Physics 211

Sections 1 & 70

Dr. Geoffrey Lovelace

Fall 2012

Lecture 10 (10/01/12)

Lecture 10 outline

- Announcements
- Laws of motion
  - Summary & demos: laws of motion
  - Forces: weight, normal force, string tension
  - Problem strategy
    - Constant force = constant acceleration
    - Free-body diagrams
      - Example: blocks & string (Ex. 4.3)
      - Example & demo: Atwood's machine
- Class participation

Announcements

- Exam grades posted to Titanium
- Homework #5: due Thursday at 11:59PM
  - Forces, Laws of motion
  - Will announce on piazza when available
- Reading: finish chapter 4

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Newton’s 3 laws

- Summary
  - 1. $\text{If } \vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{0}} \text{ then } \vec{\mathbf{a}} = \vec{\mathbf{0}}$
  - 2. $\text{If } \vec{\mathbf{F}}_{\text{net}} \neq \vec{\mathbf{0}} \text{ then } \vec{\mathbf{a}} = \dfrac{\vec{\mathbf{F}}_{\text{net}}}{m}$
    - Applies to system as a whole or do individual parts
  - 3. $\vec{\mathbf{F}}_{\text{BA}} = -\vec{\mathbf{F}}_{\text{AB}}$
- The challenges
  - Conceptual: often counter-intuitive predictions
  - Quantitative: applying to problems
- Demos: Newton’s 3 laws of motion

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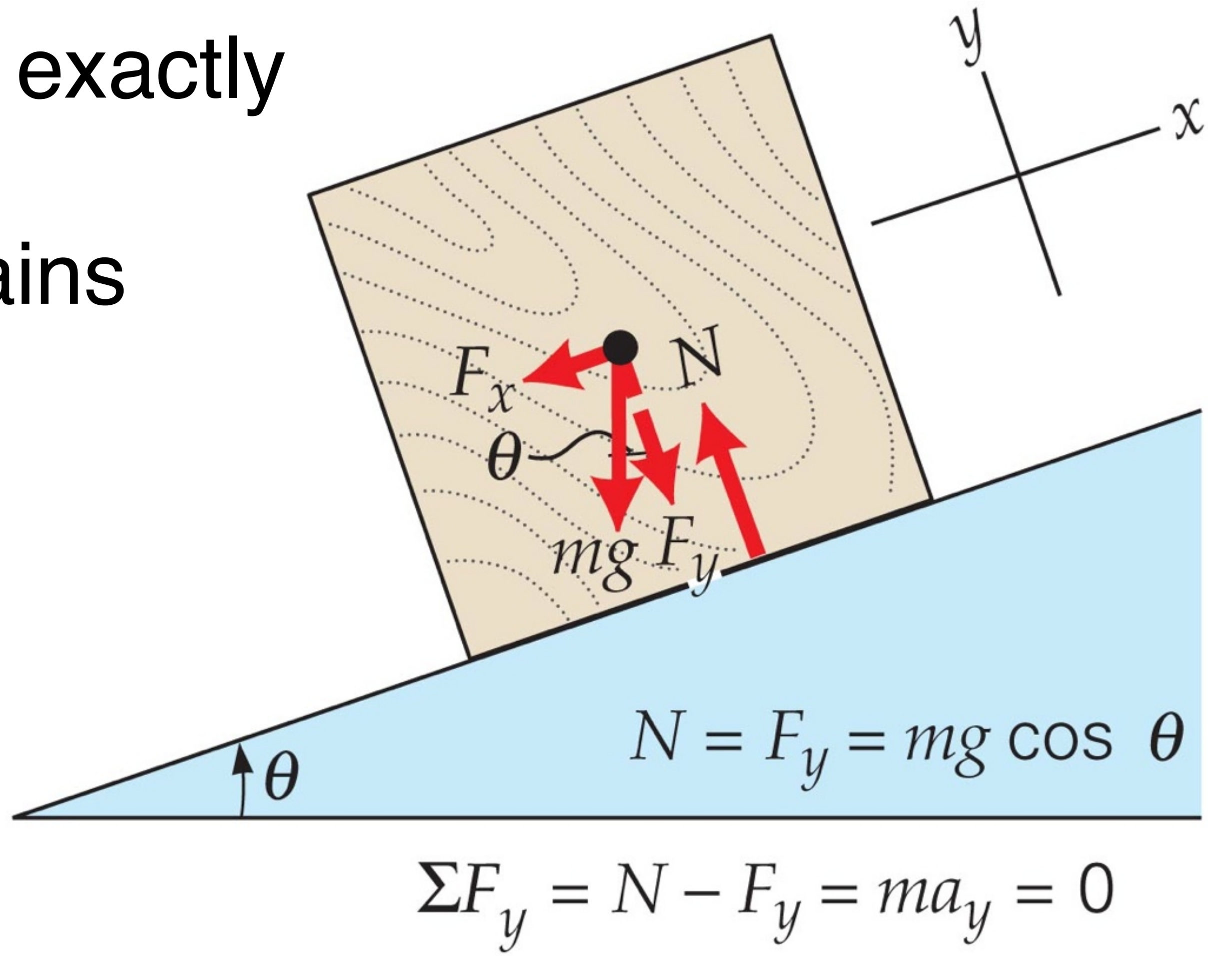
Weight & normal force

- Weight: force of magnitude *mg*, downward
- Normal force
  - Direction: perpendicular to surface
  - Magnitude: exactly enough so object remains on surface

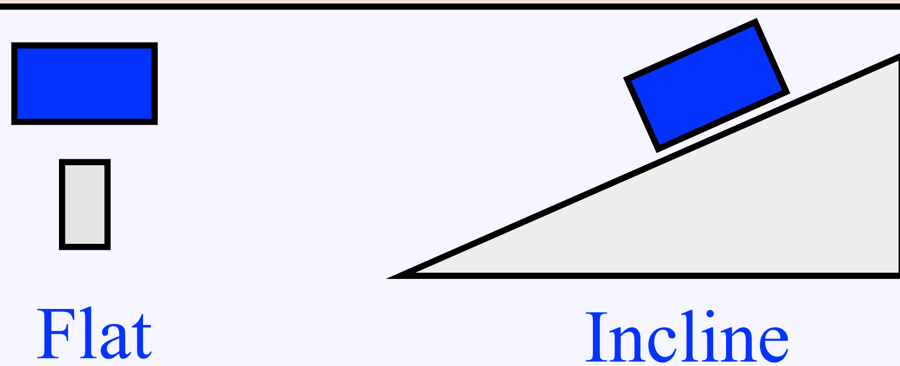


Clicker question #39

Question 4.11 On an Incline

Consider two identical blocks, one resting on a flat surface and the other resting on an incline. For which case is the normal force greater?

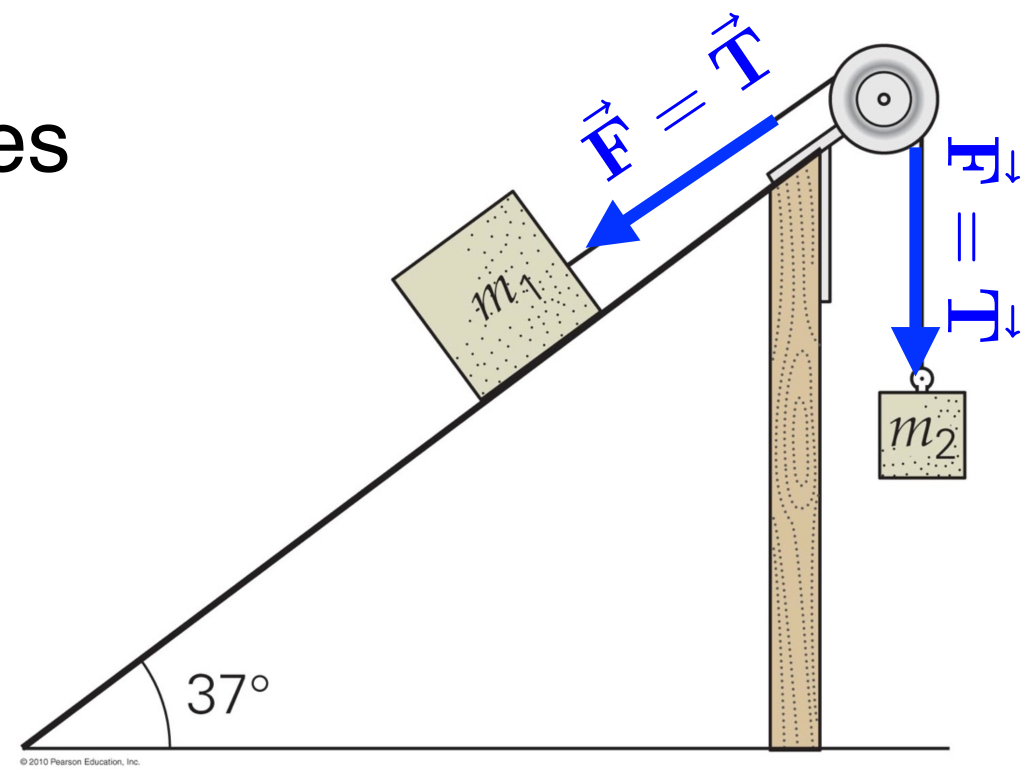
A. For the block on the flat surface
B. For the block on the incline
C. both the same ($N = mg$)
D. both the same ($0 < N < mg$)
E. both the same (N = 0)



String tension

- Taut string = string "under tension"
- The force at each end…
  - **Pulls**, same magnitude of force at each end

  - Pulley: only changes **tension direction**



Clicker question #40

Question 4.16c Tension III

You and a friend can each pull with a force of 20 N. If you want to rip a rope in half, what is the best way?

A. you and your friend each pull on opposite ends of the rope

B. tie the rope to a tree, and you both pull from the same end

C. it doesn't matter—both of the above are equivalent

D. Neither choice will rip the rope

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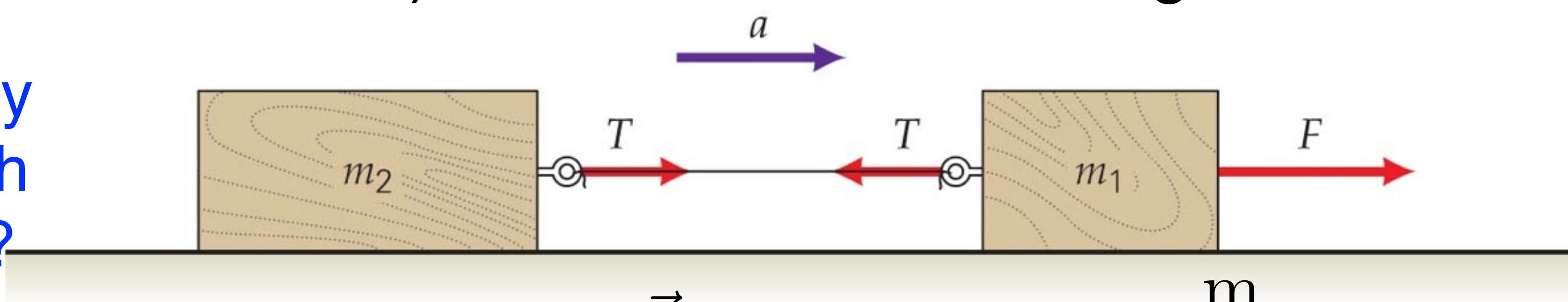
Ex. 4.3

- Ex. 4.3 in textbook
  - 2.5 kg & 3.5 kg masses tied together by taut string. A 12 N force pulls on one mass. Find a) the acceleration, and b) the tension in the string.

1. Read carefully
2. Draw a sketch
3. Given? Goal?



Given: $\vec{\mathbf{F}} = 12\ \mathrm{N} = 12\ \mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}^2}$

$$m_1 = 2.5\ \mathrm{kg}$$

$$m_2 = 3.5\ \mathrm{kg}$$

Goals: $\vec{\mathbf{a}}$ $\quad T$

Ex. 4.3

1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Principles & eqns.?

4a. Free body diagrams
   i. Axes
   ii. Force vectors
   iii. Force components

4b. Newton's 2nd law

Given: $\vec{\mathbf{F}} = 12\ \mathrm{N} = 12\ \mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}^2}$

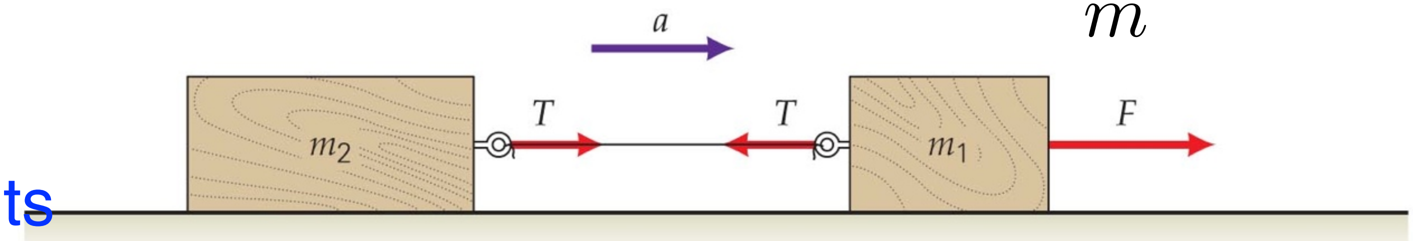
$m_1 = 2.5\ \mathrm{kg}$

$m_2 = 3.5\ \mathrm{kg}$

Goals: $\vec{\mathbf{a}}$ $\quad T$

Principle: Second law

Equation: $\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}_{\mathrm{net}}}{m}$



Entire system:

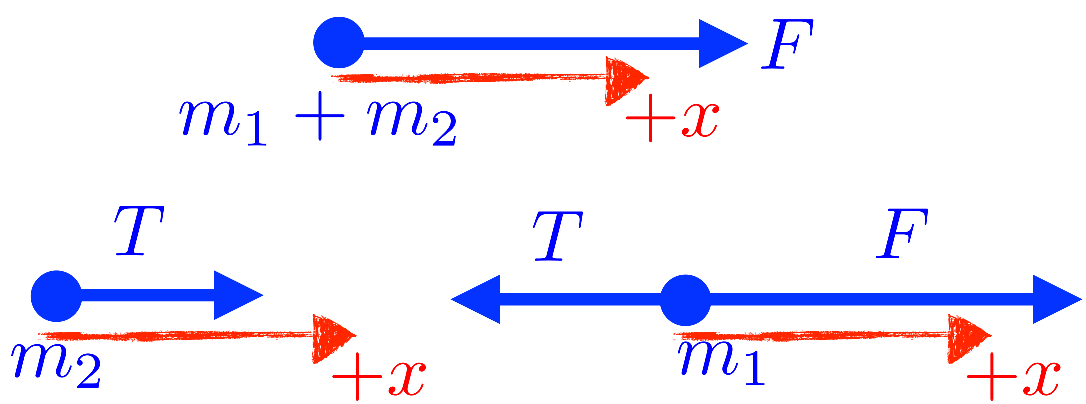
$$a = F/(m_1 + m_2)$$

Individual blocks:

$$F - T = m_1 a$$

$$T = m_2 a$$

Free-body diagrams:



Ex. 4.3

1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Principles & eqns.?
5. Calculate
6. Plug in numbers
7. Is answer reasonable?

Given: $\vec{\mathbf{F}} = 12\ \mathrm{N} = 12\ \mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}^2}$

$m_1 = 2.5\ \mathrm{kg}$

$m_2 = 3.5\ \mathrm{kg}$

Goals: $\vec{\mathbf{a}}$ $\quad T$

Principle: Second law

Equation: $\vec{\mathbf{a}} = \dfrac{\vec{\mathbf{F}}_{\mathrm{net}}}{m}$

Entire system:

$$\vec{\mathbf{a}} = \vec{\mathbf{F}}/(m_1 + m_2)$$

$$a = F/(m_1 + m_2)$$

Individual blocks:

$$F - T = m_1 a$$

$$T = m_2 a$$

$$a = \frac{12\ \mathrm{N}}{6\ \mathrm{kg}} = 2.0\ \mathrm{m/s^2}$$

$$T = (3.5\ \mathrm{kg})(2.0\ \mathrm{m/s^2}) = 7.0\ \mathrm{N}$$

$$F - T = 12\ \mathrm{N} - 7\ \mathrm{N} = 5\ \mathrm{N}$$

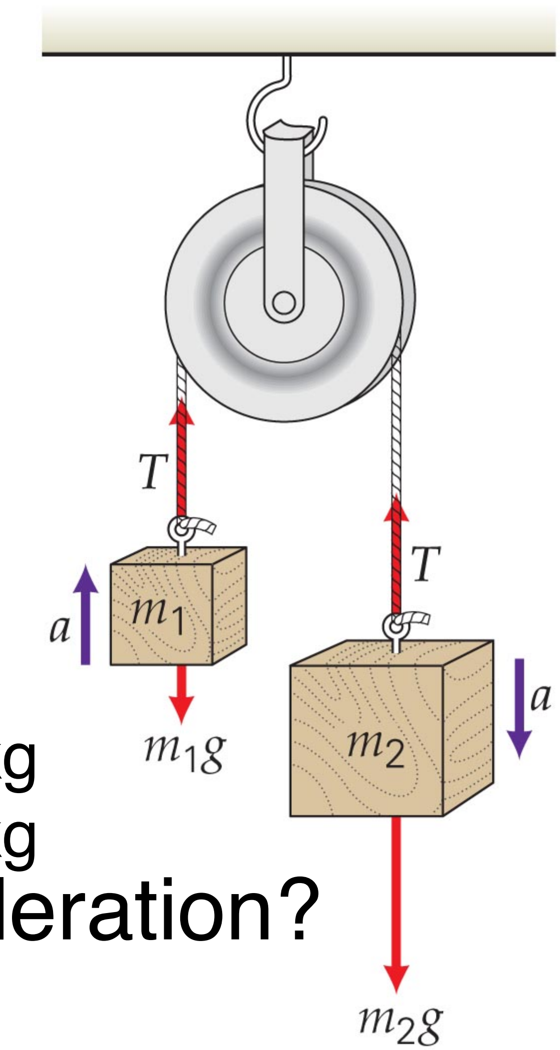
$$= (2.5\ \mathrm{kg})(2.0\ \mathrm{m/s^2}) = m_1 a$$

Atwood's machine

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

Given: m_1, m_2

Goal: a

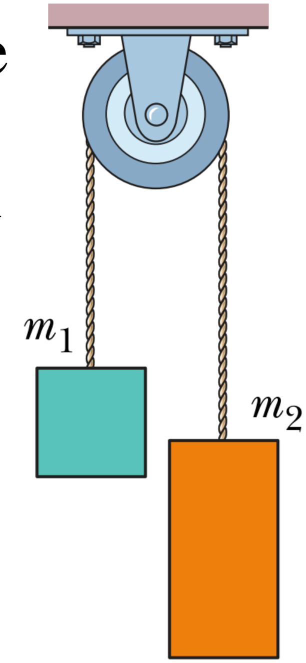


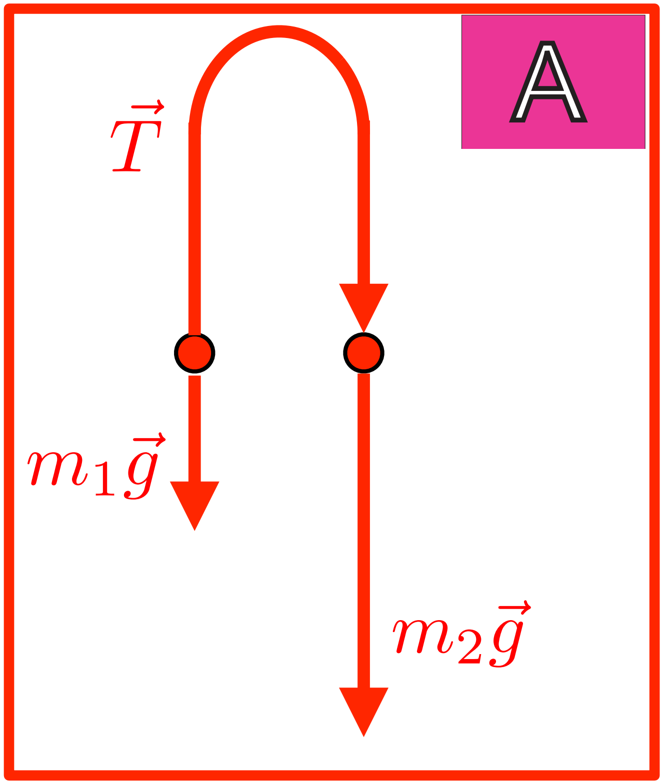
$m_1 = 1.0$ kg

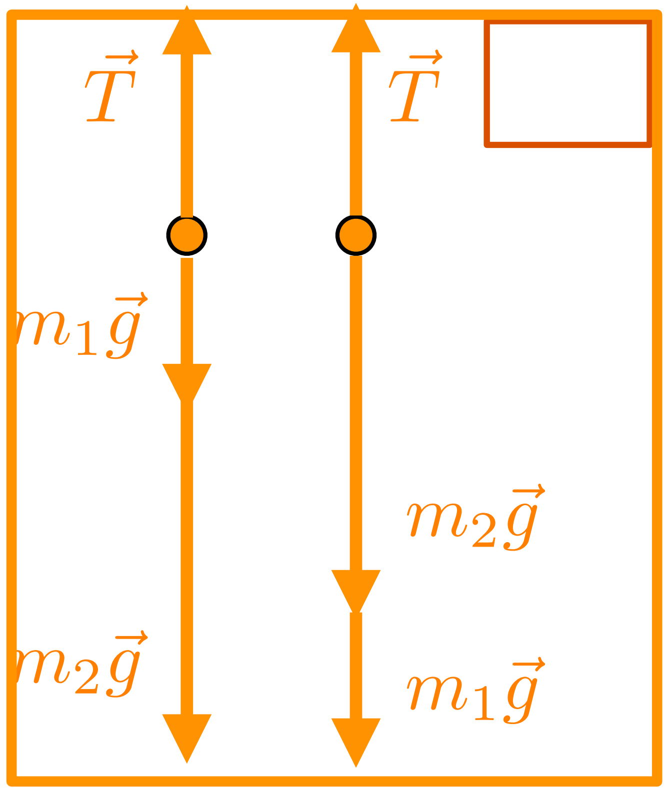
$m_2 = 2.0$ kg

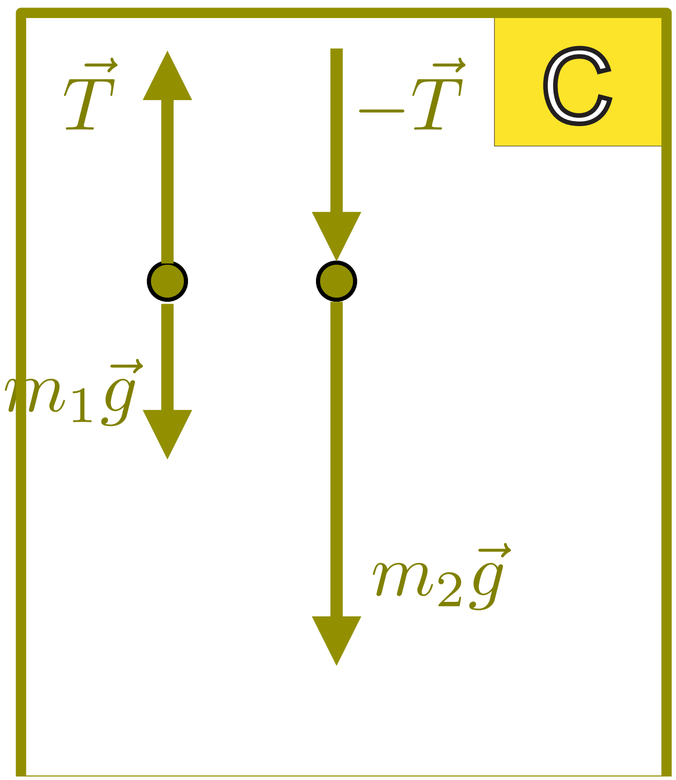
Acceleration?

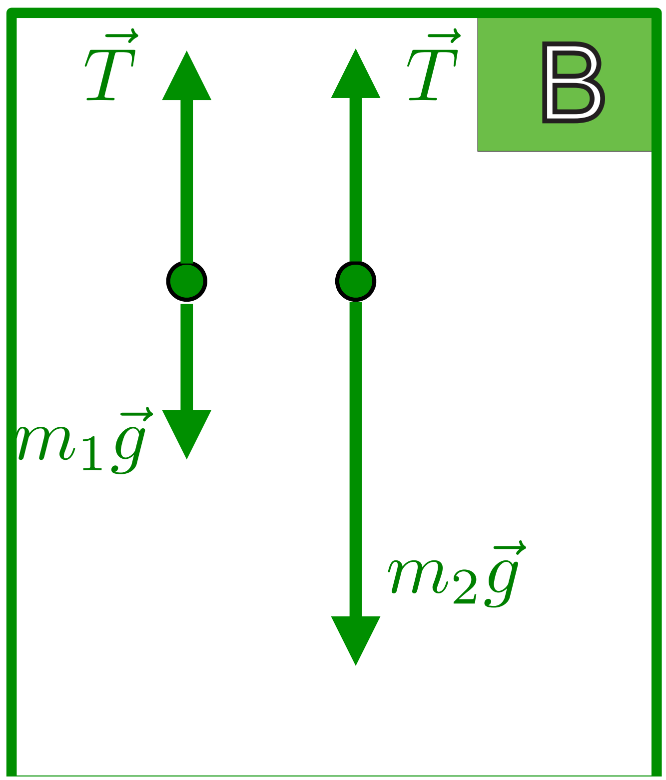
Which is the correct pair of free-body diagrams for Atwood's machine?

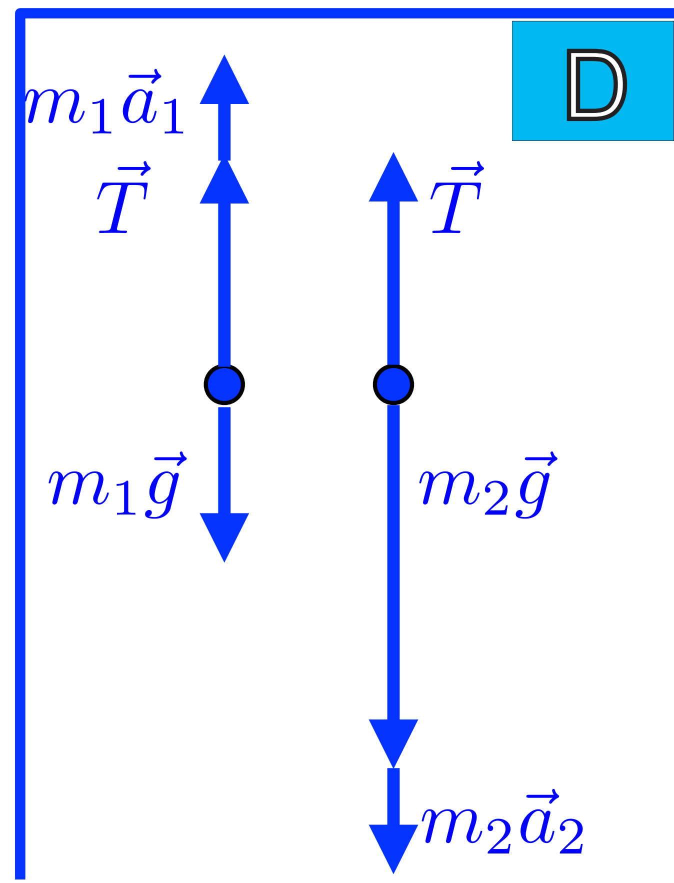










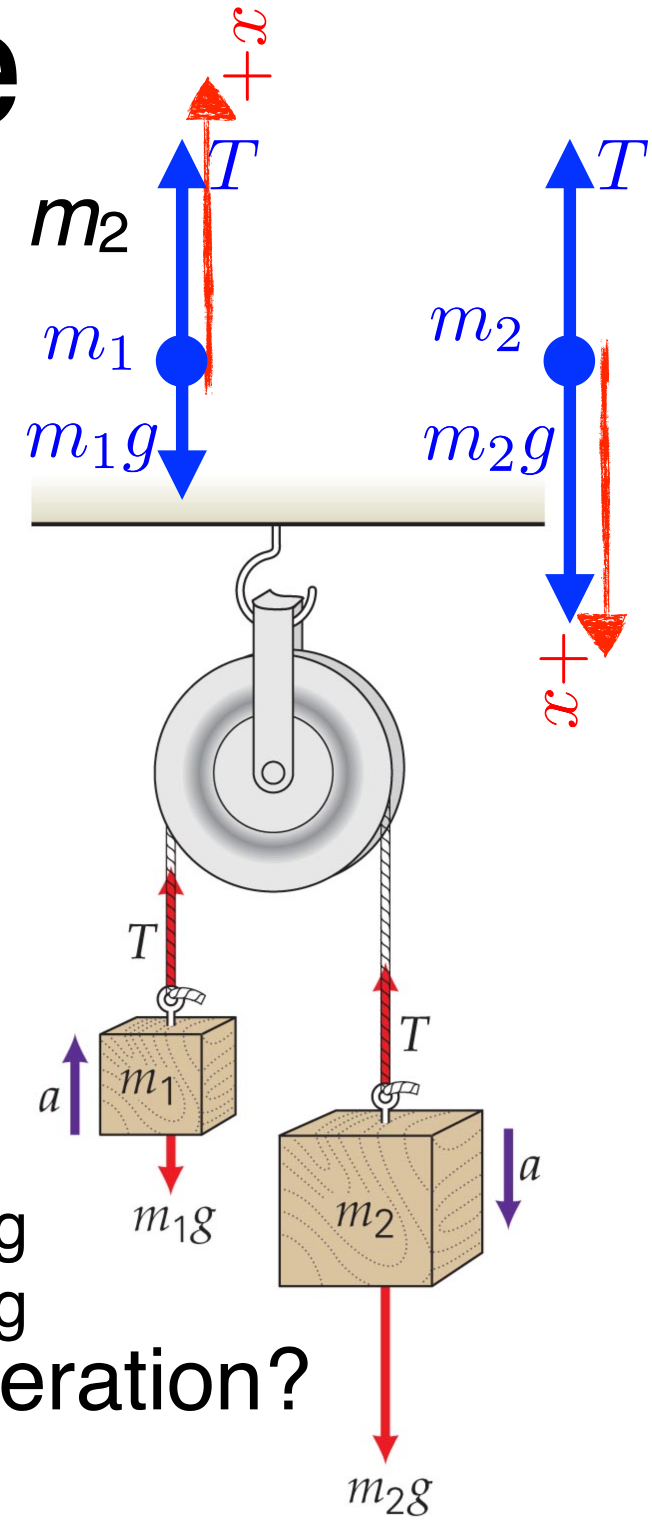


Atwood's machine

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
        - i: draw axes: along accel., origin where forces applied
        - ii: draw force vectors from origin
        - iii: resolve forces into components
    - 4b. Apply Newton's 2nd law

Given: m_1, m_2

Goal: a



$m_1 = 1.0$ kg

$m_2 = 2.0$ kg

Acceleration?

A

$$a_1 = \frac{m_2 - m_1}{m_2 + m_1}$$

$$a_2 = \frac{m_1 - m_2}{m_2 + m_1}$$

$$T = \frac{2m_1 m_2}{m_2 + m_1}$$

B

$$a_1 = \frac{-m_1 - m_2}{m_1 - m_2} g$$

$$a_2 = \frac{m_1 + m_2}{m_1 - m_2} g$$

$$T = -\frac{2m_1 m_2}{m_1 + m_2} g$$

C

$$a_1 = -g$$

$$a_2 = g$$

$$T = 0$$

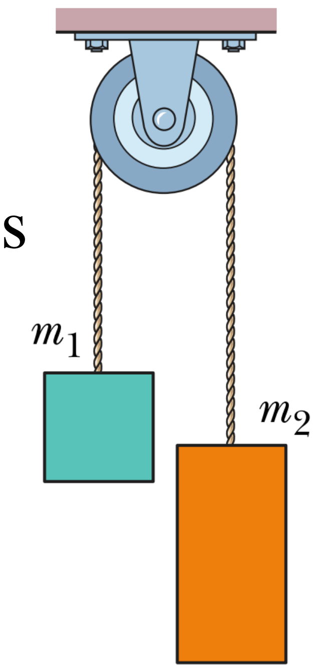
D

$$a_1 = \frac{m_2 - m_1}{m_2 + m_1} g$$

$$a_2 = -\frac{m_2 - m_1}{m_2 + m_1} g$$

$$T = \frac{2m_1 m_2}{m_2 + m_1} g$$

Which has the correct accelerations and string tension for Atwood's machine ***before*** plugging in numbers?



Atwood

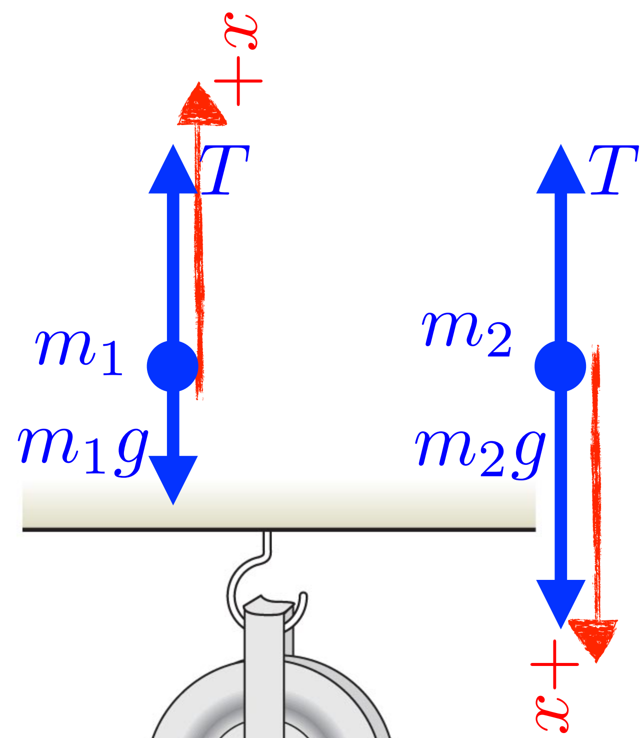
Given: m_1, m_2, θ
Goal: a

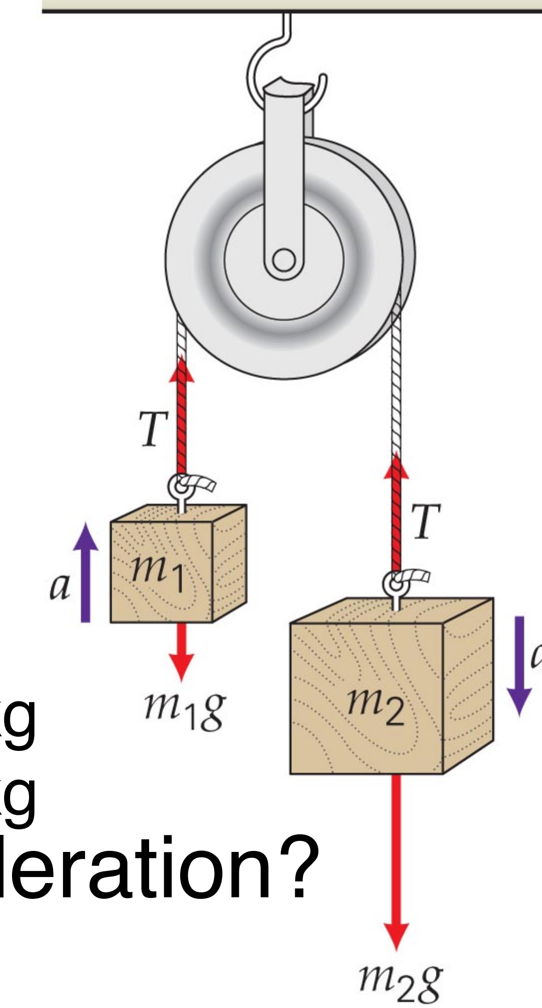
1. Read carefully
2. Draw a sketch = space diagram
3. Given? Goal?
4. Brainstorm: 2nd law problem
   4a. For each body, draw a free-body diagram
   4b. Apply Newton's 2nd law
5. Calculate

$$T - m_1 g = m_1 a$$
$$m_2 g - T = m_2 a$$

$$T = m_1(a+g) = m_2(g-a)$$
$$m_1 a + m_2 a = m_2 g - m_1 g$$

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





m_1 = 1.0 kg
m_2 = 2.0 kg
Acceleration?

Atwood

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

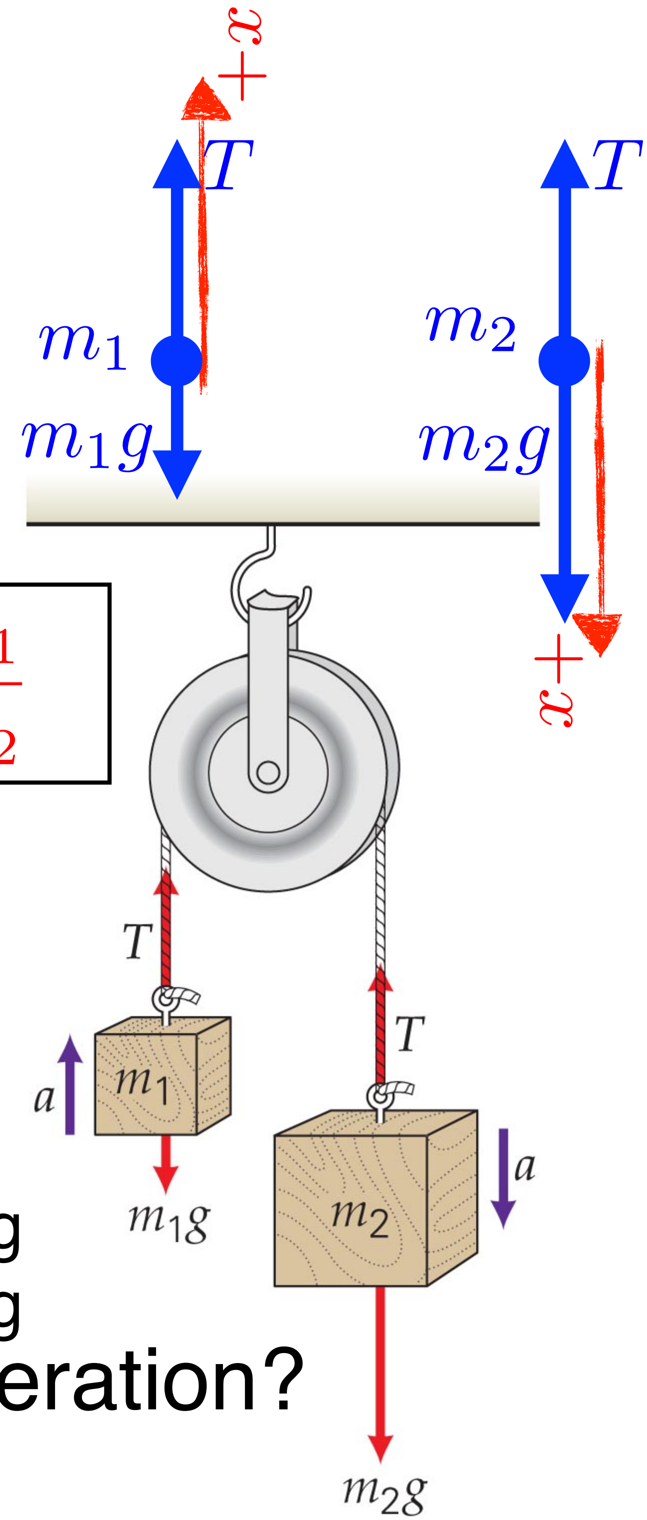
$$a = g\frac{m_2 - m_1}{m_1 + m_2}$$

$$a = (9.8\ \mathrm{m/s^2})\frac{1.0}{3.0} = 3.27\ \mathrm{m/s^2}$$

7. Is the answer reasonable?
    Units?
    What happens when…
        $m_1 = m_2$?
        $m_1 = 0$?
        $m_2 = 0$?

$m_1 = 1.0$ kg
$m_2 = 2.0$ kg

Acceleration?



Demo: Atwood's machine

- Demo: Atwood's machine
- Example: Cairngorm Mountain Funicular Train
  http://www.youtube.com/watch?v=H8x-v6FIIbU

Class participation #9

- 0. Name
- 1. What is your vote and why?

Question 4.12 **Climbing the Rope**

When you climb up a rope, the first thing you do is pull down on the rope. How do you manage to go up the rope by doing that?

A. this slows your initial velocity, which is already upward

B. you don't go up, you're too heavy

C. you're not really pulling down—it just seems that way

D. the rope actually pulls you up

E. you are pulling the ceiling down