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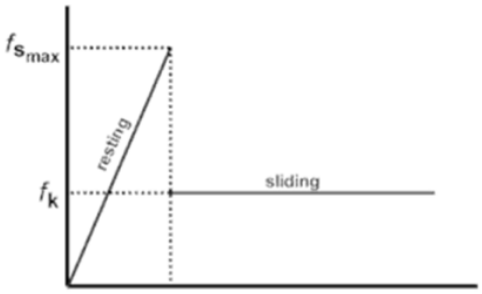
Unit 1: Kinematics and Dynamics
Lesson 1.6: Friction (Chapter 2.4)

Figure 1 The sprinter is using the static friction between his shoes, $\vec{F}_s$, and the running surface to accelerate.

$$\mu_S = \frac{\vec{F}_S}{\vec{F}_N} \qquad \mu_K = \frac{\vec{F}_K}{\vec{F}_N}$$



Kinetic Frictions and Static frictions:

- Static Friction ($\vec{F}_s$) **prevents** the sliding of two surfaces relative to one another
- Kinetic Friction ($\vec{F}_k$) is the force exerted on a moving object by a surface opposite to the direction of motion of the object. It **opposes** motion.

Surface	μ_K	μ_S	Surface	μ_K	μ_S
rubber on dry concrete	0.6–0.85		steel on ice	0.01	0.1
rubber on wet concrete	0.45–0.75		rubber on ice	0.005	
rubber on dry asphalt	0.5–0.80		wood on dry snow	0.18	0.22
rubber on wet asphalt	0.25–0.75		wood on wet snow	0.10	0.14
steel on dry steel	0.42	0.78	Teflon on Teflon	0.04	0.04
steel on greasy steel	0.029–0.12	0.05–0.11	near-frictionless carbon	0.001	
leather on oak	0.52	0.61	synovial joints in humans	0.003	0.01
ice on ice	0.03	0.1			

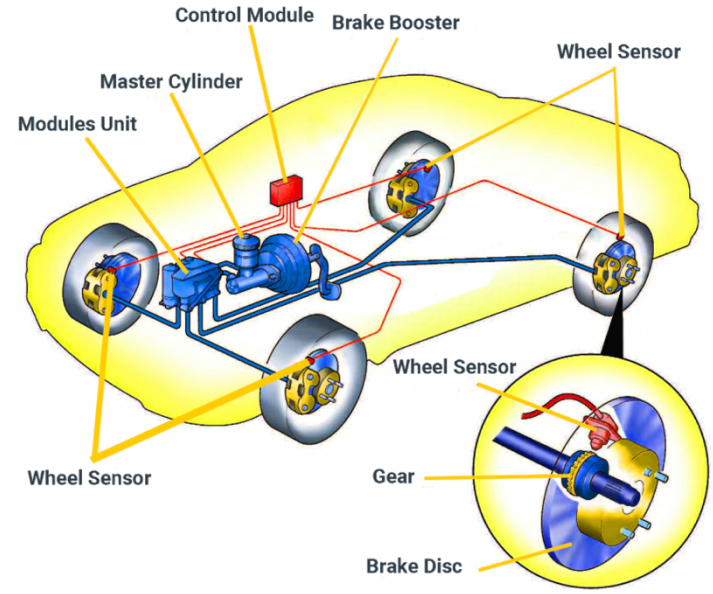
Note: The values for μ_S for rubber and concrete are not normally provided because there are no reliable methods to determine them. In addition, the range depends on a variety of conditions.

Interactive Animation:
https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html

Application: How ABS (Anti-lock Braking System) works?

- ABS is anti-lock braking system, it is very useful to help cars to stop on slippery surface and it is designed to prevent you from"locking up" when you suddenly slams on the brakes to avoid any potential collision.
- Without ABS, when a driver slams on the brakes, the tires begin to lock up and stop rolling.
- When the tires are rolling, tire constantly push against the ground in order to speed up or slow down, and constantly working against **static** friction to keep the car in motion.
- However, when your wheels are sliding over the road instead of rolling, static friction no longer exist and the force to slow down the car now is **kinetic** friction.
- Kinetic friction is less than static friction.
- Therefore, the car takes less distance to stop if the wheels are rolling as compare to the case when the wheels are sliding.
- ABS makes it so the wheels of a car do not lock (ie., do not slide) and keep wheels rolling. So car can stop quickly within shorter distance.

- Mechanism: https://www.youtube.com/watch?v=ru4JIZ-x8yo



Example 1: Kinetic friction & motion

A 300 kg box slides across a level floor. The μ_K us 0.25. A person sees the box moving 1.5 m/s [left] and applies a horizontal force of 150 N [right] to stop the box. How far does it travel before coming to rest?

Example 2: Static friction acting on 2 objects

Two sleds are tied together with a rope. The μ_S between each sled and the snow is 0.22. A child with a mass of 25 kg is on sled 1 and a child with a mass of 34 kg is on sled 2.

a) What is the greatest horizontal force that the adult pulling the sleds can exert without moving the sleds?

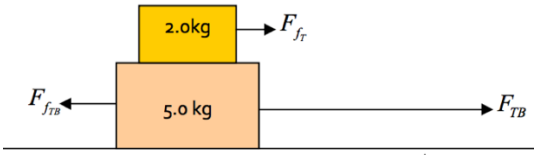
b) Calculate the magnitude of the tension force on the rope between the two sleds when the adult exerts the max. horizontal force.

Example 3:

Two boxes are sitting on top of each other. The top box has a mass of 2.00 kg and the bottom box has a mass of 5.00 kg. The coefficient of static friction between the top box and the bottom box is 0.45. If the coefficient of kinetic friction between the floor and the bottom box is 0.25. Determine:

a) The maximum acceleration of the system before the top box starts to slip.

b) The force applied to the bottom box to make the system accelerate at that rate.



Example 4: (pg 88)

Figure 6 shows two blocks joined with a rope that runs over a pulley. The mass of m_2 is 5.0 kg, and the incline is 35°. The coefficient of static friction between m_1 and the inclined plane is 0.25. Determine the largest mass for m_1 such that both blocks remain at rest.

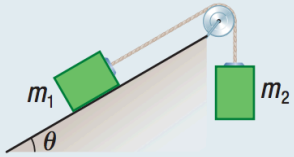
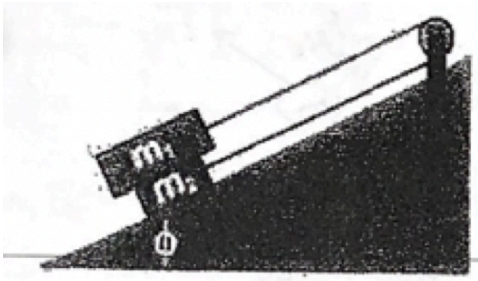


Figure 6

Example 5:



a. A 20.0 kg block, m_1, is sliding on a 10.0 kg block, m_2. The blocks are on a 20° (2 s.d.) slope and are connected by a light string looped over a pulley. All surfaces are frictionless. Find the magnitude of the acceleration of each block and the tension in the sting that connects the blocks.

b. Derive a formula for the acceleration of the blocks and the tension in the string, in terms of m_1, m_2, g, and θ.

c. For a real challenge, answer this question, if the blocks are on a 40° (2 s.d.) slope, the coefficient of kinetic friction between m_1 and m_2 as 0.12 and the coefficient of kinetic friction between the surface of the ramp and m_2 as 0.090.

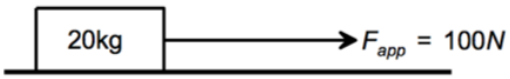
d. For a further challenge, derive a formula to express the answers to c, in terms of m_1, m_2, μ_{k1} (between m_1 and m_2), μ_{k2} (between m_2 and the surface of the ramp), θ (the angle of the ramp), and g (the local value for the acceleration due to gravity). Assume that m_1 is larger than m_2.

Homework:

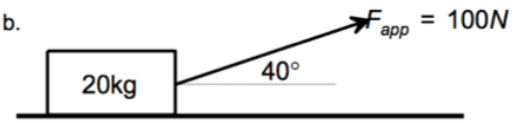
A $2.0x10^1$ kg box is dragged across a level floor with a force of $1.00x10^2$N. The coefficient of kinetic friction between the box and the floor is 0.32.

a. If the force is applied parallel to the floor (see diagram below), what is the acceleration of the box?
b. If the force is applied at an angle of 40° above the horizontal, what is the acceleration of the box?

a.



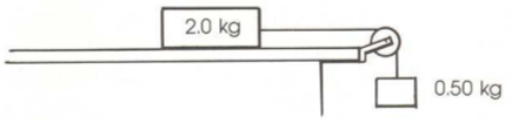
b.



Answer: a. a=1.9m/s^2[right] b. a=1.7 m/s^2 [right]

A 2.0 kg wooden block is attached to a 0.50 kg mass by a string passing through a frictionless pulley, as illustrated.

(a) If the mass of 0.50 kg provides the minimum force required to just get the block to move, what is the coefficient of friction? (0.25)



(b) If the same plane surface is now inclined 20° to the horizontal, what minimum mass, attached to the string, will just get the block moving? (1.2 kg)