# Newton's Law of Motion

Physics 211
Syracuse University, Physics 211 Spring 2017
Walter Freeman

February 9, 2017

# Announcements

- Homework 3 due next Friday (will be posted sometime this weekend)
- You will get new groups in recitation next Wednesday
- Do not miss Friday's recitation – exam review and return
- TA's will also give you a chance to practice some very important skills that people had trouble with on the exam

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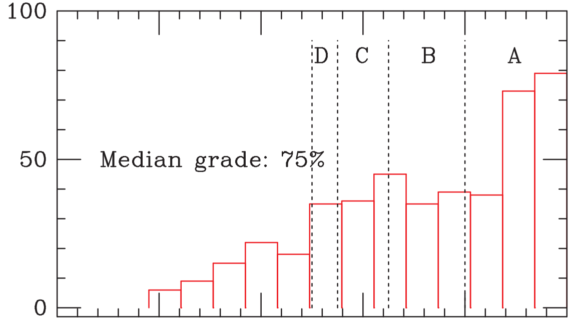

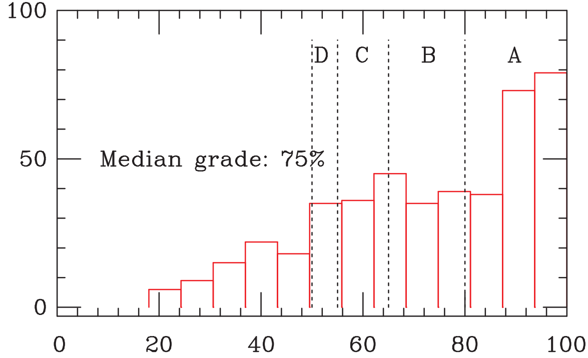


Last year's exam had a median of 65% (B-). That exam was perhaps a bit easier – and had extra credit.

Your class median was **75% (B+).** Be very, very proud of yourselves!

Why do you think you did better than last year's class? (Seriously – I'm curious to hear your guesses)

- A: We're more motivated, smarter, or just overall more awesome than last year
- B: Group work in recitations / the group practice exam
- C: The physics practices on Wednesday evenings help
- D: The recitation TA's are a particularly good bunch
- E: This year's exam was easier

# Ask a Physicist: general relativity and "multiverses"

# Newton's laws

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- Forces on an object cause it to accelerate
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- You intuitively know this already
- 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

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

# 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)

# 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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- Electromagnetic forces, nuclear forces, radiation pressure...
- Acceleration is not a force!
- ... it's the *result* of forces

## One particular force: gravity

Gravity exerts a downward force on all objects (on Earth), with a magnitude of $mg$.

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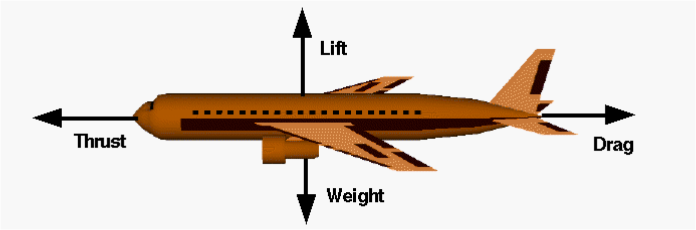
Why is the acceleration of a falling object $g(-\hat{j})$?

- A: Because $g$ is the acceleration of all objects within Earth's gravitational field
- B: Solve Newton's law: $\vec{F} = m\vec{a} \to mg(-\hat{j}) = m\vec{a} \to \vec{a} = -g\hat{j}$
- 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

# Force diagrams

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



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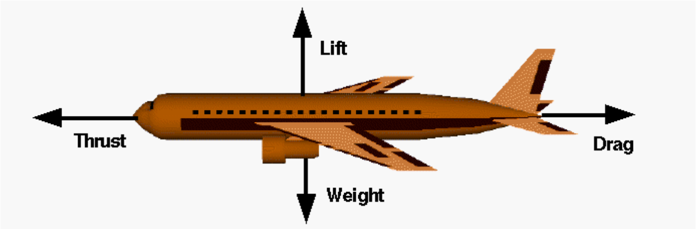


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- Label each force and its direction
- These are also called "free body diagrams"

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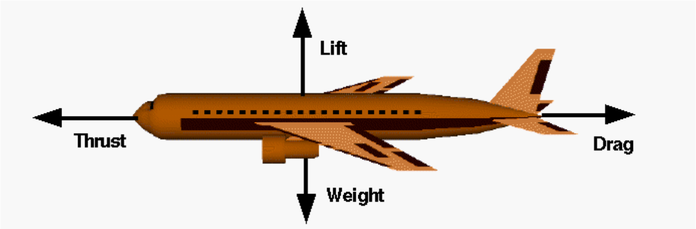


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(Examples on document camera)

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

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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
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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"

# 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