Mechanics
Newton's Laws (cont'd)

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Oct 16, 2018

Last time

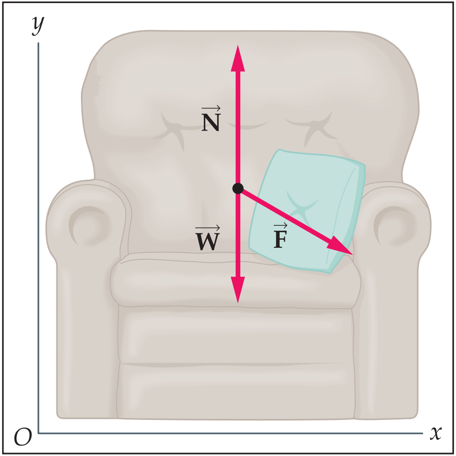
- net force example
- Newton's first law
- Newton's second law
- mass vs weight
- force diagrams

Overview

- Newton's second law examples
- Newton's third law
- action-reaction pairs of forces

Diagrams of Forces: Free-Body Diagram

This is a free-body diagram. We represent the chair as a point-particle with force vectors pointing outward.



We also picked a coordinate system (x, y axes).

Force Diagrams, Newton's Second Law, and Kinematics

An astronaut uses a jet pack to push on a 655-kg satellite. If the satellite starts at rest and moves 0.675 m after 5.00 seconds of pushing, what is the force, **F**, exerted on it by the astronaut?

(a) Physical picture

Force Diagrams, Newton's Second Law, and Kinematics

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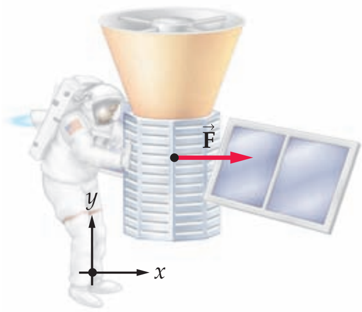
Sketch:



(b) Free-body diagram

Force Diagrams, Newton's Second Law, and Kinematics

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Given: $\boldsymbol{\Delta x}$, t, m
Want: **F**

Force Diagrams, Newton's Second Law, and Kinematics

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Strategy: to find the force we must find the acceleration.

$$\Delta x = v_{0x}t + \frac{1}{2}a_x t^2$$

Force Diagrams, Newton's Second Law, and Kinematics

$$\Delta x = \cancelto{0}{v_{0x}t} + \frac{1}{2}a_x t^2$$

$$a_x = \frac{2(\Delta x)}{t^2}$$

$$a_x = 0.0540 \text{ m/s}^2$$

Force Diagrams, Newton's Second Law, and Kinematics

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a_x &= 0.0540 \text{ m/s}^2
\end{aligned}$$

Newton's second law (x-component):

$$\begin{aligned}
F_x &= m a_x \\
F_x &= 35.4 \text{ N}
\end{aligned}$$

$$\underline{\mathbf{F} = 35.4 \text{ N } \mathbf{i}}$$

Newton's Second Law Implications

Quick Quiz 5.3.[1] You push an object, initially at rest, across a frictionless floor with a constant force for a time interval Δt, resulting in a final speed of v for the object. You then repeat the experiment, but with a force that is twice as large. What time interval is now required to reach the same final speed v?

A $4\Delta t$

B $2\Delta t$

C $\frac{\Delta t}{2}$

D $\frac{\Delta t}{4}$

[4] S&J page 116.

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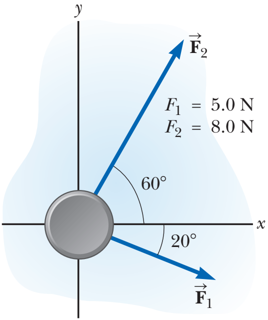
[4]S&J page 116.

Example

Consider a 0.3 kg hockey puck on frictionless ice. Find its acceleration.



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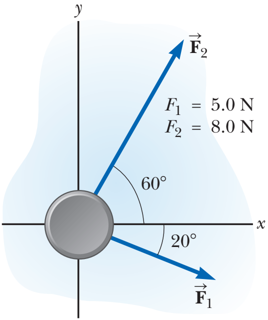

$$
\begin{aligned}
\mathbf{F}_{\text{net}} &= \mathbf{F}_1 + \mathbf{F}_2 \\
&= (F_1 \cos(-20) + F_2 \cos(60))\,\mathbf{i} \\
&\quad + (F_1 \sin(-20) + F_2 \sin(60))\,\mathbf{j} \\
&= 8.70\,\mathbf{i} + 5.21\,\mathbf{j}\ \text{N}
\end{aligned}
$$

Example

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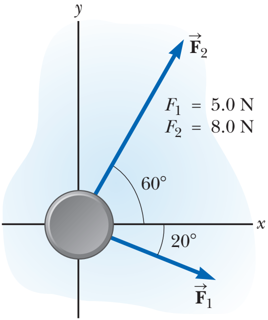

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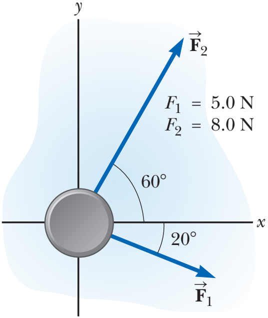
&= 8.70\,\mathbf{i} + 5.21\,\mathbf{j}\ \text{N}
\end{aligned}$$

$$\begin{aligned}
\mathbf{a} &= \frac{\mathbf{F}_{\text{net}}}{m} \\
&= \frac{8.70\ \text{N}\,\mathbf{i} + 5.21\ \text{N}\,\mathbf{j}}{0.3\ \text{kg}} \\
&= 29.0\,\mathbf{i} + 17.4\,\mathbf{j}\ \text{ms}^{-2}
\end{aligned}$$

Example

Consider a 0.3 kg hockey puck on frictionless ice. Find its acceleration.



$$\mathbf{a} = 29.0\,\mathbf{i} + 17.4\,\mathbf{j}\ \mathrm{ms}^{-2}$$

$$a = \sqrt{29.0^2 + 17.4^2} = 34\ \mathrm{ms}^{-2}$$

at an angle

$$\theta = \tan^{-1}\left(\frac{17.4}{29.0}\right) = 31^\circ$$

above the horizontal (x-axis).

Newton's Third Law

Newton's Third Law is commonly stated as "For every action, there is an equal and opposite reaction."

However it is more precisely stated:

Newton III

If two objects (1 and 2) interact the force that object 1 exerts on object 2 is equal in magnitude and opposite in direction to the force that object 2 exerts on object 1.

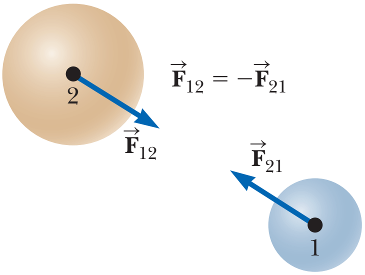
$$\mathbf{F}_{1\to 2} = -\mathbf{F}_{2\to 1}$$

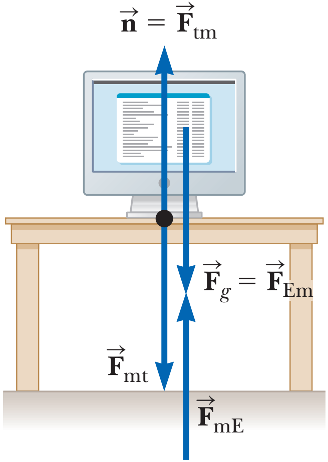
Newton's Third Law

Main idea: you cannot push on something, without having it push back on you.

If object 1 pushes on (or interacts with) object 2, then the force that object 1 exerts on object 2, and the force that object 2 exerts on object 1 form an **action reaction pair**.

Newton's Third Law: Action Reaction Pairs





Summary

- Newton's third law
- action-reaction pairs

Homework

- Ch 5 Ques: 9; Probs: 17, 29, 31, 33, 39, 45, 49, 53, 55, 87