

Using PhET Interactive Simulations in Homework

Engaging students in scientist-like exploration to introduce new topics or to deepen understanding post-instruction.

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 homework.

Using an Inquiry Approach

PhET simulations allow homework assignments to use a guided inquiry approach where students engage in scientist-like exploration, an approach which might ordinarily require an instructor present to facilitate students' progress. How does this work? The simulation is designed to cue students to explore productively by using implicit (as opposed to explicit) guidance – with the choice of controls, the visual representations, and the immediate feedback provided by visual changes as students explore. This approach allows homework assignments to be less directed, and to use more open conceptual questions.

Tips for Inquiry-style HWs

Use open conceptual questions, and minimize specific directions:

Our research shows that too much guidance and specific direction shift students away from scientist-like exploration and limit their interaction with the sim to only exploring the specific directions mentioned.

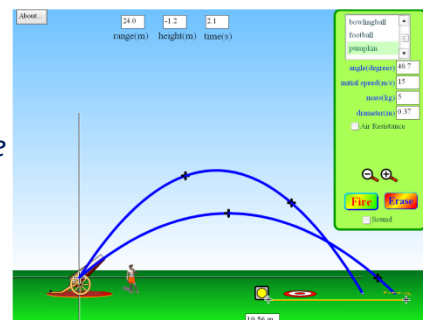
Encourage sense-making by eliciting student thinking and requiring reasoning in words and diagrams:

The sims are designed to support student discovery of causal relationships and to help students connect multiple representations.

Motivate activities through connections to students' real-world experiences.

Using PhET sims prior to instruction.

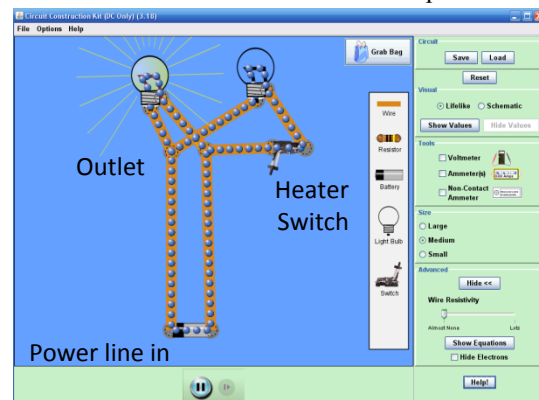
Here, the instructor elicits students ideas about an everyday action and then has them explore the *Projectile Motion* sim to begin developing a framework of ideas about what is important when considering projectile motion, providing a foundation for class discussion.



1. One day after school, you are enjoying a soda in the back yard. When the can is empty, you decide to throw it in the trashcan. What effects whether or not it gets in the can?
2. Use *Projectile Motion* to test your ideas about the things that affect the landing location of a projectile.
 - Make a complete list of things that affect the landing site of a projectile including your ideas from question #1 and any discoveries you made using the simulation.
 - Next to each item, briefly explain why you think the landing location changes.

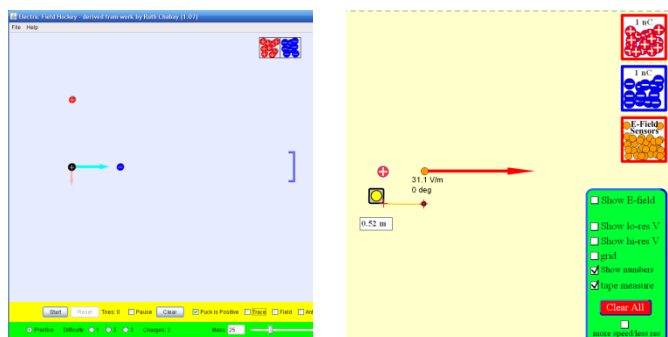
Exploring deeper ideas. Here, students probe deeper into circuits using the Circuit Construction Kit to explore household wiring and the effect of old thin wires versus new wiring – the wire resistivity.

1. If the circuit at right is to represent a light and a heater plugged into the same outlet, what would make sense for how their two resistances would compare? Explain your reasoning.
2. Use the simulation to explore the impact of the quality of the wires – old thin wires vs new thick wires. As you turn the heater on and off, what changes do you see? Why do lights dim in old houses when you turn the heater on?
3. Where do electrons lose their energy as they flow around the circuit? What is it converted into?



Making Measurements with Sims

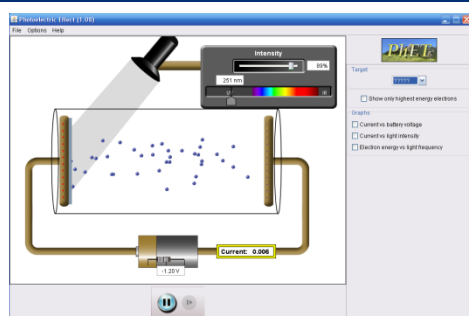
Excerpts from a HW using the *Electric Field Hockey* and *Charges and Field* sims **begin with a qualitative conceptual investigation**. Then students **collect data** and **examine the relationships** that determine electric field strength. While this activity is guided, the teacher has carefully avoided telling students specifically how to do each challenge.



4. Play around with *Electric Field Hockey*. As you put charges onto the playing area, arrows appear on the puck.

- What do you think the arrows on the puck are illustrating? How do the arrows from the positive charges compare and contrast to the ones from the negative balls?
 - Do you think the puck is positively or negatively charged? Explain
 - Investigate how you can use the arrows to predict the motion of the puck.
5. Play around with the *Charges and Field* sim. In this simulation, a little different model is used: the little yellow "E field sensors" are like the hockey puck but they are on a high friction surface, so they stay in place allowing for measurements. Collect data by turning on Show Numbers & Tape Measure.
- Investigate to see if your answers to #4 still make sense using this model. Write how the results of your investigation support or change your ideas.
 - Determine the relationship between distance and the strength of the electric field around a charged body. Use Excel to document your data, graph and determine the equation for the relationship.
 - Determine the relationship between amount of charge and the strength of the electric field around a charged body. Use Excel to document your data, graph, and determine the equation for the relationship.

Using sims with auto-graded homework assignments



Excerpts from a HW around the *Photoelectric Effect* sim demonstrate a range of approaches. First, **students make predictions and then investigate** with the sim.

To answer the following questions, you should use the [PhET photoelectric effect simulation](#).

7. (1 pt) Suppose you set up the experiment so that the plate is ejecting electrons. Predict which of the following changes to the experiment could increase the maximum initial kinetic energy of the ejected electrons. (Select all that apply) Then test your prediction.

- ☐ A. Increasing the intensity of the light beam
- ☐ B. Decreasing the intensity of the light beam
- ☐ C. Increasing the wavelength of light
- ☐ D. Decreasing the wavelength of light
- ☐ E. Increasing the frequency of light
- ☐ F. Decreasing the frequency of light
- ☐ G. Increasing the voltage of the battery
- ☐ H. Decreasing the voltage of the battery
- ☐ I. Replacing the target with a material that has a larger work function
- ☐ J. Replacing the target with a material that has a smaller work function

A short essay is used to emphasize the importance of **explaining concepts in every-day language**.

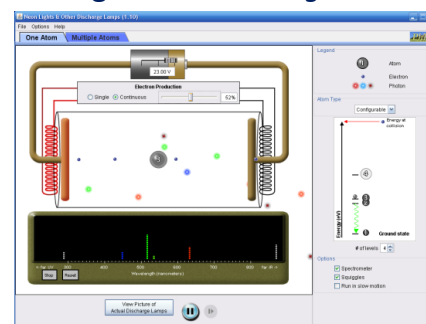
12. (essay) Explain what the phrase - 'the work function for sodium' - means in a way that would make sense to a non-science person.

Finally, using the simulation's "mystery metal" feature, students have to **develop their own procedure** for measuring the work function in a real experiment (there are several ways to do this with the sim).

You have a plate of metal, but you have no idea what kind of metal it is. You come up with the brilliant idea of measuring the work function of this metal by using it as the target in a photoelectric effect experiment. You can perform this experiment virtually by selecting "???" as the target in the simulation. What is the work function, in eV, of the mystery metal?

For the very large classes typically found at big universities, auto-grading is often a requirement. This situation does not preclude sim use, but does require being creative with HW questions. At CU, we have used a combination of conceptual multiple choice and numeric answer questions to support student learning; however, including at least a few short essay questions which require students to explain their reasoning is highly desirable.

A series of challenging True/False questions – based on many incorrect student ideas voiced in class – **requires students to investigate** the *Neon Lights and Discharge Lamp* sim.



a. (2 pts; 0.2 each) Begin by exploring the 1-atom panel and the Configurable Atom. (A few non-obvious simulation controls: You can select the # of empty electronic energy levels in the configurable atom and adjust their location. And you can move the atom about in the discharge tube.) Consider the following True/False statements:

- ☐ True ☐ False If the spacing between two electronic energy levels in atom A is larger than in atom B, then the wavelength of the light emitted by atom B will be longer.
- ☐ True ☐ False If the spacing between two electronic energy levels in atom A is smaller than in atom B, then fewer photons will be emitted by atom B.
- ☐ True ☐ False Photons are emitted *as* electrons in the atom jump up in energy
- ☐ True ☐ False The colors emitted by an atom depends on how much kinetic energy the free electron has when it hits the atom
- ☐ True ☐ False The colors emitted depends on the number of free electrons passing through the lamp.
- ☐ True ☐ False When a free electron hits an atom, the atom is always excited to the highest energy level possible.
- ☐ True ☐ False The kinetic energy of the free electron at the point of collision increases as the voltage of the battery increases.
- ☐ True ☐ False The kinetic energy of the free electron at the point of collision is higher if the atom is closer to the source of electrons
- ☐ True ☐ False The *only* way to emit IR photons is if there are empty electronic energy levels really close to the ground state (lowest energy level).
- ☐ True ☐ False When atomic electrons are excited to a higher level, they always return to their lowest energy level by jumping down one level at a time.