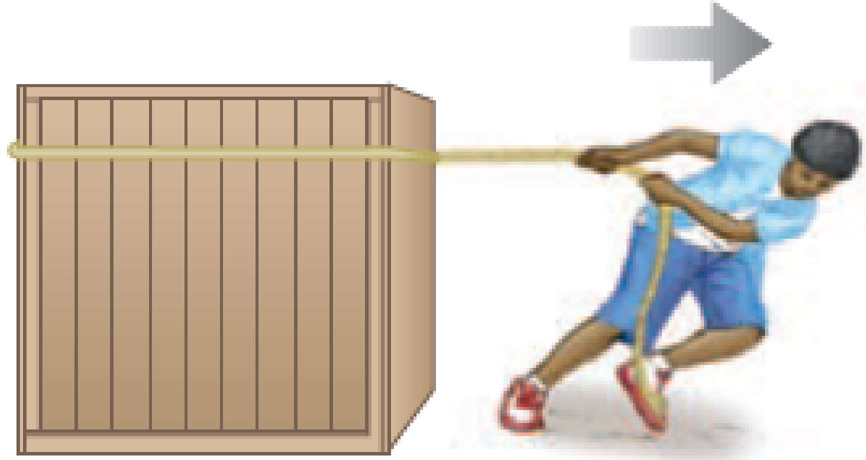
PHY101: Introduction to Physics I

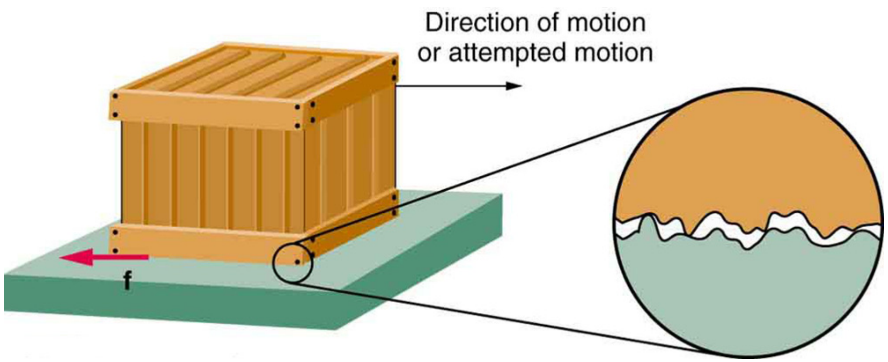
Monsoon Semester 2024
Lecture 10

Department of Physics, School of Natural Sciences,
Shiv Nadar Institution of Eminence, Delhi NCR

Previous Lecture

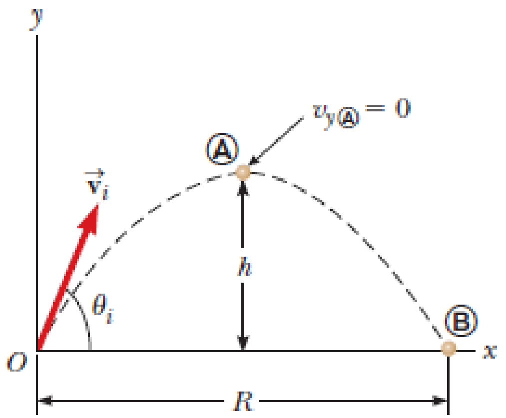
Tension
Problem solving





This Lecture

Contact force
Friction
Projectile motion



Surface Contact Force

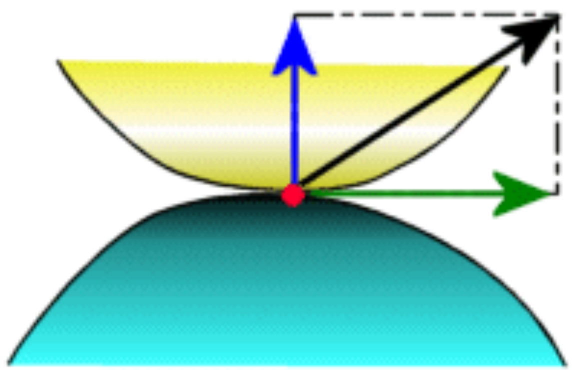
Surface Contact force comes into play when surfaces of two objects are in contact. It can be resolved into two components:

1. Normal component

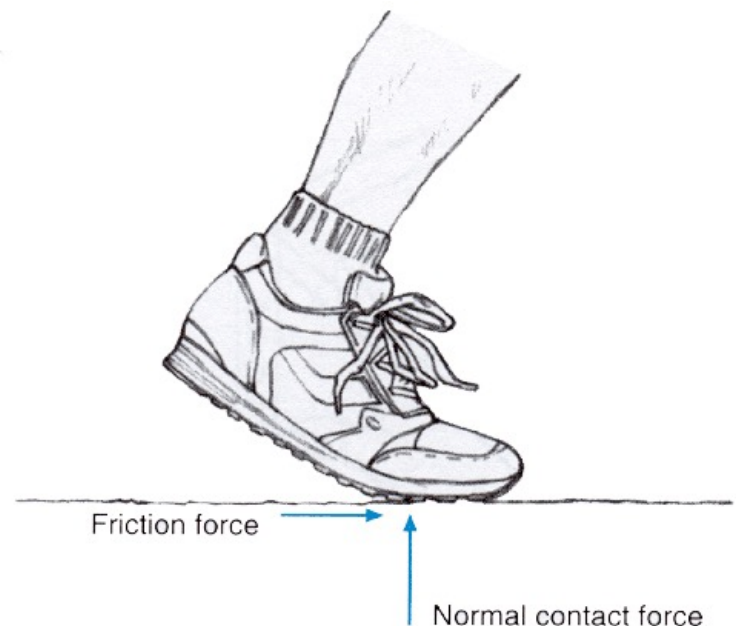
2. Tangential component (Friction)

Normal (to the surface) component

Total contact force



Tangential (to the surface) component

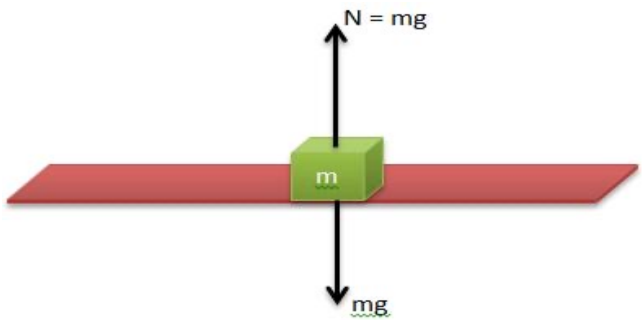


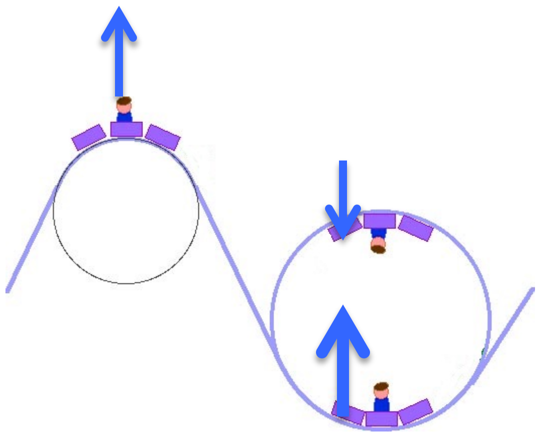
Forces by the ground on the shoe.

Image Sources:
http://biomechanics.byu.edu/exsc362%28hunter%29/images/runfriction.gif
http://help.solidworks.com/2013/English/SolidWorks/cworks/doc1292870117702.image

Normal Force

The perpendicular to the surface (normal) component of the total contact force exerted by a surface on a body in contact with it.





The reaction corresponding to the weight (not a contact force) of the box is the gravitational pull (not a contact force) exerted by the box on the earth.

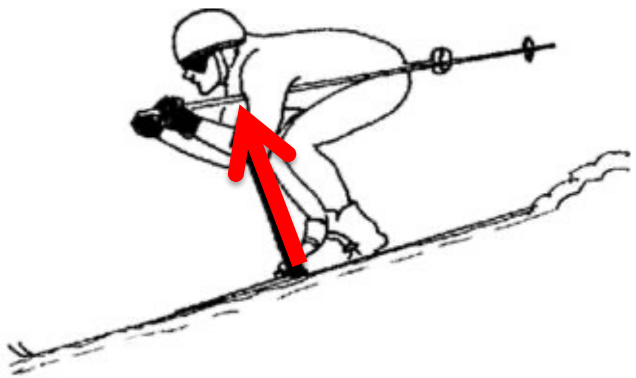


Image Sources:
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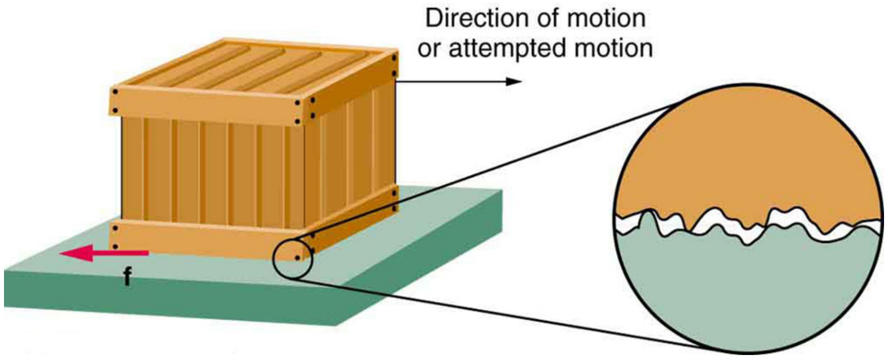
http://www.ux1.eiu.edu/~cfadd/1350/06CirMtn/Images/RCoaster1.jpg
http://content.answcdn.com/main/content/img/oxford/Oxford_Sports/0199210896.normal-reaction-force.1.jpg

Frictional force

The tangential to the surface component of the total force exerted by a surface on a body in contact with it. It arises when the surface of one body moves or tries to move, **relative** to the surface of a second body.

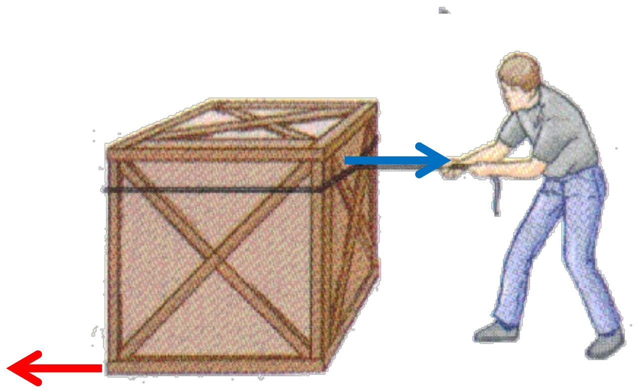


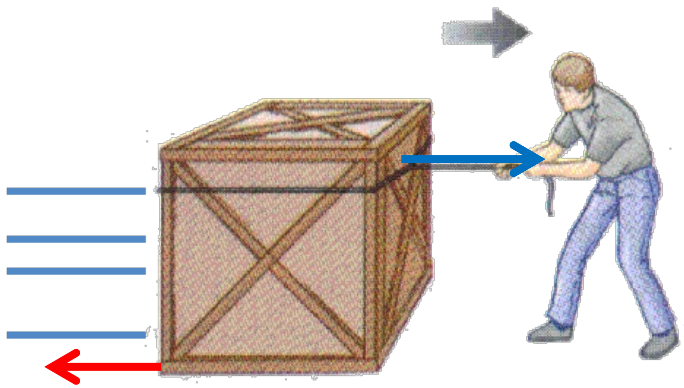
Some ususal properties of friction

- Note that **friction opposes the relative motion**!
- We won't be able to walk if there was no friction!
- An undesirable effect of friction is wear, which may lead to performance degradation and/or damage to components in a machine with moving parts.

Friction can be immensely powerful !!
Watch this:: http://youtu.be/QNo8unbVtEo

Static vs. Kinetic friction

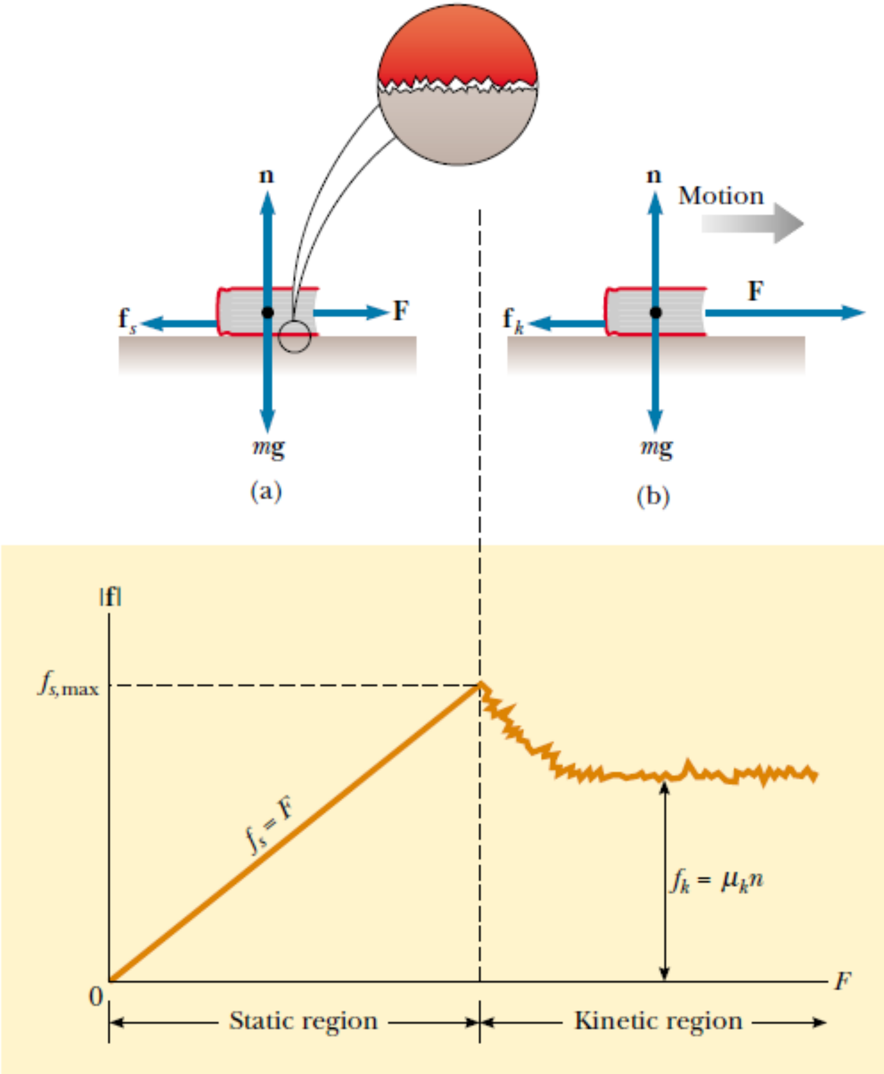




The man tries to pull the box by applying a force F (via tension in the rope). Frictional force (**static**) tries to prevent the relative motion between the lower surface of the box and the ground. The box does not move. The person increases the value of F. Friction also increases its value to counterbalance F, starting from 0 (when F is zero) up to a maximum value of $f_{s,max} = \mu_s N$

As soon as F> $f_{s,max}$, the box starts to slide. The frictional force (**kinetic**) trying to oppose the relative motion is $f_k = \mu_k N$ with μ_k, usually, slightly less than μ_s. The box moves with an acceleration $(F - f_k)/m$. If $F = f_k$, the box moves with a constant velocity.

Static vs. Kinetic friction



The behavior of friction force against the applied external force:

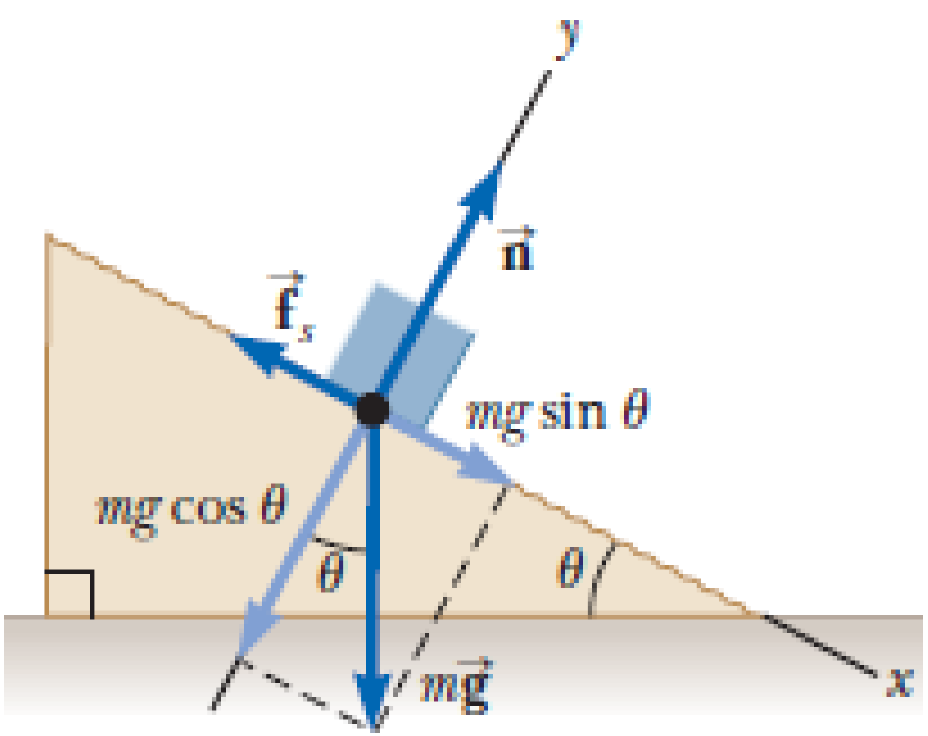
As an external force is applied to produce relative motion between an object and the surface in contact, the static friction comes into play. It keeps adjusting its value to counterbalance the external force till it reaches its maximum value (limiting friction = $\mu_s N$). After that the body starts to move relative to the surface, and kinetic friction $\mu_k N$ comes into the picture and acts against the relative motion.

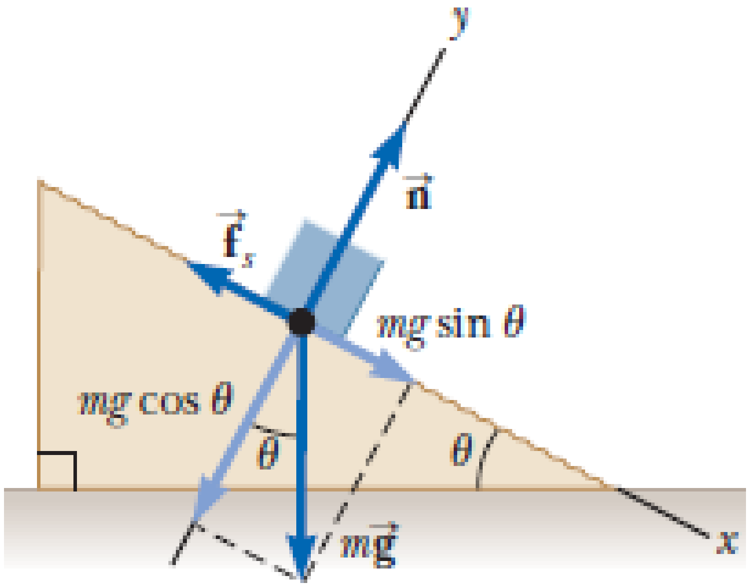
Problem 1: Threshold of the force against the static friction on a inclined surface

A block is placed on a rough surface inclined to the horizontal. The incline angle is increased until the block starts to move. Show that

$$\mu_s = tan\theta_c$$

θ_c is the angle at which the slipping just occurs.





$$(1) \quad \sum F_x = mg \sin \theta - f_s = 0$$

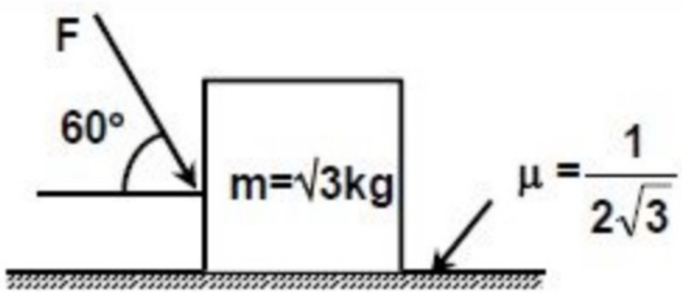
$$(2) \quad \sum F_y = n - mg \cos \theta = 0$$

$$(3) \quad f_s = mg \sin \theta = \left(\frac{n}{\cos \theta}\right) \sin \theta = n \tan \theta$$

$$\mu_s n = n \tan \theta_c$$

$$\mu_s = \tan \theta_c$$

Problem 2: Threshold of the force against the static friction on horizontal surface



The maximum value of the force F such that the block shown in the arrangement, does not move is given by:

Block does not move till the horizontal force on it becomes more than the maximum static frictional force.

$$F_{max} \cos\frac{\pi}{3} = \mu \left(mg + F_{max} \sin\frac{\pi}{3}\right)$$

$$= \frac{1 \times \left(\sqrt{3} \times 10 + \frac{\sqrt{3}F_{max}}{2}\right)}{2\sqrt{3}}$$

$$\Rightarrow \quad F_{max} = 20\text{ N}$$

Problem 3: (Homework)

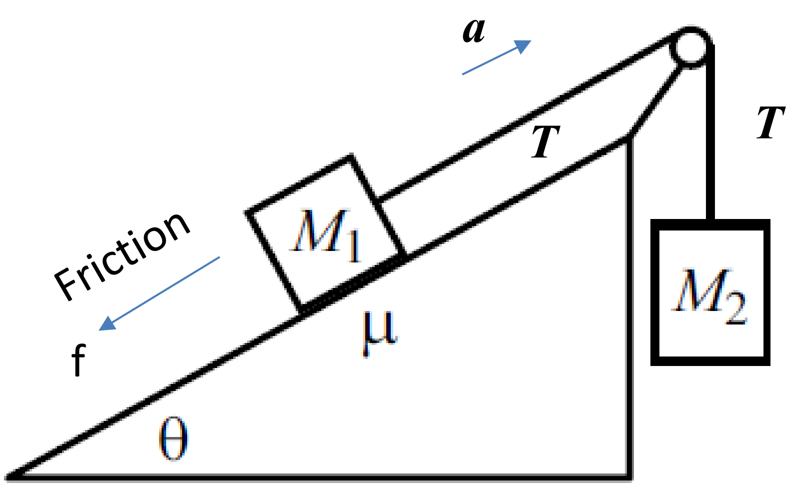
Mass M_1 is held on a plane with inclination angle θ, and mass M_2 hangs over the side. The two masses are connected by a massless string which runs over a massless pulley. The coefficient of kinetic friction between M_1 and the plane is μ_k. M_1 is released. Assuming that M_2 is sufficiently large so that M_1 gets pulled up the plane, what is the acceleration of the masses? What is the tension in the string?

Hints: Utilize these equations:

$$T - M_1 g \sin\theta - f = M_1 a$$

$$f = N\mu_k = \mu_k M_1 g \cos\theta$$

$$M_2 g - T = M_2 a$$



Next Lecture

Projectile motion