Physics 211

Sections 1 & 70
Dr. Geoffrey Lovelace
Fall 2012
Lecture 11 (10/04/12)

Lecture 11 outline

- Announcements
- More quantitative 2nd-law problems
  - Free-body diagrams
  - Example: Atwood machine & ramp
- Friction & air resistance
  - How friction works
  - Example: friction
- Class participation

Announcements

- piazza.com lecture materials updated
- Homework
  - Homework #5: due 11:59PM
  - Homework #6: will be posted today
- Reading: for next week, begin reading chapter 5
- Office hours
  - 10-11AM, 4PM-5PM today in MH-601B
  - Questions about homework, lecture? Review your exam? … come to office hours!

Today

Sep 25	**Exam 1**
Sep 27	Laws of motion, *HW #4 due*
Oct 2	Free body diagrams
Oct 4	Free body diagrams, friction, *HW #5 due*
Oct 9	Work, introduction to energy
Oct 11	Energy, kinetic & potential energy, conservation of energy, *HW #6 due*
Oct 16	Conservation of energy
Oct 18	Linear momentum, conservation of linear momentum, *HW #7 due*
Oct 23	**Exam 2**
Oct 25	Conservation of momentum, collisions, *HW #8 due*
Oct 30	Collisions, center of mass, rockets
Nov 1	Circular motion, gravitation, *HW #9 due*
Nov 6	Gravitation, Kepler's laws, intro to rigid body rotation
Nov 8	Rotation, torque, angular momentum
Nov 13	Conservation of angular momentum *HW #10 due*
Nov 15	**Exam 3**
Nov 20	*Fall Recess — No class*
Nov 22	*Fall Recess — No class*
Nov 27	Temperature, gas laws
Nov 29	Phase changes, heat transfer, *HW #11 due*
Dec 4	Laws of thermodynamics, entropy
Dec 6	Harmonic motion, *HW #12 due*
Dec 11	Harmonic motion & waves
Dec 13	Gravitational waves, harmonic motion, black holes, *HW #13 due*
Dec 20	**Final exam 9:30AM–11:20AM**

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- More quantitative 2nd-law problems
  - Free-body diagrams
  - Example: Atwood machine & ramp
- Friction & air resistance
  - How friction works
  - Example: friction
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Free-body diagrams

Free-body diagrams

1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Brainstorm: 2nd law
   4a. **For each body, draw a free-body diagram**
5. Calculate
6. Plug in numbers
7. Is answer reasonable?

Free-body diagrams

- Guide: how to apply $F = ma$

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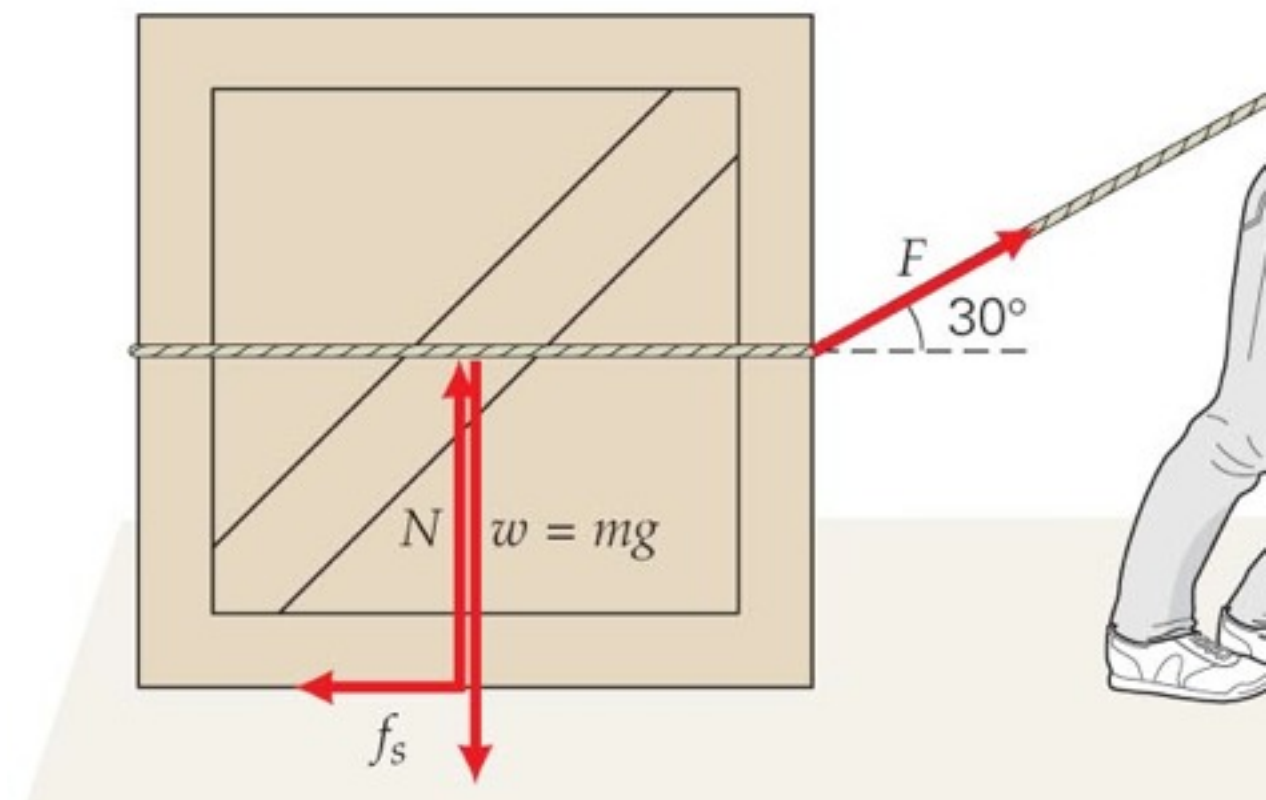

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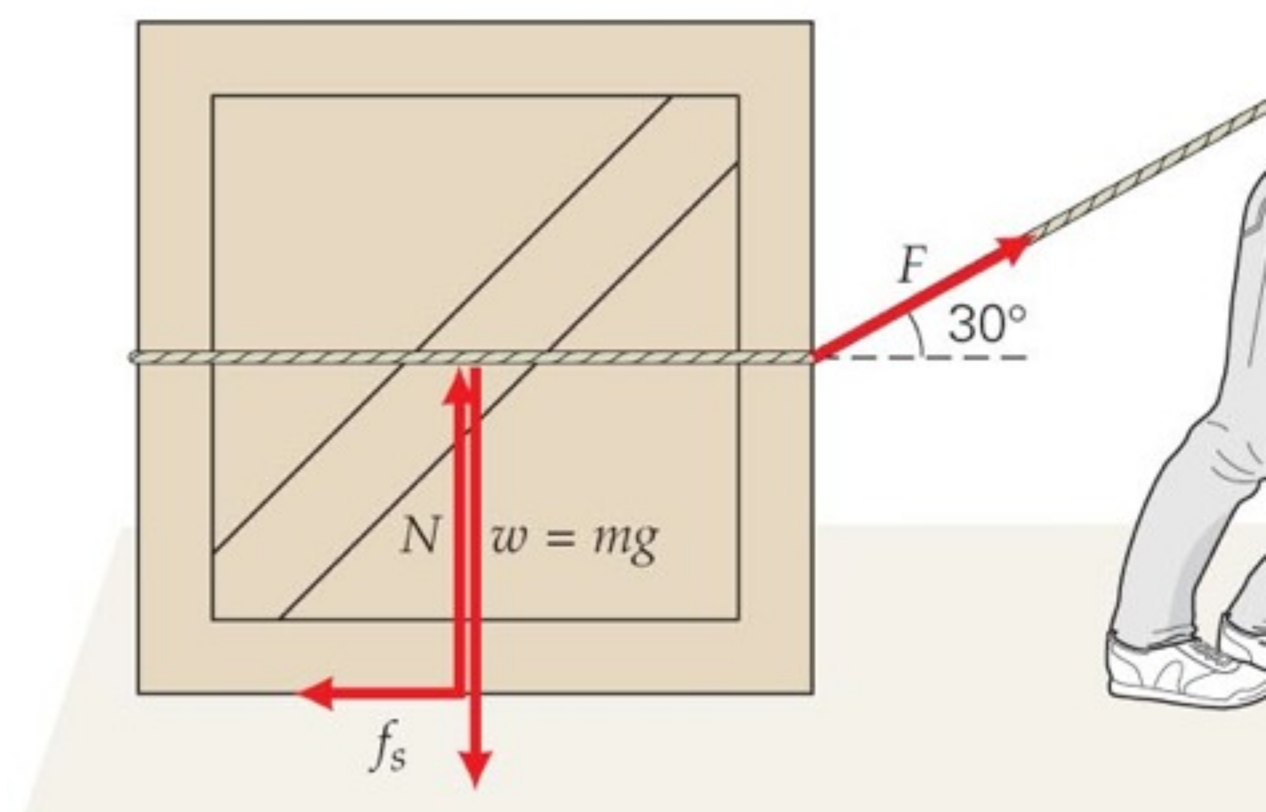

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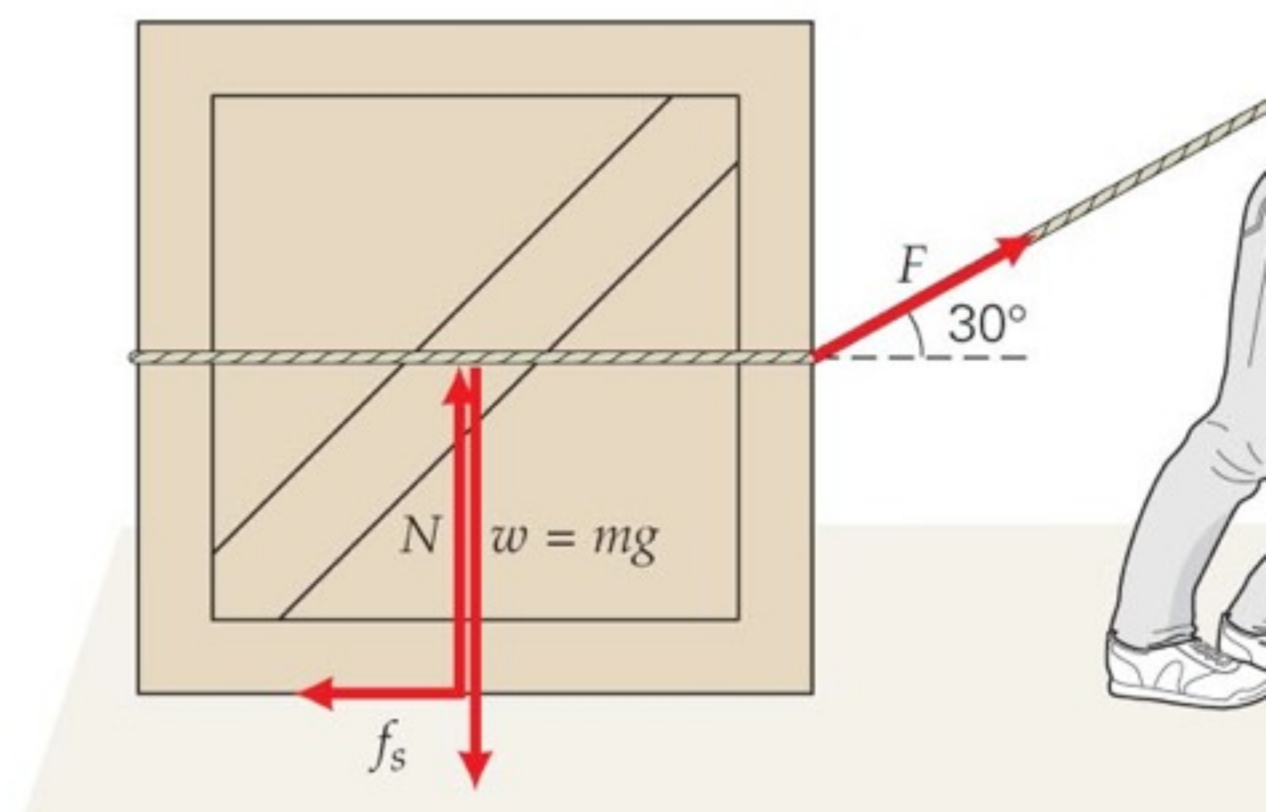

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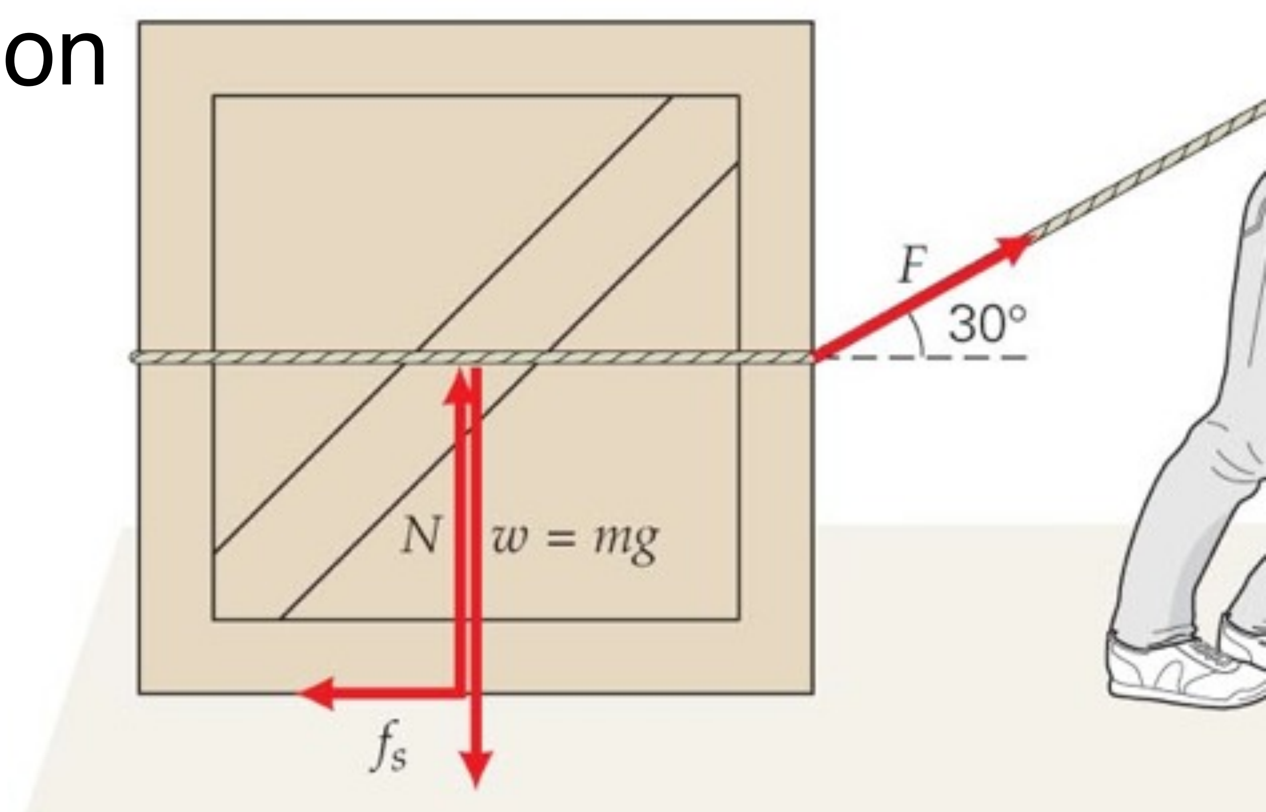

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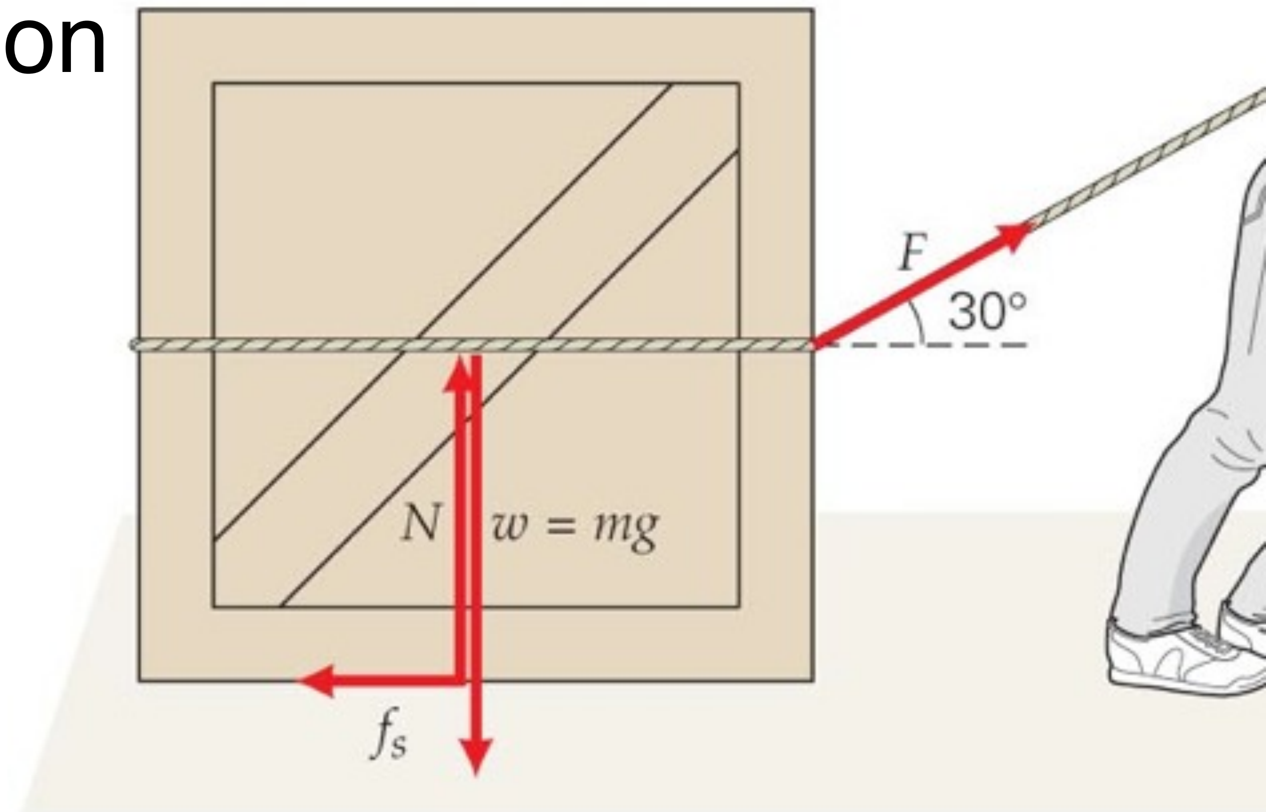

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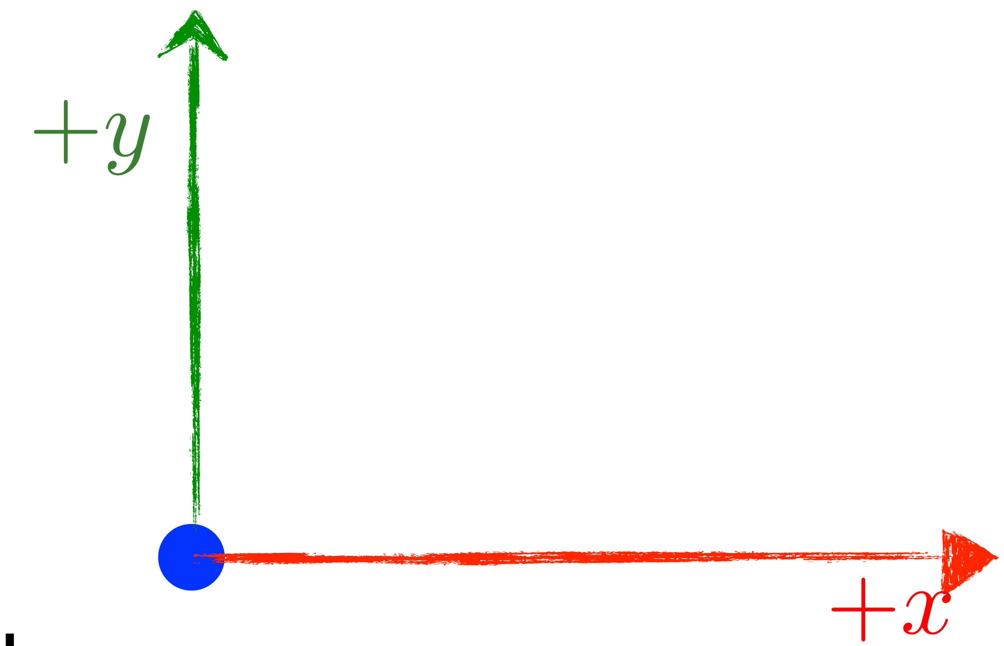

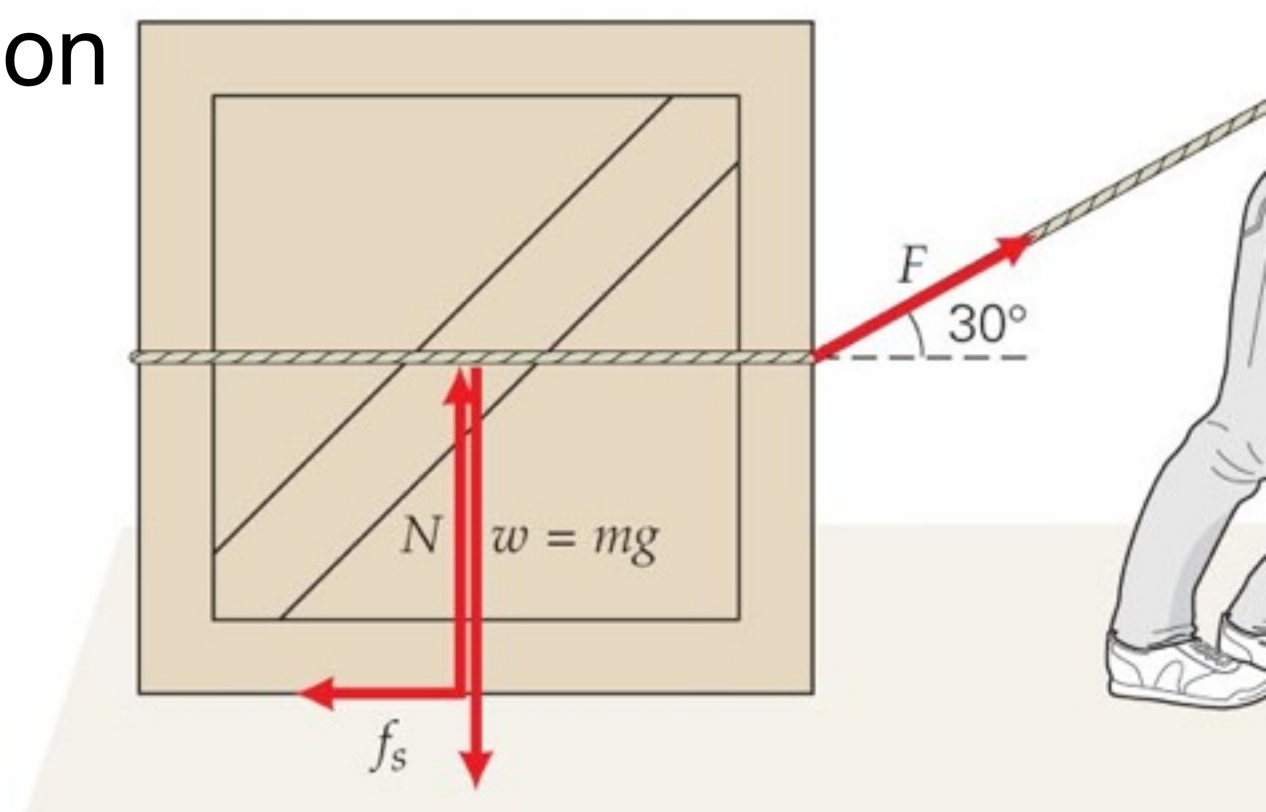

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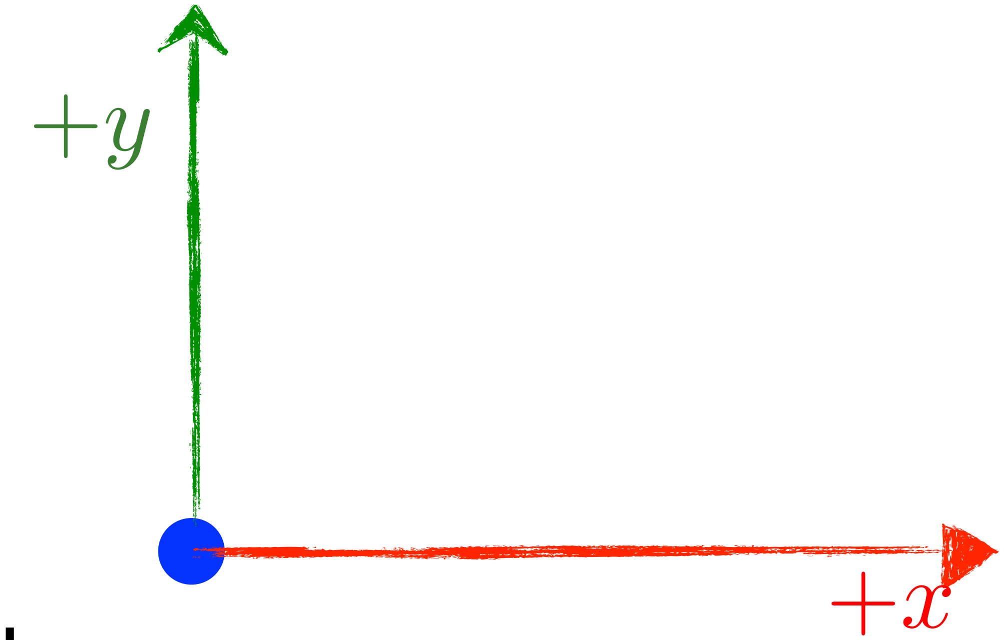

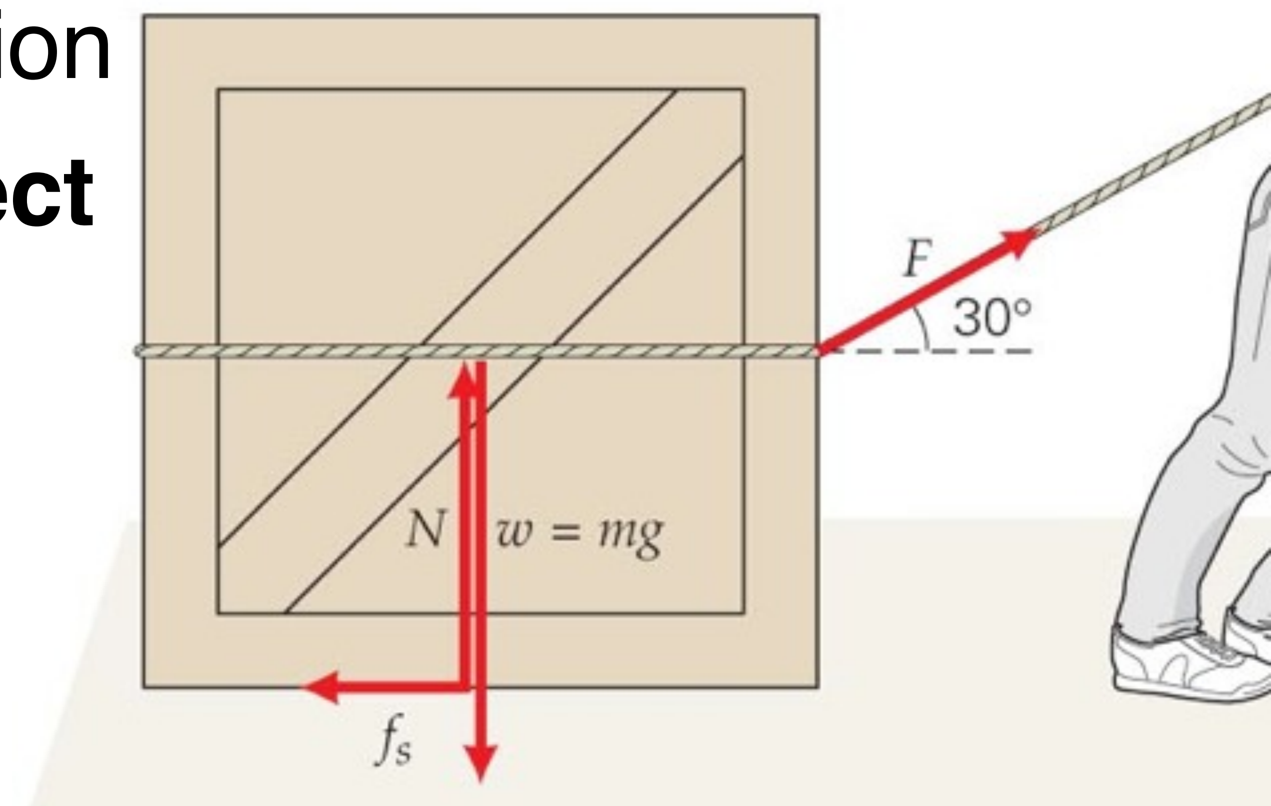

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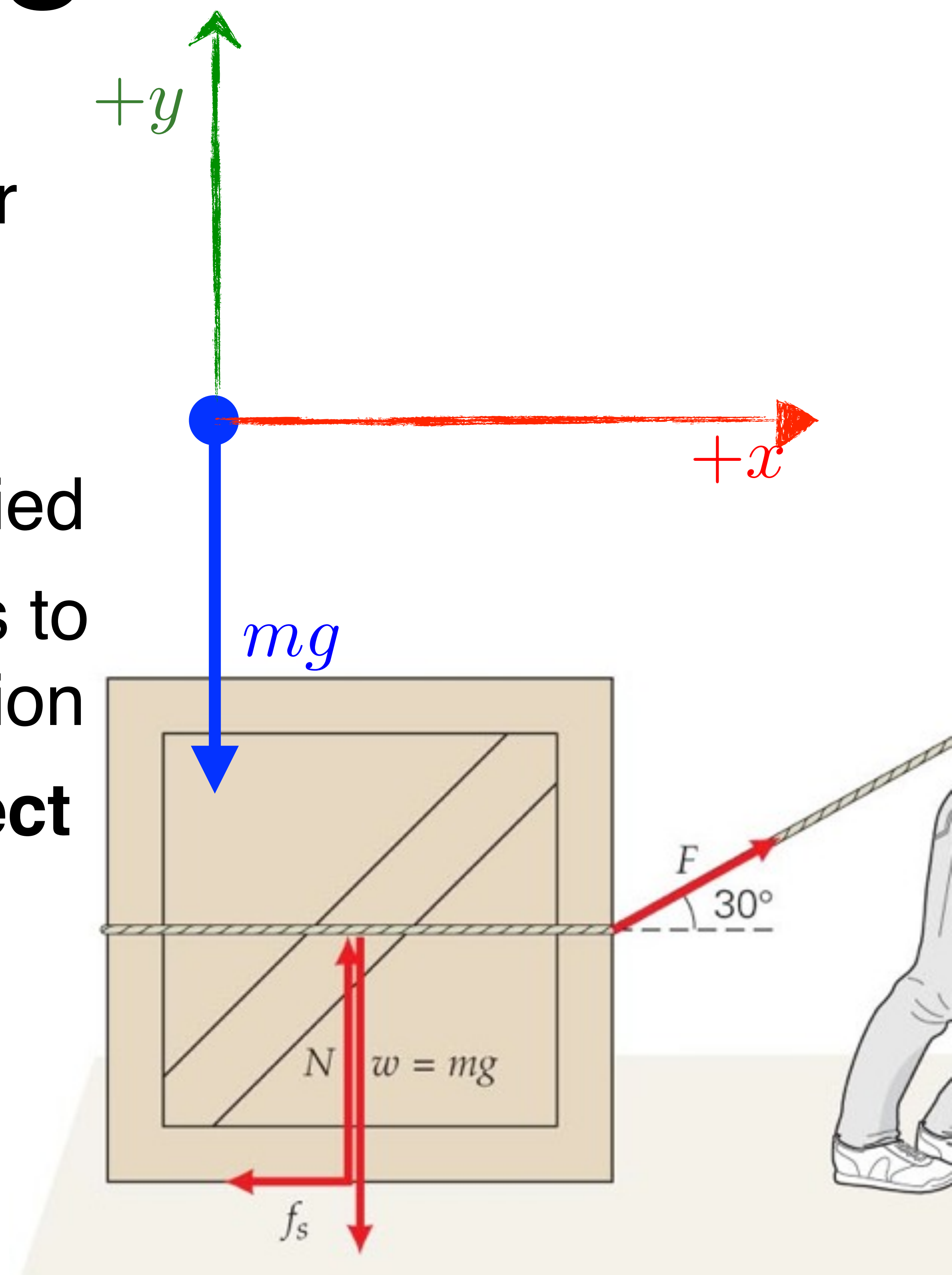

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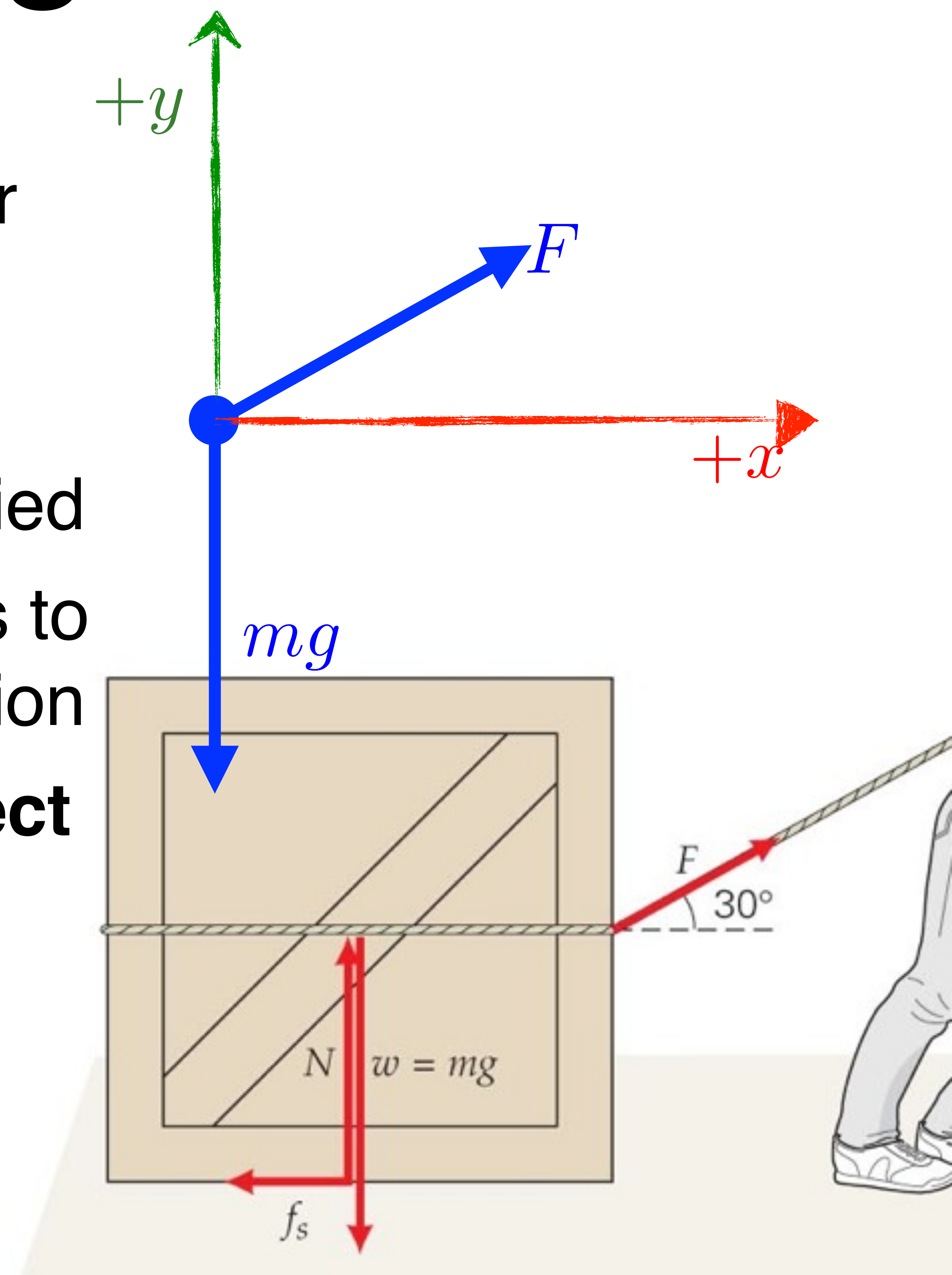

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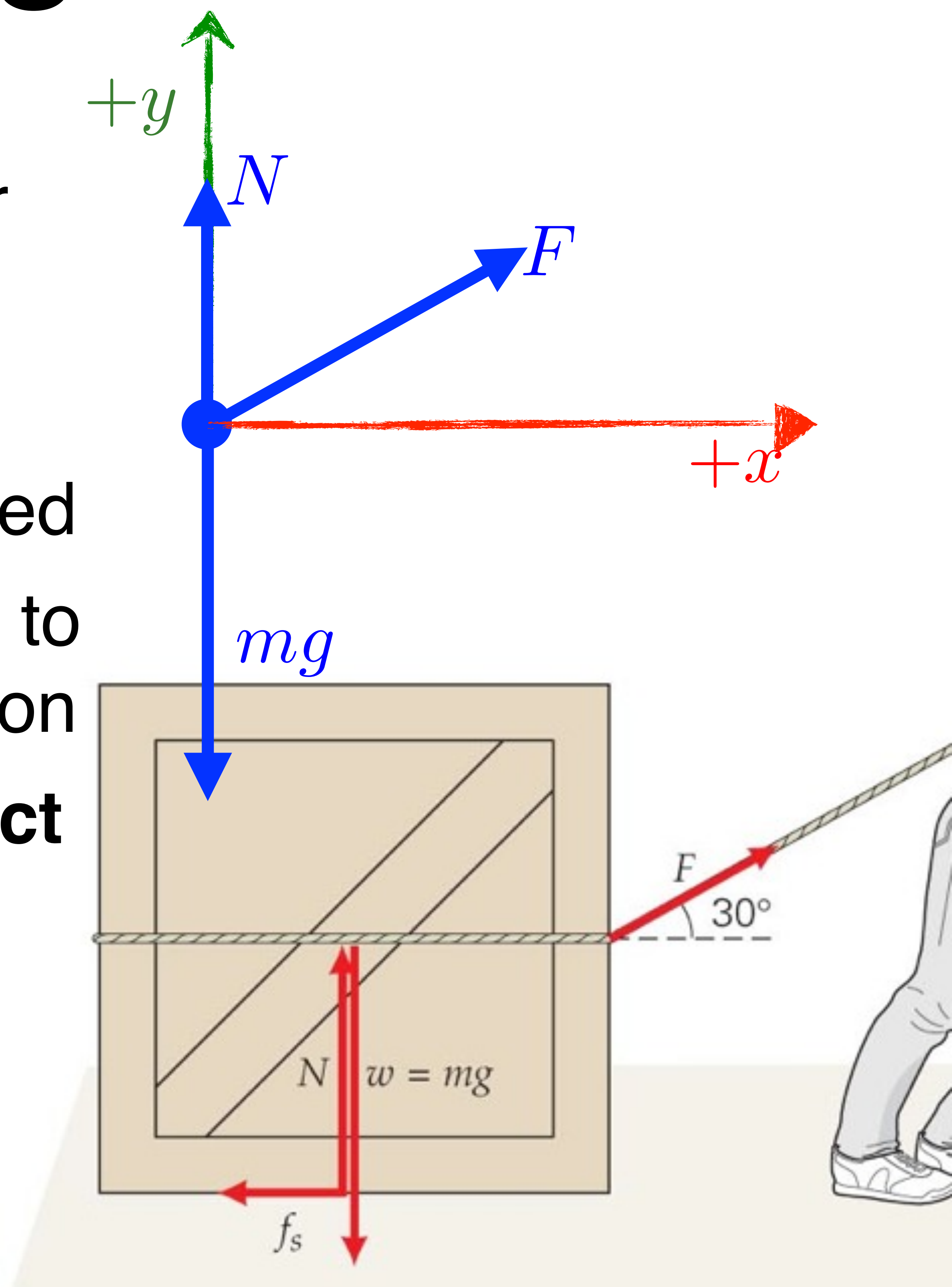

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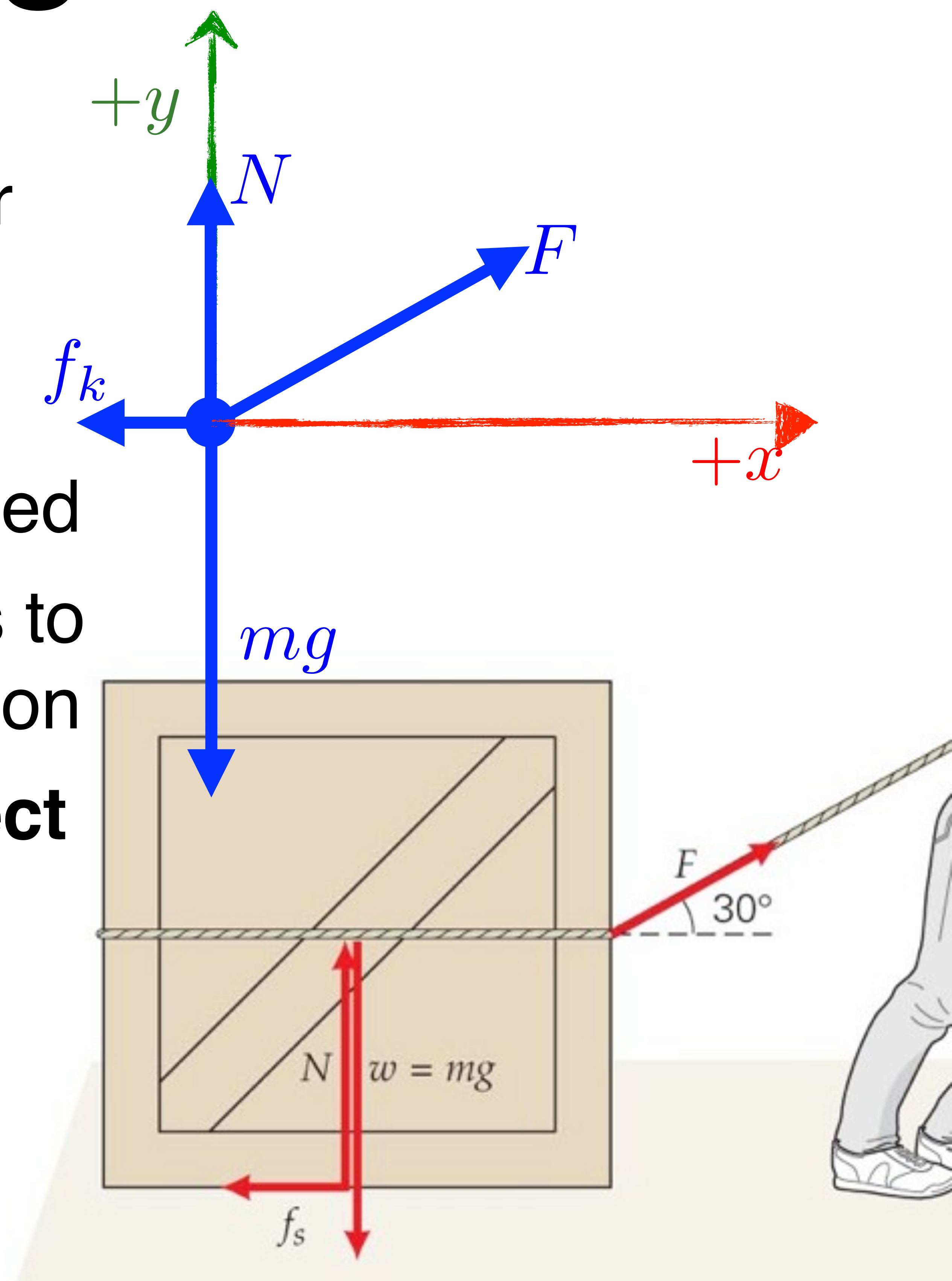

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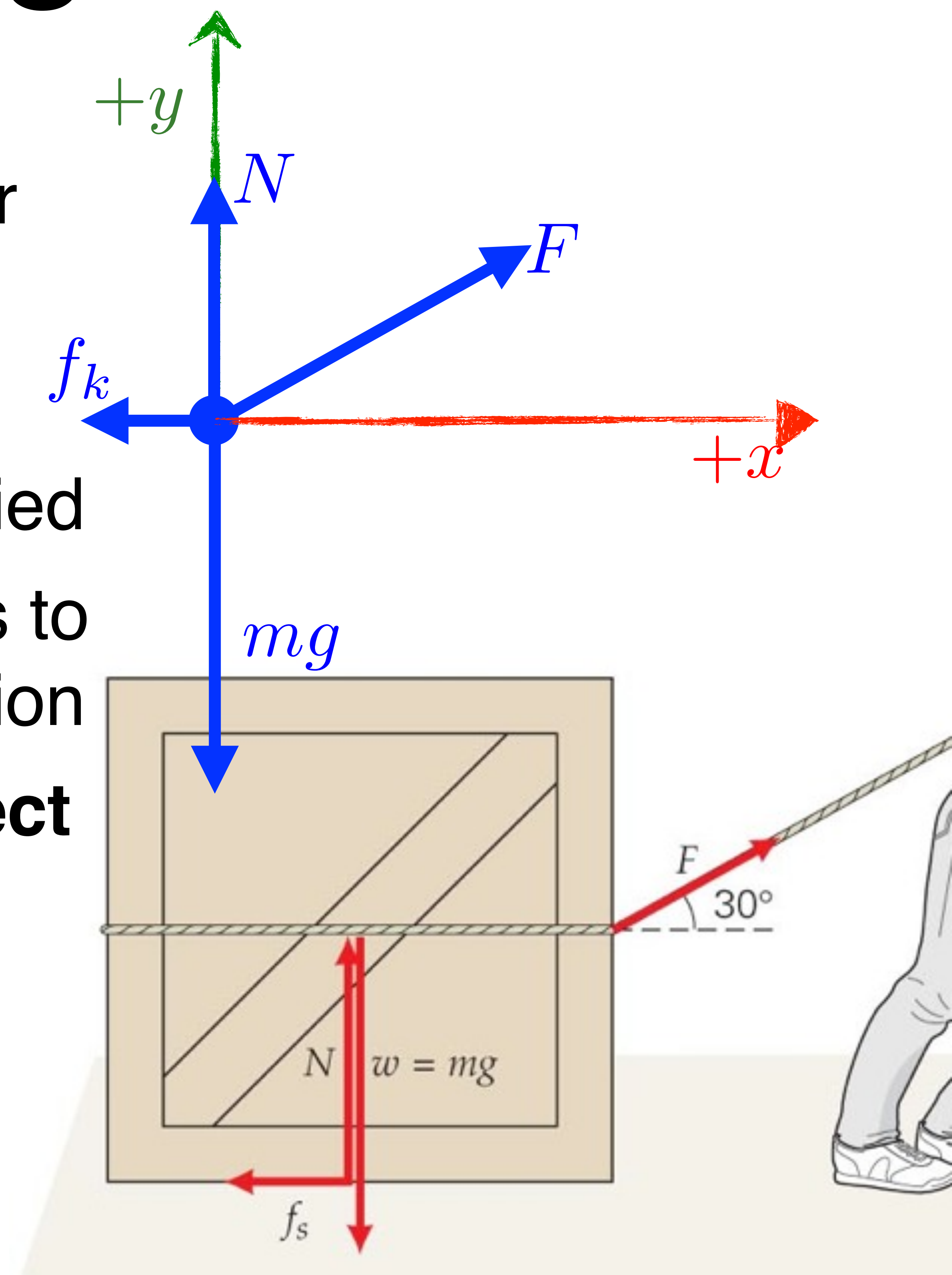

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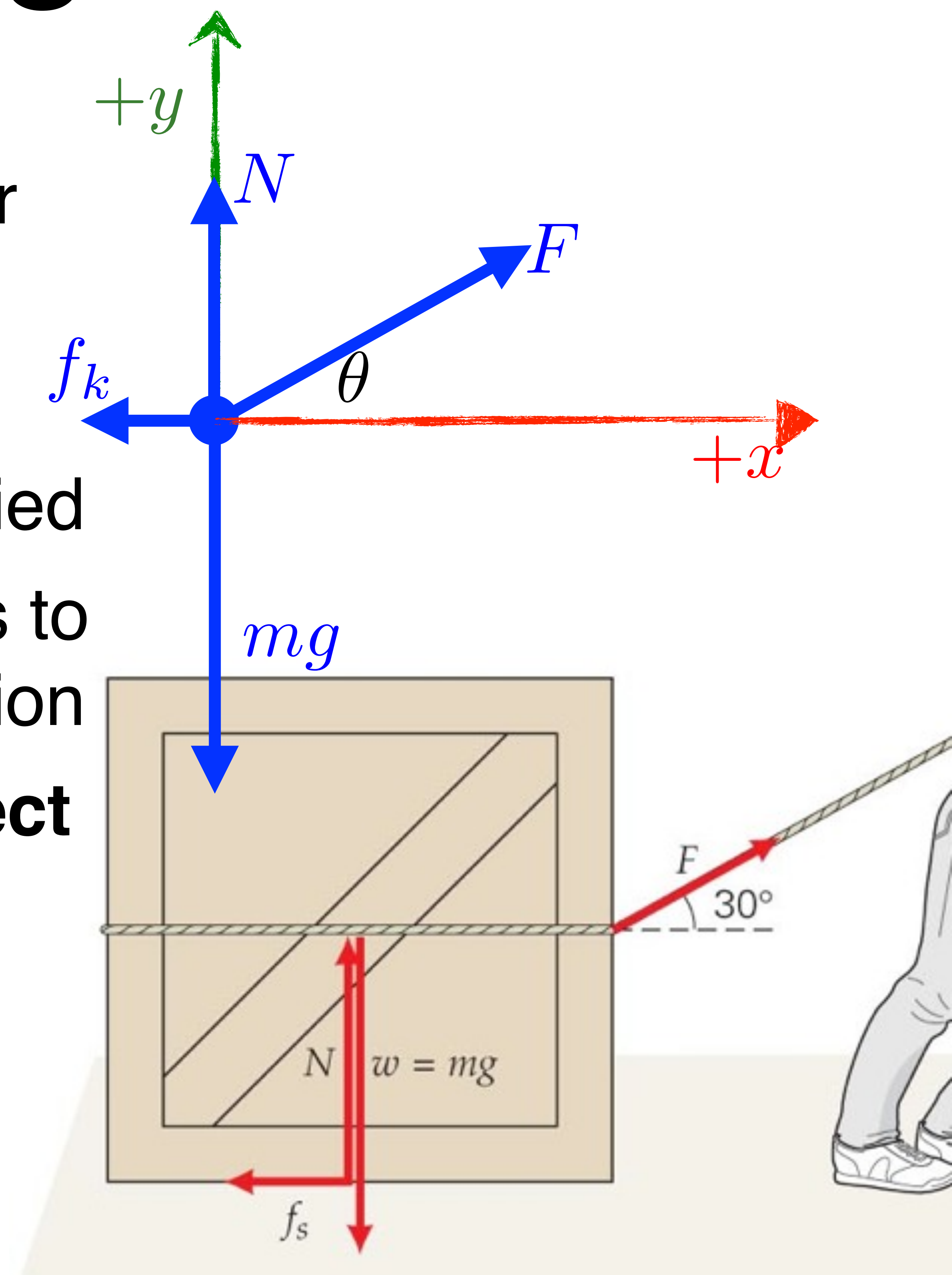

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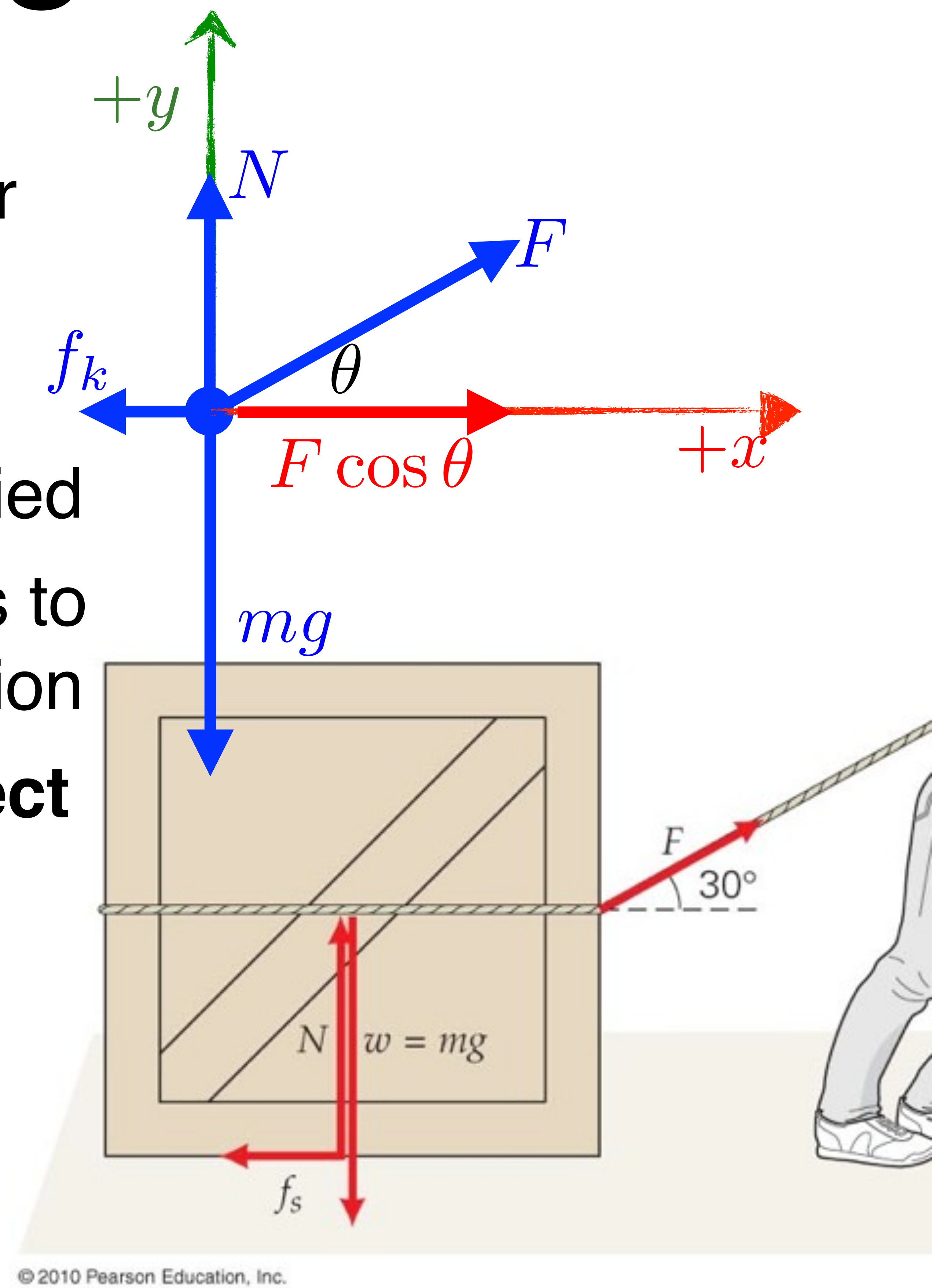

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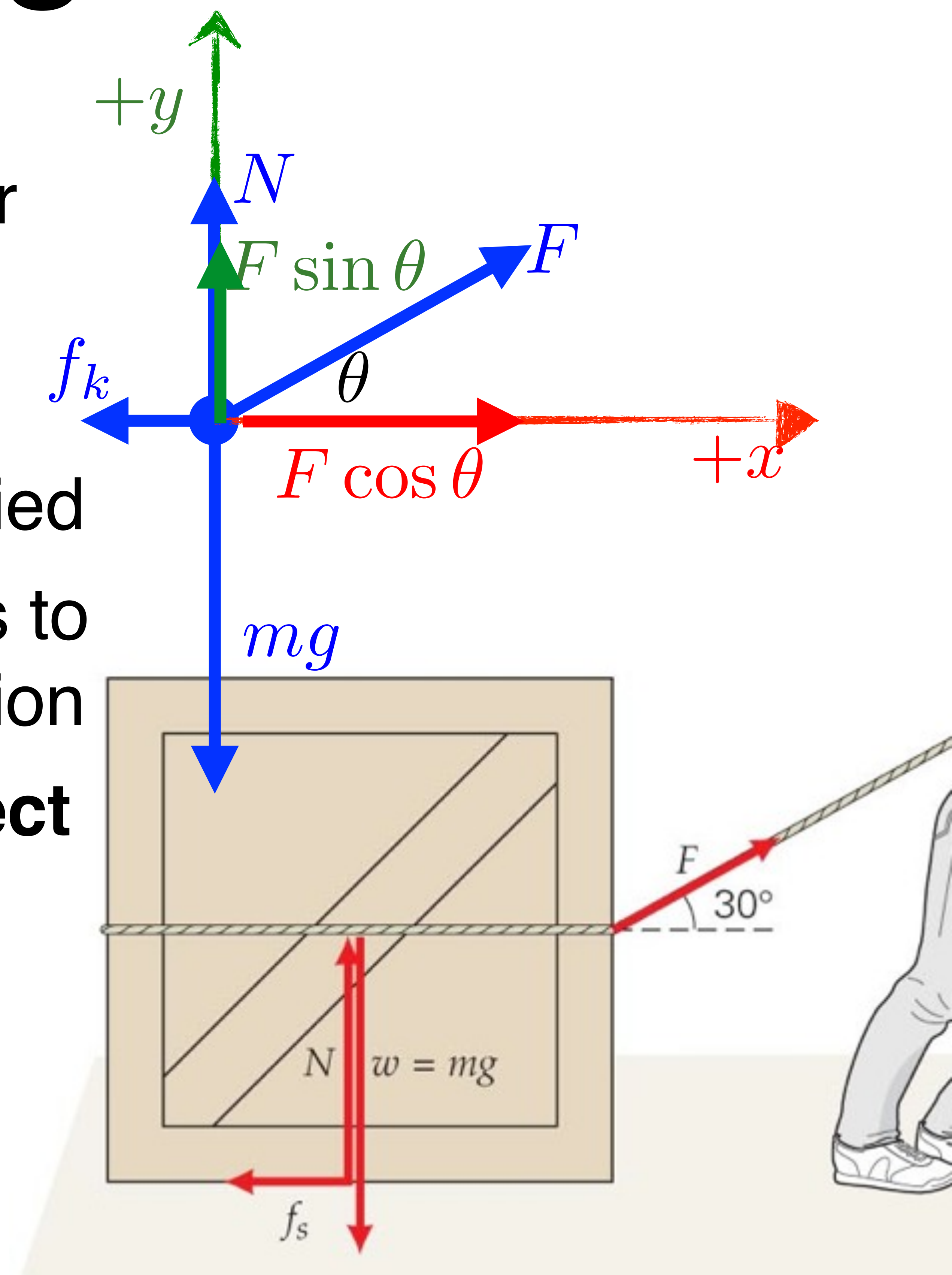
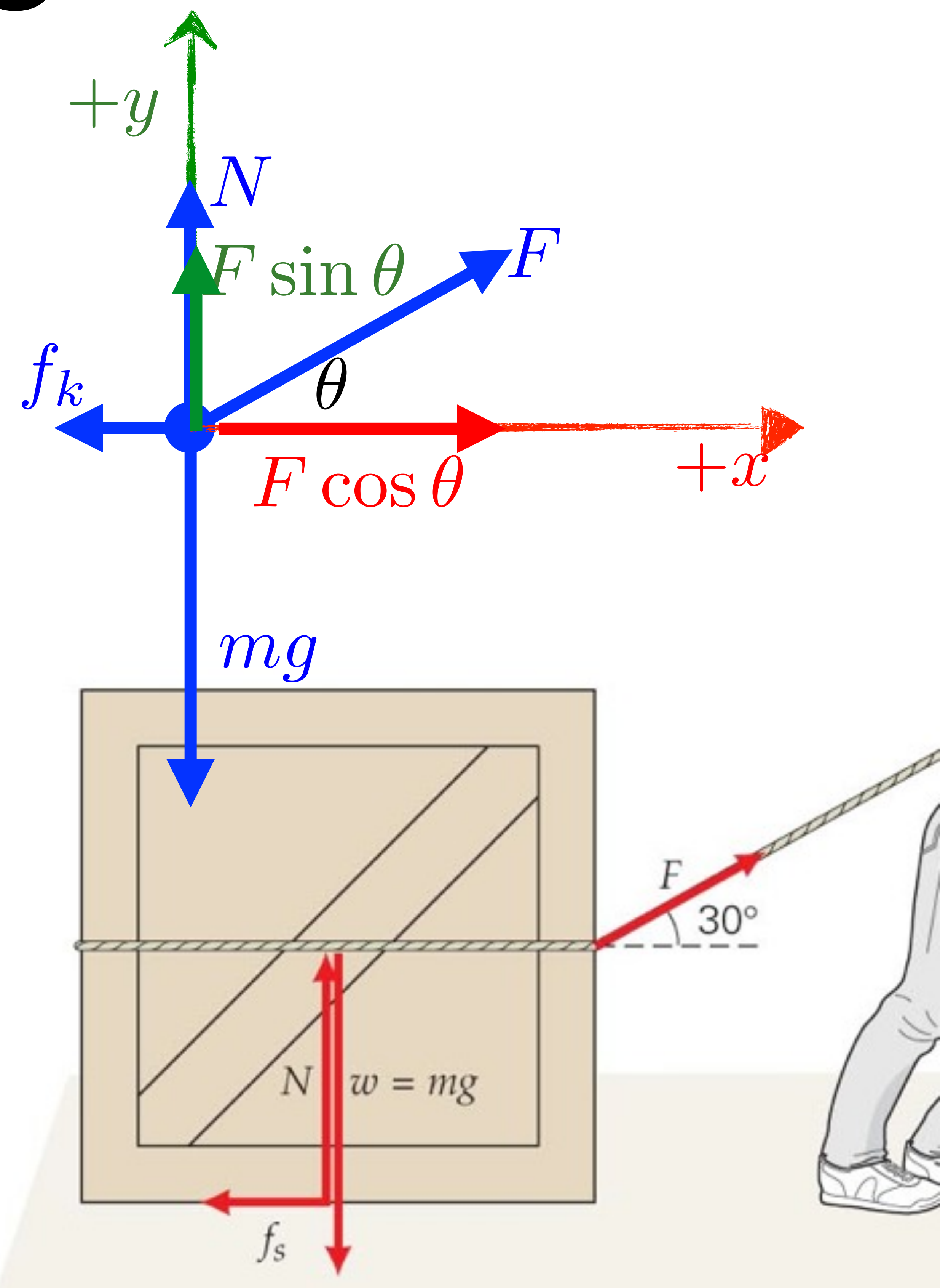


Free-body diagrams

- Guide: how to apply *F* = *ma*
- Draw a *separate* diagram for each object
- Use the horizontal and vertical free-body diagrams to compute the net forces for *F* = *ma*



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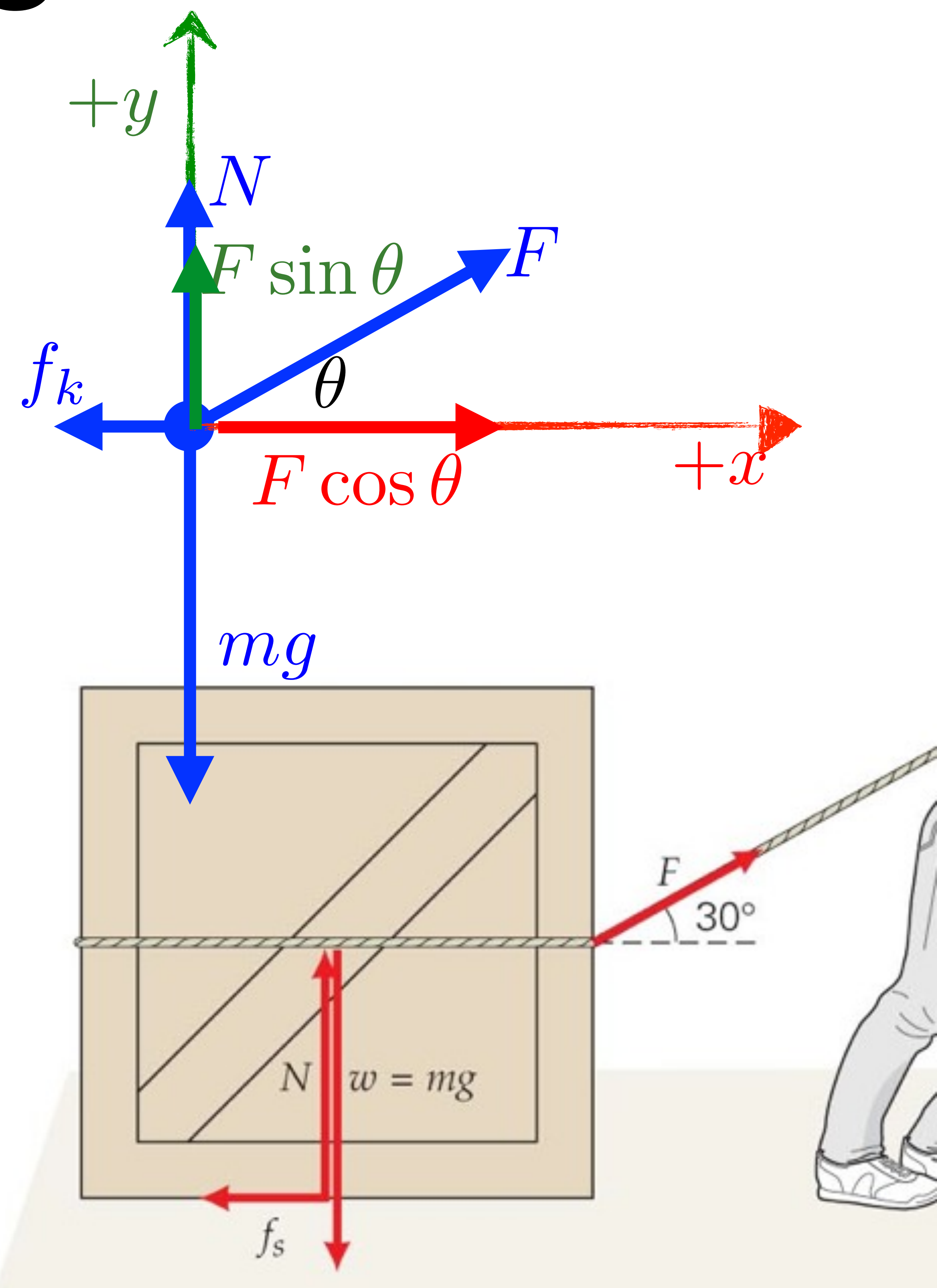
$$F\cos\theta - f_k = ma_x$$



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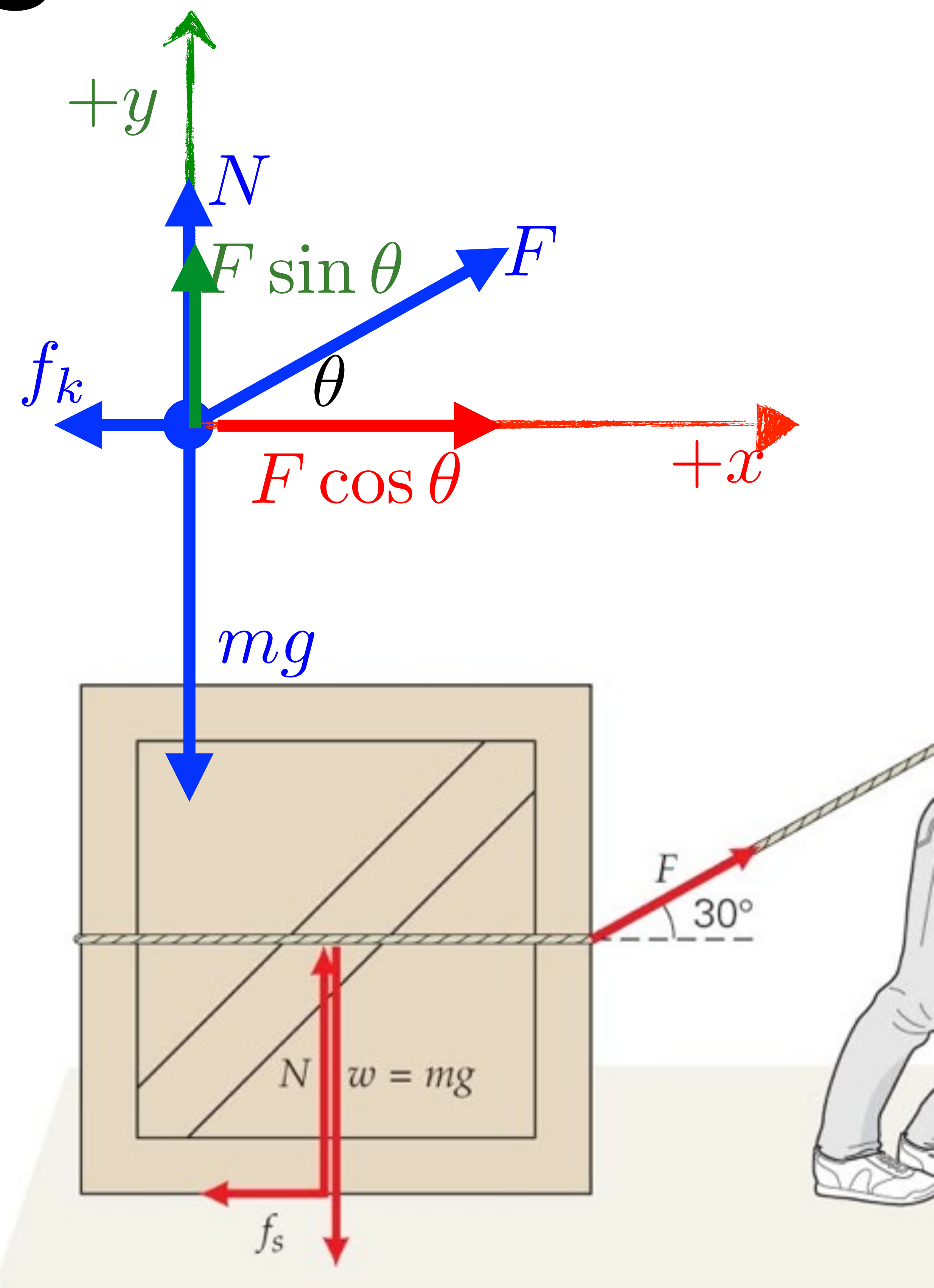
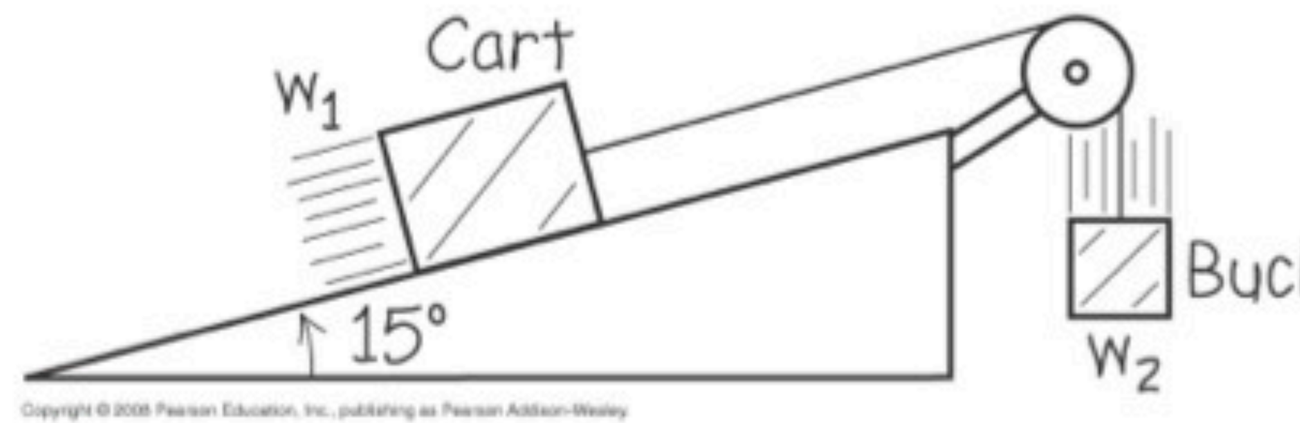
$$F\cos\theta - f_k = ma_x$$

$$F\sin\theta + N - mg = 0$$



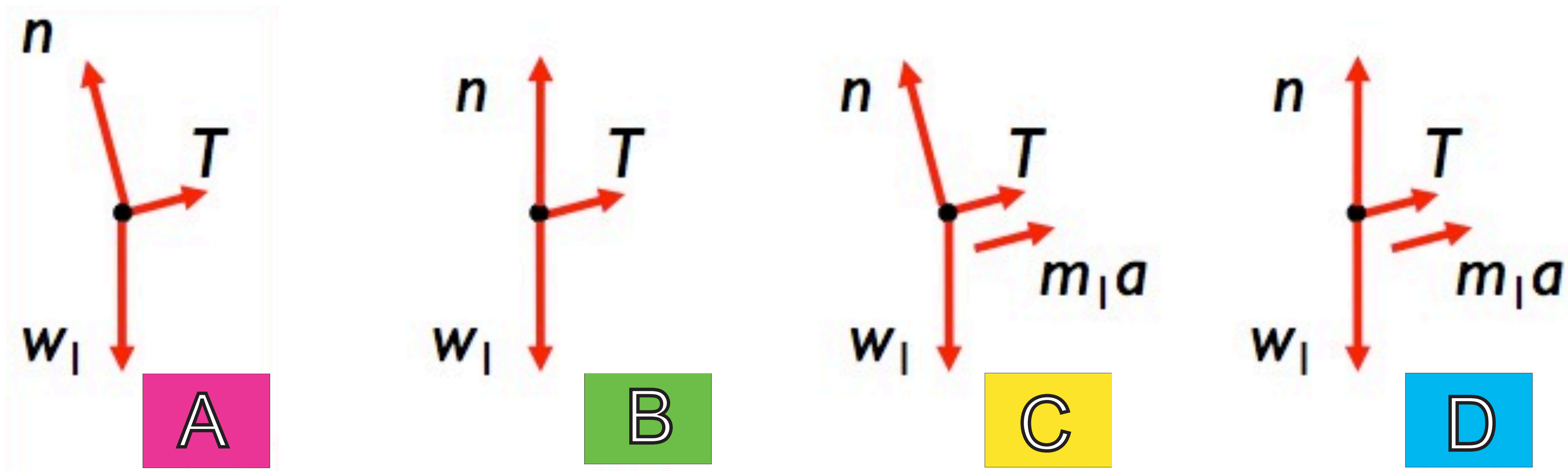
Clicker question #41

A cart (weight w_1) is attached by a lightweight cable to a bucket (weight w_2) as shown. The ramp is frictionless.



When released, the cart accelerates up the ramp.

Which of the following is a *correct* free-body diagram for the *cart?*



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- Announcements
- Quantitative force examples
  - Free-body diagrams
  - Example: Atwood machine & ramp
- Friction & air resistance
  - How friction works
  - Example: friction
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Ex. 4.6

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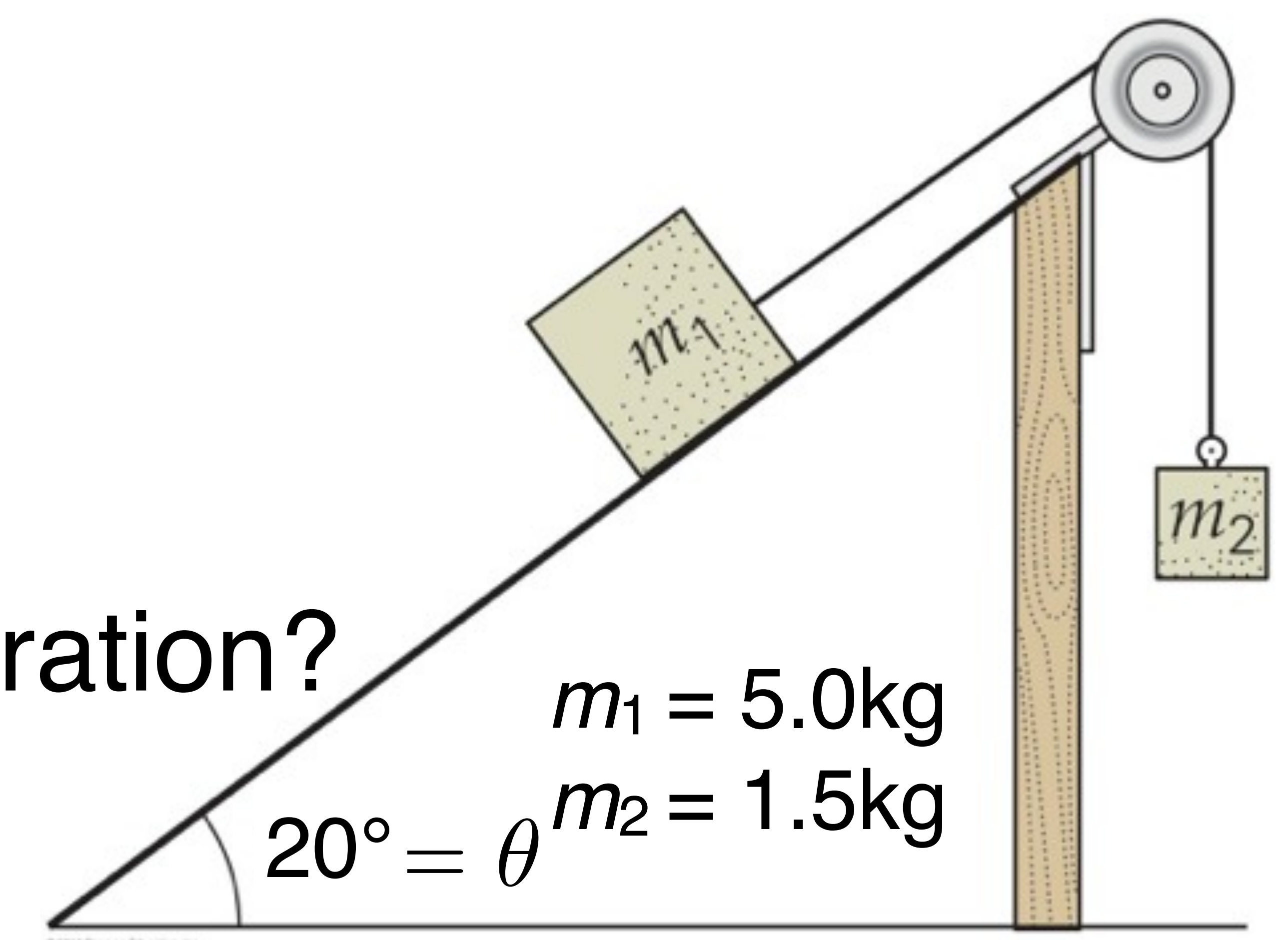


Acceleration?

$m_1 = 5.0\text{kg}$

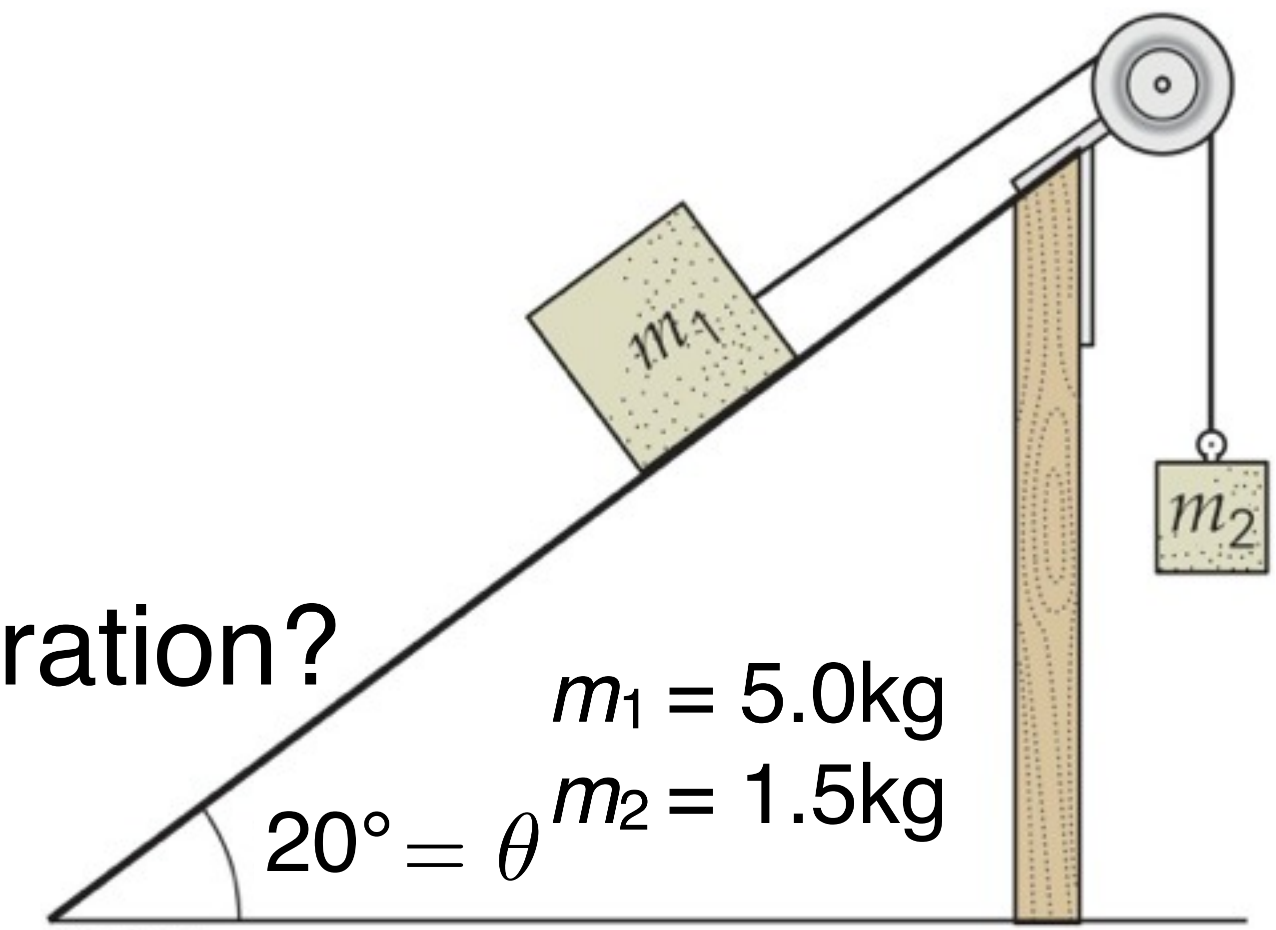
$m_2 = 1.5\text{kg}$

$20° = \theta$

Ex. 4.6

1. Read carefully

Acceleration?



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1. Read carefully
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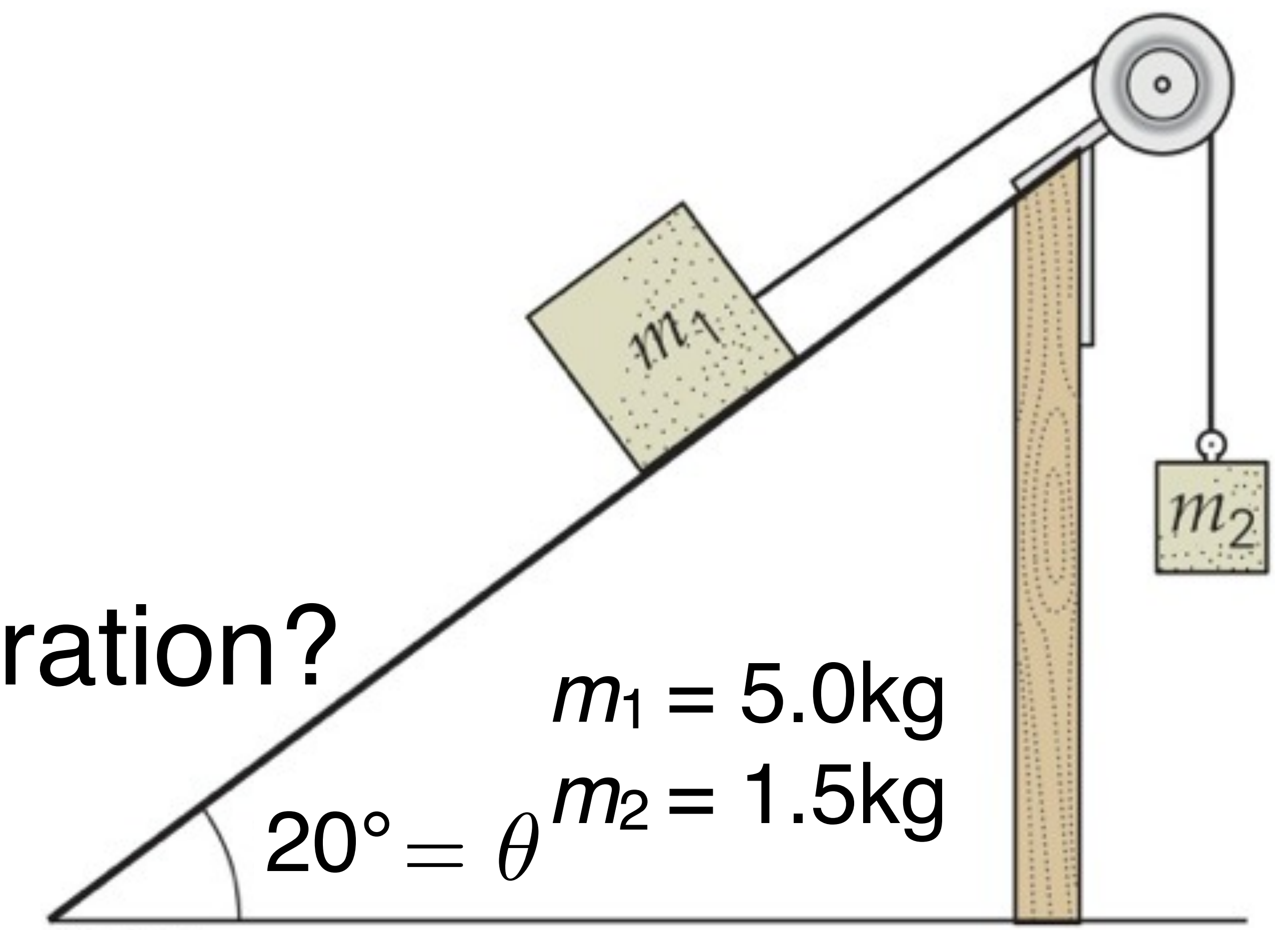

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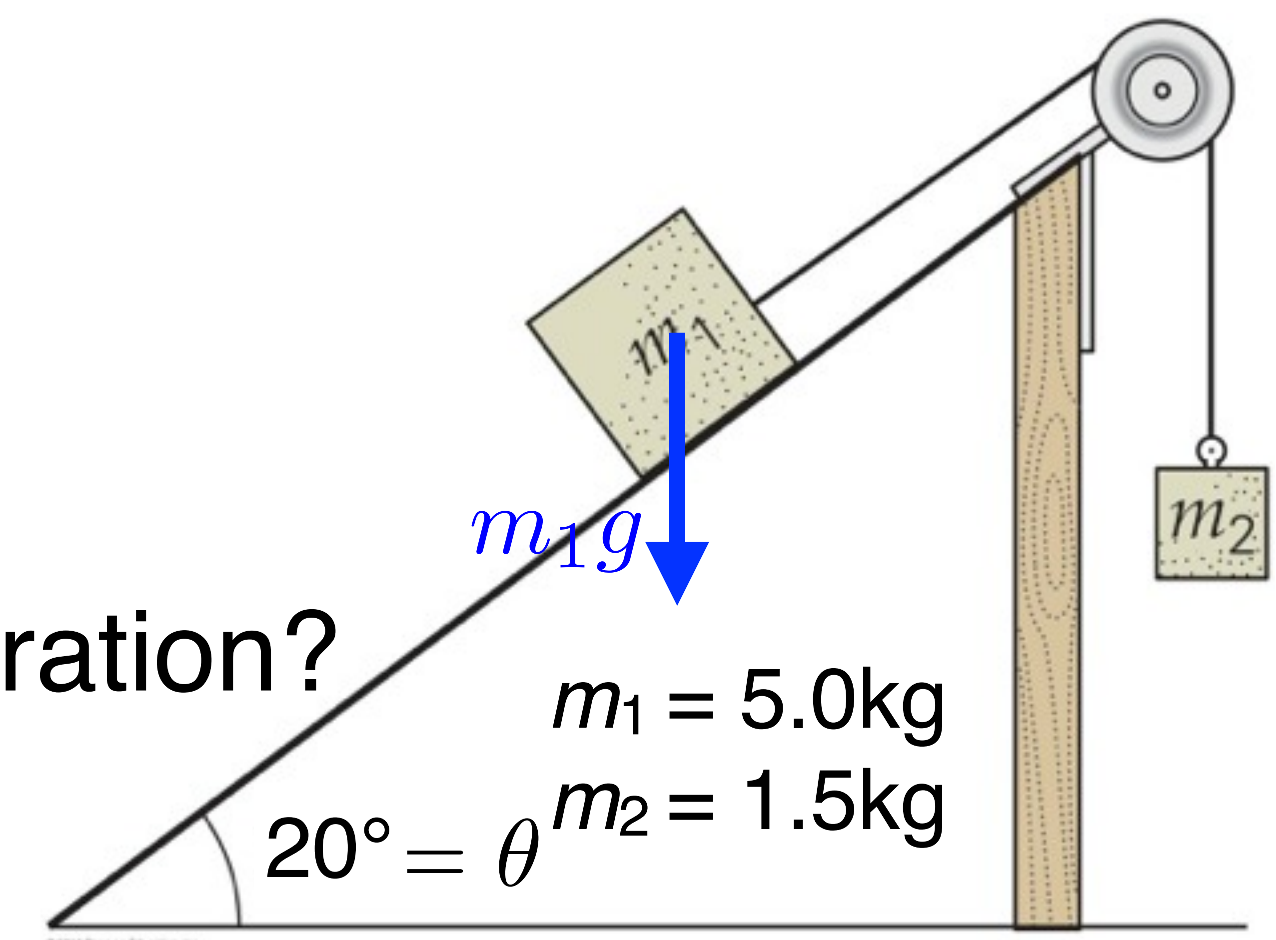

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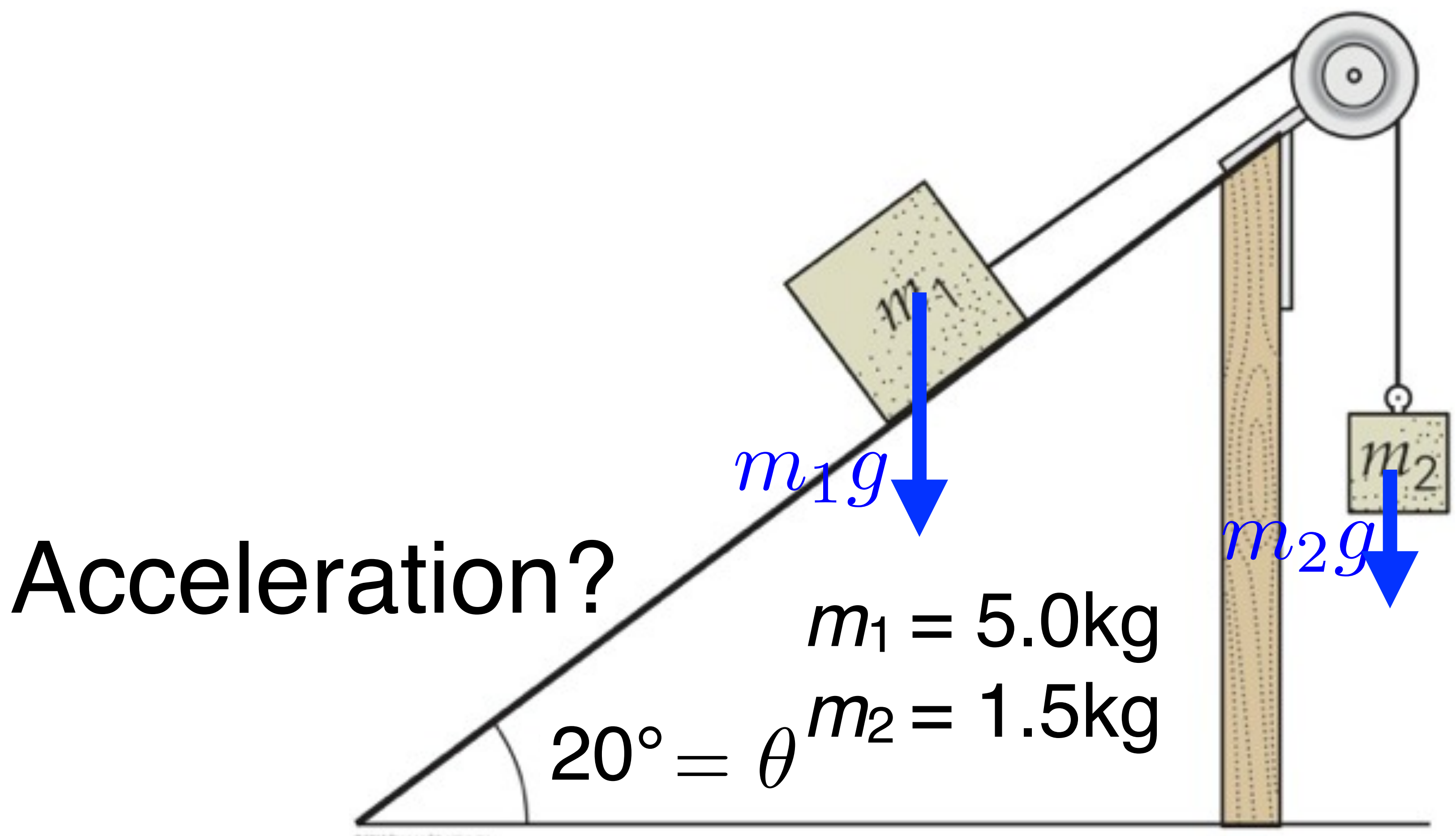

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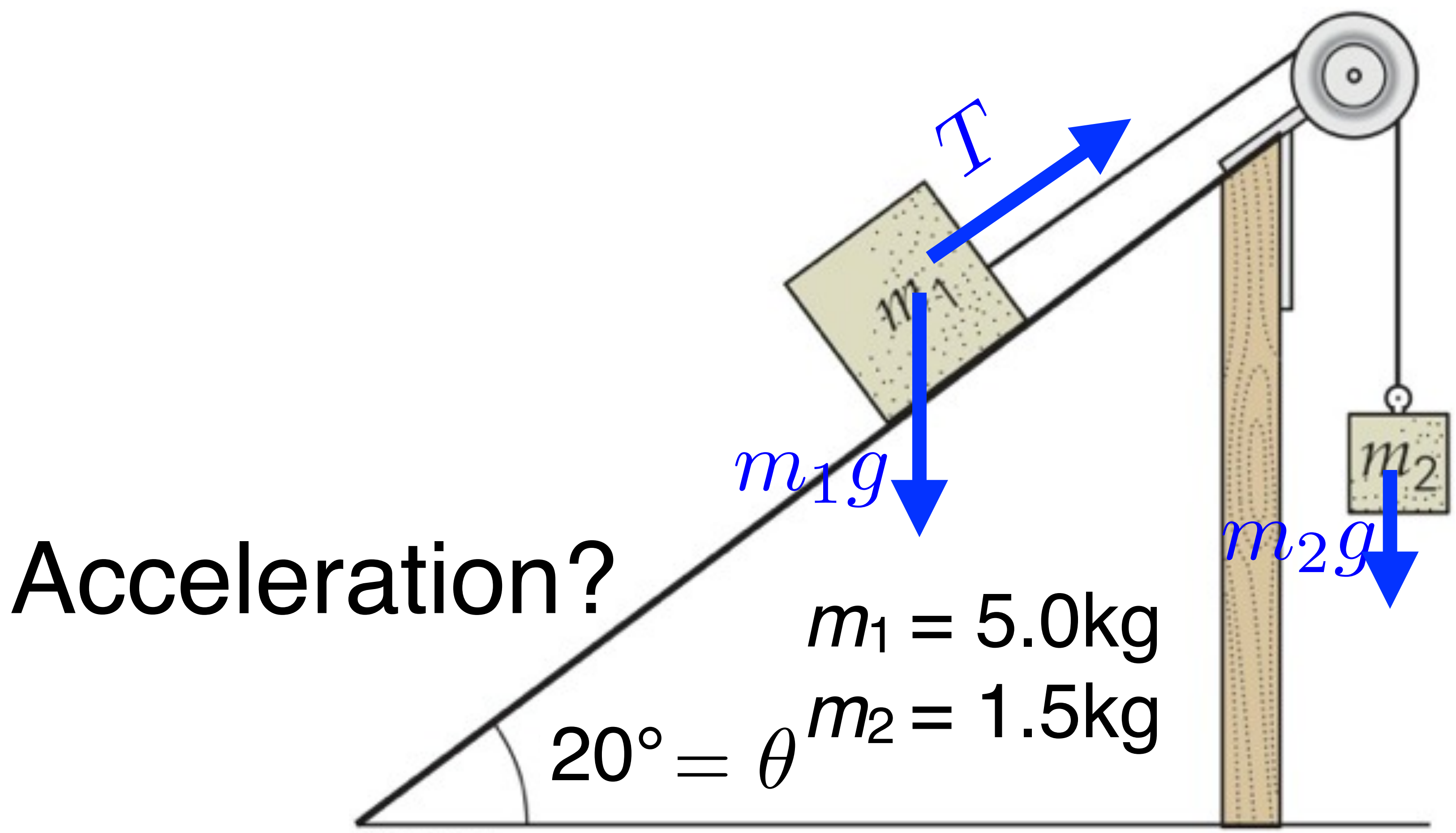

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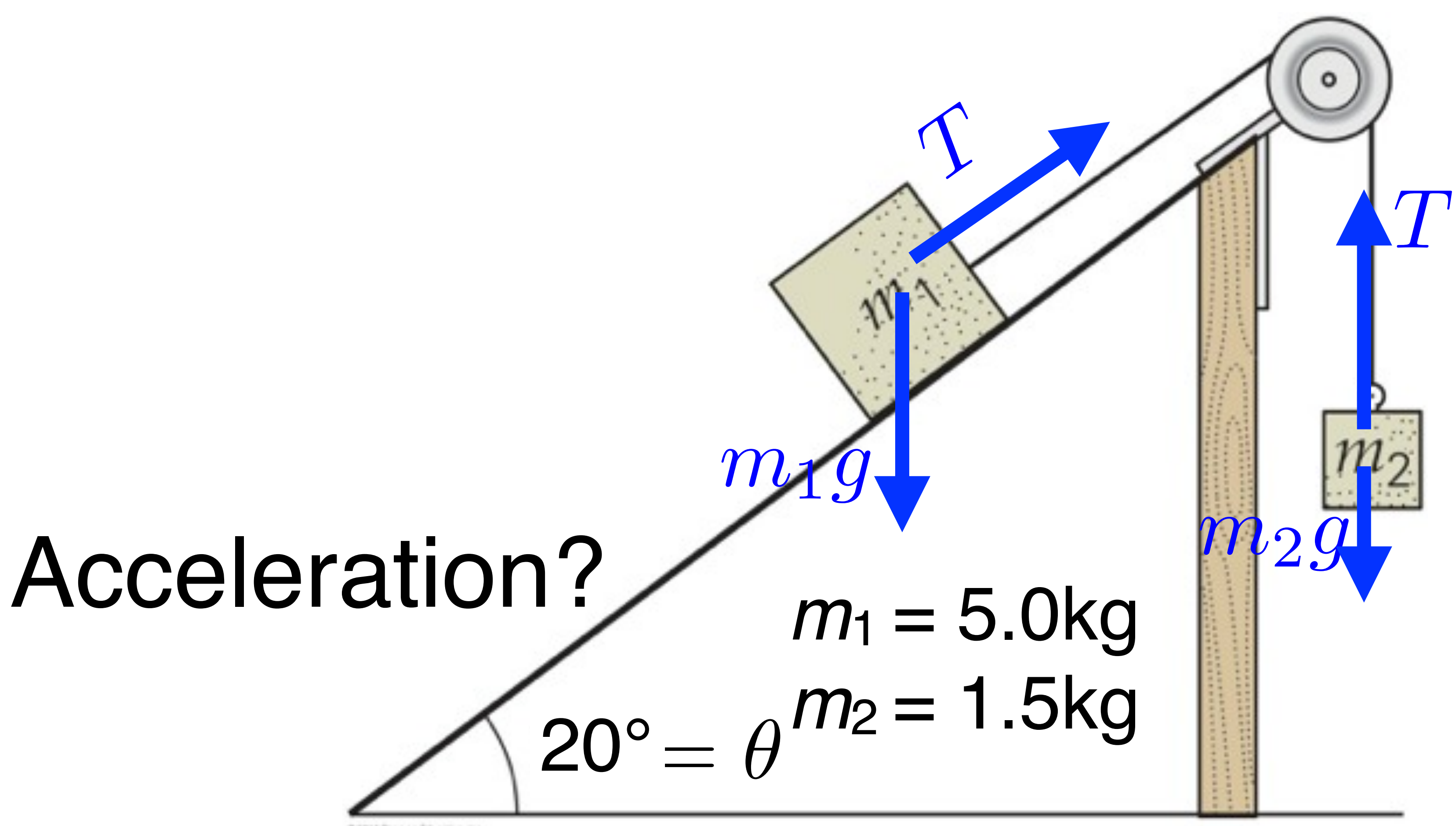

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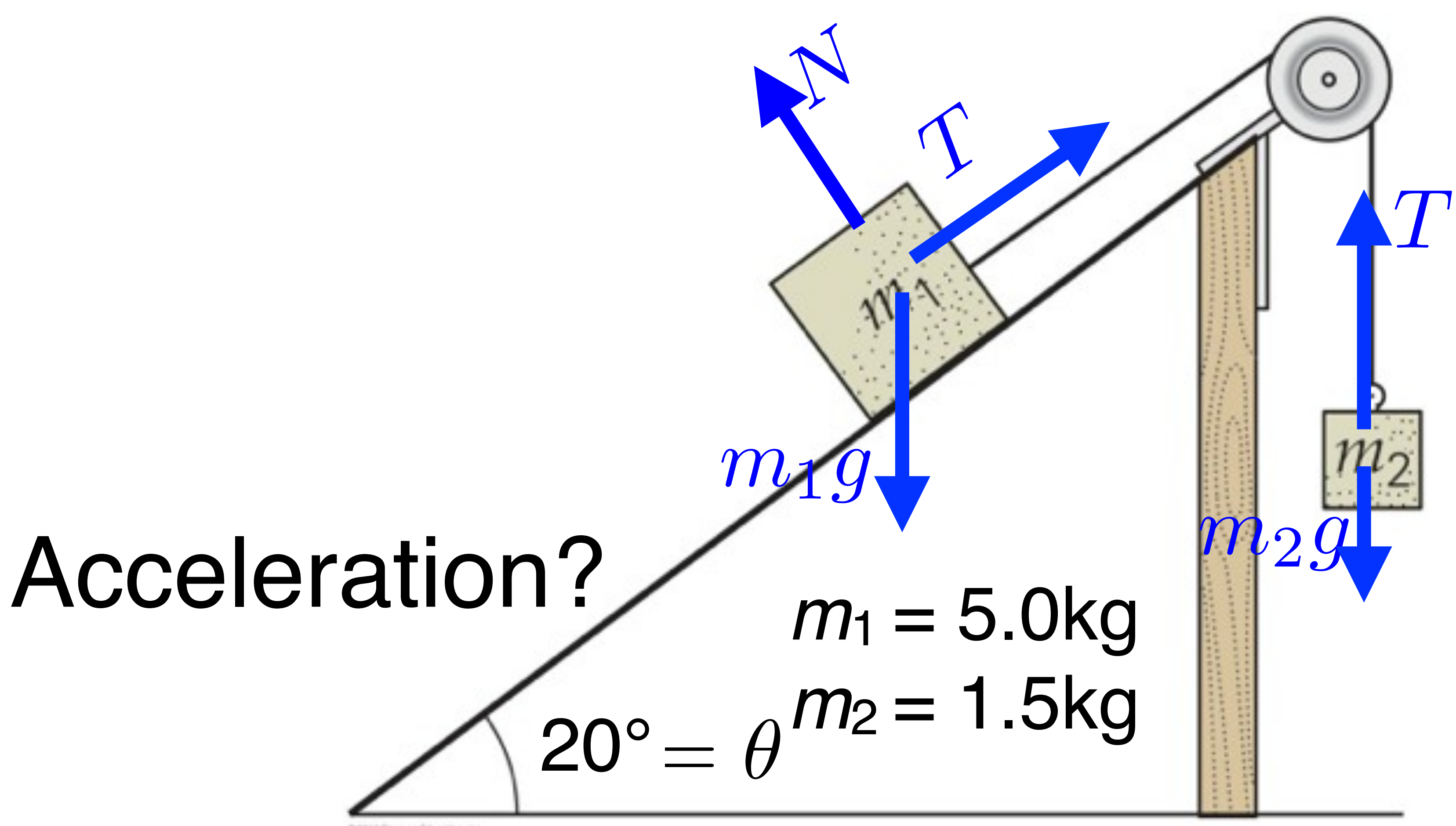

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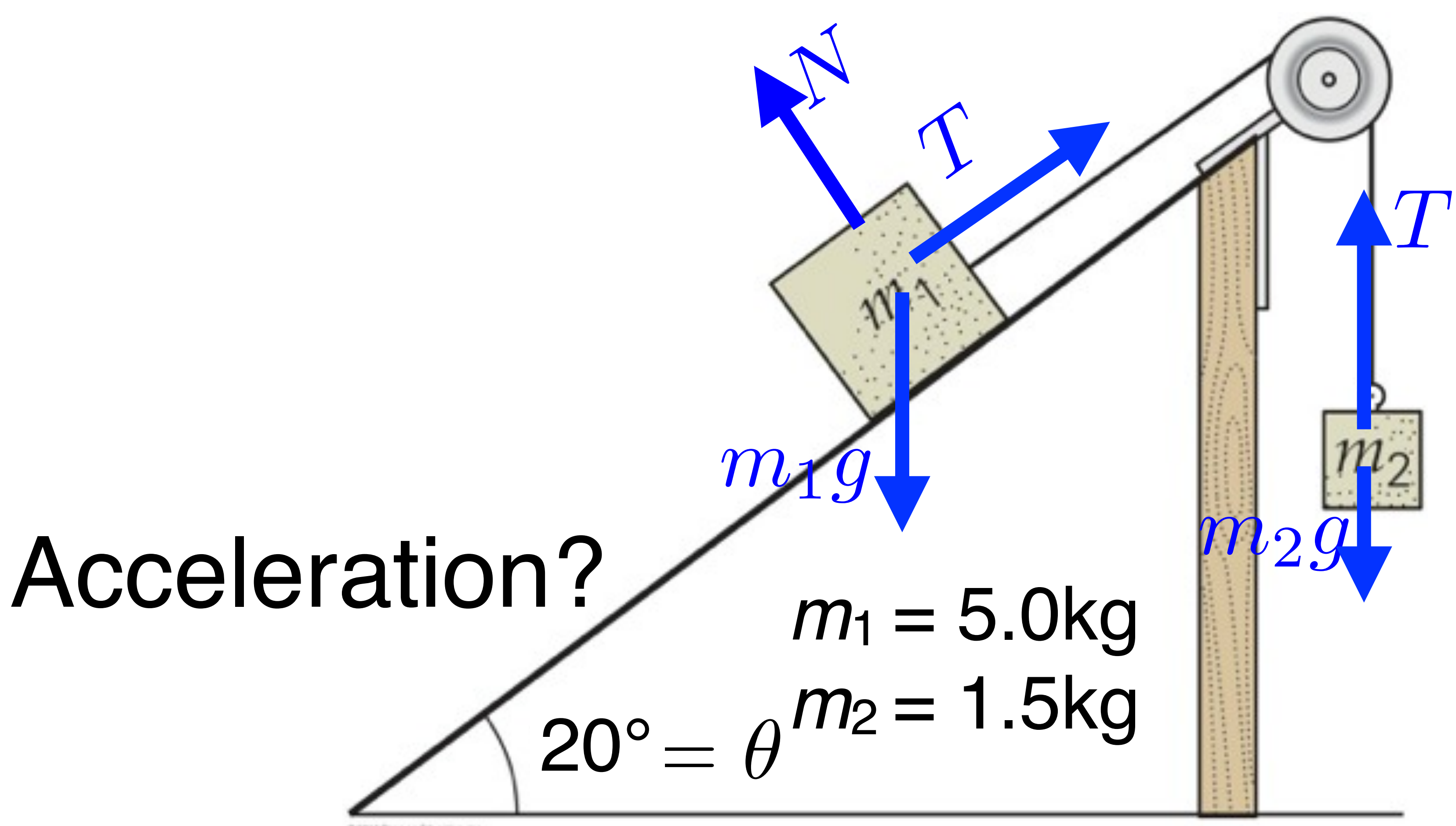

Ex. 4.6

Given: m_1, m_2, θ

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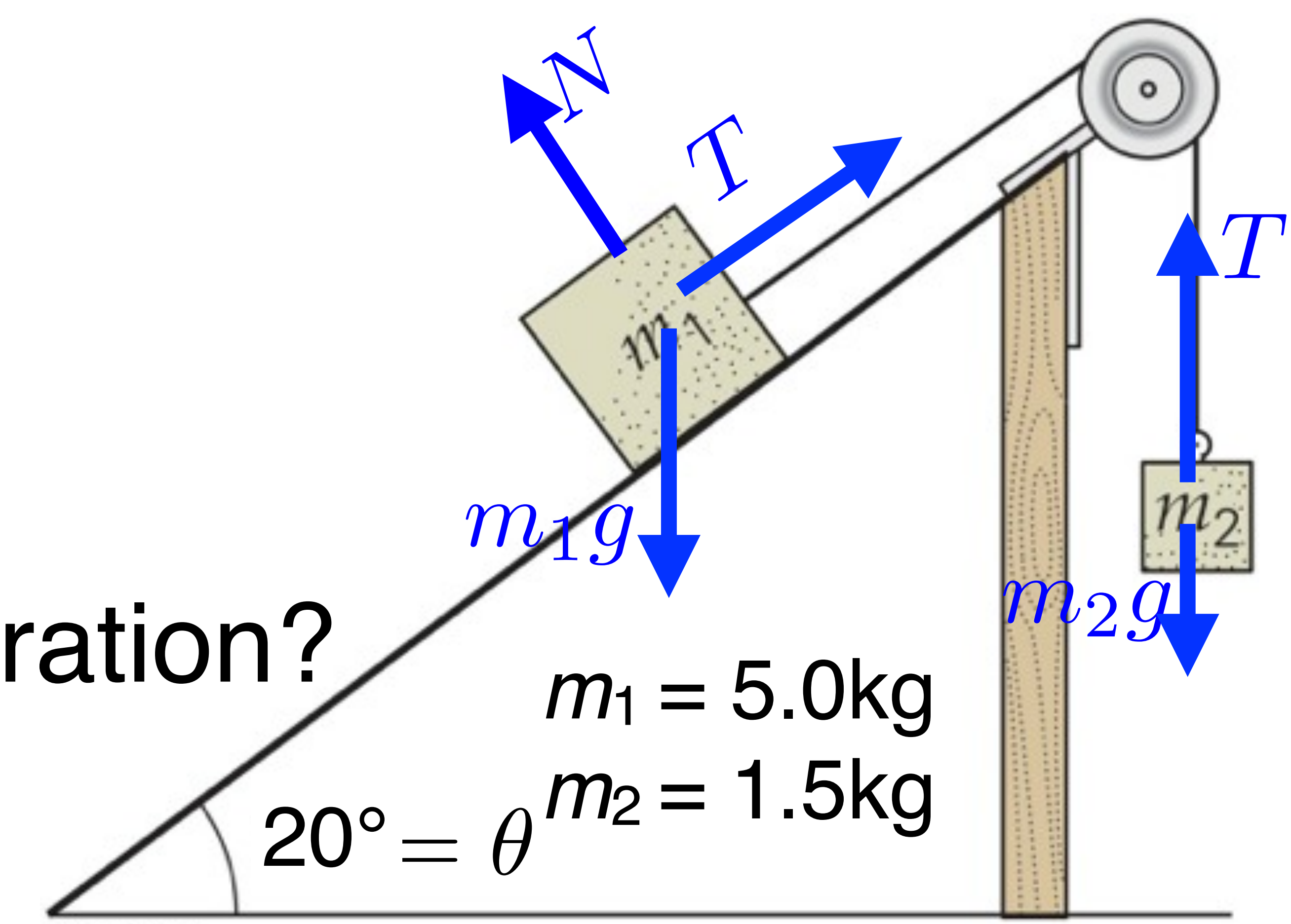
Acceleration?



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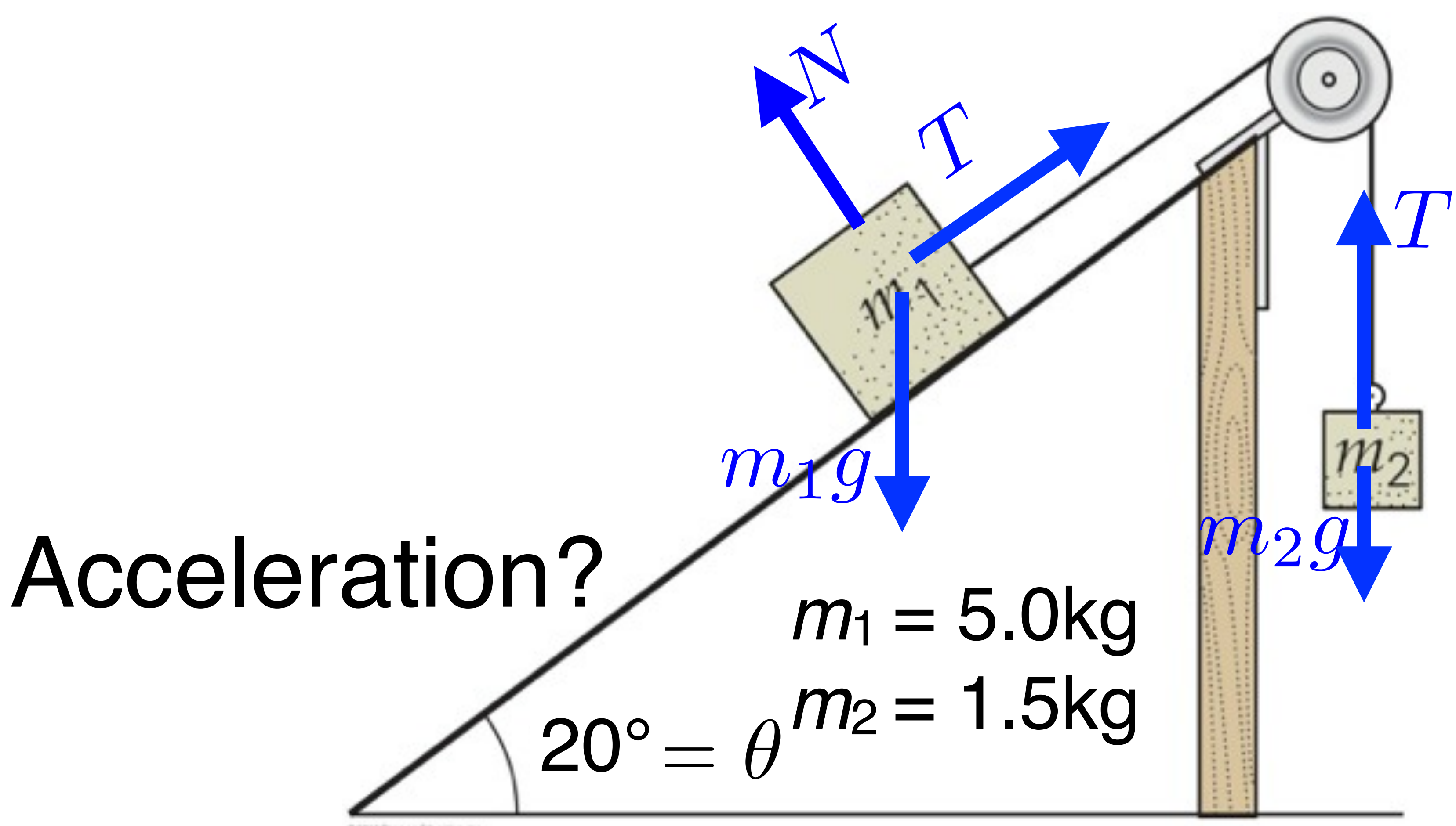

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Given: m_1, m_2, θ
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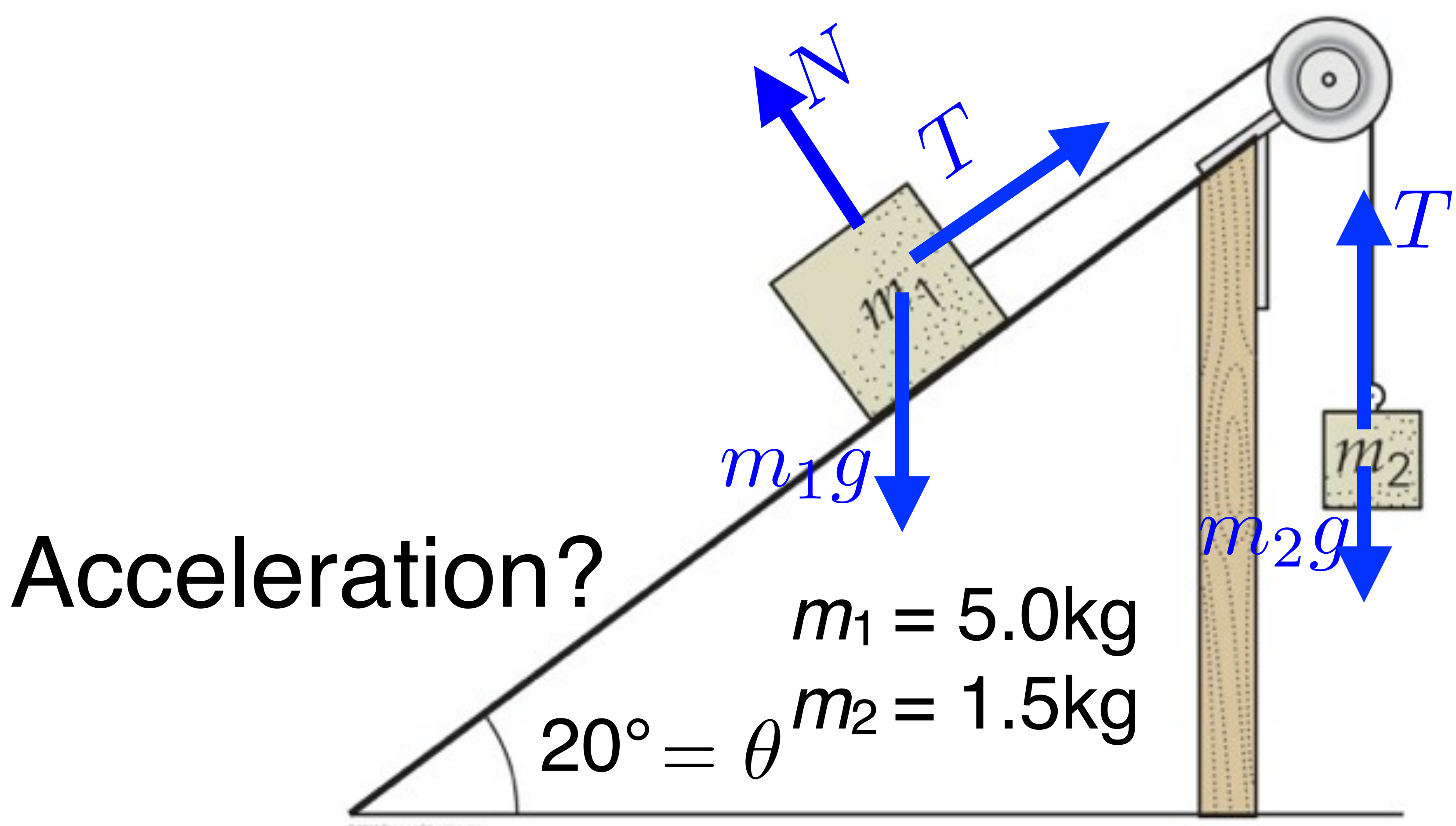

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Given: m_1, m_2, θ
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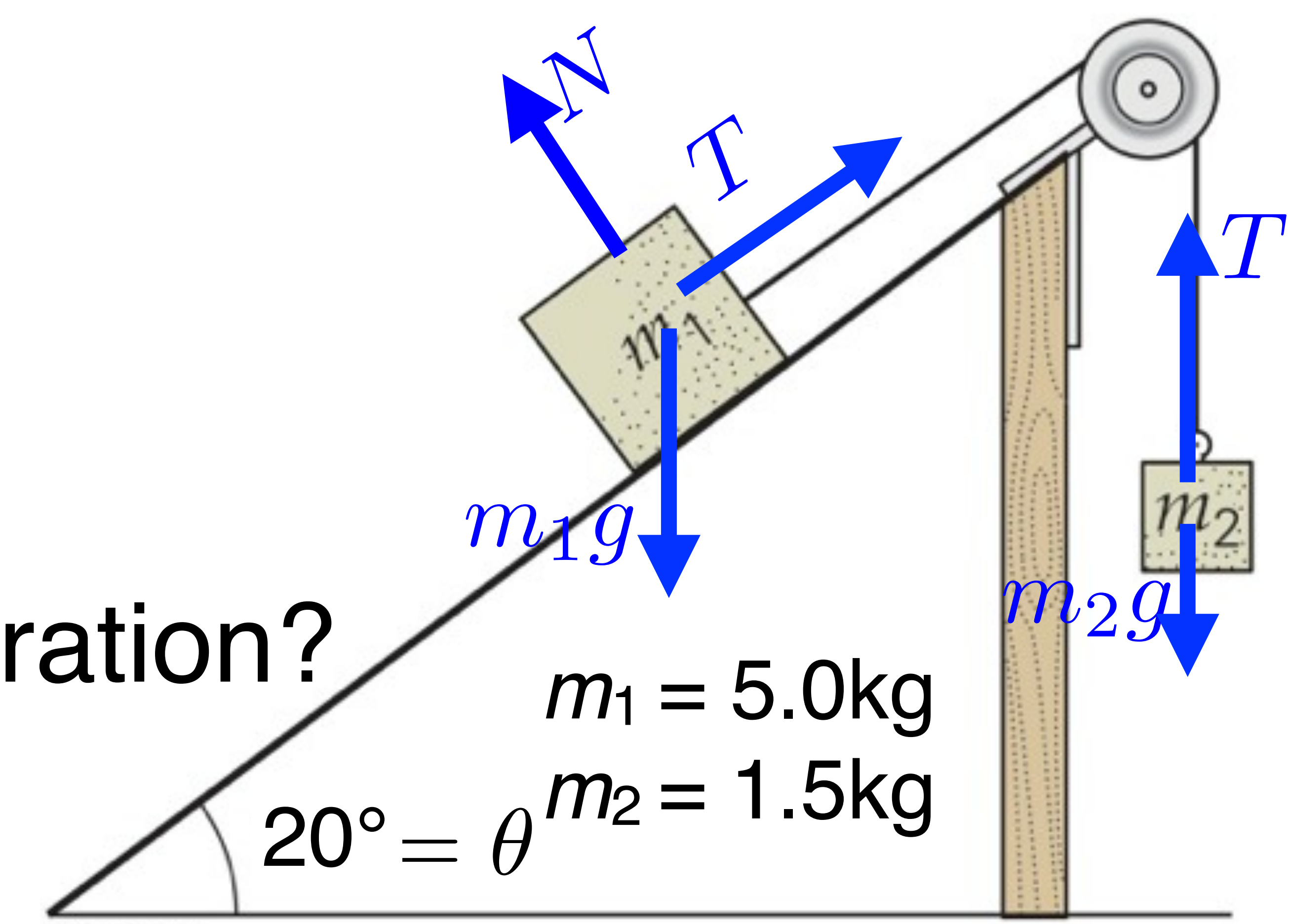
    4a. For each body, draw a free-body diagram

m_1

Acceleration?



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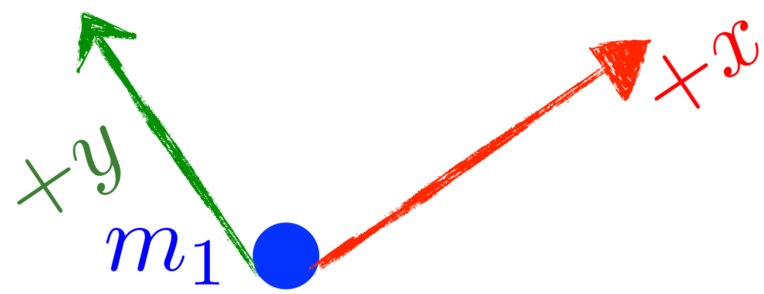

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    4a. For each body, draw
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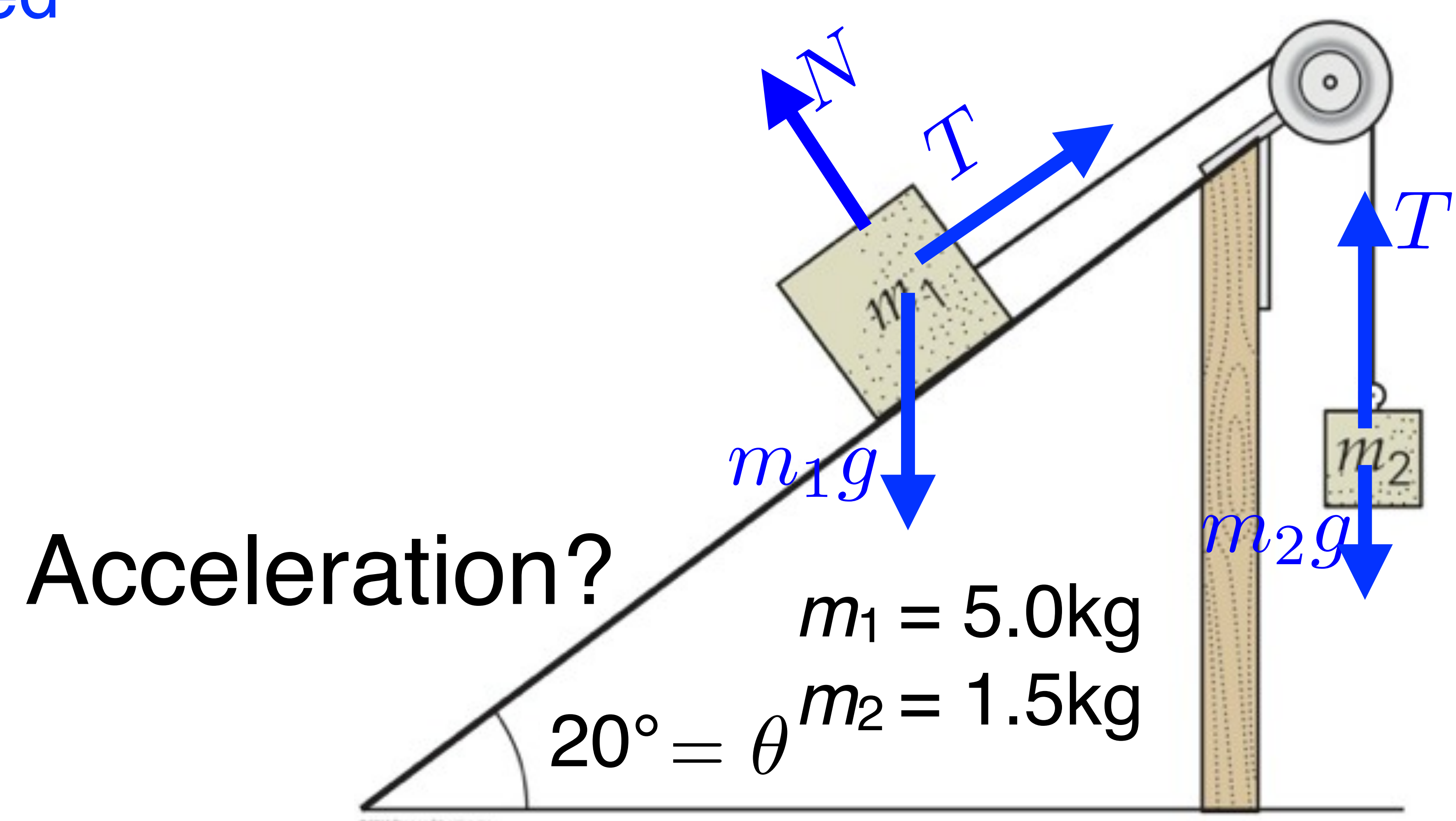
        i: draw axes: along accel., origin
        where forces applied



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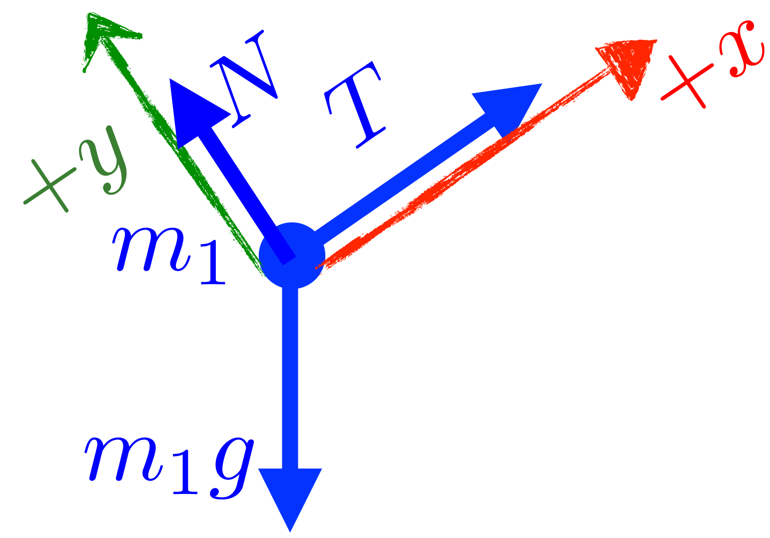

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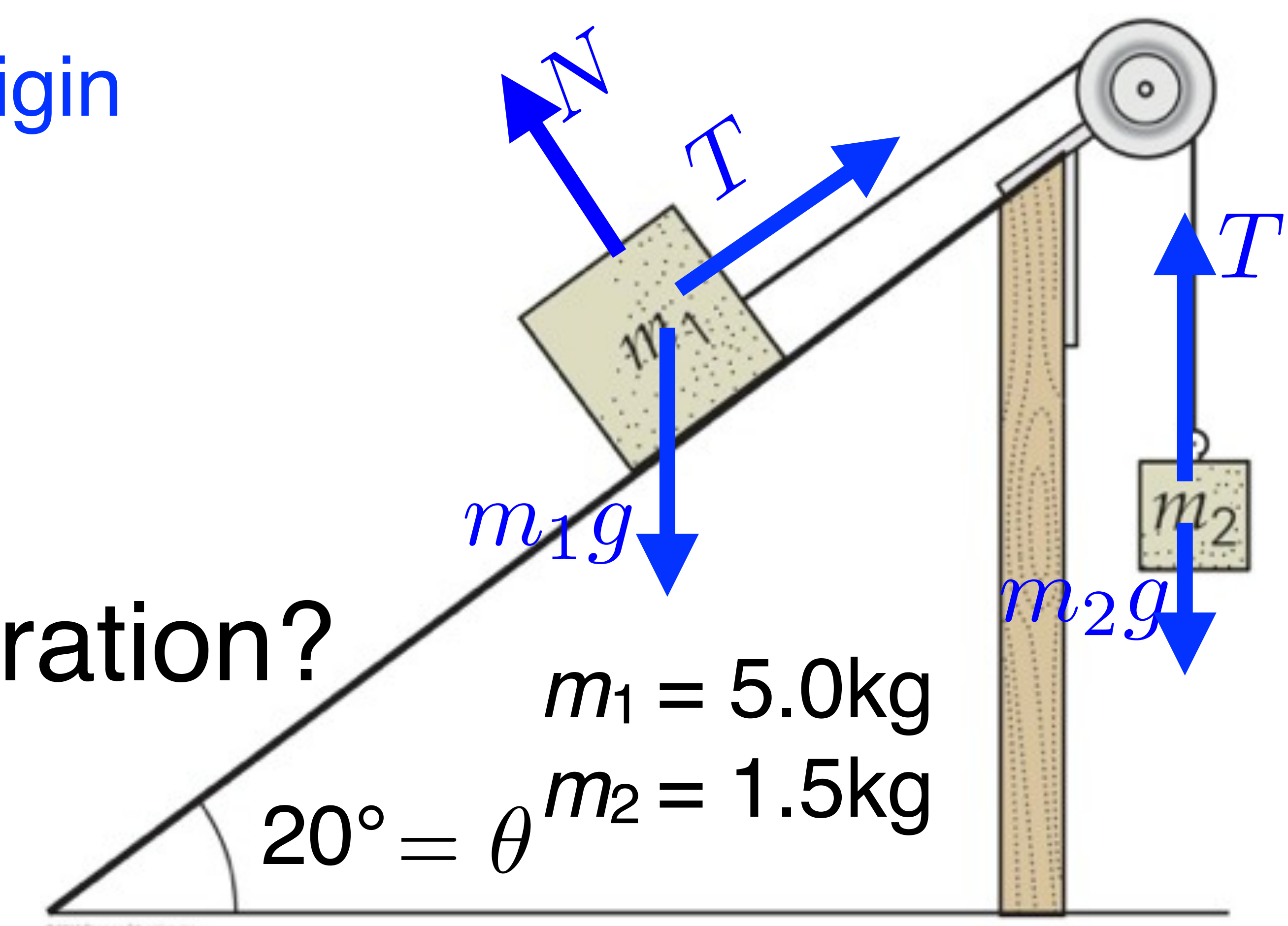

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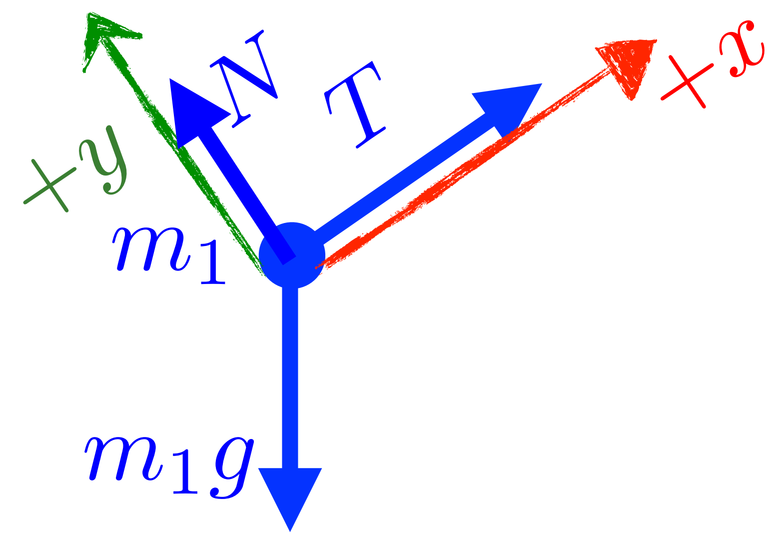
        - iii: resolve forces into components



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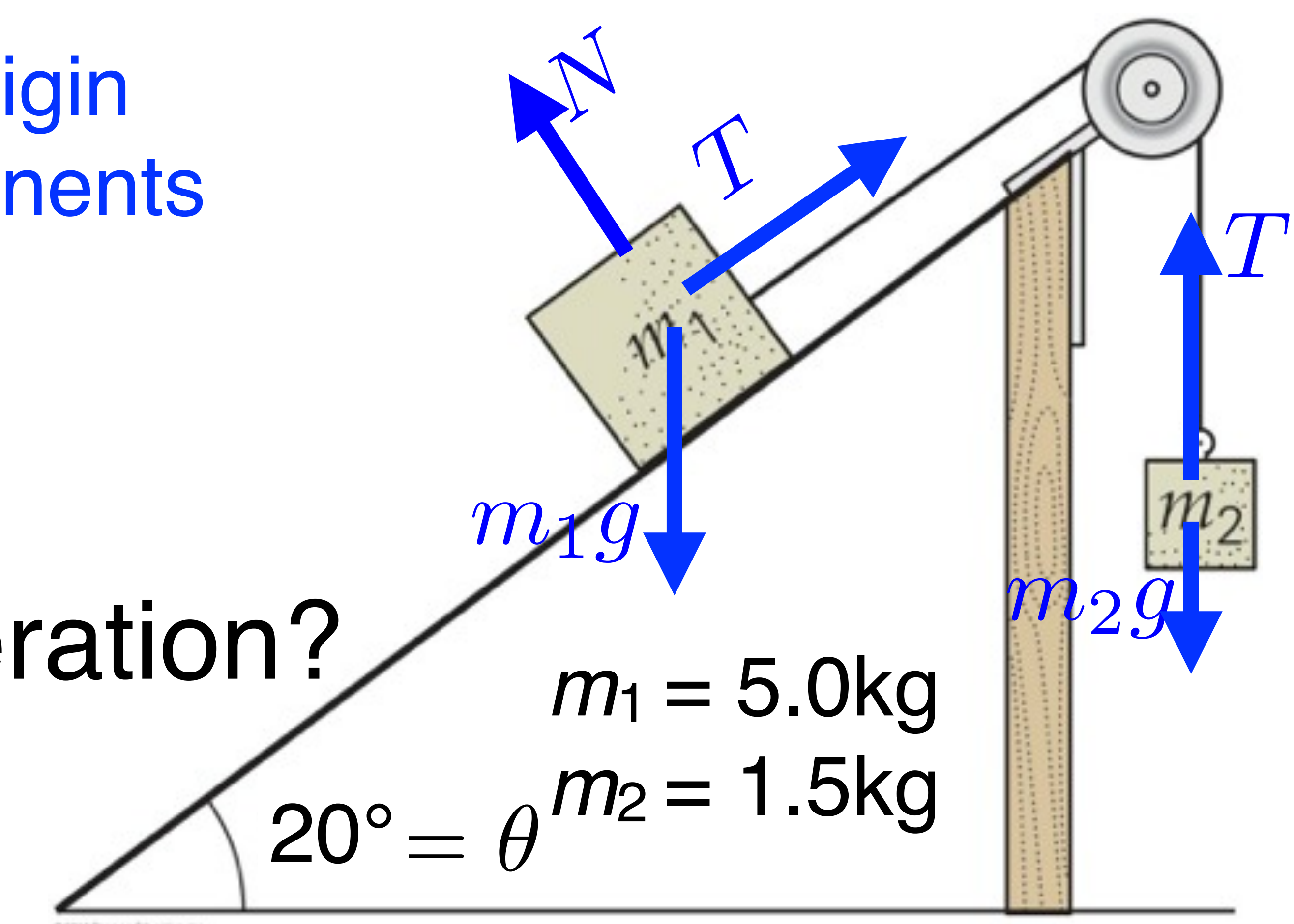

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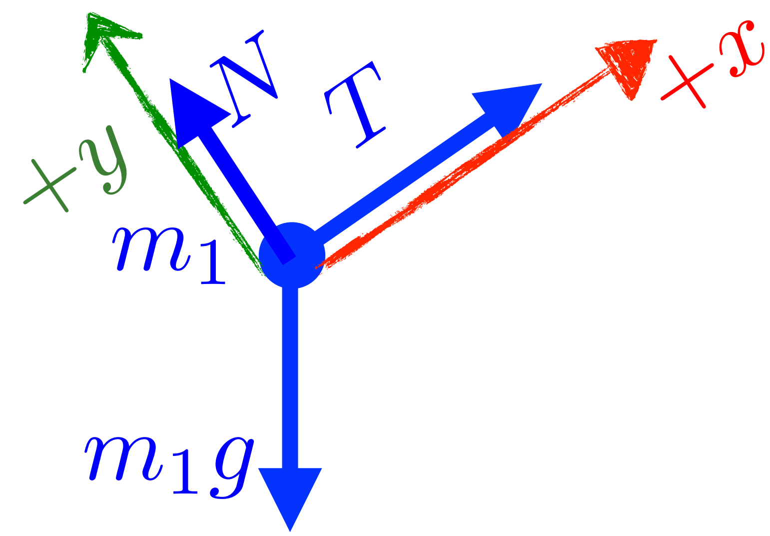
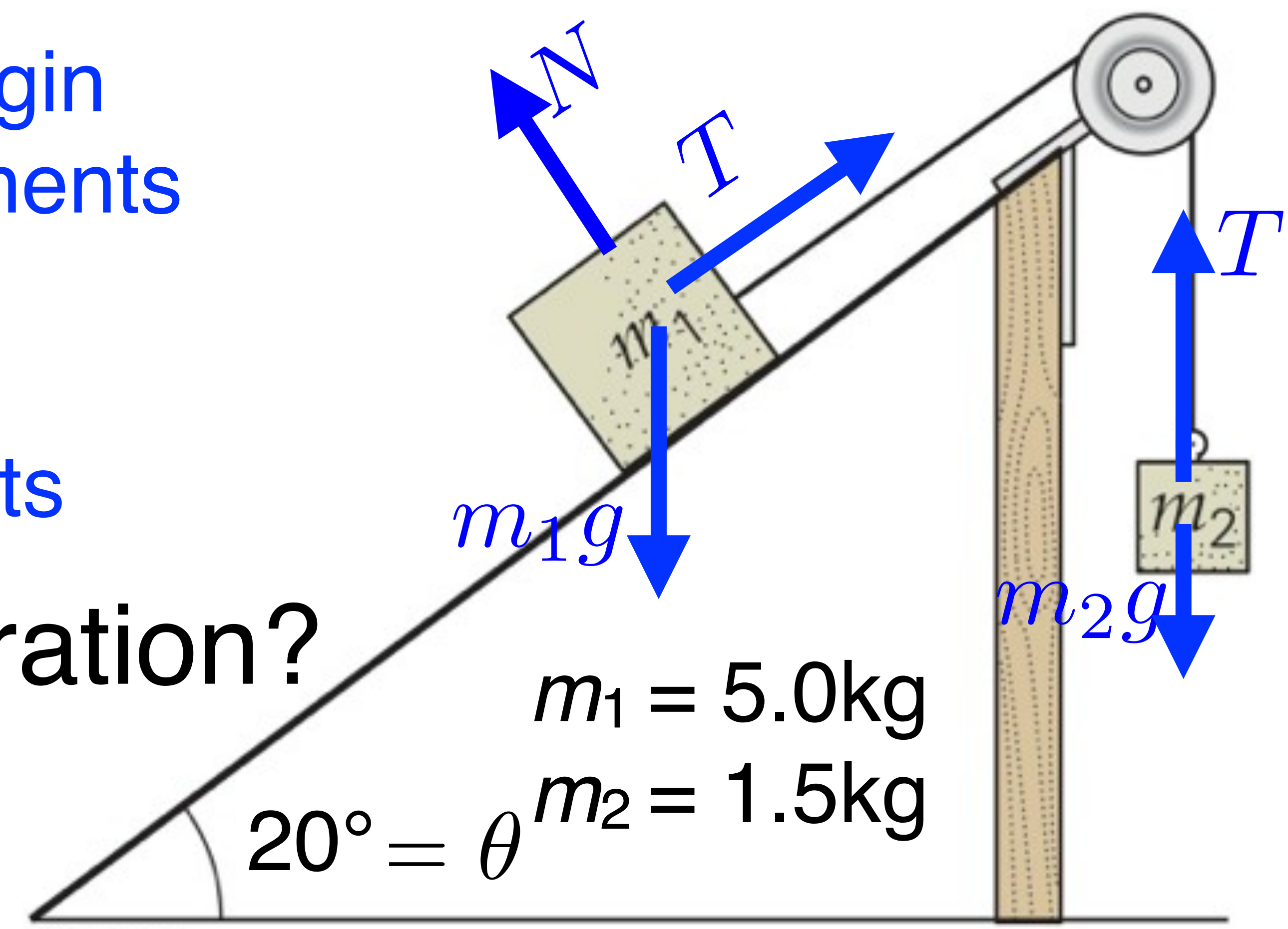
     - ii: draw force vectors from origin
     - iii: resolve forces into components
       - Use colors
       - OR draw new, separate diagrams for x,y components



Acceleration?



Ex. 4.6

Given: m_1, m_2, θ

Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
    4a. For each body, draw a free-body diagram
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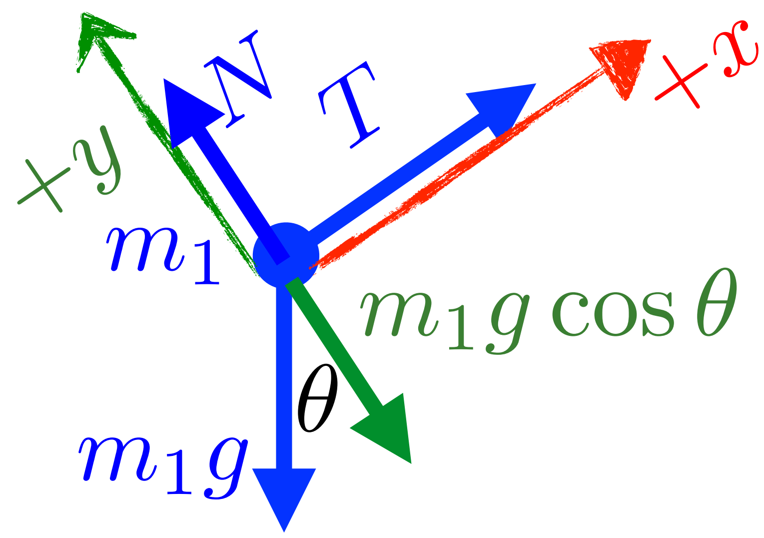
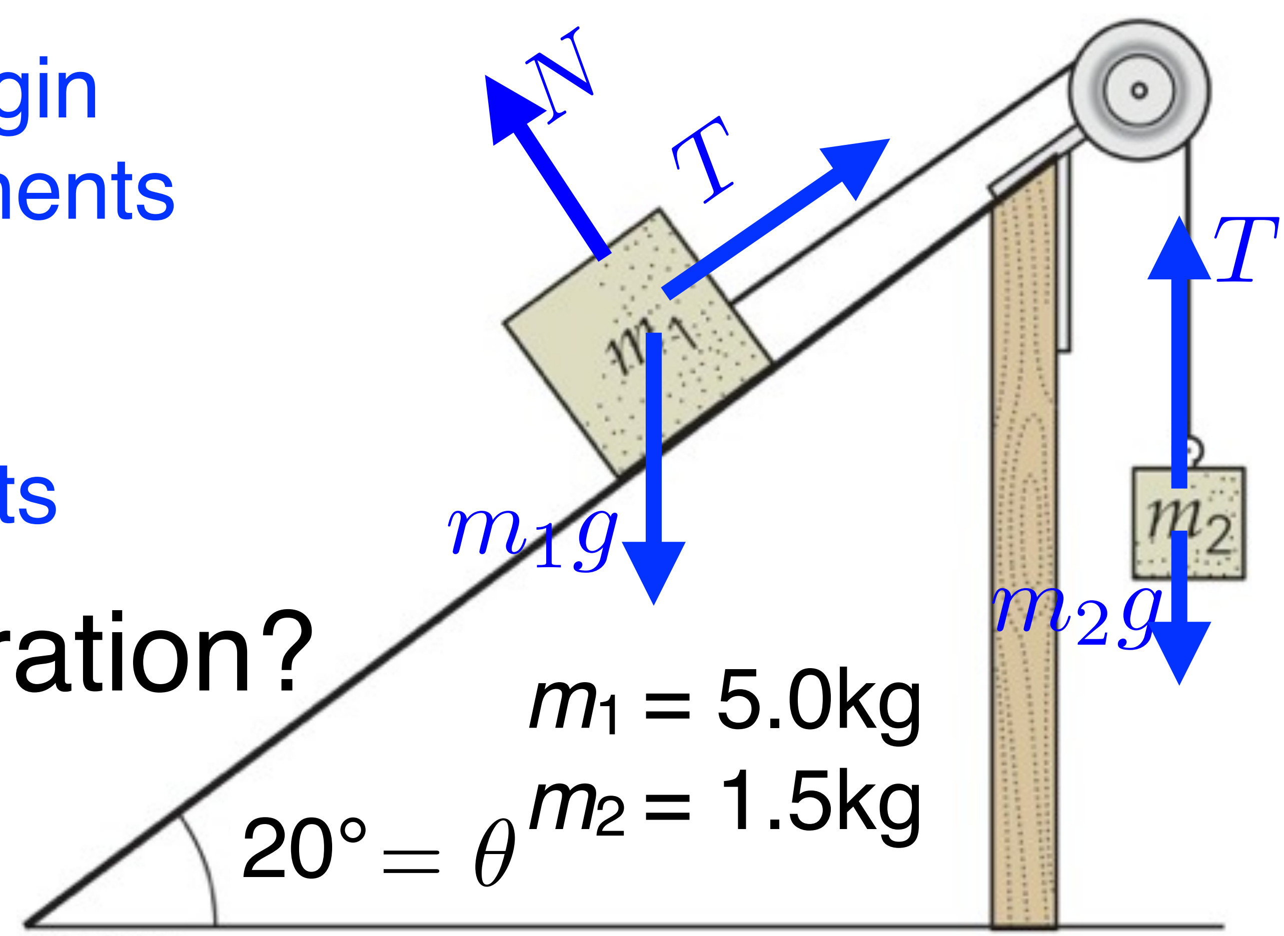


Acceleration?



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Given: m_1, m_2, θ
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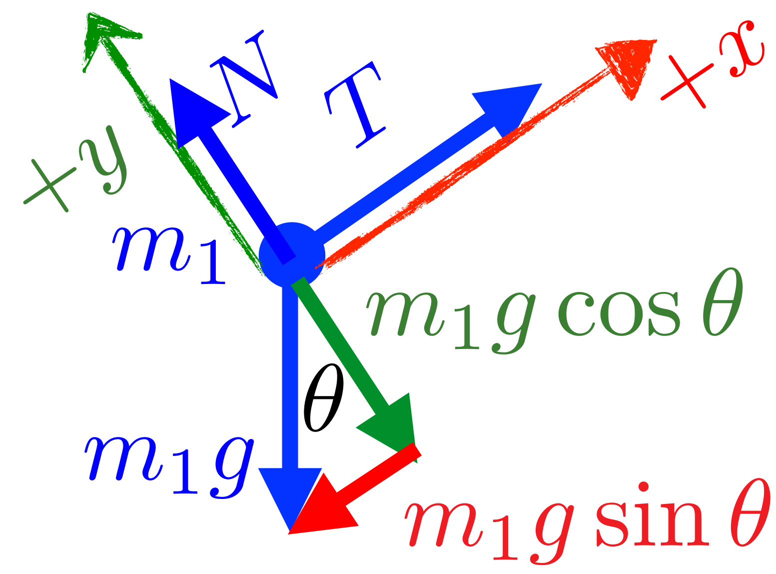

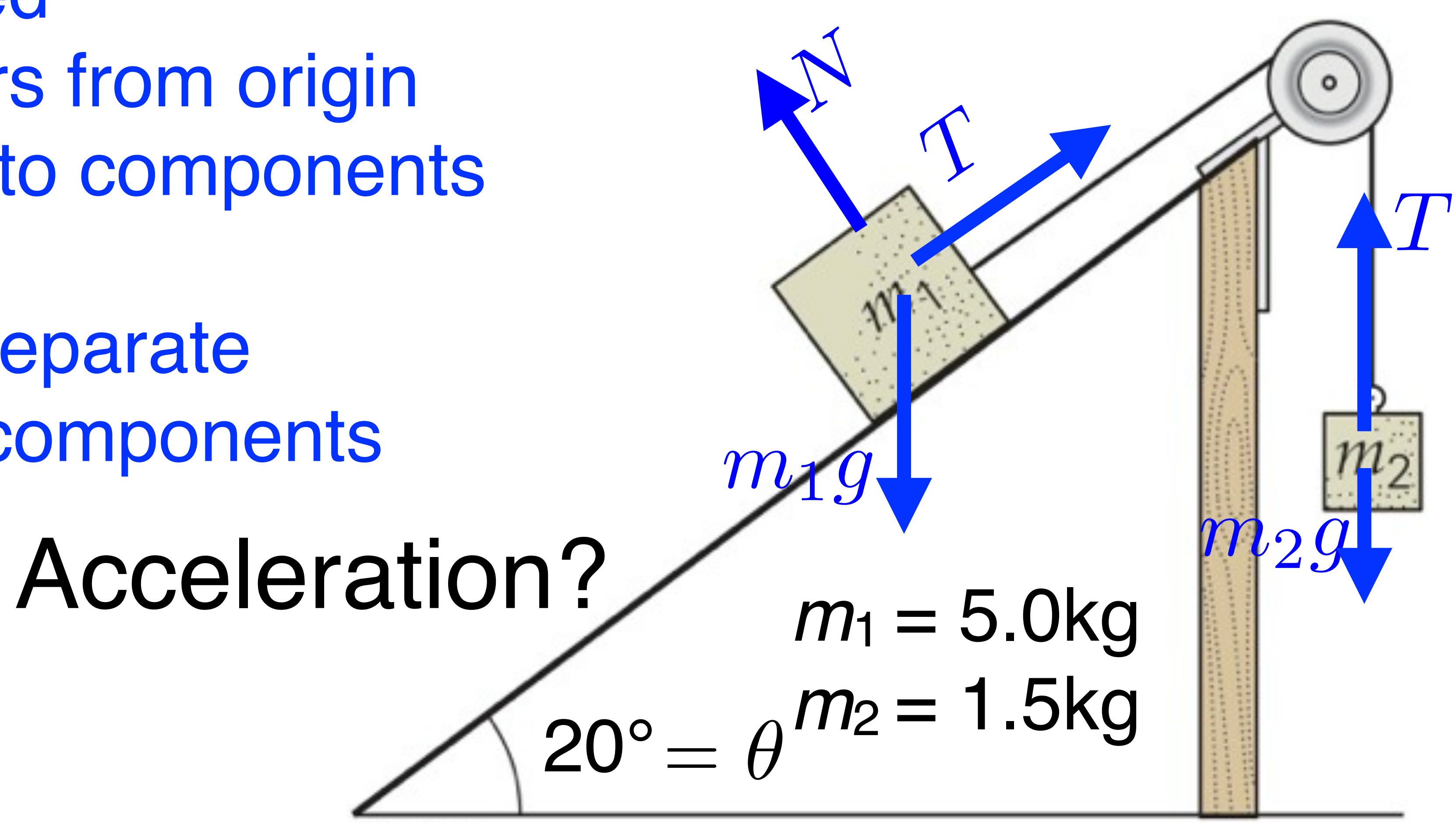

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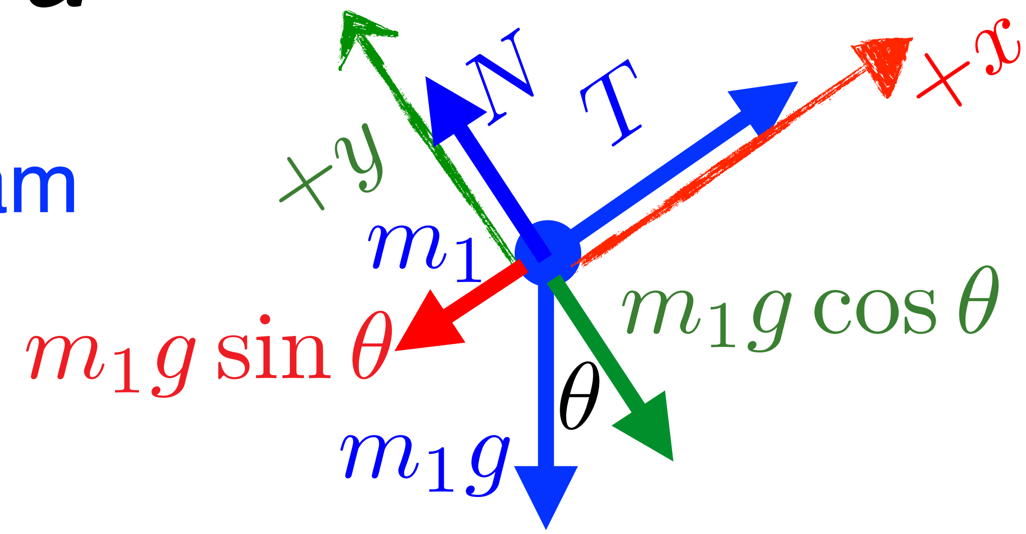
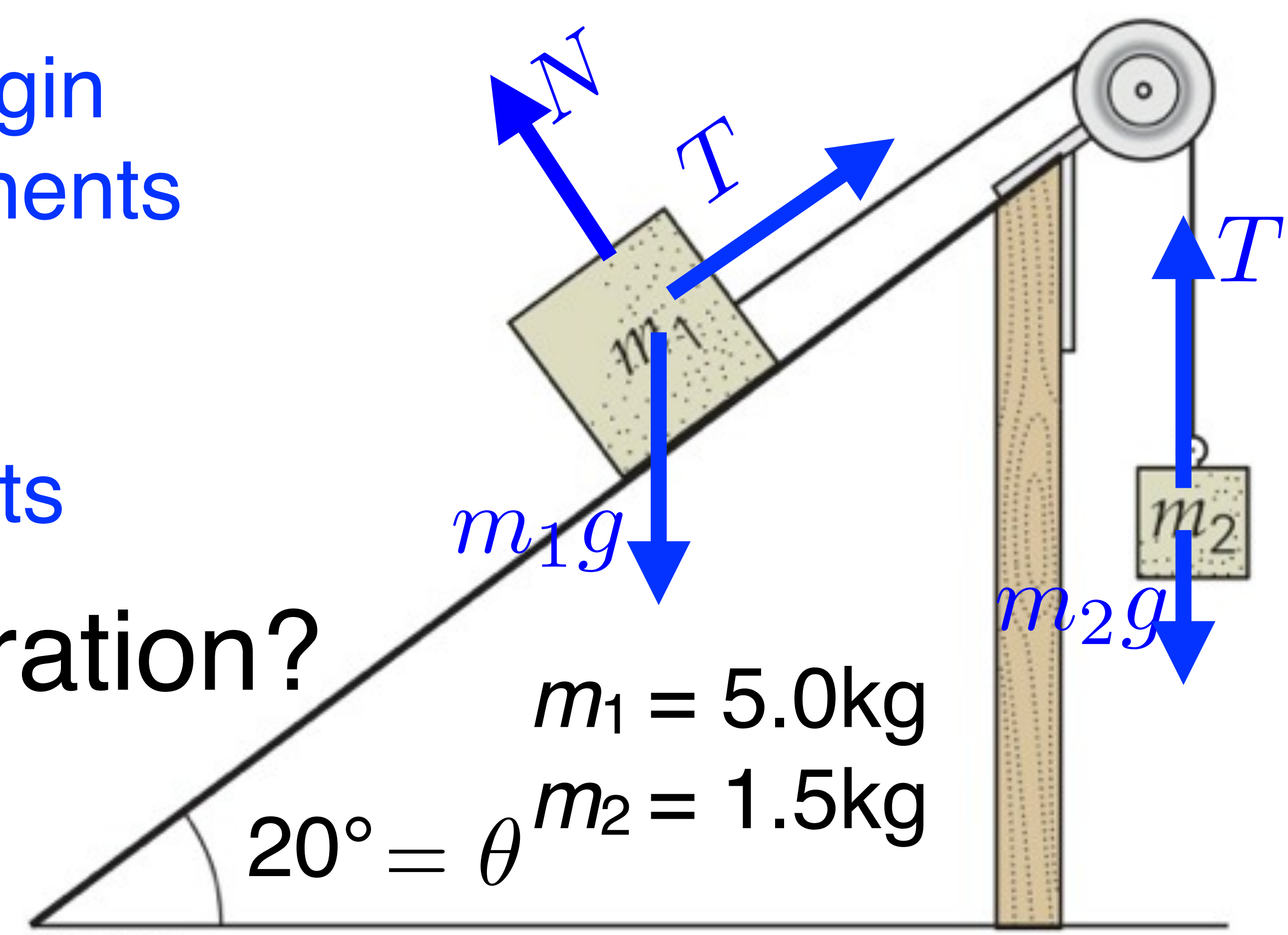


Acceleration?



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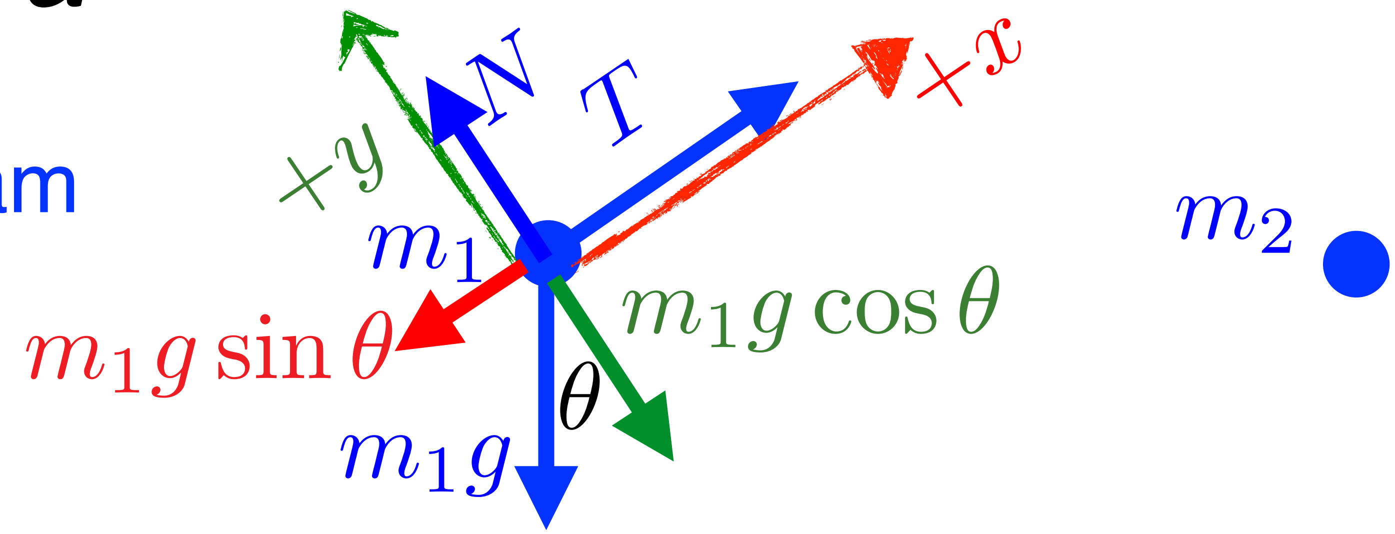

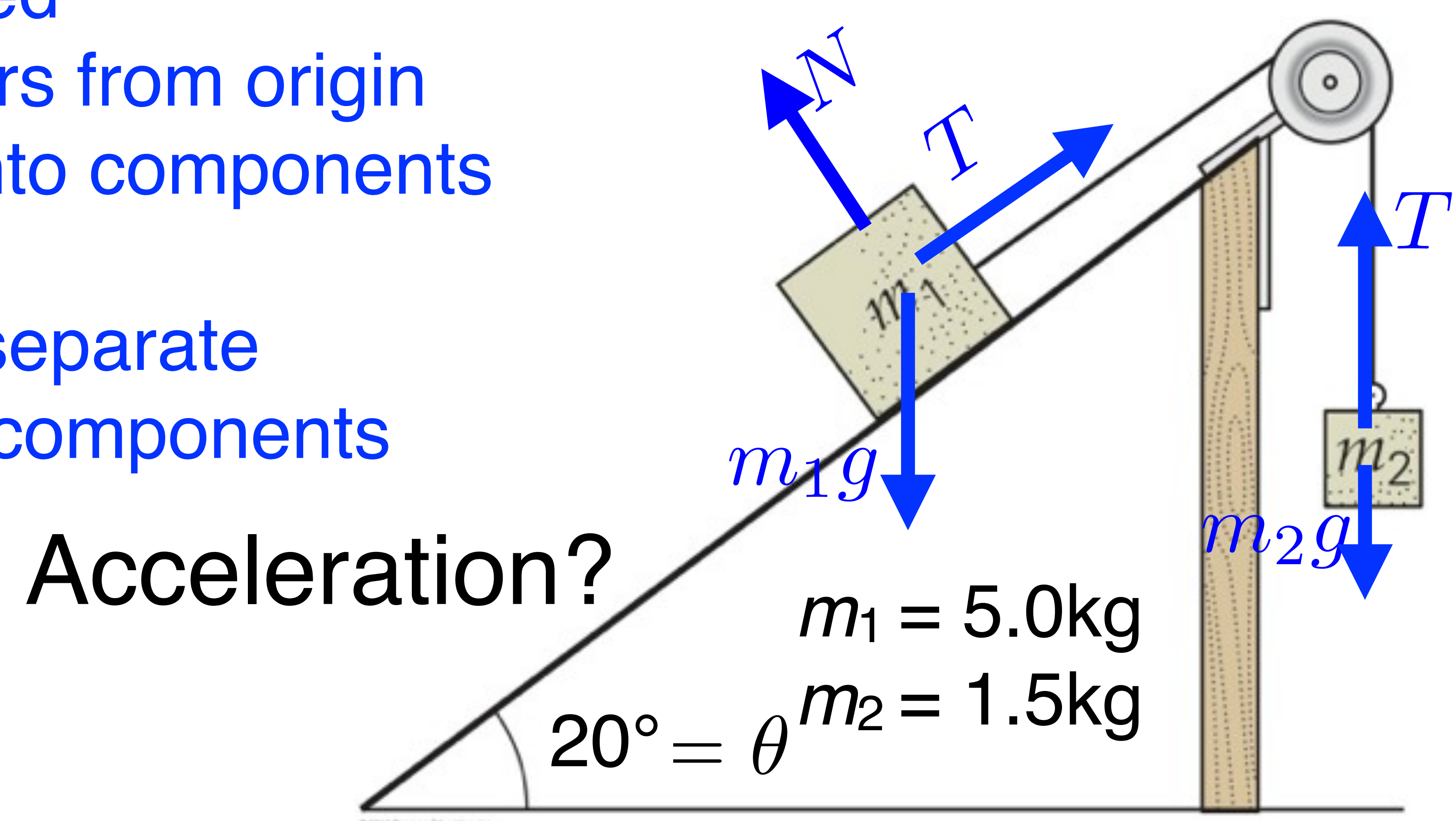

Ex. 4.6

Given: m_1, m_2, θ
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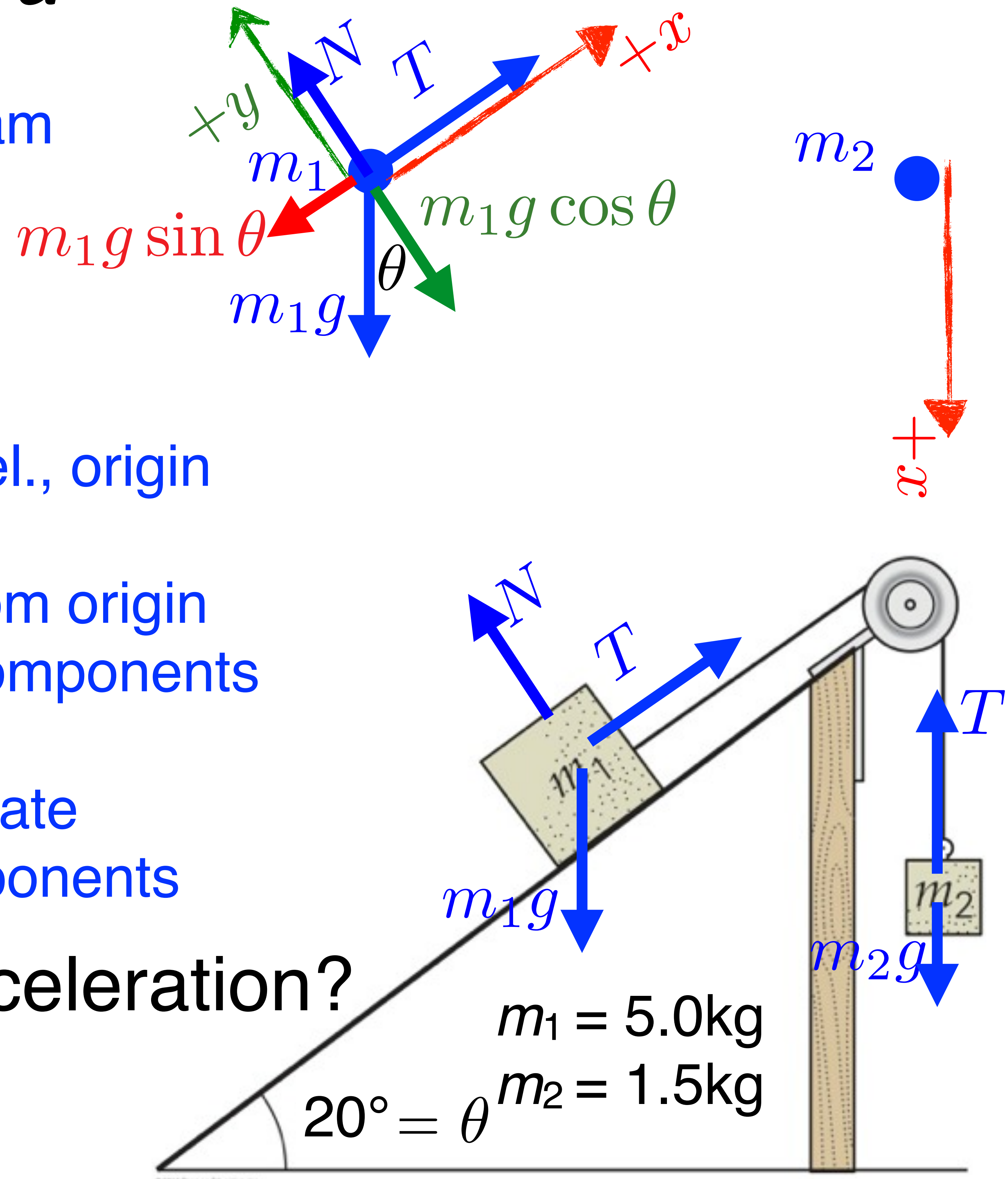

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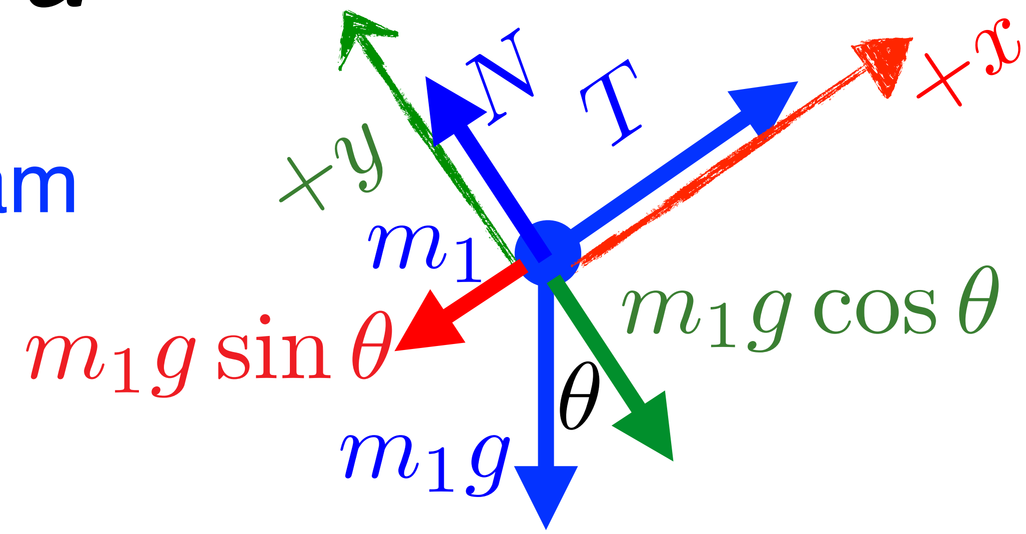
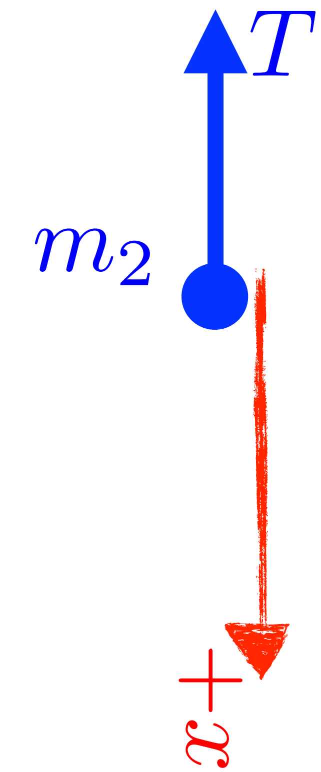
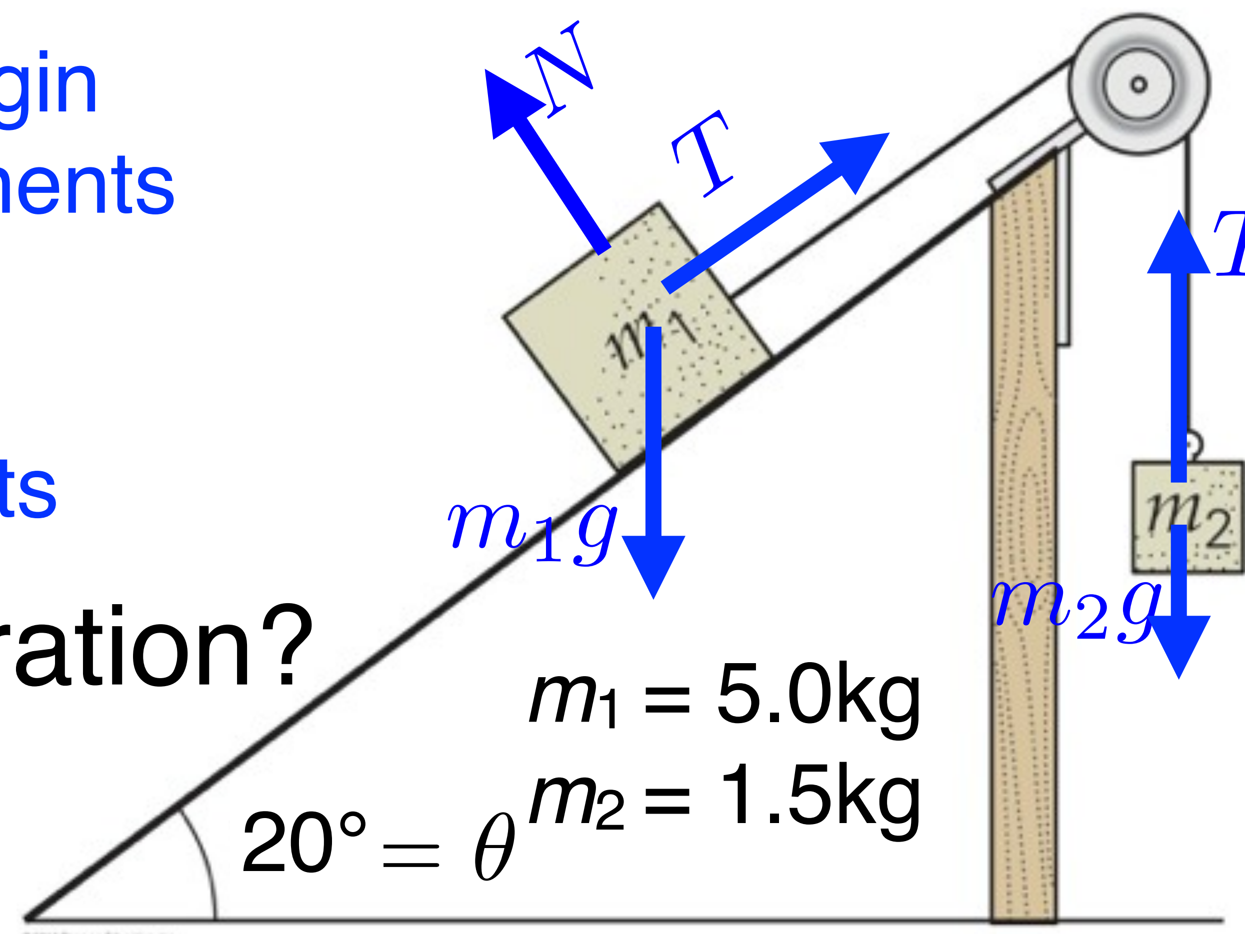




Acceleration?



Ex. 4.6

Given: m_1, m_2, θ
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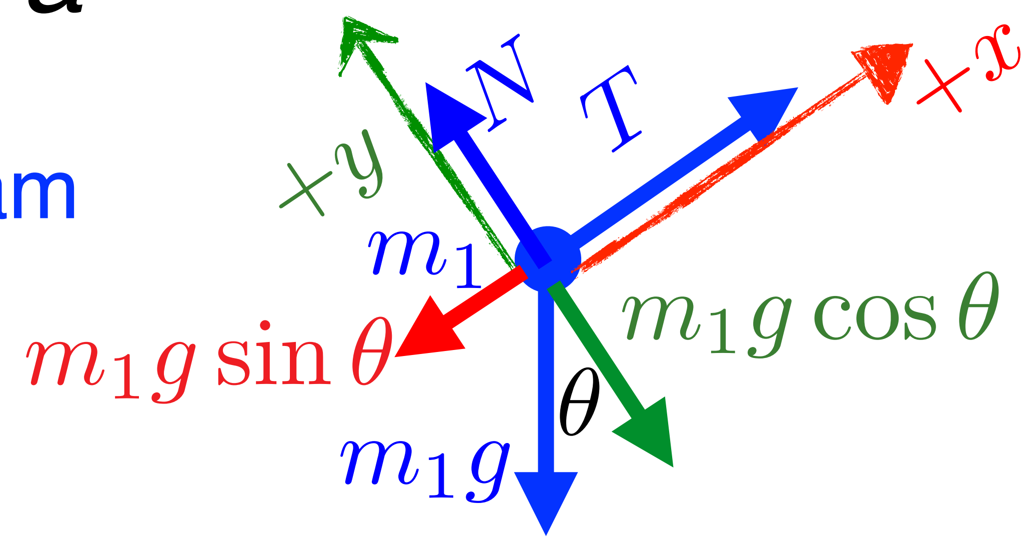
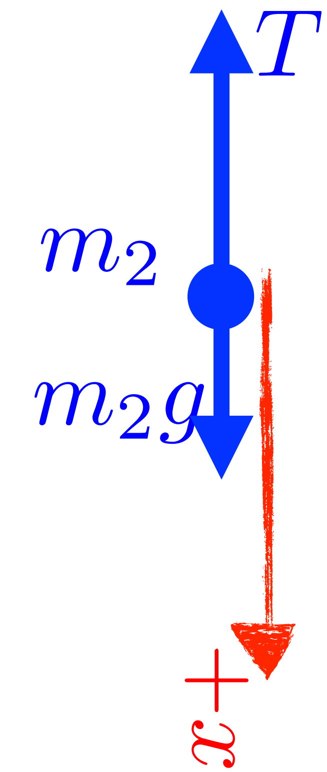
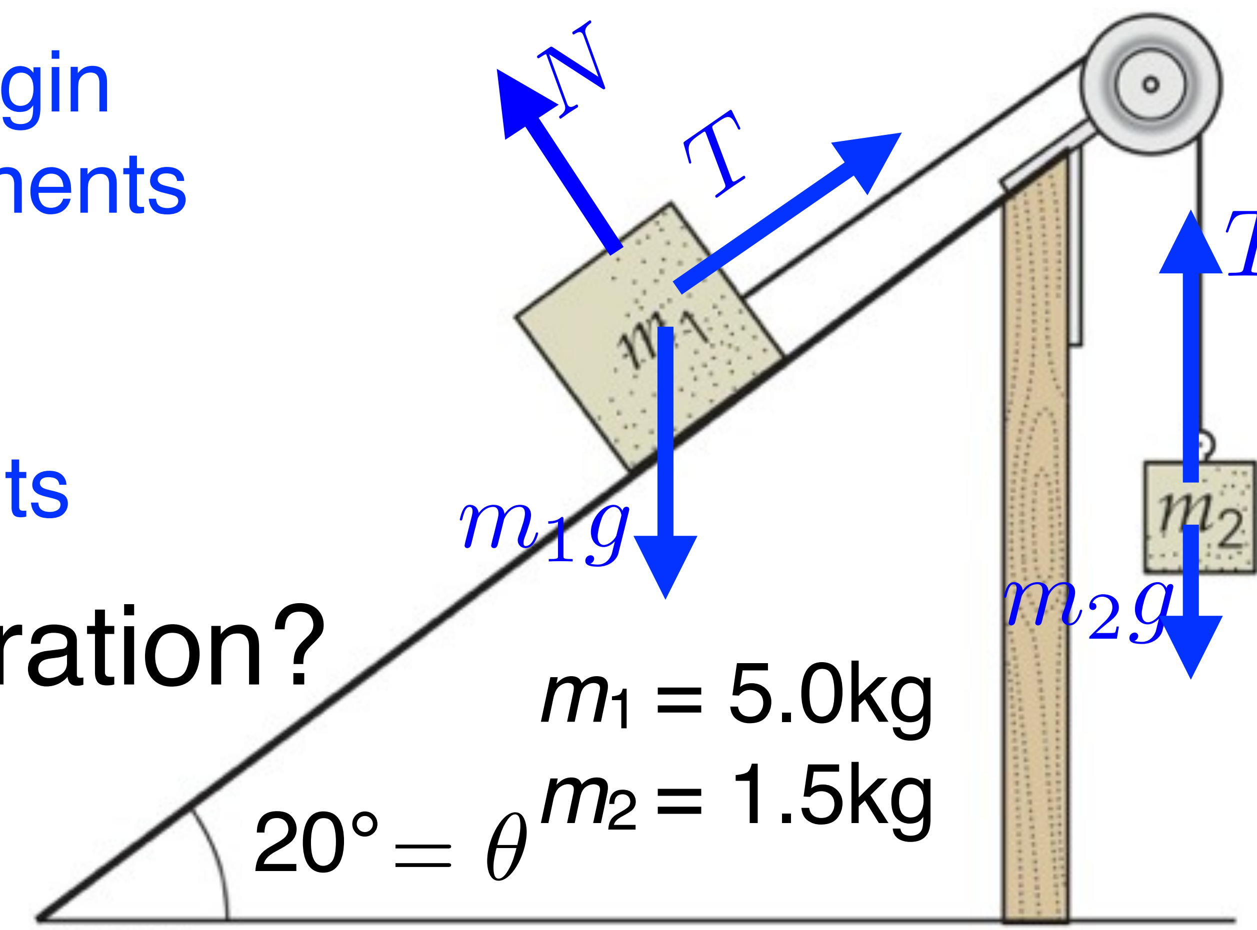




Acceleration?



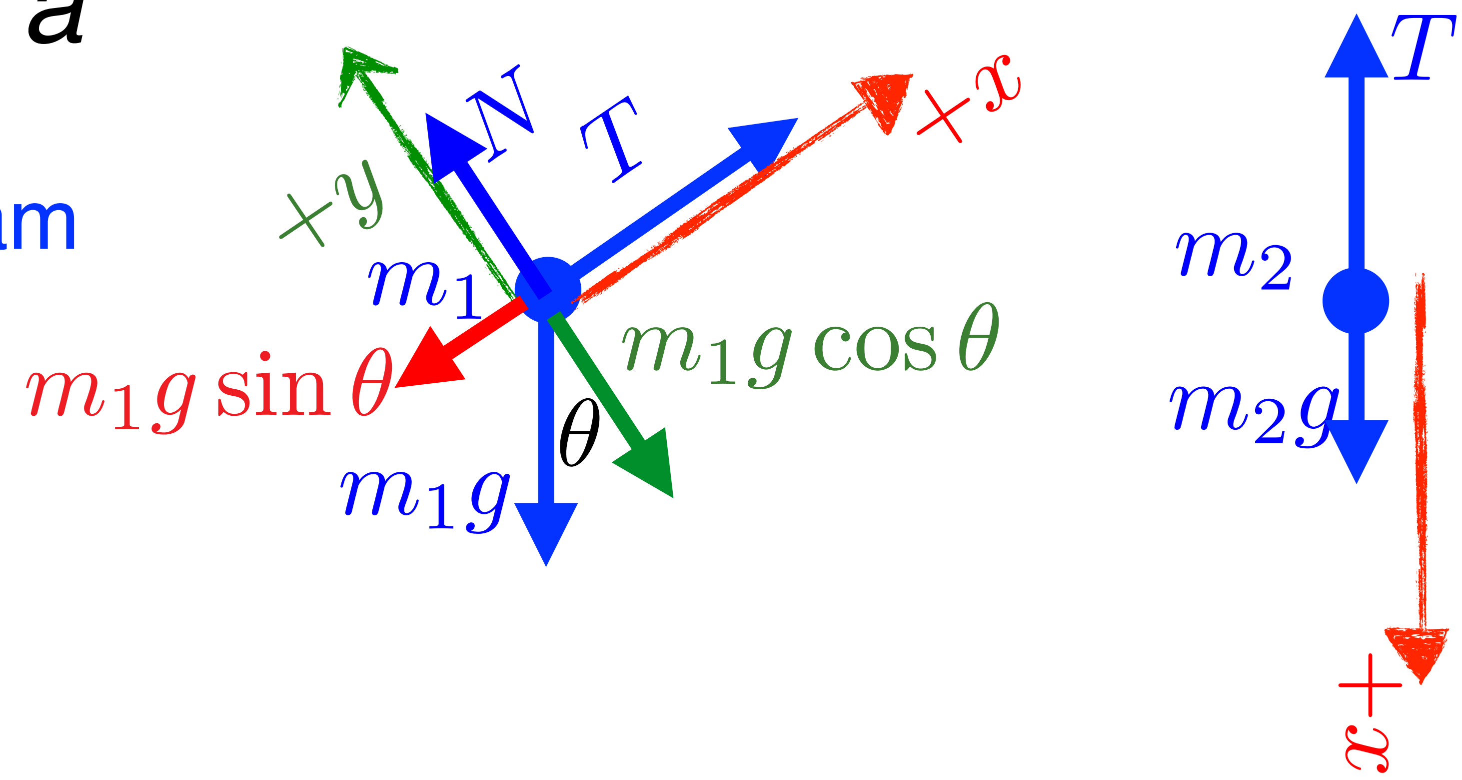
Ex. 4.6

Ex. 4.6

Given: m_1, m_2, θ

Goal: a

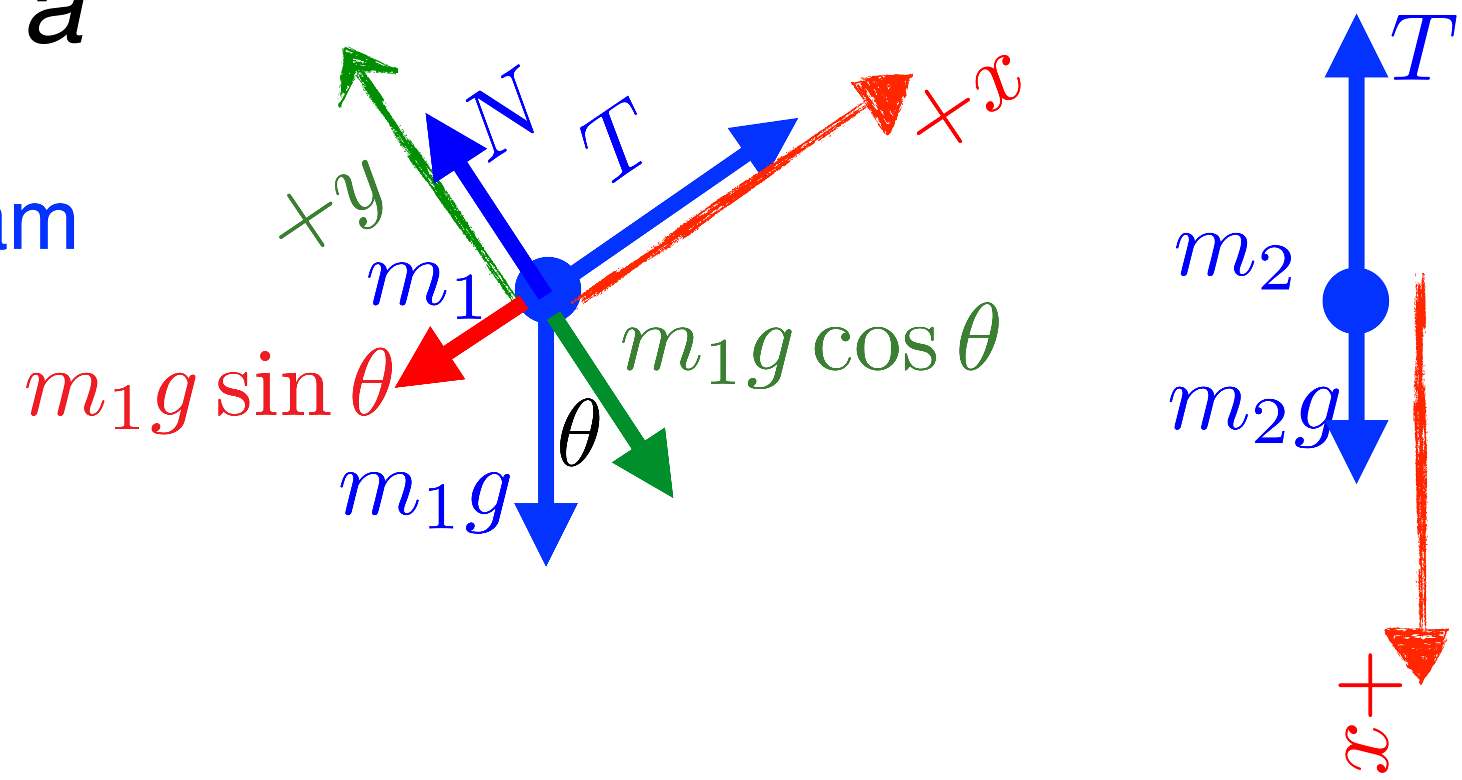
1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
    4a. For each body, draw a free-body diagram



Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   4a. For each body, draw a free-body diagram
   4b. Apply Newton's 2nd law



Ex. 4.6

Given: m_1, m_2, θ

Goal: a

1. Read carefully
2. Draw a sketch = space diagram
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   4a. For each body, draw a free-body diagram
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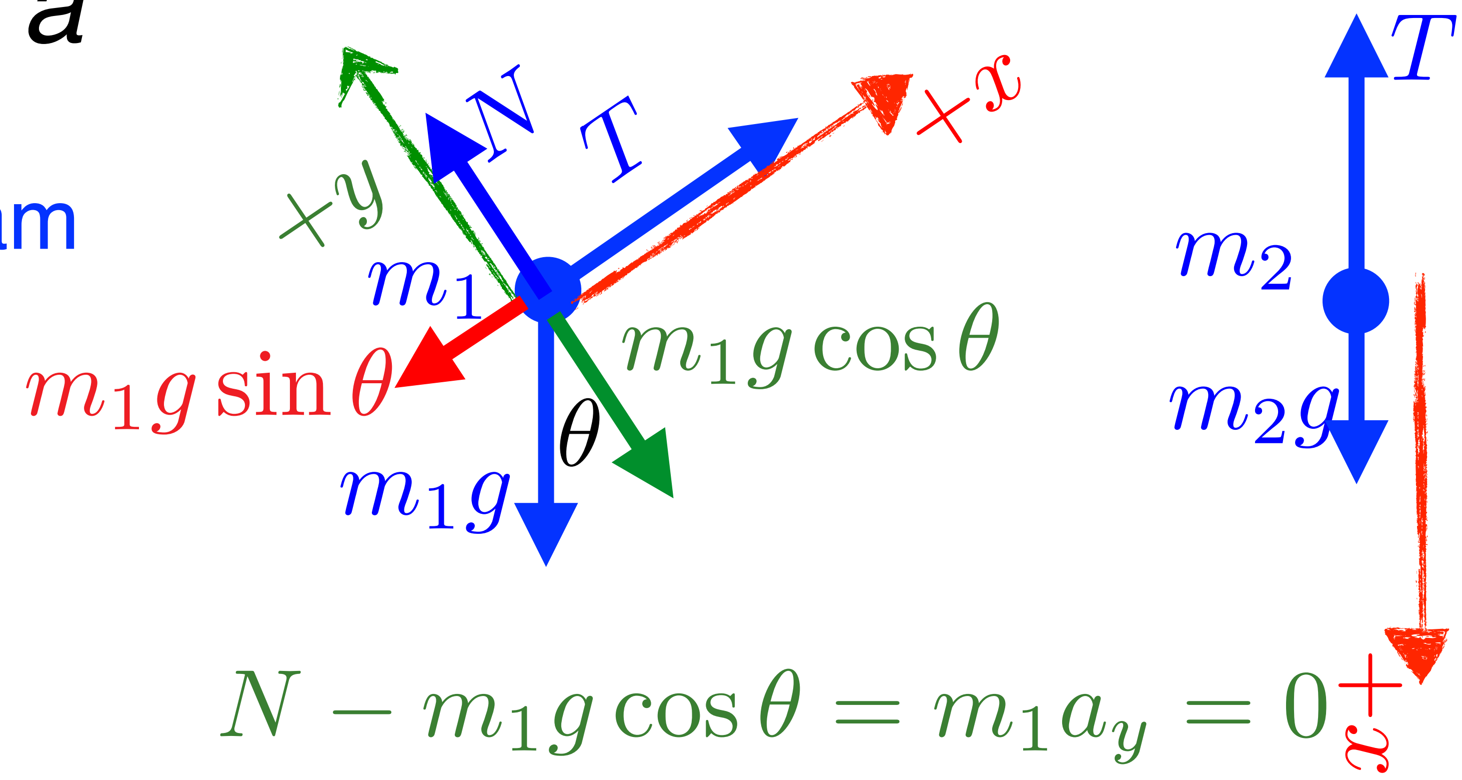
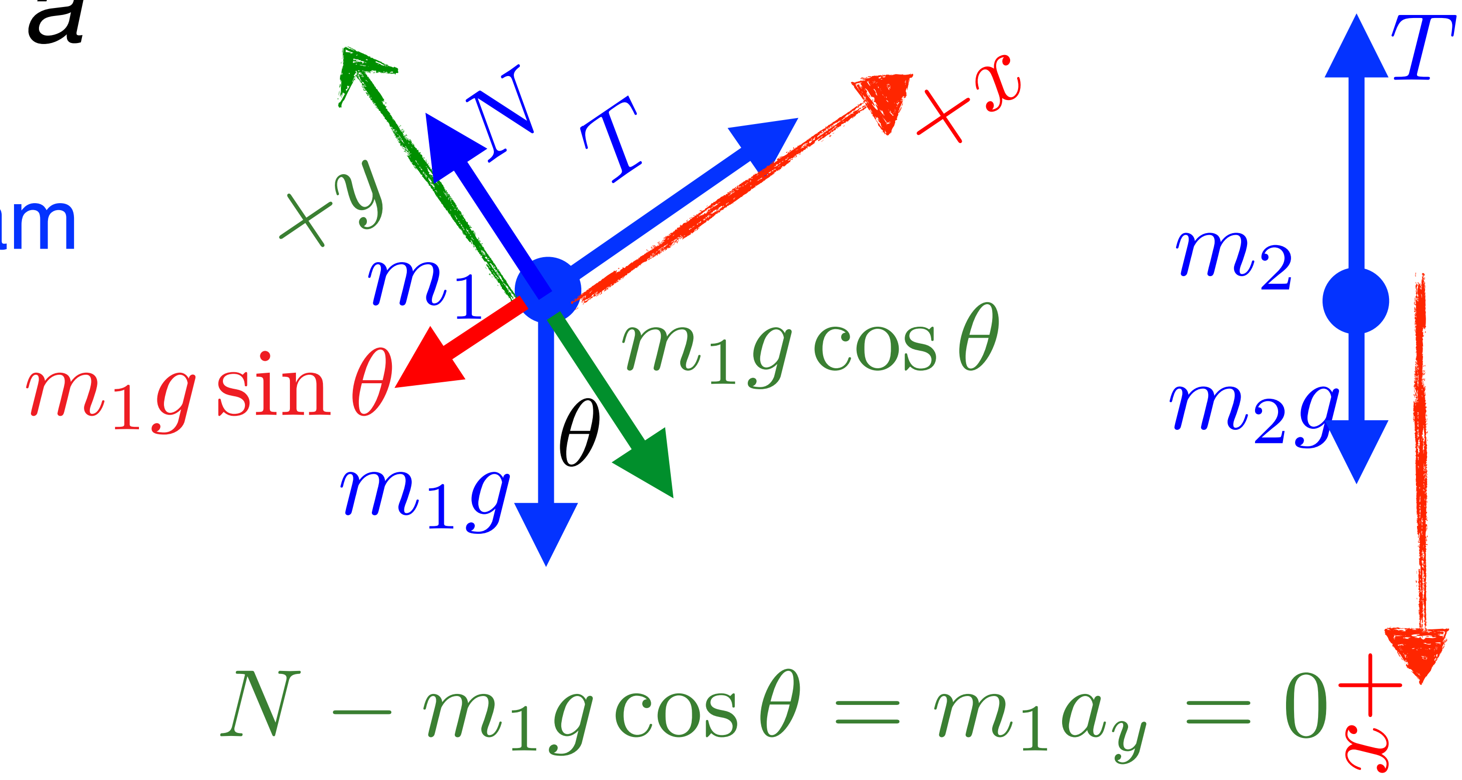


$$N - m_1 g \cos\theta = m_1 a_y = 0$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   4a. For each body, draw a free-body diagram
   4b. Apply Newton's 2nd law



$$N - m_1 g \cos\theta = m_1 a_y = 0$$

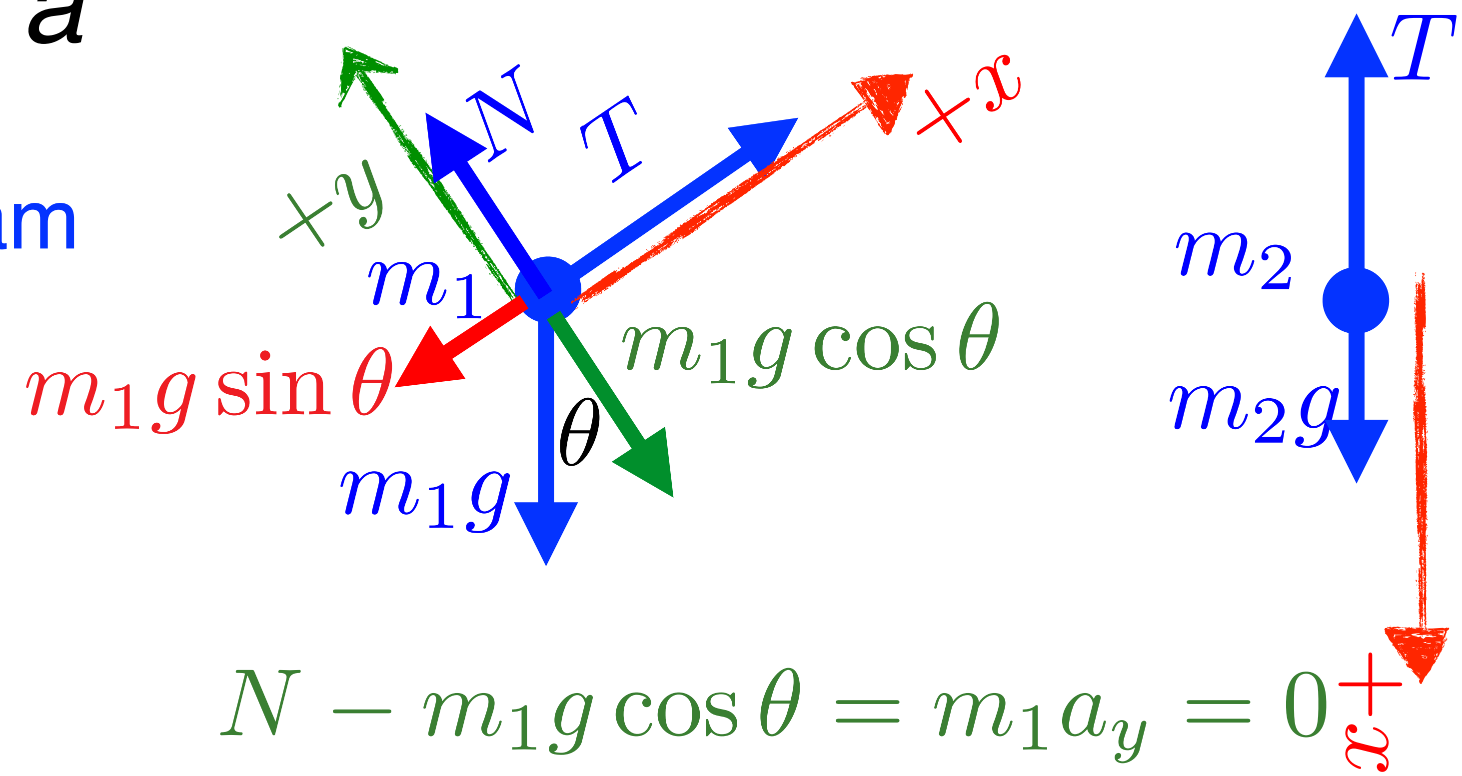
$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

Ex. 4.6

Given: m_1, m_2, θ

Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
    4a. For each body, draw a free-body diagram
    4b. Apply Newton's 2nd law



$$N - m_1 g \cos\theta = m_1 a_y = 0$$

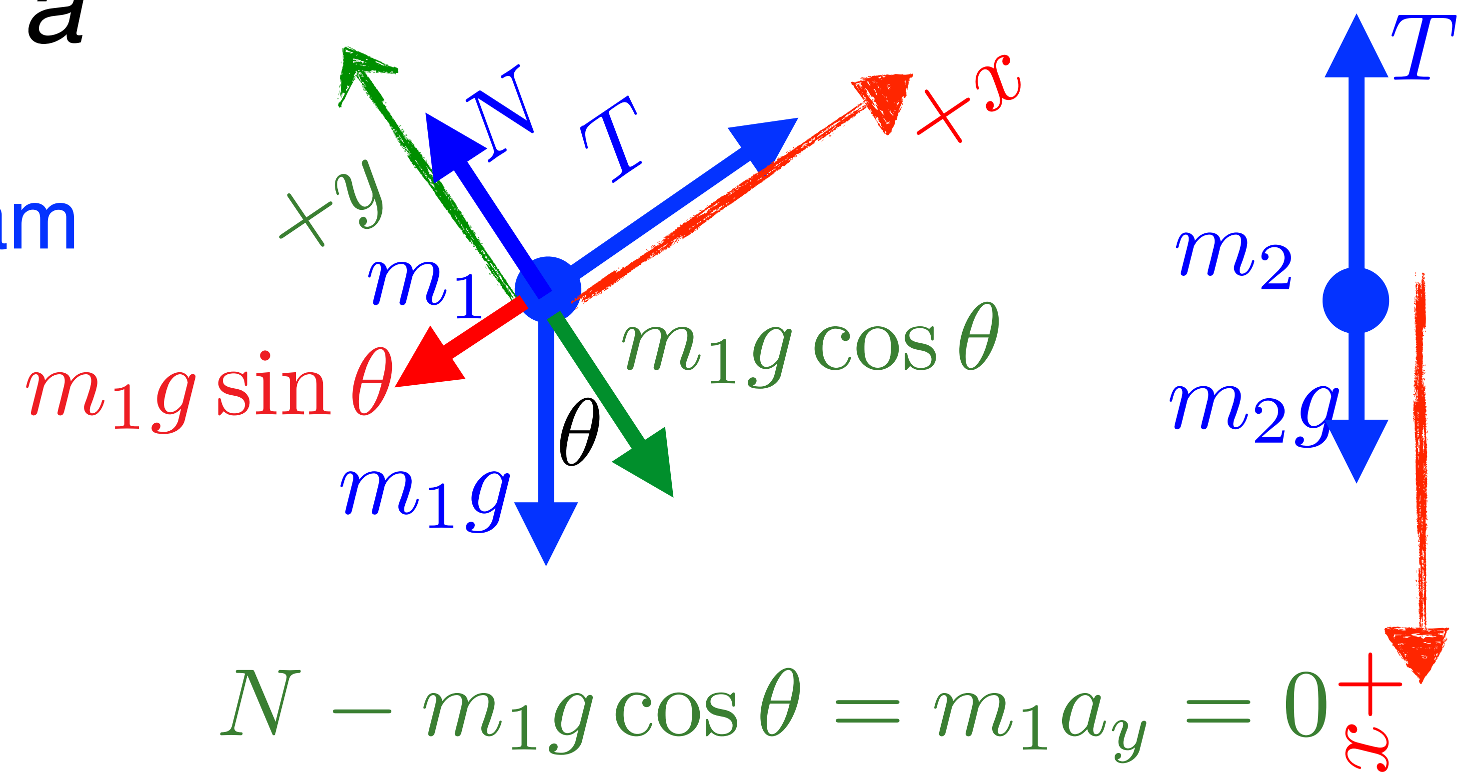
$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   - 4a. For each body, draw a free-body diagram
   - 4b. Apply Newton's 2nd law
     - *Note: if const. force, constant acceleration kinematic equations also apply*



$$N - m_1 g \cos\theta = m_1 a_y = 0$$

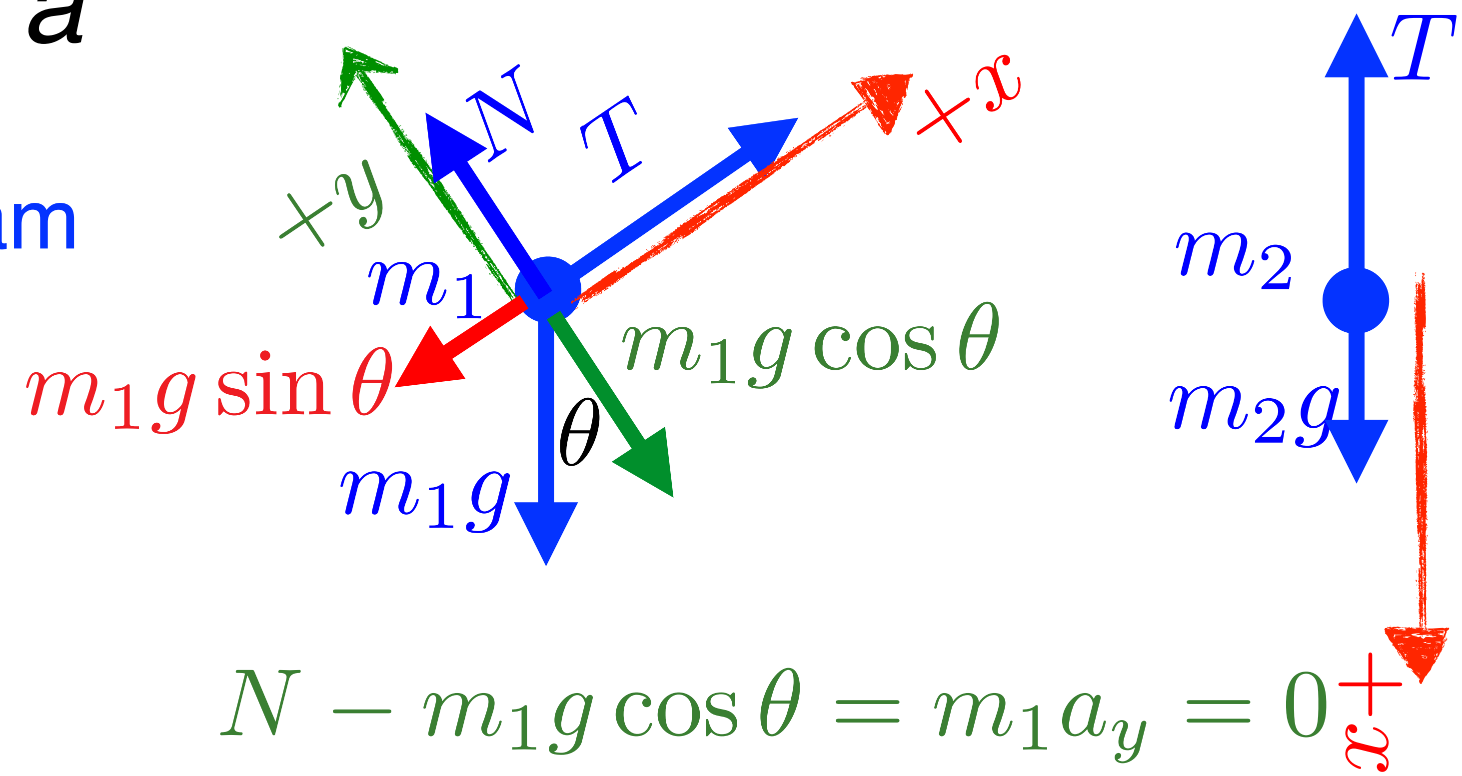
$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
    4a. For each body, draw a free-body diagram
    4b. Apply Newton's 2nd law
        Note: if const. force, constant acceleration kinematic equations also apply
5. Calculate



$$N - m_1 g\cos\theta = m_1 a_y = 0$$

$$T - m_1 g\sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
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    4a. For each body, draw a free-body diagram
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        Note: if const. force, constant acceleration kinematic equations also apply
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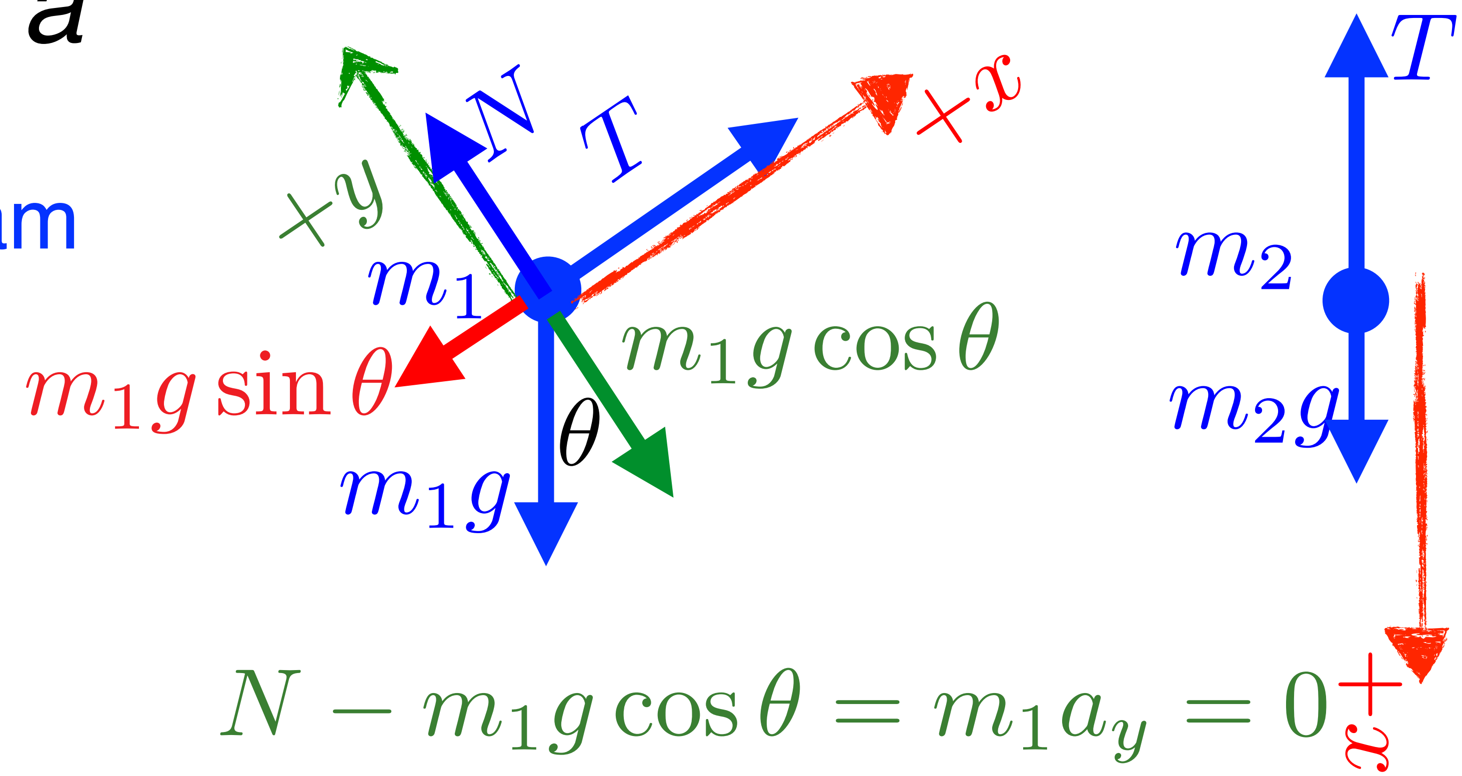

$$N - m_1 g\cos\theta = m_1 a_y = 0$$

$$N = m_1 g \cos\theta$$

$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

Ex. 4.6

Given: m_1, m_2, θ

Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
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    4a. For each body, draw a free-body diagram
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        Note: if const. force, constant acceleration kinematic equations also apply
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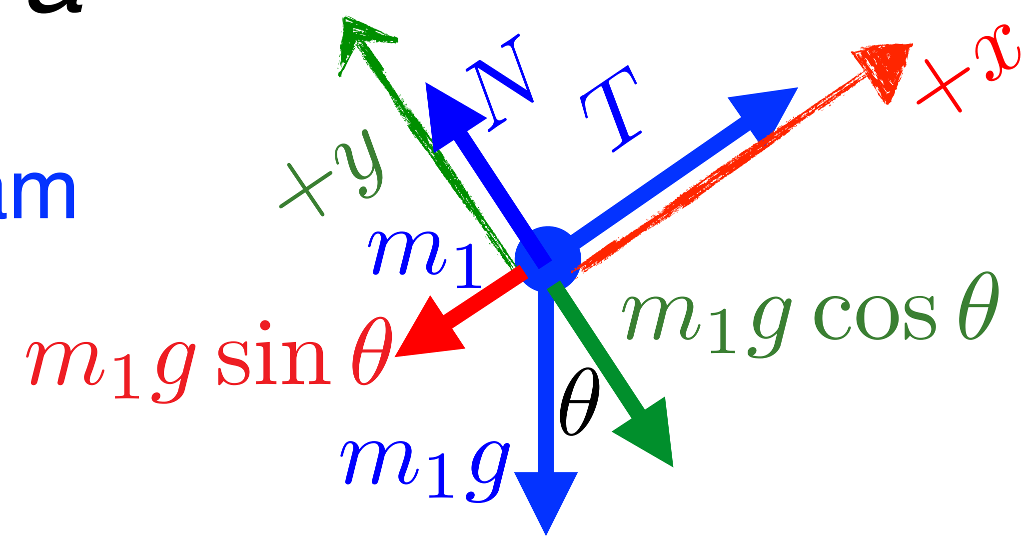
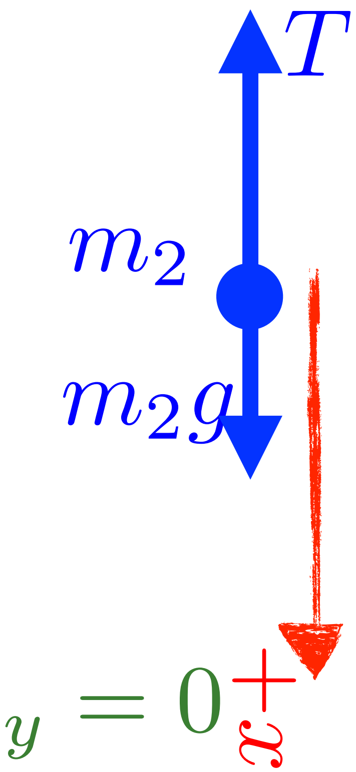




$$N - m_1 g \cos\theta = m_1 a_y = 0$$

$$N = m_1 g \cos\theta$$

$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

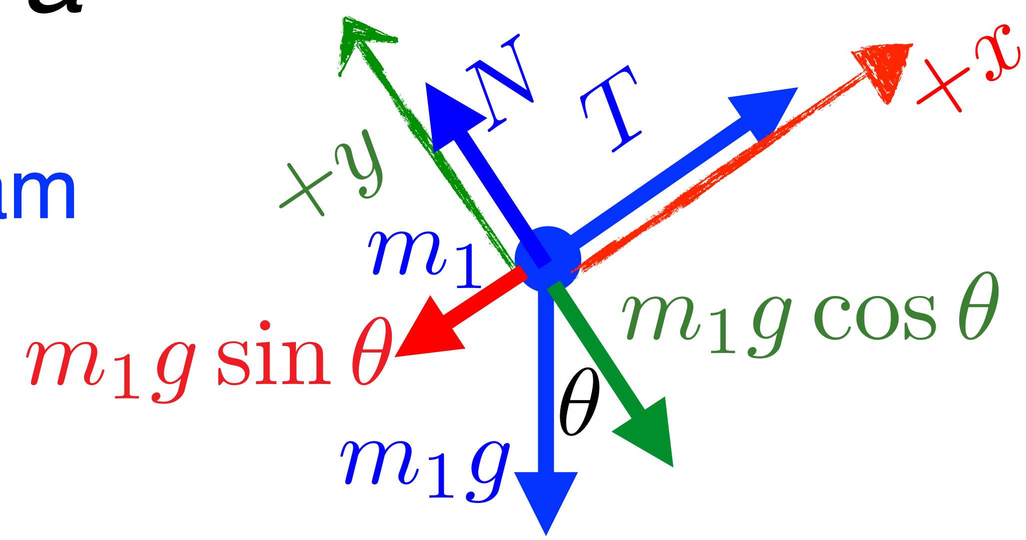
$$m_2 g - T = m_2 a_x = m_2 a$$

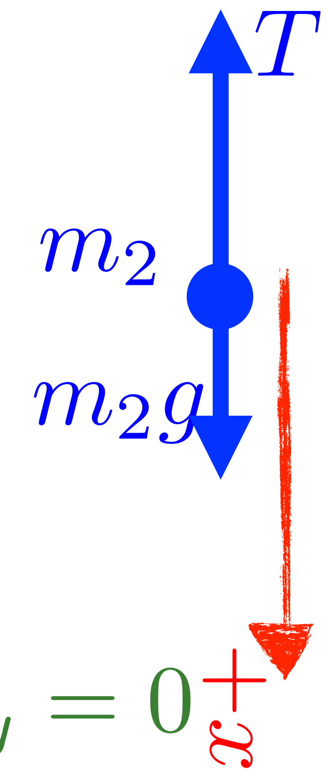
$$T = m_1(a + g\sin\theta)$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   - 4a. For each body, draw a free-body diagram
   - 4b. Apply Newton's 2nd law
     - *Note: if const. force, constant acceleration kinematic equations also apply*
5. Calculate





$$N - m_1 g \cos\theta = m_1 a_y = 0$$

$$N = m_1 g \cos\theta$$

$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

$$T = m_1(a + g\sin\theta) \quad T = m_2(g - a)$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

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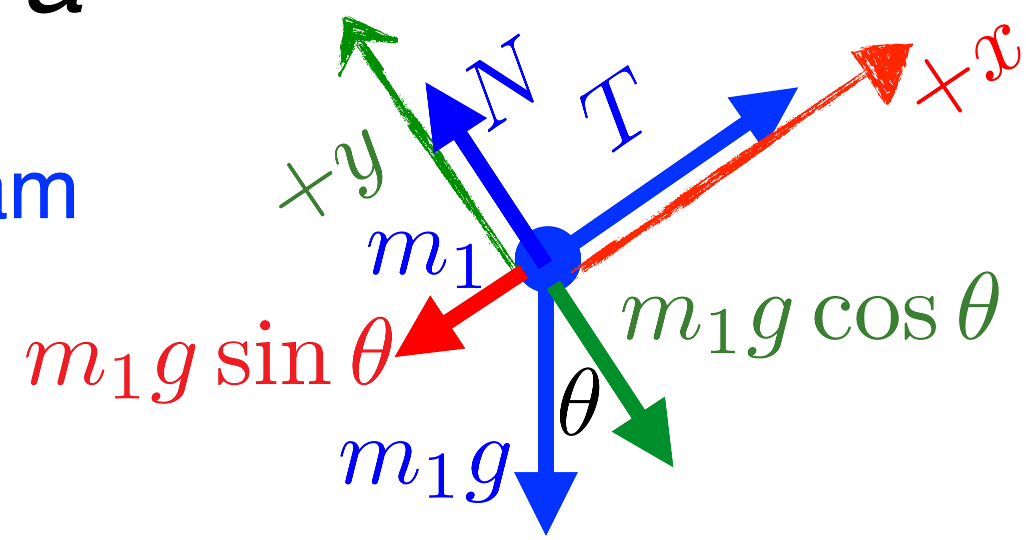
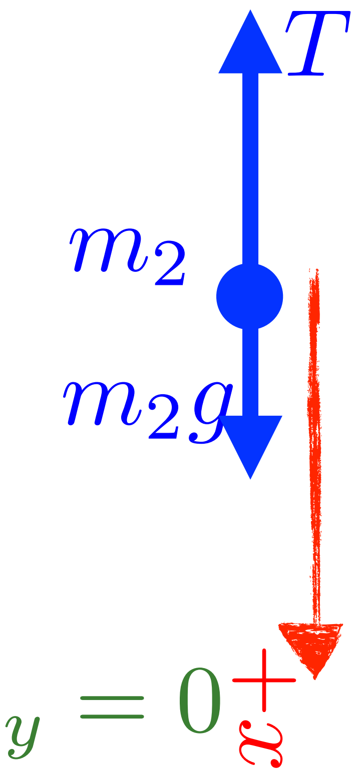
        Note: if const. force, constant acceleration kinematic equations also apply
5. Calculate





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$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

$$T = m_1(a + g\sin\theta) \quad T = m_2(g - a)$$

$$m_1 a + m_1 g \sin\theta = m_2 g - m_2 a$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
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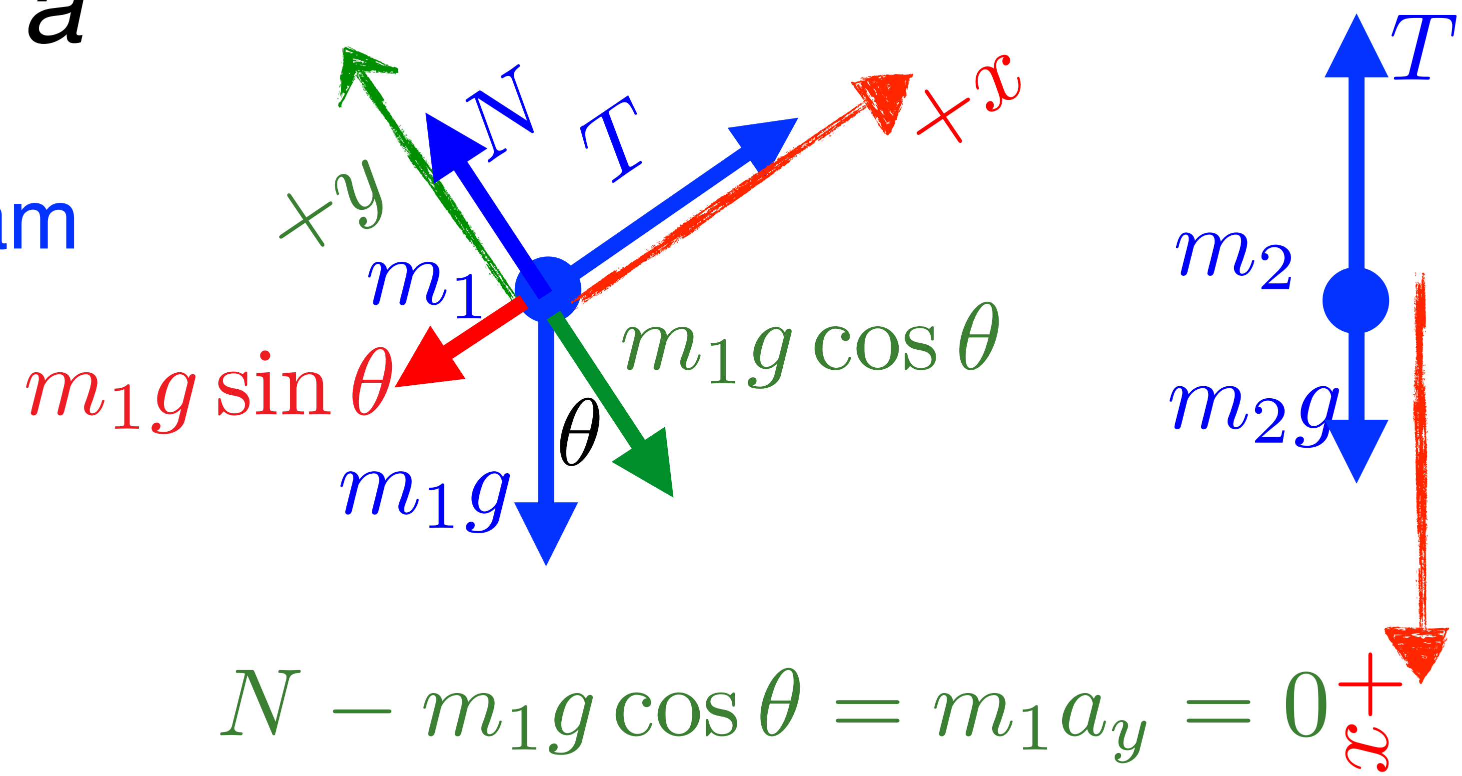

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$$m_2 g - T = m_2 a_x = m_2 a$$

$$T = m_1(a + g\sin\theta) \quad T = m_2(g - a)$$

$$m_1 a + m_1 g \sin\theta = m_2 g - m_2 a$$

$$(m_1 + m_2)a = g(m_2 - m_1 \sin\theta)$$

Ex. 4.6

Given: m_1, m_2, θ

Goal: a

1. Read carefully
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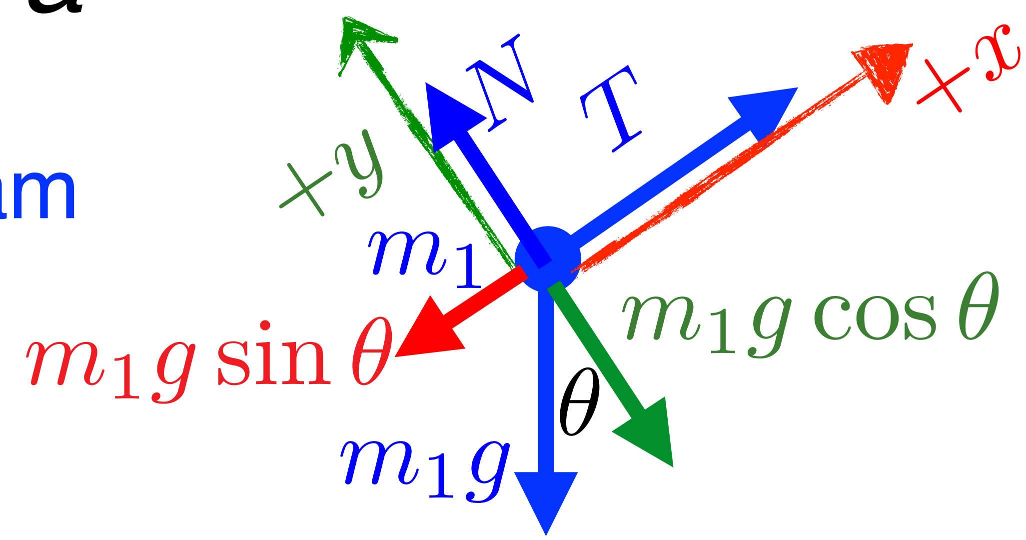
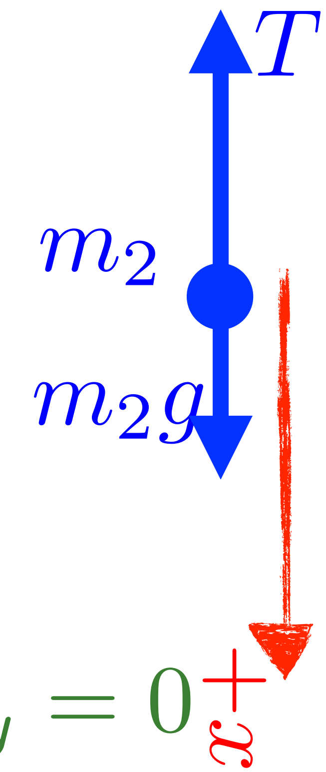




$$N - m_1 g\cos\theta = m_1 a_y = 0$$

$$N = m_1 g \cos\theta$$

$$T - m_1 g \sin\theta = m_1 a_x = m_1 a$$

$$m_2 g - T = m_2 a_x = m_2 a$$

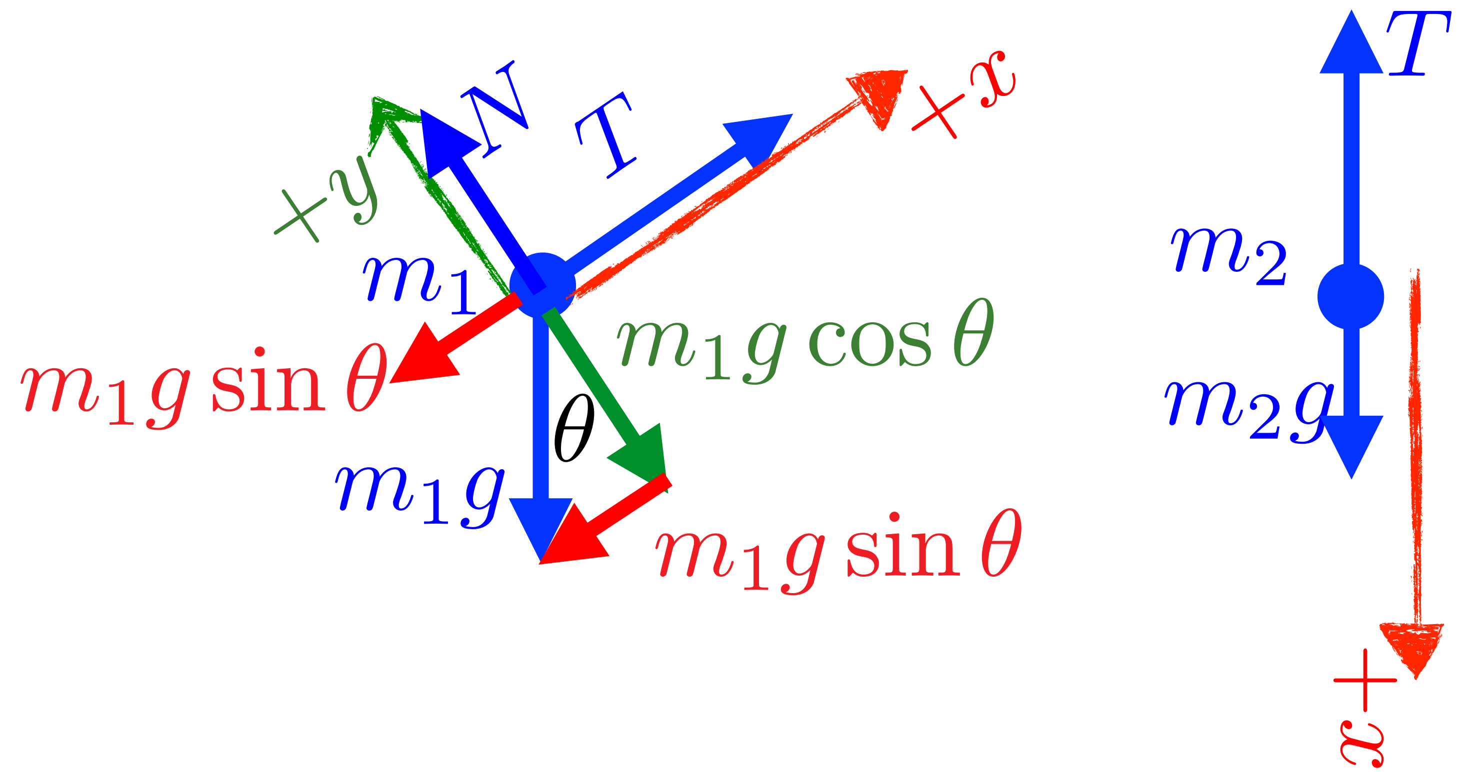
$$\boxed{a = g\frac{m_2 - m_1\sin\theta}{m_1 + m_2}}$$

$$T = m_1(a + g\sin\theta) \quad T = m_2(g - a)$$

$$m_1 a + m_1 g \sin\theta = m_2 g - m_2 a$$

$$(m_1 + m_2)a = g(m_2 - m_1\sin\theta)$$

Ex. 4.6

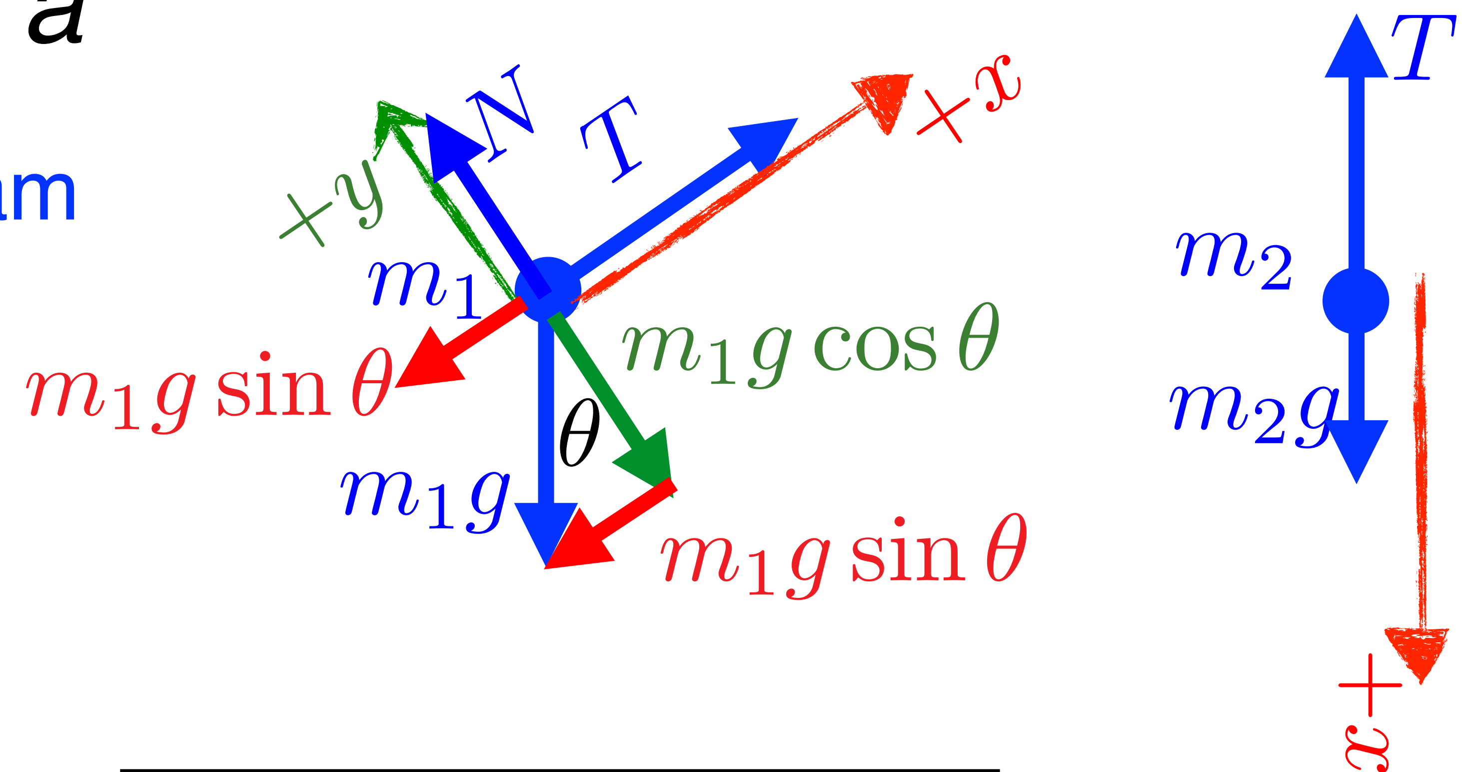


$$a = g\frac{m_2 - m_1 \sin\theta}{m_1 + m_2}$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   - 4a. For each body, draw a free-body diagram
   - 4b. Apply Newton's 2nd law
5. Calculate
6. Plug in numbers



$$\boxed{a = g\frac{m_2 - m_1 \sin\theta}{m_1 + m_2}}$$

Ex. 4.6

Given: m_1, m_2, θ

Goal: a

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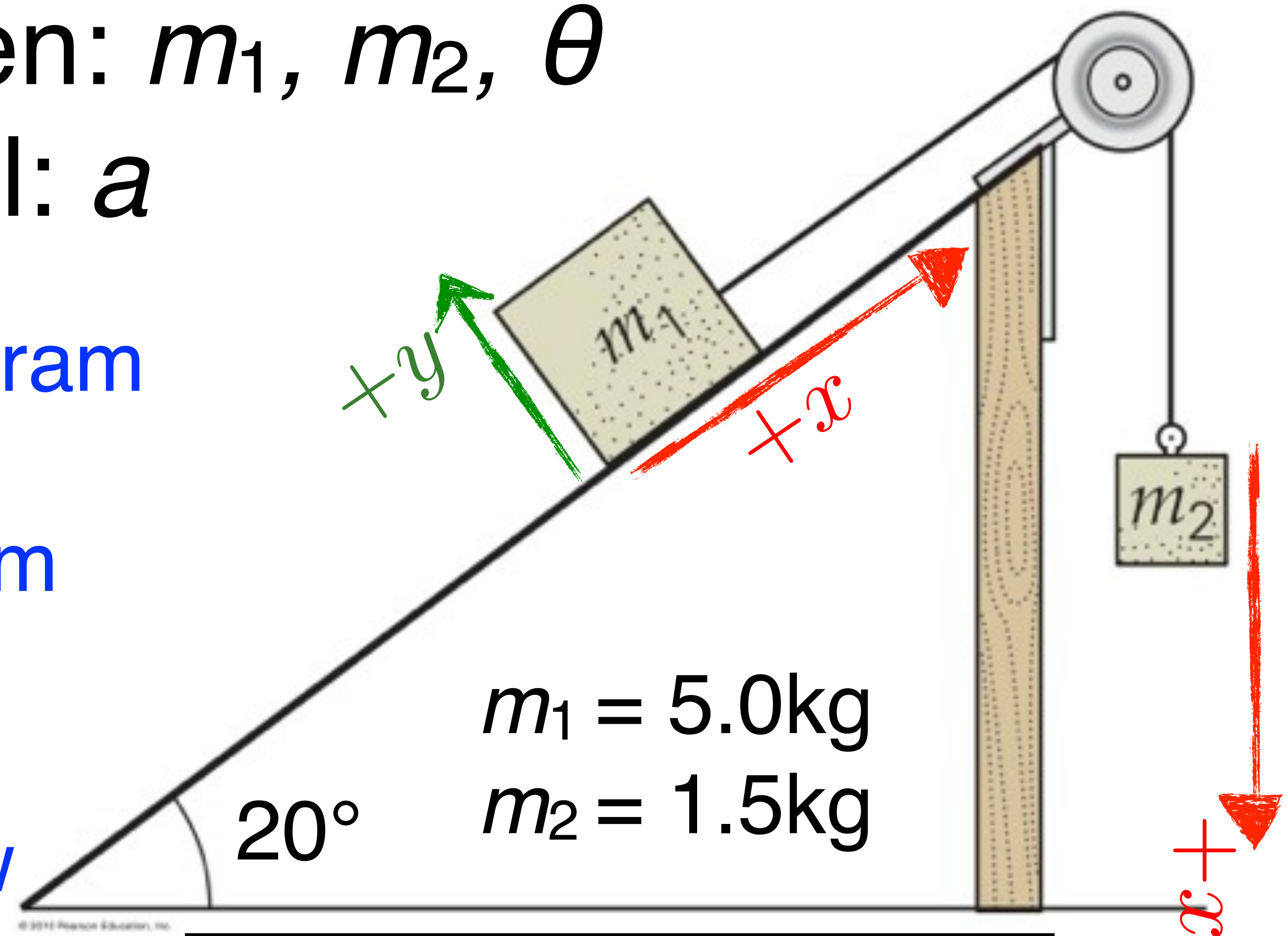

$$\boxed{a = g\frac{m_2 - m_1 \sin\theta}{m_1 + m_2}}$$

Ex. 4.6

Given: m_1, m_2, θ

Goal: a

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2. Draw a sketch = space diagram
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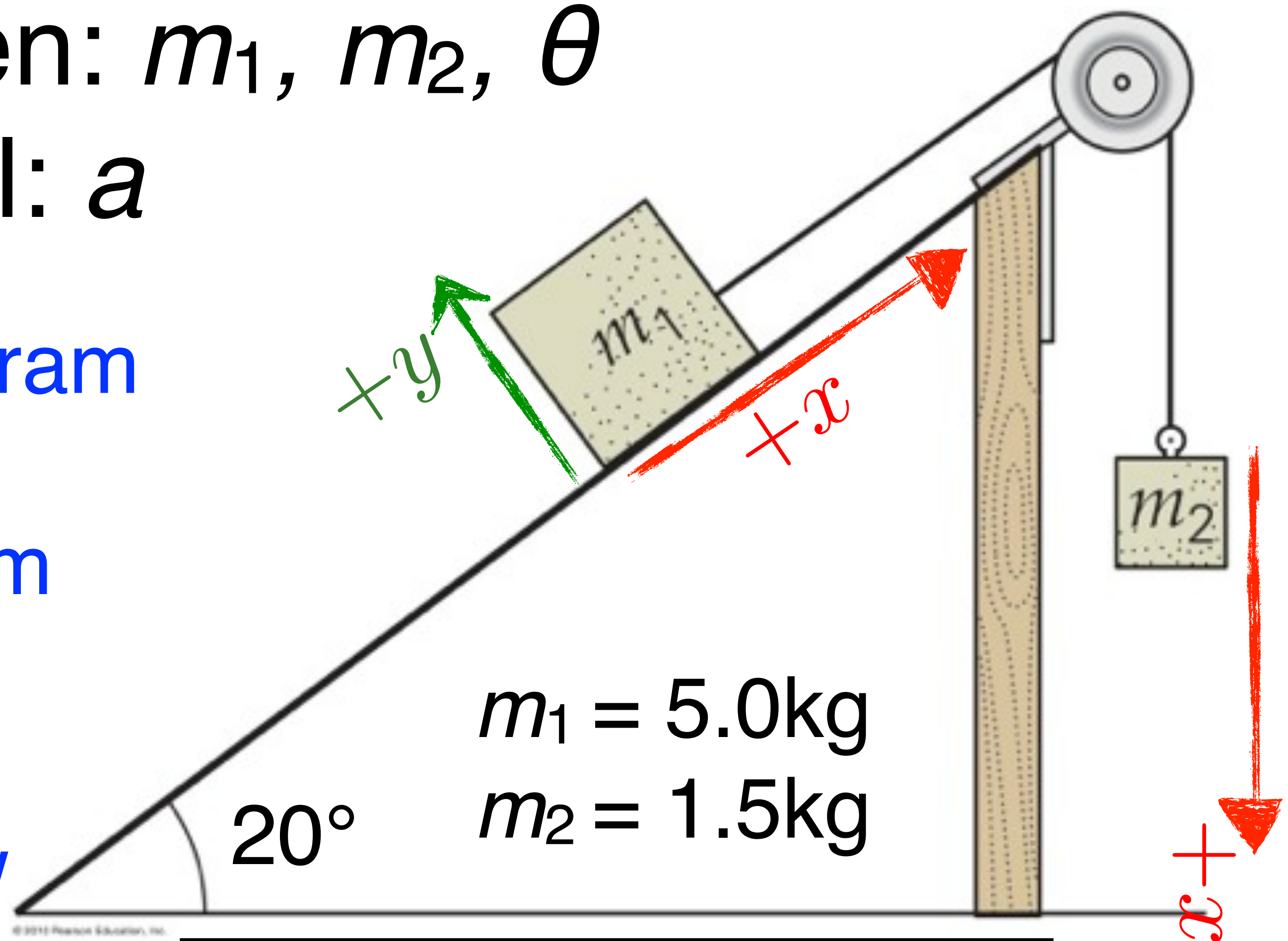

$$\boxed{a = g\frac{m_2 - m_1\sin\theta}{m_1 + m_2}}$$

$$a = (9.8\ \mathrm{m/s^2})\frac{1.5\ \mathrm{kg} - (5\ \mathrm{kg})\sin(20°)}{1.5\ \mathrm{kg} + 5\ \mathrm{kg}} = -0.32\ \mathrm{m/s^2}$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   4a. For each body, draw a free-body diagram
   4b. Apply Newton's 2nd law
5. Calculate
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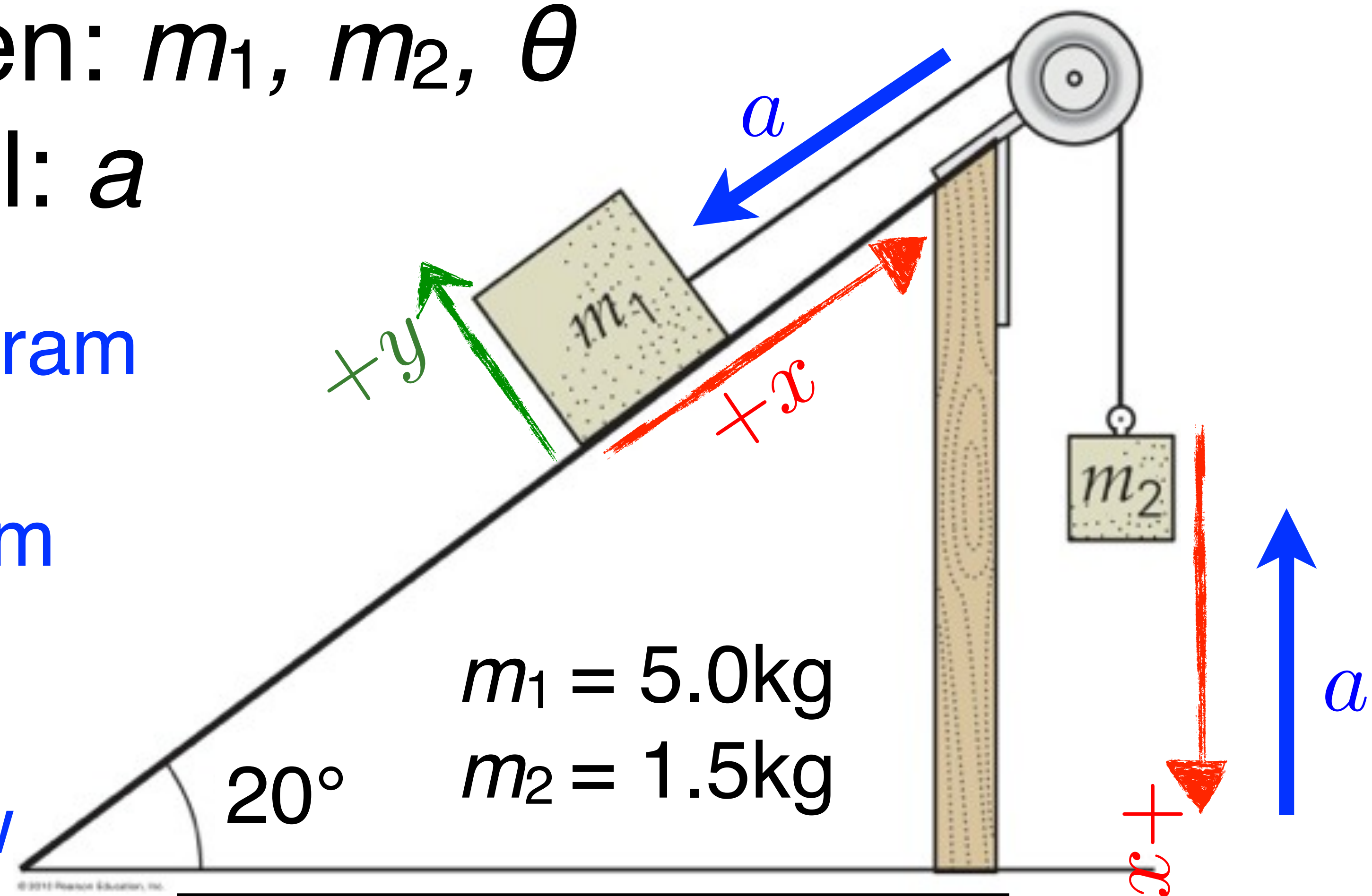


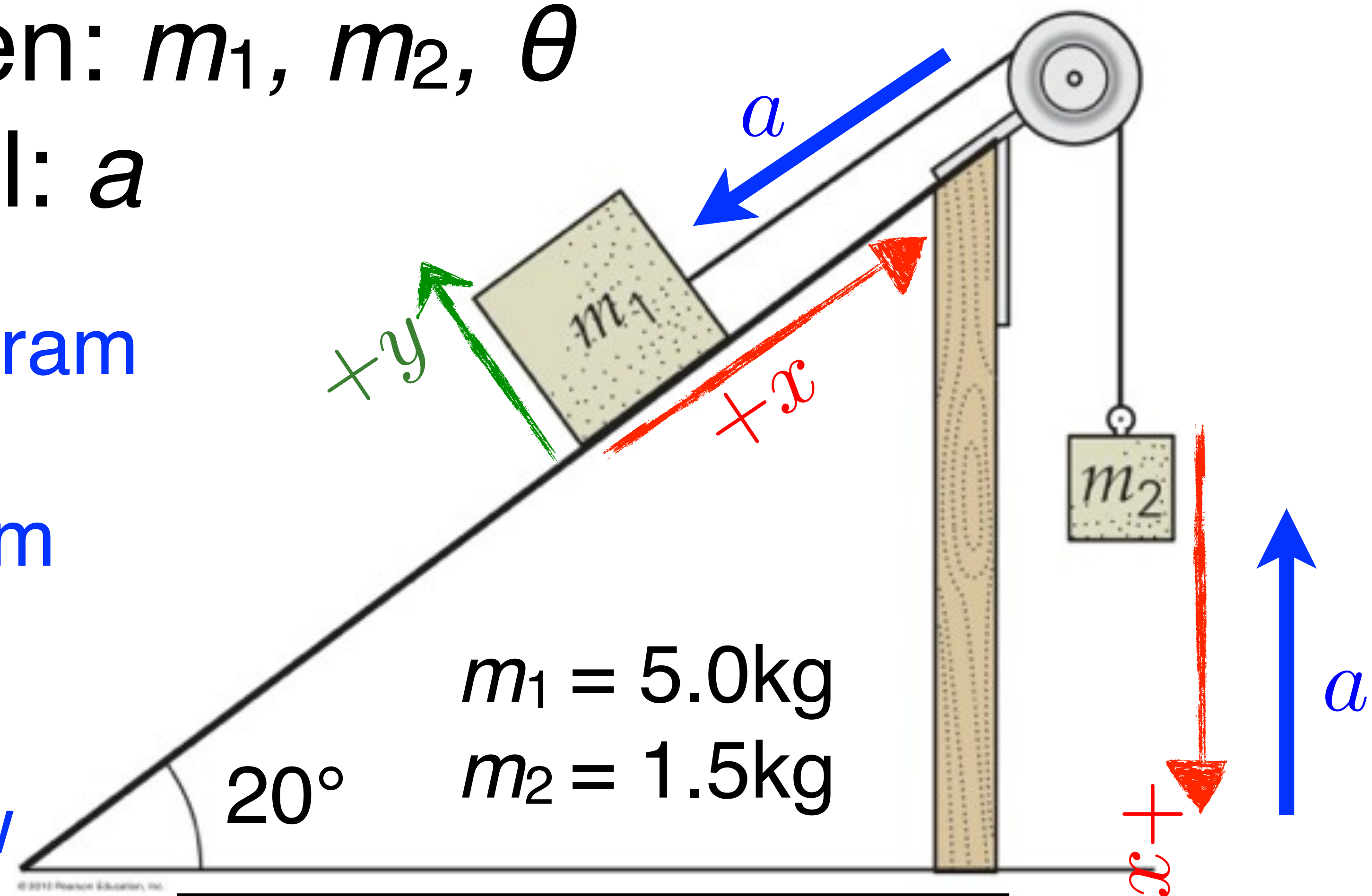
$$\boxed{a = g\frac{m_2 - m_1 \sin\theta}{m_1 + m_2}}$$

$$a = (9.8\ \mathrm{m/s^2})\frac{1.5\ \mathrm{kg} - (5\ \mathrm{kg})\sin(20^\circ)}{1.5\ \mathrm{kg} + 5\ \mathrm{kg}} = -0.32\ \mathrm{m/s^2}$$

Ex. 4.6

Given: m_1, m_2, θ
Goal: a

1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   4a. For each body, draw a free-body diagram
   4b. Apply Newton's 2nd law
5. Calculate
6. Plug in numbers
7. Is answer reasonable?



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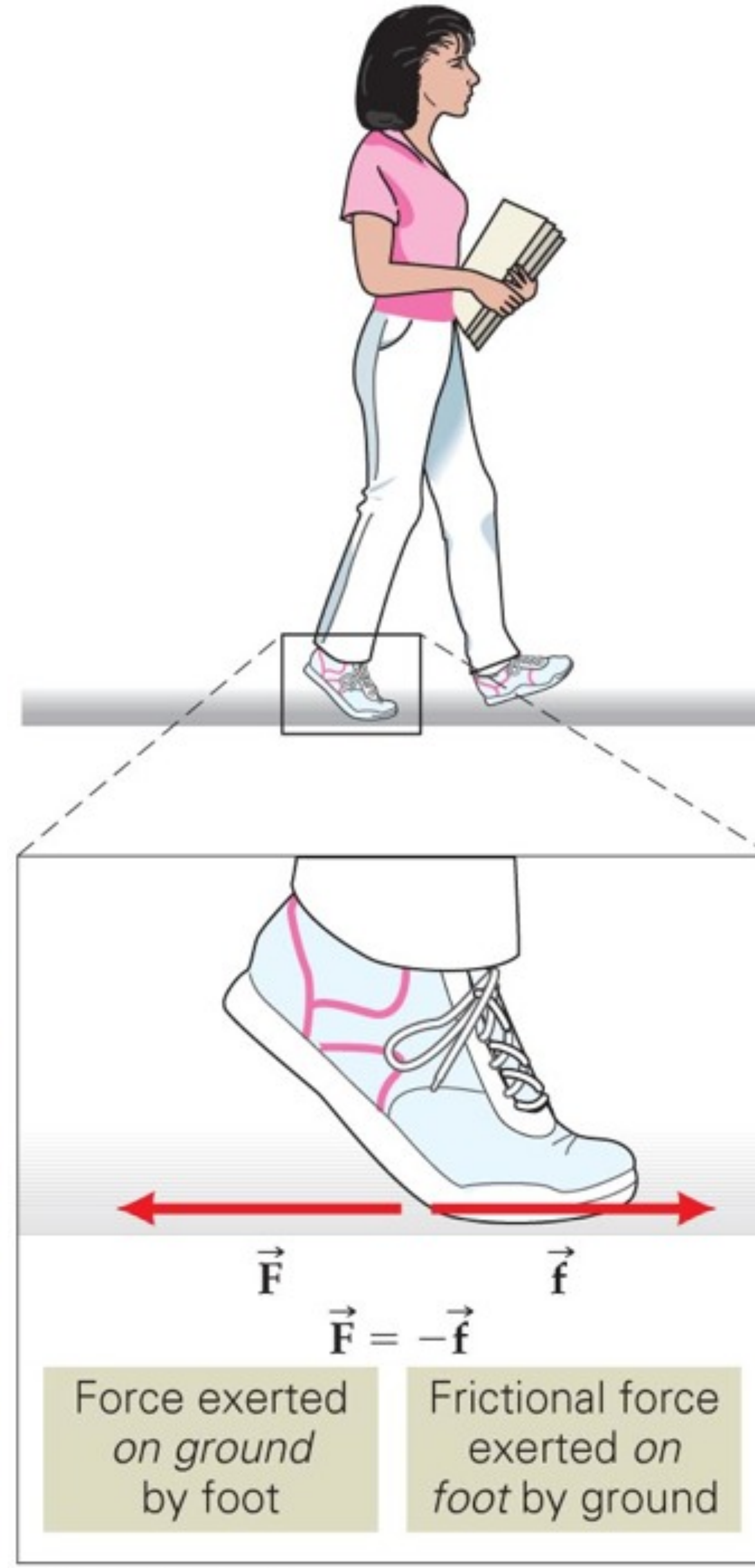
Lecture 11 outline

- Announcements
- Quantitative force examples
  - Free-body diagrams
  - Example: Atwood machine & ramp
- Friction & air resistance
  - How friction works
  - Example: friction
- Class participation

Friction

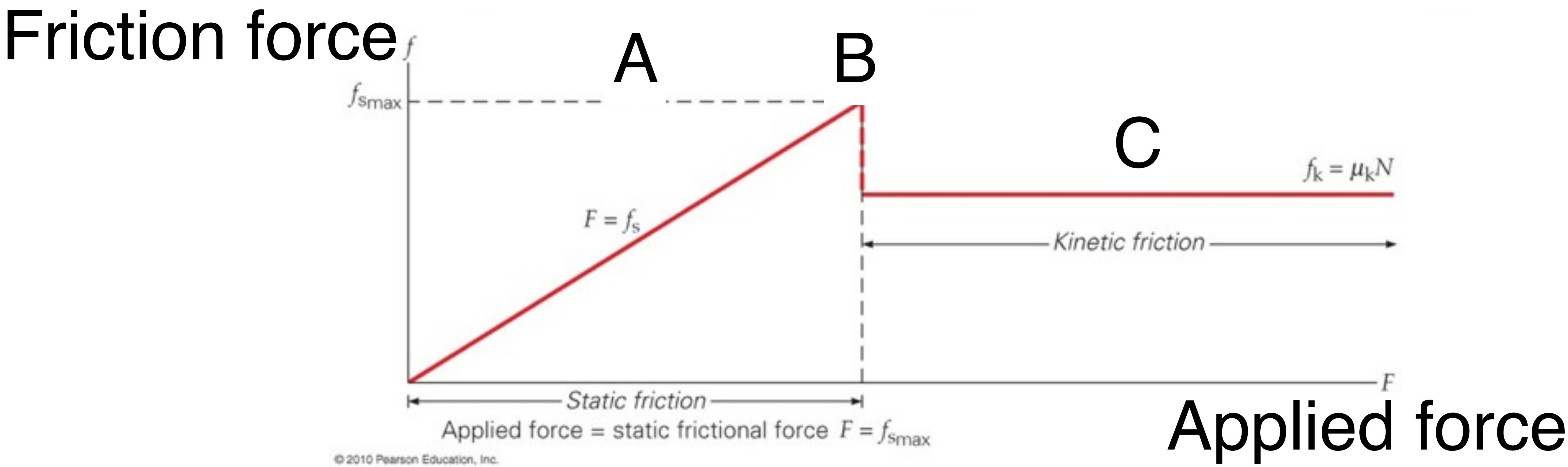
- Friction = force resisting motion when 2 materials are in contact
- Friction between solid surfaces
  - Origin: surfaces are rough (microscopically)
  - “High spots” on the surface temporarily bond



Types of friction

- Static: no relative motion of the surfaces
- Kinetic ("sliding"): surfaces slide

$f_s < \mu_s N$ $f_{s\max} = \mu_s N$ $f_k = \mu_k N$



Clicker question #42

Question 4.19 Friction

A box sits in a pickup truck on a frictionless truck bed. When the truck accelerates forward, the box slides off the back of the truck because:

- A the force from the rushing air pushed it off
- B the force of friction pushed it off
- C no net force acted on the box
- D truck went into reverse by accident
- none of the above

Clicker question #43

Question 4.22 Will It Budge?

A box of weight 100 N is at rest on a floor where $\mu_s = 0.4$. A rope is attached to the box and pulled horizontally with tension T = 30 N. Which way does the box move?

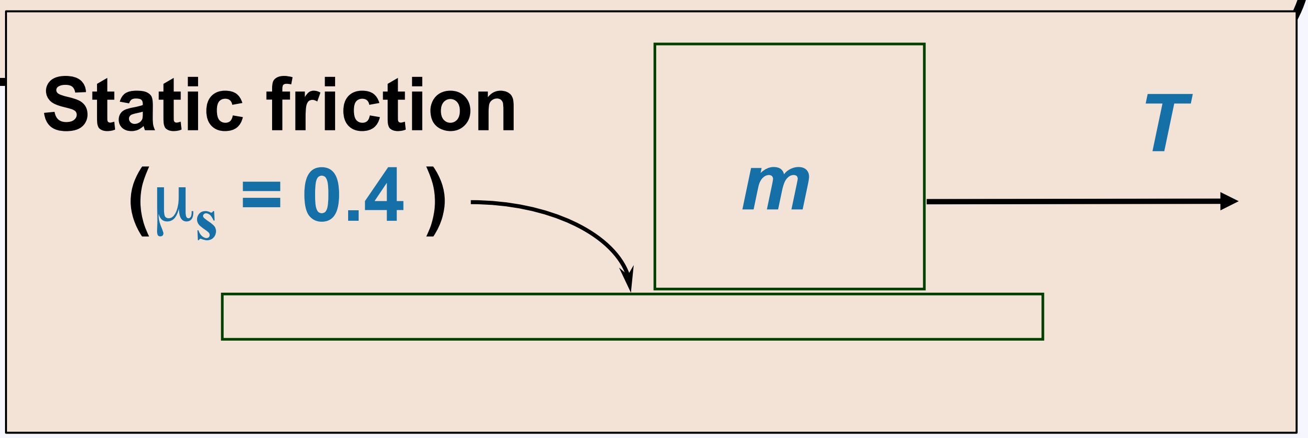
A moves to the left

B moves to the right

C moves up

D moves down

the box does not move

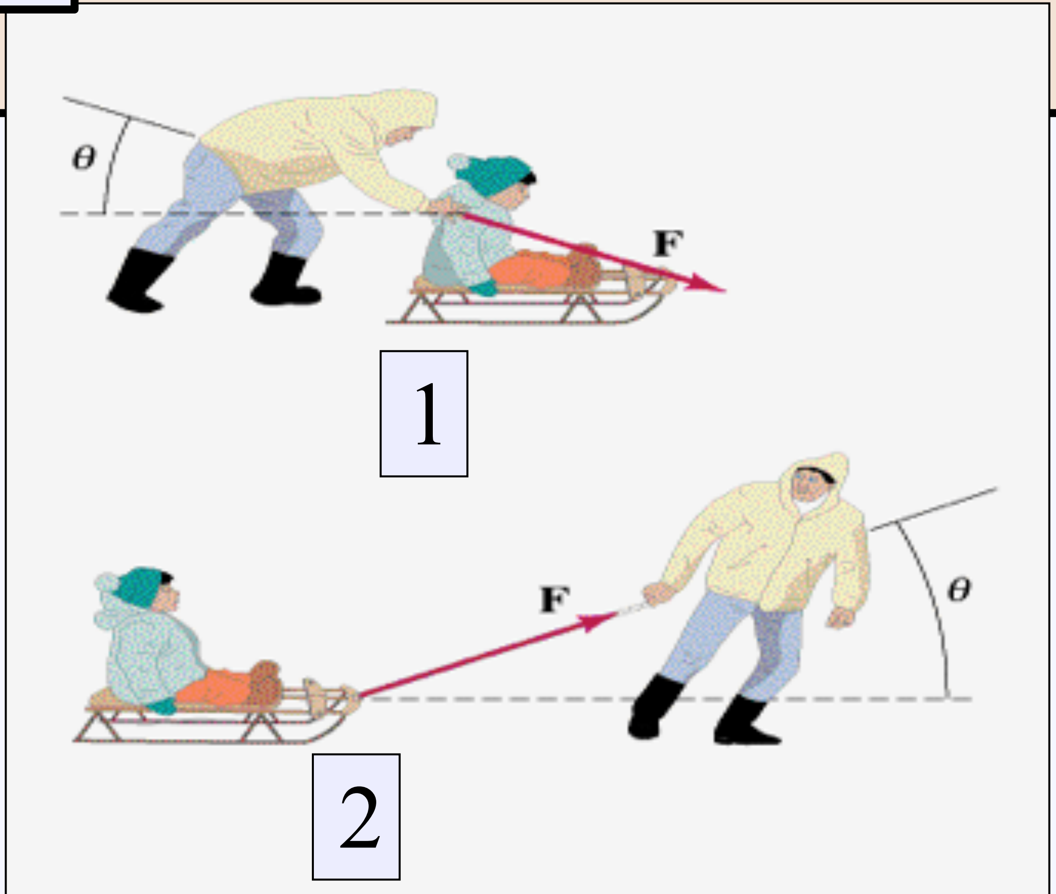


Clicker question #45

Question 4.21 Going Sledding

Your little sister wants you to give her a ride on her sled. On level ground, what is the easiest way to accomplish this?

- A pushing her from behind [1]
- B pulling her from the front [2]
- C both [1] and [2] are equivalent
- D it is impossible to move the sled
- tell her to get out and walk



Class participation #10

- 0. Name
- 1. Draw a free-body diagram for example from the textbook:
  - A car is sliding through a puddle. Superman arrives at the last moment and tries to stop the car.
  - Hint: list **all** of the forces acting on the car. Then draw the diagram.