Lecture 12
(Equilibrium, Dynamics, and Friction)

Physics 160-01 Fall 2012
Douglas Fields

Equilibrium and Dynamics

- Equilibrium = no acceleration = sum of forces = 0

$$\sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum F_z = 0$$

- Dynamics = acceleration = sum of forces = ma

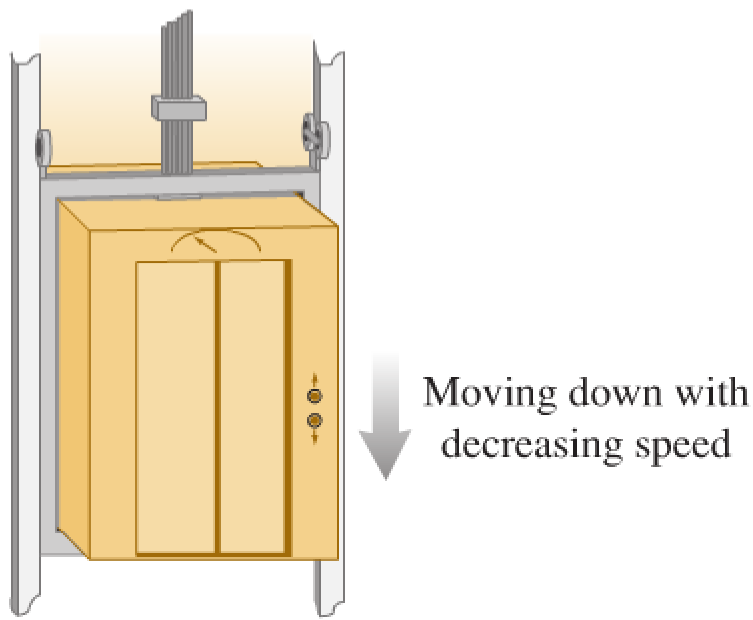
$$\sum F_x = ma_x \qquad \sum F_y = ma_y \qquad \sum F_z = ma_z$$

- Both of these cases are covered with Newton's second law: $\sum \vec{F} = m\vec{a}$
  so, I won't treat them differently.

Elevators…

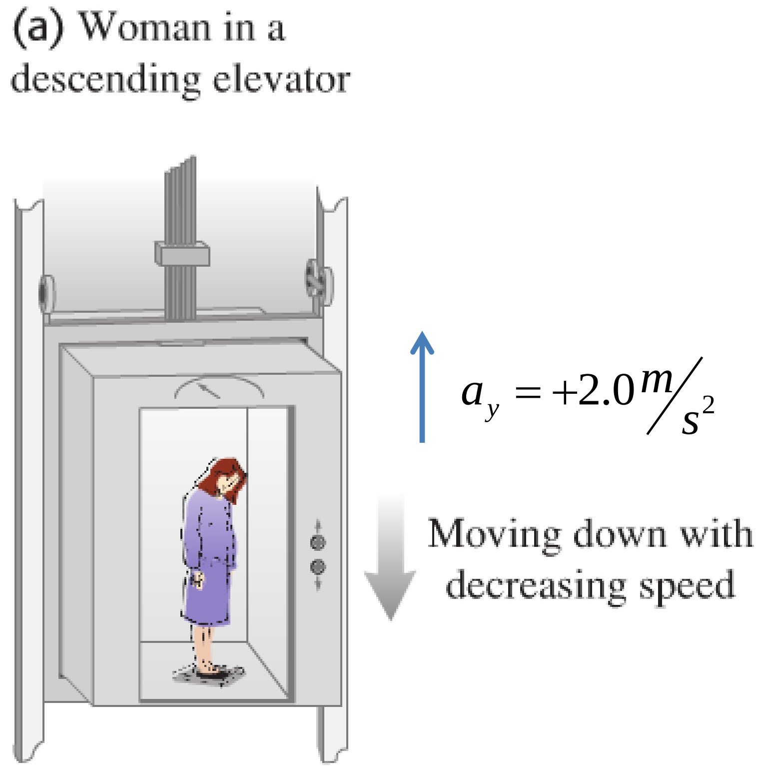
An elevator and its load have a combined mass of 800 kg (Fig. 5.9a). The elevator is initially moving downward at 10.0 m/s; it slows to a stop with constant acceleration in a distance of 25.0 m. What is the tension T in the supporting cable while the elevator is being brought to rest?

(a) Descending elevator



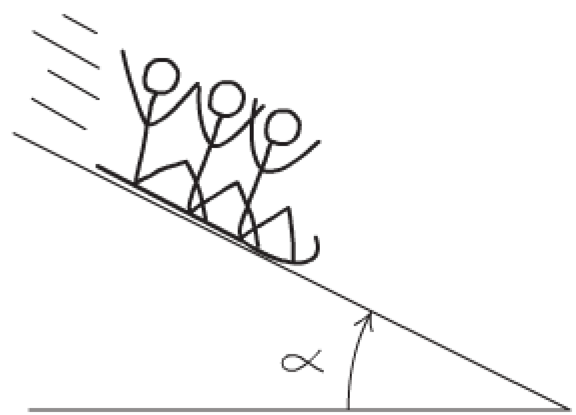
Elevators…

A 50.0-kg woman stands on a bathroom scale while riding in the elevator in Example 5.8. What is the reading on the scale?



Inclined Planes

A toboggan loaded with students (total weight w) slides down a snow-covered slope. The hill slopes at a constant angle α, and the toboggan is so well waxed that there is virtually no friction. What is its acceleration?

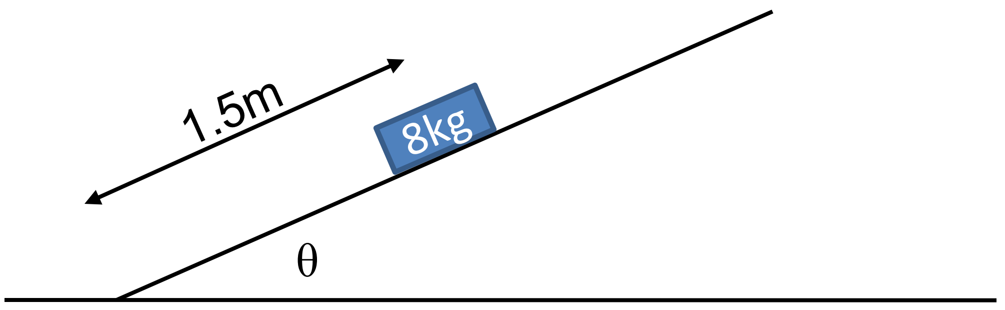


Problem

5.20. A 8.00-kg block of ice, released from rest at the top of a 1.50-m-long frictionless ramp, slides downhill, reaching a speed of 2.50 m/s at the bottom. (a) What is the angle between the ramp and the horizontal? (b) What would be the speed of the ice at the bottom if the motion were opposed by a constant friction force of 10.0 N parallel to the surface of the ramp?

Two Problems:

1) 1D motion with acceleration
2) Newton's Second Law



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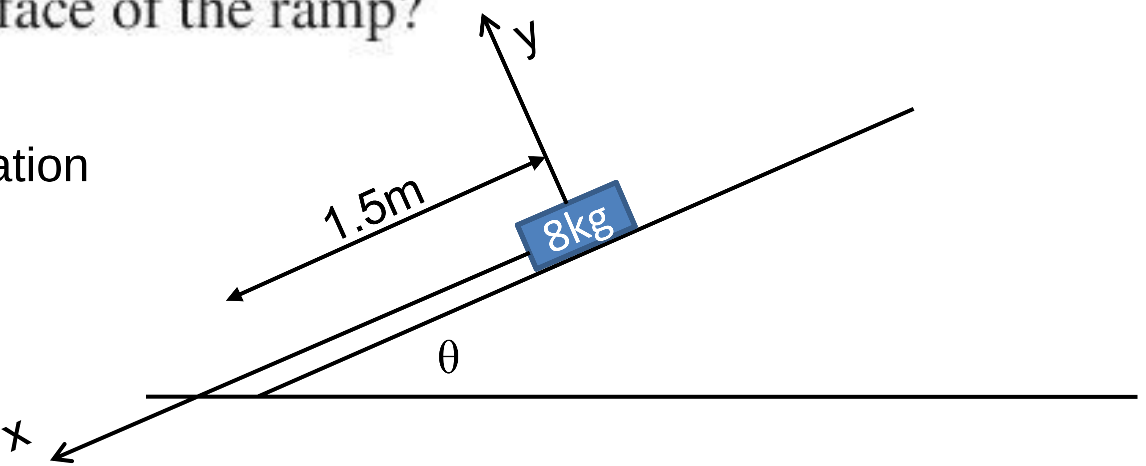

1) 1D motion with acceleration

$x_0 = 0m$
$x_f = 1.5m$
$v_{x0} = 0m/s$
$v_{xf} = 2.5m/s$
$a_x = ?$
$t = ?$

$$v_{xf}^2 = v_{x0}^2 + 2a_x(x_f - x_0)$$

Problem

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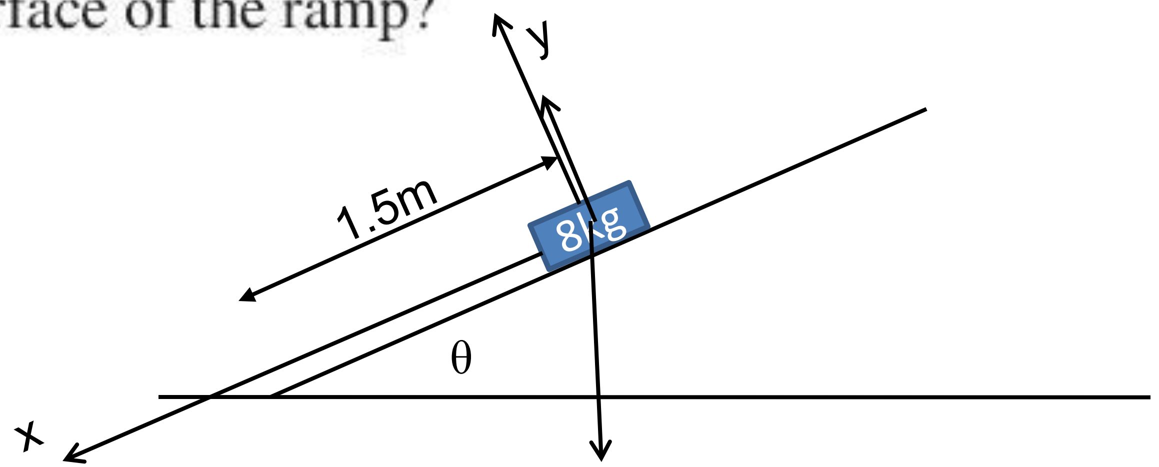
2) Newton's Second Law

a_x = from last slide

$$\sum F_x = ma_x$$



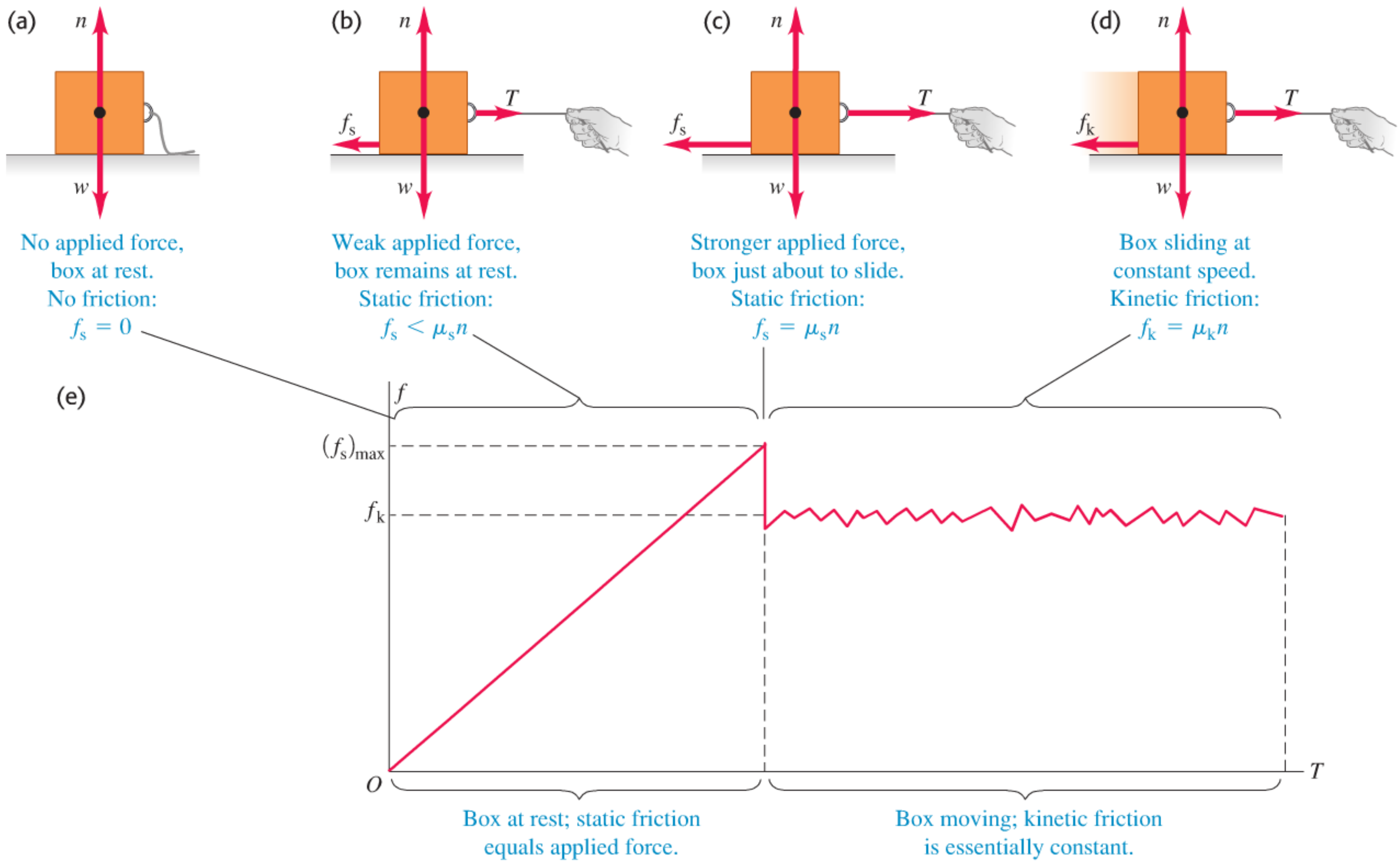
Friction

- Static Friction:
  - Magnitude depends on situation.
  - Has a maximum value = $\mu_s F_N$.
  - Opposes force to move something.
- Kinetic (motion) friction:
  - Always has the same magnitude = $\mu_k F_N$
  - $\mu_k < \mu_s$
- Neither depend upon surface area!

Other Friction Forces

- Rolling Friction
  - $f = \mu_r F_N$
- Fluid Resistance
  - For low speeds: $f = kv$
  - For high speeds: $f = Dv^2$
- Terminal speed:
  - For low speeds: $v_t = mg/k$
  - For high speeds: $v_t = \sqrt{(mg/D)}$

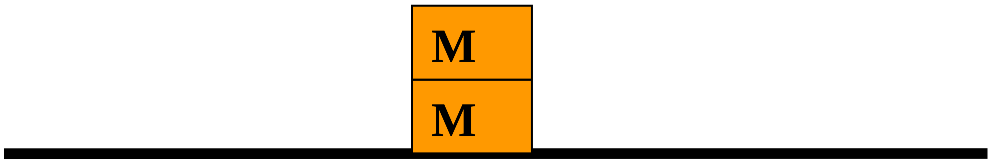
Friction



(a)
n
w
No applied force,
box at rest.
No friction:
$f_s = 0$
(b)
n
T
f_s
w
Weak applied force,
box remains at rest.
Static friction:
$f_s < \mu_s n$
(c)
n
T
f_s
w
Stronger applied force,
box just about to slide.
Static friction:
$f_s = \mu_s n$
(d)
n
T
f_k
w
Box sliding at
constant speed.
Kinetic friction:
$f_k = \mu_k n$
(e)
f
$(f_s)_{max}$
f_k
O
T
Box at rest; static friction
equals applied force.
Box moving; kinetic friction
is essentially constant.

CPS Question 11-1

- **A block of mass M sits on a horizontal plane with a coefficient of static friction of μ_s. Another mass M is added on top of the block. What happens to the force of friction between the bottom block and the table?**



A) It doubles.

B) It's halved.

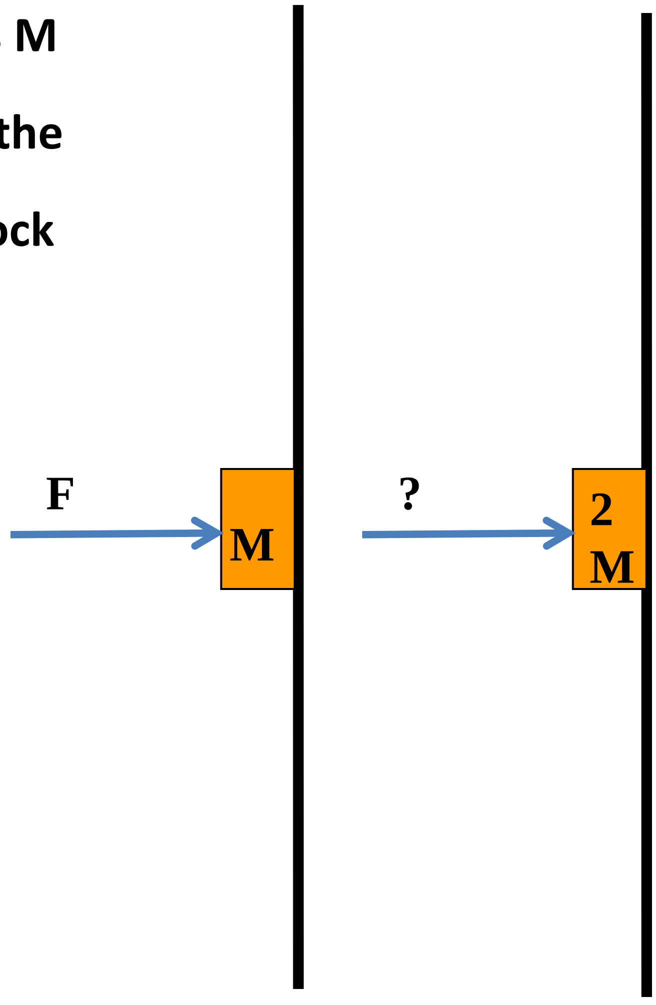
C) It stays the same.

D) It depends upon the surface of the table.

E) It cannot be determined.

CPS Question 11-2

- **A person pushes with force F on a block of mass M held against a wall with a coefficient of static friction of μ_s. If the mass is replaced with twice the mass but remains held against the wall, what happens to the force of friction between the block and the wall?**



A) It doubles.

B) It's halved.

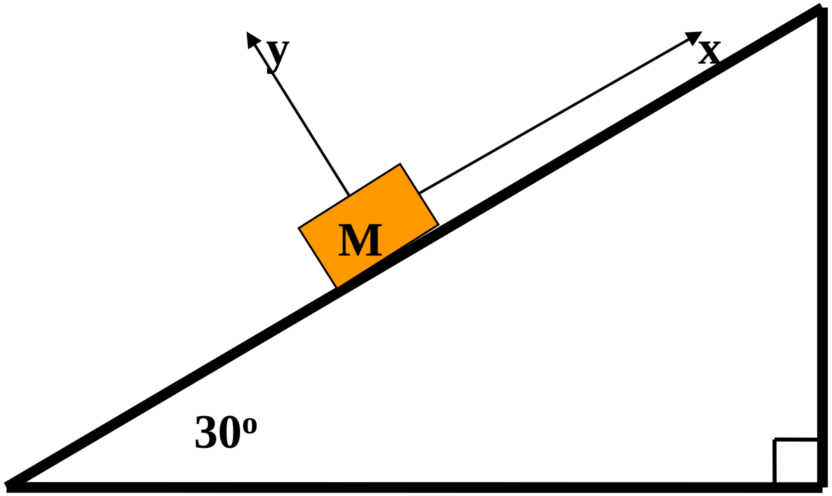
C) It stays the same.

D) It depends upon the surface of the wall.

E) It cannot be determined.

CPS Question 11-3

- **A block of mass M sits on an inclined plane with a coefficient of static friction of μ_s. Which best describes the force of friction on the block?**



A) μ_s*Mg in the positive x-direction

B) μ_s*Mg in the negative x-direction

C) Mg*sin(30) in the negative x-direction

D) Mg*sin(30) in the positive x-direction

E) μ_s*Mg*cos(30) in the negative x-direction