel	0.6	0.7
Waxed ski on snow	0.05	0.1
Rubber on concrete	about 1	about 1

So how could we reduce this level of friction? We could add a lubricant such as oil between the two surfaces: the coefficient of friction between two well-oiled metallic surfaces is about **μ = 0.01**.

Can you think of other ways friction can be reduced? One way is replace sliding with rolling. We can use ball-bearings, this greatly reduces friction and gives a coefficient of friction about **μ = 0.002**. Other ways include the use of air cushions (e.g. hovercrafts) and by streamlining (car design, cyclists helmets etc.).

Example: A 5 kg object is pushed on a horizontal surface. If $\mu = 0.35$ find the force of friction.
This is one of the first force problems that we do. Make sure that directions of axes are labelled and that you use vector forces.



1) draw F.B.D.
Tip: make v point left ← to show students that the choice of axes is up to them, as long as they are perpendicular. +x is normally in the direction of motion.

2) since there is no acceleration in the vertical direction (and surface is horizontal), then there is not net force in the vertical direction.

$$\vec{F}_{net} = 0 = \vec{F}_N + \vec{F}_g$$

$$\therefore \vec{F}_N = -\vec{F}_g$$

3) find Fg, then find F_N.

Fg = mg   <u>F</u>g = (5kg)(-9.8 N/kg)
<u>F</u>g = -49N
<u>F</u>$_N$ = +49N (vector form) F_N = 49N (non-vector)

4) $F_f = \mu F_N$
F_f = 0.35 (49N) = 17 N ← *the answer*

What is the applied force if a = 0?

Since there is no acceleration the net force in the horizontal direction is also balanced.
So $F_a = F_f$ and Fa = 17 N

What is the applied force if a = 2 m/s^2

$$\vec{F}_{net} = m\vec{a}$$ $\therefore$ <u>Fnet</u> = (5kg)(+2m/s^2)
= +10 N

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$

+10N = <u>F</u>a + (–17N)

$\therefore$ <u>F</u>a = +27N

Homework:

~~Give 5 examples where friction is a problem.~~
~~Give 5 examples where friction is useful.~~

1. Nelson: p103 #3 (see below)

2. Nelson p103 #6 (see below)

3. What is the coefficient of friction if you slide a brick on a surface and it comes to a stop in 0.7 seconds over a distance of 1.0 m ?

Practice

Understanding Concepts

Note: "Force" in the following questions refers only to the magnitude of the force.

1. Based on **Table 1**, which type of road, asphalt or concrete, provides better traction (friction of a tire on a road) for rubber tires under
   (a) dry conditions?
   (b) wet conditions?
2. Use the data in **Table 1** to verify that driving on an icy highway is much more dangerous than on a wet one.
3. Determine the appropriate coefficient of friction in each case.
   (a) It takes 59 N of horizontal force to get a 22-kg leather suitcase just starting to move across a floor.
   (b) A horizontal force of 54 N keeps the suitcase in (a) moving at a constant velocity.
4. A 73-kg hockey player glides across the ice on skates with steel blades. What is the force of friction acting on the skater?
5. A 1.5-Mg car moving along a concrete road has its brakes locked and skids to a smooth stop. Calculate the force of friction (a) on a dry road and (b) on a wet road.
6. A moving company worker places a 252-kg trunk on a piece of carpeting and slides it across the floor at constant velocity by exerting a horizontal force of 425 N on the trunk.
   (a) What is the coefficient of kinetic friction?
   (b) What happens to the coefficient of kinetic friction if another 56-kg trunk is placed on top of the 252-kg trunk?
   (c) What horizontal force must the mover apply to move the combination of the two trunks at constant velocity?

Answers

3. (a) $\mu_s = 0.27$
   (b) $\mu_K = 0.25$
4. 7.2 N
5. (a) 1.5×10^4 N
   (b) 1.4×10^4 N
6. (a) 0.17
   (c) 5.2×10^2 N

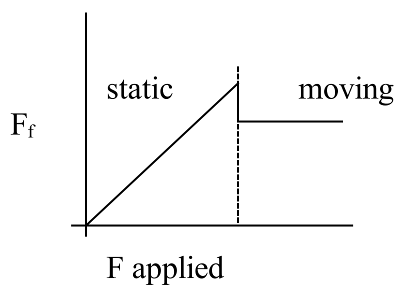
STATIC FRICTION

Friction of a sliding object is called kinetic friction. The coefficient is really the coefficient of kinetic friction (μ_k).

There is also something called static friction. This is the friction that opposes a stationary object from moving. Unless we specifically mention it, assume we are talking about kinetic friction. When referring to static friction we will use the symbols: F_S and μ_S .

Static friction tends to be greater than kinetic friction. As soon as the object starts moving, kinetic friction is the quantity that is involved. The force of static friction only exists when an external force is acting on an object resting on a plane and the object is not moving. F_S is || and opposite to the applied force.

$$0 \leq F_s \leq \mu_s F_N$$



Examples:
1) If $\mu_s = 0.40$ what is the maximum force that you can push a 10 kg block with without it moving?

You can push with any force up to $\mu_S \times F_N$. F = 0.40 (10kg)(9.8N/kg)
= 39 N

Note there is no static friction in liquids. You can lean up against a ship in a calm harbour and it will eventually start moving. Even a small force will produce an acceleration as per F=ma.

<u>How to solve force problems:</u>
1. Draw a Free Body Diagram.
2. Set the axes to the most convenient orientation.
3. Write an equation for the net force in the y-axis (normally vertical)
4. Write an equation for the net force in the x-axis (normally horizontal)
5. Solve the equations as needed.