Newton's Law of Motion

Physics 211
Syracuse University, Physics 211 Spring 2019
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February 7, 2019

Announcements

- Homework 3 due next Friday (will be posted tonight/tomorrow)
- You will get new groups in recitation next Wednesday
- Exam grading is still ongoing (we finally went home at 8pm yesterday)
  - If these slides are a little rough, it's because we spent all day grading
  - I'll catch up on messages this afternoon
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  - **Preliminary: exam grades were quite good!**

Ask a Physicist: extra dimensions

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...history!

Two revolutions in one!

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1. The development of classical mechanics as a way to describe and predict things move
2. The emergence of *science* as a powerful means to develop models like classical mechanics

We're going to spend most of our time learning classical mechanics, but we should spend some time studying science, too!

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- What does it look like?

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- What do they **not** look like?
- How can we ensure that the scientific process is done well and honestly?

Aristotelian mechanics

Newton's first law was historically important because it overturned the previous knowledge, from Aristotle:

- Things on Earth that move eventually come to a stop
- Things on Earth fall at a constant speed, depending on their weight and the density of the fluid they fall in
- Things in the sky don't fall, but move in circles, because they are perfect and heavenly and circles are perfect
- How things move is intimately connected to the reasons people (etc.) have for making them move

(These first two are actually reasonable in a situation where fluid drag is very large, which is what he studied.)

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- Science as an objective and non-anthropocentric explanation:
  - Scientific ideas are bigger than any particular person's perspective; they should be universal
  - Humans don't have a special role in the laws of nature; if we are special, it's not because we have special rules

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- No forces $\rightarrow$ no acceleration: not necessarily no motion!

- Forces come in pairs (Newton's third law)
  - "If A pushes on B, B pushes back on A"
  - Very important to be clear about what forces you're talking about

Newtons

We need a new unit for force: the newton

$$\vec{F} = m\vec{a} \rightarrow \text{Force has dimensions kg m/s}^2$$

- 1 N = 1 kg m/s^2: about the weight of an apple
- 4 N is about a pound
- 9.8 N is the weight of a kilogram

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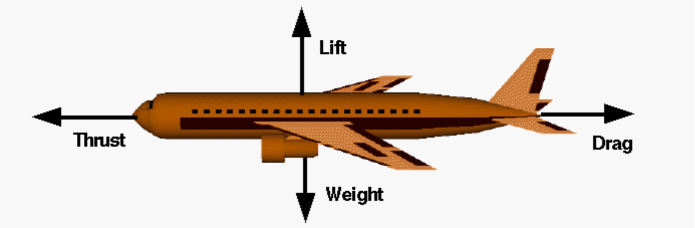
(dragging disc demo)

Force diagrams

- Lots of forces, easy to get confused
- Draw a picture!



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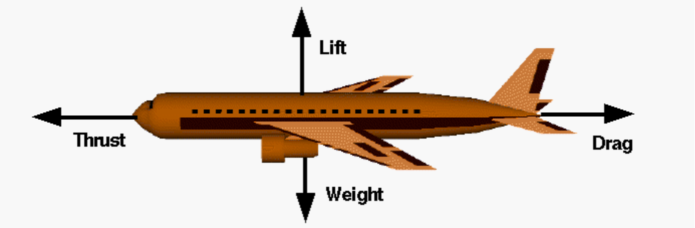

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- Label each force and its direction
- These are also called “free body diagrams”

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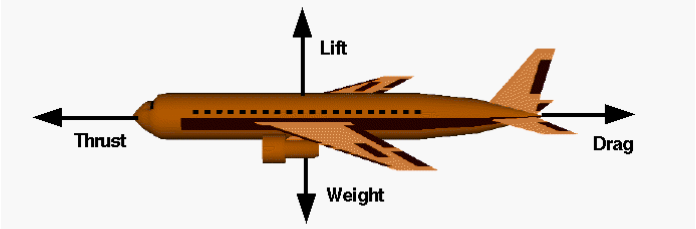

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(Examples on document camera)

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \to a = g$
  - Gravity pulls down on everything (on Earth) with a force mg, called its weight
  - If something isn't accelerating downward, some other force must balance its weight

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  - However big it needs to be to stop objects from sliding through each other
  - Directed "normal" (perpendicular) to the surface
  - Really caused by electric force/Pauli exclusion principle

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- Acceleration is not a force!
- ... it's the *result* of forces

One particular force: gravity

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Why is the acceleration of a falling object g downward?

- A: Because g is the acceleration of all objects within Earth's gravitational field
- B: Solve Newton's law: $\vec{F} = m\vec{a} \rightarrow mg(-\hat{j}) = m\vec{a} \rightarrow \vec{a} = -g\hat{j}$
- C: Because the definition of g is the acceleration that a falling object undergoes
- D: It's only g if there are no other forces besides gravity acting on it

Suppose an object is moving in a straight line at a constant speed. Which number of forces could *not* be acting on it?

- A: Zero
- B: One
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- D: Three
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Suppose an object is moving in a circle at a constant speed. Which number of forces could *not* be acting on it? (Hint: what is the definition of velocity? Of acceleration?)

- A: Zero
- B: One
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- D: Three
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Sample questions

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(Use $\vec{F} = m\vec{a}$ to connect force to acceleration, and then kinematics to connect acceleration to motion)

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- If two things don’t touch, or interact by gravity, electricity, etc., they don’t exchange forces
- “A force is something that can send you to the doctor”

Which of the following is/are *not* an example of Newton's third law?

- A: a subway car accelerates forward; you are thrown back
- B: the propeller on an airplane pushes the air backwards; the air pushes the airplane forwards
- C: an elevator accelerates upward; passengers are pushed downward
- D: the Earth's gravity pulls downward on me; my gravity pulls upward on the Earth
- E: a rocket pushes downward on its exhaust; the exhaust pushes upward on the rocket

A sample problem

A stack of two books sits on a table. Each book weighs 10 newtons. Draw a force diagram for each one, and calculate the size of all the forces.

(Your answer should match what you know about how this works!)

Summary

- Forces: anything that pushes or pulls
- Forces cause accelerations: $\sum \vec{F} = m\vec{a}$
  - If $\sum \vec{F} = 0$, $\vec{a} = 0$: motion at a constant velocity
- Forces come in pairs: if A pushes on B, B pushes back on A
- It's the vector sum $\sum \vec{F}$ that matters
- Draw force diagrams to keep all of this straight