Spring 2014

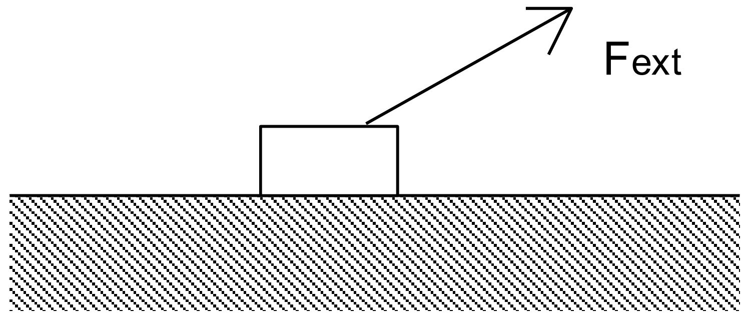
PHYS-2010

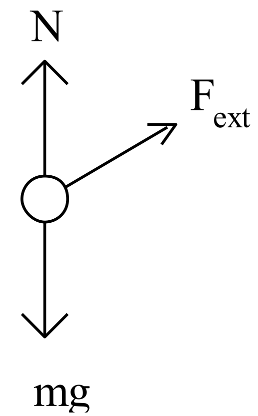
Lecture 18

Clicker Question

Room Frequency BA

A mass *m* is pulled along a frictionless table by <u>constant</u> external force F_{ext} at some angle above the horizontal. The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions of the forces are correct.





Which statement below must be true?

A) N < mg

B) N > mg

C) N=mg

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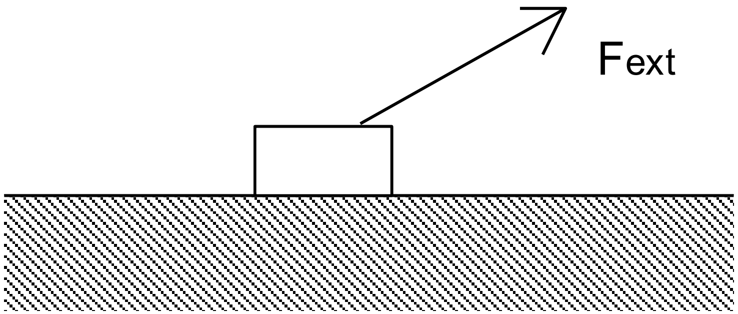
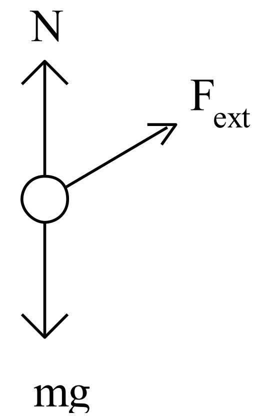




Which statement below must be true?

A) $N < mg$

B) $N > mg$

C) $N=mg$

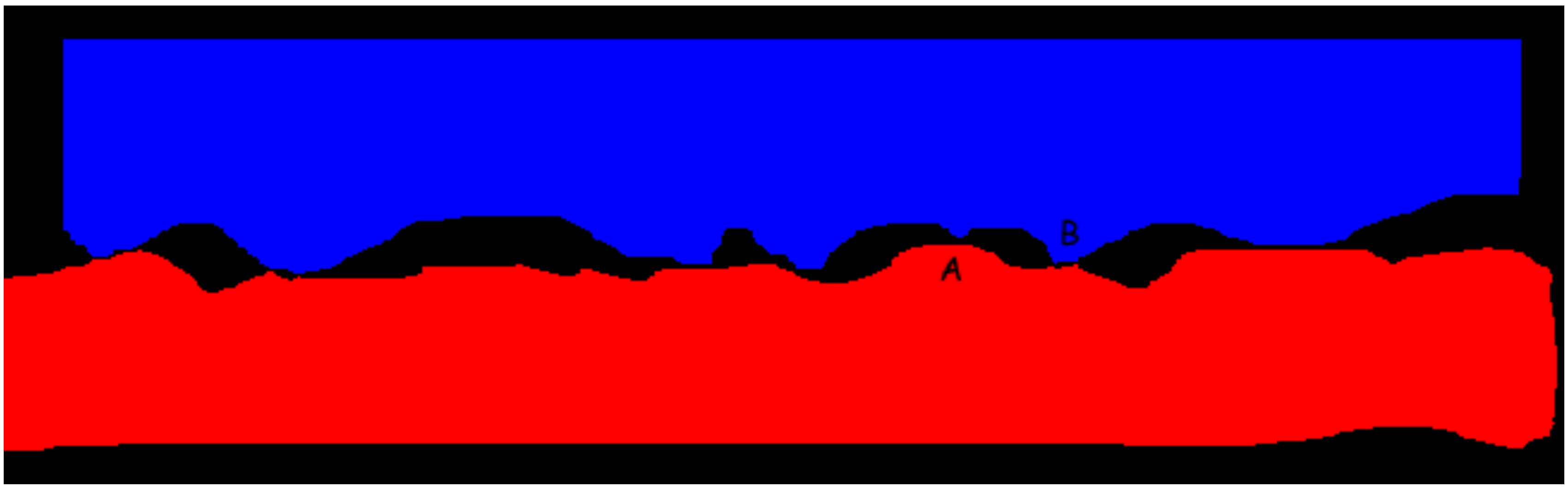
The F_{ext} force is assisting the table in holding up the mass, so the table does not have to exert as large a force as it would without F_{ext}.

$$N + F_{ext} \sin \theta = mg$$

Announcements

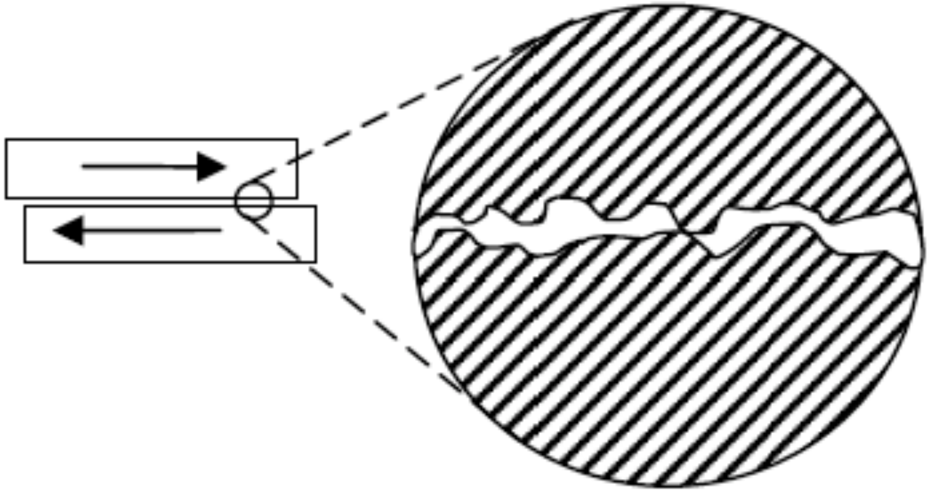
- Read Giancoli Chapter 5.
- **CAPA # 6** due Tuesday at 11 pm.
- **Written homework # 5** due Friday at 4 pm.
- This week in Section: **Recitation # 4, "Newton's Laws".**
- **Study Sessions** by Prof. Pollock will be held on Tuesdays, Feb. 25 and March 4, in G125, 5-6 pm.
- **Midterm II** will be on Thursday, March 6, at 7:30 pm.

Friction



Friction

Caused by microscopic surface roughness.



Friction Force is the contact force resisting the movement of two objects in physical contact past each other along the surface of contact.

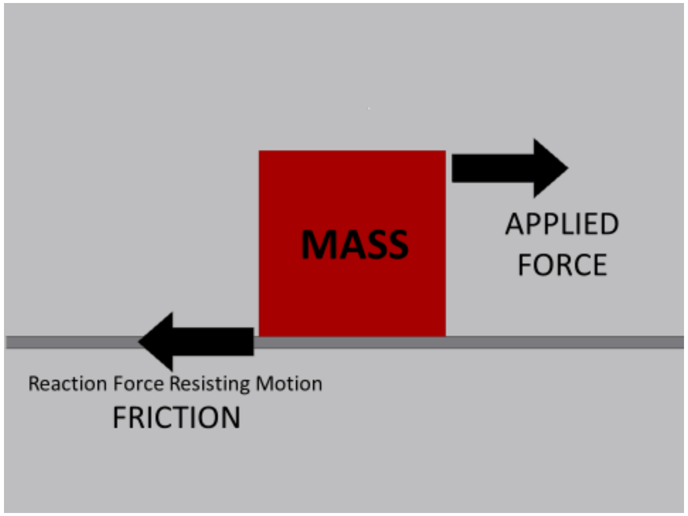
Force of Friction depends on:

1. **Relative motion of the two objects**
2. **Normal force pushing the materials together**
3. **Characteristics of materials**

Static versus Kinetic Friction: Direction

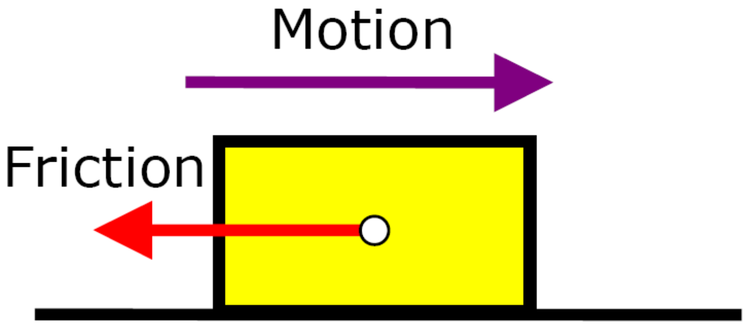
Static Friction: the objects are not moving relative to each other:

- Direction of friction of force is opposite to parallel component of the sum of all the other forces.

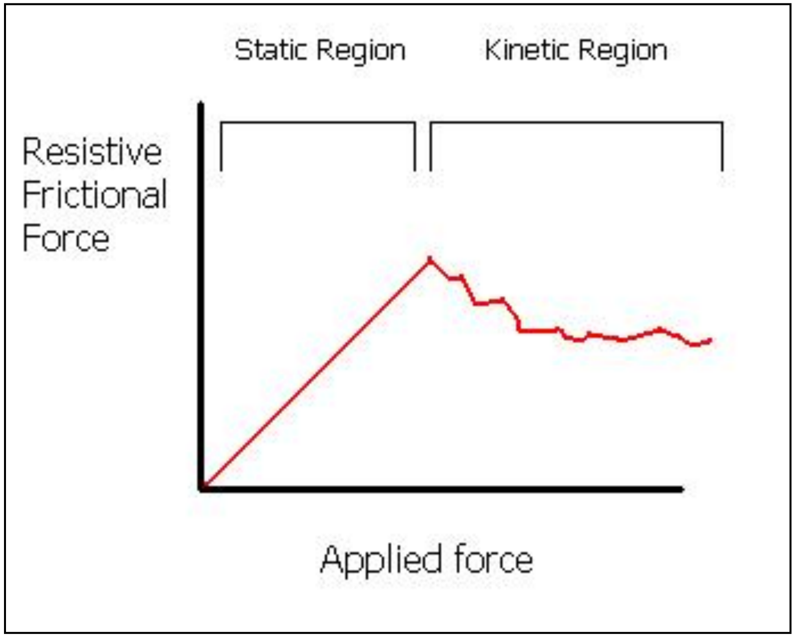


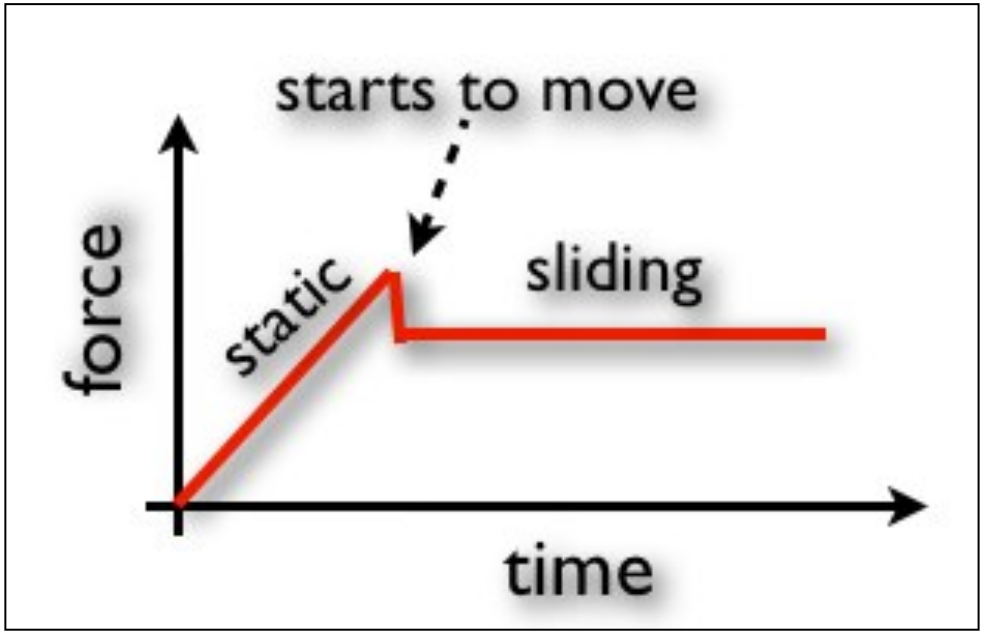
Kinetic Friction: objects are moving past each other:

- Direction of friction force is opposite to that of relative velocity.



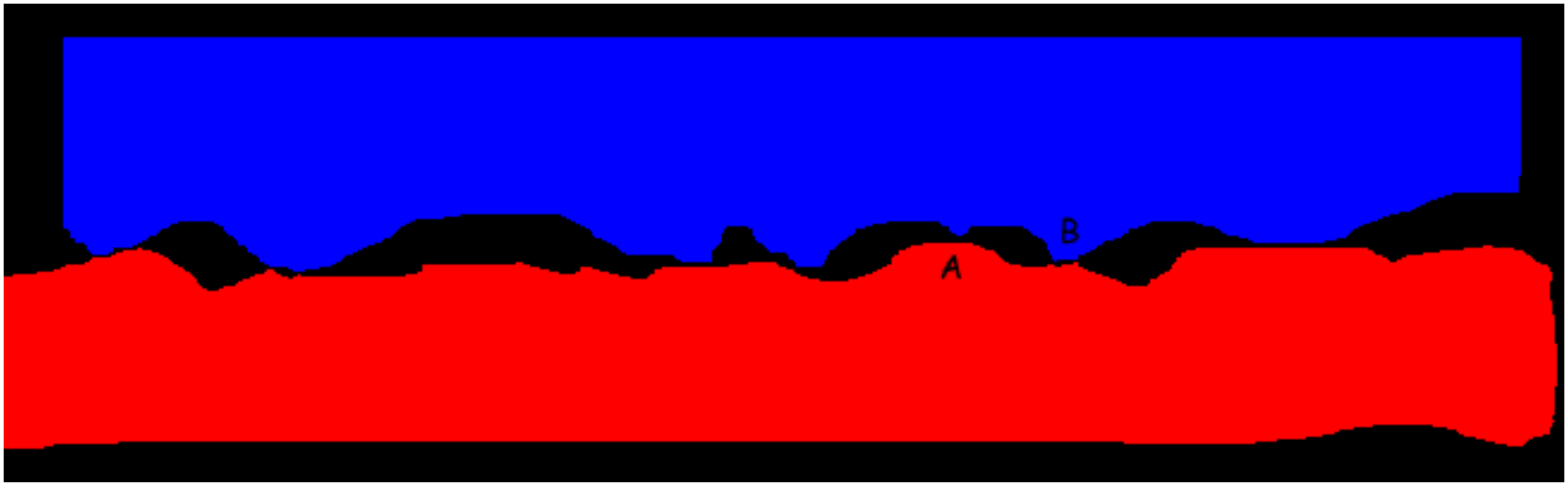
Static versus Kinetic Friction: Magnitude





- As long as the object is ***not moving***, the magnitude of the static friction force is equal to the parallel applied force.
- There exist a ***maximum static friction force***; once the applied force exceeds this maximum, the object starts to slide.
- The ***kinetic friction force*** on a moving/sliding object is independent of the pushing force.

Coefficient of Friction (μ)



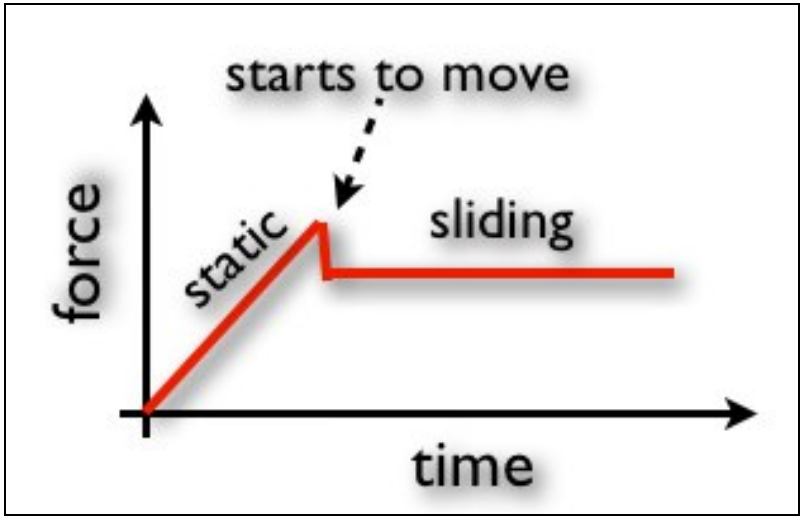
•Empirical observation: Both the maximum static friction force and the sliding friction force are proportional to the normal force – ***not to the area of contact!***

Force of Friction = coefficient of friction (μ) x
Normal Force pushing objects together

$$F_f\,(\text{stat,max}) = \mu_s\, N \qquad\qquad F_f\,(\text{kin}) = \mu_k\, N$$

Static versus Kinetic Friction

When an object is not moving (static), molecules can form more bonds and materials can deform into each other.



Thus, the coefficient of friction can be larger (coefficient of **static friction μ_s**).

Once the object is moving, friction is lower (coefficient of **kinetic friction μ_k**).

Static friction is different than and usually greater than kinetic (or sliding) friction:

$$\mu_S > \mu_K$$

Surfaces	μ (static)	μ (kinetic)
Steel on steel	0.74	0.57
Glass on glass	0.94	0.40
Metal on Metal (lubricated)	0.15	0.06
Ice on ice	0.10	0.03
Teflon on Teflon	0.04	0.04
Tire on concrete	1.00	0.80
Tire on wet road	0.60	0.40
Tire on snow	0.30	0.20

Clicker Question

Room Frequency BA

You are pushing horizontally with a force of 5,000 Newtons on a car that has a weight of 10,000 Newtons.

The car is not moving.

What can you say for certain about the coefficient of friction?

A) $\mu_s = 0$

B) $\mu_s = 0.1$

C) $\mu_s = 0.5$

D) $\mu_k = 0.5$

E) None of the above

$F_{net} = 0 = F_{push} - F_{friction}$

$0 = F_{push} - \mu_s \times N$

$\mu_s \times Mg = F_{push}$

$\mu_s = F_{push}/Mg = 5000/10000$

$\mu_s = 0.5$

But actually, μ_s could be even larger since we do not know if we have reached the maximum.