Forces and Newton's Laws of Motion

by

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P3.2A Identify the magnitude and direction of everyday forces (e.g., wind, tension in ropes, pushes and pulls, weight).

Items:

1. Frictional Static Force.

2. Frictional Kinetic Force.

3. Tension Force.

Types of Forces in Nature

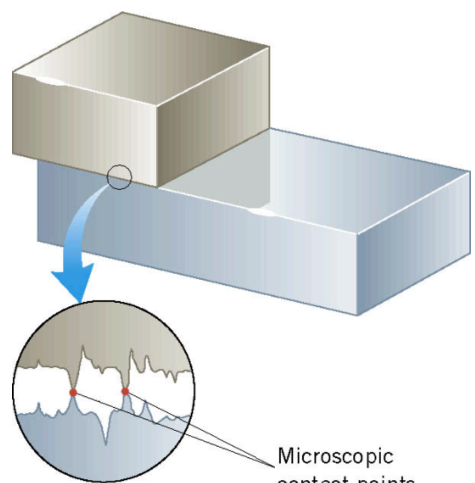
There are two types of forces in nature:

1- fundamental forces such as gravitational force, strong nuclear force and electroweak force.

2- non-fundamental forces such as normal or support force, friction force and tension in a rope force.

Frictional Force

When an object, in contact with a surface, moves or attempts to move, there is a force acting on that object. The component of this force that is parallel to the surface is called the frictional force.



There are only few contact points between two polished surfaces that are in contact.

Static Frictional Force (f_s) in contact- No motion

When the two surfaces, that are in contact, are not sliding across one another the friction is called static friction. Static friction has the symbol f_s

The magnitude or value (f_s) of the static friction can be calculated when multiplying the coefficient of static friction by the normal force or support force.

Static Frictional Force
$f_s = \mu_s F_N = \mu_s mg$

μ_s is the coefficient of static friction ($0 < \mu_s < 1$)

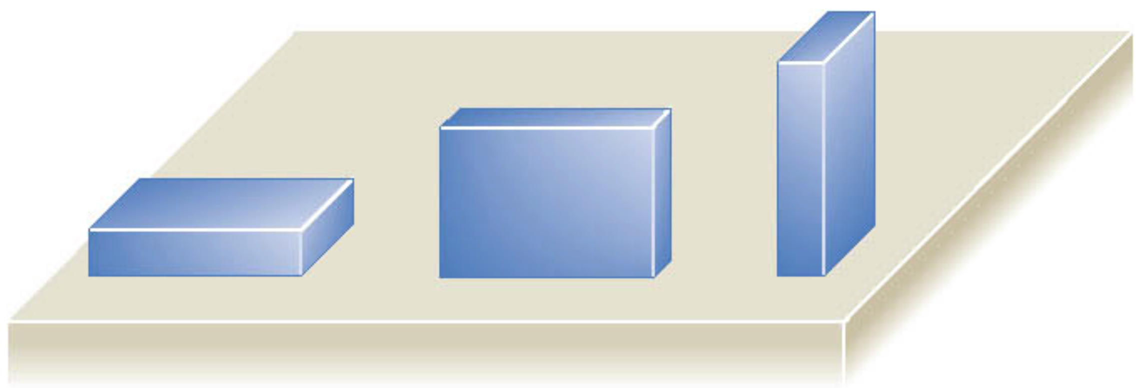
F_N is the normal or support force.

m is the mass, g = 9.8 m/s^2

Static Frictional Force depends on the mass only.

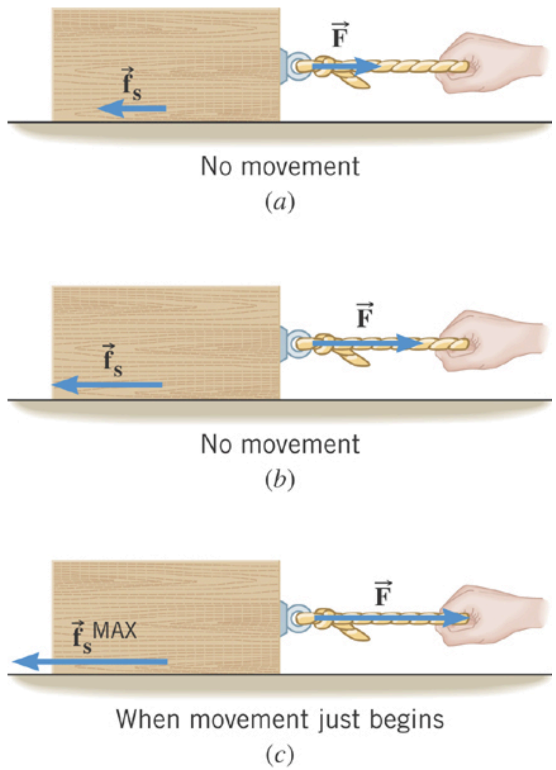
The static frictional force depend only on the mass and does not depend on the way the mass is in contact with the surface.

So, for the block in contact with the table below, the maximum static frictional force is the same, no matter which side of the block is in contact with the table.



To move an object, you need to pull with a force that is greater than the maximum static frictional force ($F > \mathbf{f_s}^{MAX}$).

Example 1: A box is on a table, and a hand is trying to pull a box with a rope by applying a horizontal force (F) as shown in figures a, b and c.



In (a) the hand is pulling with a force F that is less than the static frictional force f_s. Therefore, there is no movement.

In (b) the hand is pulling with a force F equals the static frictional force f_s. Still, there is no movement.

In (c) the box just begins to moves because the force pulls more than the maximum static frictional force $\mathbf{f_s}^{\mathbf{MAX}}$.

Kinetic Frictional Force in contact

Opposing the sliding motion

Kinetic frictional force opposes the relative sliding motion between two objects that are in contact. Kinetic frictional force has the symbol (f_k)

The magnitude (value) of the Kinetic frictional force (f_k) can be calculated when multiplying the coefficient of kinetic friction by the normal force or support force.

Kinetic Frictional Force
$f_k = \mu_k F_N = \mu_k mg$

μ_k is the coefficient of static friction ($0 < \mu_k < 1$)

F_N is the normal or support force.

m is the mass, $g = 9.8$ m/s^2

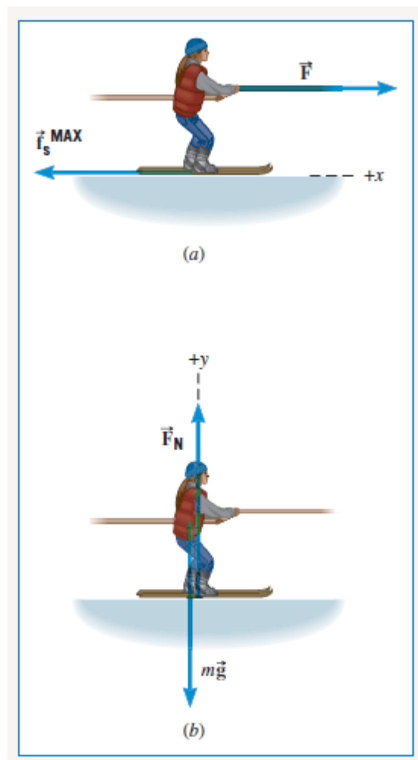
Table 4.2 **Approximate Values of the Coefficients of Friction for Various Surfaces**

Materials	Coefficient of Static Friction, μ_s	Coefficient of Kinetic Friction, μ_k
Glass on glass (dry)	0.94	0.4
Ice on ice (clean, 0 °C)	0.1	0.02
Rubber on dry concrete	1.0	0.8
Rubber on wet concrete	0.7	0.5
Steel on ice	0.1	0.05
Steel on steel (dry hard steel)	0.78	0.42
Teflon on Teflon	0.04	0.04
Wood on wood	0.35	0.3

Usually $\mu_s > \mu_k$

Example 2: *The force Needed to Start a Skier Moving.*

A skier standing on snow and holding onto a rope, which is about to pull her with a force F. The skier mass m is 59 kg. The coefficient of the static friction between the skier and the snow is $\mu_s = 0.14$. What is the maximum force that the tow rope should pull without causing her to move?



$m = 59$ kg, $g = 9.8$ m/s^2, $\mu_s = 0.14$

To move an object, you need to pull with a force that is greater than the maximum static frictional force ($F > \mathbf{f_s}^{\mathbf{MAX}}$).

The static frictional force $f_s^{\mathbf{MAX}}$ can be calculated:

$$f_s^{\mathbf{MAX}} = \mu_s F_N = \mu_s mg$$

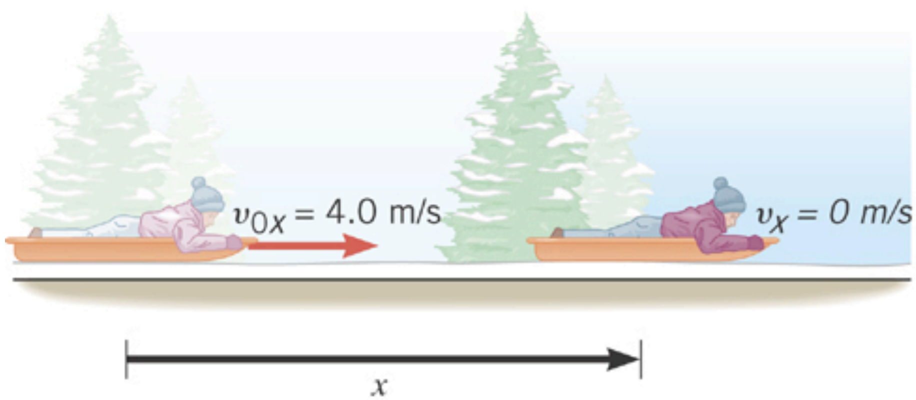
$$= 0.14 \times 59 \times 9.8 = 81 \text{ N}$$

So, the maximum force that the tow rope should pull without causing her to move is 81 N.

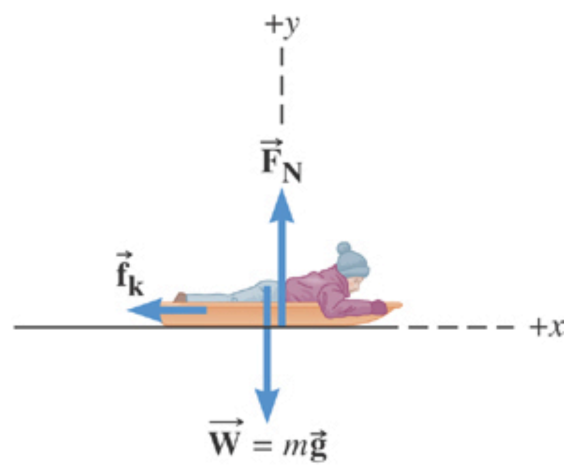
For the skier to move forward, the force should pull with more than 81 N.

Example 3: *A Sled and a Rider*

A sled and a rider are moving at a speed of 4.0 m/s along an horizontal stretch of snow. The snow exerts a kinetic frictional force on the runners of the sled, so the sled slows down and eventually comes to a stop.



(*a*)



(*b*) Free-body diagram for the sled and rider

The *free-body-diagram* is a diagram that represents the object and the forces that act on it.

The Tension Force (T):

The tension force T is used to pull objects. Cables and ropes transmit forces through tension.

Example 4: *A Hand is Pulling a Box with a Rope.*

(a)

A force $\vec{\mathbf{T}}$ is being applied to the right end of a rope.

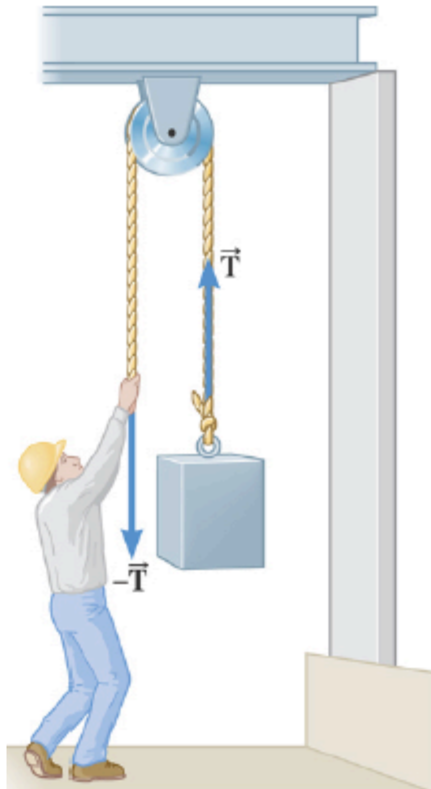
(b)

The force is transmitted to the box from the left end of the rope.

(c)

The box exerts an equal and opposite force to the left end of the rope via Newton's 3rd law.

Example 4: *Frictionless Pulley*



A massless rope will transmit tension undiminished from one end to the other.

If the rope passes around a massless, frictionless pulley, the tension will be transmitted to the other end of the rope undiminished.

References:

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2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

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