Using PhET Interactive Simulations in Lecture

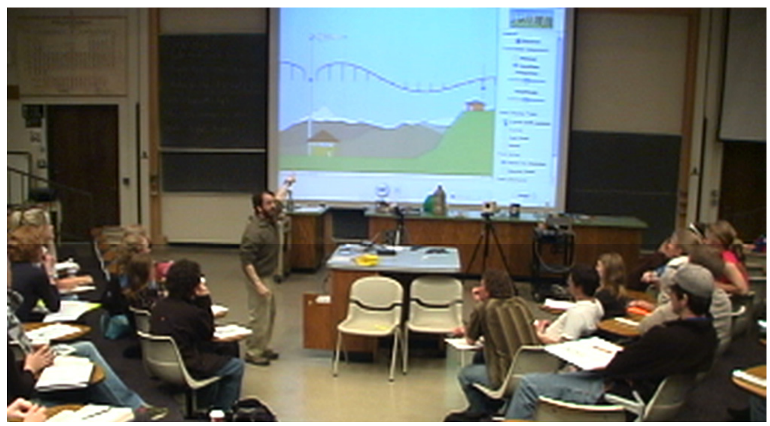
Facilitating Communication, Improving Understanding, and Enabling Classroom Inquiry

University of Colorado's PhET Project has developed over 85 interactive simulations for teaching and learning science. These simulations provide animated, interactive, and game-like environments which enable scientist-like exploration. They emphasize the connections between real life phenomena and the underlying science, make the invisible visible (e.g. atoms, molecules, electrons, photons), and include the visual models that experts use to aid their thinking. Here we provide ideas for using these simulations in lecture.

As Visual Aids and Demos

When we use sims as an animated illustration, we find that we can more easily and more effectively communicate with our students. The sims **show the dynamic processes** and these **can be slowed down or sped up** depending on the concept being shown; the **invisible is made visible**; and **multiple representations are linked.** Finally, the sims are **easily adjusted** by the instructor during the discussion. These features often make sims more effective for learning and more practical to use than static drawings or demos.

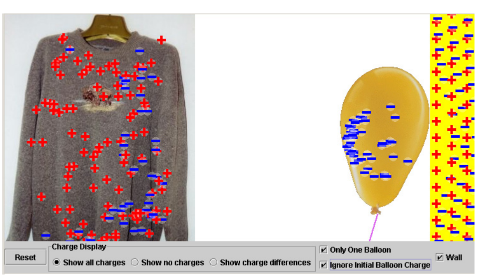
The *Radio Waves* sim helps faculty communicate ideas about: creating E/M waves, oscillating electric field strength, and the speed of light.



Enabling Classroom Inquiry

Using PhET sims in class can have a profound effect upon the learning environment. Students often ask many more, and deeper questions. Once student's realize the ease with which the simulation's controls can be changed by the instructor, it is common for student ideas to direct investigation of a sim through a series of "what-if" questions.

A short demo of charge transfer and polarization with *Balloons and Buoyancy* generates a series of student questions:



Students say:

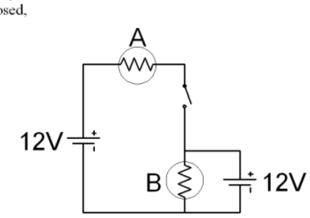
If you rub the sweater on the balloon will electrons transfer the other way? (rather than balloon on sweater)

Can you polarize something where the protons move?

Are there any situations in which the +'s move?

An in-class question at right resulted in a class-led "what if" exploration with the *Circuit Construction Kit*.
(Only 25% got correct Ans D)

The light bulbs in the circuit are identical. When the switch is closed,



A: bulb A glows, and bulb B changes brightness
B: bulb A glows, and bulb B stays the same
C: bulb A does not glow, and bulb B changes brightness
D: bulb A does not glow, and bulb B stays the same

Students say:

I don't get it. It's a closed circuit.

Can you explain one more time why Bulb A doesn't light up?

What if that battery is increased in voltage?
(Instructors says "let's try it. Which way will current flow?")

What happens to Bulb B current? Does it get brighter?

What happens if you flip one (of the batteries) over?
(Instructors tries it.)

Concept Tests

Step 1: Pose question

↓

Step 2: Student-student discussion

↓

Step 3: Vote

↓

Step 4: Follow-up discussion

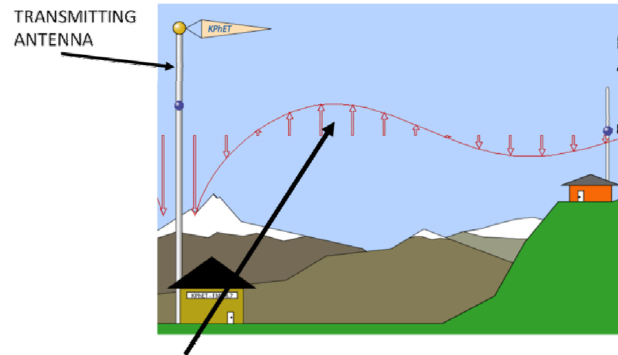
Strategies for Writing Questions*

1. Apply an idea to predict outcome of an experiment.
2. Compare and contrast cases.
3. Interpret different representations (e.g. graphs, pictures, vectors).
4. Rank cases (e.g. which bulb with be brightest).
5. Extend idea to new situations.
6. Have multiple believable/reasonable answers (promotes discussion).
7. Be vague on purpose (promotes discussion).
8. Don't give all information. Require students to make (good) assumptions.
9. Connect to real world applications and student interests (motivate students).
10. Debug a problem (e.g. given data, which step in process isn't working).

*adapted from Beatty et al., AJP, 2006

Instructor probes common student difficulty and then helps students' visualize speed of light with the *Radio Waves* sim.

How do you measure the propogation speed of the wave (signal)?

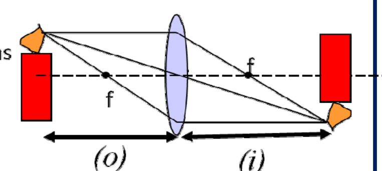


The speed of the wave (signal) is measured as…

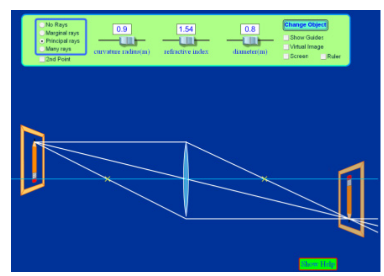
a. how fast this peak moves towards antenna.
b. how fast this peak moves up and down.
c. both a or b

What will happen to image if we increase focal length of lens?
(Keeping the object distance fixed)

a. Image is same size, same place
b. Image is same size and further from lens
c. Image is bigger and further from lens
d. Image is smaller and closer to lens



After peer discussion and voting, instructor elicits student reasoning and then settles debate by "doing the experiment" with PhET's *Geometric Optics* simulation.



Interactive Lecture Demos*

Pose scenario and ask for predictions

↓

Students make individual predictions

↓

Student-student discussions. Revise predictions.

↓

Instructor elicits predictions and reasoning

↓

Instructor conducts "experiment" with simulation

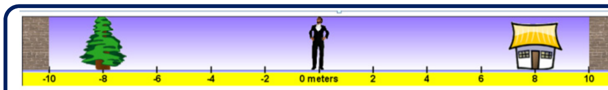
↓

Students record result and how different from prediction.

↓

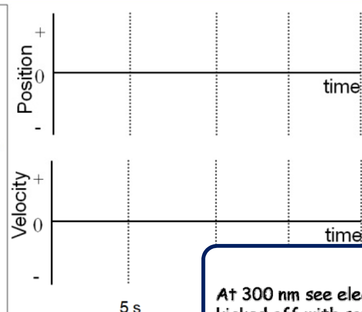
Whole class discussion with student participation. Focus on reasoning.

*see Sokoloff and Thornton, *Physics Teacher*, 35, 340–346 (1997)



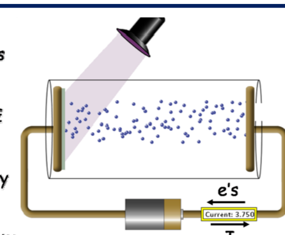
Demo 4:
Sketch **position vs time** and **velocity vs time** graphs for when Moving Man:
walks steadily towards the tree for 6 seconds,
then stands still for 6 seconds, and
then towards the house twice as fast as before for 6 seconds.

Do yours as a dashed lines. Compare with team members then make solid line based on group.

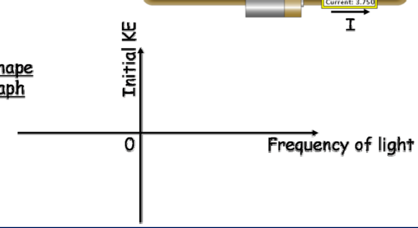


Question elicits students ideas about graphs. Sim allows instructor to dynamically generate graph, and play back motion during further discussions

At 300 nm see electrons kicked off with some initial KE. Predict what happens to the initial KE of the electrons as the *frequency* of light changes? (Light intensity is constant)



Predict shape of the graph



Many students will predict a linear graph starting at origin. The sim "experiment" dramatically shows that below a certain frequency, no electrons are kicked off even at high intensities.