Newton's Law of Motion

Physics 211
Syracuse University, Physics 211 Spring 2017
Walter Freeman

February 13, 2017

Announcements

- Homework 3 due Friday
- You will get new groups in recitation tomorrow
- I am very (very) far behind on answering mail; I will catch up ASAP

Announcements

- Homework 3 due Friday
- You will get new groups in recitation tomorrow
- I am very (very) far behind on answering mail; I will catch up ASAP
- Group exams from last Friday will be "curved" to equalize difficulty

Announcements

- Homework 3 due Friday
- You will get new groups in recitation tomorrow
- I am very (very) far behind on answering mail; I will catch up ASAP
- Group exams from last Friday will be "curved" to equalize difficulty
- Exam misgrades/grade appeals: talk to your TA's

Forces

Rational mechanics must be the science of the motions which result from any forces, and of the forces which are required for any motions, accurately propounded and demonstrated. For many things induce me to suspect, that all natural phenomena may depend upon some forces by which the particles of bodies are either drawn towards each other, and cohere, or repel and recede from each other: and these forces being hitherto unknown, philosophers have pursued their researches in vain. And I hope that the principles expounded in this work will afford some light, either to this mode of philosophizing, or to some mode which is more true.

-Isaac Newton, *Philosophiae Naturalis Principia Mathematica* (1687), translated from the Latin by Whewell (1837)

Forces

*Mechanics involves figuring out how things move from knowing the forces that act on them, and figuring out what forces act on them if we know how they move. I suspect that all physical things involve things exerting forces on each other, and since we don't know what forces these are, nobody's been able to figure much out. Hopefully someone will read this book and figure this stuff out, either following my suspicion that it's all forces under the hood (***classical physics!***), or with some deeper understanding of nature (***quantum physics!***)*

-Isaac Newton, *Philosophiae Naturalis Principia Mathematica*, in modern English

Summary from last time

- 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

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

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
  - 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 $mg = ma \rightarrow a = g$
- "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 $mg = ma \rightarrow a = g$
- "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
- Electromagnetic forces, nuclear forces, radiation pressure...

What is a force?

A force is anything that pushes or pulls something:

- Gravity: $F = mg$, so $mg = ma \rightarrow a = g$
- "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
- Electromagnetic forces, nuclear forces, radiation pressure...
- Acceleration is not a force!
- ... it's the *result* of forces

Ask a physicist: static electricity

"Can we bottle it and use it to power a house?" – we already do!

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. 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. 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!)

Forces in 2D (and 3D)

Force is a vector; handle it like any other

One copy of Newton's second law in each direction (per object)

$$\vec{F} = m\vec{a} \rightarrow \begin{pmatrix} F_x = ma_x \\ F_y = ma_y \end{pmatrix}$$

Forces in 2D (and 3D)

Force is a vector; handle it like any other

One copy of Newton's second law in each direction (per object)

$$\vec{F} = m\vec{a} \rightarrow \begin{pmatrix} F_x = ma_x \\ F_y = ma_y \end{pmatrix}$$

Important: When dealing with inclines, choose your axes to align with the incline! (F_N is easy that way)

Forces in 2D (and 3D)

Force is a vector; handle it like any other

One copy of Newton's second law in each direction (per object)

$$\vec{F} = m\vec{a} \rightarrow \begin{pmatrix} F_x = ma_x \\ F_y = ma_y \end{pmatrix}$$

Forces in 2D (and 3D)

Force is a vector; handle it like any other

One copy of Newton's second law in each direction (per object)

$$\vec{F} = m\vec{a} \rightarrow \begin{pmatrix} F_x = ma_x \\ F_y = ma_y \end{pmatrix}$$

Important: When dealing with inclines, choose your axes to align with the incline! (F_N is easy that way)

A problem-solving recipe (remember this!)

- Accounting: Draw force diagrams for every object
  - Work out components (trigonometry) of vectors in funny directions – no need for numbers

A problem-solving recipe (remember this!)

- Accounting: Draw force diagrams for every object
  - Work out components (trigonometry) of vectors in funny directions – no need for numbers
- Physics: Write down $\sum F = ma$ in each dimension, for each object

A problem-solving recipe (remember this!)

- Accounting: Draw force diagrams for every object
  - Work out components (trigonometry) of vectors in funny directions – no need for numbers
- Physics: Write down $\sum F = ma$ in each dimension, for each object
- Math: Put in the stuff you know, solve for the stuff you don't

A problem-solving recipe (remember this!)

- Accounting: Draw force diagrams for every object
  - Work out components (trigonometry) of vectors in funny directions – no need for numbers
- Physics: Write down $\sum F = ma$ in each dimension, for each object
- Math: Put in the stuff you know, solve for the stuff you don't
- Kinematics: Connect acceleration to motion

A problem-solving recipe (remember this!)

- Accounting: Draw force diagrams for every object
  - Work out components (trigonometry) of vectors in funny directions – no need for numbers
- Physics: Write down $\sum F = ma$ in each dimension, for each object
- Math: Put in the stuff you know, solve for the stuff you don't
- Kinematics: Connect acceleration to motion

It really is this easy; I promise!

A problem-solving recipe (remember this!)

- Accounting: Draw force diagrams for every object
  - Work out components (trigonometry) of vectors in funny directions – no need for numbers
- Physics: Write down $\sum F = ma$ in each dimension, for each object
- Math: Put in the stuff you know, solve for the stuff you don't
- Kinematics: Connect acceleration to motion

It really is this easy; I promise!
"Ask physics the question, don't tell it the answer"

Sample questions: dealing with two dimensions

A stone hangs from the roof of a car by a string; the car accelerates forward at 3 $\mathrm{m/s^2}$.

- What happens to the string?

Sample questions: dealing with two dimensions

A stone hangs from the roof of a car by a string; the car accelerates forward at 3 $\mathrm{m/s^2}$.

- What happens to the string?
- What angle does the string make with the vertical?

Sample questions: dealing with two dimensions

A stone hangs from the roof of a car by a string; the car accelerates forward at 3 $\mathrm{m/s^2}$.

- What happens to the string?
- What angle does the string make with the vertical?
- What is the tension in the string?

Sample questions: dealing with two dimensions

A cart slides down a frictionless track elevated at angle θ; what is its acceleration?

Sample questions: dealing with multiple objects

Two masses of m_1 and m_2 kg hang from a massless pulley on either side. How do they move?

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