

# **Week 4-6 Topics**

**Chapter 3. Relative position and velocity**

**Chapter 4. Newton's laws of motion**

**Types of forces**

**Free body diagrams**

**Chapter 5. Friction and centripetal force**

**Exam I follows Chapter 5.**

# Outline for Day W4,D3

Return Quiz 2 (mean = 5.4/7)

Relative Velocity & Newton's 1<sup>st</sup> law

Types of Forces

## Homework

Ch. 4 P. 1-5,7,12-14,28,33,42,45,47,48

MisQ 1-11 (odd), Read Sec 1-8. Due 2/23

## Notes:

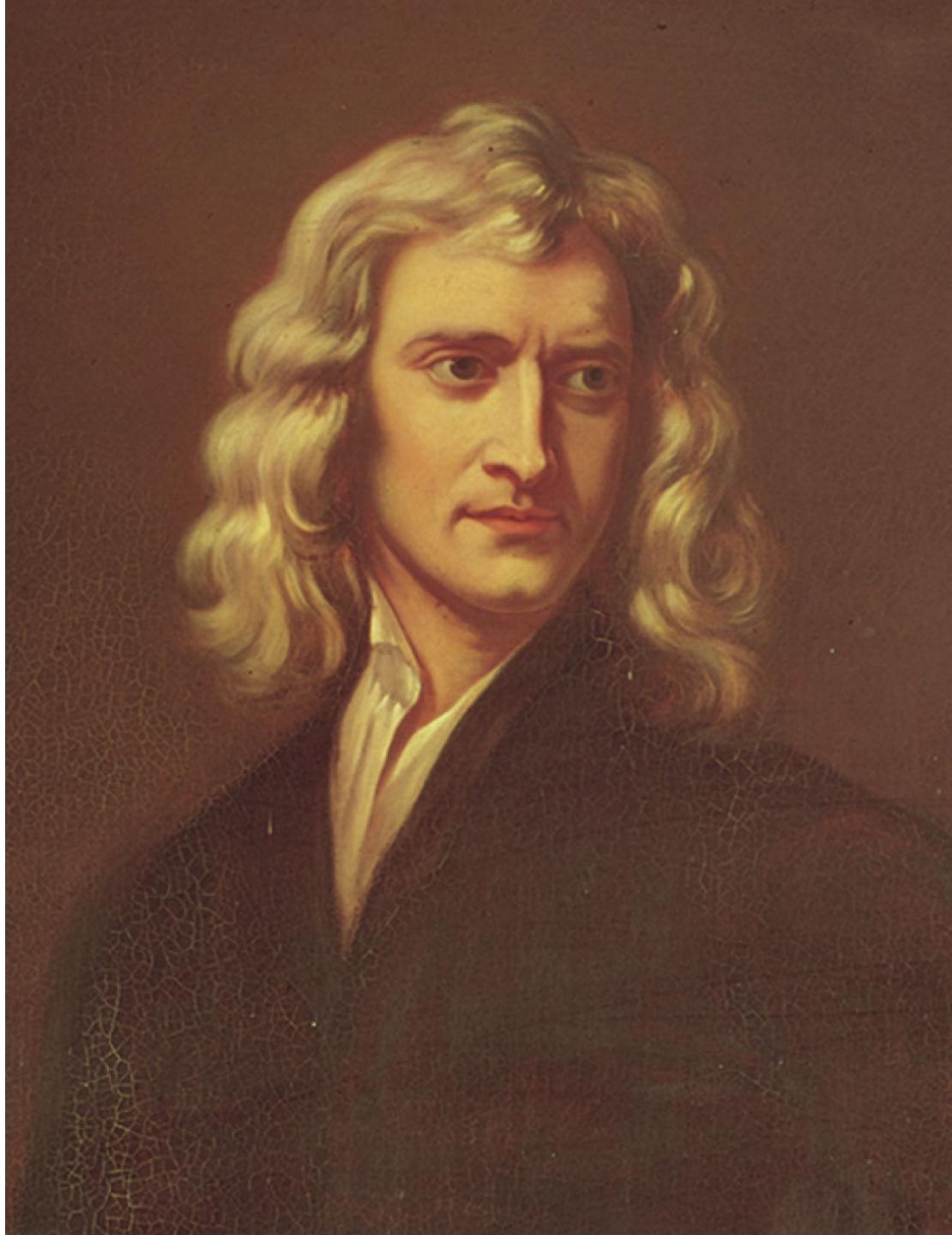
“NEW STUFF” has new PPT, YouTube (FOR), rel. motion problems, practice problems on force.

Exam I follows Chapter 5 material.

Isaac Newton  
(1642 - 1727)

3 laws of motion

1 law of Universal  
Gravitation

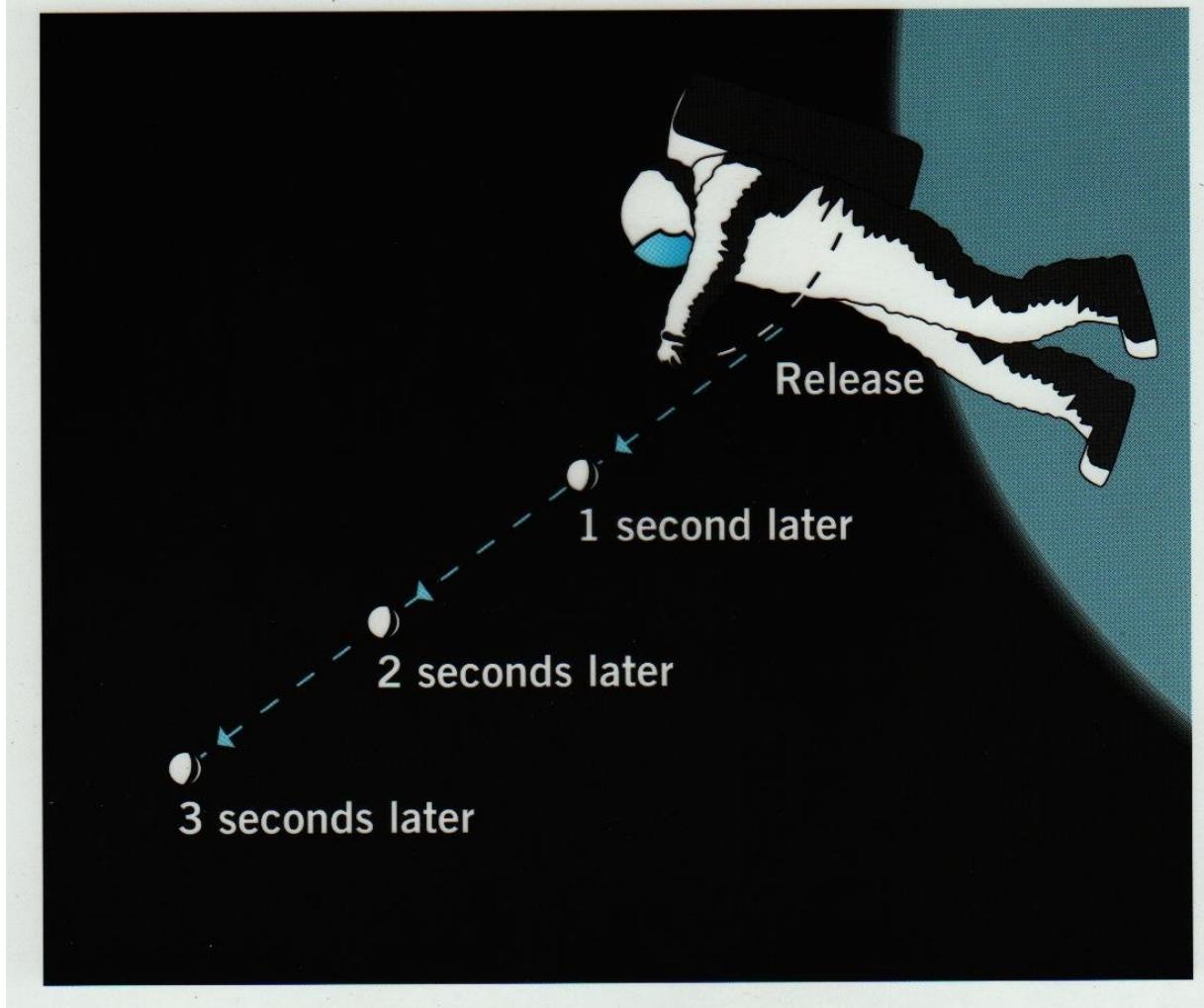


Newton's 1<sup>st</sup> law = inertial frames of reference exist such that an object will move with a constant velocity if no forces act upon it.

Overthrows Aristotle and medieval ideas:

“natural state” is at rest

“impetus” pushes an arrow along



# Relative Motion Problem

Each person is in a different inertial frame-of-reference!

So we can say

$$v_{CA} = v_{CB} + v_{BA}$$

The woman standing on the beltway sees the man moving with a slower speed than does the woman observing the man from the stationary floor.

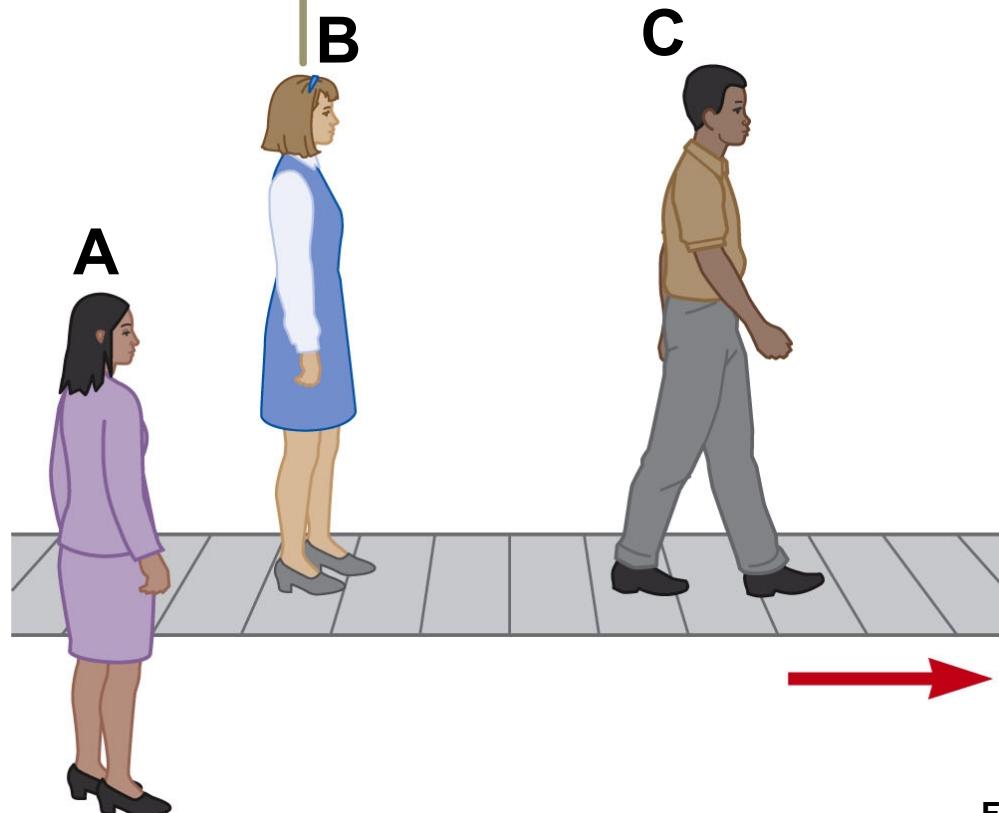


Fig. 4.19, p. 90

Transforming between two frames of reference, A and B.

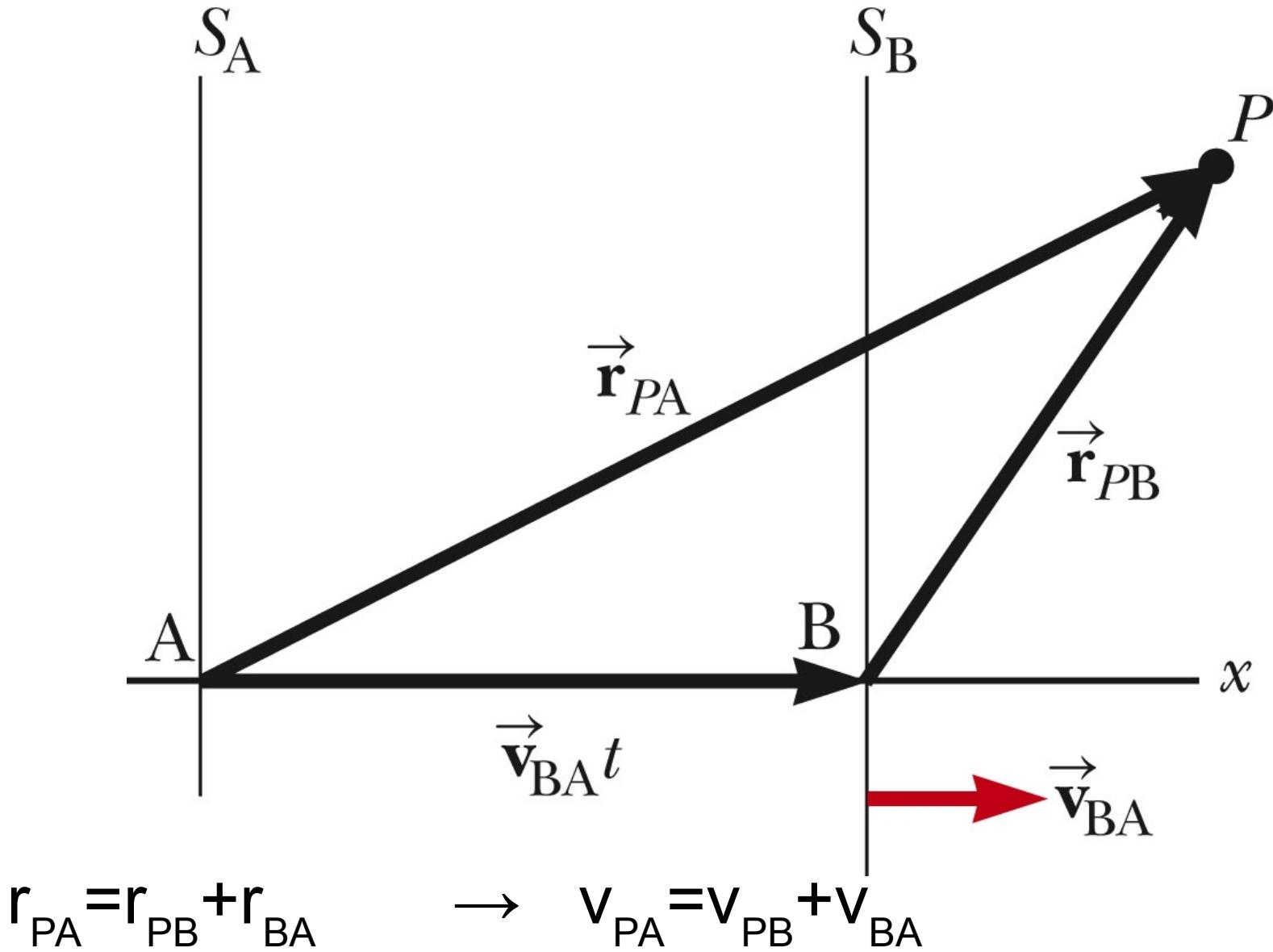


Fig. 4.20, p. 91

## **Examples of non-inertial frames of reference**

- 1) Inside of a truck that is accelerating in a line.
- 2) Inside of a car that is turning (even if moving at a constant speed).
- 3) Standing on a rotating platform. (See movie “Frames of Reference”)
- 4) The planet Earth! (See movie “Frames of Reference” and the Foucault pendulum.)

# Forces – the cause of acceleration

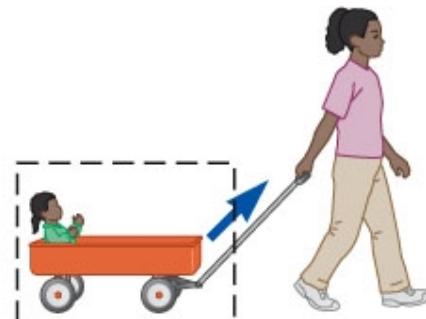
Forces are vectors

Forces act between systems (the dashed boxes)

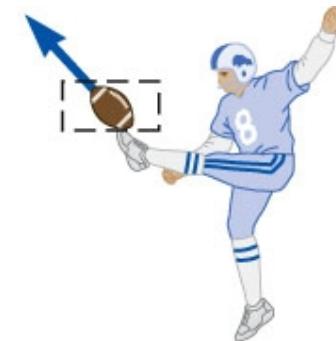
Contact forces



a

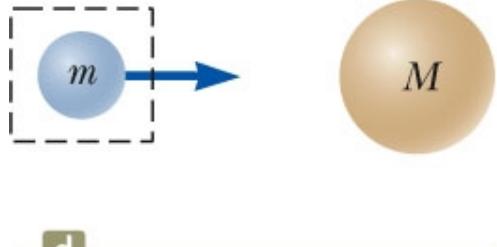


b

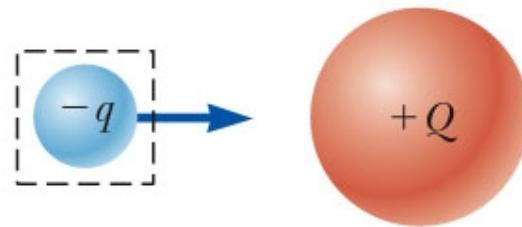


c

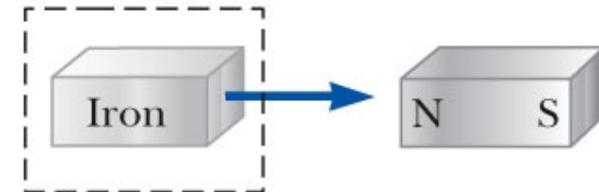
Field forces



d



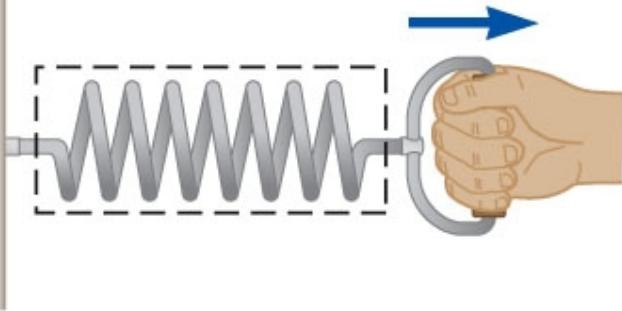
e



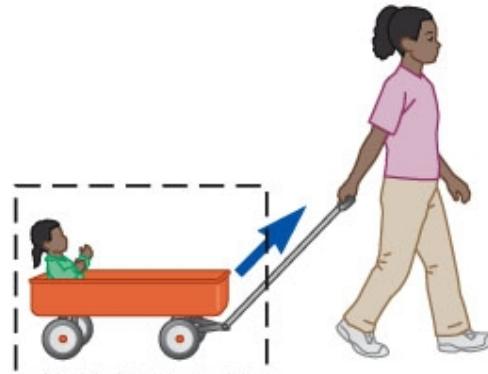
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# Types of forces

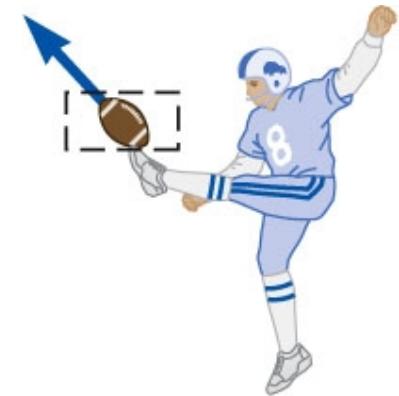
Contact forces



a



b



c

contact forces

tension – pulling apart

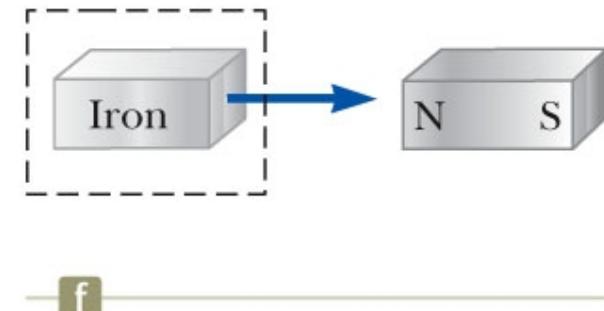
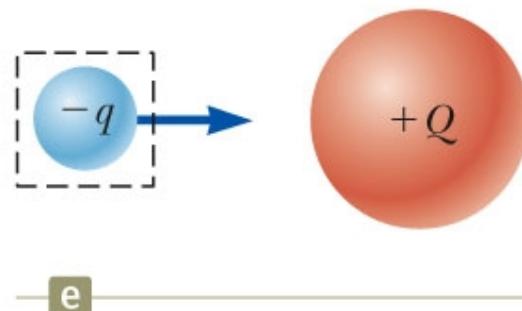
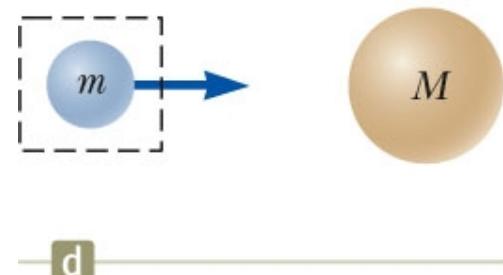
compression – pushing together

shear – pushing tangentially

torsion - twisting

# Types of forces

Field forces



Field forces

gravitational

electric

magnetic

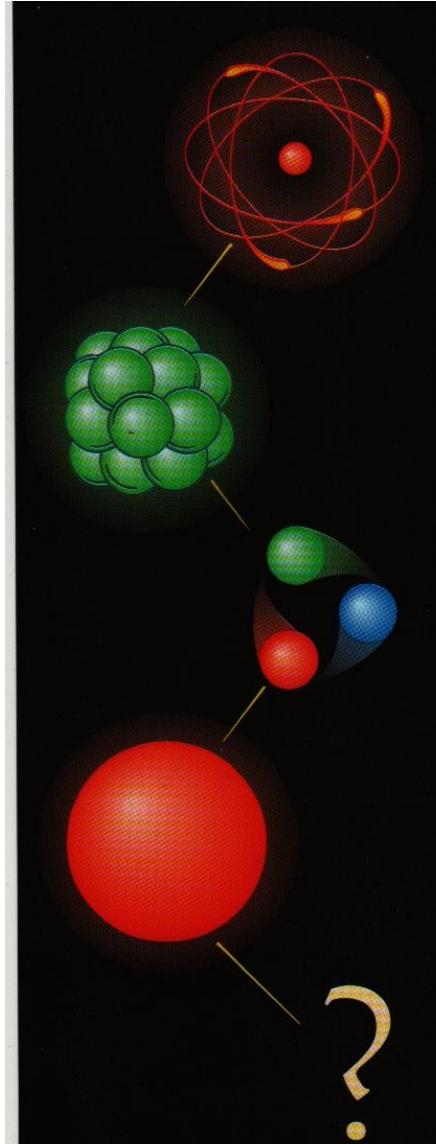
# The 4 Fundamental forces

Gravity

Electromagnetic Force

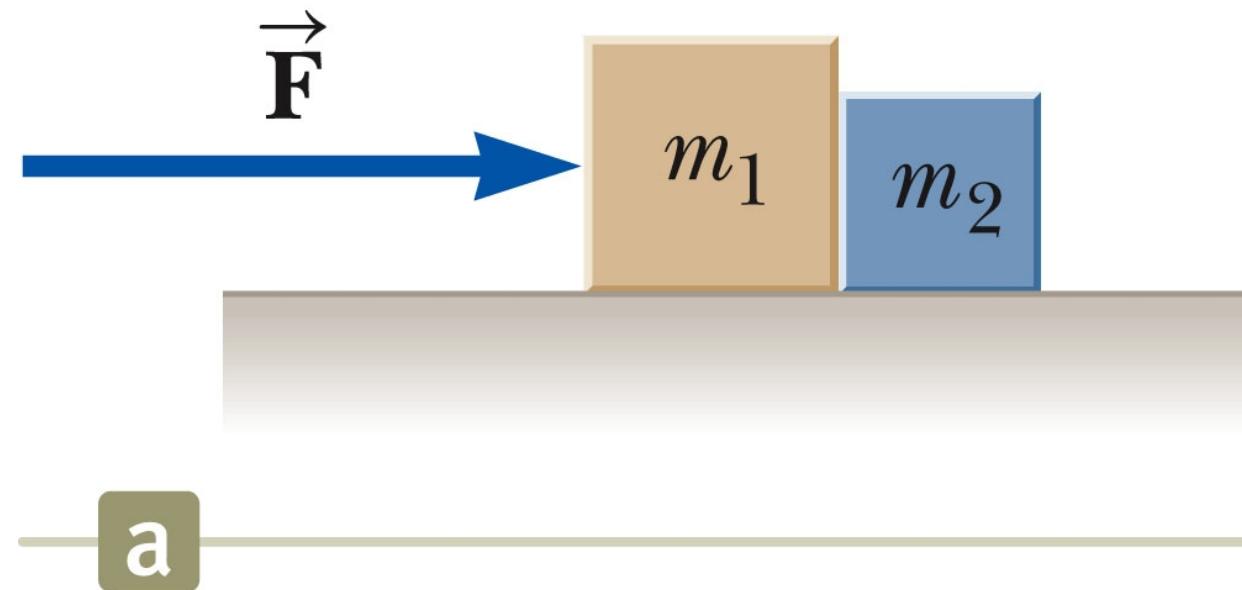
Nuclear Strong Force – holds nuclei together

Nuclear Weak force – decay of n and p



*Distances at the frontier of nuclear physics are astonishingly short. An atom is so small that 250,000 fit into the thickness of aluminum foil. The nucleus at the atom's center is a cluster of nucleons, each 100,000 times smaller than the atom itself. The three quarks inside each nucleon are smaller still.*

Newton's 2<sup>nd</sup> law = the acceleration of an object is proportional to the net force and inversely proportional to the mass.



$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

If same force acts on  $m_1$ ,  $m_2$ , and  $m_1+m_2$ , the accelerations are different.

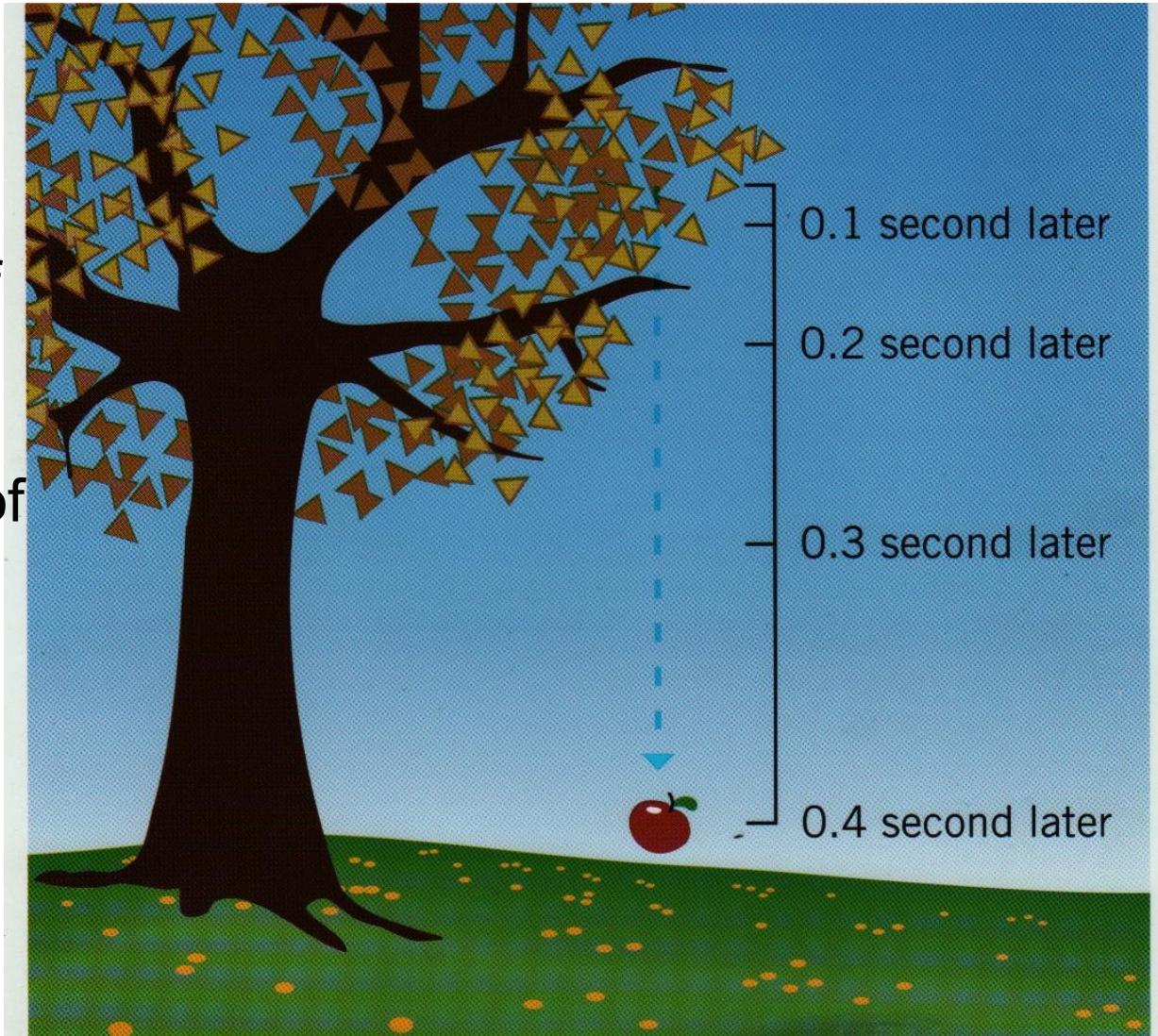
## Newton's 2<sup>nd</sup> law (cont.)

Example: free fall due to gravity obeys  $a = F_{\text{grav}}/m = mg/m = g$

Weight = the force of gravity on an object

Mass = the amount of matter in an object

Inertial mass = gravitational mass



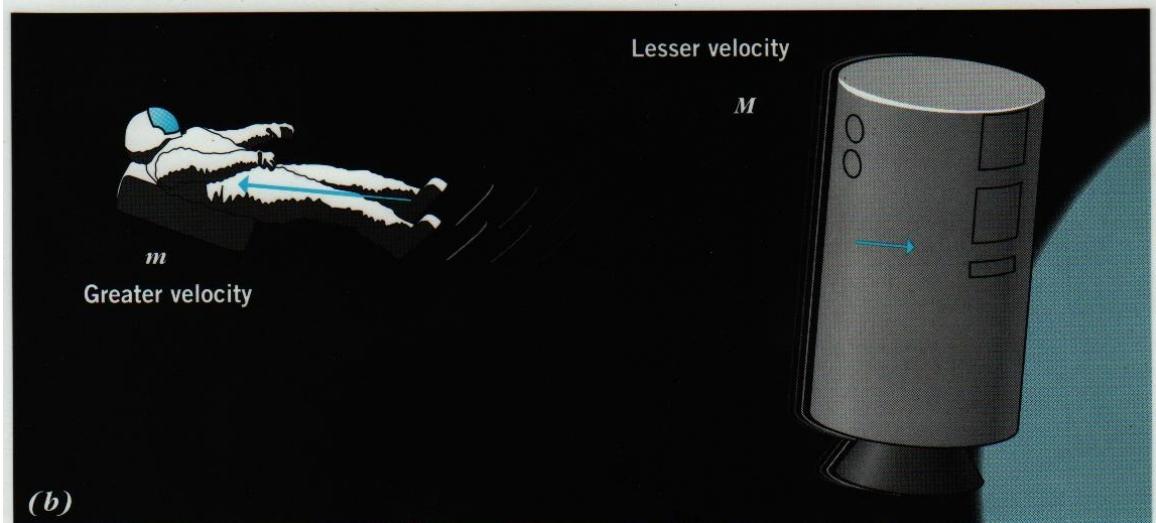
## Newton's 3<sup>rd</sup> law (cont.)

“For every action there is an equal but opposite reaction.”  
“Forces come in equal but opposite pairs.”

$$F_{12} = -F_{21}$$



(a)



(b)

## Newton's 3<sup>rd</sup> law (cont.)

Gravity and the electromagnetic forces obey Newton's 3rd.

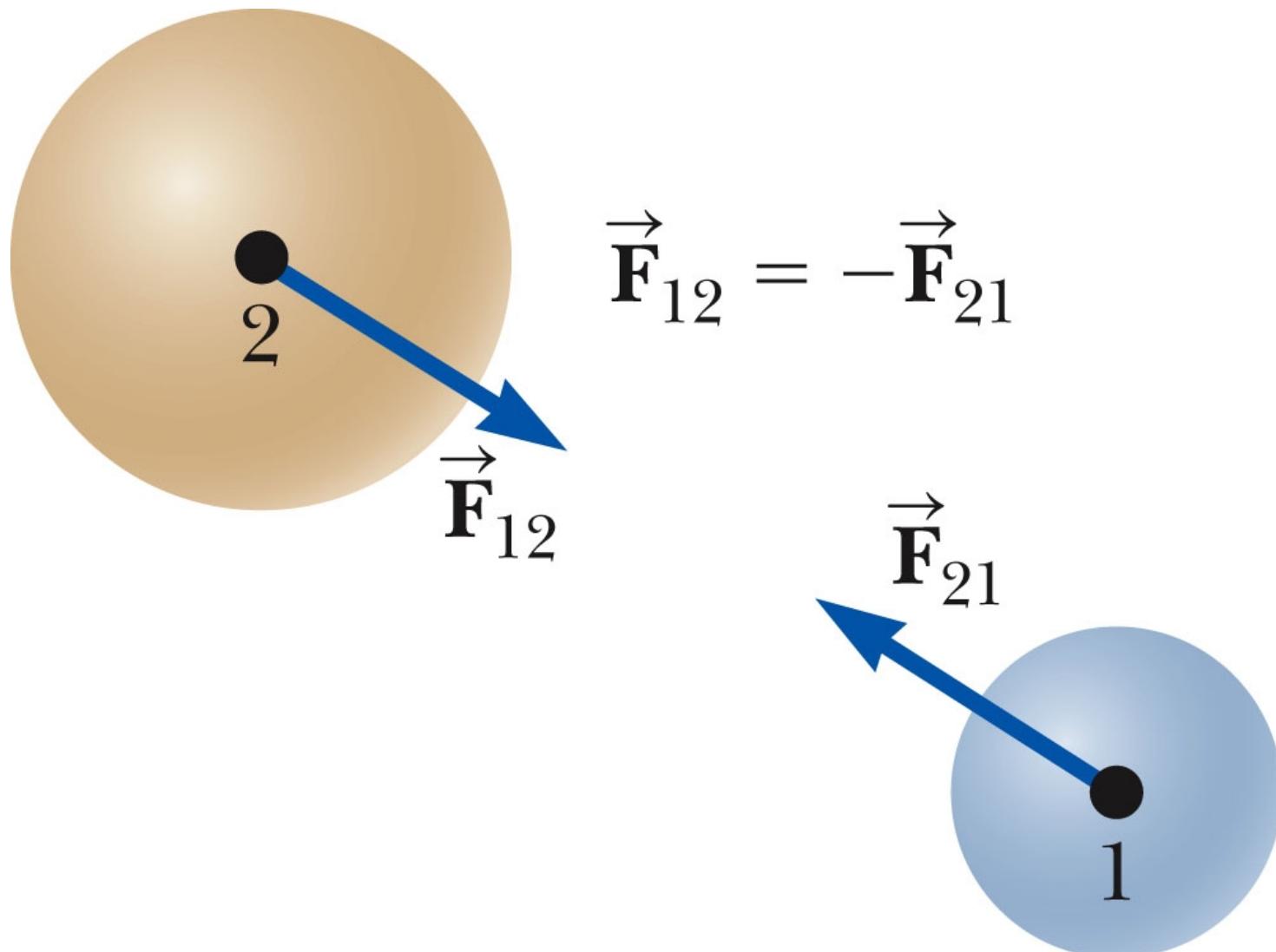
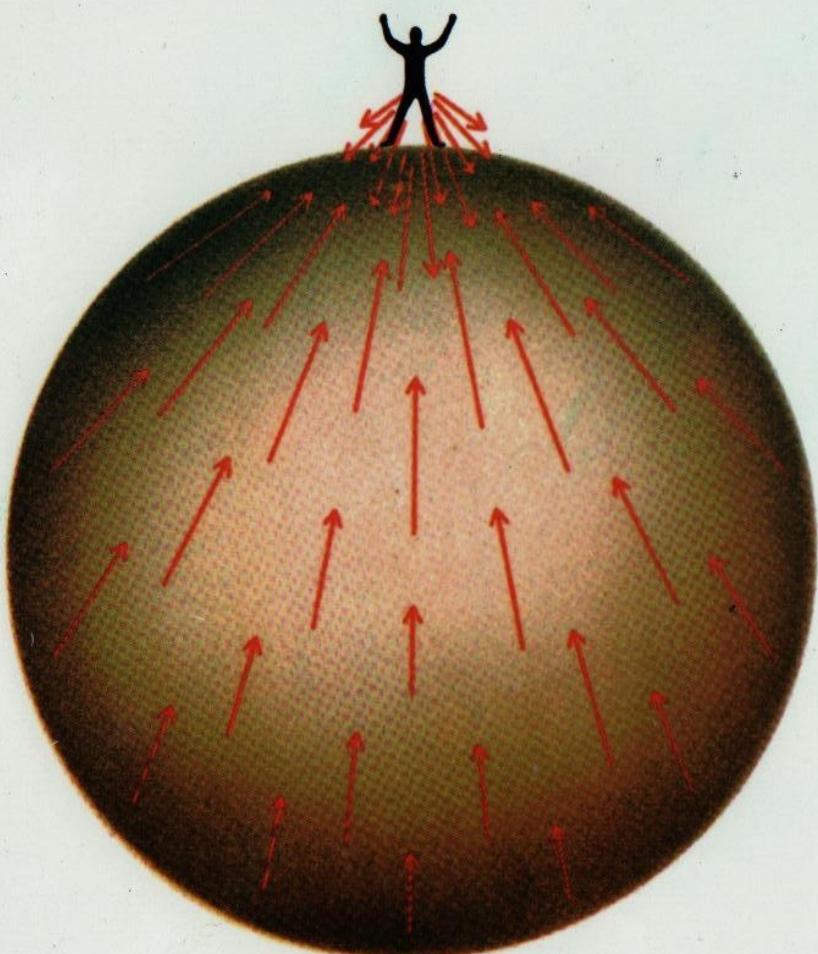
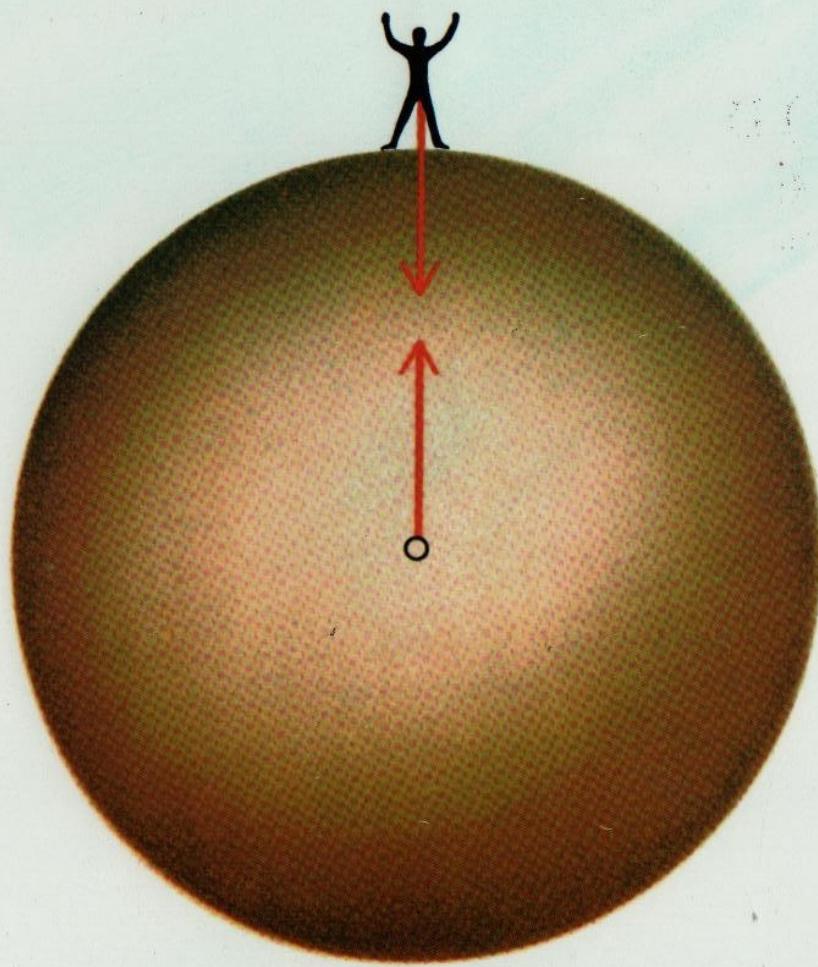


Fig. 5.5, p. 111

## Newton's 3<sup>rd</sup> law (cont.)



(a)

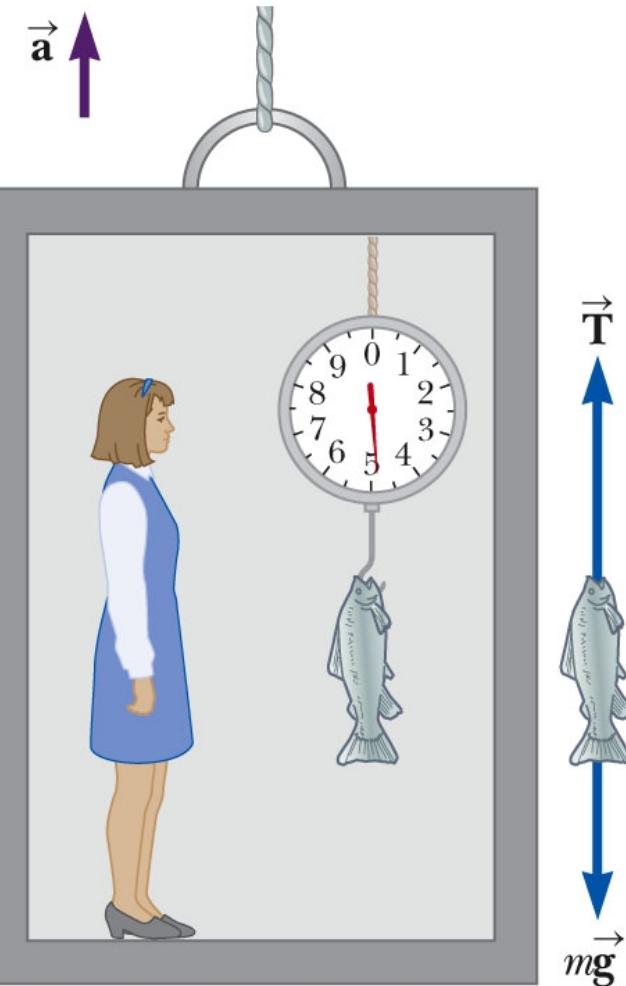


(b)

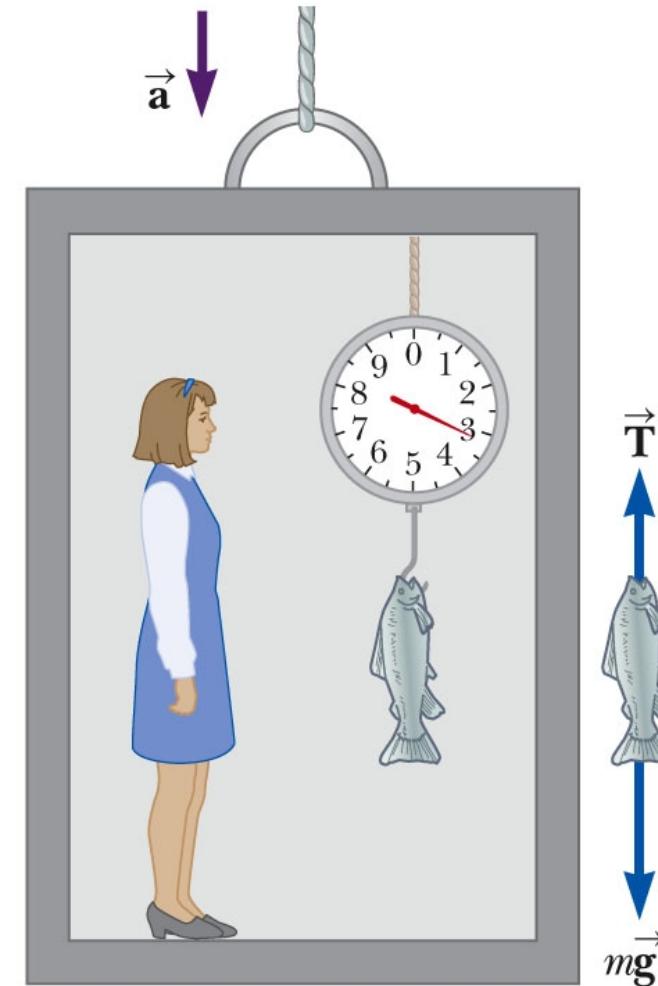
Weight = the |force| of gravity near a planet =  $mg = F_g$

*Apparent* weight may differ from weight in accelerating reference frames or when buoyant forces are present.

When the elevator accelerates upward, the spring scale reads a value greater than the weight of the fish.



When the elevator accelerates downward, the spring scale reads a value less than the weight of the fish.



a

b

# The Application of Newton's Laws

Problem solving method

## 1. Conceptualize

- What is problem asking for?
- Write down knowns and unknowns.
- Draw picture.

## 2. Categorize

- Equilibrium problem – object stationary (or constant velocity)
- Newton's 2<sup>nd</sup> law problem – object accelerates

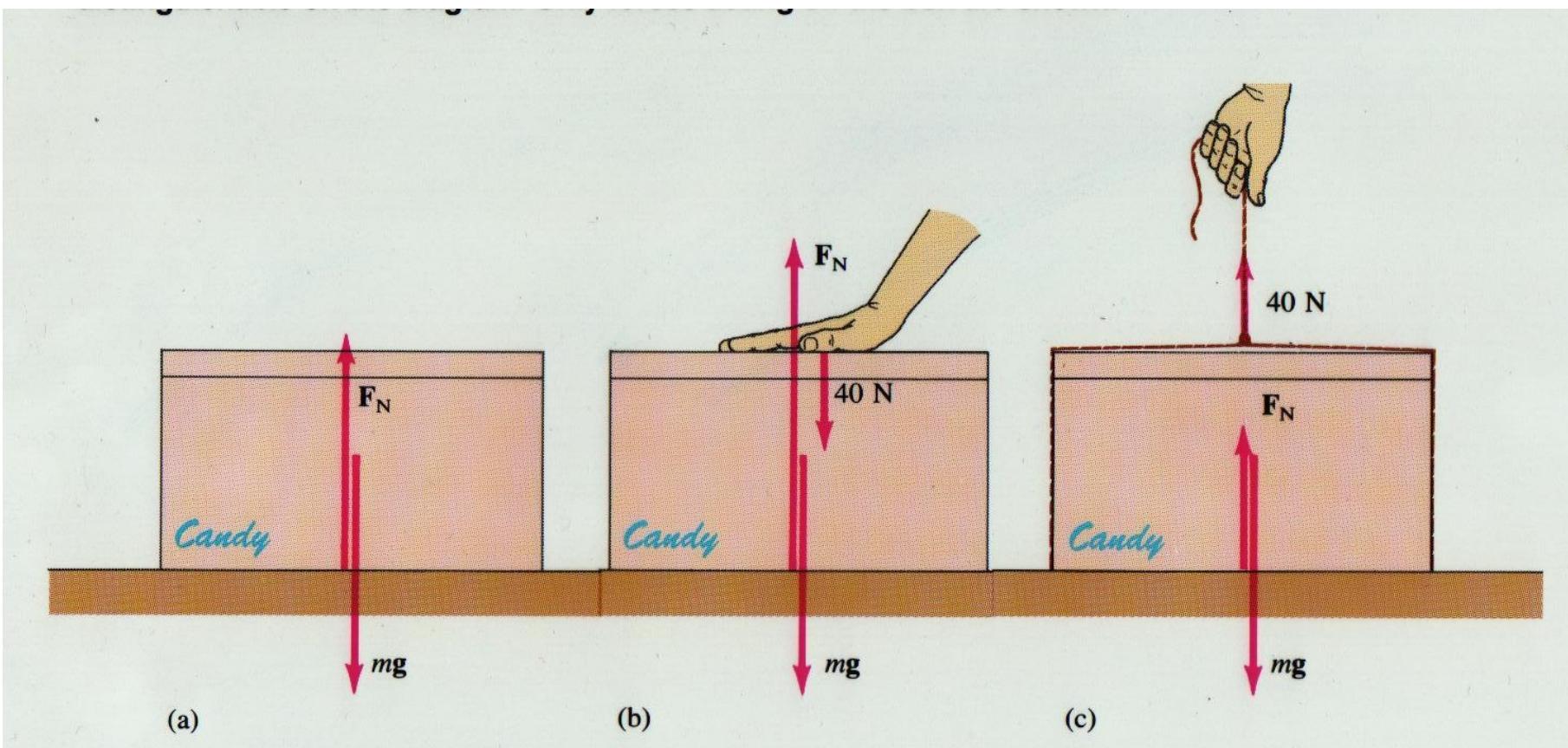
## 3. Analyze

- Isolate object of interest and draw forces acting on it.
- Don't draw the forces object exerts on surroundings (usually).
- Form equations for x and y components independently.
- Plug and chug.

## 4. Finalize – check units, dimensions, etc.

# The Application of Newton's Laws

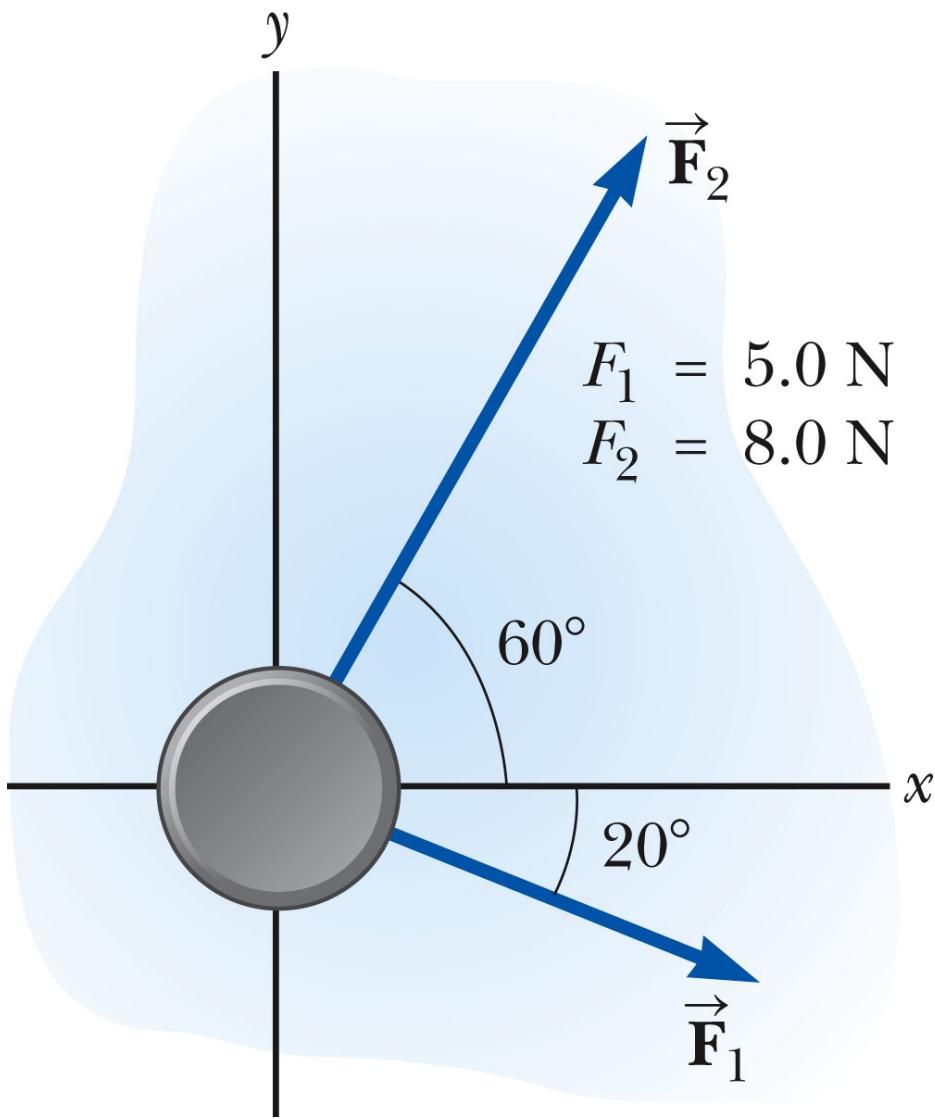
Find the normal force in each case if  $m=1 \text{ kg}$ . (Use  $g=10 \text{ m/s}^2$ )

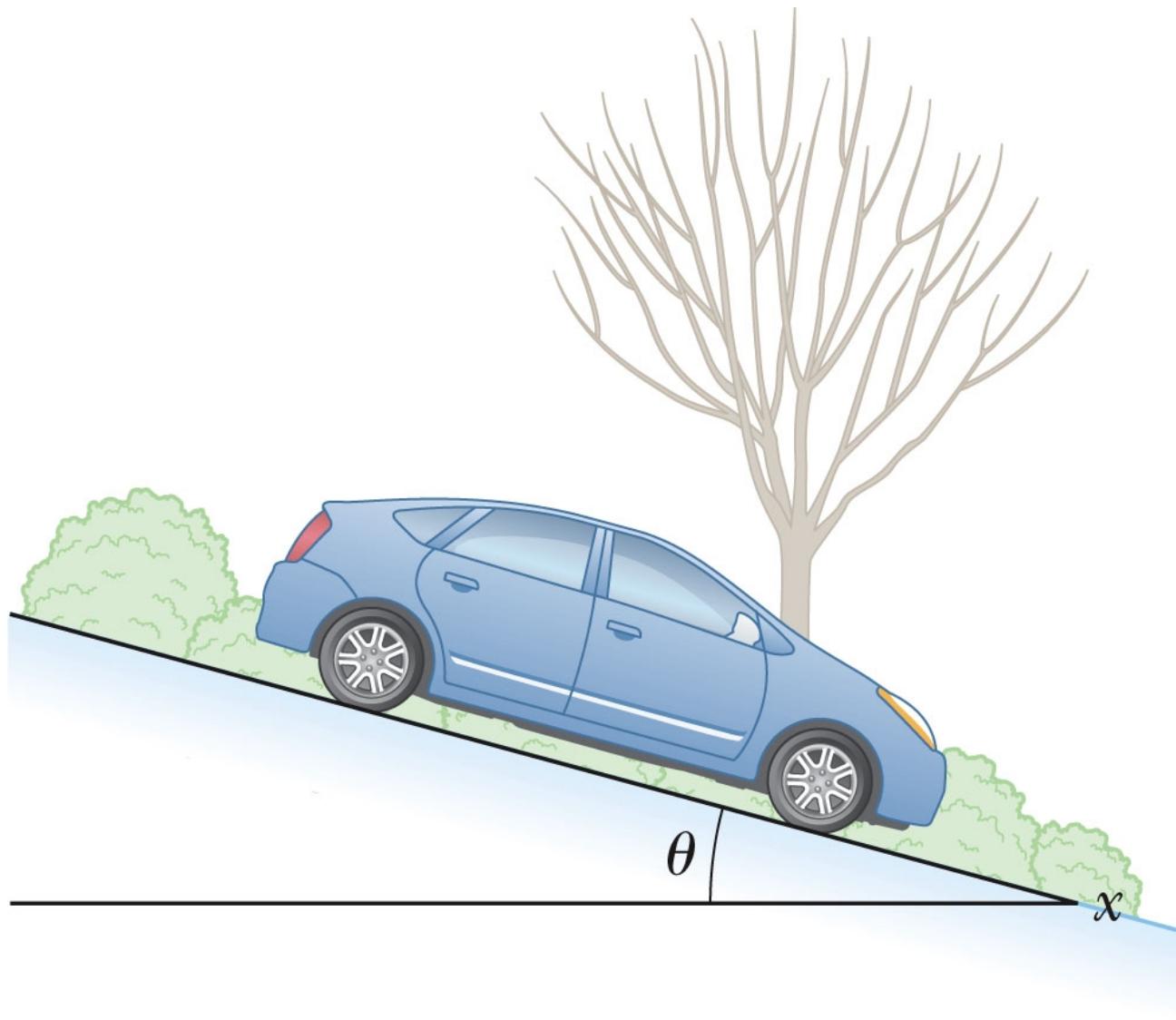


**Note:** if  $m=5 \text{ kg}$ , you get a more realistic normal force in (c).

# The Application of Newton's Laws

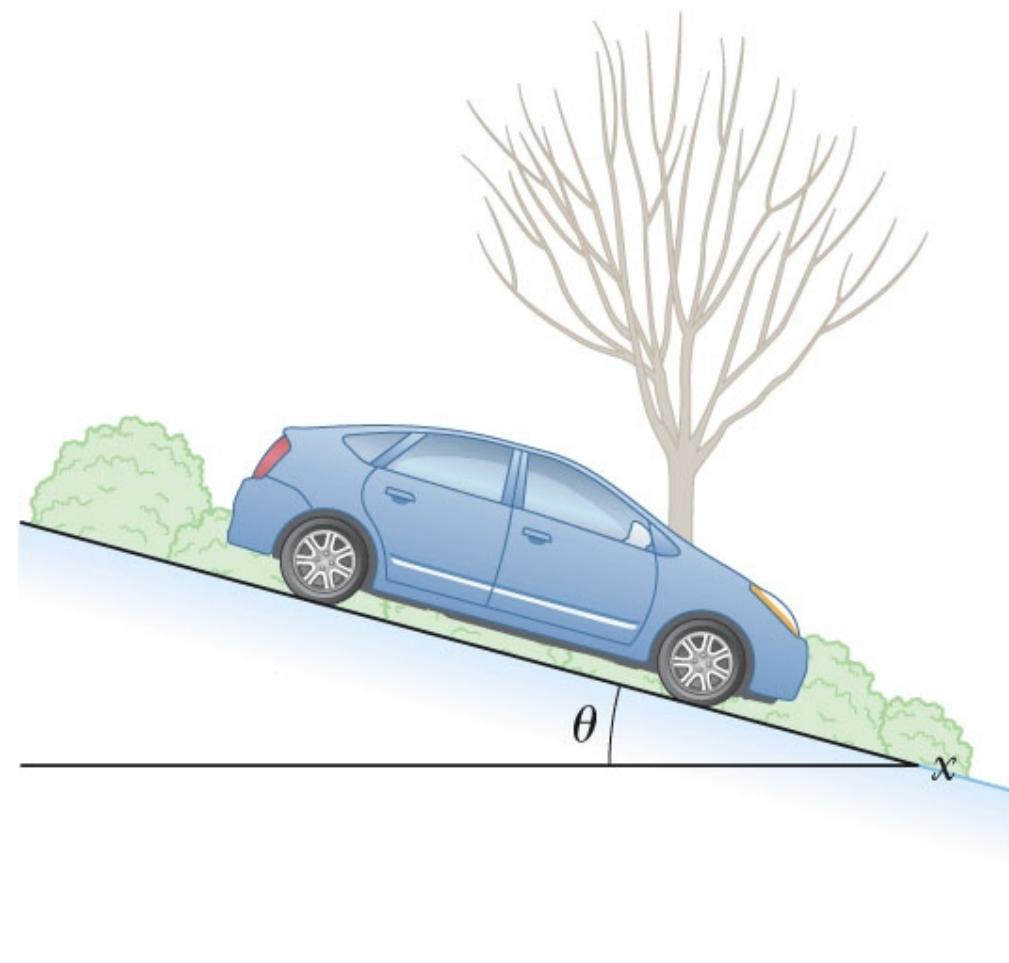
Find the acceleration vector for the 0.2 kg hockey puck.



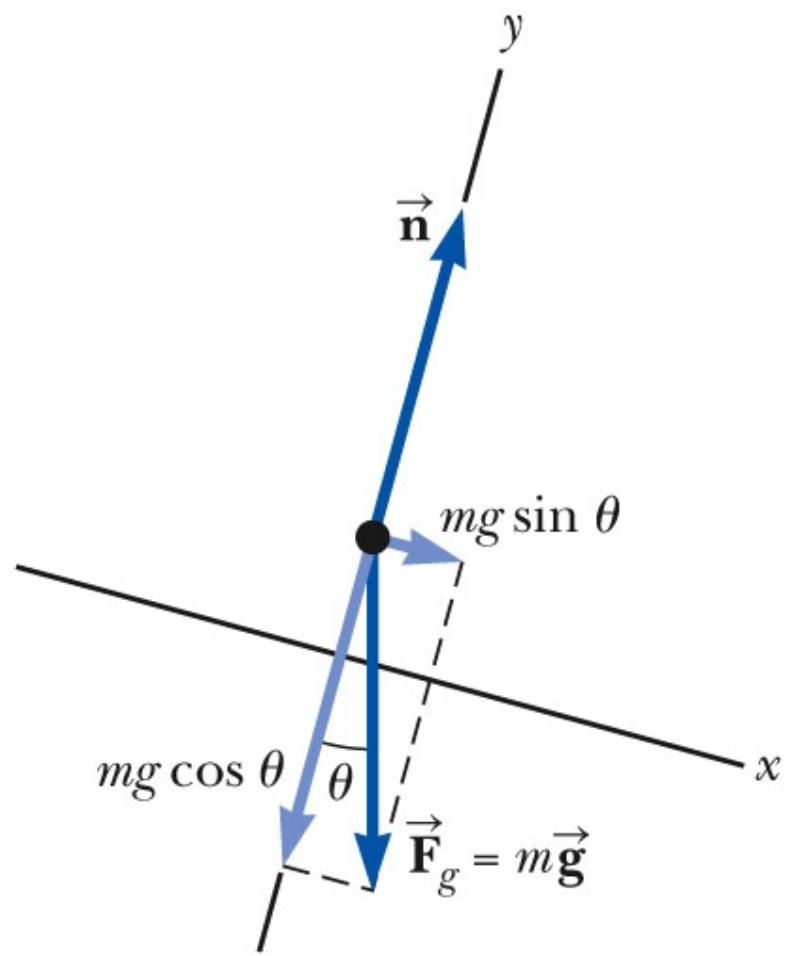


a

Fig. 5.11, p. 116



a



b

Fig. 5.11, p. 116

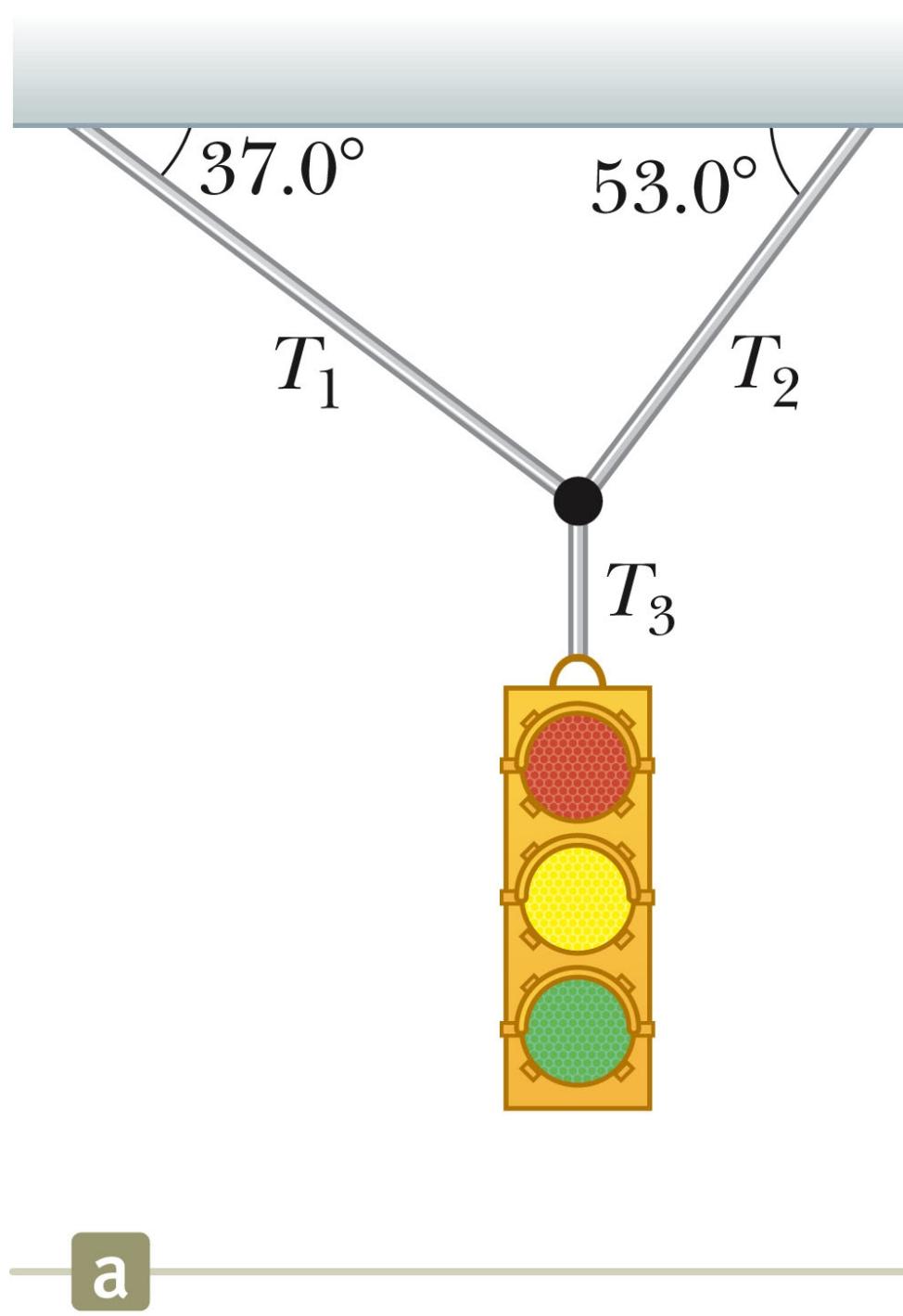


Fig. 5.10, p. 114

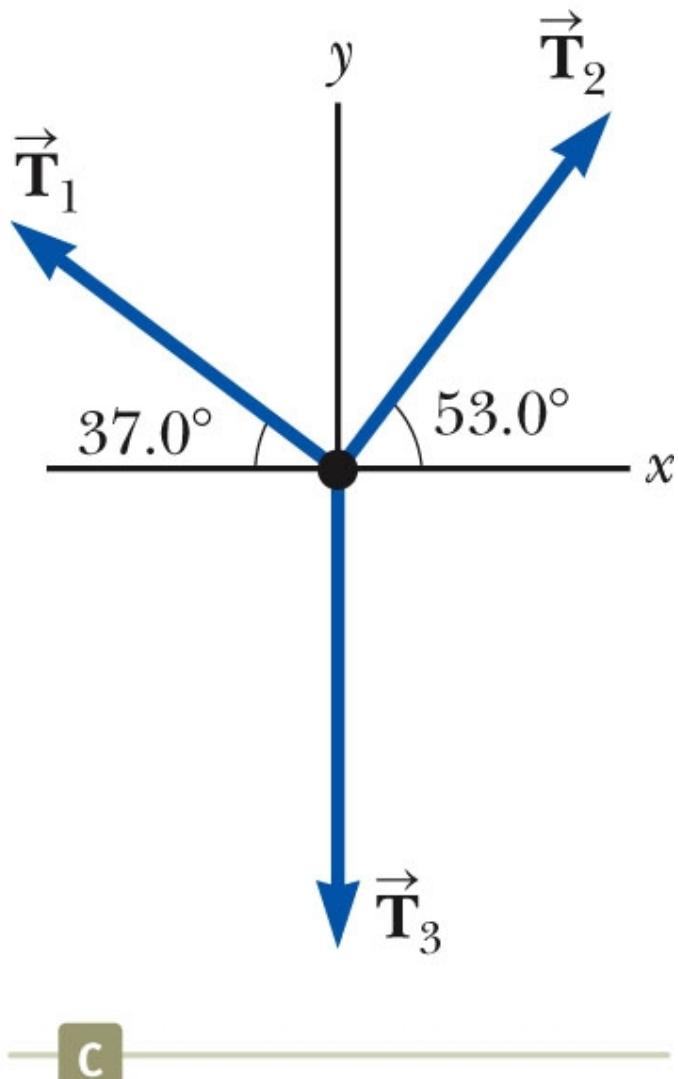
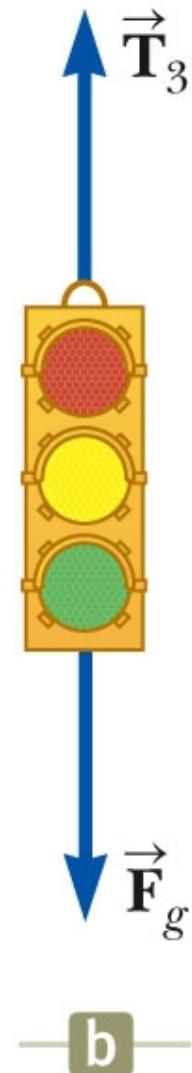
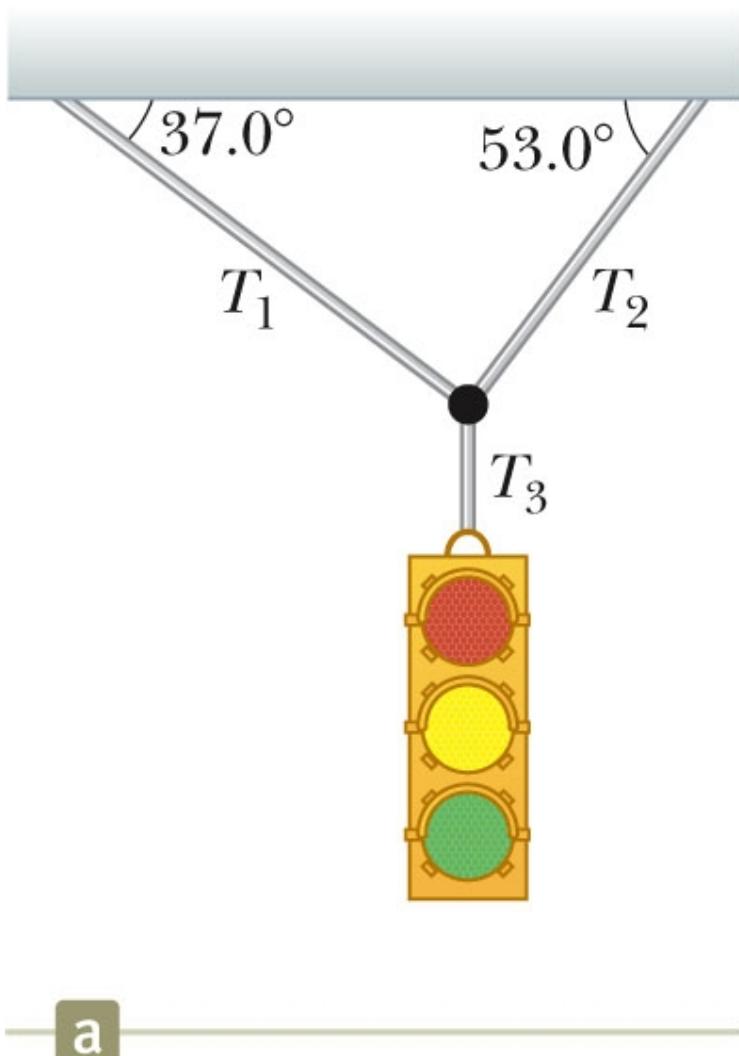


Fig. 5.10, p. 114

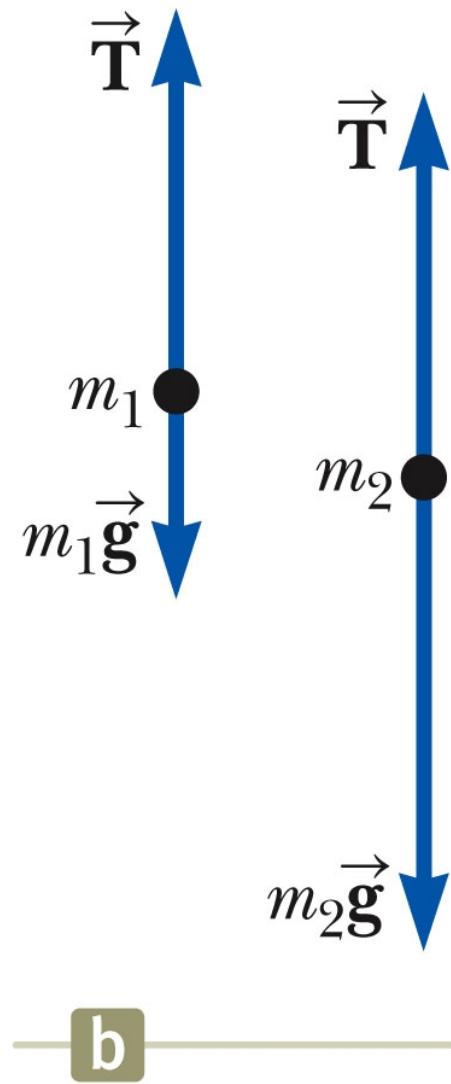
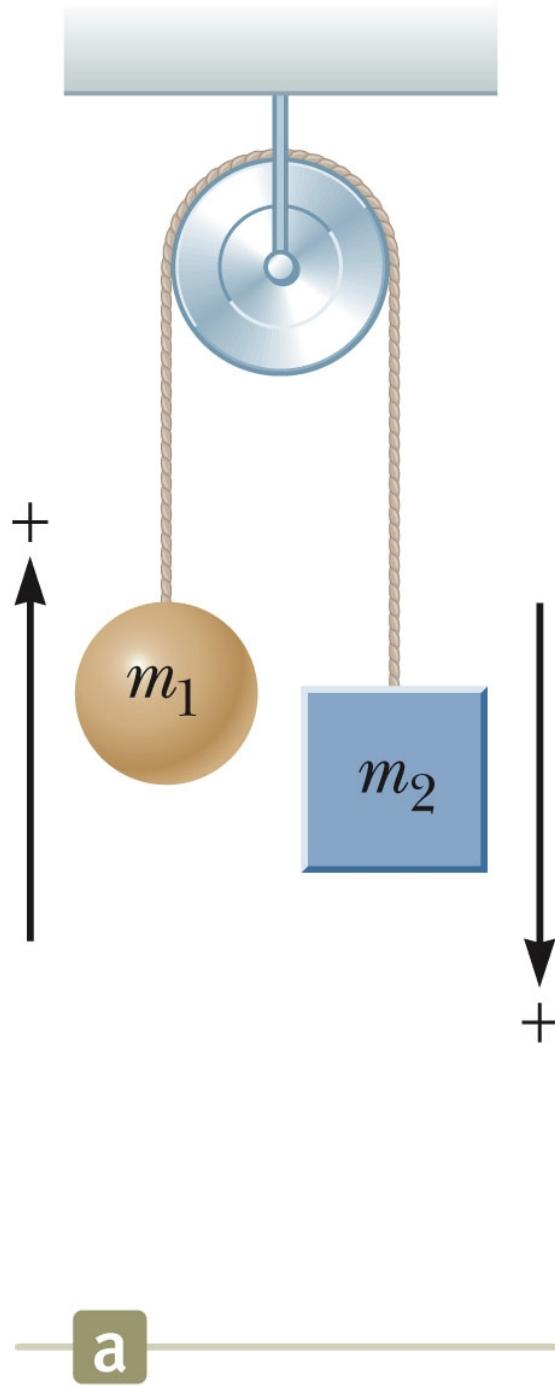


Fig. 5.14, p. 120

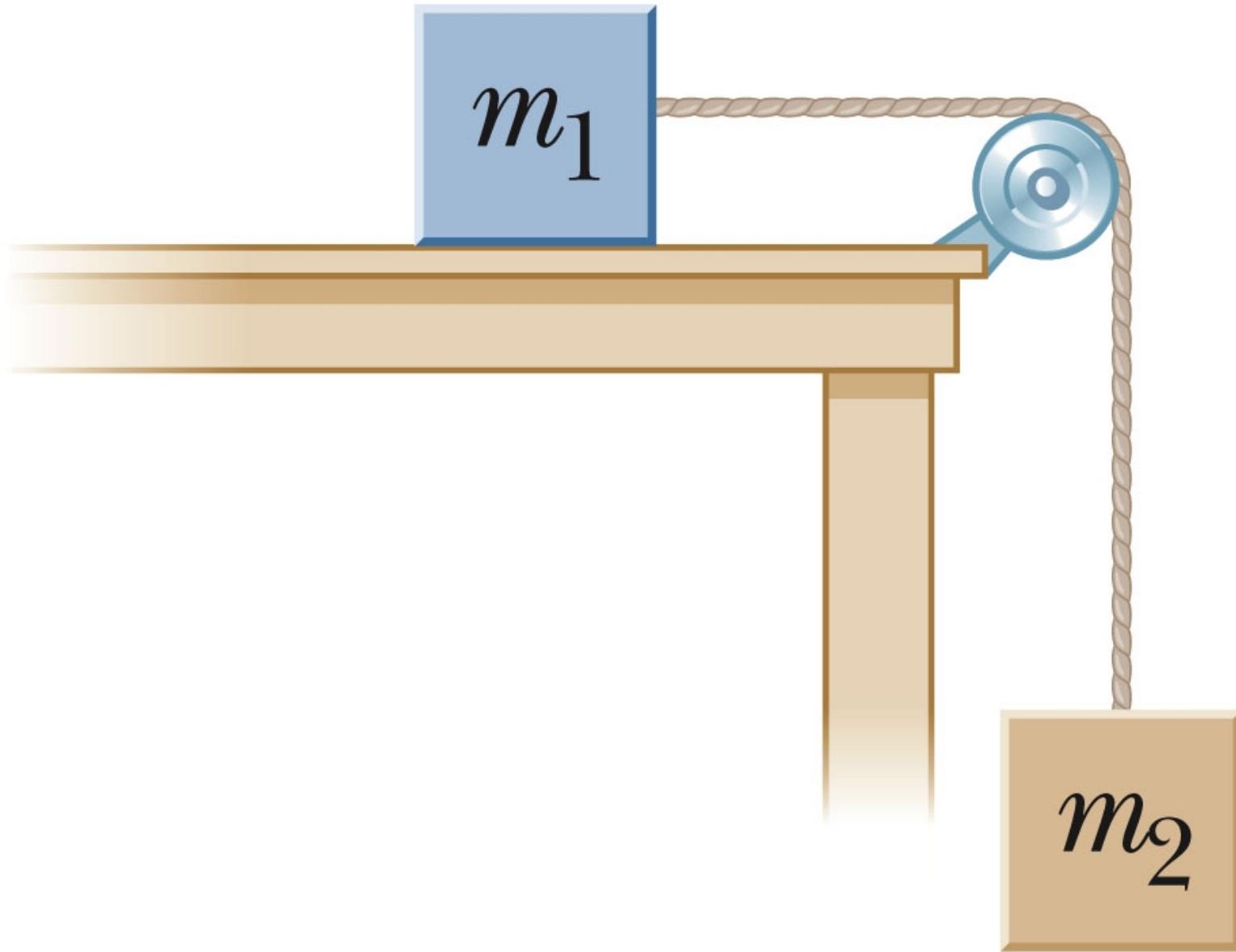
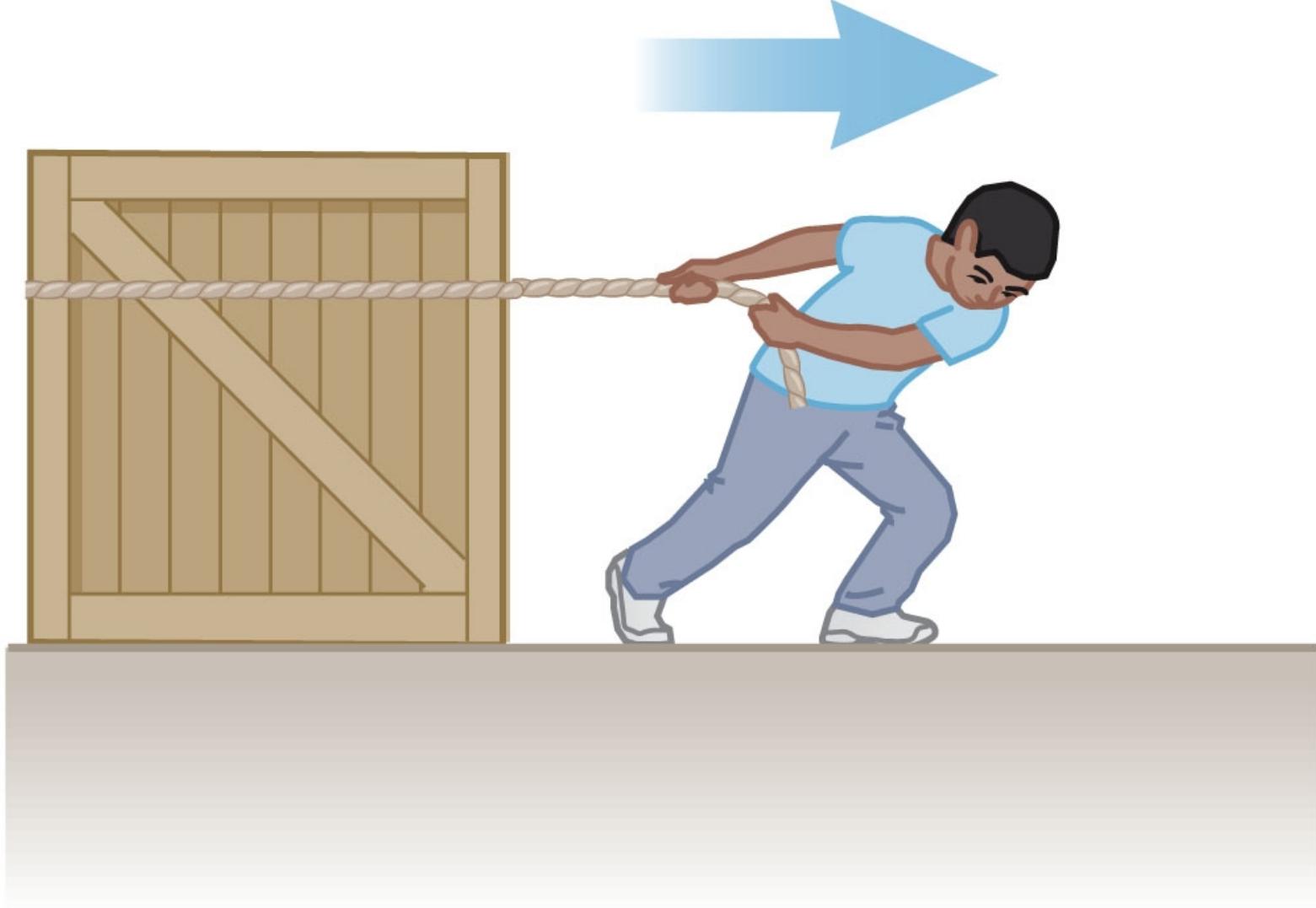


Fig. P5.28, p. 133



a

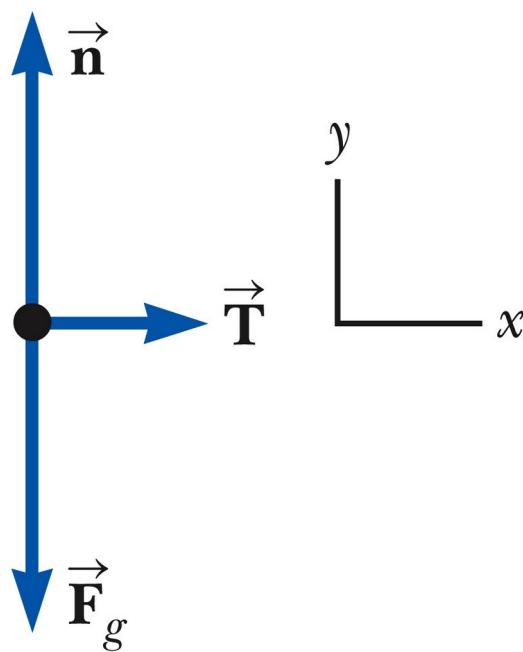


Fig. 5.8, p. 113

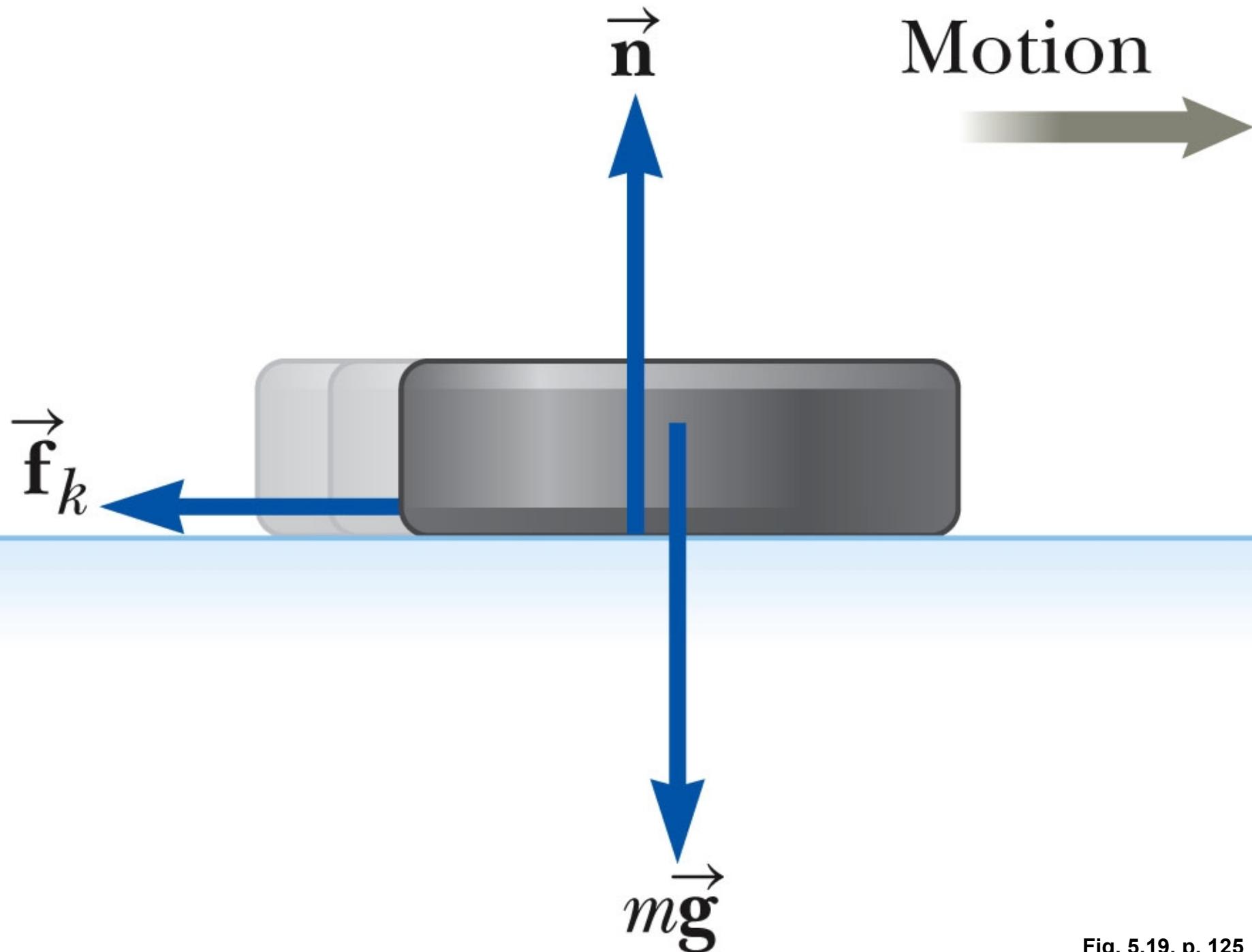
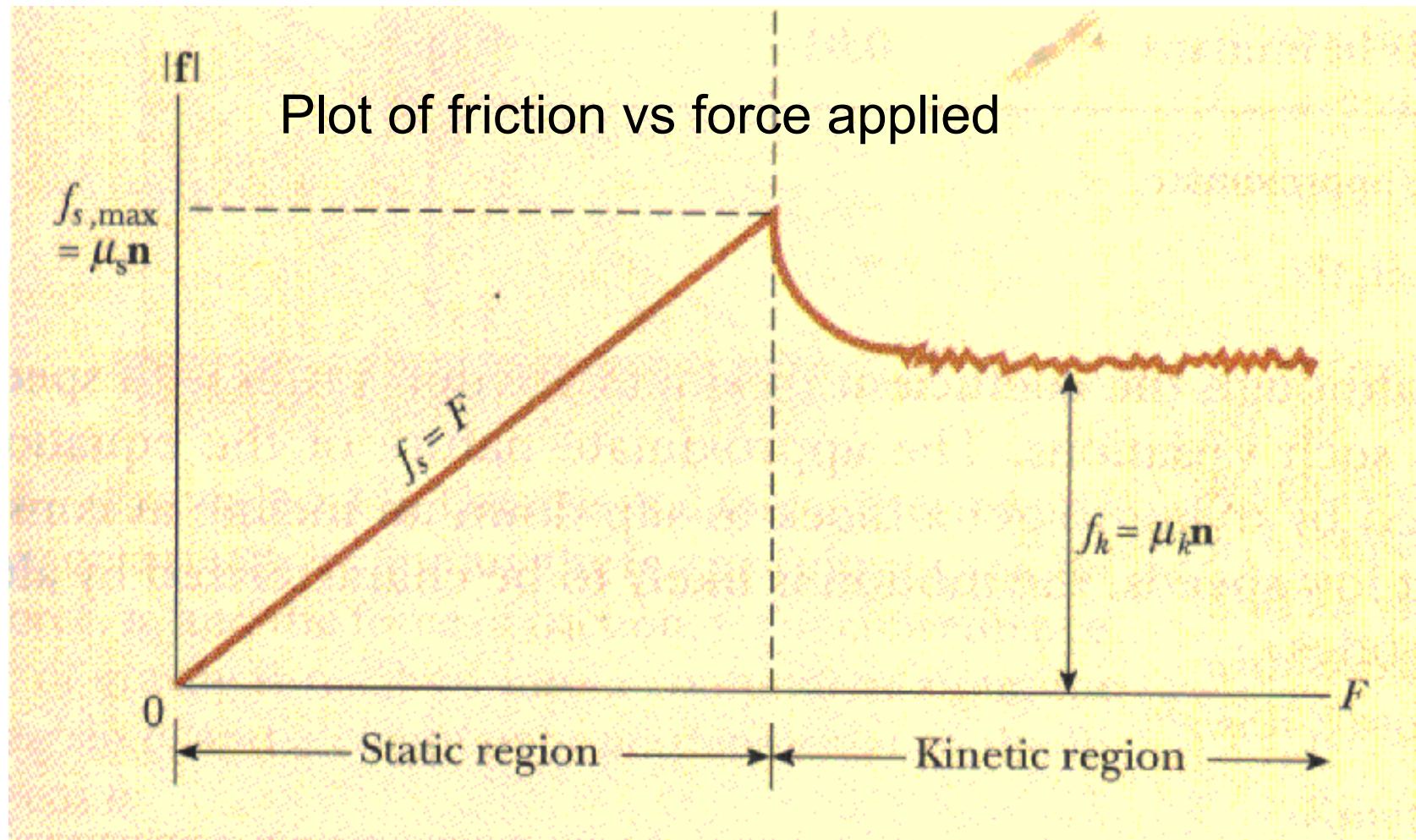
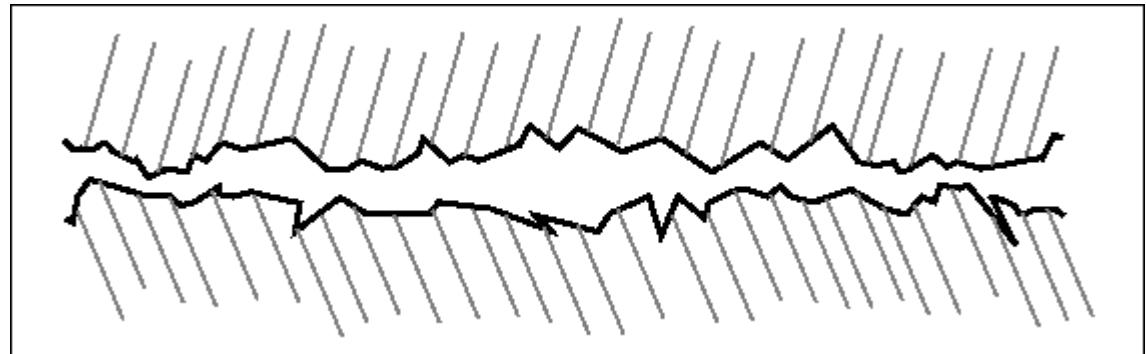
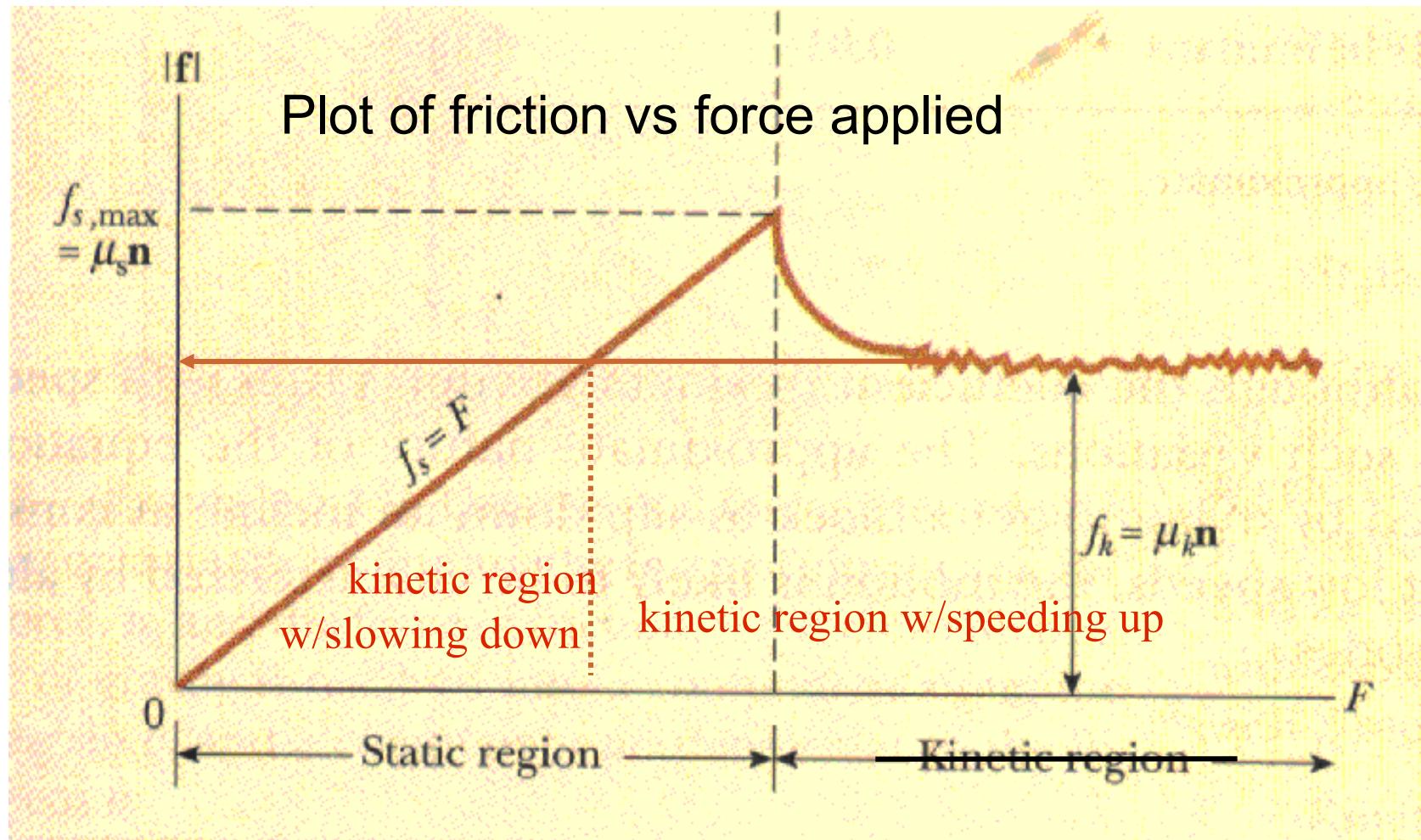
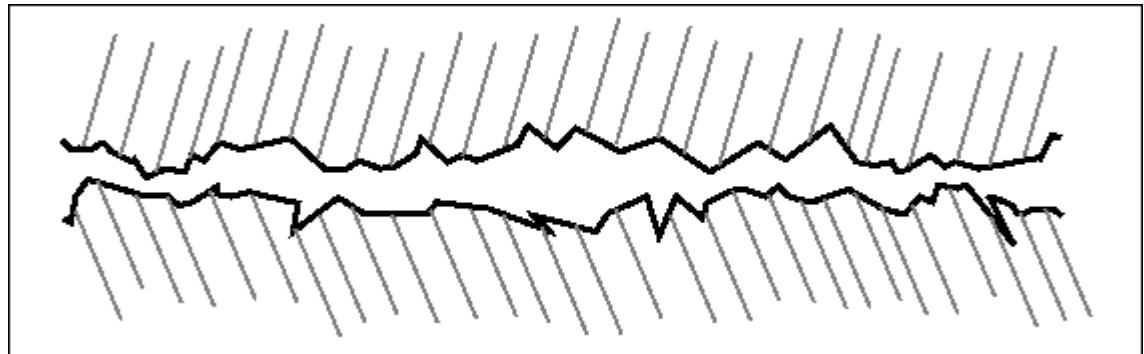


Fig. 5.19, p. 125

Close-up of surfaces.



Close-up of surfaces.



**TABLE 5.1***Coefficients of Friction*

	$\mu_s$	$\mu_k$
Rubber on concrete	1.0	0.8
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Glass on glass	0.94	0.4
Copper on steel	0.53	0.36
Wood on wood	0.25–0.5	0.2
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	—	0.04
Metal on metal (lubricated)	0.15	0.06
Teflon on Teflon	0.04	0.04
Ice on ice	0.1	0.03
Synovial joints in humans	0.01	0.003

*Note:* All values are approximate. In some cases, the coefficient of friction can exceed 1.0.

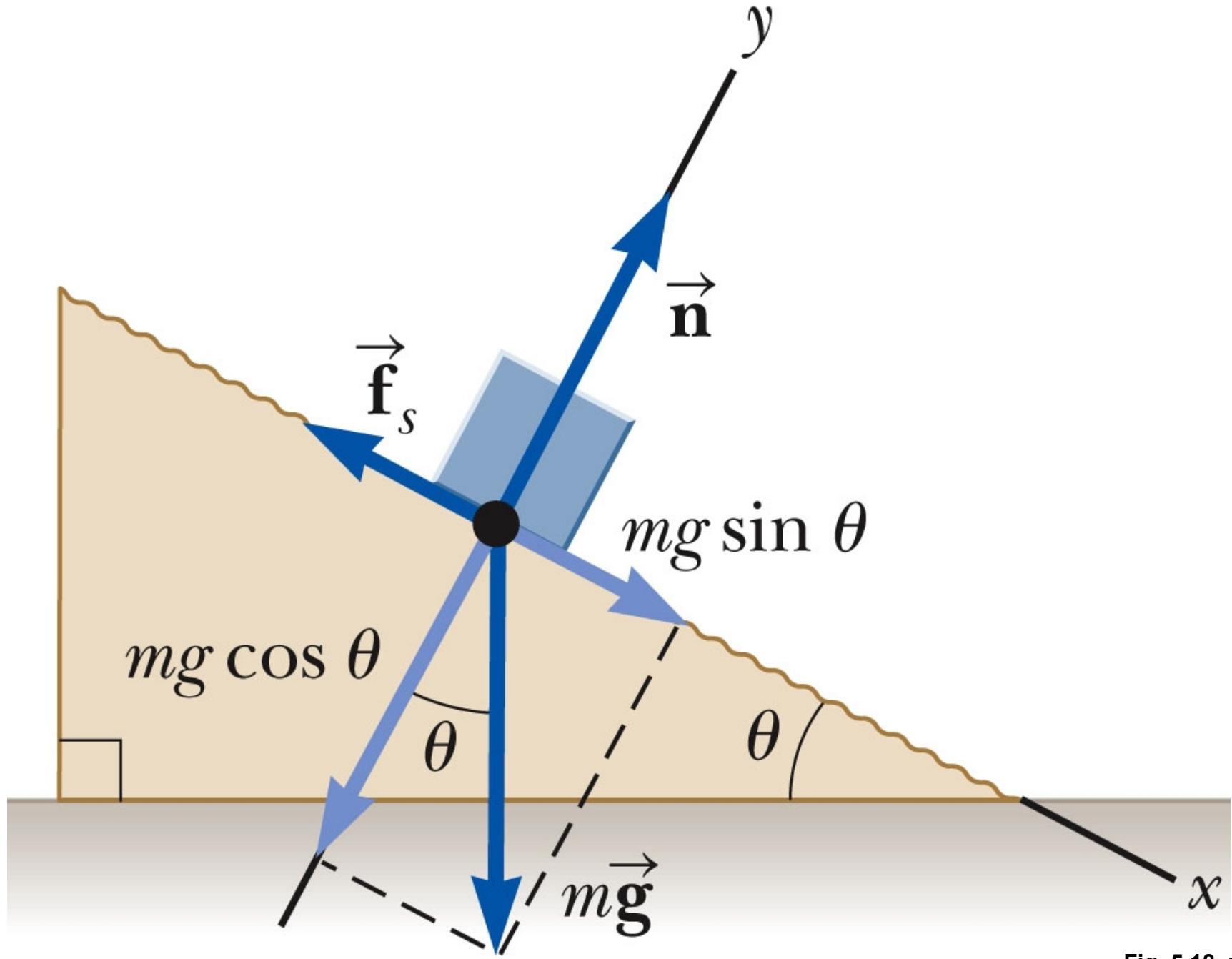
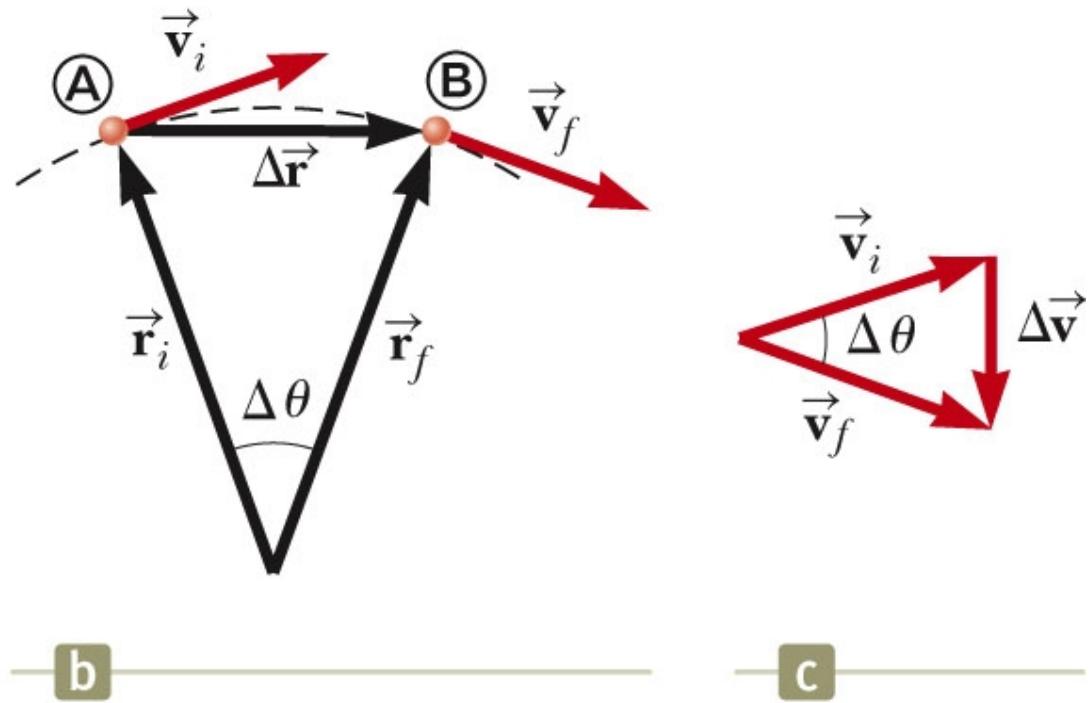
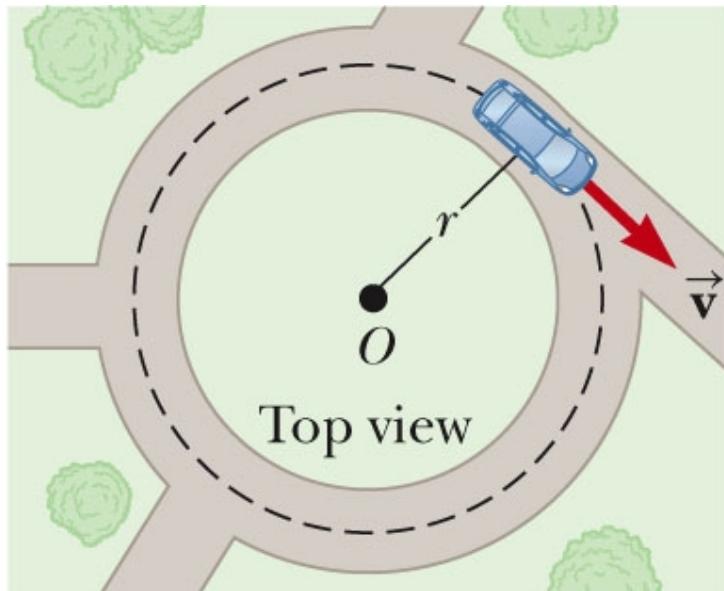


Fig. 5.18, p. 124

Uniform circular motion = object moves at constant speed in a circular path.



Time to make one cycle = period =  $T$  = circumf/speed

## Total acceleration – sum of tangential and centripetal components

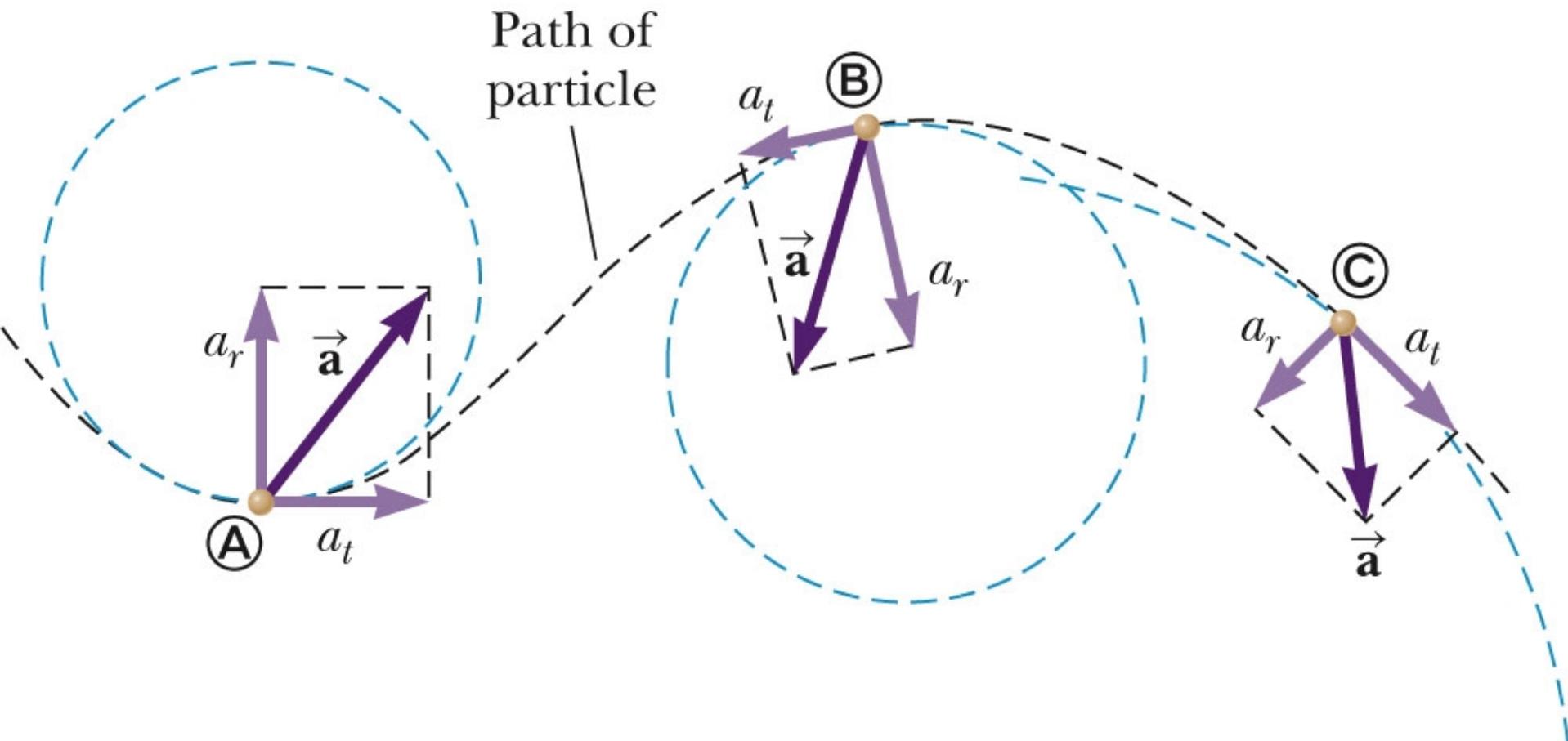
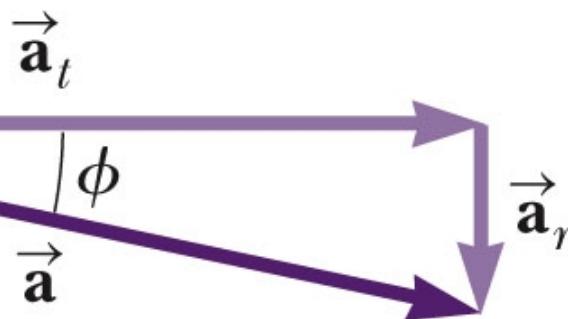


Fig. 4.16, p. 88

$$a_t = 0.300 \text{ m/s}^2$$



a



b

Fig. 4.17, p. 89