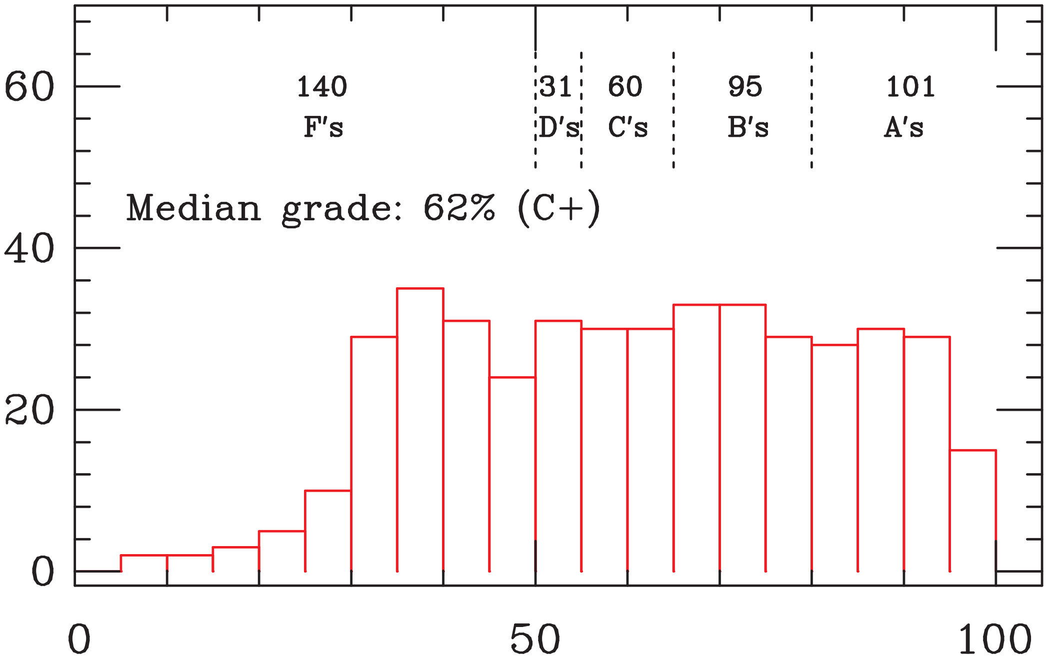
Friction

Physics 211
Syracuse University, Physics 211 Spring 2019
Walter Freeman

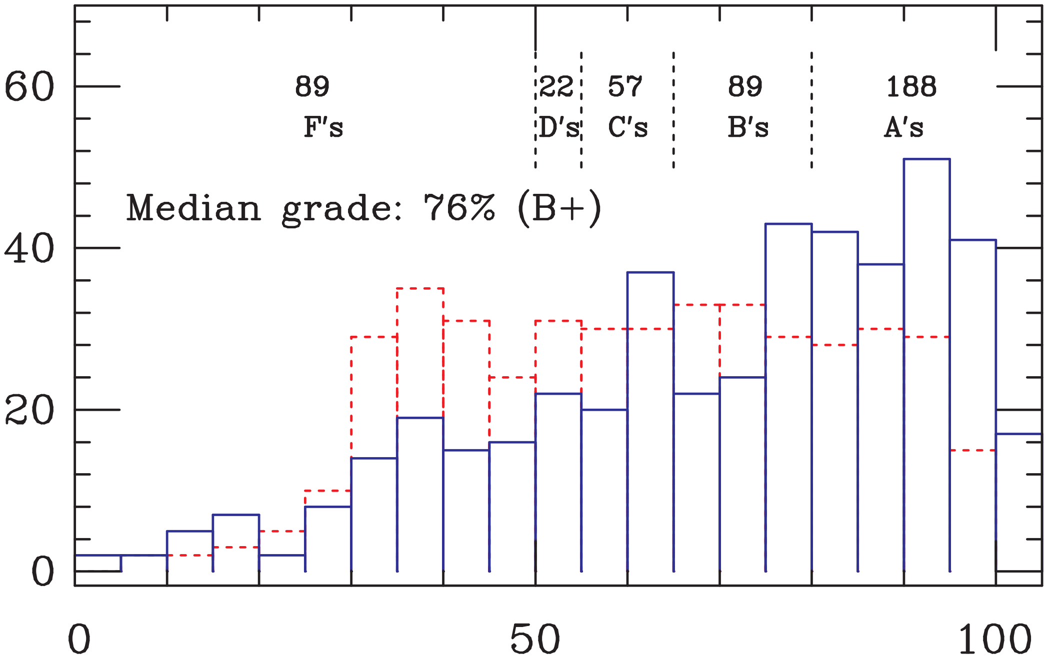
February 13, 2019

Announcements

- Homework 3 extended until Monday 5PM (turn in to your TA's mailbox)
- Homework 4 posted over the weekend
  - It will contain a short essay question as well
  - You'll have a week and a half to do it
- Office hours today: 1:45-3:45 PM
- Office hours Friday: 10:30-1:00 and 3:30-5:00



Grade distribution from Exam 1



Grade distribution from the *2019* Exam 1...

Ask a physicist: imaginary time

Is imaginary time meaningful?

Is it, at least, ever *useful?*

A comment from a student in 2017

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The overarching concept:

- Newton's second law $\sum \vec{F} = m\vec{a}$ tells us the relation between the forces on an object and how it moves
- If we know the forces on an object, we can use those to compute its acceleration
  - Once we find its acceleration, we can learn about its movement, using kinematics
- If we know its acceleration, we can go the other way, and learn about the forces that act on it

Breaking these bits down

Everything we're dealing with here is a vector:

- Decompose all forces into $x-$ and $y-$components
- Newton's second law becomes $(\sum F_x = ma_x, \sum F_y = ma_y)$

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Knowing about the forces on objects:

- Newton's *third* law tells us that forces come in pairs: $\vec{F}_{ab} = -\vec{F}_{ba}$
- Normal forces are however big they need to be to stop objects from moving through each other
- Tension is the same at all points in a rope
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Keeping the forces straight:

- Draw a force diagram: a dot representing each object, with arrows going outward for each force
- You're going to need to break forces not aligned with the (x,y) axes into components
- Draw your diagram big enough to do the trigonometry

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Applying this to Newton's second law:

- You can look at your diagrams and read off the $x-$ and $y-$components of the forces that are present
- This will let you write down things like

$$\text{list of forces in x} = ma_x$$
$$\text{list of forces in y} = ma_y$$

- Do this separately for each object
- This will give you a bunch of equations
- Solve the system of equations by substitution for whatever you want

A problem-solving recipe

- Accounting: Draw force diagrams for every object
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  - Write down any constraints you have: are the accelerations of two objects related?
  - Are two forces the same magnitude by Newton's third law?

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The Atwood machine, from recitation

Two weights, of mass M and m, hang from a light, frictionless pulley. How do they move when they are released?

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:
- $F_{f,s,\text{max}} = \mu_s F_N$

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	

- These depend only on the *materials*, not on anything else.
- μ is almost always less than 1, and μ_k is always less than μ_s.
- I will give you these values; no need to memorize.

A block slides down a track elevated at angle θ with μ_k known; what is its acceleration?

Sample questions

A block 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

An object slides down a ramp with coefficient of kinetic friction μ_k. How fast does it accelerate?

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An object slides **up** a ramp with coefficient of kinetic friction μ_k. How fast does it accelerate?

Traction

Things with feet or wheels use friction between their feet/wheels and the ground to accelerate themselves.

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We call this force "traction". It can point in any direction that the driver or person wants, based on how they move their feet/wheels.

In normal use, though, the thing 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 forwards, backwards, or to the side, depending on what the engine/brakes/feet/etc. are doing.

Sample questions

What is the fastest that an automobile can go from 0-60 miles per hour? (roughly 0-100 km/hr)

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Why do cars have anti-lock brakes? What is *traction control*, and why might you want it?