Interactive Engagement in Upper-Level Physics

Lessons from the Paradigms Program

http://physics.oregonstate.edu/portfolioswiki

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& the whole
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Support

- National Science Foundation
  - DUE-9653250, 0231194, 0618877
  - DUE-0837829, 1023120, 1323800
  - DUE-0088901, 0231032, 0837829
- Oregon State University
- Oregon Collaborative for Excellence in the Preparation of Teachers
- Grinnell College
- Mount Holyoke College
- Utah State University

Take-home Message

- Good teaching is like picking up someone else's baby.

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- Good teaching is like picking up someone else's baby.
  - Believe it will be a good experience for you and the baby!
  - Hold the baby firmly so it feels safe.
  - Engage the baby's attention with something fascinating.

What if you are not charismatic?

ISRO's Female Scientists

- After the success of the Mars Orbiter Mission on 24 September 2014. Women are 20% of the space agency's total workforce.

How is the upper-division different from the lower division?

The Upper-Division

- The upper-division is different from the lower division:
  - Smaller classes.
  - Invested students.
  - More complicated content.
  - More time/courses.
  - Opportunity to spiral.

My Agenda Today

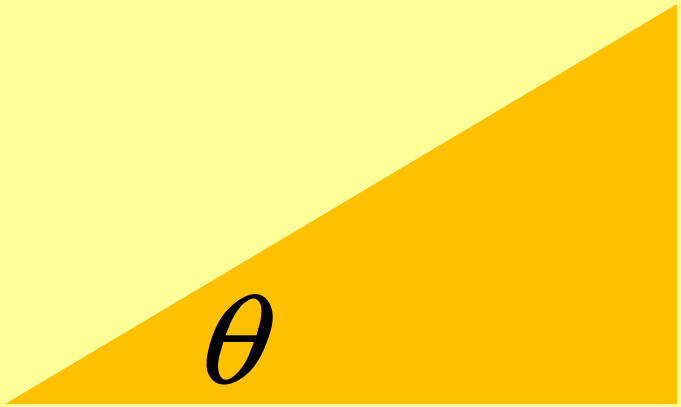
- Discuss a few “teaching principles” and related “teaching suggestions.”
- Model and discuss different types of activities.

Teaching Principles

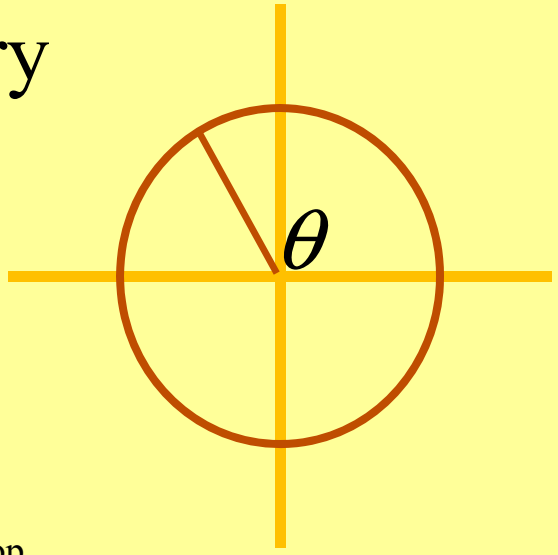
- Develop pedagogical content knowledge (PCK)
  - Use the results of PER
  - Talk with other faculty
  - Talk to advanced students
  - In the classroom: increase communication FROM students TO you

PER Result

- Most students know triangle trigonometry



- But not circle trigonometry



Teaching Principle

- Students have little experience with geometric visualization.

Suggestion

- Use kinesthetic activities to tap into students' embodied cognition.

Spin 1/2 Systems

- Stand up.
- Your left shoulder is the origin.
- Rotate your left arm to show the whole complex plane.
- Straight out in front of you, represents reals.
- Straight up represents the pure imaginaries.
- Show $\frac{1}{\sqrt{2}}(1-i)$

Spin 1/2 Systems

- Choose a partner.
- Together, show the state

$$|+\rangle_y = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\ i\end{pmatrix}$$

Spin 1/2 Systems

- Show the states that are physically equivalent to this state.

$$|+\rangle_y = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\ i\end{pmatrix}$$

Teaching Principle

- It takes effort to bring information into working memory.

Suggestion

- Use small whiteboards to help students activate the relevant information.

Small Whiteboards

- On your small whiteboard, write the electrostatic potential due to this point charge.

Using Small Whiteboards

- Make it safe to be wrong:
  - Insist that students answer, but allow a question mark.
  - Make answers anonymous at first.
- Different types of questions:
  - Review, comparing multiple representations.
  - Bring out common problems.
- Model professional problem-solving.

Teaching Principle

- Working memory has 7+/- 2 slots.

Suggestion

- Don’t occupy working memory slots with non-physics concerns.

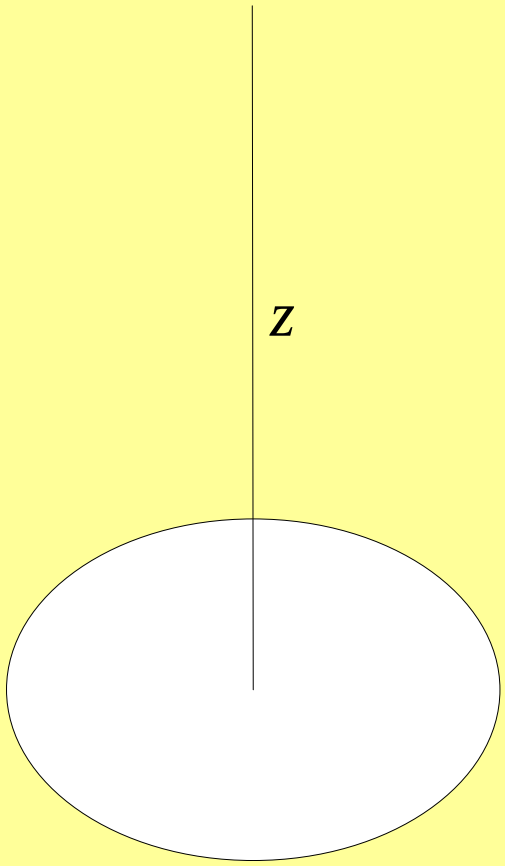
Teaching Principles

- Students must learn how to break a problem up into manageable pieces.
- Students must understand that solving physics problems is not just “doing math” about physics problems.

An Example

- Typical of EARLY upper-division work for physics majors and many engineers.
- Solution requires:
  - many mathematical strategies,
  - many geometrical and visualization strategies,
  - only one physics concept.
- Demonstrates different use of language.

Potential Due to Charged Disk



What is the electrostatic potential at a point, on axis, above a uniformly charged disk?

One Physics Concept

- Coulomb's Law:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

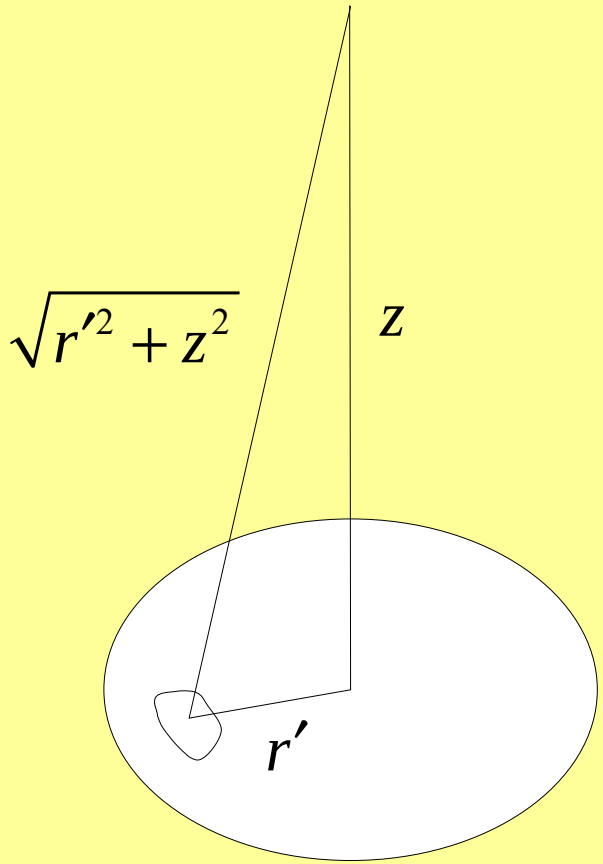
Superposition

- Superposition for solutions of linear differential equations:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$\rightarrow V(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma(\vec{r}')da'}{\left|\vec{r} - \vec{r}'\right|}$$

Chopping and Adding



Integrals involve chopping up a part of space and adding up a physical quantity on each piece.

Computational Skill

- Can the students set-up and do the integral?

$$V(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma(r')\,da'}{|\vec{r}-\vec{r}'|}$$

$$= \frac{\sigma}{4\pi\varepsilon_0}\int_0^{2\pi}\int_0^{R} \frac{dr'\,r'\,d\theta'}{\sqrt{r'^2+z^2}}$$

$$= \frac{2\pi\sigma}{4\pi\varepsilon_0}\left(\sqrt{R^2+z^2}-z\right)$$

Limits (Far Away)

$$V(\vec{r}) = \frac{2\pi\sigma}{4\pi\varepsilon_0}\left(\sqrt{R^2+z^2}-z\right)$$

$$= \frac{2\pi\sigma}{4\pi\varepsilon_0}\left(z\sqrt{1+\frac{R^2}{z^2}}-z\right)$$

$$= \frac{2\pi\sigma}{4\pi\varepsilon_0}\left(z\left(1+\frac{1}{2}\frac{R^2}{z^2}+\ldots\right)-z\right)$$

$$\approx \frac{1}{4\pi\varepsilon_0}\frac{\pi R^2\sigma}{z}$$

Constants vs. Variables

- Which of these symbols are constants and which are variables?

$$V(r,\phi,z)=\frac{\lambda}{4\pi\varepsilon_0}\int_0^{2\pi}\frac{R\,d\phi'}{\sqrt{r^2+R^2-2rR\cos(\phi-\phi')+z^2}}$$

Socratic vs. Groups

How does it feel to teach in these ways?

ò *d knowledge* vs ò *d questions*

class *class*

Everyone knows everything vs. No one knows anything

We Can Help!

- We have developed lots of materials: contact us and check out our wiki and ComPADRE.

  physics.oregonstate.edu/portfolioswiki

- Try our new online text:

  physics.oregonstate.edu/BridgeBook

- And published texts:

  McIntyre (QM), Dray (SR)

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Paradigms in Physics

Teaching is the art of leading students into a situation in which they can only escape by thinking.
— Dr. C. T. Bassoppo-Moyo

The Paradigms in Physics team is embarking on a new project to put detailed information about the various activities that we have developed on the web to encourage adoption by faculty at other institutions. We have already described our program as a whole in two papers and a general website. We are currently experimenting with a wiki format so that users will be able to offer detailed feedback. We expect this site to be updated on a nearly daily basis. Check back often!

You may enter this website at six different levels: individual activities arranged by content, individual activities arranged by pedagogical strategy, sequences of activities that we have found work well together to achieve particular pedagogical goals, descriptions of our courses, descriptions of things we have learned about how students learn and descriptions of things we have learned about how departments and teachers change.

- **More about us and our partners**
- **Reading mathematics in this Wiki**

This material is based upon work supported by the National Science Foundation under DUE Grant Nos. 9653250, 0088901, 0231032, 0231194, 0618877, 0837829.

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