Using PhET Interactive Simulations in College Lecture

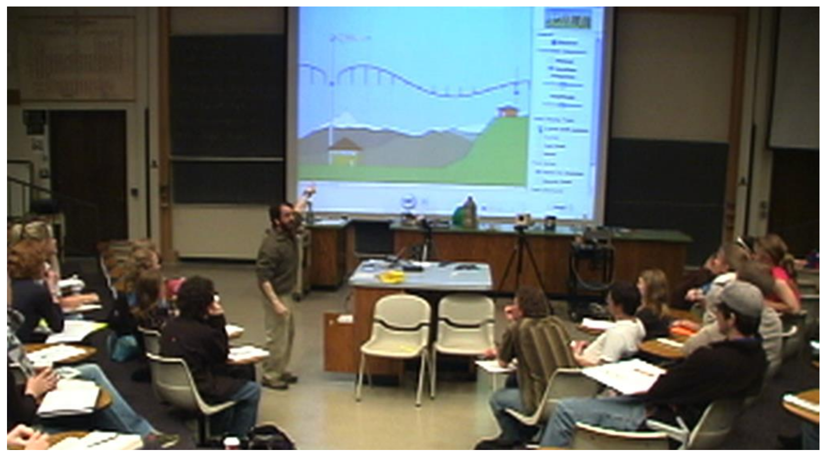
Ideas for engaging students through inquiry in lecture settings

University of Colorado's PhET Project has developed over100 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. **More, including examples, at phet.colorado.edu**

Visual Aids and Demos

By using sims as an animated illustration, instructors find that it is easier to communicate effectively with their students. The sims **show dynamic processes** and these **can be slowed down, sped up, or paused,** 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 live demos.

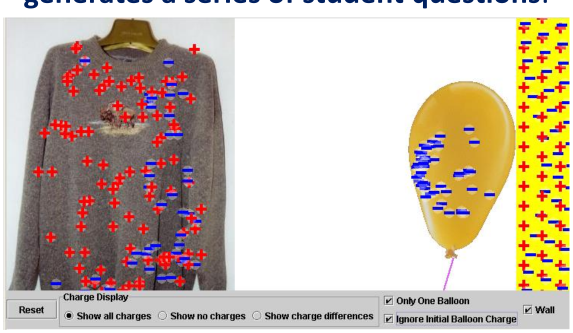
The *Radio Waves* sim helps faculty **communicate ideas** about: creating electromagnetic waves, oscillating electric field strength, and the speed of light.



Student-driven Discussions

PhET is designed to help students develop science inquiry skills by exploring cause-and-effect relationships. Instructors can facilitate **whole-class inquiry** by creating a scenario in the simulation, and asking students to predict the effect of manipulating variables. In such classrooms, students often spontaneously ask **many more, and deeper questions.** It is common for students to ask **a series of "what-if" questions** and direct the teachers' use of the sim.

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



Students say:

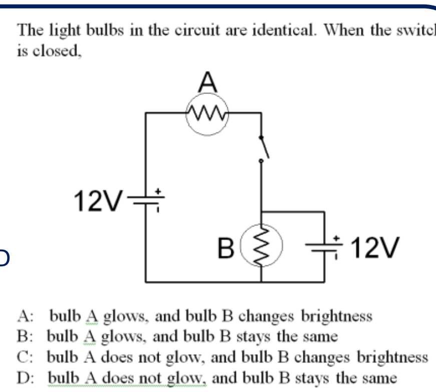
If you rub the sweater on the balloon (rather than balloon on sweater) *will electrons transfer the other way?*

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% correctly answer D



Students say:

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

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

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?

Concept or "Clicker" Questions

Concept tests give students an opportunity to discuss and make sense of concepts related to the simulation.

Pose question
↓
Student-student discussion
↓
Vote
↓
Follow-up discussion

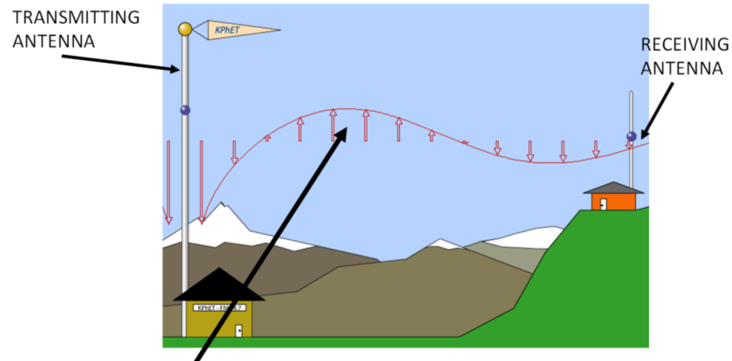
Strategies for Writing Questions*

1. Predict an outcome of an "experiment" with the simulation (e.g., what will happen if? Which change in the sim setup would result in the desired behavior?)
2. Rank cases (e.g. which bulb with be brightest).
3. Compare contrasting cases (e.g., two different waves)
4. Interpret different representations (e.g. graphs, pictures, vectors).
5. Connect to real-world applications

*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)?

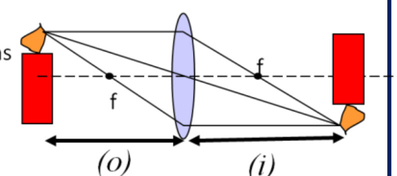


The speed of the wave (signal) is measured as…

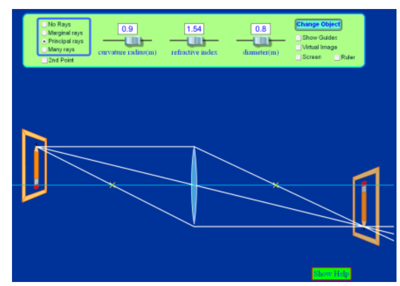
a. how fast this peak moves towards antenna.
b. how fast this peak moves up and down.
c. both a or b

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



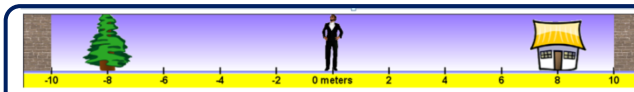
After peer discussion and voting, instructor **elicits student reasoning** and then **settles debate by "doing the experiment"** with PhET's *Geometric Optics* simulation.



Interactive Lecture Demos (ILDs)*

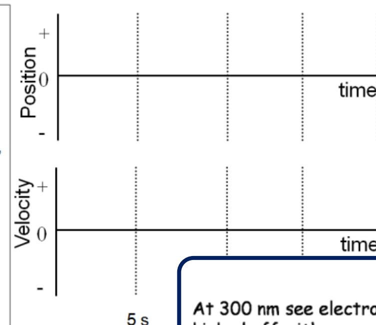
ILD's increase student learning from demos by having students actively identify expectations, and resolve any inconsistencies.

Pose scenario
↓
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.



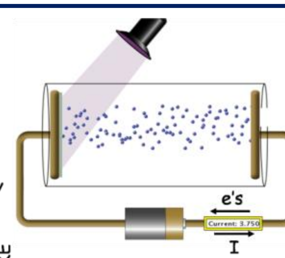
Demo 4:
Sketch **position vs time** and **velocity vs time** graphs for when Moving Man:
walks steadily towards the tree for 6 seconds,
then stands still for 6 seconds, and
then towards the house twice as fast as before for 6 seconds.

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

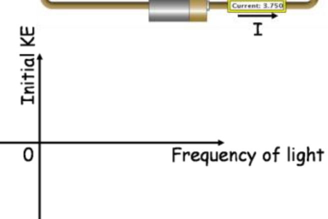


Question elicits students ideas about graphs. Sim then allows instructor to **dynamically generate** graph, and **play back** motion during further discussions

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.

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