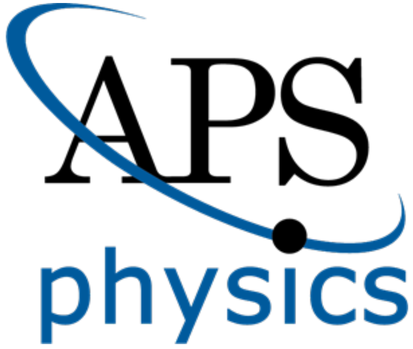
Listening to students in upper-division physics courses

Michael Wittmann
American Physical Society



Physics Teaching

Get the Facts Out

PhysTEC Physics Teacher Education Coalition

Thriving Depts.

EP3 Effective Practices for Physics Programs

APS physics

Leadership

workshop for new physics and astronomy faculty

NPRLG NSF Physics REU Leadership Group

2021 PHYSICS DEPARTMENT CHAIRS CONFERENCE

June 3–4, 2021 ◆ Virtual

APS Community

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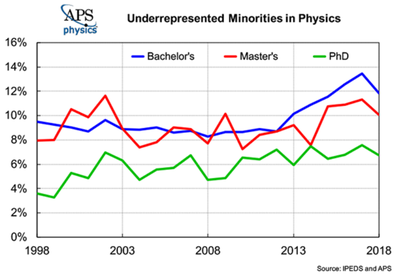

Careers In Physics

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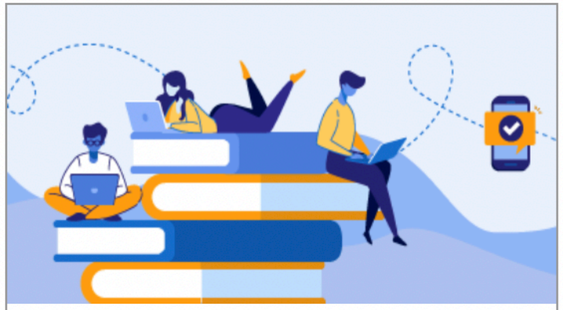
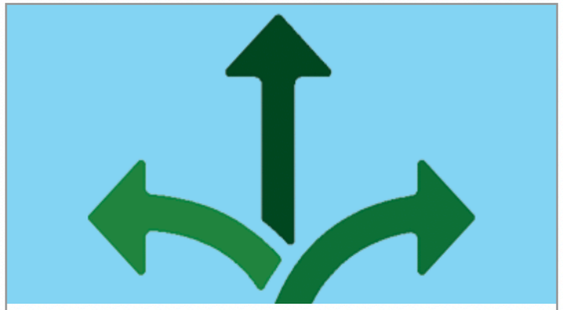
Resources for Job Seekers



A step-by-step guide to physics careers that align with your interests, talents, and values — and how to build a successful road toward them.

Professional Guidebook

Explore Physics Careers



See the breadth of opportunities for physics graduates in industry, national labs, and beyond — and get the guidance you need to land those jobs.

Careers 2022 Guide

Webinars for Physicists

Webinars offering discussion, career guidance, and advice. View Webinars

Career Paths

Explore the career options available to you and learn how to get there. Learn more

Career Mentoring Fellows Program

The Career Mentoring (CM) Fellows program seeks physicists working in industry, government/national labs, or academia, who are interested in mentoring undergraduate students, learning and teaching about diverse career paths of physics degree holders, and establishing a stronger connection with the physics community. Once you become a Career Mentoring Fellow, you can continue participate as long as you are still interested. We will keep your information and may contact you for future mentoring opportunities beyond 2022-2023. You may also reach out to us at careers@aps.org.

Applications for 2023 Career Mentoring Fellows are now open. Apply by Friday, August 15, 2022.

Philosophy

I. Listening to students is the FUN part

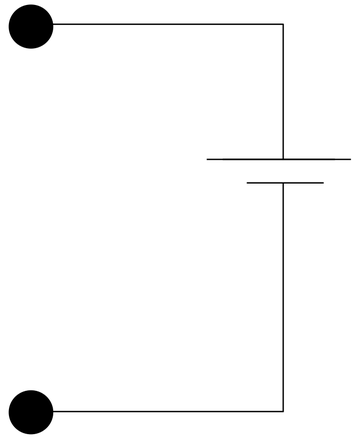
II. All the things that work in intro physics also work in advanced physics, because people learn the way people learn

III. Mathematics is a conceptual expression of the physics, but students need to learn that.

IV. Classes are smaller, engagement is more intense, students are human, and you are, too.

I. Listening to students…

Consider placing a steel wire in an open circuit;
what happens when a paper clip is placed
across open leads from a battery?

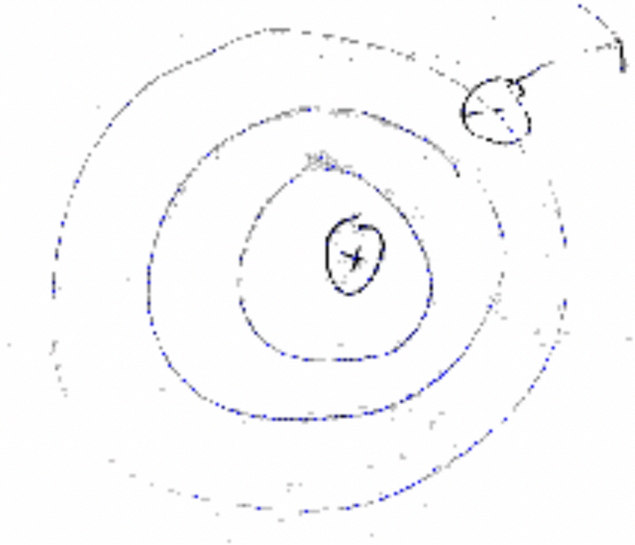


Inter.: How do [electrons in the steel wire] move?

Thomas: … Just the ones on the most outer shell would move.
They'd get pulled off the atom.

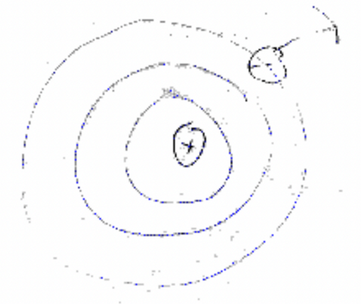
Inter.: And how do they get pulled off the atom?

Thomas: By the electric field. It attracts them and
pulls them away from the positive nucleus of the atom.



Students construct ideas

How does conduction work in this case?



David: Electrons get out from one atom…
This electron takes the place of this electron here,
this one takes the place of this one, and then this one,
… [The electron] comes again out of the atom
and it moves to the next one.”

Students build comparisons

What about doped substances - what effect does this have?

Thomas: I think the doped ones are better conductors
because I think it takes a lot of energy to remove the silicon electrons,
but if you add electrons from a different metal, like aluminum,
which require less energy to be removed,
then you'd get more current using less energy.

Job #1

LISTEN TO YOUR STUDENTS

They’re really good at sense making with too little information.
You need to help them with that.

(Also: find someone else to talk to about the things you hear.
It’s super important to have colleagues
who can reflect your curiosity back at you.)

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II. A smorgasbord of teaching

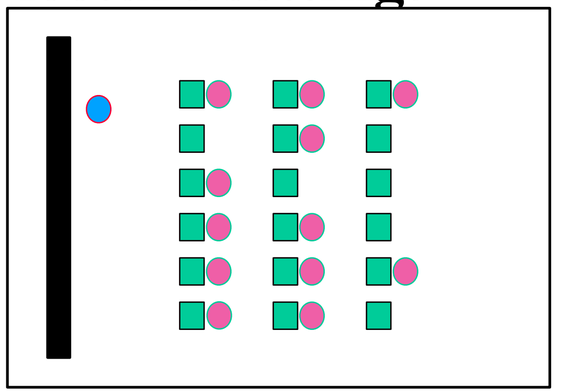
- Teach in the ways that work best for you. Plural.
- Use methods shown to be successful at the introductory level
- Create and adapt materials as needed.

Use what works - be creative!

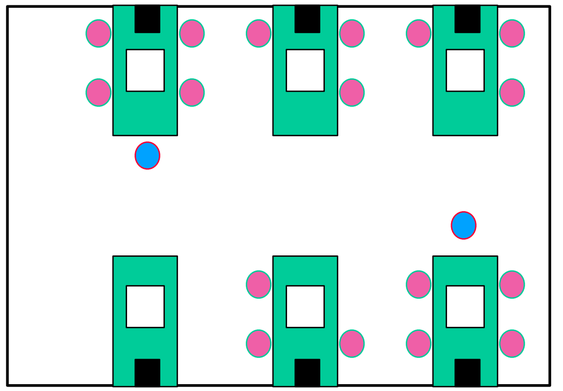
For a junior level quantum course, we used:

- Lecture *and* Tutorials, mixed in various ways.
- Just-in-Time-Teaching web essay assignments
- Applied physics homework assignments
- Simulations, sensors, interactive programs, etc.
- Examination questions with conceptual questions, not just mathematics (plus… essays!)

lecture setting:



tutorial:



Connect basics to bigger things

You can use real examples to teach basic QM,
rather than using abstract math problems.

Talking about X lets you talk about Y

- photoelectric effect → photomultiplier tubes
- LEDs and conductivity model → diodes
- Quantum tunneling → scanning tunneling microscopes

Things I've done:

- **QM:**
  interactive lectures, tutorials, JITT, simulations, applied examples, conceptual exam questions

- **Classical mechanics:**
  Overview Case Study, interactive lectures, tutorials, JITT, simulations, Group Problem Solving, flipped classroom

- **Math methods:**
  flipped classroom, group problem solving

How to flip - the case for math

How to flip - the case for math

$+A(-mr^2+k)\sin rt = 0$

only always true when $-mr^2+k=0$

$\Rightarrow r^2 = \frac{k}{m} \qquad r = \sqrt{\frac{k}{m}}$

not an unknown.

Need a 2nd solution

keep + only b/c symmetric and sign of A & B changing but being unknown as yet

let $x = B\cos rt$

then $-mBr^2\cos rt + kB\cos rt = 0$

$\Rightarrow r = \sqrt{\frac{k}{m}}$ again, B 2nd unknown

$$x(t) = A\sin\sqrt{\frac{k}{m}}t + B\cos\sqrt{\frac{k}{m}}t$$

Interpret $\sqrt{\frac{k}{m}}$ as units of $\frac{1}{\text{sec}}$

So a frequency, cyclic in 2π (for sin & cos)

$\Rightarrow$ call it $\omega_0 = \sqrt{\frac{k}{m}}$

the angular frequency

Try a second function

$x(t) = Ce^{rt}$

$Cmr^2e^{rt} + Ck\,e^{rt} = 0 \quad \Rightarrow C\left(mr^2+k\right)e^{rt} = 0$

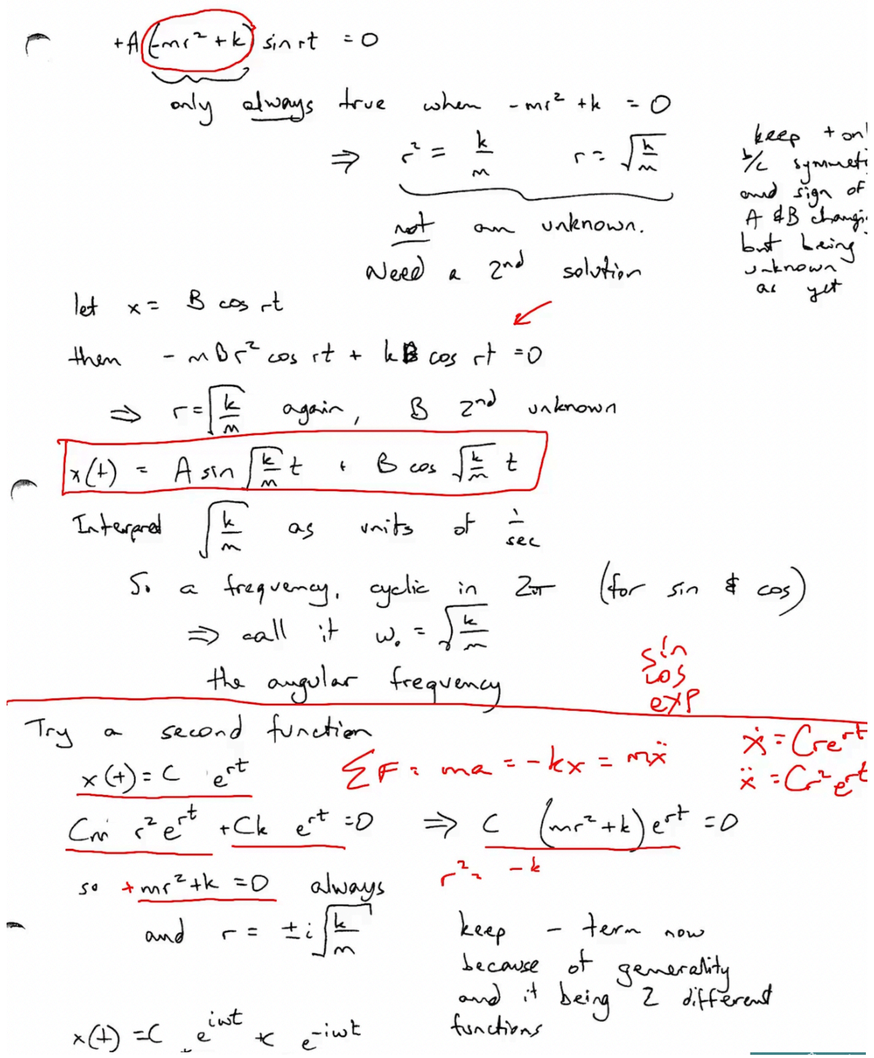
so $mr^2+k=0$ always

and $r = \pm i\sqrt{\frac{k}{m}}$

keep − term now because of generality and it being 2 different functions

$x(t) = C_+e^{i\omega t} + C_-e^{-i\omega t}$

How to flip - the case for math



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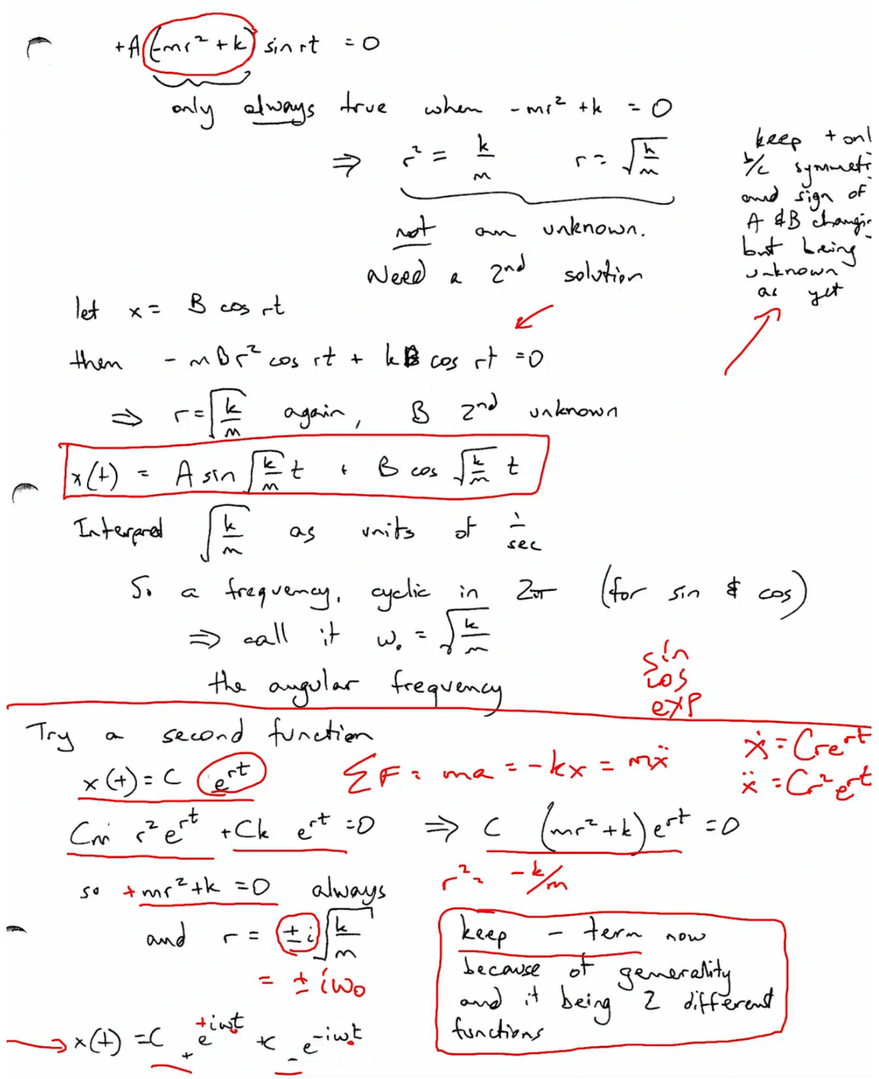
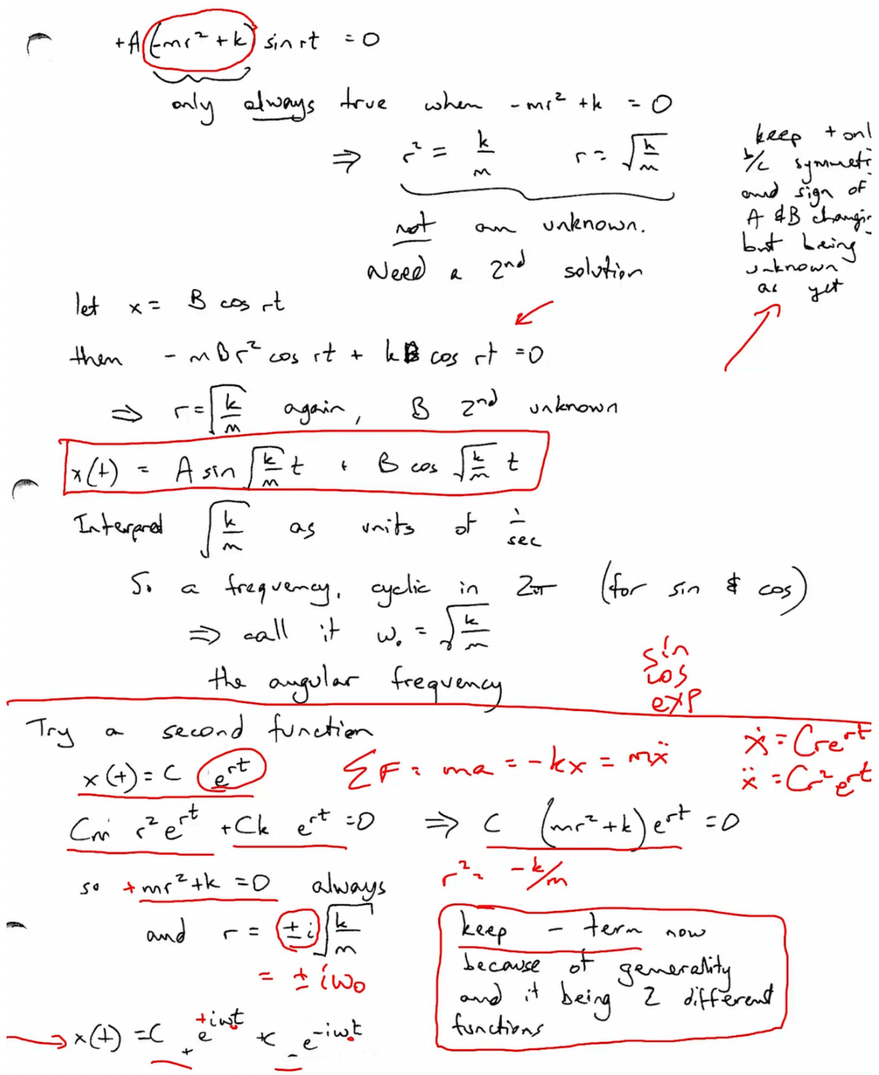


How to flip - the case for math



**Remember who you are teaching,
not the best in the class,
but the *whole* class.**

**Go slow. Be careful. Give reasons.
Unpack the math carefully.**

**Help them see what you see
and how you learned to see it.**

Job #2

BUILD ON WHAT WORKS

We know a lot about good teaching. Use it.

(Also: find someone else to talk to about your teaching.
It’s super important to have colleagues
who can observe and improve your exploration.)

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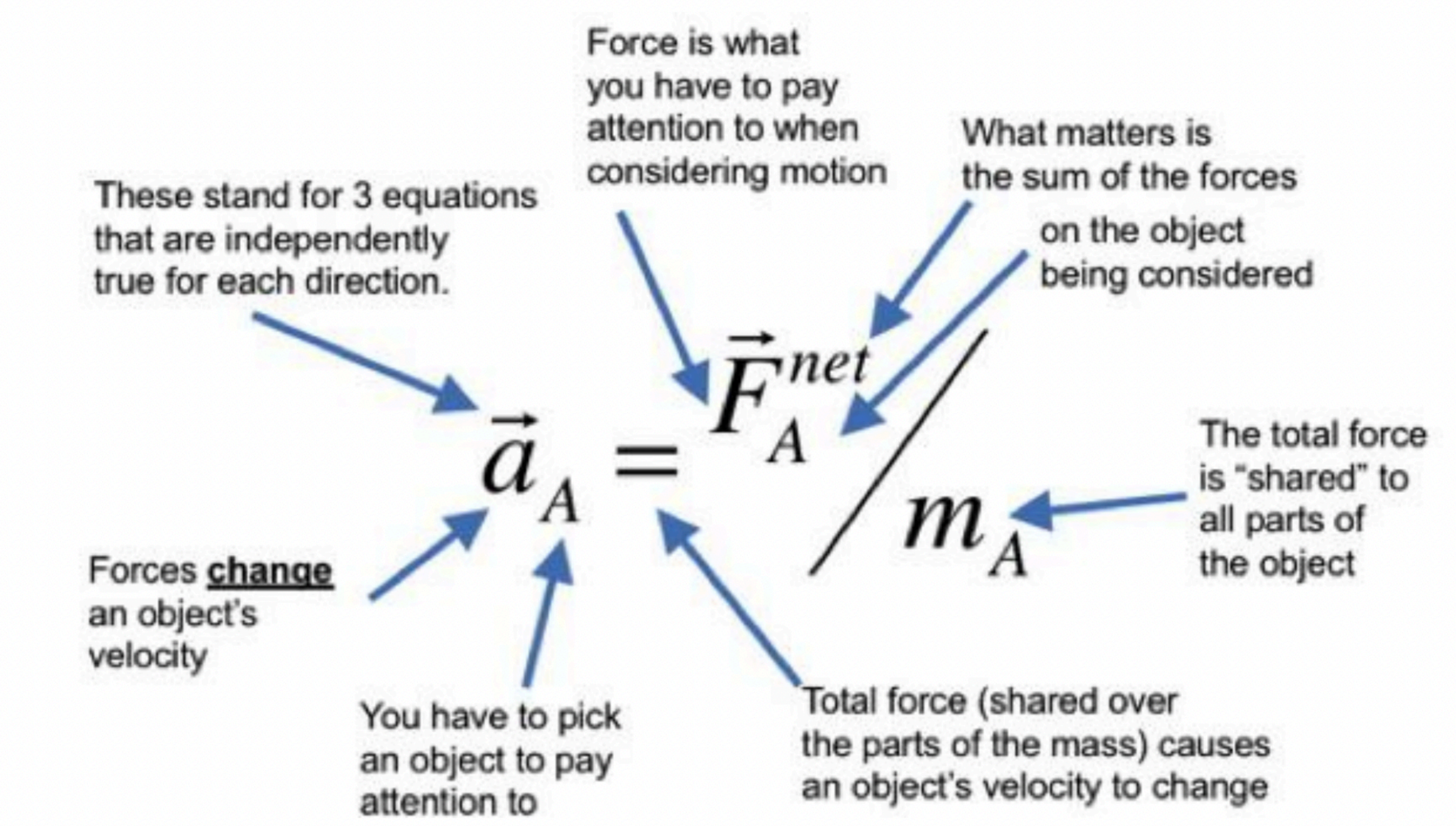
Mathematics and meaning

Let’s start with a typical TLE. What does the equation “F=ma” mean?



Developing meaning from math

- Let’s do some of a tutorial in classical mechanics…

Reflection

- What did you notice?
- Where do you think your students will struggle?
- What will your students bring to the class that helps them succeed?

Job #3

GO DEEP ON THE MATHEMATICS, BUT SLOWLY

They have to learn how physics finds meaning in math.

(Also: find someone to talk to about this transition.
It’s super important to think about
what students have done before and they will do next.)

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Being human, in all its richness

- Small classes are chances to truly get to know your students
- They are developing their identities as physicists
- They are novices but not beginners
- They are *wonderful* human beings
- So are you - meet them in this place as a mentor and a guide

Reflection

- Students want to see a pathway. What parts of you might offer that path?

Job #4

BRING YOUR SELF INTO THE CLASSROOM

They need it.

(Everyone has that teacher that they remember.
Try to be that person to at least some of them, all the time.)

Philosophy

I. Listen

II. Build on the known

III. Add meaning to math

IV. Be human

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