Problem Solving in Upper-Level Courses

Lessons from the Paradigms Program

http://physics.oregonstate.edu/portfolioswiki

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Teaching Principle

- Students have little experience with geometric visualization.

Suggestion

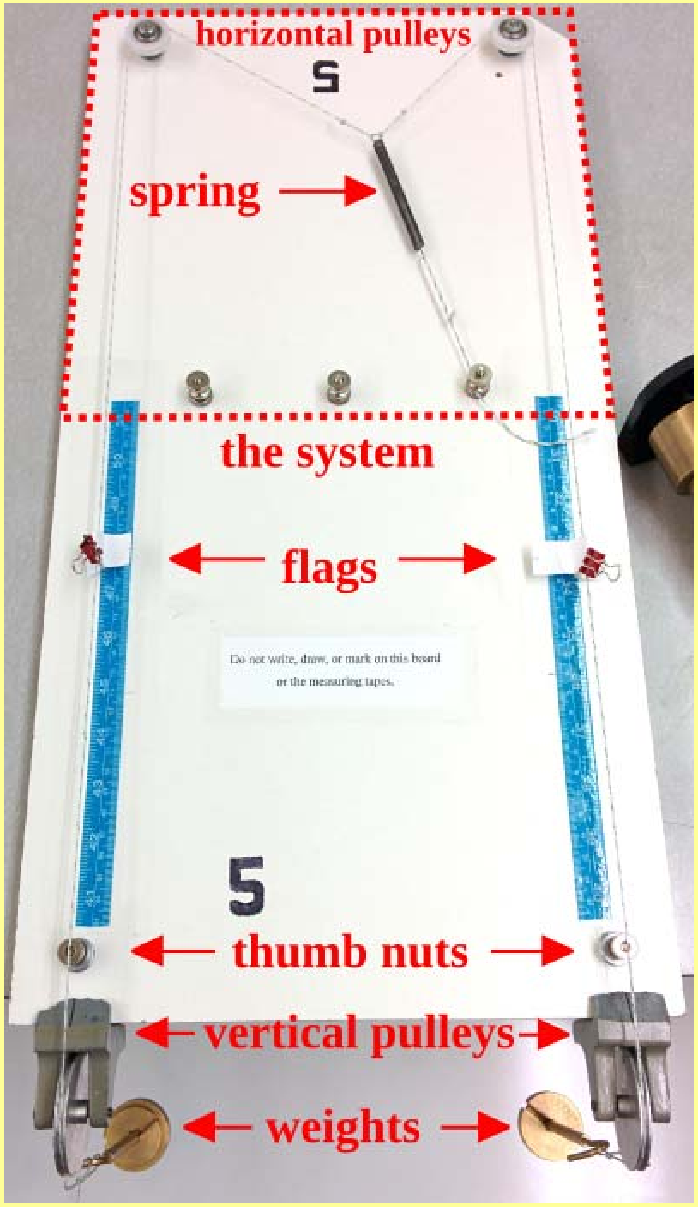
- Use tangible metaphors and kinesthetic activities to tap into students' embodied cognition.

Tangible Metaphors

- Raising Calculus (Physics) to the Surface

Tangible Metaphors

- Partial Derivatives Machine



Kinesthetic Activities

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

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 something you know about the dot product.

Affordances of Small White Board Questions

- Allow the instructor to see if everyone is on the same page.
- "Quiet" members of the class are encouraged to participate.
- Students vie to have their answers chosen.
- Keep everyone engaged and awake.
- Professional development: communication skills.

Teaching Principle

- Don't try to answer a question that students don't yet have.

Suggestion

- Use active engagement to prime "the teachable moment."

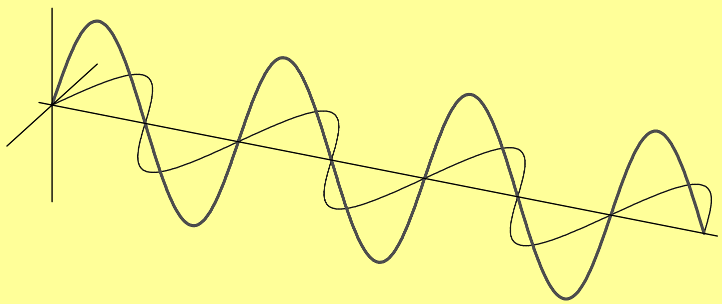
Compare and Contrast Activities

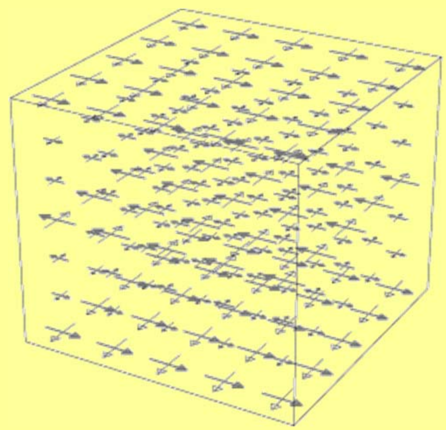
- On your medium whiteboards, construct a square grid of points, approximately two inches apart, at least 7 by 7.
- I will draw an origin and a vector $\vec{k}$ on your grid.
- For every point on your grid, imagine drawing the position vector $\vec{r}$ to that point, calculate $\vec{k} \cdot \vec{r}$
- Connect the points with equal values of $\vec{k} \cdot \vec{r}$

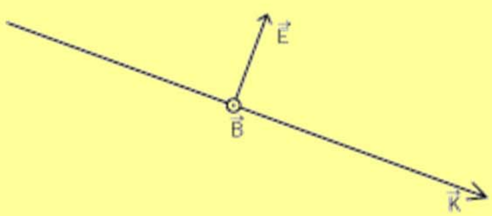
Affordances of Medium Whiteboards

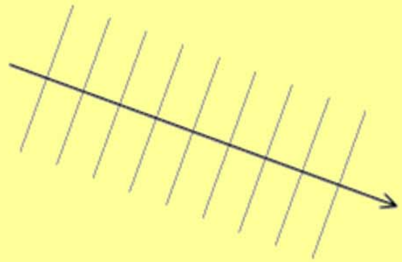
- Provide the opportunity:
  - to develop and practice problem-solving strategies,
  - to compare and contrast answers,
  - for mini-presentations,
  - to discuss synthesis, evaluation, decision-making, etc.

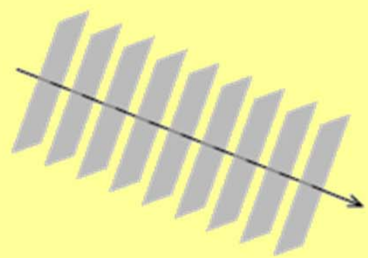
Plane Wave Representations











Teaching Principle

- To become good problem-solvers, students must LEARN to move smoothly between multiple representations.

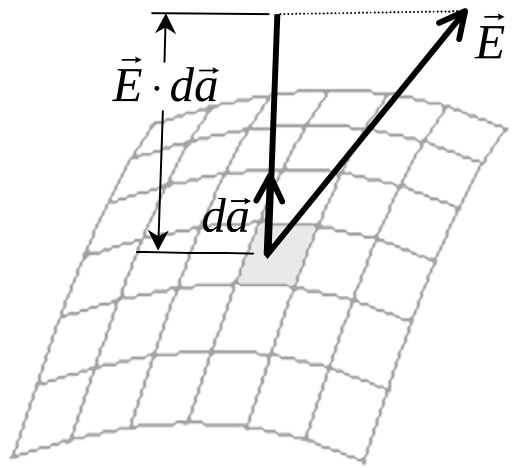
Suggestion

- Use activities that require students to go back and forth between multiple representations.

Multiple Representations

1. Flux is the total amount of electric field through a given area.

2. $$\Phi = \int \vec{E} \cdot d\vec{a}$$

3. 

	Ket	Function	Matrix
Hamil-tonian	$\hat{H}$	$-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$	$\begin{pmatrix} E_1 & 0 & 0 & \cdots \\ 0 & E_2 & 0 & \cdots \\ 0 & 0 & E_3 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{pmatrix}$
Eigen-state	$\|n\rangle$	$\psi_n(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)$	$\begin{pmatrix} 1 \\ 0 \\ 0 \\ \vdots \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}, \quad \cdots$
Coeff-icient	$c_n = \langle n \| \psi \rangle$	$c_n = \int_0^L \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)\psi(x)\,dx$	$\begin{pmatrix} 0 & \cdots & 1 & \cdots \end{pmatrix}\begin{pmatrix} c_1 \\ \vdots \\ c_n \\ \vdots \end{pmatrix}$

Effective Activities

- Are short, containing approximately 3 questions.
- Ask different groups to apply the same technique to different examples.
- Involve periodic lecture/discussion with the instructor.

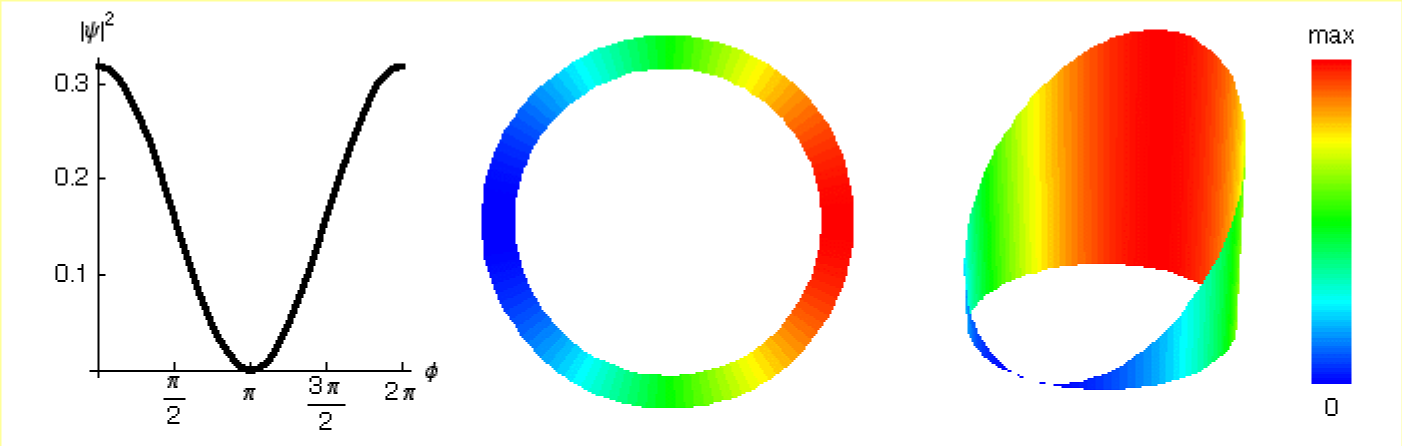
Teaching Principle

- Students are smarter than you think, but know far less.

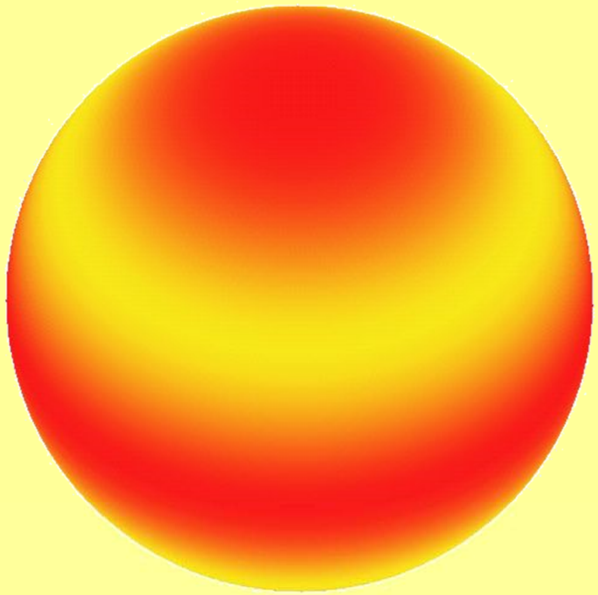
Suggestions

- Ask yourself when students would have learned something you expect them to know.
- Keep a list of "surprising" things that students don't know and use it to choose activities (PCK).
  - How to interpret the vertical axis.

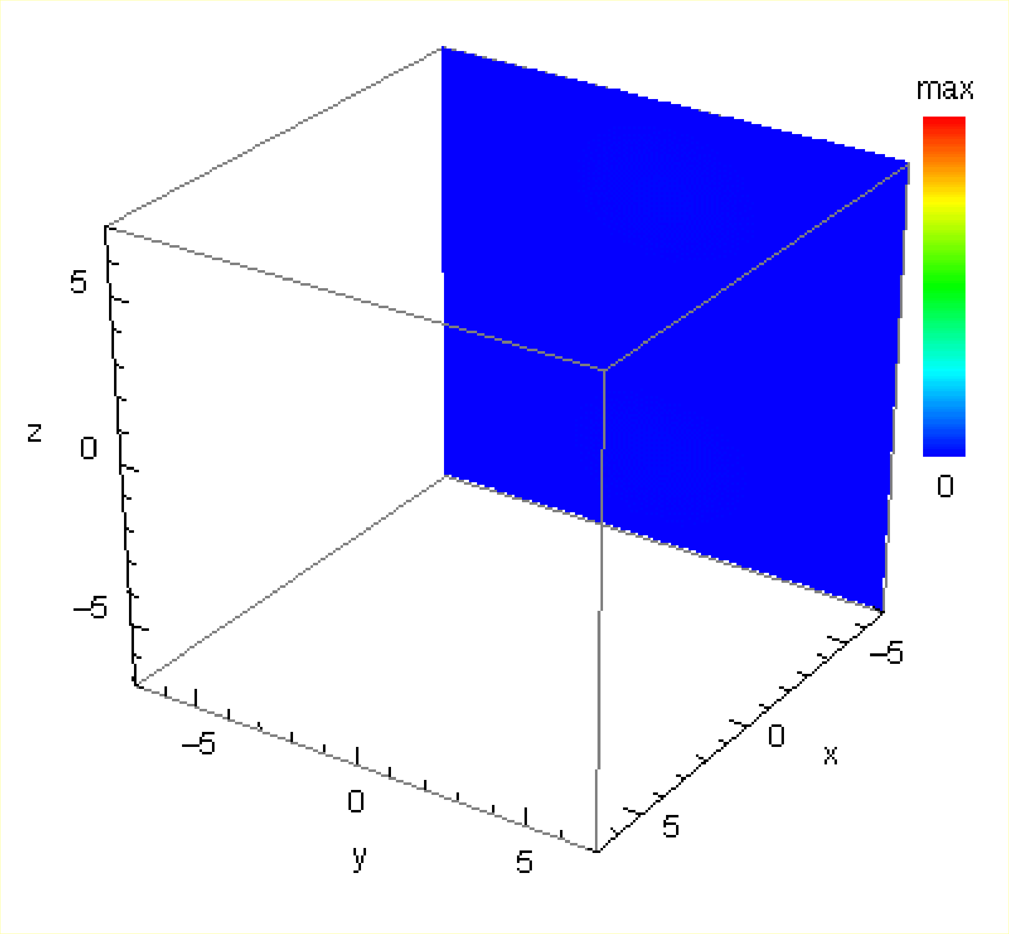
Quantum Ring



Rigid Rotor—Spherical Harmonics



Hydrogen Atom



Simulations

- Design experiences based on known student problems.
- Choose thoughtfully:
  - "black box" (e.g. PhETs, OSP)
  - "open" (e.g. Mathematica/Maple)
  - "student code writing"
- Avoid "Ooooh-Aaahh!!!" by asking students to answer specific questions.

Active Engagement

- Effective but Slow
  - Precious commodity
  - Use wisely
- Special Needs of Upper-Division
- Easily Over-Scheduled
- Can Get Out-of-Synch
- Short Activities Mid-Lecture
- Moving Rooms: awkward but possible

Take-home Message

- You are in this for the long haul!
  - Join or build a learning community, preferably in your own department.
  - Make it safe for each person to grow in their own way.
  - Use reflective practice: If it worked, figure out why so you can do it again and share it. If it didn't work, figure out why so you can do it differently next time.

Lecture vs. Activities

- The Instructor:
  - Paints big picture.
  - Inspires.
  - Covers lots fast.
  - Models speaking.
  - Models problem-solving.
  - Controls questions.
  - Makes connections.
- The Students:
  - Focus on subtleties.
  - Experience delight.
  - Slow, but in depth.
  - Practice speaking.
  - Practice problem-solving.
  - Control questions.
  - Make connections.