Newton's Law of Motion

Physics 211
Syracuse University, Physics 211 Spring 2023
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Announcements

- Homework 3 due next Wednesday (will be posted today; shorter than HW2)
- You will get new groups in recitation Friday or Wednesday
- Exam 1 is mostly graded; you will get your grades back in recitation this week or next

Newton's laws

$$\vec{F} = m\vec{a}$$

- Forces on an object cause it to accelerate
- The larger the force, the larger the acceleration
- The larger the mass, the smaller the acceleration
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- You intuitively know this already
- No forces → 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

Force is a vector

$$\vec{F} = m\vec{a}$$

- Force is a *vector*
- Multiple forces on an object add like vectors do
- Really, we should write

$$\sum \vec{F} = m\vec{a}$$

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \rightarrow a = g$
  - 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
  - We are now switching the way we think about gravity!
    - Before: gravity makes objects in free fall accelerate downward at g
    - Now: gravity is just one of *many* forces that can act on objects

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  - Are there normal forces on me right now?
  - However big it needs to be to stop objects from sliding through each other
  - The normal force is usually an unknown you will need to solve for, not a thing you know
  - 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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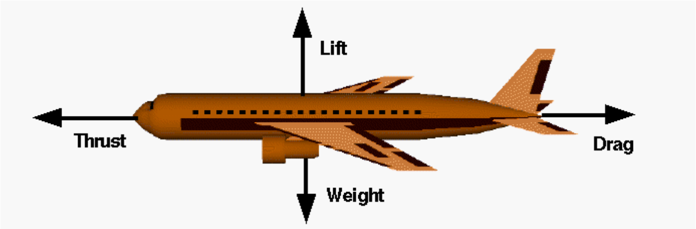
Why is the acceleration of a falling object g downward?

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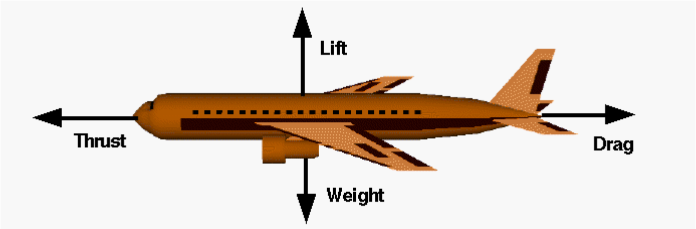

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- Label each force and its direction
- These are also called "free body diagrams"

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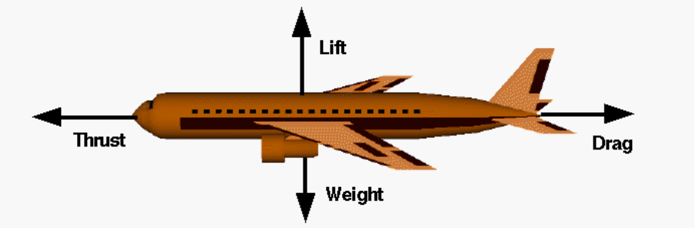

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(Examples on document camera)

An example

(Use 10 m/s^2 for g, please!)

An aircraft at an air show has a mass of 10,000 kg and its engine produces a maximum thrust of 130 kN.

If it is using its engine at full power to take off (on the ground), what is its acceleration?

(Neglect air resistance for now – this only matters once it is moving quickly)

- A: 10 m/s^2 downward
- B: 13 m/s^2 forward
- C: 23 m/s^2 forward
- D: 3 m/s^2 forward

An example

The pilot wants to show off for the crowd, so they point the aircraft straight upward once it is in the air.

(Again, it has a mass of 10,000 kg and its engine has a thrust of 130 kN.)

What is its acceleration now?

- A: 10 m/s^2 downward
- B: 3 m/s^2 downward
- C: 13 m/s^2 upward
- D: 3 m/s^2 upward
- E: 23 m/s^2 upward

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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
- C: Two
- D: Three
- E: Four

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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