Newton's Law of Motion

Physics 211
Syracuse University, Physics 211 Spring 2018
Walter Freeman

February 15, 2018

Announcements

- Clinic hours today: 1:30-5
- Prof. Plourde is out of town and will return tomorrow
- HW3 is posted

Announcements

- Clinic hours today: 1:30-5
- Prof. Plourde is out of town and will return tomorrow
- HW3 is posted
- An opportunity for you to get some minor extra credit and help uphold academic honesty...

Announcements

- Clinic hours today: 1:30-5
- Prof. Plourde is out of town and will return tomorrow
- HW3 is posted
- An opportunity for you to get some minor extra credit and help uphold academic honesty...
  - Two people sitting next to each other turned in suspiciously similar papers
  - We are pretty sure that this isn't a coincidence, but want to make sure
  - We can study this rigorously based on how often people made particular choices in solving a problem
  - Give your exams to your TA tomorrow; we'll look at them, give you +1 point, and give them back

Exam 1

Any questions?

Newton's laws

Newton's second law: $\vec{F} = m\vec{a}$

- Forces on an object cause it to accelerate
- The larger the force, the larger the acceleration
- The larger the mass, the smaller the acceleration
- You intuitively know this already

Newton's second law: $\vec{F} = m\vec{a}$

- Forces on an object cause it to accelerate
- The larger the force, the larger the acceleration
- The larger the mass, the smaller the acceleration
- You intuitively know this already
- No forces $\rightarrow$ no acceleration: not necessarily no motion!

Newton's third law: Forces come in pairs

- "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

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

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

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

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

(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

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \to a = g$
- "Normal force": stops things from moving through each other
    - Are there normal forces on me right now?

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \to a = g$
- "Normal force": stops things from moving through each other
  - Are there normal forces on me right now?
  - 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

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \rightarrow a = g$
- "Normal force": stops things from moving through each other
- Tension: ropes pull on both sides equally
    - What are the forces in a contest of tug-of-war?

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \rightarrow a = g$
- "Normal force": stops things from moving through each other
- Tension: ropes pull on both sides equally
  - What are the forces in a contest of tug-of-war?
  - What about the forces on the people?
- Friction: a force opposes things sliding against each other

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \to a = g$
- "Normal force": stops things from moving through each other
- Tension: ropes pull on both sides equally
  - What are the forces in a contest of tug-of-war?
  - What about the forces on the people?
- Friction: a force opposes things sliding against each other
- Electromagnetic forces, nuclear forces, radiation pressure...

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \to a = g$
- "Normal force": stops things from moving through each other
- Tension: ropes pull on both sides equally
  - What are the forces in a contest of tug-of-war?
  - What about the forces on the people?
- Friction: a force opposes things sliding against each other
- 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.

In symbols: $\vec{F}_g = mg$ downward.

One particular force: gravity

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

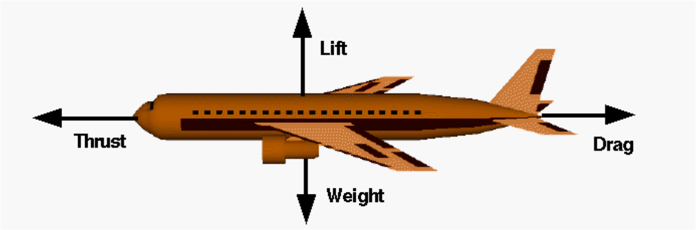
In symbols: $\vec{F}_g = mg$ downward.

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

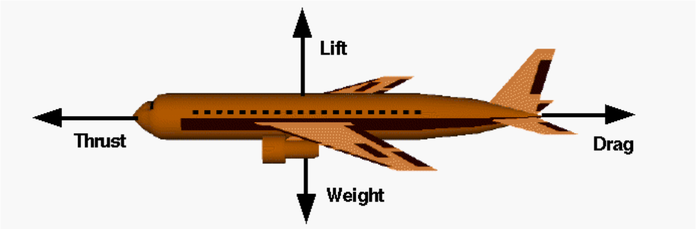
Force diagrams

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



Force diagrams

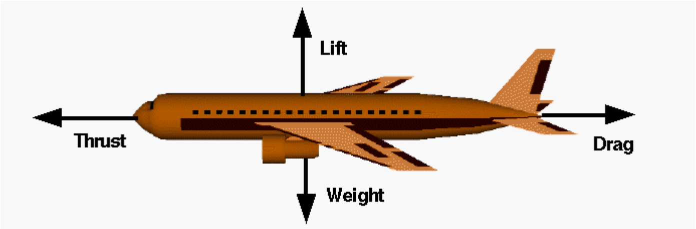
- Lots of forces, easy to get confused
- Draw a picture!



- Each object feeling forces gets a separate diagram
- Label each force and its direction
- These are also called “free body diagrams”

Force diagrams

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



- Each object feeling forces gets a separate diagram
- Label each force and its direction
- These are also called “free body diagrams”

(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?

- A: Zero
- B: One
- C: Two
- D: Three
- E: Four

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

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

Sample questions

- What forces act on a car?

Sample questions

- What forces act on a car?
- Which forces are bigger or smaller if it's driving at a constant speed?

Sample questions

- What forces act on a car?
- Which forces are bigger or smaller if it's driving at a constant speed?
- Which forces are bigger or smaller if it's slowing down?

Sample questions

- What forces act on a car?
- Which forces are bigger or smaller if it's driving at a constant speed?
- Which forces are bigger or smaller if it's slowing down?
- A 1000 kg car slows from 20 m/s to a stop over 5 sec. If we ignore air resistance, what force is required to do this?

Sample questions

- What forces act on a car?
- Which forces are bigger or smaller if it's driving at a constant speed?
- Which forces are bigger or smaller if it's slowing down?
- A 1000 kg car slows from 20 m/s to a stop over 5 sec. If we ignore air resistance, what force is required to do this?

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

An important note

- Only *real physical things* are forces

An important note

- Only *real physical things* are forces
- Acceleration is not a force
- “Net force” is not a force (it’s the sum of them)
- Velocity certainly isn’t a force

An important note

- Only *real physical things* are forces
- Acceleration is not a force
- "Net force" is not a force (it's the sum of them)
- Velocity certainly isn't a force
- If two things don't touch, or interact by gravity, electricity, etc., they don't exchange forces

An important note

- Only *real physical things* are forces
- Acceleration is not a force
- "Net force" is not a force (it's the sum of them)
- Velocity certainly isn't a force
- 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