PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

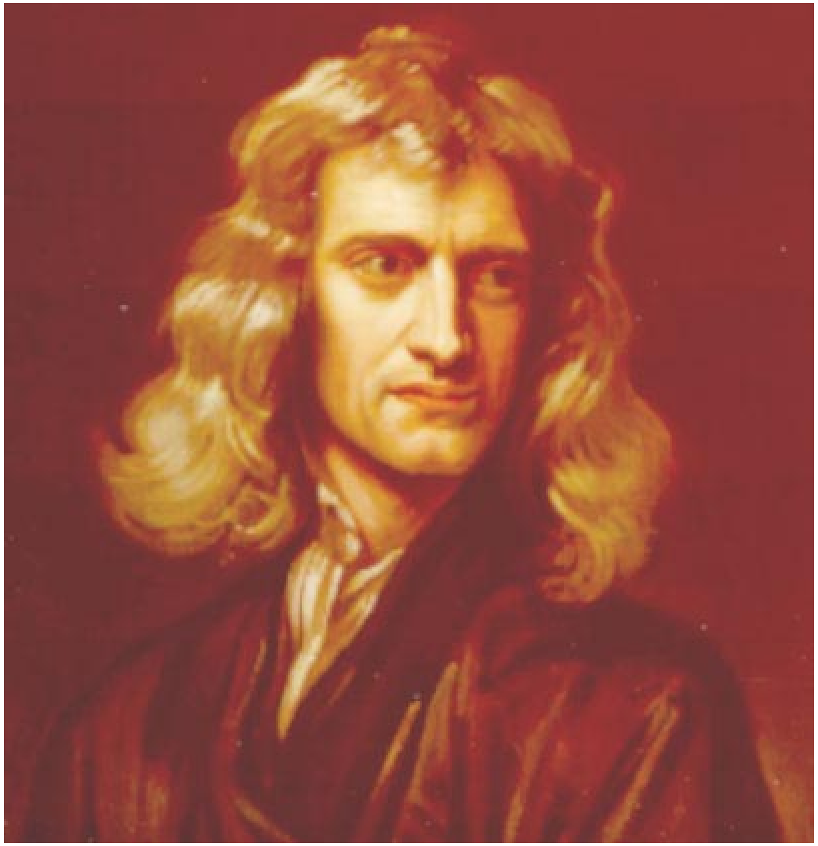
Plan for Lecture 8:

Chapter 5 – More applications of Newton's laws

1. Two dimensional statics and dynamics
2. Friction forces

No.	Lecture Date	Topic	Text Sections	Problem Assignments	Assignment Due Date
1	08/29/2012	Units & measurement	1.1-1.6	1.2,1.6,1.13,1.20	
2	08/31/2012	Motion in 1d -- constant velocity	2.1-2.3	2.1,2.8	09/07/2012
3	09/03/2012	Motion in 1d -- constant acceleration	2.4-2.8	2.13,2.16	09/07/2012
4	09/05/2012	Vectors	3.1-3.4	3.3,3.22	09/07/2012
5	09/07/2012	Motion in 2d	4.1-4.3	4.3,4.50	09/10/2012
6	09/10/2012	Circular motion	4.4-4.6	4.29,4.30	09/12/2012
7	09/12/2012	Newton's laws	5.1-5.6	5.1,5.13	09/14/2012
8	09/14/2012	Newton's laws applied	5.7-5.8	5.20,5.30,5.48	09/17/2012
	09/17/2012	Review	1-5		
	09/19/2012	Exam	1-5		
9	09/21/2012	More applications of Newton's laws	6.1-6.4		09/24/2012
10	09/24/2012	Work	7.1-7.4		09/26/2012

Isaac Newton, English physicist and mathematician (1642—1727)



1. In the absence of a net force, an object remains at constant velocity or at rest.
2. In the presence of a net force F, the motion of an object of mass m is described by the form F=ma.
3. $F_{12} = -F_{21}$.

http://www.newton.ac.uk/newton.html

Detail: "Inertial" frame of reference

Strictly speaking, Newton's laws work only in a reference frame (coordinate system) that is stationary or moving at constant velocity. In a non-inertial (accelerating) reference frame, there are some extra contributions.

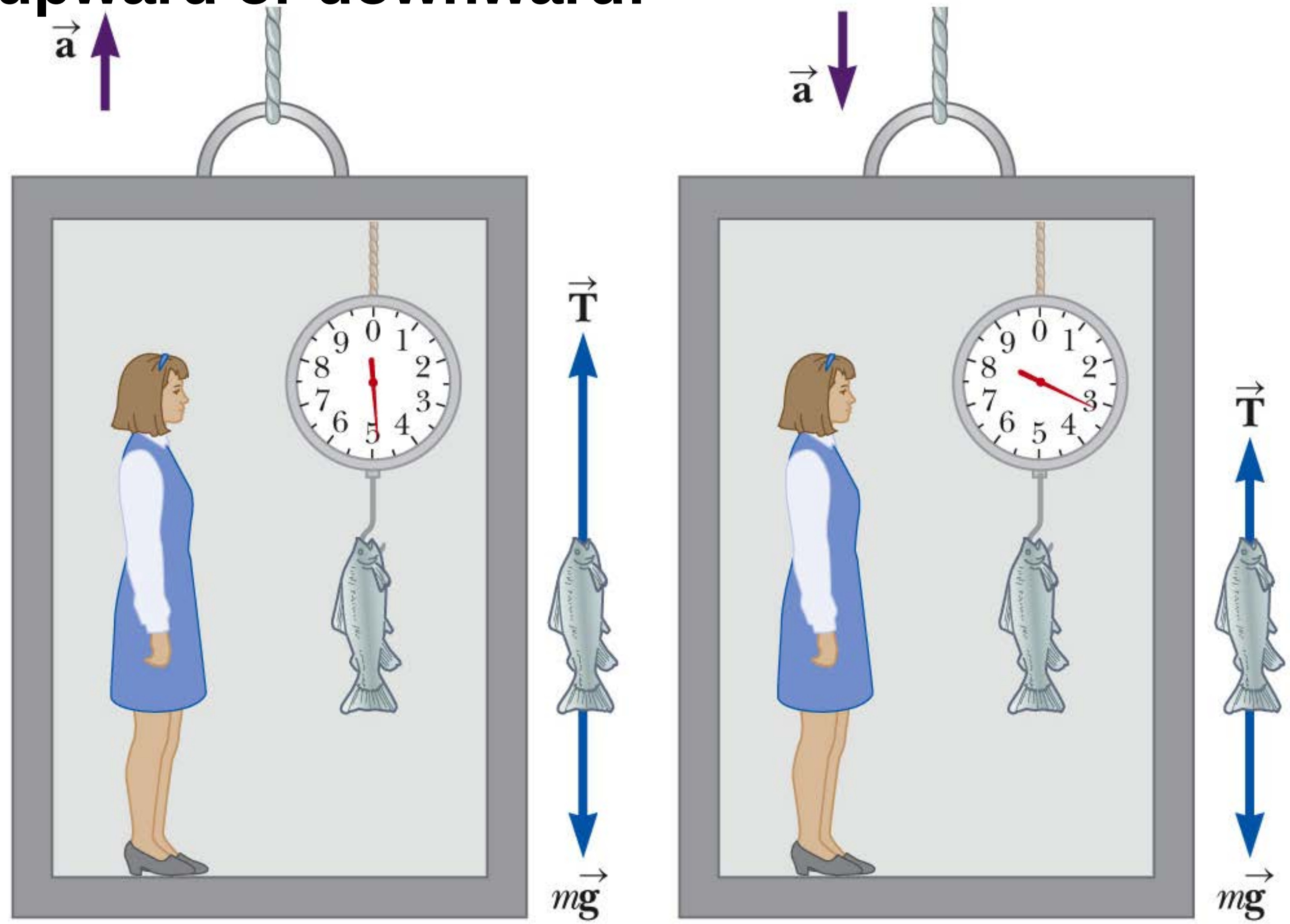
iclicker question:

Are we (here in Winston-Salem)

A. In an inertial frame of reference (exactly)
B. In a non-inertial frame of reference

Newton's laws are only approximately true in Winston-Salem, but the corrections are very small.

Example from last time – elevator accelerating upward or downward:

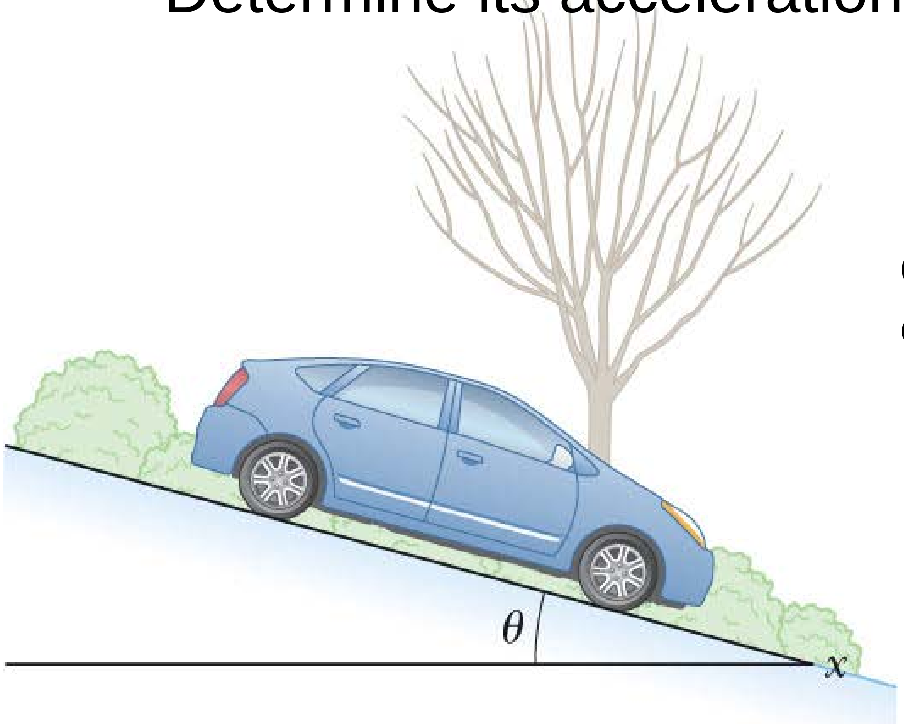


$$T - mg = ma$$
$$T = m(g + a)$$

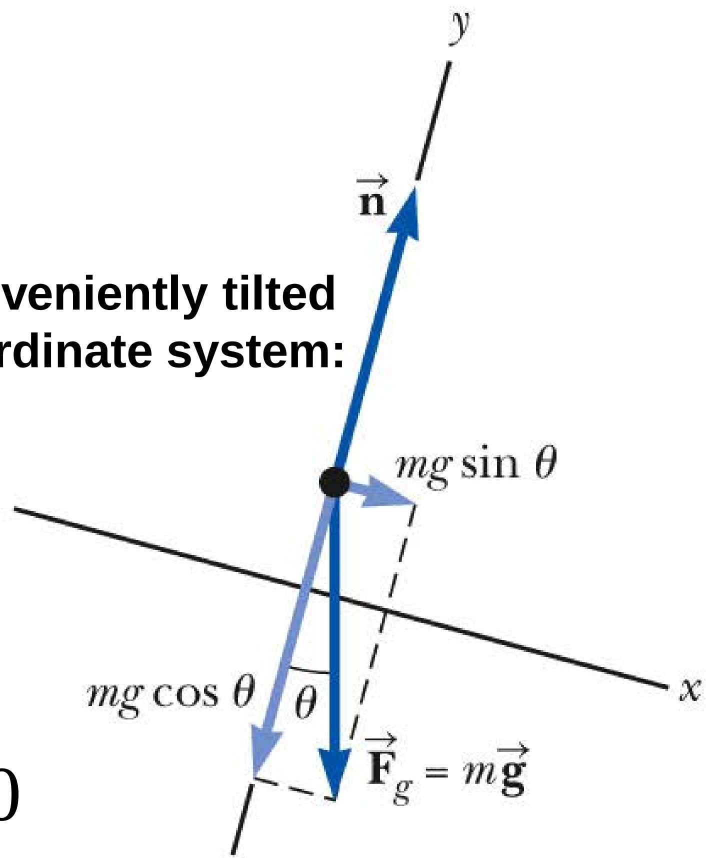
$$T - mg = -ma$$
$$T = m(g - a)$$

Example: 2-dimensional forces

A car of mass m is on an icy (frictionless) driveway, inclined at an angle t as shown. Determine its acceleration.



Conveniently tilted coordinate system:



$$\text{Along } y: \quad n - mg\cos\theta = 0$$

$$\text{Along } x: \quad mg\sin\theta = ma_x$$

$$a_x = g\sin\theta$$

Friction forces

The term “friction” is used to describe the category of forces that *oppose* motion. One example is surface friction which acts on two touching solid objects. Another example is air friction. There are several reasonable models to quantify these phenomena.

Surface friction: $f = \begin{cases} -F_{applied} \\ \pm \mu N \end{cases}$

Normal force between surfaces (N)

Material-dependent coefficient (μ)

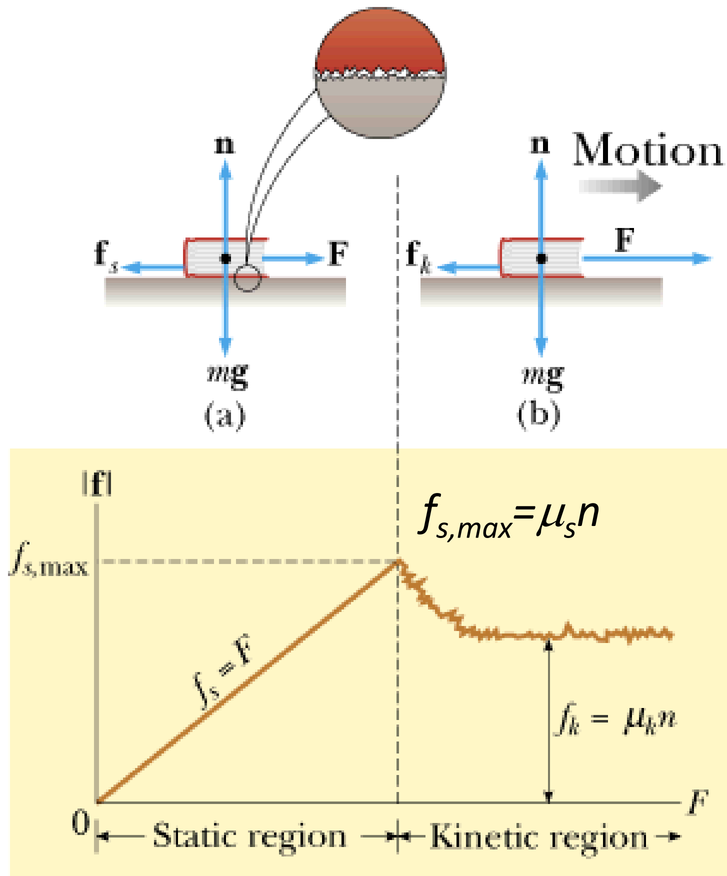
Air friction: $D = \begin{cases} -Kv & \text{at low speed} \\ -K'v^2 & \text{at high speed} \end{cases}$

K and *K’* are materials and shape dependent constants

Models of surface friction forces

Serway, Physics for Scientists and Engineers, 5/e
Figure 5.17

surface friction force



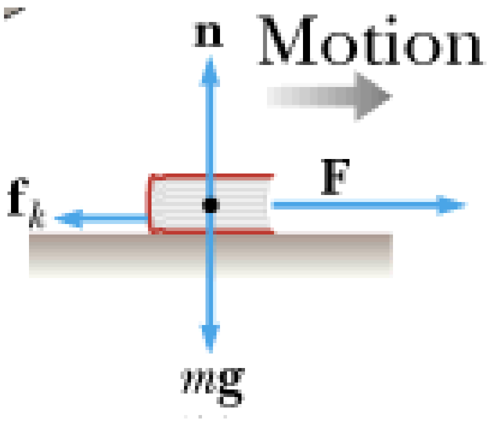
(applied force)

Coefficients μ_s , μ_k depend on the surfaces; usually, $\mu_s > \mu_k$

Some estimates of static and kinetic friction:

Material	μ_s	μ_k
Rubber on concrete	1.0	0.8
Wood on wood	0.3	0.2
Steel on steel with lubrication	0.09	0.05
Teflon on teflon	0.04	0.04

Surface friction:



$F\text{-}f_s = 0$ if $F < \mu_s n = \mu_s mg$

if $F > \mu_s n = \mu_s mg$, then $F\text{-}f_k = ma$ $(f_k = \mu_k mg)$

$$a = \frac{F - \mu_k mg}{m}$$

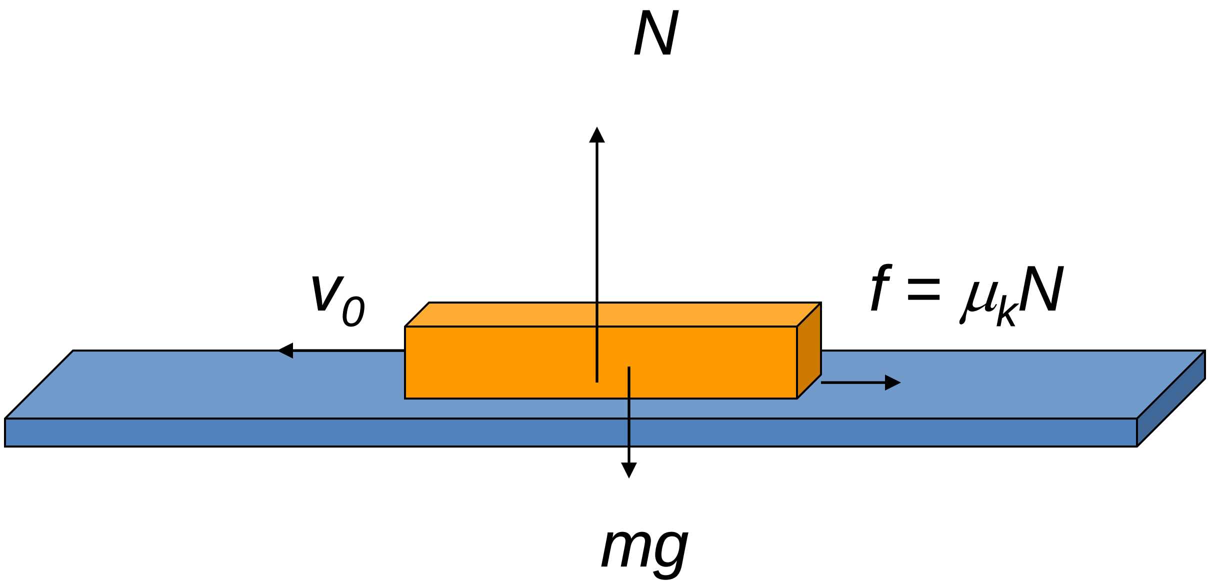
iclicker exercise:

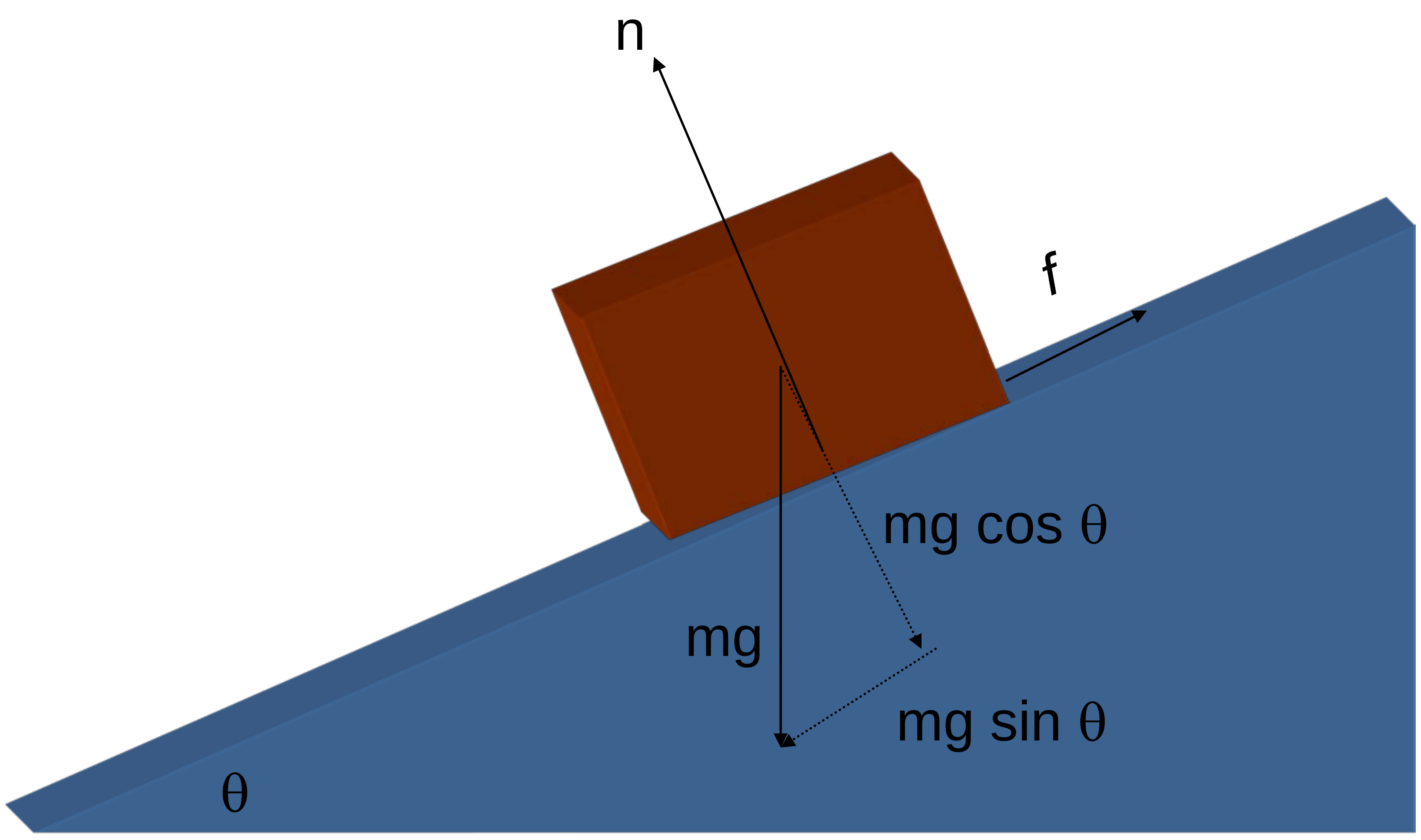
The figure below shows a block of mass m moving to left at constant velocity v_0. How is this possible?

A. There is an additional horizontal force pulling the block to the left.

B. There is and additional horizontal force pulling the block to the right.

C. This is not a possible physical situation.





just before block slips:

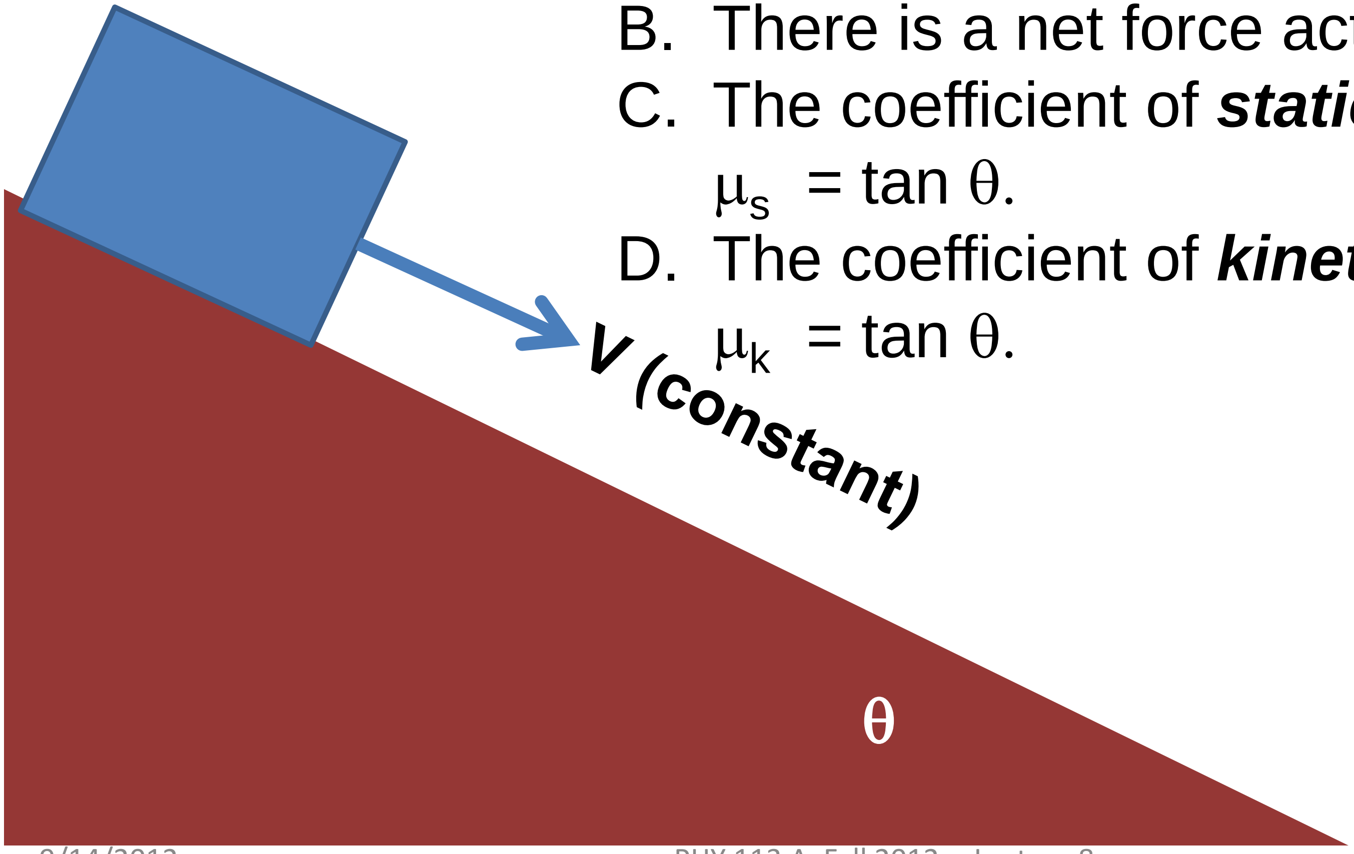
$$f_{s,max} - mg \sin\theta = \mu_s n - mg \sin\theta = \mu_s mg \cos\theta - mg \sin\theta = 0$$

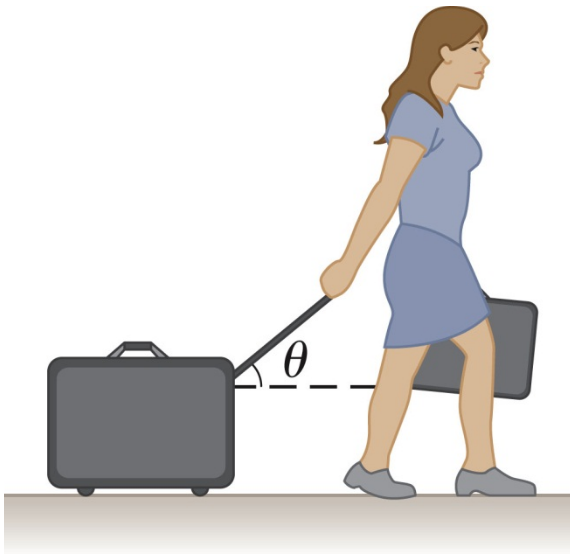
➔ **$\mu_s = \tan\theta$**

iclicker exercise:

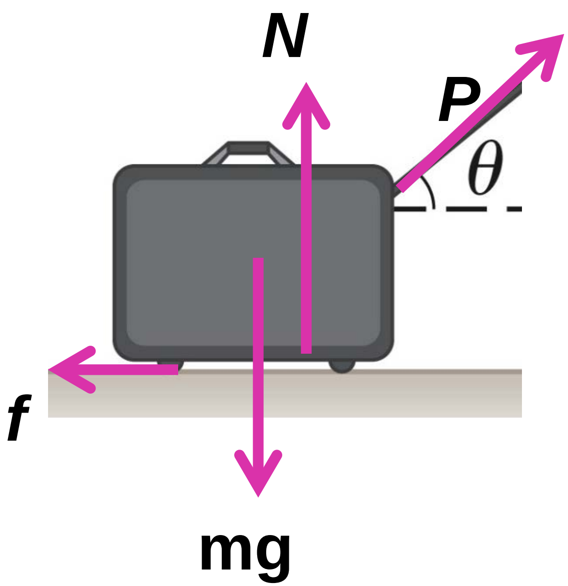
Suppose you place a box on an inclined surface as shown in the figure and you notice that the box slides down the incline at constant velocity V. Which of the following best explains the phenomenon:

A. There is no net force acting on the box.
B. There is a net force acting on the box.
C. The coefficient of ***static*** friction is $\mu_s = \tan\theta$.
D. The coefficient of ***kinetic*** friction is $\mu_k = \tan\theta$.





A women at an airport is towing her 20 kg suitcase at constant speed by pulling on a strap at an angle θ above the horizontal. She pulls on the strap with a *P*=35 N force, and the friction force on the suitcase is *f*=20 N. What is the value of the angle θ ?

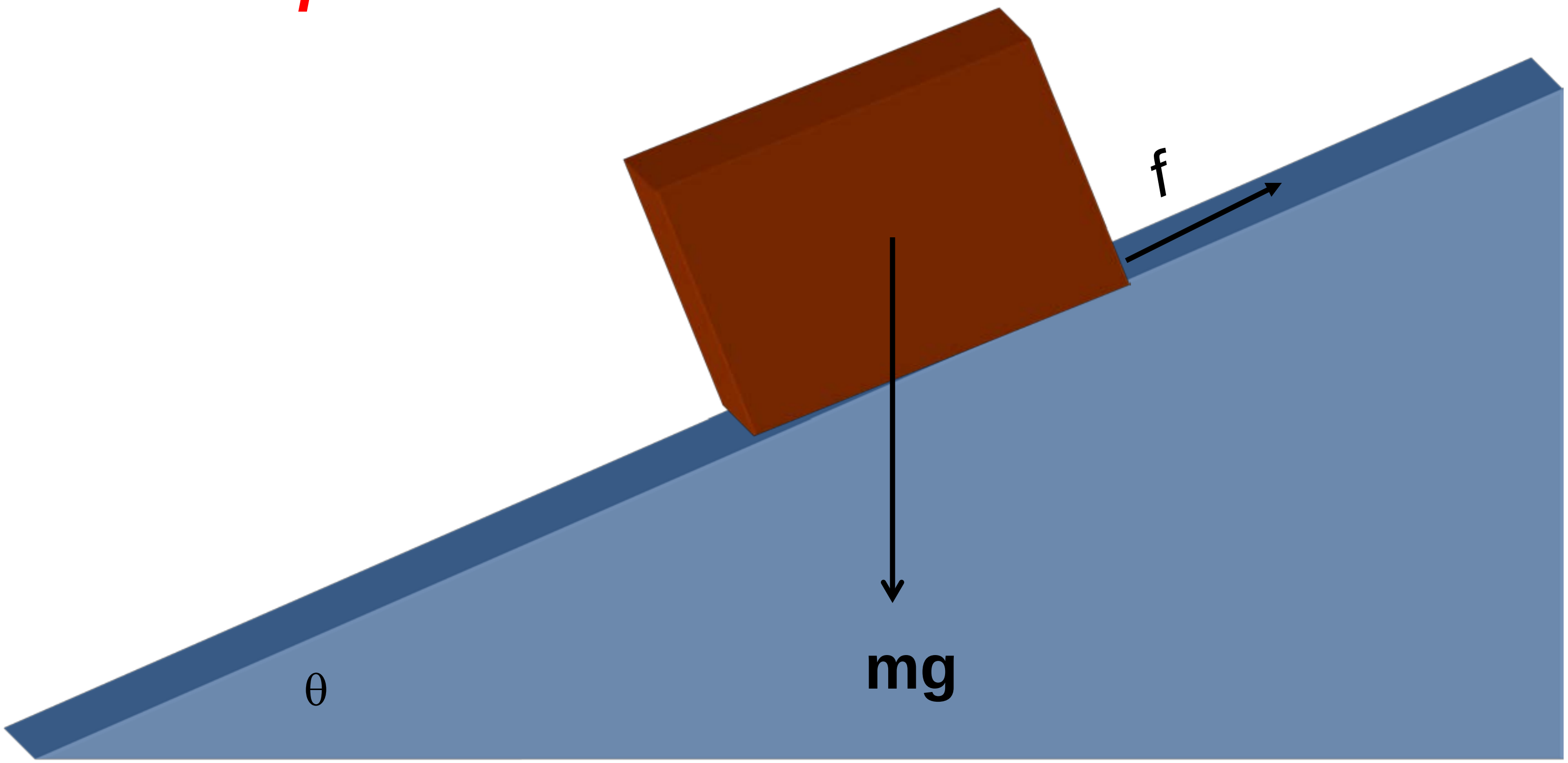


$$\text{Horizontal components: } P\cos\theta - f = 0$$

$$\text{Vertical components: } P\sin\theta + N - mg = 0$$

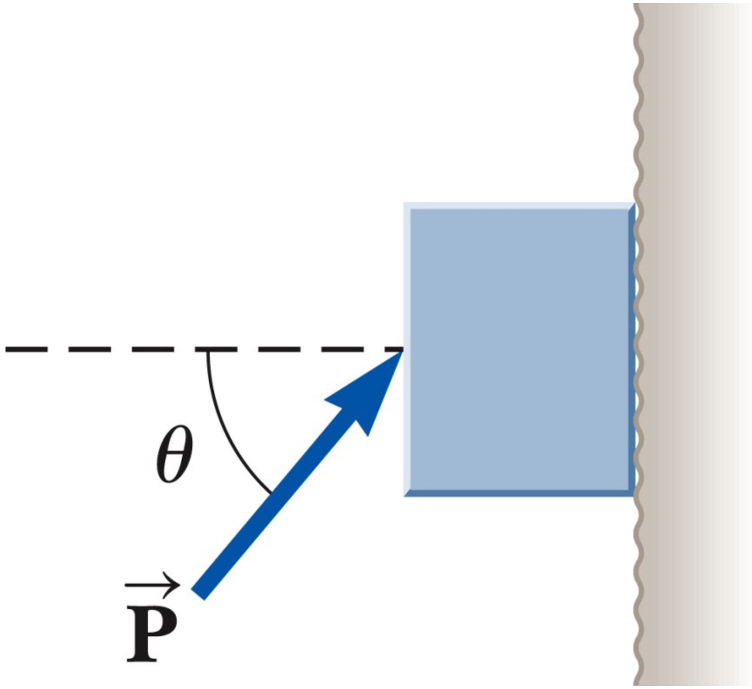
$$\Rightarrow \cos\theta = \frac{f}{P} = \frac{20}{35} \qquad \theta = 55.15^o$$

iclicker questions:

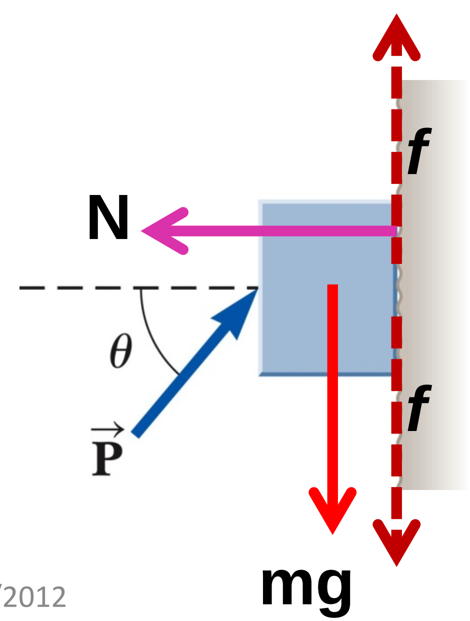


Suppose that μ_s=0.75 which means that the block starts to slide when θ= $\tan^{-1}(0.75)$ = 37°. What is *f* when θ= 20°?

A. mg sinθ B. μ_s mg sinθ C. mg cosθ D. μ_s mg cosθ

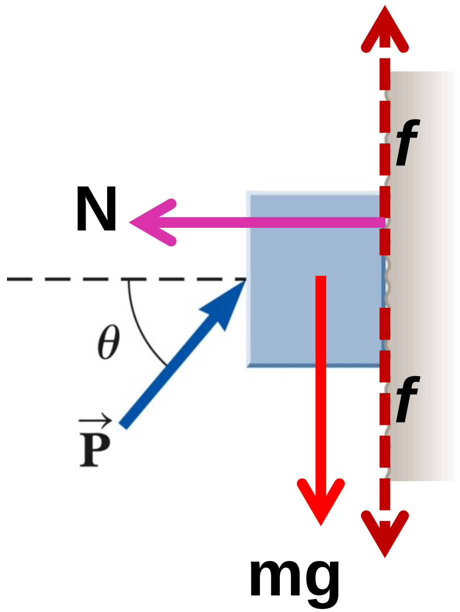


A block of mass 3 kg is pushed up against a wall by a force **P** that makes an angle of $\theta = 50^o$ with the horizontal. $\mu_s = 0.25$. Determine the possible values for the magnitude of P that allow the block to remain stationary.



$$\text{Vertical forces:} \quad \pm \mu_s N + P \sin\theta - mg = 0$$

$$\text{Horizontal forces:} \quad P \cos\theta - N = 0$$



$$\text{Vertical forces:}\quad \pm\mu_s N + P\sin\theta - mg = 0$$

$$\text{Horizontal forces:}\quad P\cos\theta - N = 0$$

$$N = P\cos\theta$$

$$\pm\mu_s P\cos\theta + P\sin\theta - mg = 0$$

$$\text{Solving for } P:\quad P = \frac{mg}{\sin\theta \pm \mu_s\cos\theta}$$

$$P = \frac{3\cdot 9.8\ \text{N}}{\sin 50^o \pm 0.25\cos 50^o}$$

$$= \begin{cases} 31.72\ \text{N} \\ 48.57\ \text{N} \end{cases}$$