

# Outline for Day W4,D2

Newton's 1<sup>st</sup> law

Relative velocity and motion

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 Fri

Read 3.9 (rel motion)

Notes: Lab this week: “Acceleration of Gravity”

“NEW STUFF” has new PPT, YouTube (FOR), exam-like problems for Ch. 3, rel. motion problems.

Exam I follows Chapter 5 material.

# **Week 4-6 Topics**

**Chapter 3. Relative velocity**

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

**Types of forces**

**Free body diagrams**

**Chapter 5. Friction and centripetal force**

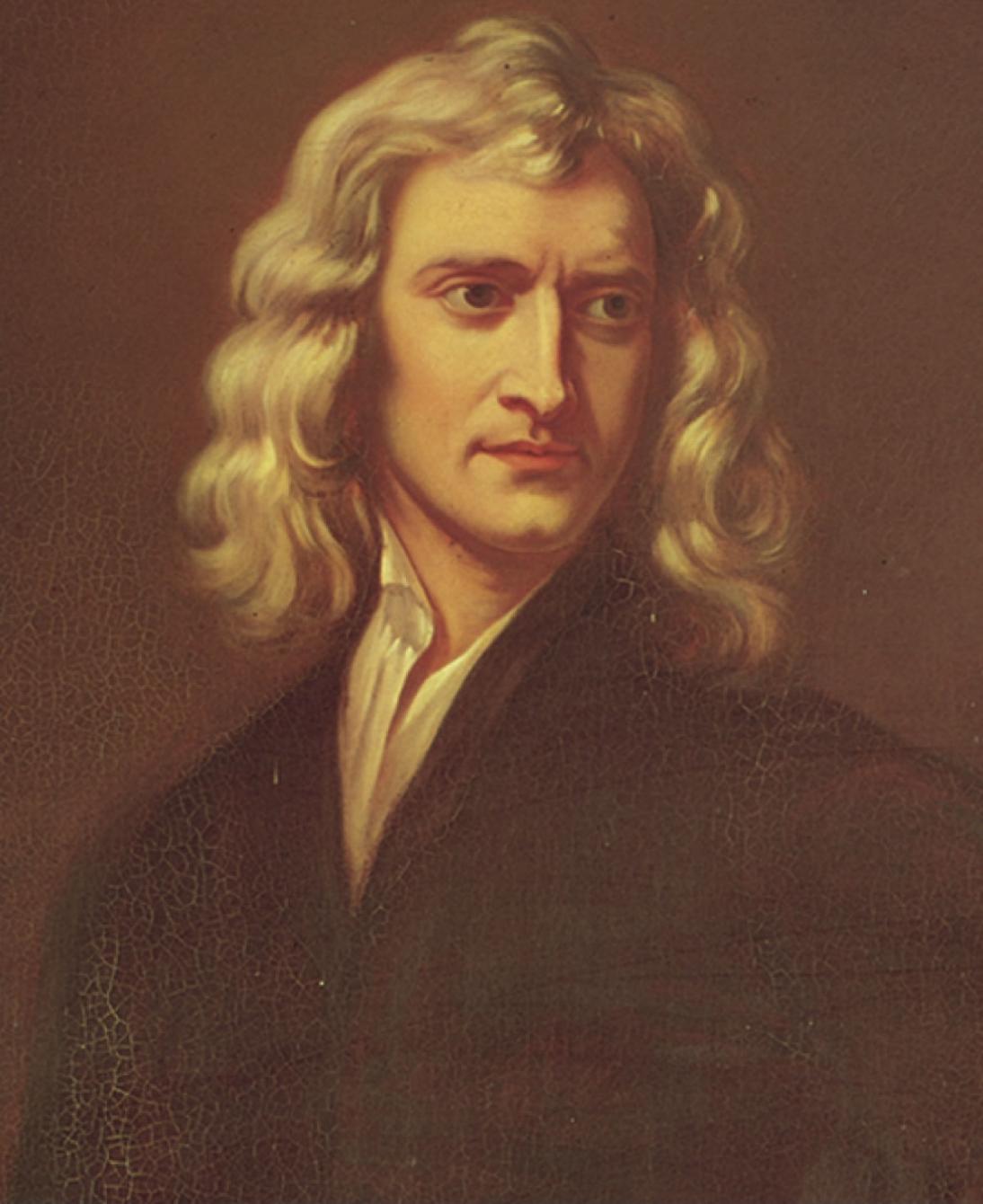
**Exam I follows Chapter 5.**

Isaac Newton  
(1642 - 1727)

3 laws of motion

1 law of Universal  
Gravitation

Co-invented calculus



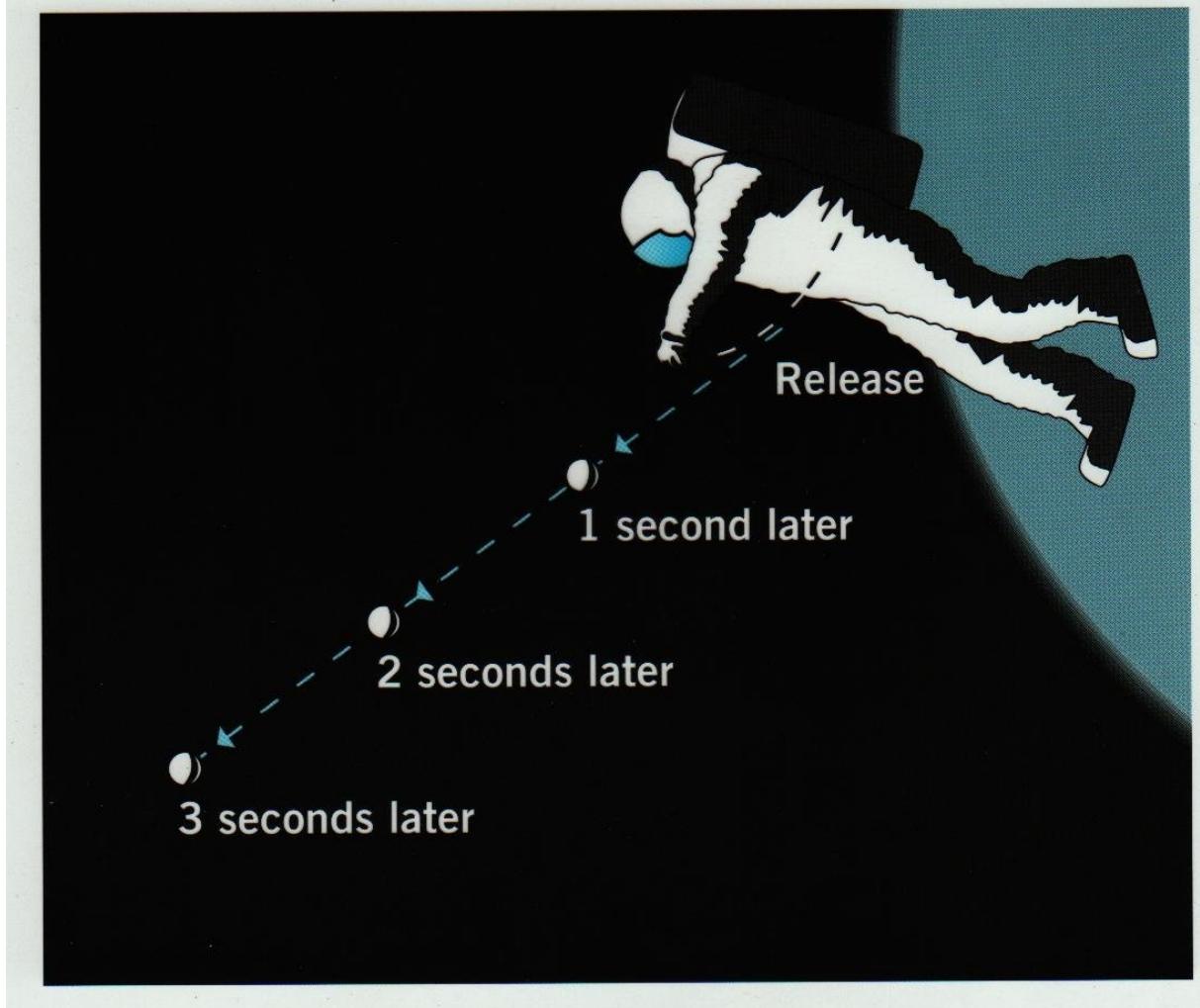
Newton's 1<sup>st</sup> law = inertial frames of reference exist such that an object will move with a constant velocity if no forces act upon it.

$$v = \text{const} \text{ if } F_{\text{net}} = 0$$

Overthrows Aristotle and medieval ideas:

“natural state” is at rest

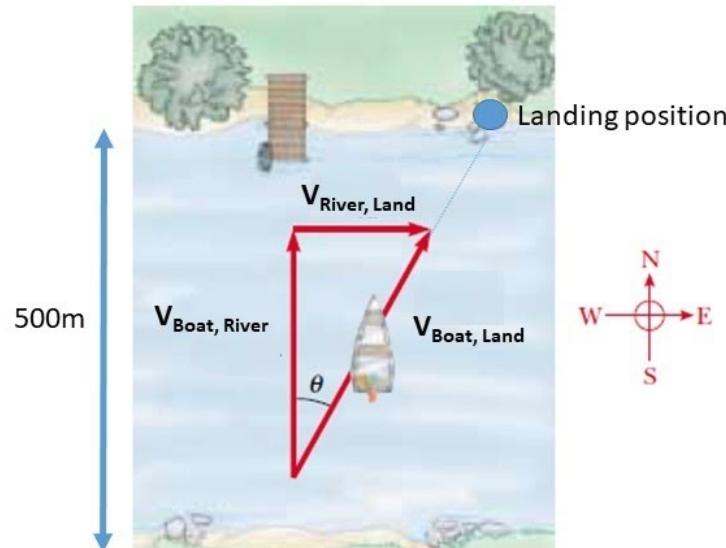
“impetus” pushes an arrow along



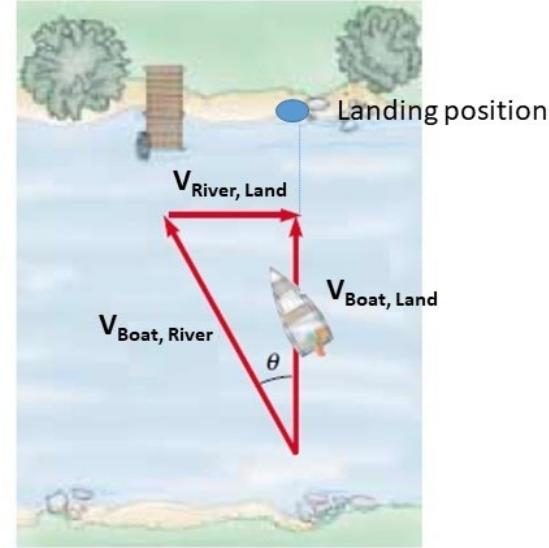
# Frames of reference and relative motion

The assumption of inertial frames of reference was implicit in Ch. 3's "relative velocity" examples.

## Problem 1



## Problem 2



3 frames of ref: the boat (B), the land (L) and the river (R).

Given  $v_{RL} = 3 \text{ m/s E}$ ,  $v_{BR} = 8 \text{ m/s N}$ .

P1) If the boat moves N relative to the river, find  $v_{BL}$ .

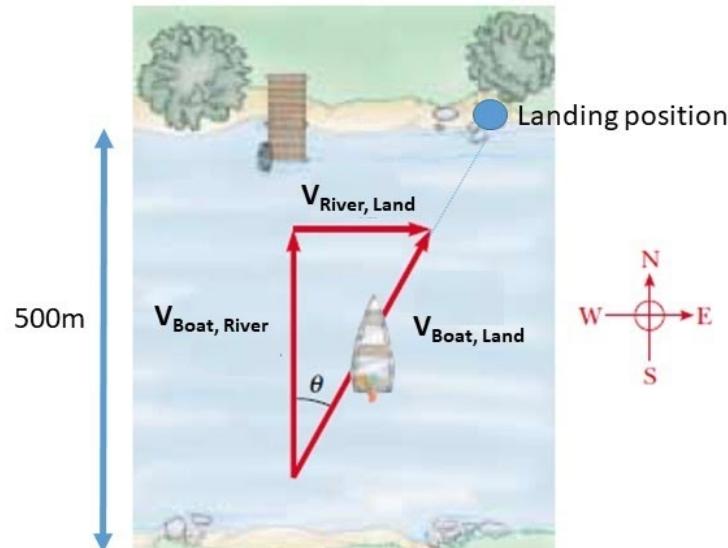
Find  $v_{BL}$ .  $v_{BL} = v_{BR} + v_{RL} = 8\hat{j} + 3\hat{i}$ ,  $|v_{BL}| = 8.54 \text{ m/s}$ ,  $\theta = 20.6^\circ$

How far East does it drift?  $X/500 = \tan \theta$ .  $X = 188 \text{ m}$ .

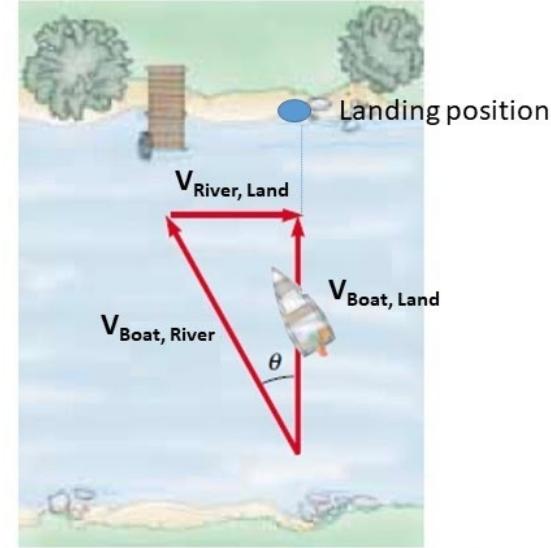
# Frames of reference and relative motion

The assumption of inertial frames of reference was implicit in Ch. 3's "relative velocity" examples.

## Problem 1



## Problem 2



3 frames of ref: the boat (B), the land (L) and the river (R).

Given  $v_{RL} = 3 \text{ m/s E}$ ,  $|v_{BR}| = 8 \text{ m/s}$ .

P2) What  $\theta$  is needed so that the boat goes straight N?

$$\text{Ans: } \sin \theta = v_{RL} / |v_{BR}| = 3/8. \quad \theta = 22.0^\circ$$

Also, what is  $v_{BL}$ ?  $v_{BL}/v_{BR} = \cos 22$ ,  $v_{BL} = 8 \cos 22 = 7.4 \text{ m/s}$

# 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.

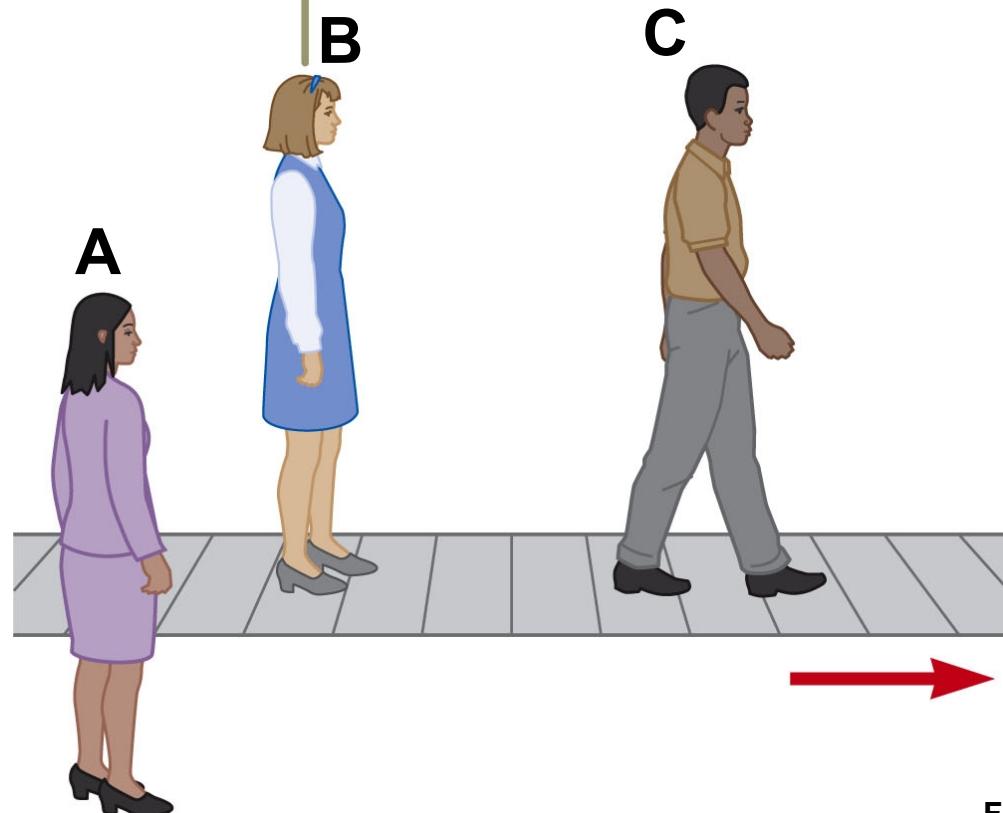
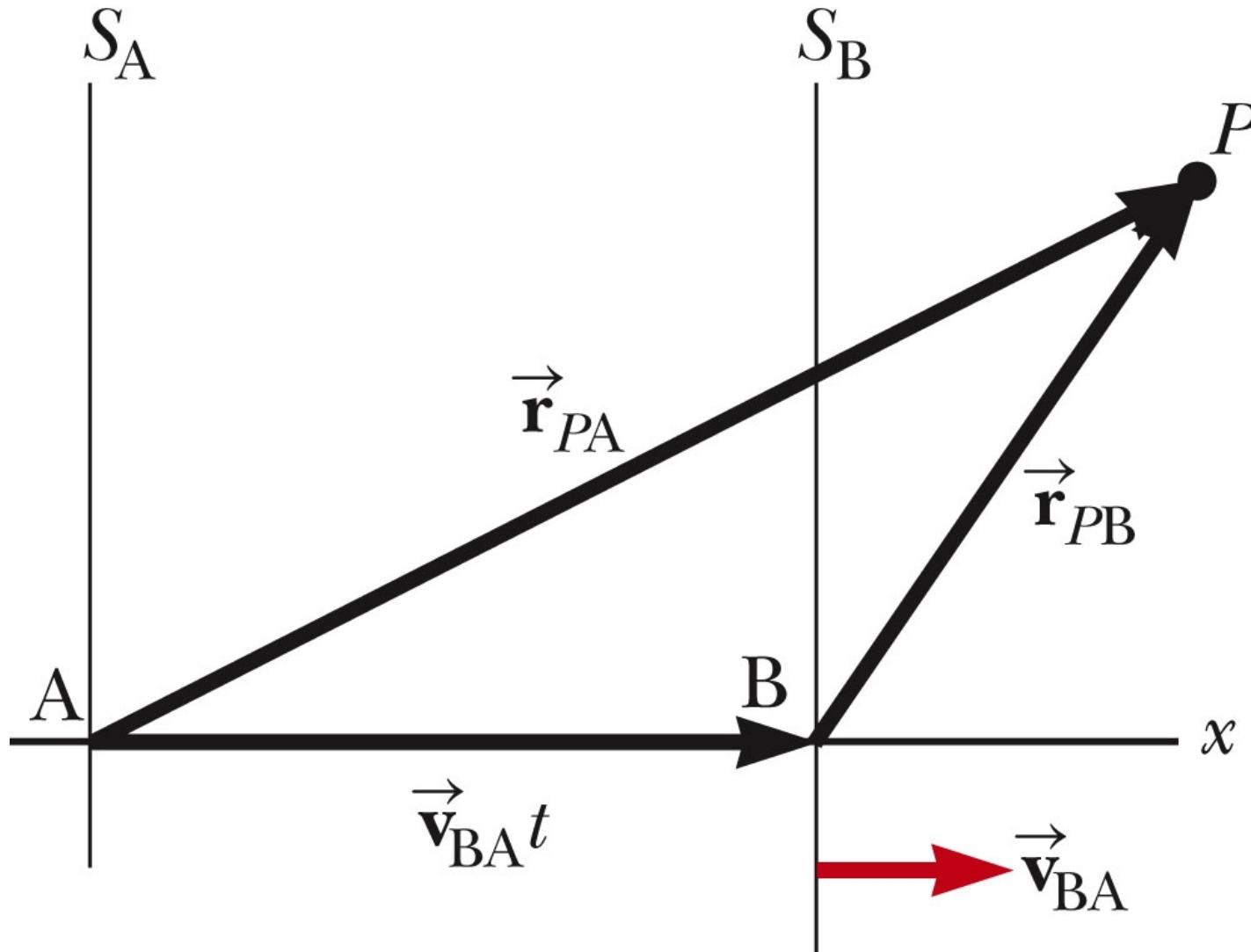


Fig. 4.19, p. 90

Transforming between two frames of reference, A and B.



$$\mathbf{r}_{PA} = \mathbf{r}_{PB} + \mathbf{r}_{BA} \rightarrow \mathbf{v}_{PA} = \mathbf{v}_{PB} + \mathbf{v}_{BA} \rightarrow \mathbf{a}_{PA} = \mathbf{a}_{PB} + 0$$

Fig. 4.20, p. 91

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

- 1) Inside of a truck that is accelerating in a line.  
(See movie “Frames of Reference” 13:27- 17:04 )
- 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” 17:05-22:00)
- 4) The Earth’s surface! (See movie “Frames of Reference” and the Foucault pendulum 24:20-26:00.)

Try “Relative motion airplane example” under NEW STUFF.

# Outline for Day W4,D3

Types of Forces

Newton's 2<sup>nd</sup> and 3<sup>rd</sup> laws.

Weight vs Mass

## Homework

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

MisQ 1-11 (odd), Read Sec 4.1-4.8, 3.9. Do by Mon  
Watch “frames of reference”

## Notes:

“NEW STUFF” has key for “exam-like questions” Ch 1-3.  
Engineering tutoring is 7-9 pm on Wednesdays, JLK 203.  
Exam I follows Chapter 5 material.

# Forces – the cause of acceleration

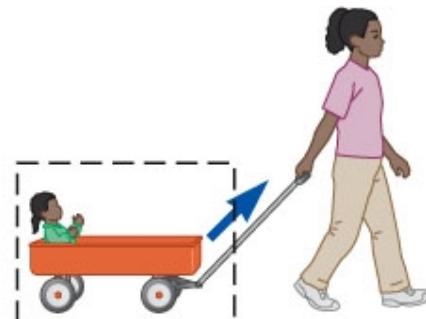
Forces are vectors

Forces act between *systems* (the dashed boxes)

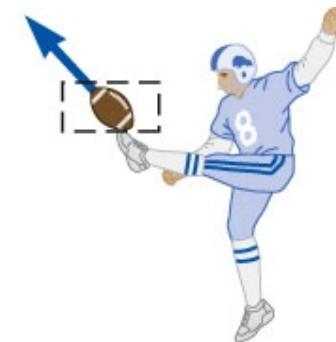
Contact forces



a

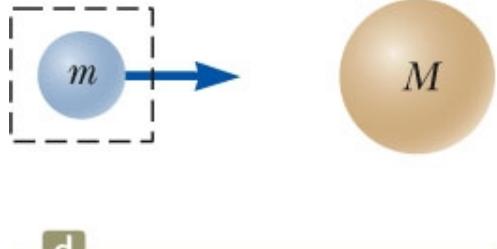


b

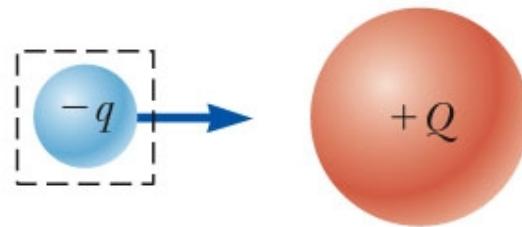


c

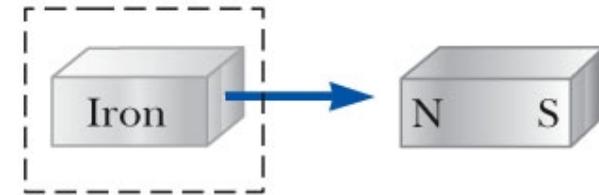
Field forces



d



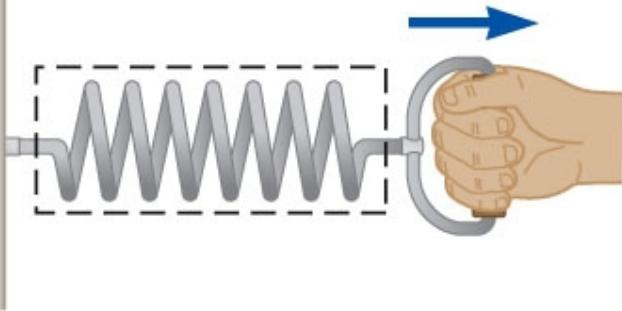
e



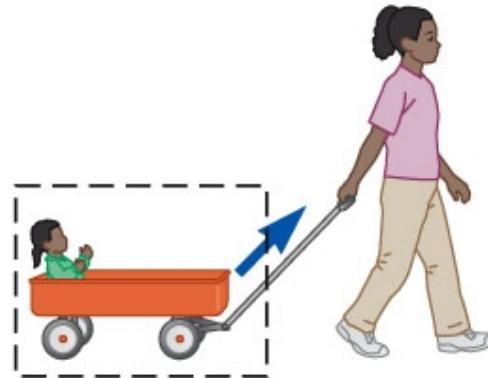
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# Types of forces

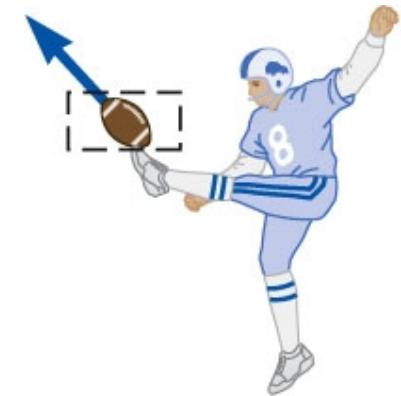
Contact forces



a



b



c

contact forces

tension – pulling apart

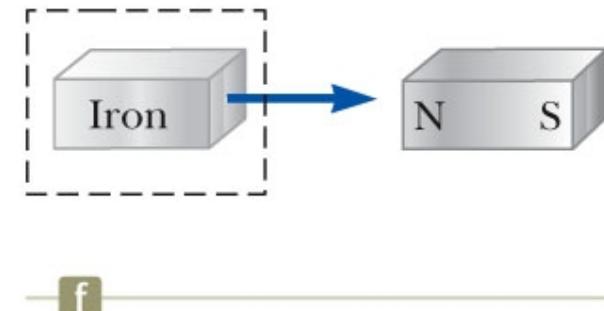
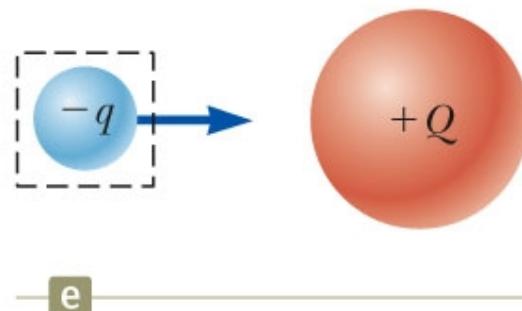
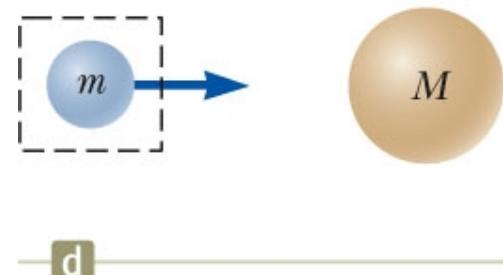
compression – pushing together

shear – pushing tangentially

torsion - twisting

# Types of forces

Field forces



Field forces

gravitational

electric

magnetic

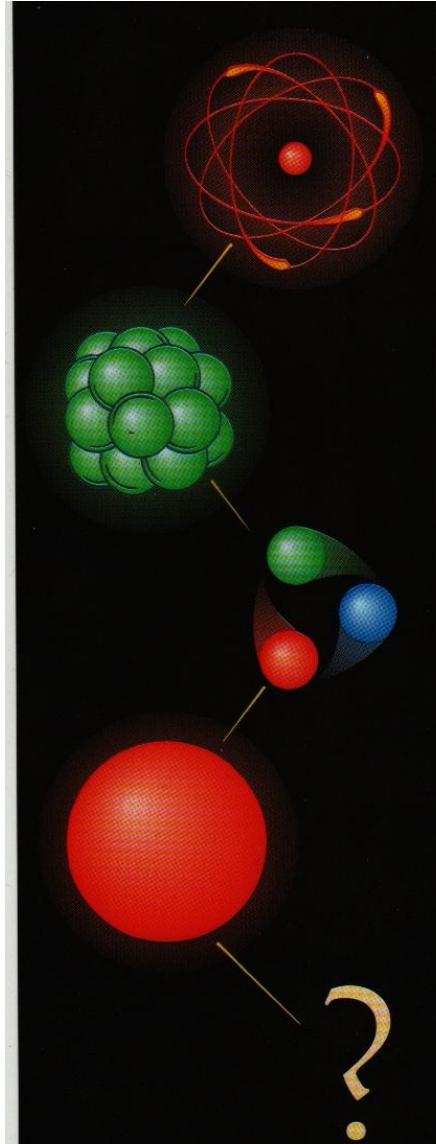
# The 4 Fundamental forces

Gravity

Electromagnetic Force

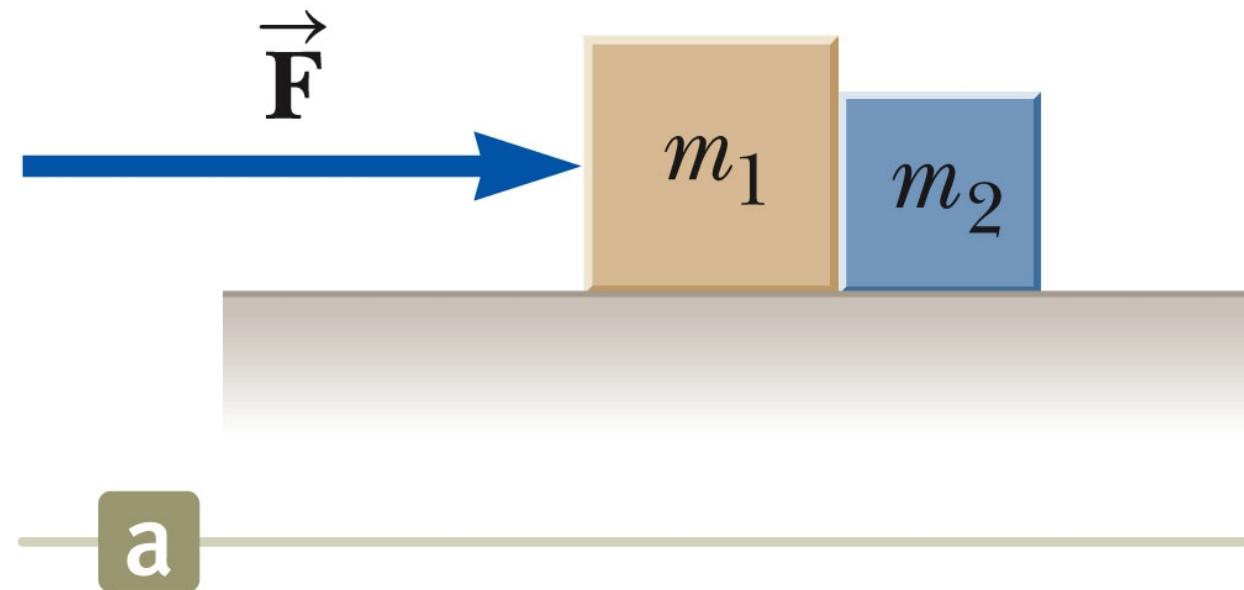
Nuclear Strong Force – holds nuclei together

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.*

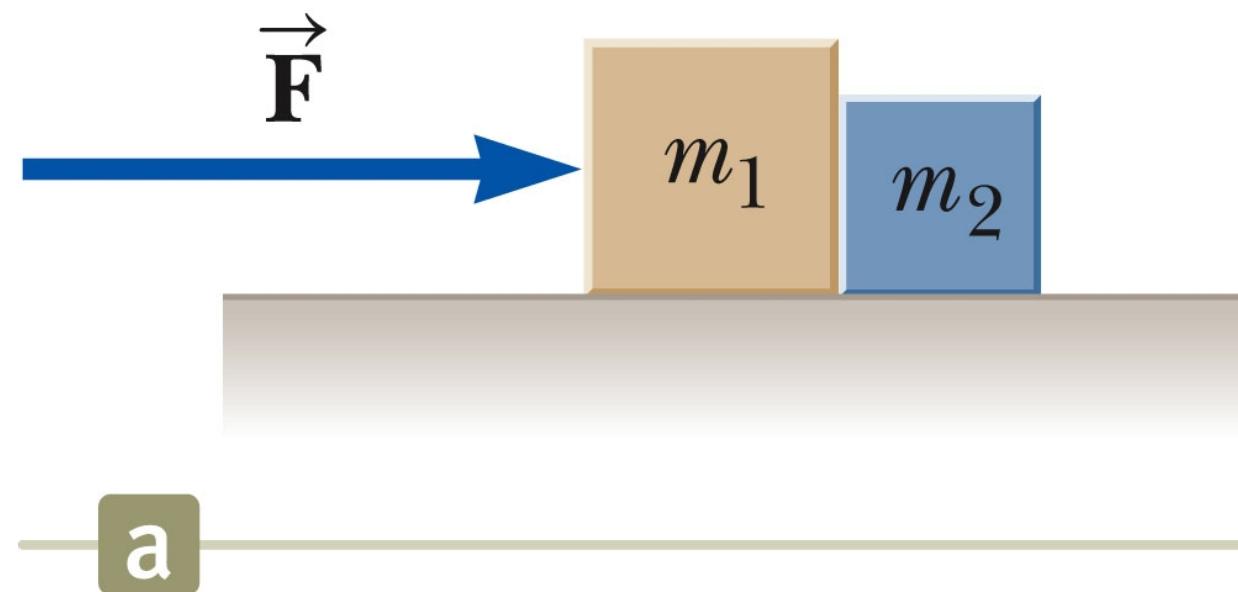
Newton's 2<sup>nd</sup> law = the acceleration of an object is proportional to the net force and inversely proportional to the mass.



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

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 = the acceleration of an object is proportional to the net force and inversely proportional to the mass.



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

Let  $m_1=5$  kg,  $m_2=2$  kg, and  $\vec{F} = 10$  N  $\hat{i}$ .

- 1) Find  $\vec{a}_1$  if  $\vec{F}$  acts only on  $m_1$ .
- 2) Find  $\vec{a}_2$  if  $\vec{F}$  acts only on  $m_2$ .
- 3) Find  $\vec{a}_{1+2}$  if  $\vec{F}$  acts on both  $m_1$  and  $m_2$ .
- 4) In #3, what is the force on  $m_1$  by  $m_2$ ,  $\vec{F}_{12}$ ?

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

Does free fall due to gravity obey Newton's 2<sup>nd</sup> law?

Yes:  $F_{\text{net}} = F_g$  if only gravity acts. Then  $a = F_g/m = mg/m = g$

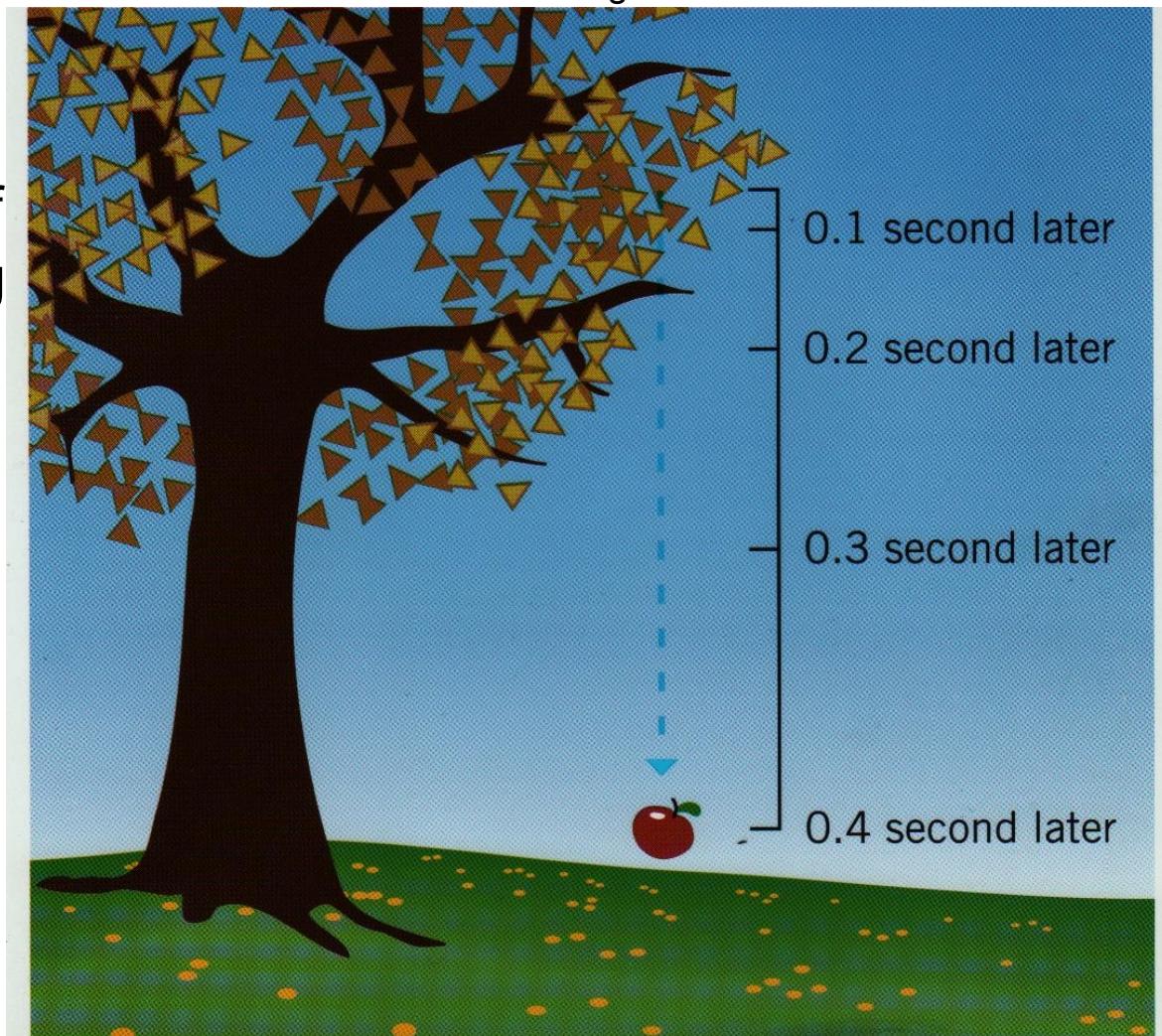
Ex) Compare the  $F_g$  and the free fall acceleration of a 0.2 kg apple and a 20 kg anvil.

Weight = the force of gravity on an object

$$W=F_g$$

Mass = the amount of matter in an object

Inertial mass = gravitational mass



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

Ex) P. 4.5. What average force is required to stop a 950 kg Car in 8.0 sec if the car is traveling at 95 km/hr?

Set up: "average force" = net force.  $F_{\text{net}} = m a$

First must find  $a_{\text{avg}} = \Delta v / \Delta t = (0 - 95 \text{ km/hr}) / 8.0 \text{ sec}$

Convert to m/s:  $95 \text{ km/hr} (1\text{hr}/3600\text{s})(1000 \text{ m/km}) = 26.4 \text{ m/s}$

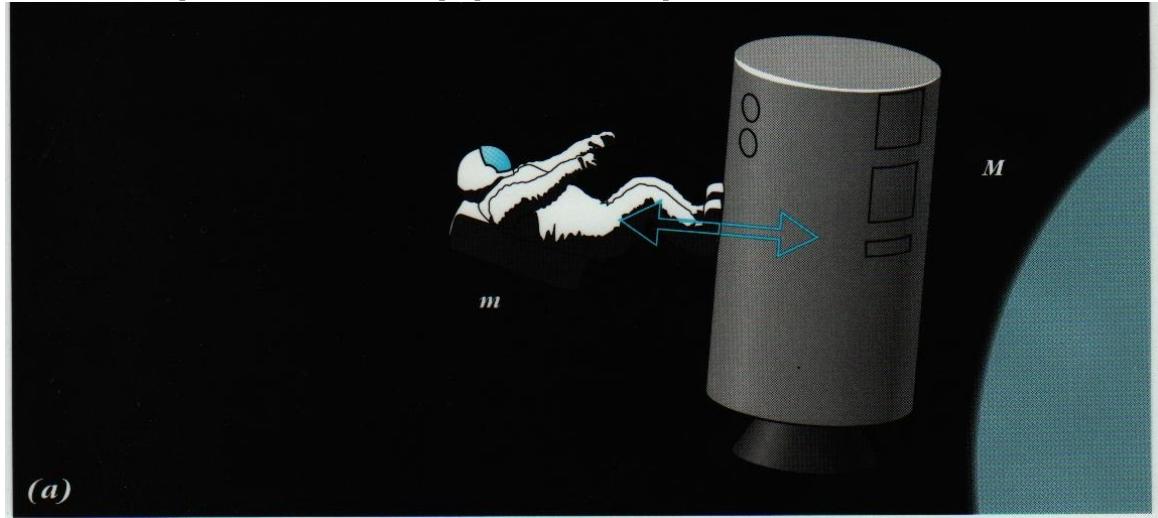
Then  $a_{\text{avg}} = 26.4 / 8.0 = 3.30 \text{ m/s}^2$

And so  $F_{\text{avg}} = ma_{\text{avg}} = 3134 \text{ N}$

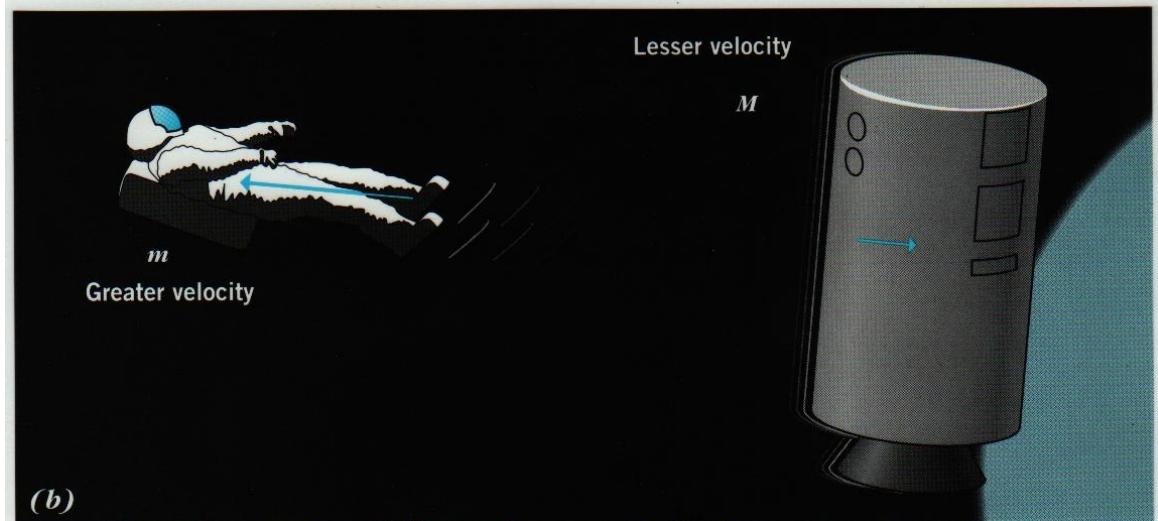
## Newton's 3<sup>rd</sup> law (cont.)

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

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$



(a)



(b)

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

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

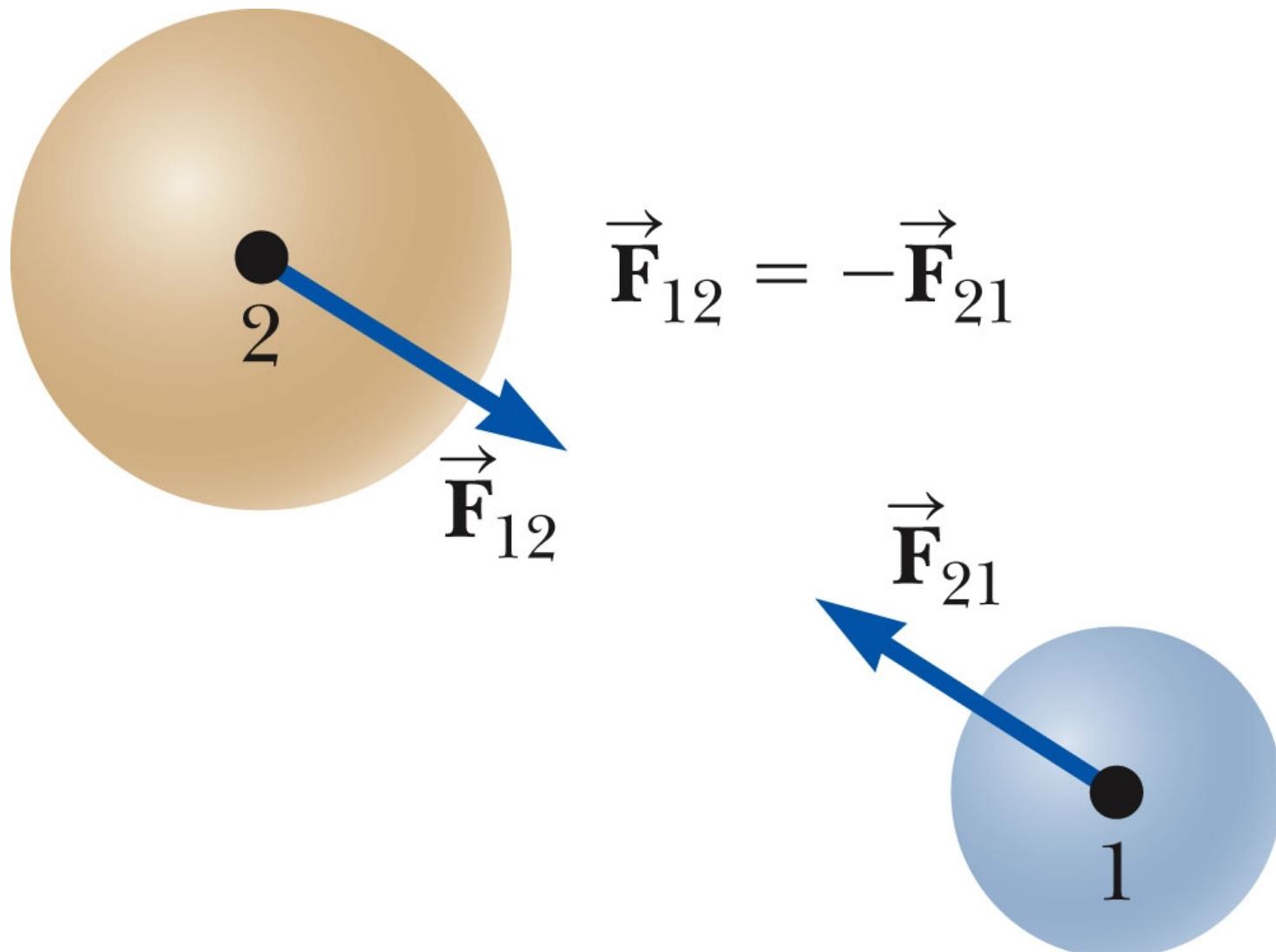
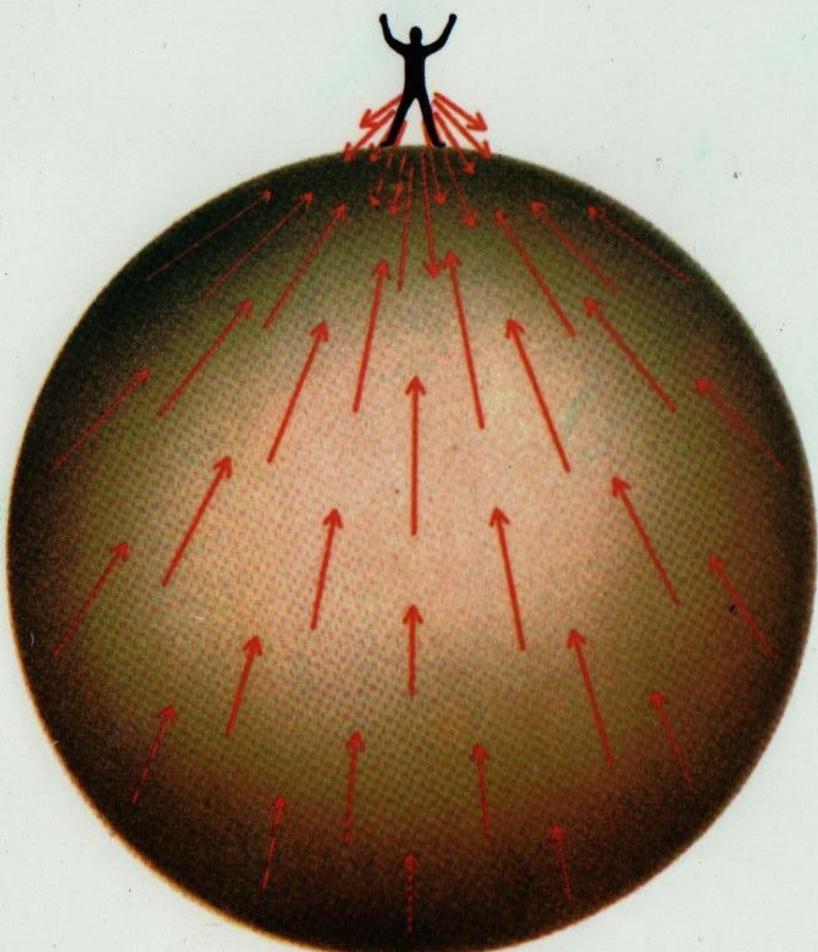
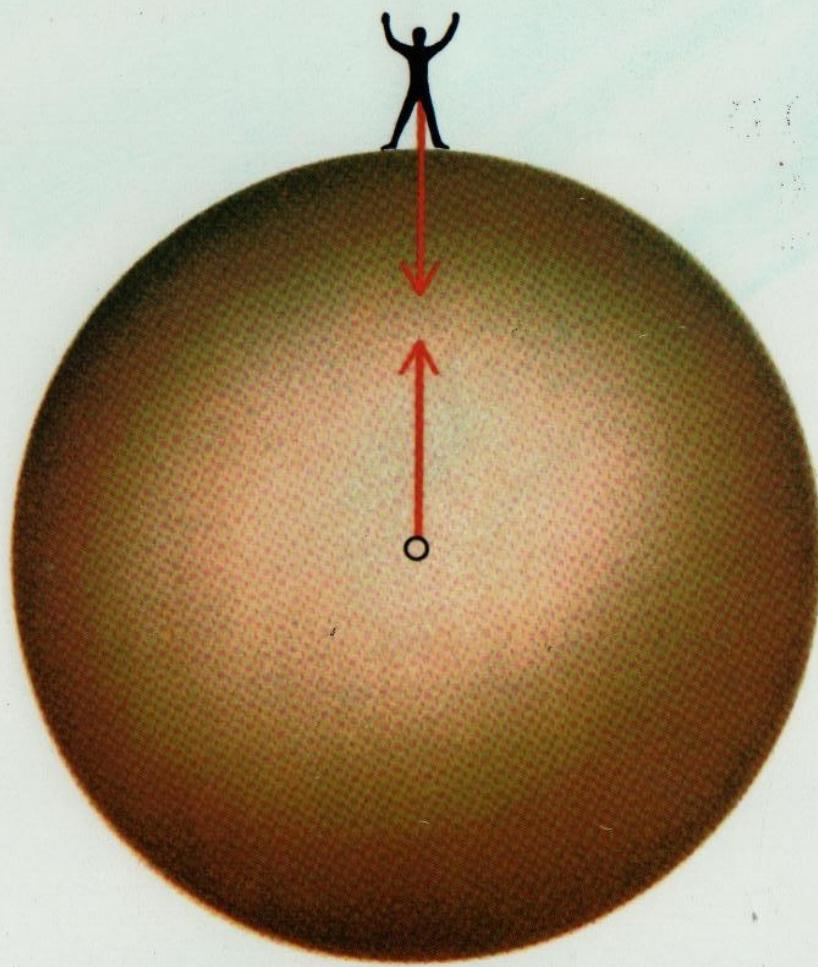


Fig. 5.5, p. 111

## 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. **DEMO**

# 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

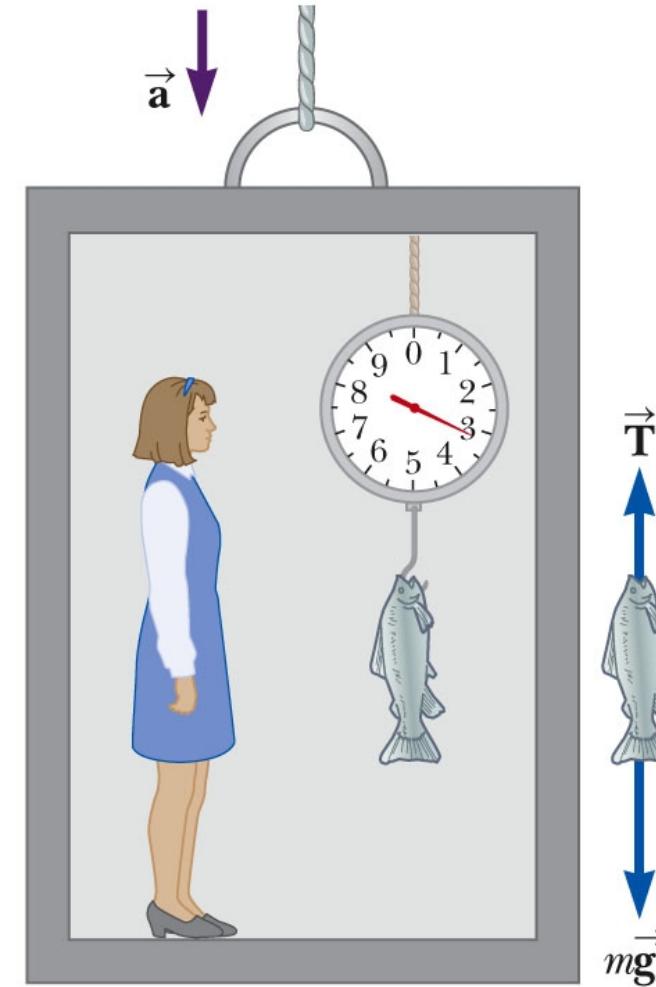
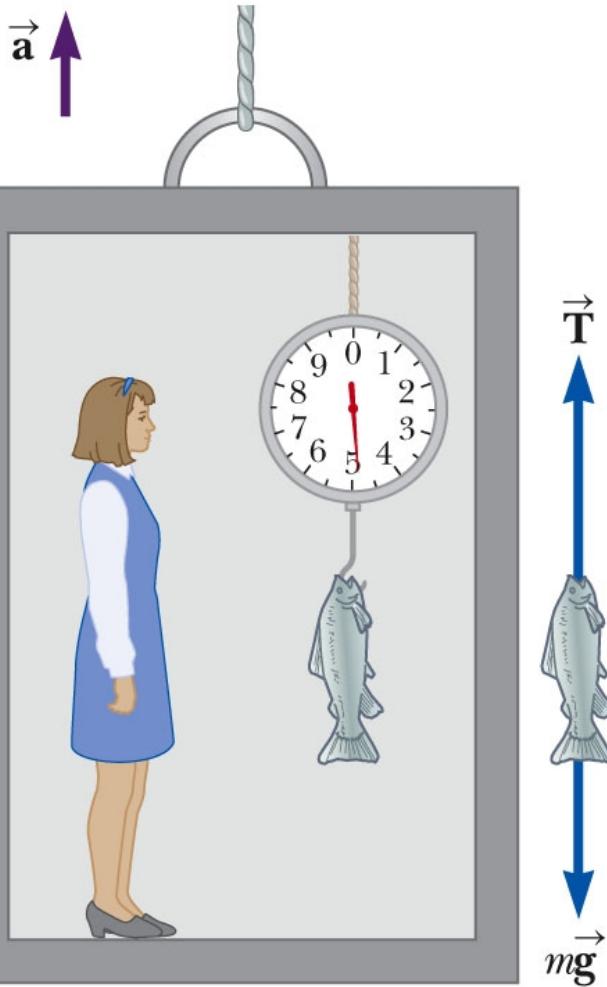
## 3. Analyze

- Isolate object of interest and draw forces acting on it. **F.B.D.!**
- 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.

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.

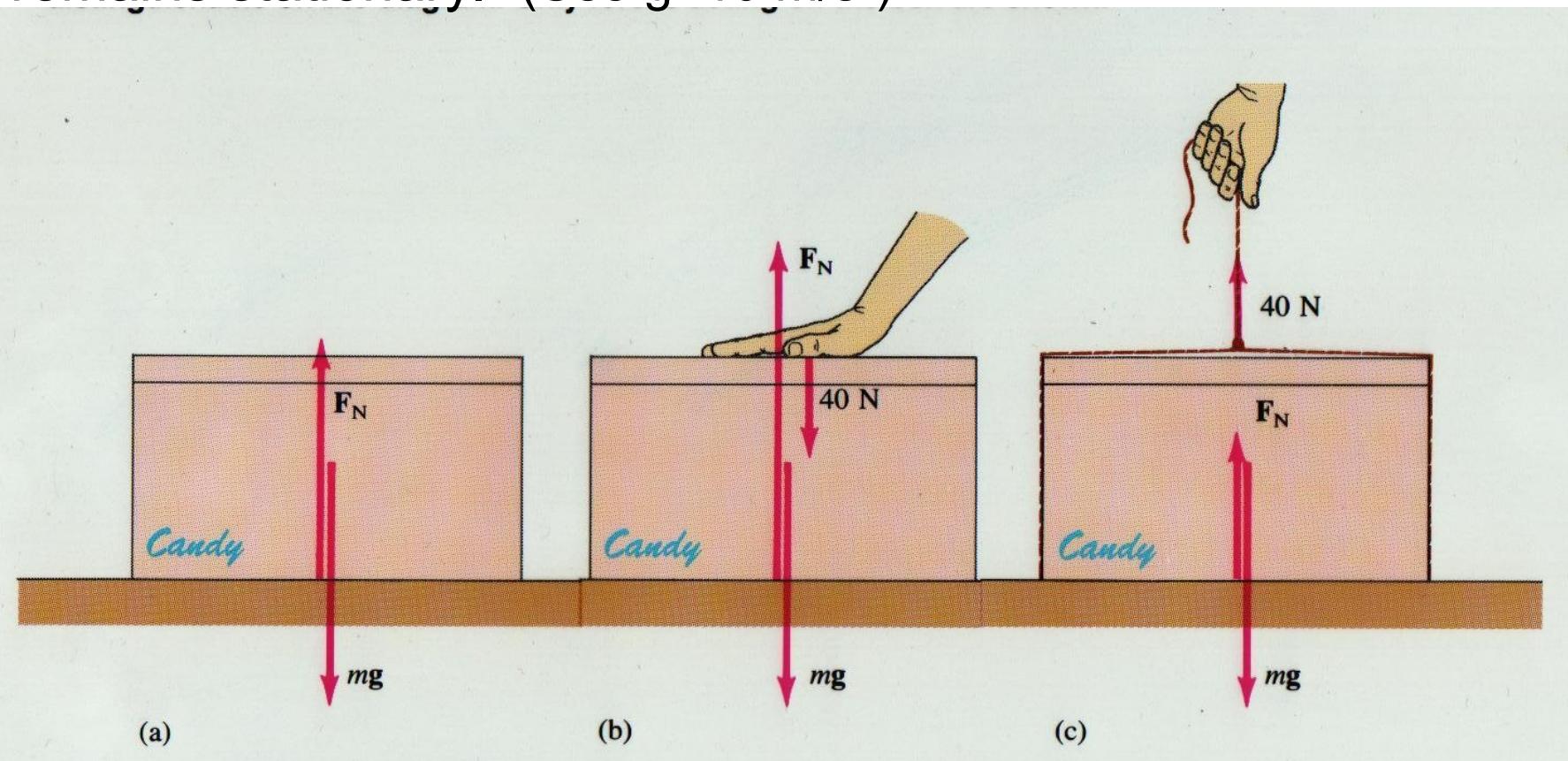


a

b

# The Application of Newton's Laws

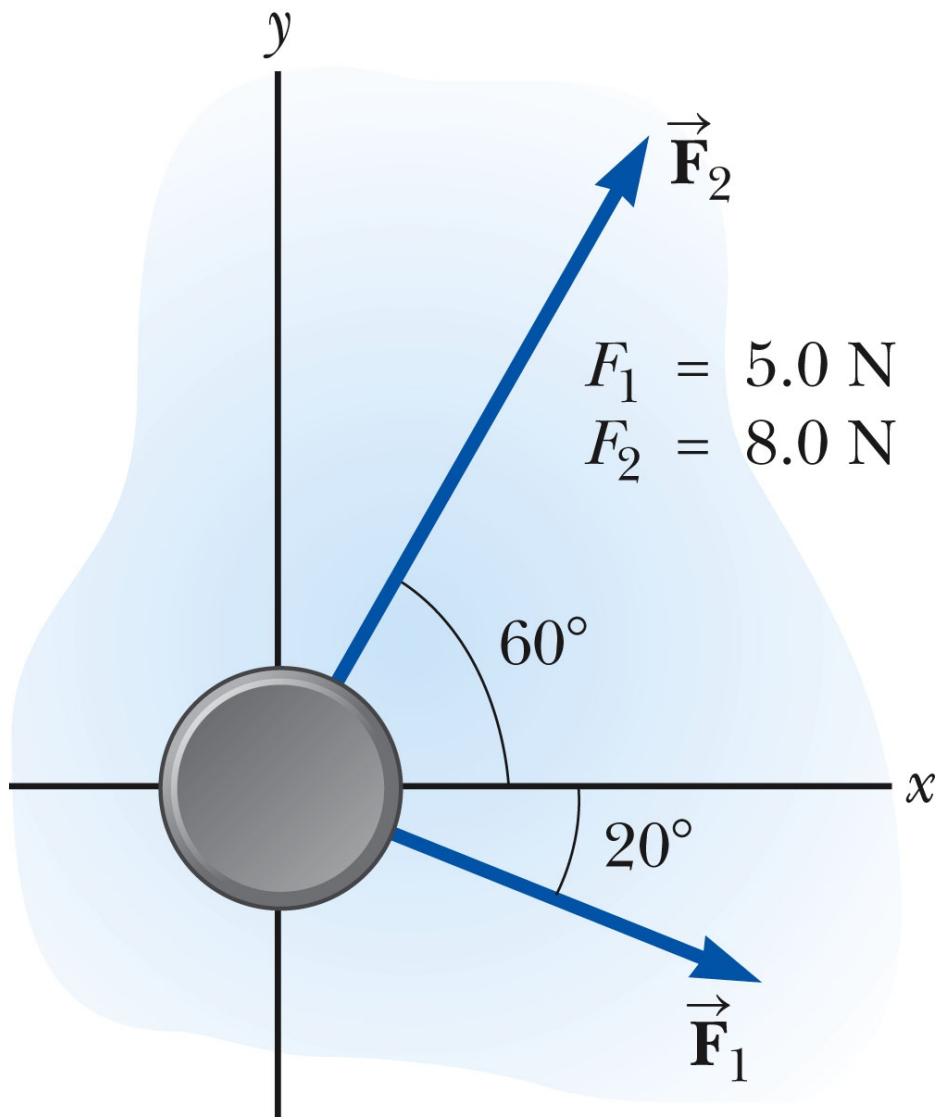
Find the normal force in each case if  $m=1\text{ kg}$  and the box remains stationary. (Use  $g=10\text{ m/s}^2$ )



**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.



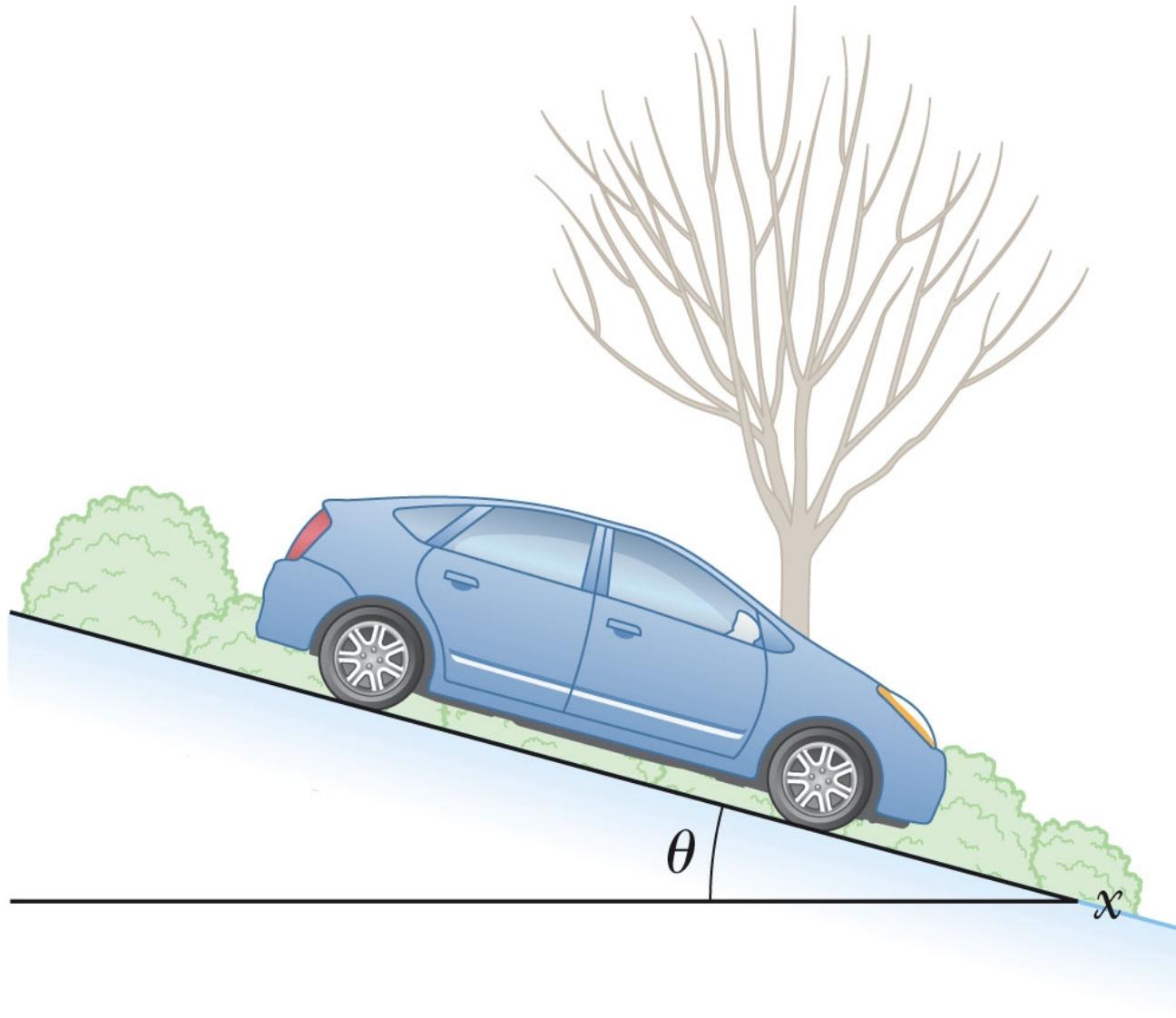
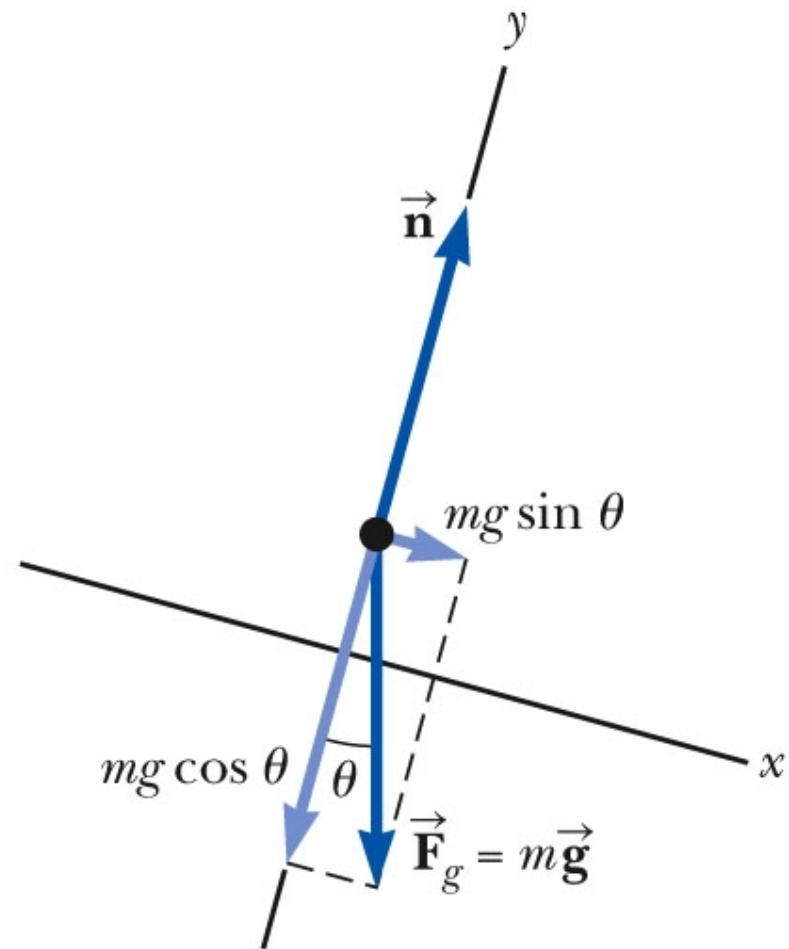
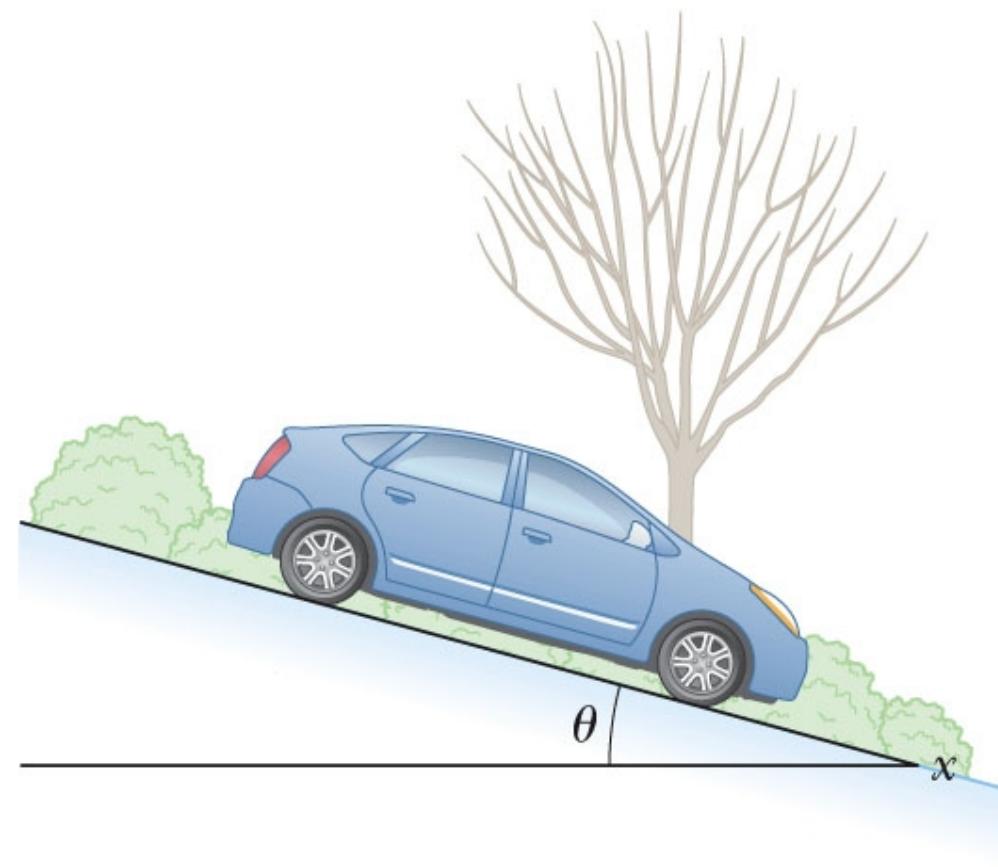


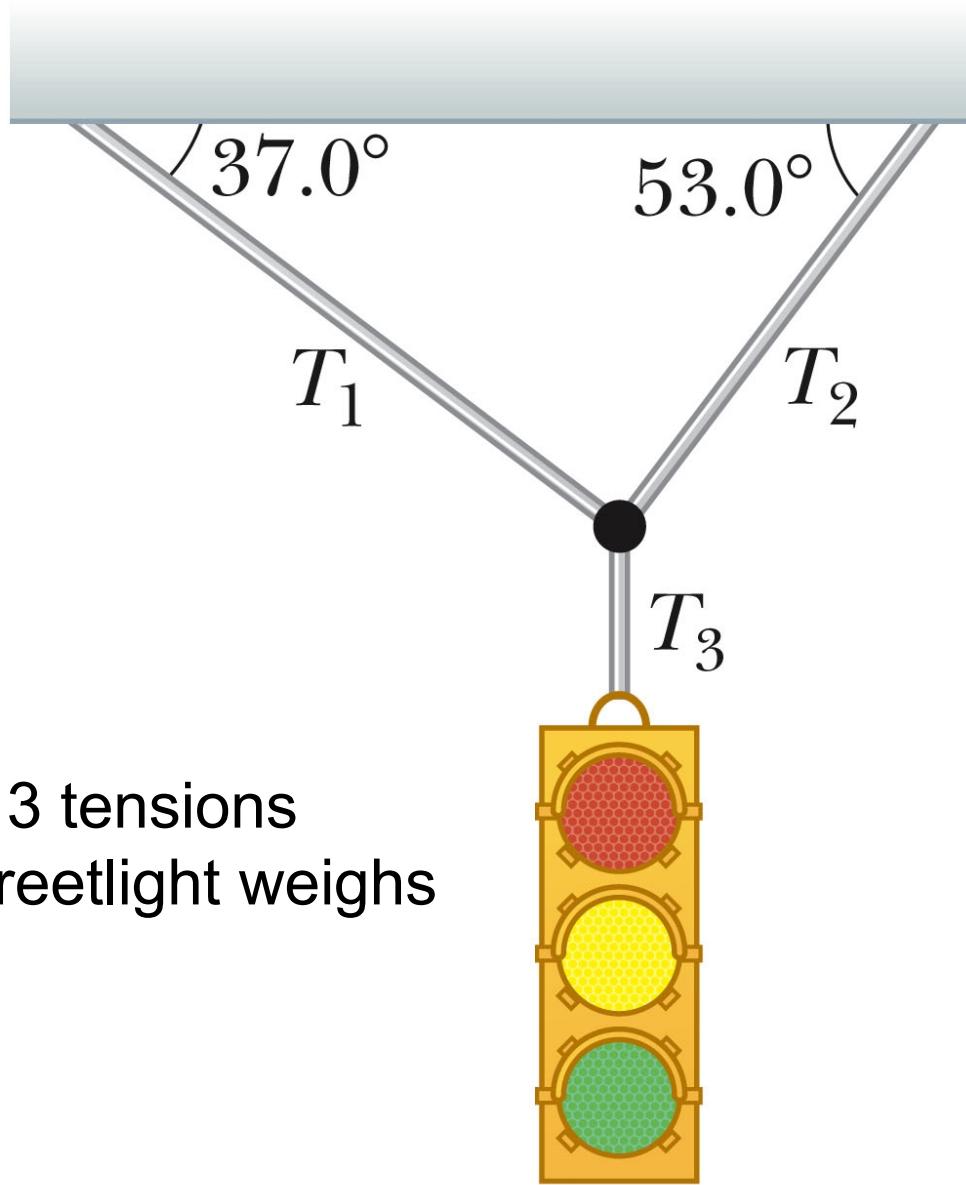
Fig. 5.11, p. 116

Find the acceleration of an object on a frictionless incline.



a

b



Find all 3 tensions  
If the streetlight weighs  
200 N.

a

Fig. 5.10, p. 114

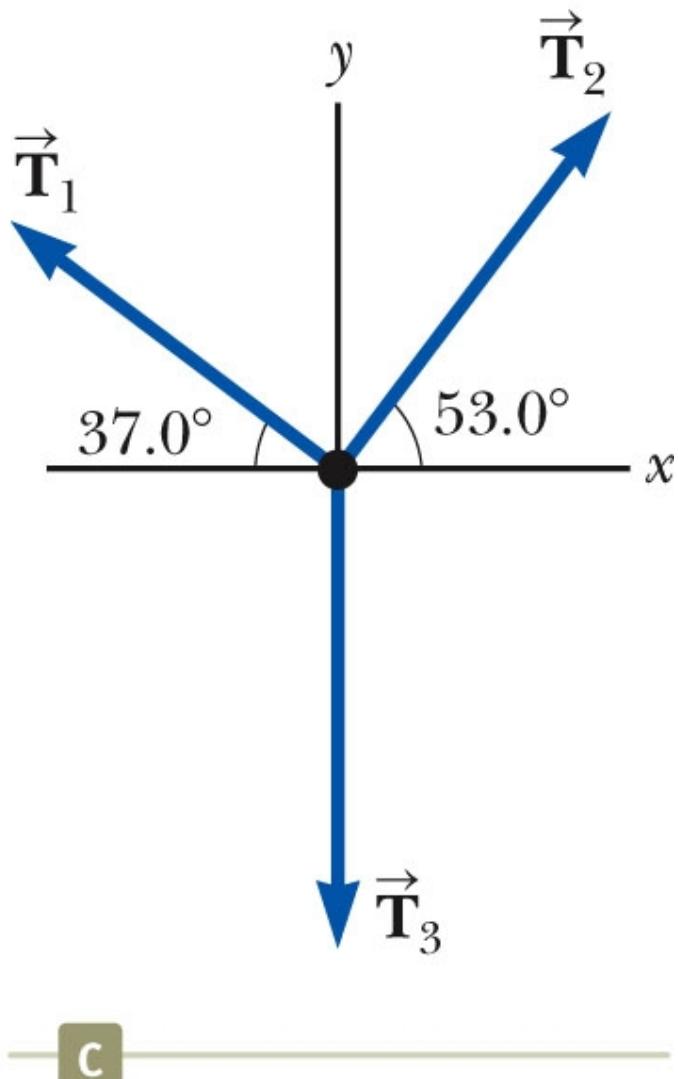
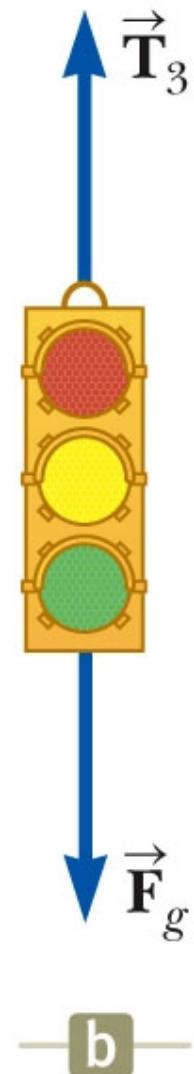
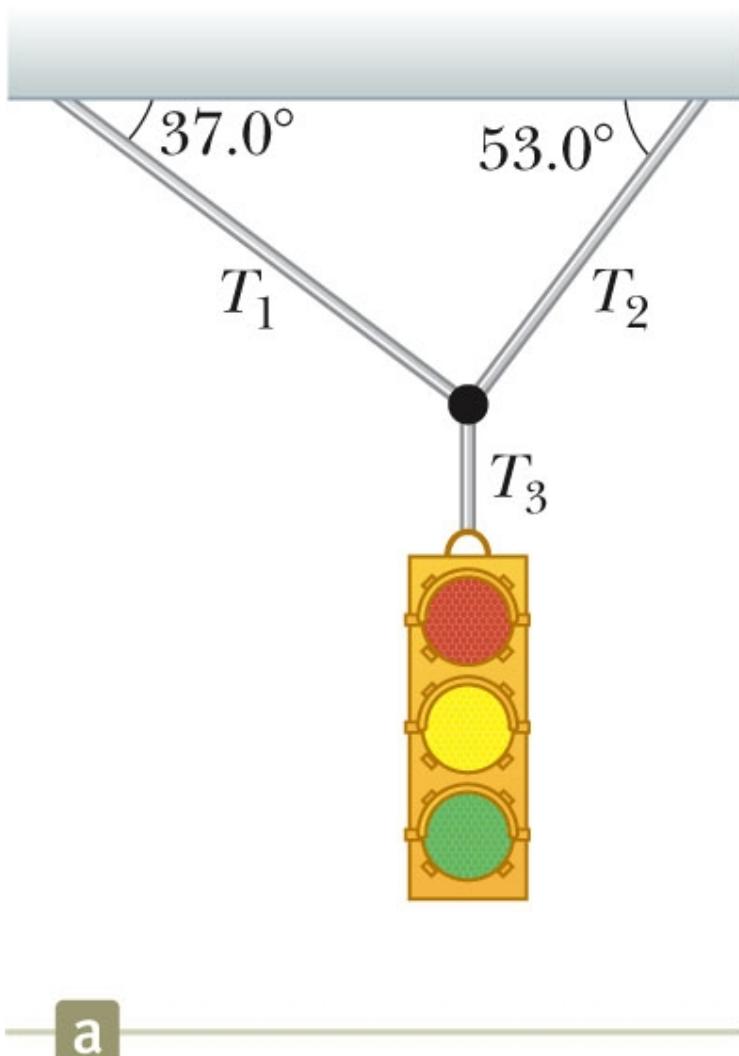


Fig. 5.10, p. 114

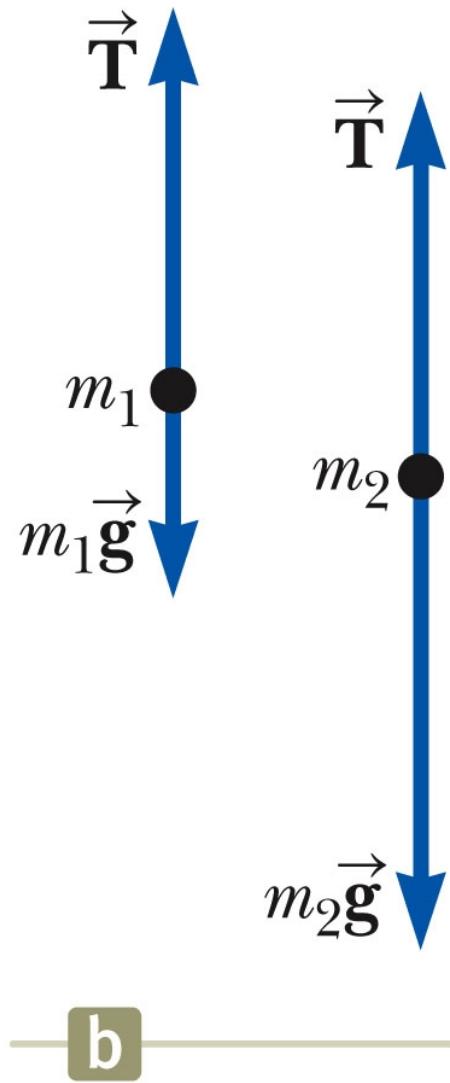
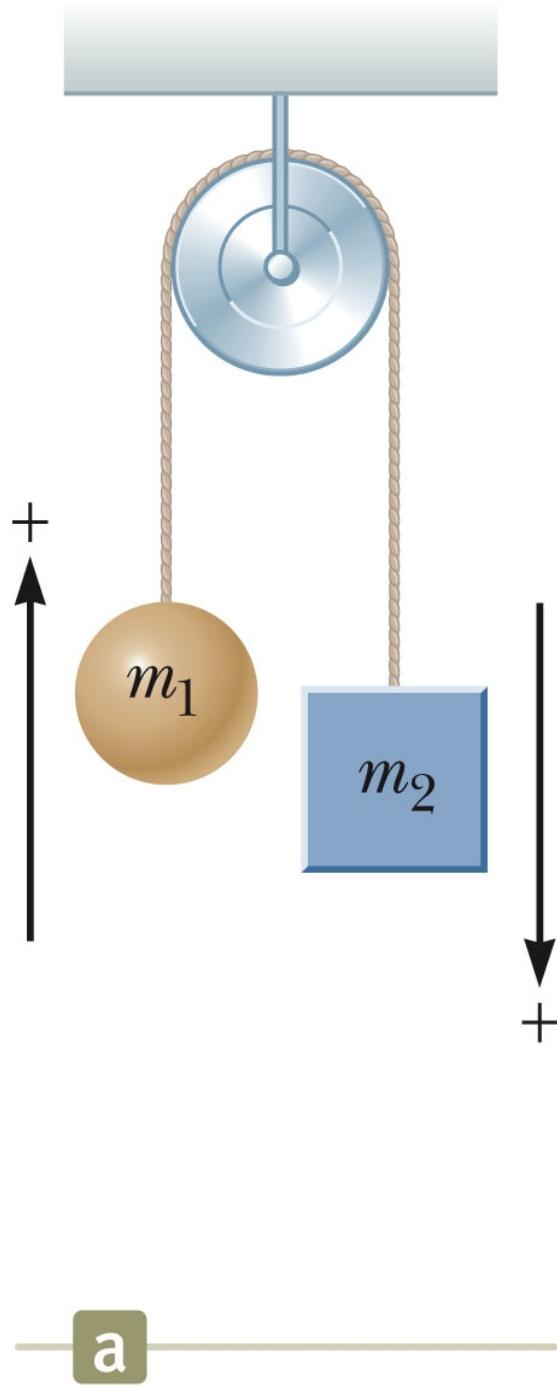


Fig. 5.14, p. 120

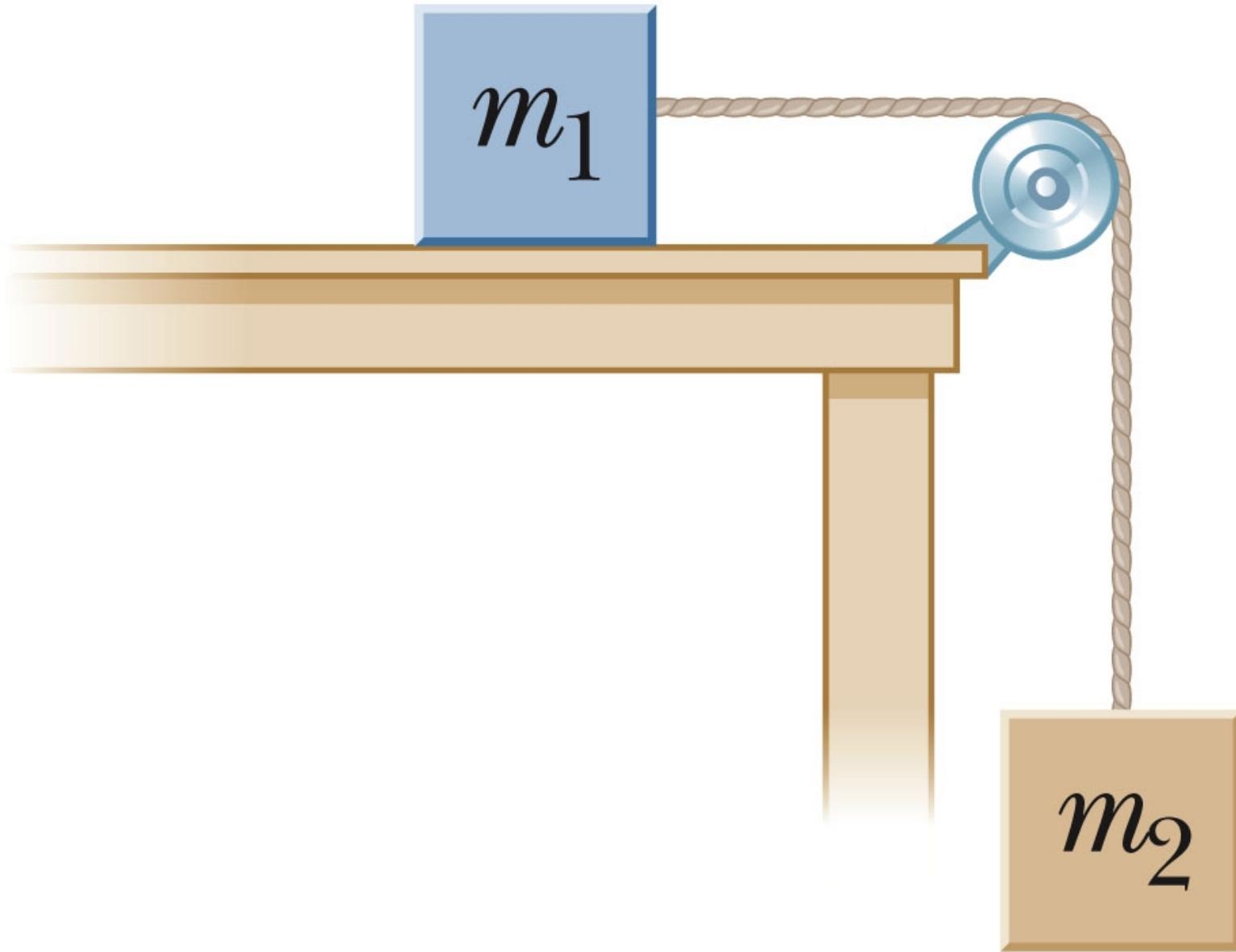
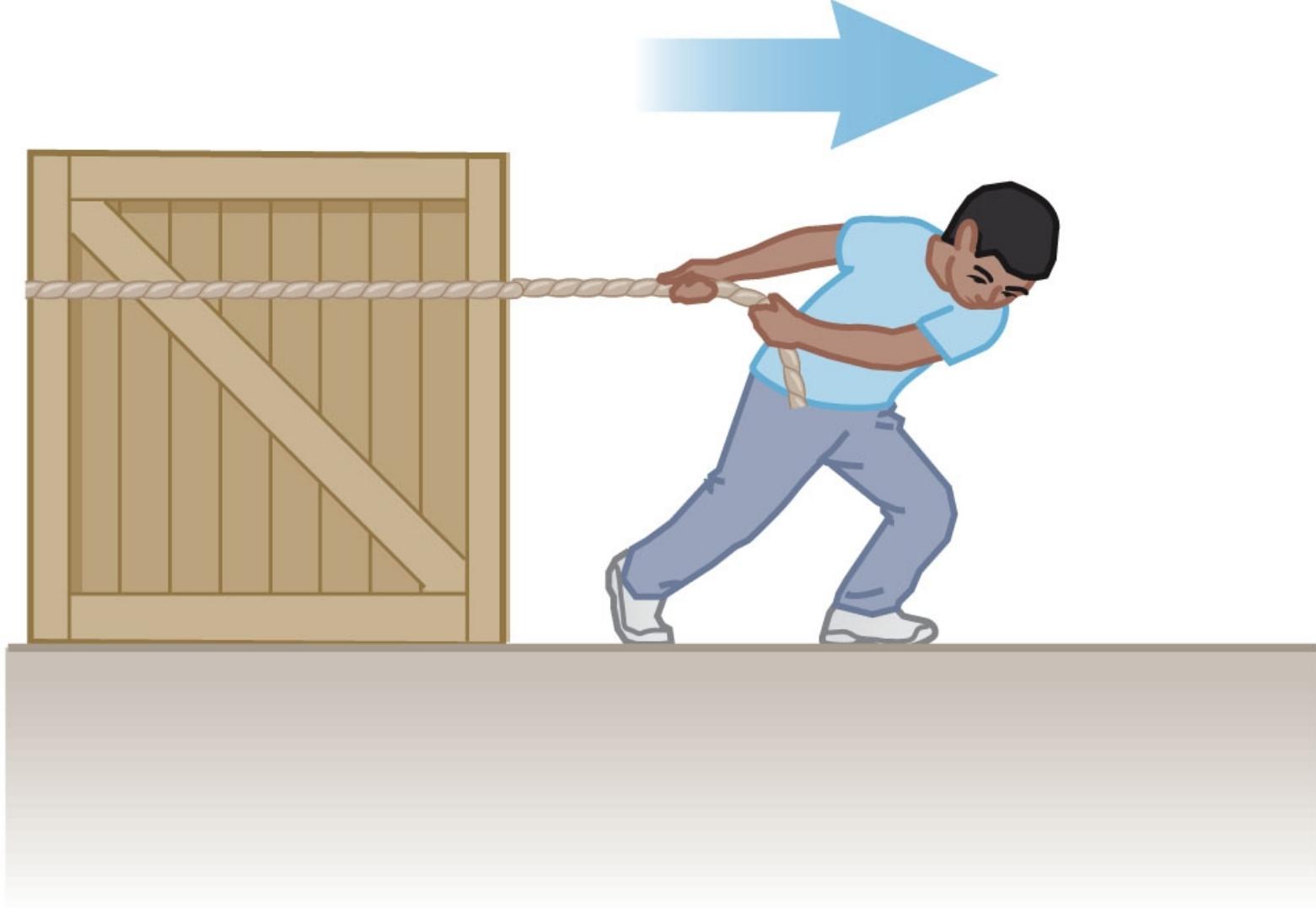


Fig. P5.28, p. 133



a

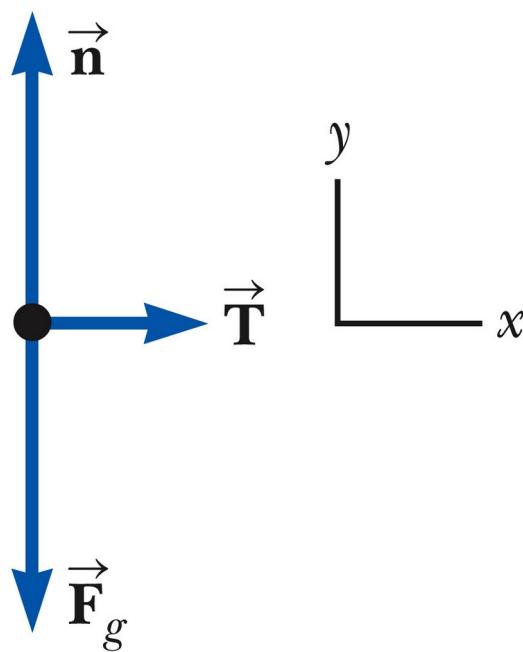


Fig. 5.8, p. 113

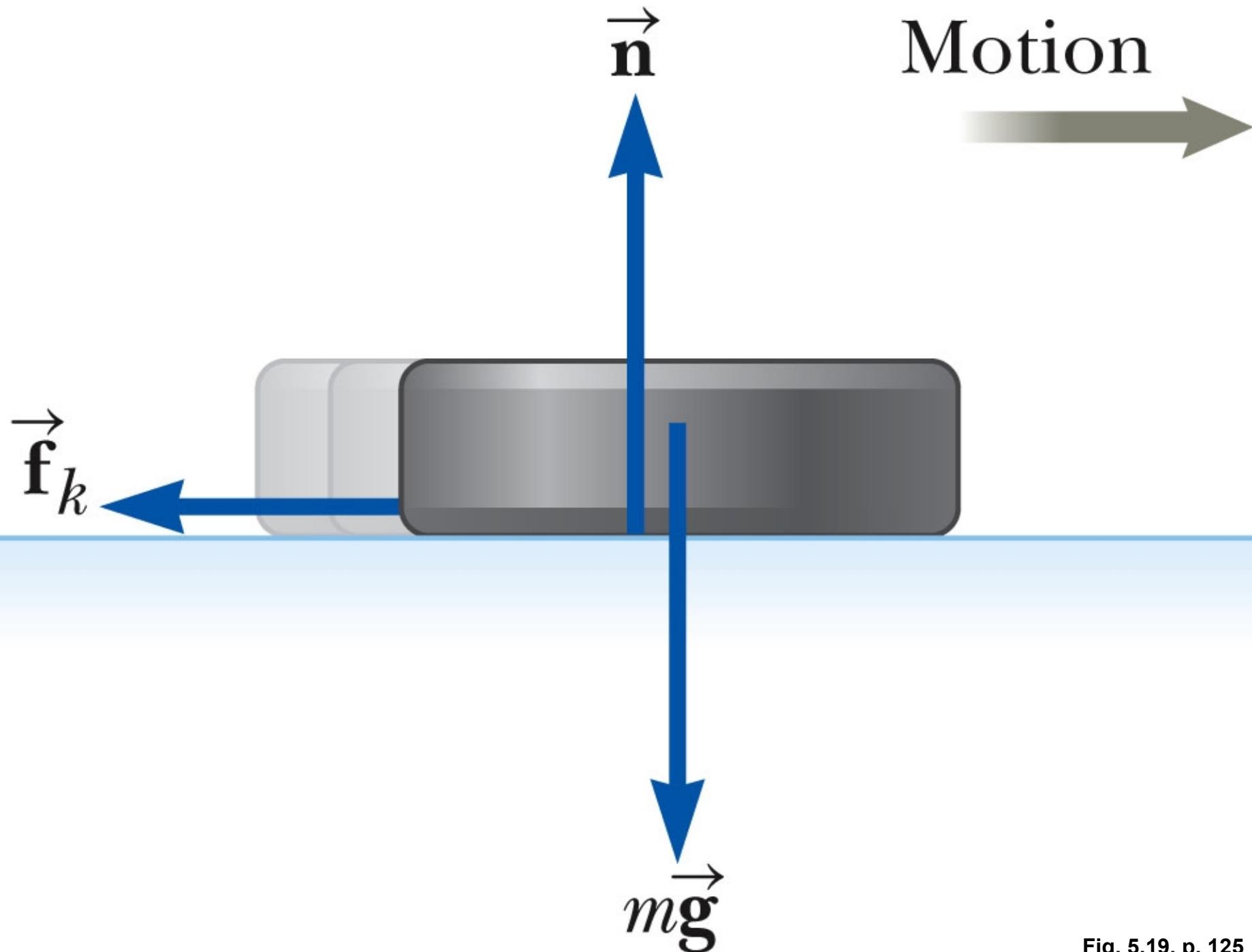
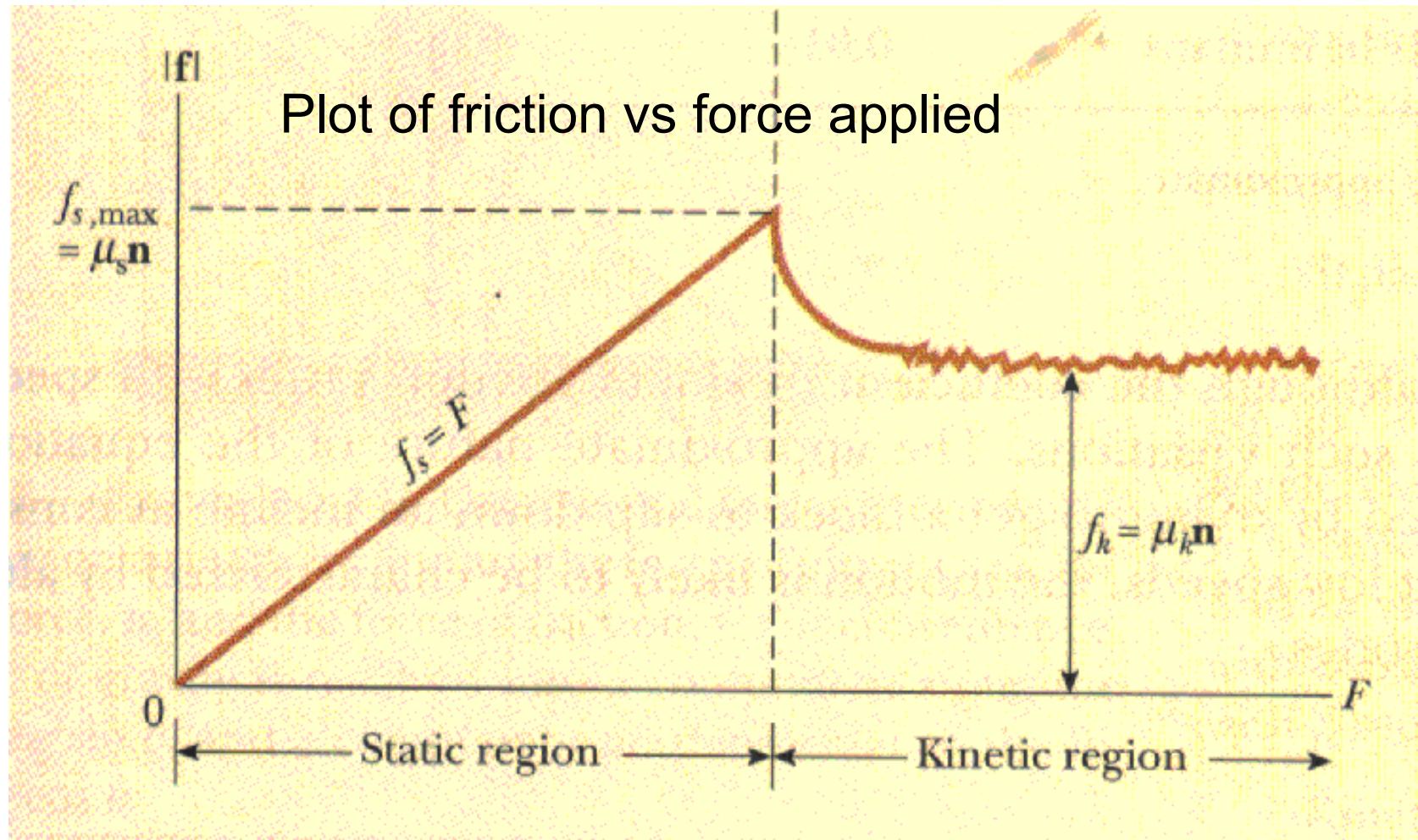
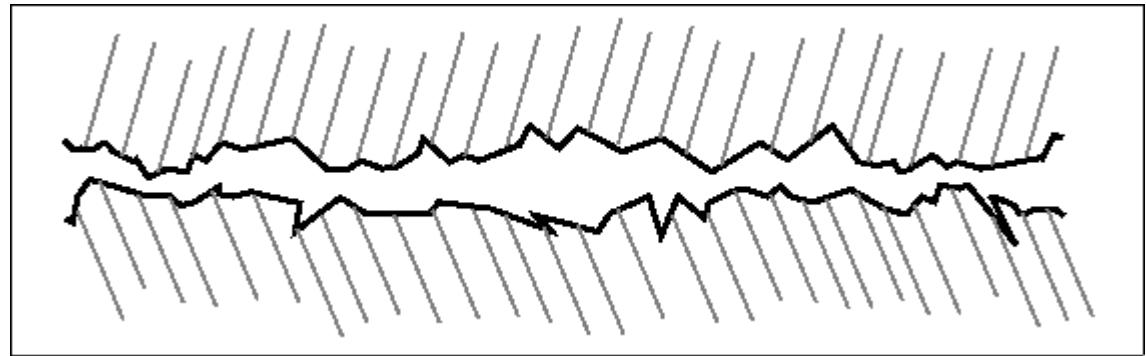
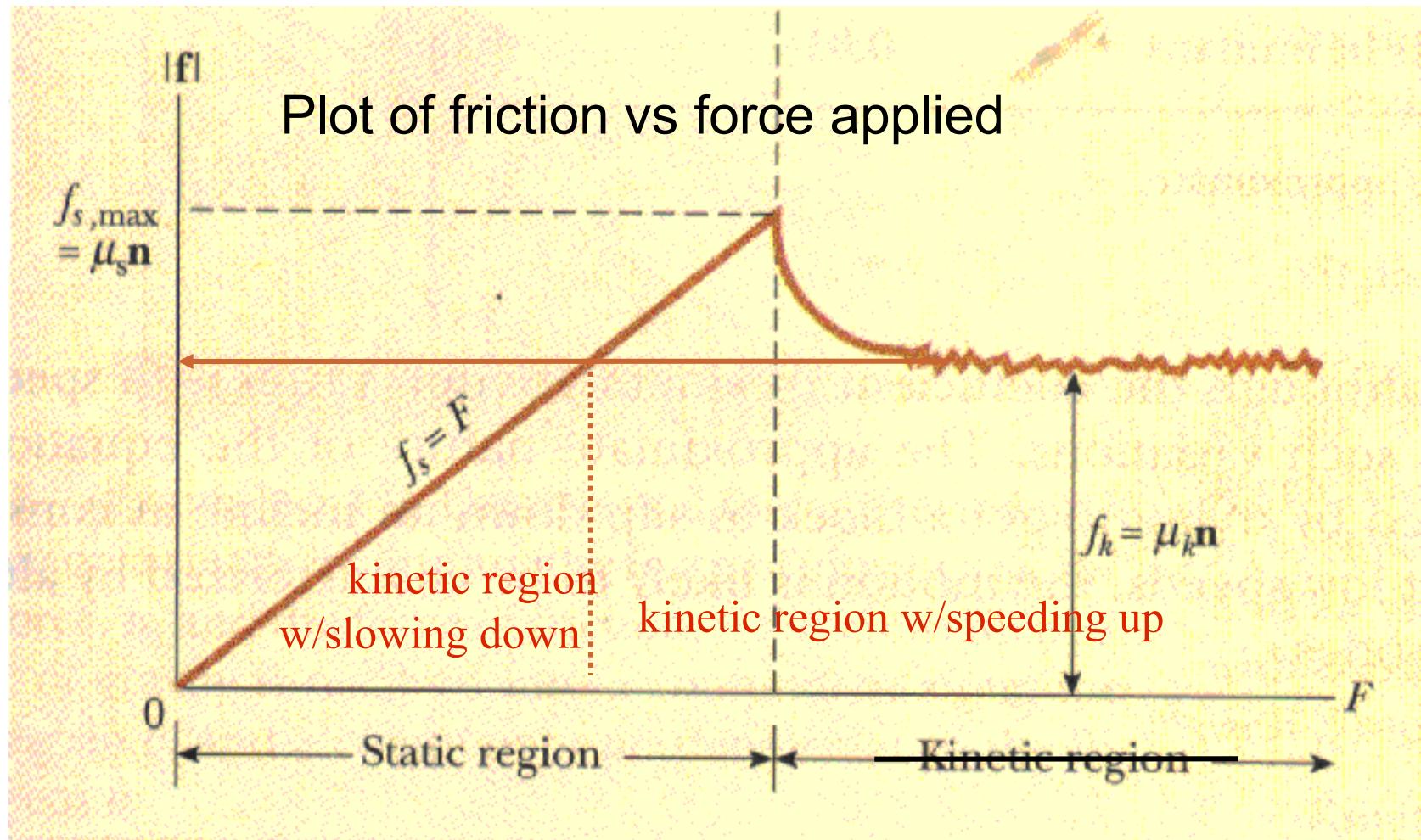
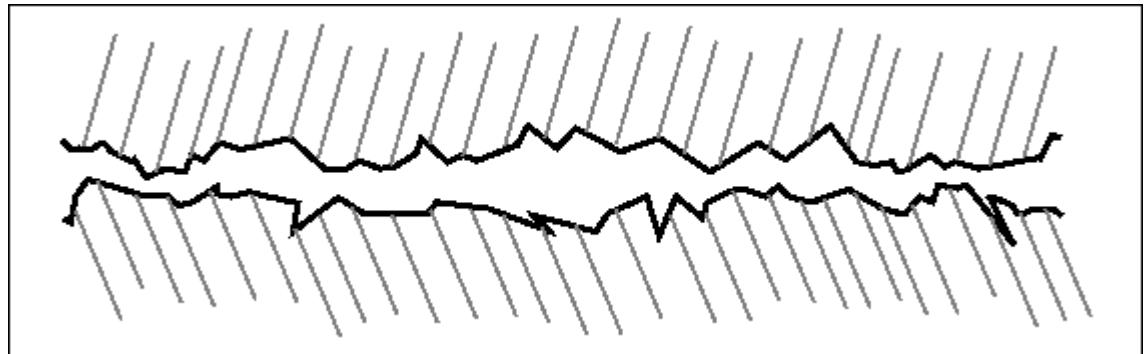


Fig. 5.19, p. 125

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.

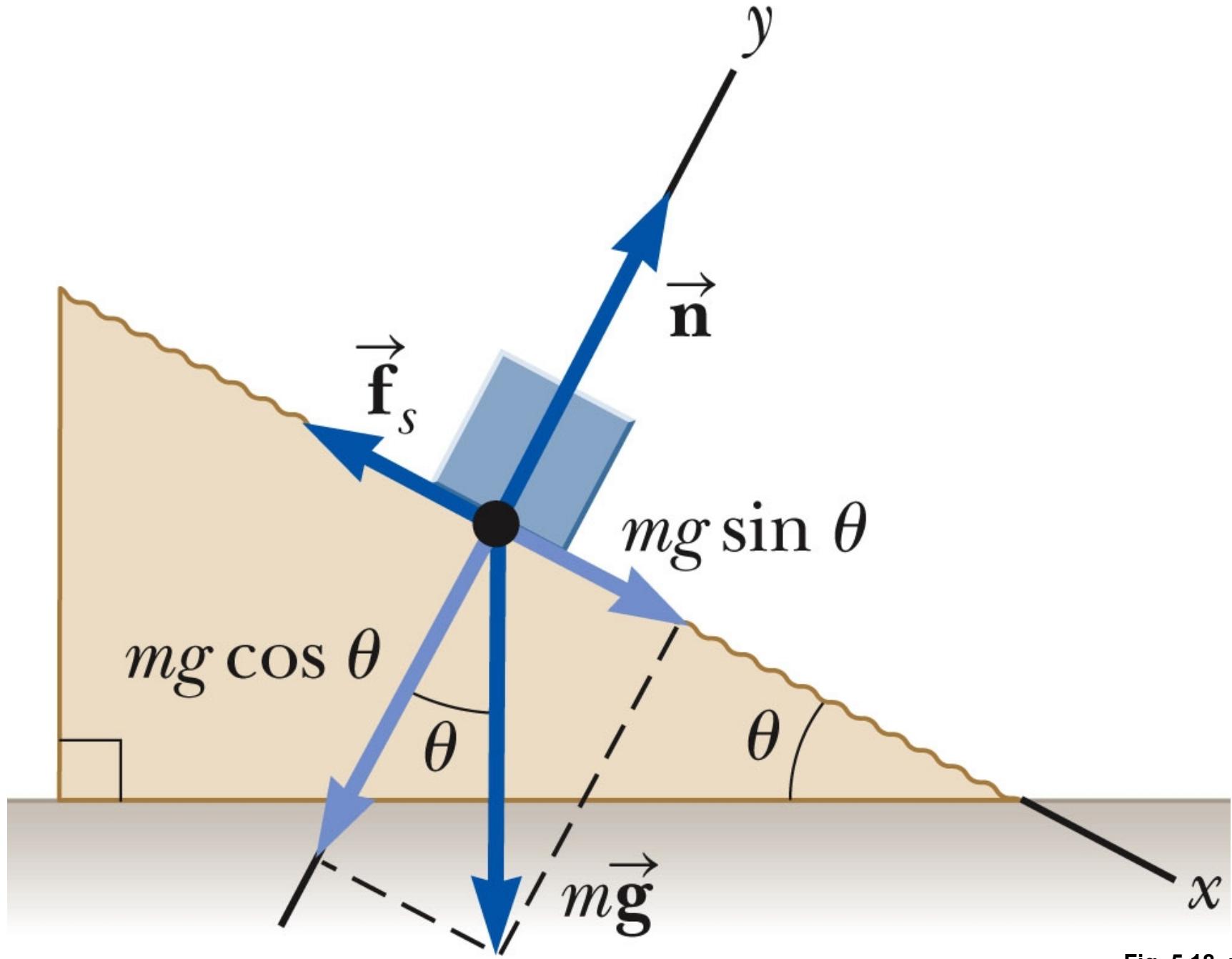
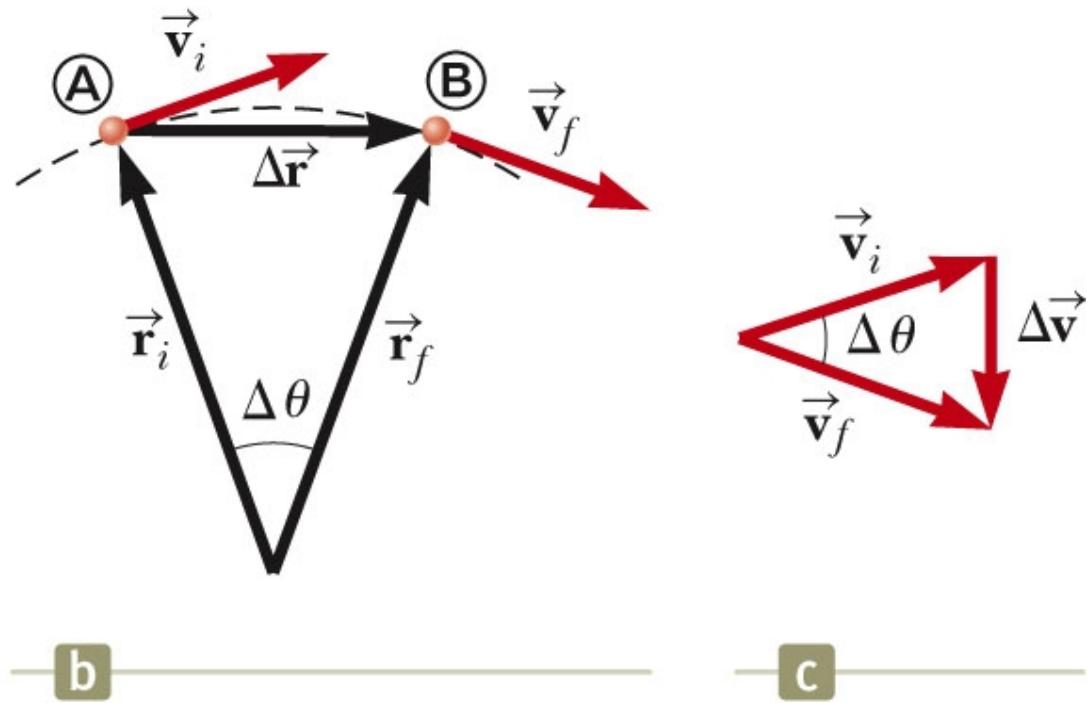
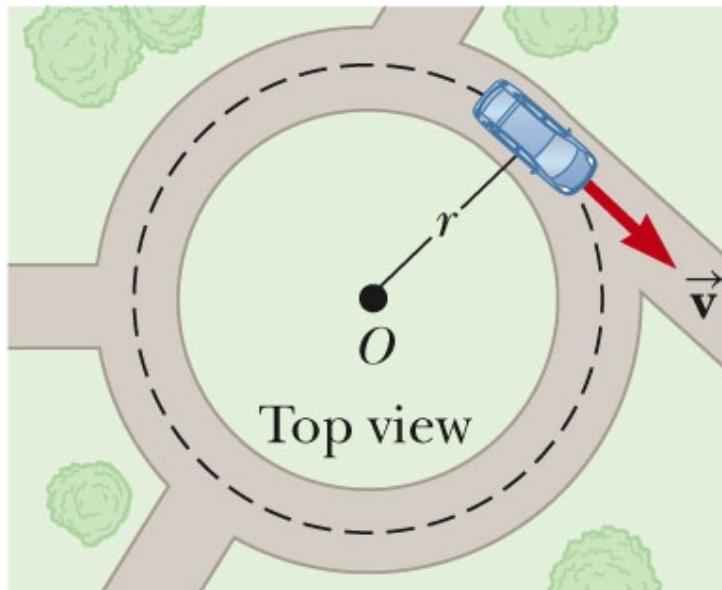


Fig. 5.18, p. 124

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

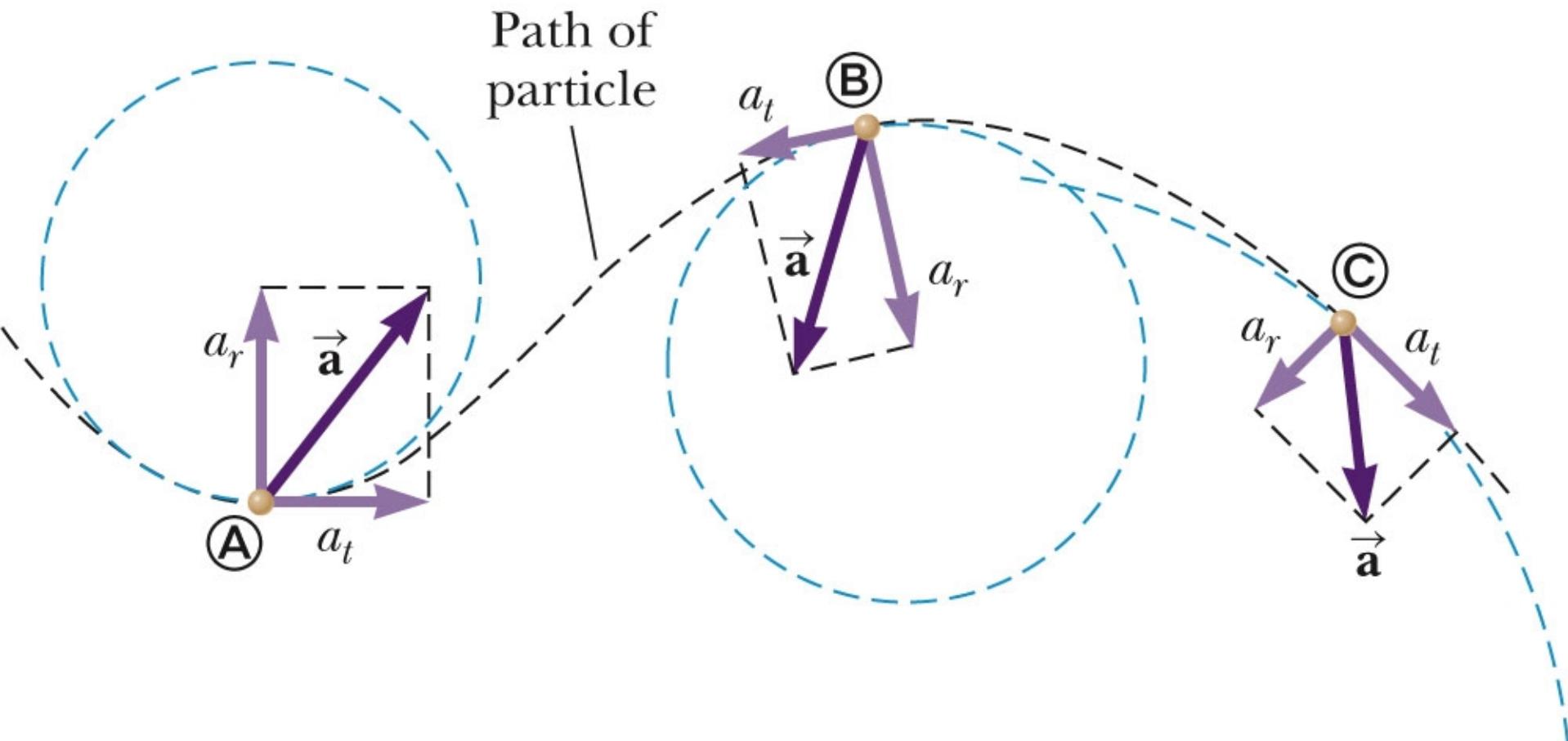
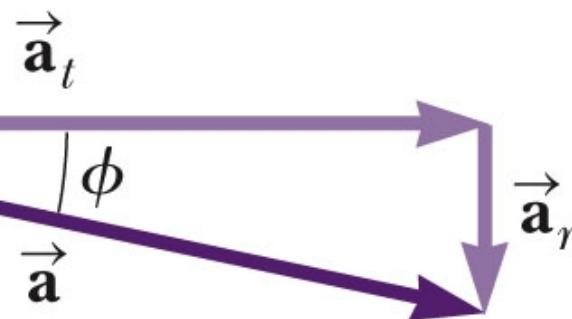


Fig. 4.16, p. 88

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



a



b

Fig. 4.17, p. 89

# Outline for Day W8,D1

Non-uniform circular motion – examples

Work by constant force

Work by non-constant force

## Homework

Ch. 7 Read 7.1-7.4, P. 1,2,5,8,12,18,20,22,25,37,  
39,41,45,55,56,59,60,65 Due next Wed.  
MiscQ: 1-13 (odd)

## Notes:

Midterm: 50% Exam I, 25% Hwk, 25% Quiz  
No class Friday!