Newton's Law of Motion

Physics 211
Syracuse University, Physics 211 Spring 2023
Walter Freeman

February 14, 2023

Clinic hours this week

My availability in the Physics Clinic is a bit limited this week because of other commitments.

You can find me in the Clinic:

- Today (Tuesday), 1:30-3:30 pm
- Wednesday, 3-5 pm

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Extra assistance

Come to B129E for extra assistance with:

- "Soccer problem" or "Football problem" from Exam 1 and related topics:
  - Today, 1:30 or 3:30
  - Tomorrow, 6:30
- "Goose problem" (vectors) or "dog problem" (graphs) from Exam 1:
  - Today, 2:00 or 4:00
  - Tomorrow, 7:00
- Solving systems of equations by substitution:
  - Today, 2:30 or 4:30
  - Tomorrow, 7:30

We can help anyone with any of these topics at any of these times, but these times are more likely to have a group for you.

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
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- "A force is something that can send you to the doctor"

Questions from homework or last week's recitation?

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)

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

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- Accounting: Draw force diagrams for every object
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"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 $\mathrm{m/s^2}$.

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- 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?

A new force: Friction

- Friction: stops two surfaces from sliding past each other
- Can either make things move or make things stop; opposes *relative* motion
- Two types:
  - Static friction: keeps two things that aren't sliding stuck together
  - Kinetic friction: opposes the relative motion of two things sliding

Coulomb's friction model

Friction is really complicated!

- Depends on details of surfaces, molecular forces, etc.
- No way to create a completely accurate general principle

There are a few general principles, though:

- Friction is higher if the normal force is higher
- Kinetic friction doesn't depend that much on the speed of travel

Simple model: often pretty close

- Friction depends on a property of the surfaces called the coefficient of friction μ
- Force of kinetic friction $= \mu_k F_N$
- Max force of static friction $= \mu_s F_N$

Friction, a summary

- Kinetic friction points in whichever direction opposes the relative motion
- $F_{f,k} = \mu_k F_N$

- Static friction points in whichever direction it needs to in order to keep the objects from sliding
- You will need to think carefully about this: the direction can change, depending on other things
- Static friction is however big it needs to be to keep the objects from sliding, up to a maximum value:
- $F_{f,s,\max} = \mu_s F_N$

Traction

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We call this force “traction”. It can point in either direction, depending on how the car is trying to turn its wheels, with the engine, brakes, or so on.

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In normal use, though, the piece of the wheel touching the ground does not move.

This means that the traction force is really **static friction**.

So

$$F_{\text{trac}} < \mu_s F_N,$$

just like for static friction. It points either forwards or backwards, depending on what the engine/brakes/bicyclist/etc. are doing.

Coefficients of friction

TABLE 6.1 Coefficients of friction

Materials	Static μ_s	Kinetic μ_k	Rolling μ_r
Rubber on concrete	1.00	0.80	0.02
Steel on steel (dry)	0.80	0.60	0.002
Steel on steel (lubricated)	0.10	0.05	
Wood on wood	0.50	0.20	
Wood on snow	0.12	0.06	
Ice on ice	0.10	0.03	

Sample questions

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What if the car is front-wheel-drive instead?

Sample questions

An object with mass m on a track is connected by a rope to a hanging weight of mass M. The coefficients of friction are μ_s and μ_k. What is the acceleration of both objects?

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?

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