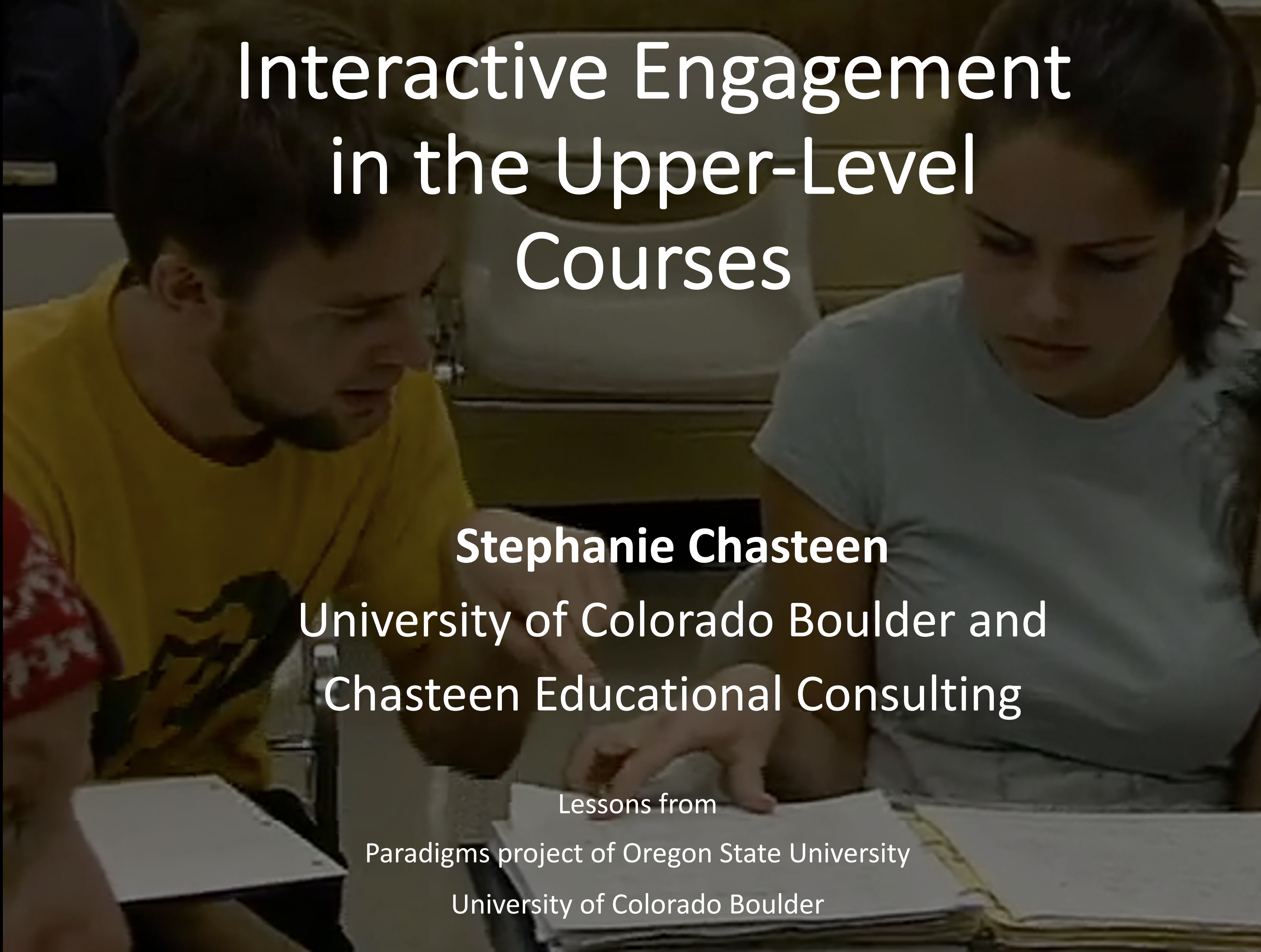

Interactive Engagement in the Upper-Level Courses

Stephanie Chasteen
University of Colorado Boulder and
Chasteen Educational Consulting

Lessons from
Paradigms project of Oregon State University
University of Colorado Boulder

- Work from **Oregon State University Paradigms** Project (Liz Gire and Corinne Manogue)
- And from **University of Colorado Boulder** (Stephanie Chasteen, Steve Pollock, and others in the physics education research group)

CU Boulder PER Group

PER @ CU-Boulder

Oregon State OSUPER Group

OSU Oregon State UNIVERSITY

Work in this talk supported by Science Education Initiative and National Science Foundation Grant # 0737118.

Paradigms in Physics
NSF DUE Grant Nos. 9653250, 0231194, 0618877, 0837829, 1023120, 1141330, 1323800, 1836603, 1836604

Raising Physics to the Surface
DUE-1612480

How is teaching upper-division courses different from teaching lower-division/intro courses?

Talk at your table as a whole group.

Table with the LONGEST list gets a prize.

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Active Learning In Upper Division

Opportunities & Challenges

Students:

- Strong personal interest
- Emerging identity as a physicist
- Planning to pursue physics-related careers
- More physics and math background

Content & Structure:

- Smaller classes
- No recitation
- Material is more advanced

Is doing active engagement in the upper division less “rigorous” for these potential future physicists?

No: The principles of teaching and learning still hold!

Steve Pollock

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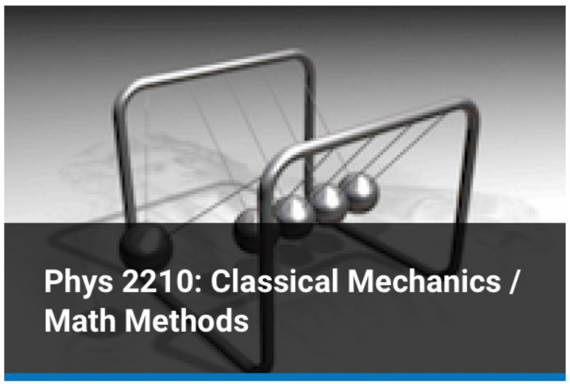
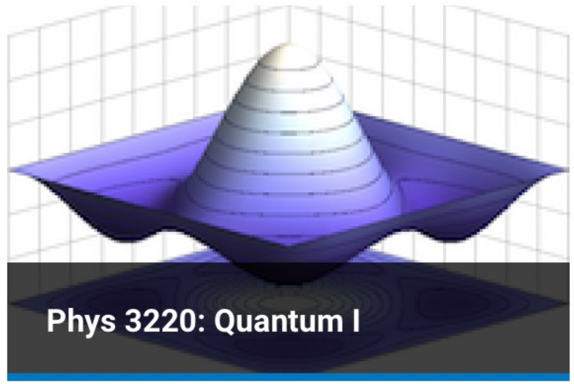
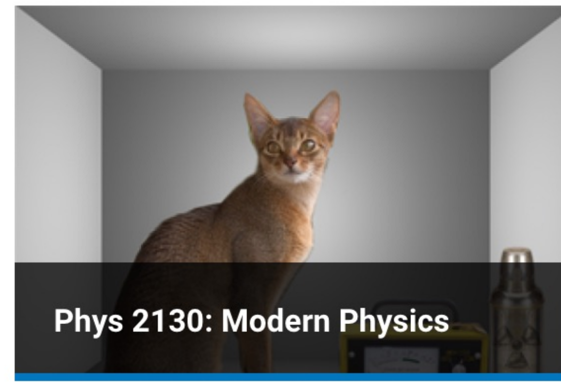
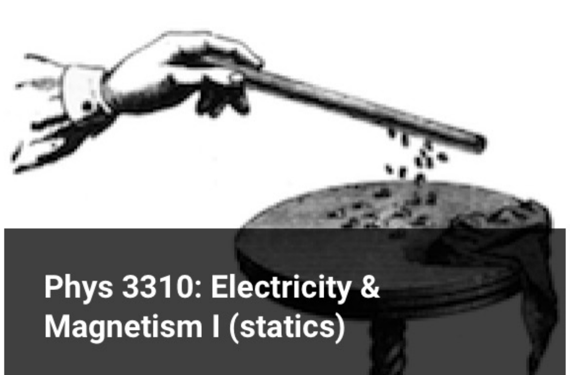
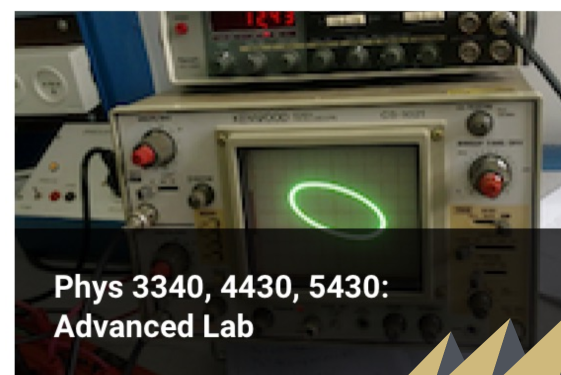
Class Mech, Quantum, **E&M**, Adv. Lab, Modern https://www.colorado.edu/sei/departments/physics











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The array of techniques

Classroom Techniques @ CU

Traditional lecture blended with interactivity.

- Explicit learning goals
- Modified HW
- Simulations & demos
- Small handheld whiteboards
- Clicker questions ("Think Pair Share")
- Kinesthetic activities
- Group activities / tutorials

OSU is more of a "flipped" class structure

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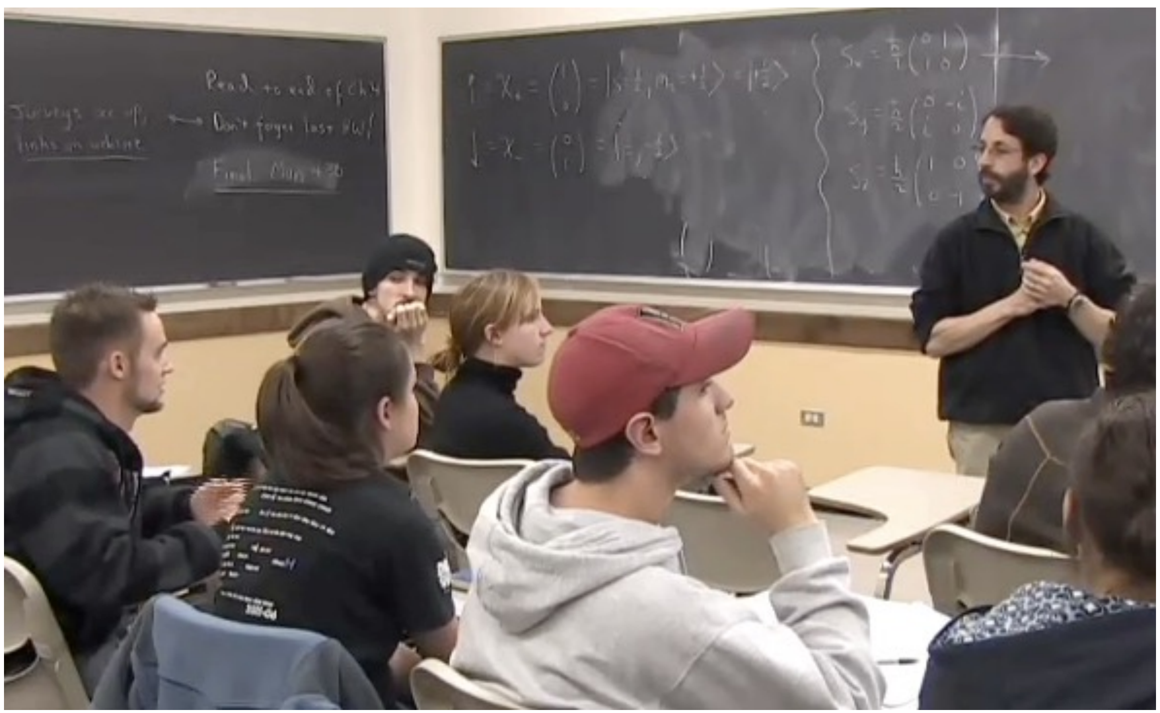
Do we lecture? Yes!

There is a time for telling.

It is just not too soon.



- Adapted from Dan Schwartz.

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Lecture & Activities Complement Each Other

In Lecture…

The Instructor:

- Inspires.
- Covers lots fast.
- Models speaking.
- Models problem-solving.
- Controls questions.
- Makes connections.

In activities…

The Students:

- Experience delight.
- Slow, but in depth.
- Practice speaking.
- Practice problem-solving.
- Control questions.
- Make connections.

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Learning goals and assessments

What are learning goals?

- What students should do as a result of instruction.
- Align **goals**, **assessment**, and **instruction**
- Called "**Backwards Design**" approach

Learning goals	Assessment	Instruction & feedback
Students should be able to… interpret graphs and use them to predict behavior.	**Exam: Show students graphs of potential energy: Which of these points on the graph is stable? Why?**	**Group activity with topographic maps as an analogy for potential energy. HW applications.**

Learning Goals

- From faculty group
- Framed course transformations & assessment
- Made explicit to students

Discuss (3 min) How might you know if a student had achieved any one of these goals?

Students should

… be able to achieve physical insight through the mathematics of a problem

… be able to choose and apply the appropriate problem-solving technique

… demonstrate intellectual maturity

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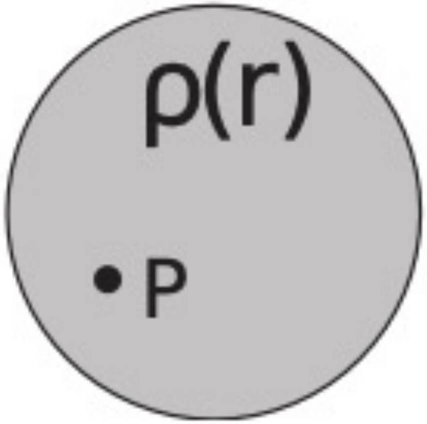
An example assessment question

Goal: Students should … be able to choose and apply the appropriate problem-solving technique

DO NOT SOLVE the problem, we just want to know:
- The general strategy (half credit)
- Why you chose that method (half credit)

A solid non-conducting sphere, centered on the origin, with a non-uniform charge density that drops off as 1/r. Find E (or V) at point P.



*Colorado Upper-Division Electrostatics Assessment, open-ended version

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Modified Homework (Griffiths)

Griffiths:

Consider a field $\boldsymbol{E} = c\,\frac{\vec{\boldsymbol{r}}}{r^2}$.

Calculate the divergence and the curl. Test your answers using the divergence and Stoke's Theorems.

Griffiths' calculation HW doesn't address our learning goals

Griffiths:

Consider a field $\boldsymbol{E} = c\,\frac{\vec{\boldsymbol{r}}}{r^2}$.

Calculate the divergence and the curl. Test your answers using the divergence and Stoke's Theorems.

Students should

... be able to achieve physical insight through the mathematics of a problem

... be able to choose and apply the appropriate problem-solving technique

... demonstrate intellectual maturity

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Modified Homework

Consider a field $\boldsymbol{E} = c\,\frac{\vec{\boldsymbol{r}}}{r^2}$.

A) Sketch it.

B) Calculate the divergence and the curl. Test your answers using the divergence and Stoke's Theorems.

C) What are the units of c?

D) What charge distribution would you need to produce this E field? Is this a δ-function at the origin? Is it physically realizable?

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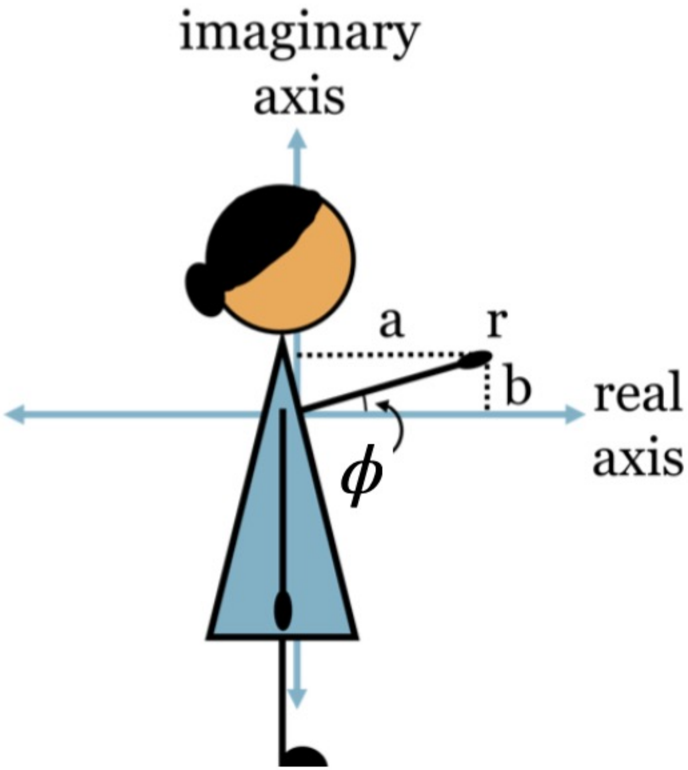
Kinesthetic Activities

Kinesthetic Activities

- Stand up.
- Each of you represents a point charge.
- Make a linear charge density.

Students form a non-uniform line charge

Complex Numbers with Arms



$$z = e^{ipi/2}$$

$$z = |z|e^{i\phi}$$

$$z = a + bi$$

Hahn, Gire, & Manogue, AJP, accepted

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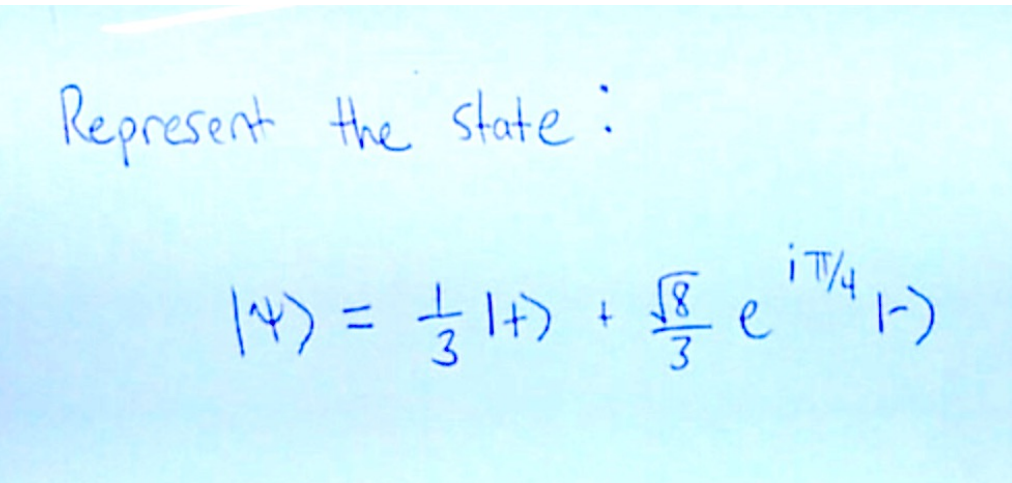
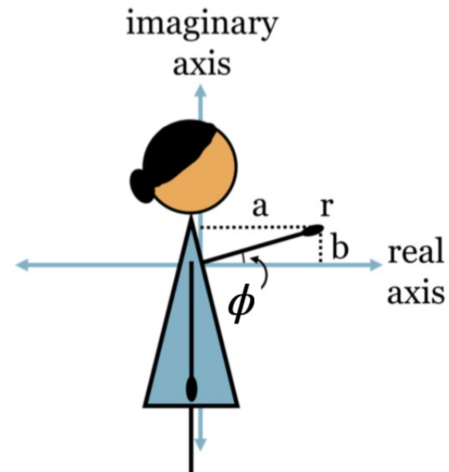
Spin states

Arms Representation of Quantum States





See Hahn, Gire, and Manogue
American Journal of Physics

Hahn, Gire, & Manogue, AJP, accepted

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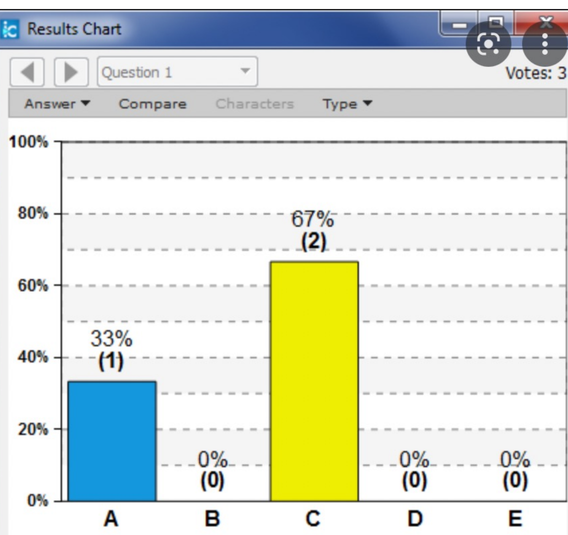
Clicker questions (“Think Pair Share” / Peer Instruction)

Clickers

Electronic response systems with histogram and anonymous vote. Different way to do Ed's Think Pair Share.

Also polleverywhere.com



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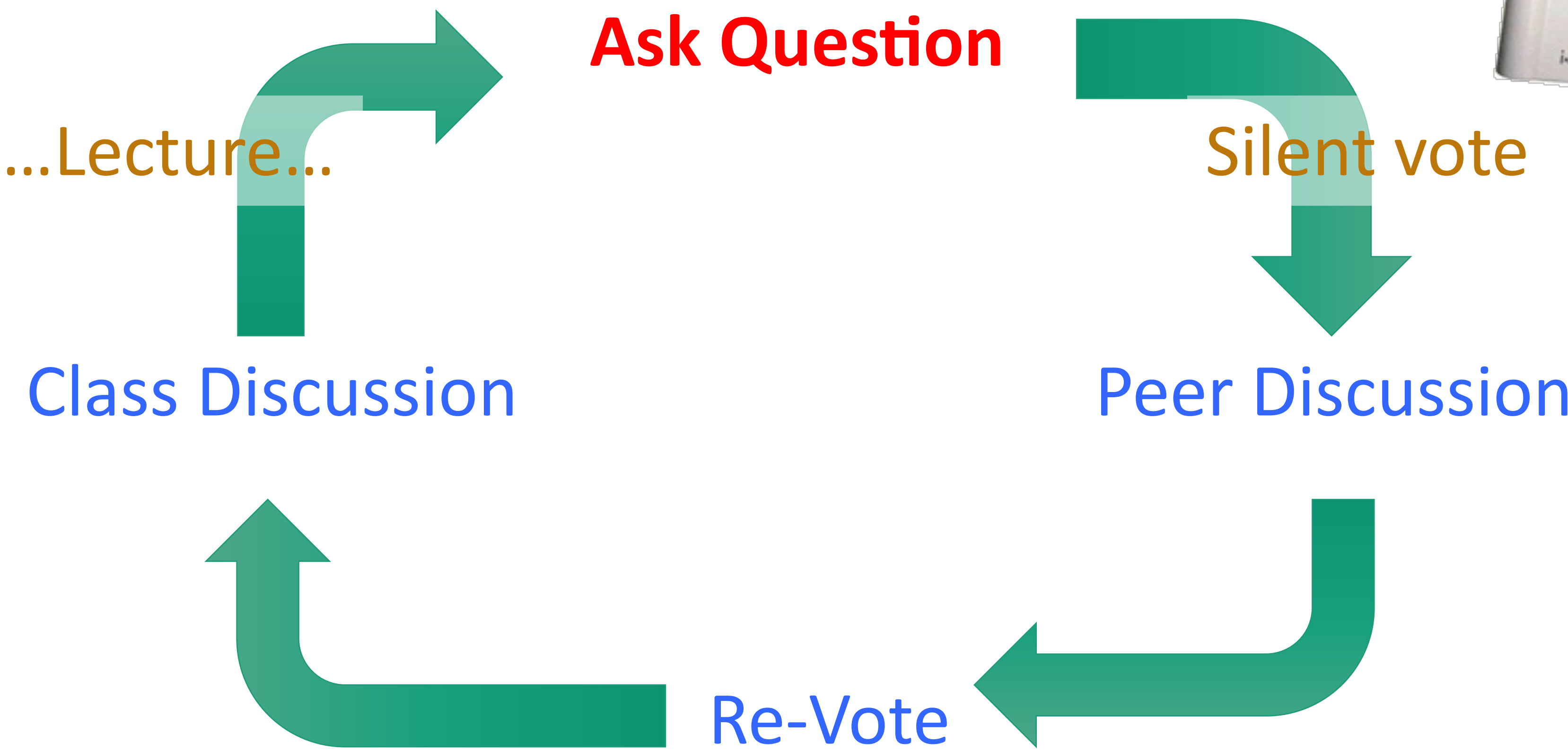
The anatomy of a clicker question



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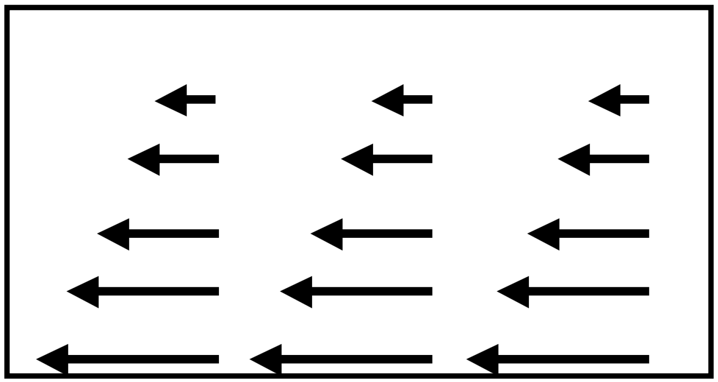
1.
4

Which of the following could be a static E field in a small region?

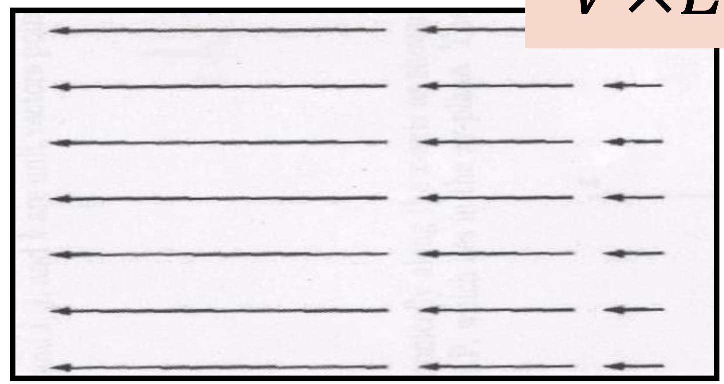
$$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$$

$$\nabla \times E = 0$$

I



II



A) Both

B) Only I

C) Only II

D) Neither

E) ??

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Example Questions

- Conceptual
- Math/Physics connection
- Application of ideas
- Step in calculation, proof, derivation

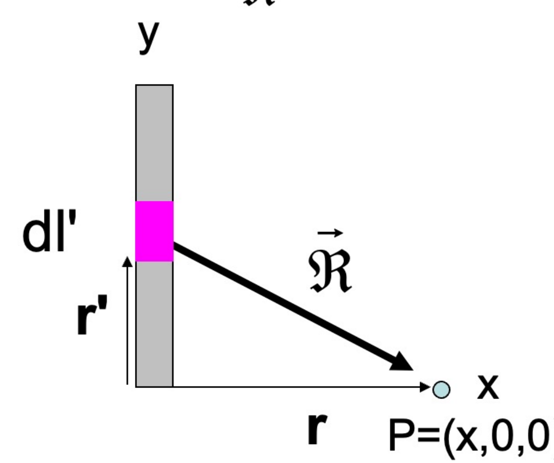
Look through your lecture notes for question opportunities

Correct answer D: Step in a calculation

To find the E- field at P from a thin line (uniform linear charge density λ):

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\int \frac{1}{\mathfrak{R}^2}\hat{\mathfrak{R}}\,\lambda dl'$$

What is $\mathfrak{R} = \left|\vec{\mathfrak{R}}\right|$?



A) X

B) y'

C) $\sqrt{dl'^2 + x^2}$

D) $\sqrt{x^2 + y'^2}$

E) Something *completely* different!!

For more see TPS breakout session later

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Clicker questions in upper division

https://www.youtube.com/watch?v=xxigdSbL3CM

More videos on clickers and interactive engagement across the curriculum at **STEMclickers.Colorado.edu**

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Questions so far on upper division reforms, learning goals, clickers?

Next up: group activities, whiteboards

Group activities: Worksheets and small whiteboards

On your whiteboard,
write down something you
know about
the dot product.

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Recall is harder than Recognize

Have students practice recall before an exam.

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Small Group Activities

- 2-3 students, each with pen
- Whiteboard or worksheet
- Hard problems
- Instructor facilitates
- Students share reasoning with the whole class
- Wrap-up discussion is crucial

In breakouts you can hear about upper division tutorials

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Brainstorm:
Neighbor chat: What are the benefits/challenges of

Worksheets vs Whiteboards

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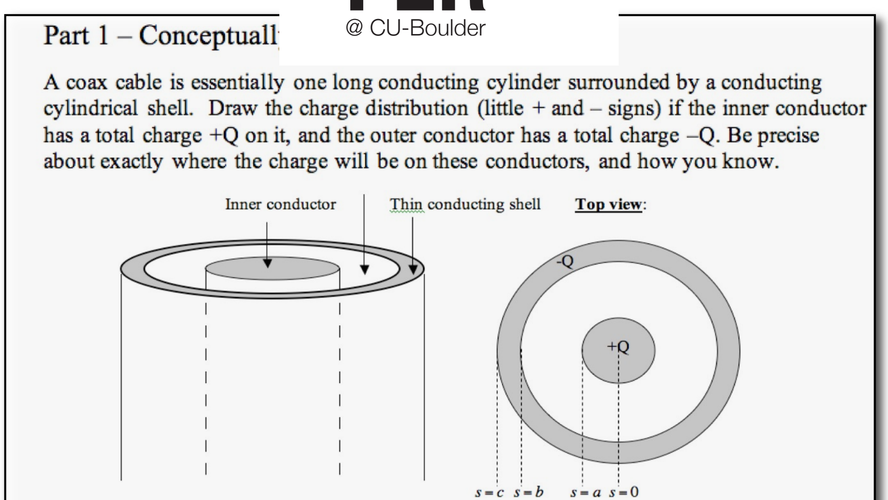
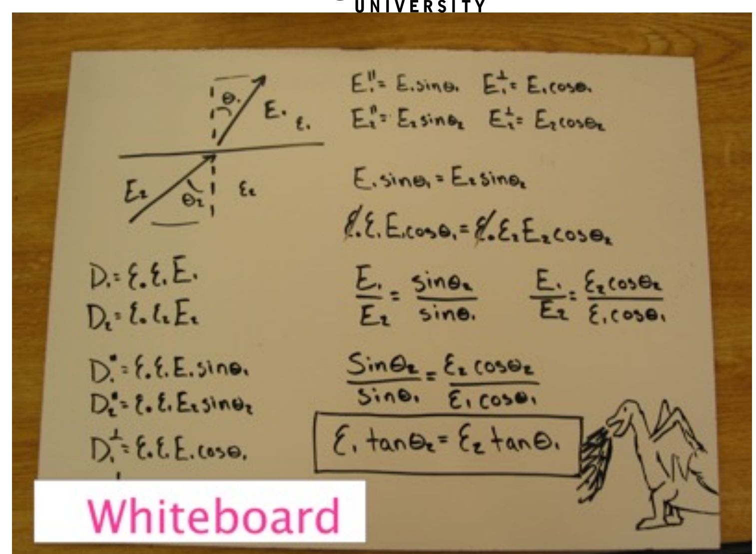

Part 1 – Conceptuall[y]

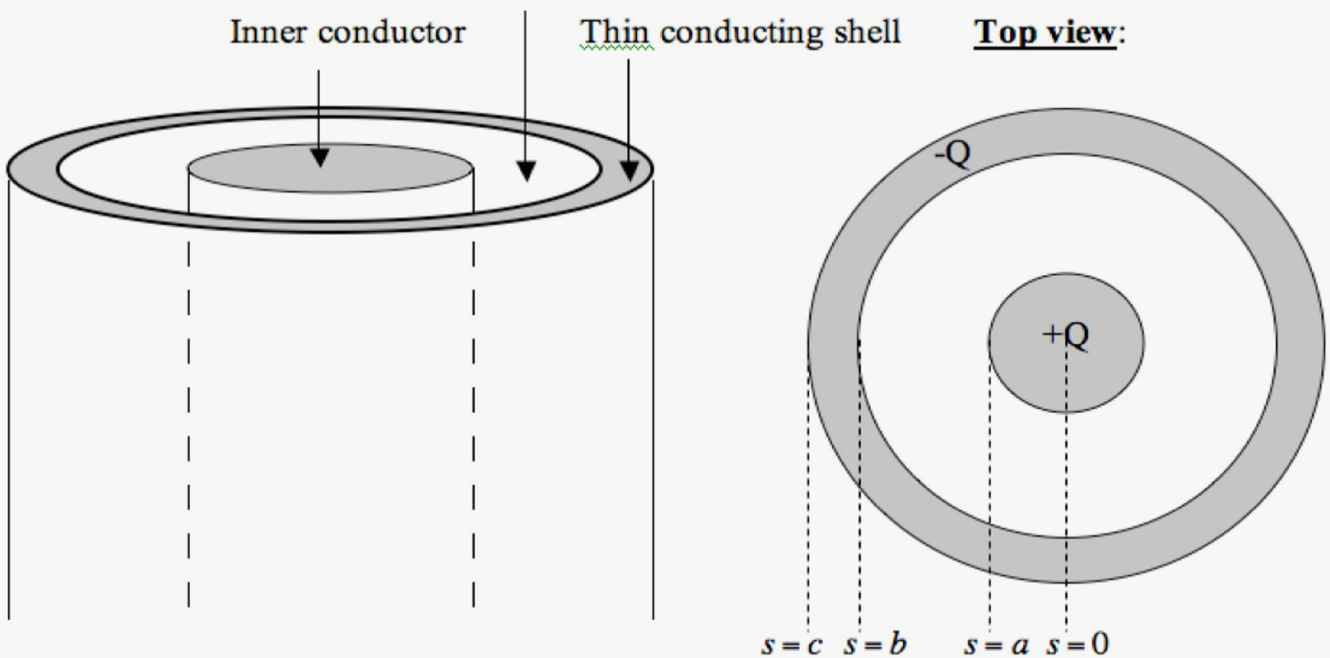
A coax cable is essentially one long conducting cylinder surrounded by a conducting cylindrical shell. Draw the charge distribution (little + and – signs) if the inner conductor has a total charge +Q on it, and the outer conductor has a total charge –Q. Be precise about exactly where the charge will be on these conductors, and how you know.



CU: Worksheets: 1-2 pages, once/week + clicker questions

Part 1 – Conceptually Understanding Conductors

A coax cable is essentially one long conducting cylinder surrounded by a conducting cylindrical shell. Draw the charge distribution (little + and – signs) if the inner conductor has a total charge +Q on it, and the outer conductor has a total charge –Q. Be precise about exactly where the charge will be on these conductors, and how you know.



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OSU: Whiteboard pedagogy: Peer instruction in flipped structure

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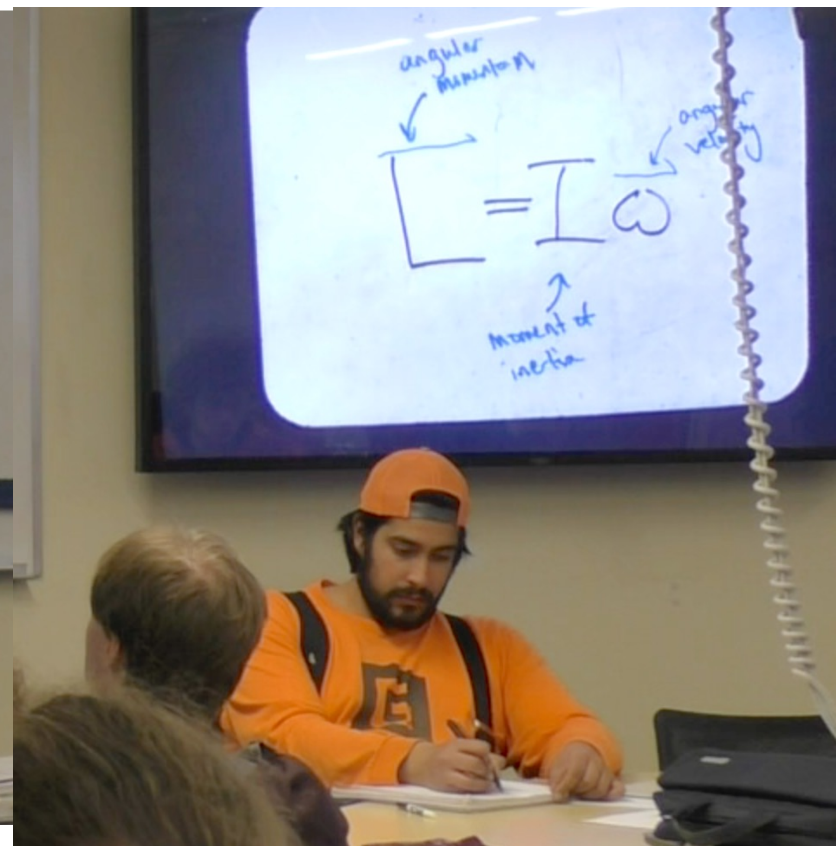
Whiteboard pedagogy

Viewable artifact. Can be made "anonymous" during share-out



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Example white board question

Calculate: $\vec{a} \cdot \vec{b}$

where $\vec{a} = 4m\hat{y}$

$\vec{b} = 2m, 60° \, cw \, from + \hat{x}$

Turn HW question into a whiteboard question

Griffiths problem 5.15

Two long coaxial solenoids each carry current I but in opposite directions.

The inner solenoid (radius a) has n1 turns per unit length, and the outer one (radius b) has n2.

Find B (i) inside the solenoid, (ii) between them, and (iii) outside both.

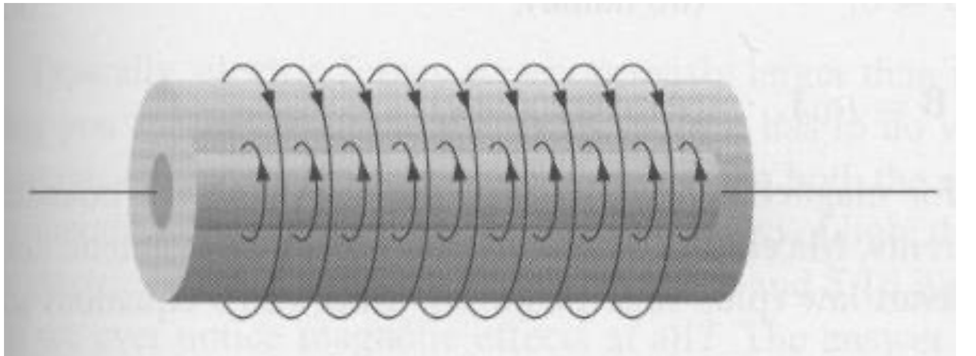
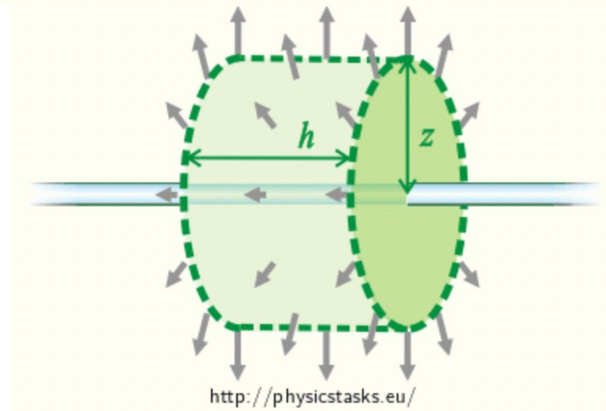


Figure 5.42

Scaffold or complete problems

An infinite line is uniformly charged with a linear charge density λ. Find a formula describing the electric field at a distance z from the line.

You write	They write
What formula do we use?	$\oint_S \vec{E}\cdot d\vec{S} = \frac{Q}{\varepsilon_0}$
Can you draw the Gaussian surface?	
$\oint_{la} \vec{E}\cdot\vec{n}dS = \oint_{la} EndS = \oint_{la} EdS\,.$	
Evaluate this integral	$\oint_{la} \vec{E}\cdot\vec{n}dS = E\,2\pi zl$

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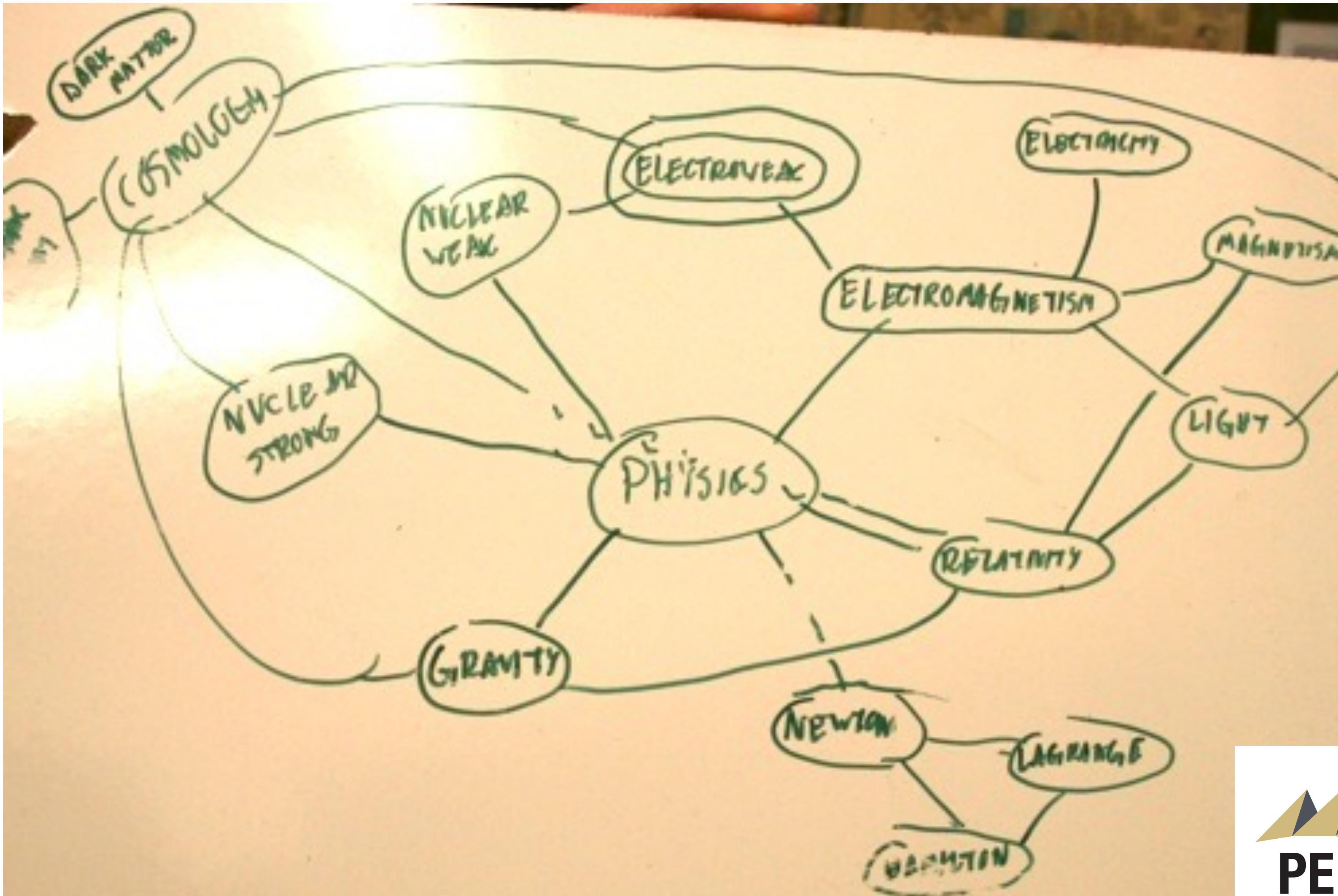
Concept mapping can be a good way to organize knowledge to see the big picture



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Small Whiteboard Questions

Great for

- Review
- sketching
- multiple representations,
- short calculations
- “next step”

Keep it short!

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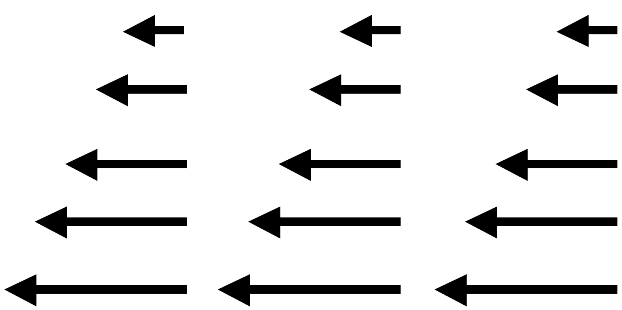
In groups of 2-3: Invent your own small whiteboard question (10 minutes)

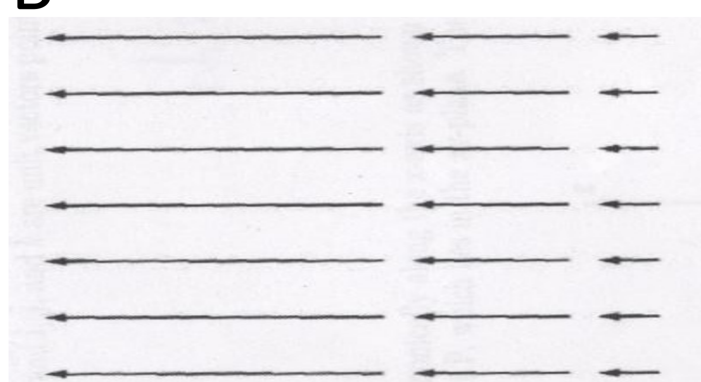
- Suggestion: Build on the clicker question below.
- Alternatively, take something from a recent course you taught.
- Can you build to the next step? Help students recall? Apply?
- Write it on your whiteboard

Which of the following could be a static E field in a small region? (Answer: B)

A



B



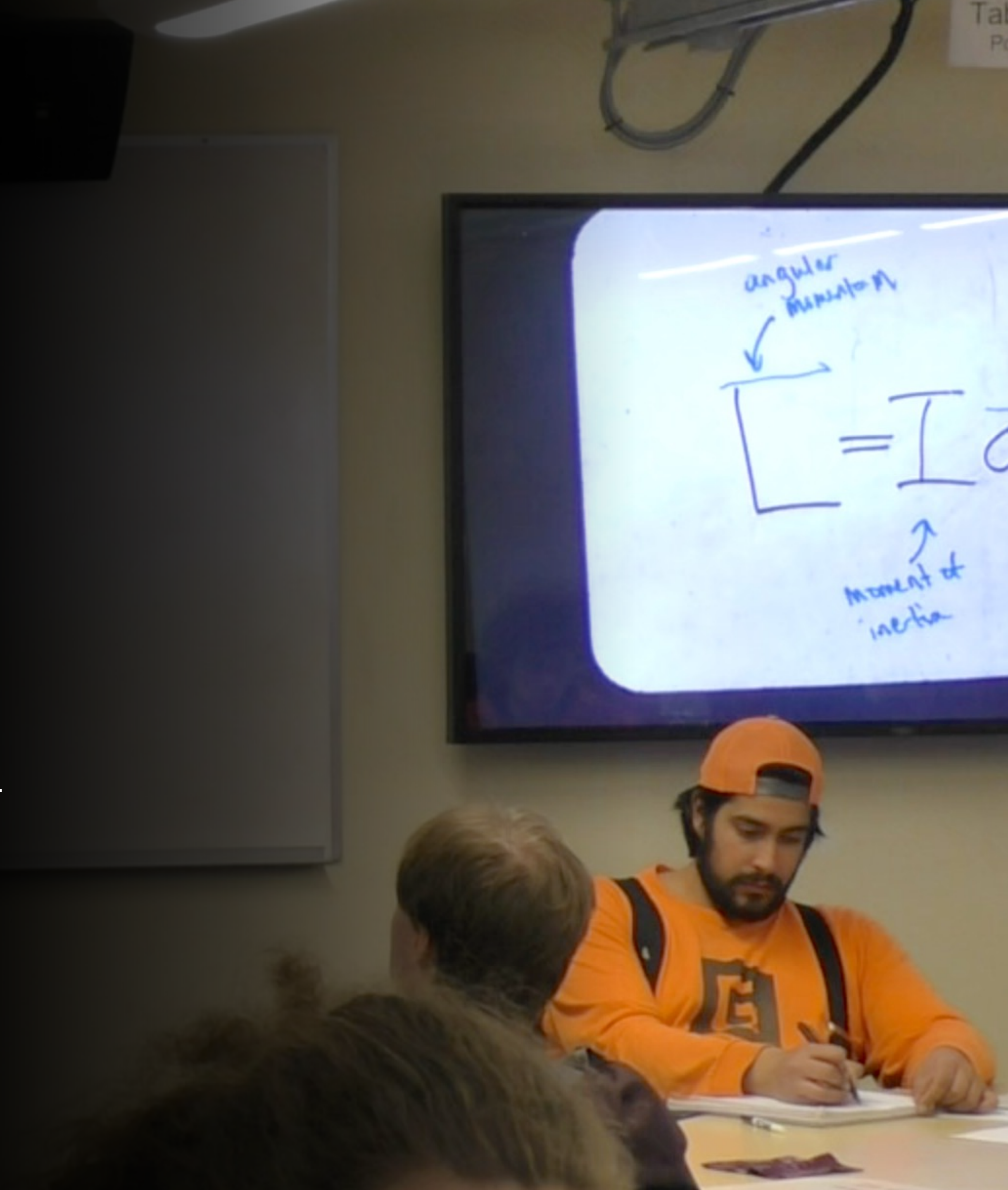
$$\nabla \cdot E = \frac{\rho}{\varepsilon_0}$$

$$\nabla \times E = 0$$

Talk with your group, and be ready to share out

- In what context would you ask this question?
- What are you hoping to learn about your students by asking this question?
- What student responses are you anticipating? (Difficulties & various forms of a correct answer?)
- What discussions could you have with your class around these responses?

Questions or comments on whiteboard activities?



Closing thoughts

Establish classroom norms that everyone sometimes gets things wrong

- It is the truth
- Promotes equity
- Encourages collaboration (it take courage to be publicly wrong)
- Isn't how we are used to doing things!

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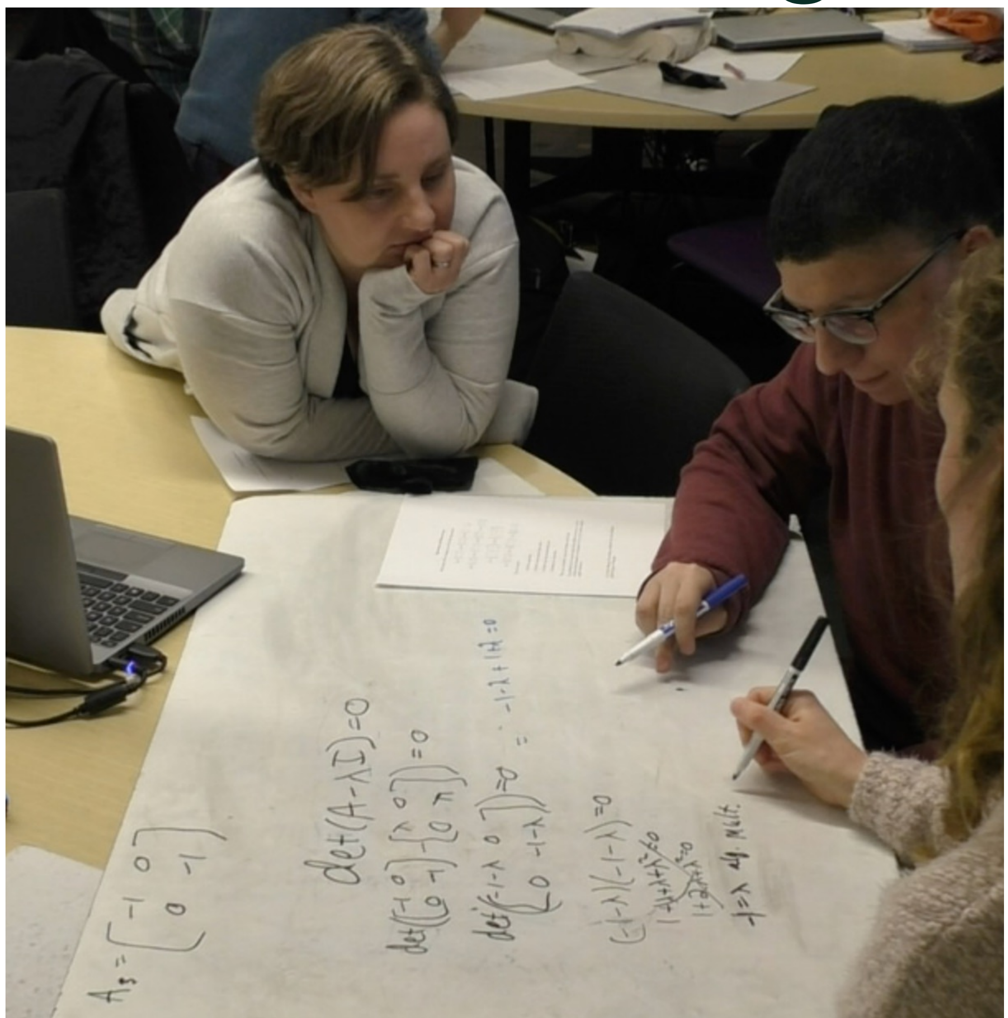
Conceptual understanding doesn't come along for free



Talk to other instructors

Summary

- Active learning pedagogies can work very well in advanced physics courses.
- Well-timed lectures enhance active learning
- Peer instruction, whiteboards, worksheets, kinesthetic activities, tutorials; many are developed
- Wrap-up discussions are essential
- Start small
- Listen to students

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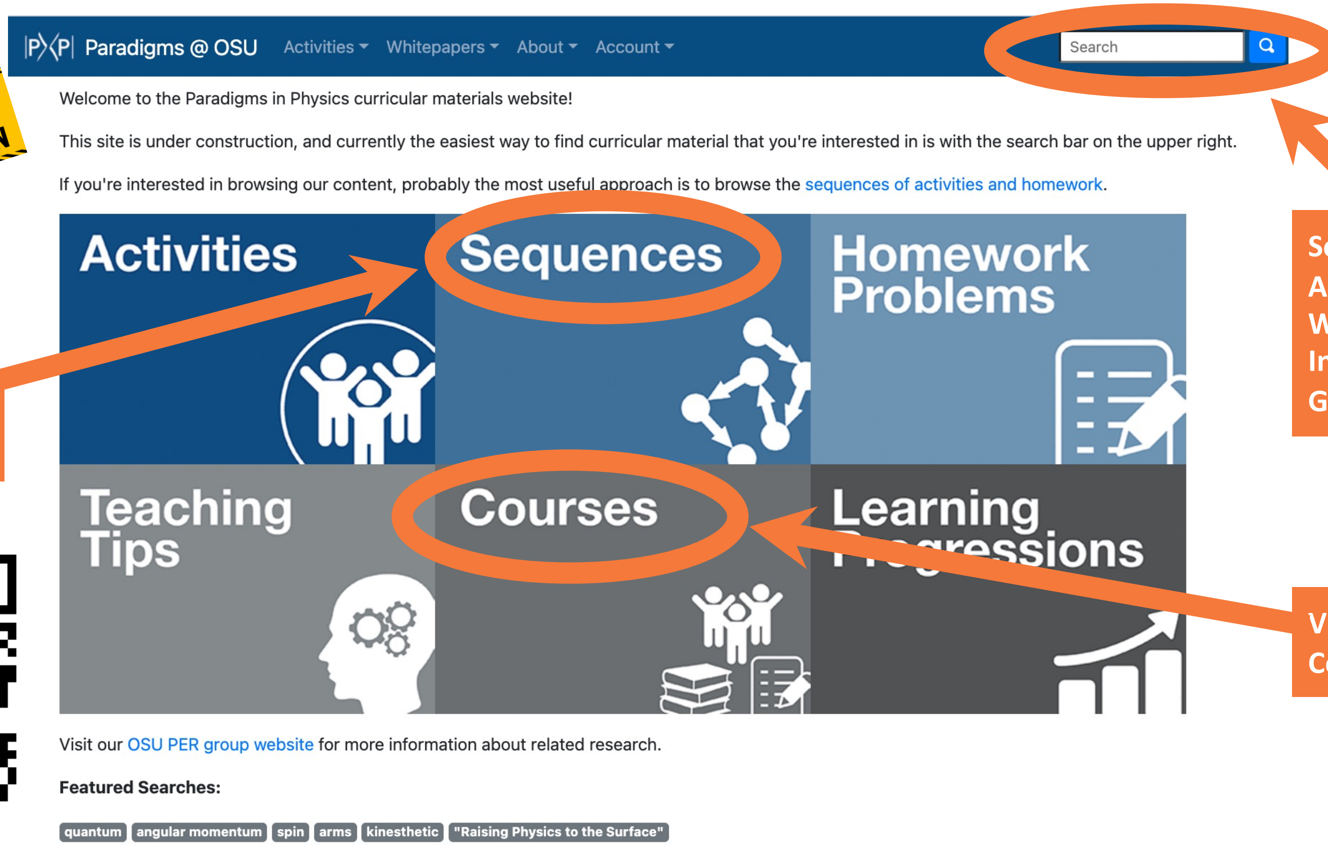
Want to learn more?

Paradigms in Physics

paradigms.oregonstate.edu



Search for Activities! With Instructor Guides

Find Actitivy Sequences!

View Whole Courses!

CU Boulder Material

Upper division CU SEI collection page
https://www.colorado.edu/sei/departments/physics/activities/courses

Videos on clickers and more
http://STEMclickers.Colorado.edu

Physport hosts CU's quantum materials at
https://www.physport.org/curricula/ACEQM/

New beta-version quantum tutorial resource is at
https://acephysics.net/

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