Friction

Lesson objectives

Students will be able to identify friction as a force that opposes relative motion.

Students will be able to calculat the frictional forces acting on an object.

1.1

Lesson objectives | Teachers' notes | Lesson notes

http://www.youtube.com/watch?v=QMW_uYWwHWQ&feature=related

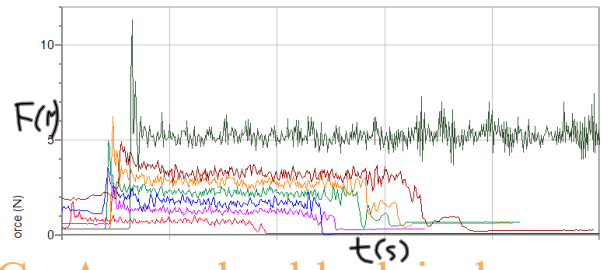
Activity: What factors effect the frictional force experienced by an object?

Experimental Design A: A wooden block is pulled gradually until it just starts to move. Further trials are conducted with increased mass.

As the mass of the block is increased, it appears that the force required to overcome friction increases

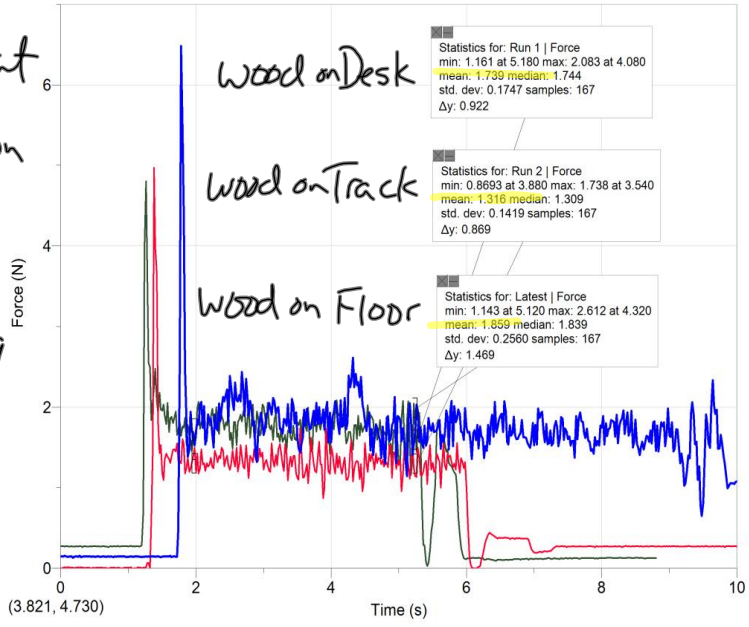
Experimental Design B: A wooden block is dragged a a constant speed with a force meter. Further trials are conducted with increased mass. (Balanced forces - a=0)

- As the mass of the block increases, the force of friction increases.



Experimental Design C: A wooden block is dragged a a constant speed with a force meter across a variety of surfaces.

It appears that force of friction depends on the surface of the sliding objects



What sorts of things effect the amount of friction experienced by an object?

Force of friction depends on:

- mass of object being dragged
- type of surface being dragged on.

Activity: Relating Friction and the Normal Force

Experimental Design: A mass is placed on a wooden block. The block is pulled at a constant velocity and the weight of the block measured. Several trials are conducted with different masses.

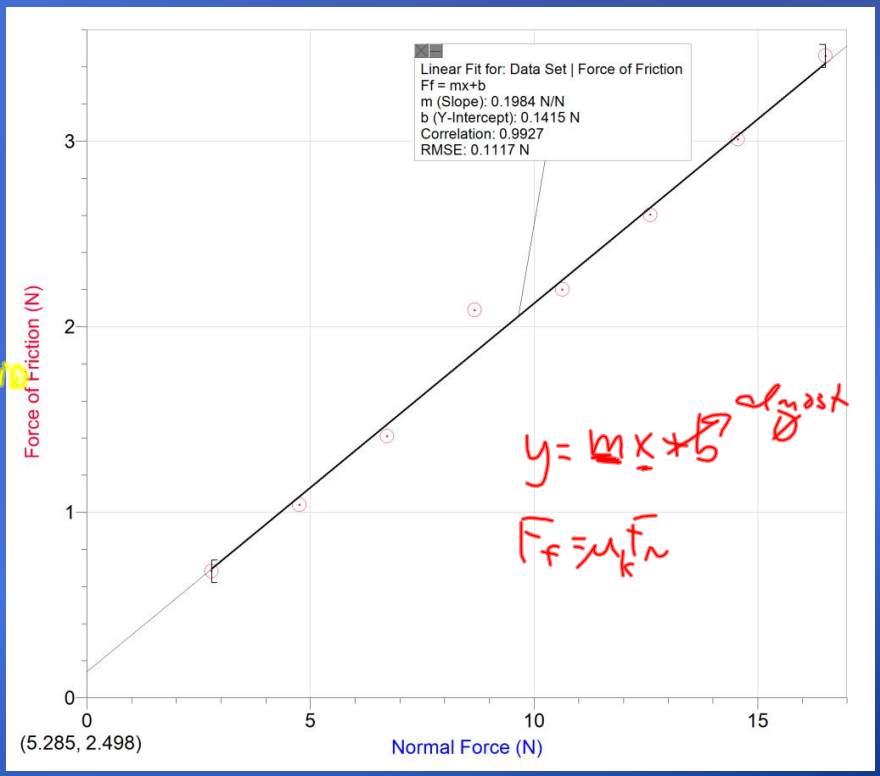
Analysis: Graph the magnitude of the force of friction as a function of the magnitude of the normal force.

What did we get?

Mass (kg)	FN (N)	Ff (N)
0.284	2.786	0.682
0.484	4.748	1.04
0.684	6.710	1.41
0.884	8.672	2.09
1.084	10.634	2.2
1.284	12.596	2.603
1.484	14.558	3.01
1.684	16.520	3.46

There is a relationship between F_f & F_N. Appears to be a linear function

Frictional force as a function of normal force



Kinetic Friction: force exerted on an object in motion that opposes the relative motion of the object

Coefficient of friction

$$F_{Fkinetic} = \mu_k F_N$$

Magnitude of the normal force (N)

on a flat, horizontal surface, $F_N = F_g$

The coefficient of friction is a proportionality constant that relates F_F and F_N.

p188 #1

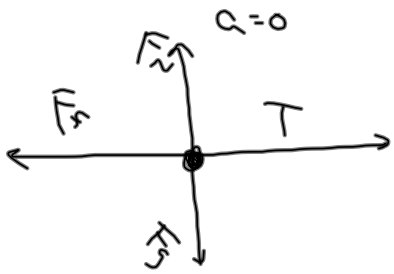
1. An applied force of 450 N [forward] is needed to drag a 1000-kg crate at constant speed across a horizontal, rough floor. Calculate the coefficient of kinetic friction for the crate on the floor.

$T = 450\,N$

$m = 1000\,kg$

$a = 0$

$\mu_k = ?$



$F_{net} = T - F_f$ ($F_{net} \to 0$)

$T = F_f$

$T = \mu F_N$

$T = \mu F_g$

$T = \mu mg$

$\mu = \frac{T}{mg}$

$\mu = \frac{(450\,N)}{(1000\,kg)(9.81\,m/s^2)}$

$\mu = 0.0459$

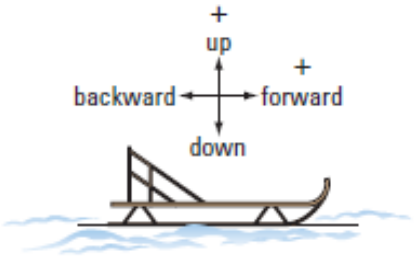
Static friction: force exerted on an object at rest that prevents the object from sliding

Since the magnitude of the force of static friction can be anywhere from zero to some maximum value (just before it moves), we cannot express the relationship as an equality.

$$F_{Fstatic} \leq \mu_s F_N$$

Example 3.17 p. 185

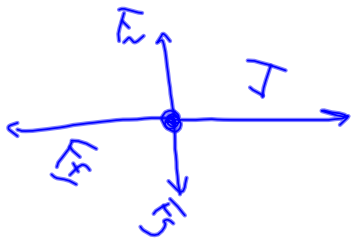
A sled with waxed hickory runners rests on a horizontal, dry snowy surface (Figure 3.88). Calculate the mass of the sled if the maximum force that can be applied to the sled before it starts moving is 46 N [forward]. Refer to Table 3.4 on page 183.



▲ Figure 3.88

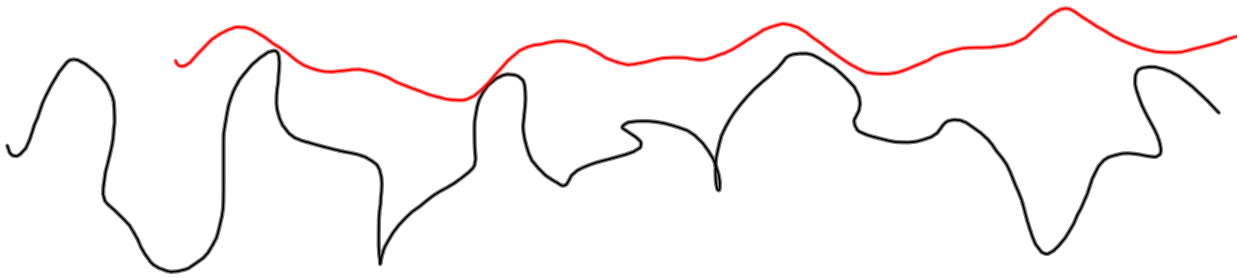
$v = 0$
$m = ?$
$T = 46\,N$

$a = 0$



$T = F_f$
$T = \mu F_N$
$T = \mu F_g$
$T = \mu mg$
$m = \frac{T}{\mu g}$
$m = \frac{(46\,N)}{(0.06)(9.81\,m/s^2)}$
$m = 78\,kg$

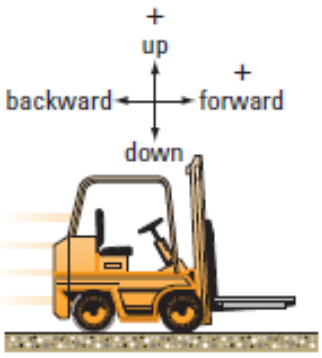
8×10^1



Practice Problems, p. 185 #1-2

Example 3.19 p. 187

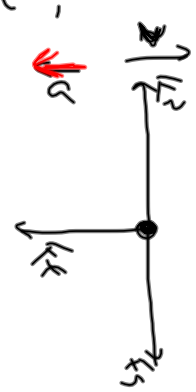
A 1640-kg lift truck with rubber tires is skidding on wet concrete with all four wheels locked (Figure 3.93). Calculate the acceleration of the truck. Refer to Table 3.4 on page 183.



▲ Figure 3.93

$m = 1640\,kg$

$a = ?$



$F_{net} = F_F$

$ma = \mu F_N$

$ma = \mu mg$

$a = (0.5)(9.81\,m/s^2)$

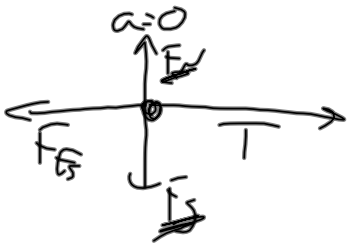
$a = 4.9\,m/s^2$

Practice Problems, p. 185 #1-2

Practice Problems p. 188, #1-2

Check and Reflect p. 190, #1-6

5. A force of 31 N [forward] is needed to start an 8.0-kg steel slider moving along a horizontal steel rail. What is the coefficient of static friction?



$a = 0$

$F_{net} = T - F_f$

$F_f = T$

$\mu F_N = T$ $\quad \mu F_G = T$

$\mu mg = T$

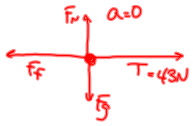
$\mu = \frac{T}{mg}$

$\mu = \frac{31\ N}{(8.0\ kg)(9.81\ m/s^2)}$

$\mu = 0.40$

Physical Evidence:
- A drag sled test was conducted on the scene. The sled weighed 15 kg and was pulled with an average force of 43 N. Tests were repeated 48 hours later when the road was clear of ice and an average pull of 94 N was required.
- Headlamp glass was found 1.7 m in front of the resting vehicle.
- Headlamps of the vehicle were 0.50 m above the ground.
- Skid marks left on 36th St. leading to the crash were 16 m long.
- Posted speed limit was 70 km/h.

- Determine the coefficient of friction for the ice covered road surface.



$T = F_F$

$T = \mu F_N$

$\mu = \frac{T}{F_N}$

$\mu = \frac{T}{F_g}$

$\mu = \frac{T}{mg}$

$\mu = \frac{(43N)}{(15kg)(9.81m/s^2)}$ 94N dry road

$\mu = 0.292$

- Calculate the velocity of the vehicle when it hit the light standard.

$\mu_{dry} = 0.639$

x	y
$V = ?$	$d = -0.50m$
$d = 1.7m$	$a = -9.81 m/s^2$
	$V_i = 0$
$V = \frac{d}{t}$	$t = ?$
	$d = V_i t + \frac{1}{2}at^2$ (0)
$V = \frac{1.7m}{0.319s}$	$t = \sqrt{\frac{2d}{a}}$
$V = 5.32 m/s$	$t = \sqrt{\frac{2(-0.50m)}{(-9.81m/s^2)}}$
	$t = 0.319s$

- Find the vehicles velocity when it started to skid.

$V_i = ?$

$V_f = 5.32 m/s$

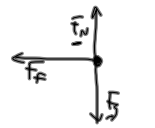
$d = 16.0m$

$+$

$a = ?$

$V_f^2 = V_i^2 + 2ad$

$V_i = \sqrt{V_f^2 - 2ad}$



$F_{net} = F_F$

$ma = \mu F_N$

$ma = \mu F_g$

$ma = \mu mg$

$a = \mu g$

$a = (0.292)(9.81 m/s^2)$

$a = 2.86 m/s^2$

$\therefore V_i = \sqrt{(5.32)^2 - 2(-2.86)(16.0)}$

$V_i = 10.9 m/s$

$39.4 km/h$

- Calculate the stopping distance for a vehicle driving at the speed limit under dry conditions.

$V_i = 70 km/h$

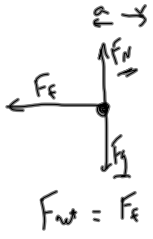
$V_f = 0$ (19.4 m/s)

$d = ?$

$V_f^2 = V_i^2 + 2ad$ (0)

$a = ?$

$d = \frac{-V_i^2}{2a}$



$F_{net} = F_F$