Mechanics
More Types of Forces

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Last time

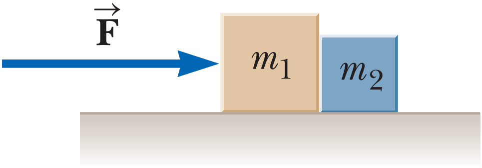
- more about Newton's 3rd law
- gravity and weight
- the normal force
  - on motionless surfaces
  - in elevators
  - on inclined surfaces

Overview

- Types of forces and new scenarios
  - contact forces
  - tension
  - pulleys

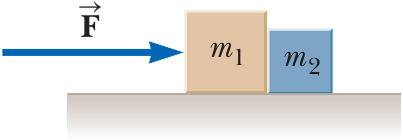
Separate Objects Pushed Together

Consider a force **F** that acts on two objects, masses m_1 and m_2, free to slide on a frictionless surface:

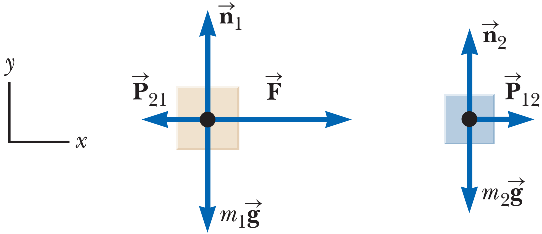


Separate Objects Pushed Together

Main Idea: if objects are pushed or pulled together, then they must *all accelerate at the same rate*.



That means that the net force on each must be different:



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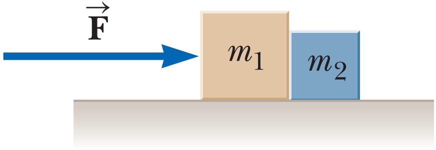
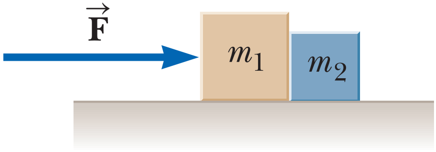


What is the acceleration of object m_2? (Hint: consider the two blocks as one.)

Separate Objects Pushed Together



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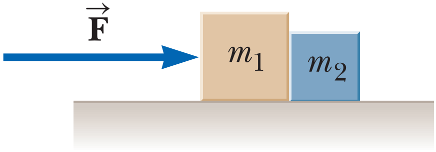
$$\mathbf{a} = \frac{\mathbf{F}}{m_1 + m_2}$$

Separate Objects Pushed Together



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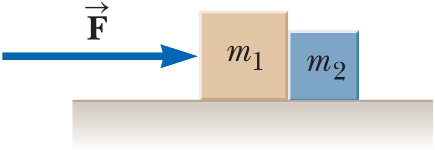

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$$\mathbf{a} = \frac{\mathbf{F}}{m_1 + m_2}$$

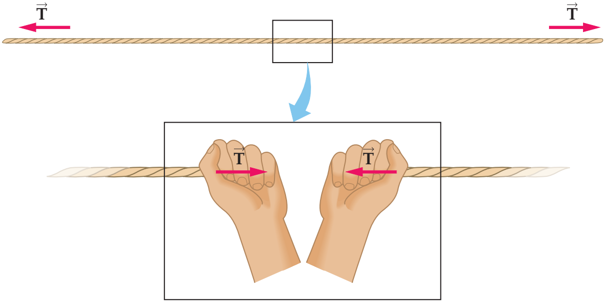
What is the net force on object m_2?

$$\mathbf{F}_{\text{net}} = \frac{m_2 \mathbf{F}}{m_1 + m_2}$$

Some types of forces

Tension

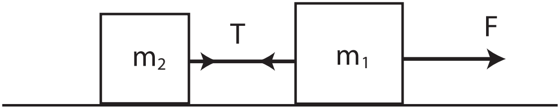
The force exerted by a rope or chain to suspend or pull an object with mass.



Problems involving tensions often require solving systems of vector equations.

[1] Figure from www.sparknotes.com

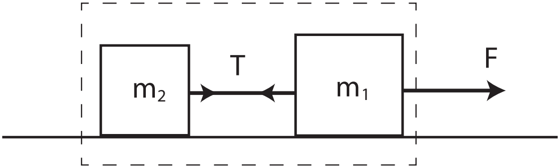
Separate Objects Pulled Along



Again, we can consider the two blocks as one system.

The accelerations of the two blocks are the same.

Separate Objects Pulled Along



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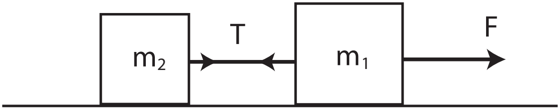
Separate Objects Pulled Along

Question. What is the acceleration of object m_2? (Hint: consider the two blocks as one.)



(A) $\frac{\mathbf{F}}{m_2}$

(B) $\frac{m_1\mathbf{F}}{m_2}$

(C) $\frac{\mathbf{F}}{m_1+m_2}$

(D) $\frac{\mathbf{F}}{m_1+m_2}+\frac{\mathbf{F}}{m_2}$

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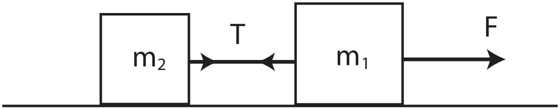

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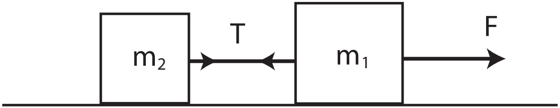
Separate Objects Pulled Along

Question. What is the tension in the connecting string, T?



(A) 0

(B) $\frac{m_1 F}{m_1+m_2}$

(C) $\frac{m_2 F}{m_1+m_2}$

(D) F

Separate Objects Pulled Along

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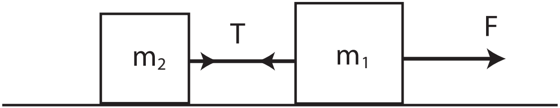

(A) 0

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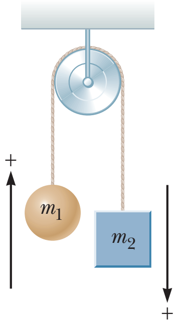
(C) $\frac{m_2 F}{m_1 + m_2}$ ←

(D) F

Pulleys

Pulleys "turn tensions around a corner".



For the moment, we are just considering *massless, frictionless* pulleys. What does that mean?

Pulleys

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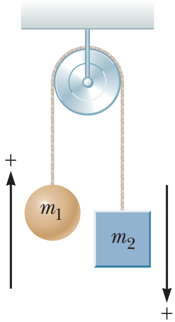
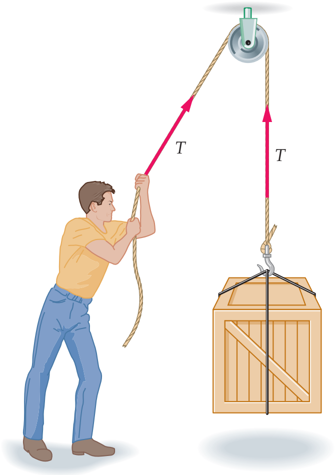


For the moment, we are just considering *massless, frictionless* pulleys. What does that mean?

- Massless: we do not have to worry about force needed to accelerate each atom in the pulley
- Frictionless: the *axle* of the pulley has no friction to resist the wheel turning

Pulleys and Tension

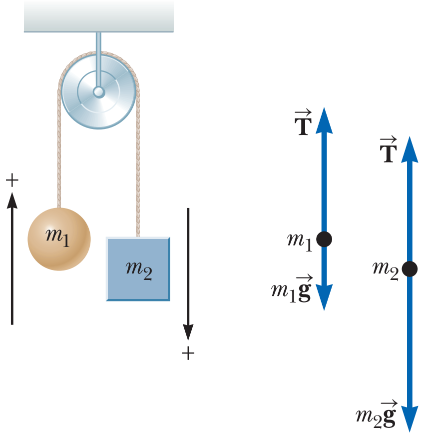
If the rope is light (massless) and the pulley is massless and frictionless, the tension in the rope on both sides of the pulley is the same.



[1]Figure from Walker, "Physics".

Pulleys and the Atwood Machine

The Atwood Machine can be used to make careful determinations of g, as well as explore the behavior of forces and accelerations.



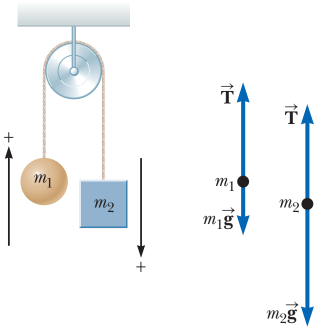
[1]Figure from Serway and Jewett, 9th ed.

Pulleys and the Atwood Machine

Notice that again, like the pushed blocks, the two objects must accelerate together at the same rate, because they are connected through an inextensible rope.

The tension in all parts of the rope will be the same (assume a light rope).

Pulleys and the Atwood Machine

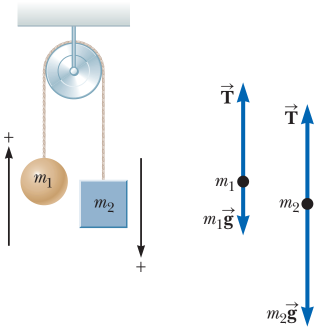


We can consider the motion for each mass separately. In the y-directions:

$$F_{\text{net},1,y} = T - m_1 g = m_1 a \qquad \text{(up positive)} \tag{1}$$

$$F_{\text{net},2,y} = m_2 g - T = m_2 a \qquad \text{(down positive)} \tag{2}$$

Pulleys and the Atwood Machine



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Be careful about the signs! Both masses must accelerate together - one up, one down.

Pulleys and the Atwood Machine

Finding acceleration and tension in the rope:

$$F_{\text{net},1,y} = T - m_1 g = m_1 a \tag{1}$$

$$F_{\text{net},2,y} = m_2 g - T = m_2 a \tag{2}$$

Take eq (1) + eq (2):

$$\begin{aligned} m_2 g - m_1 g &= m_1 a + m_2 a \\ a &= \frac{(m_2 - m_1) g}{m_1 + m_2} \end{aligned}$$

Pulleys and the Atwood Machine

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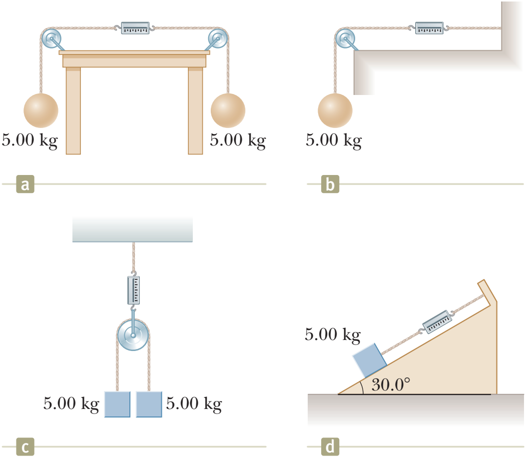
$$T = \frac{2 m_1 m_2 g}{m_1 + m_2}$$

Tension and Force Meters: #28, page 141

28. W The systems shown in Figure P5.28 are in equilibrium. If the spring scales are calibrated in newtons, what do they read? Ignore the masses of the pulleys and strings and assume the pulleys and the incline in Figure P5.28d are frictionless.



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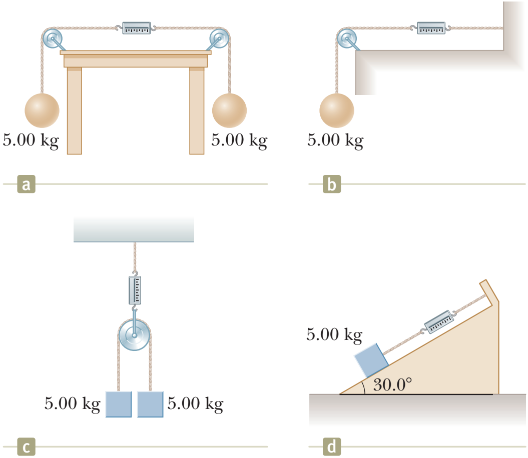

Answers: a) 49 N, b) 49 N, c) 98 N, d) 24.5 N

Summary

- contact forces
- systems of objects together and on their own
- tension
- pulleys

Homework

- (set last week) Ch 5 Ques: 9; Probs: 17, 39, 45, 49, 53, 55
- new: Ch 5 Probs: 13, 51, 57, 59, 67, 71