

Engaging Students and Supporting Learning with PhET Interactive Simulations

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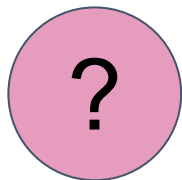
Objectives

By the end of this session, you will be able to:

- Find and use PhET simulations and lessons for your course
- Describe the PhET design philosophy
- Explain when, where, how and why you might use interactive simulations in teaching
- Write effective sim-based interactive engagement questions and activities

Have you used PhET simulations?

Your experience is a resource for others:



Discuss: Share the...

- course (intro, modern, stat mech, etc)
- context (lecture, lab, homework, etc)
- simulation

Science is...

Science is...

Curiosity

Experimentation

Evidence

Reasoning

Analysis

Inquiry

Explanation

Test

Designing Experiments

Data

Interpretation

Predict

Uncertainty

Assumptions

Limits

Representations

Mechanism

Models

The Challenge

Science learning is often far from practice.

In lab:
Directed
Procedures

In class:
Content
Knowledge

Goal: To make physics learning more:



- **ENGAGING:** Interact & discover key ideas
- **RELEVANT:** Connect to everyday life
- **ACCESSIBLE:** Intuitive and understandable
- **EFFECTIVE:** Use STEM practices and develop understanding
- **PERSONALIZED:** Student agency

Make **learning physics** more like **doing physics**.

A Brief History of PhET Interactive Simulations

To learn science and mathematics



2001 Nobel Prize in Physics

Founded by Carl Wieman in 2002
PhET (**Physics Education Technology**)

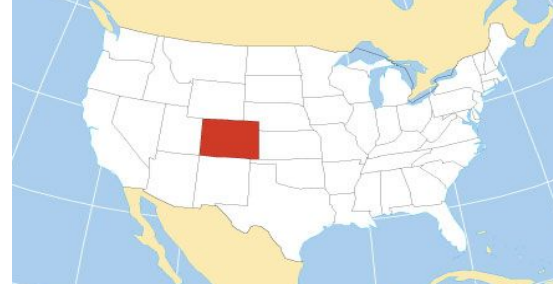
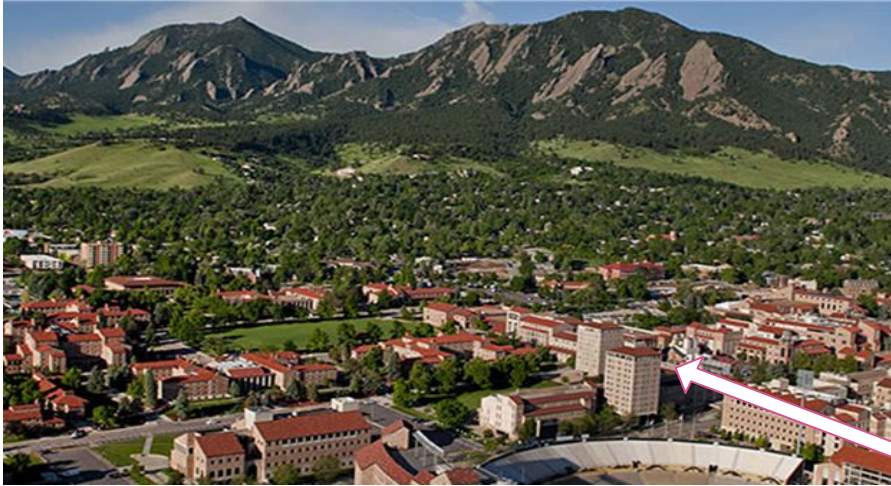
The screenshot shows the PhET Gene Expression Essentials simulation interface. At the top left is the **Biomolecule Toolbox** with the following items:

- Positive Transcription Factor (yellow diamond)
- Positive Transcription Factor (light blue star)
- RNA Polymerase (teal blob)
- Ribosome (yellow and white spheres)
- mRNA Destroyer (yellow crescent)
- Negative Transcription Factor (grey arrow)

The main simulation area shows a DNA double helix with a **Regulatory Region** and a **Transcribed Region**. A teal RNA Polymerase is bound to the regulatory region, and a yellow mRNA molecule is being transcribed. A yellow diamond (Positive Transcription Factor) is bound to the regulatory region. A yellow ribosome is translating the mRNA. A yellow mRNA Destroyer is also present. A yellow button labeled **Previous Gene** is on the left, and a yellow button labeled **Next Gene** is on the right. A yellow button labeled **Gene 2** is in the center. A yellow button labeled **Gene Expression Essentials** is at the bottom left. A yellow button labeled **Expression** is at the bottom center. A yellow button labeled **mRNA** is at the bottom right. A yellow button labeled **Multiple Cells** is at the bottom right. A yellow button labeled **PhET** is at the bottom right. A yellow button labeled **Gene Expression Essentials** is at the bottom left. A yellow button labeled **Expression** is at the bottom center. A yellow button labeled **mRNA** is at the bottom right. A yellow button labeled **Multiple Cells** is at the bottom right. A yellow button labeled **PhET** is at the bottom right.

At the top right is the **Your Protein Collection** panel, which shows a yellow diamond (5), a yellow hexagon (0), and a yellow rectangle (0). Below this, it says **You have: 1** and **of 3 protein types.**

A Brief History of PhET Interactive Simulations



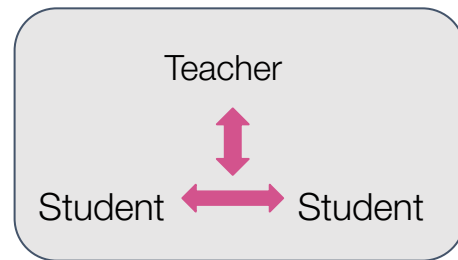
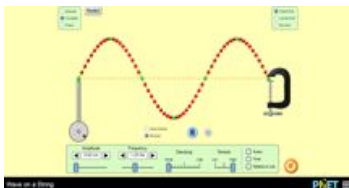
Physics Education Research Group

Simulation Development

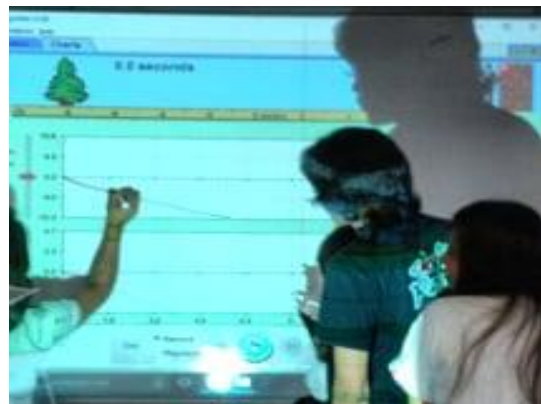
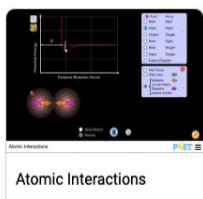
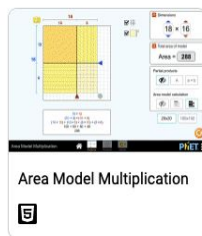
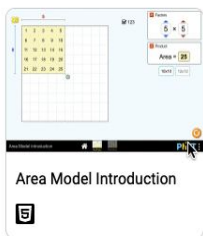
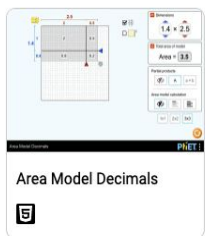
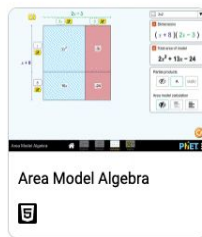
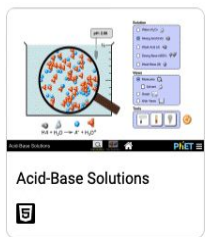
Product Development



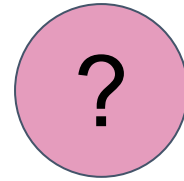
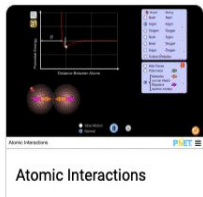
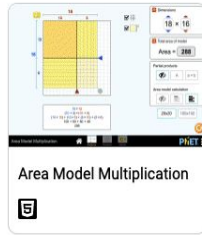
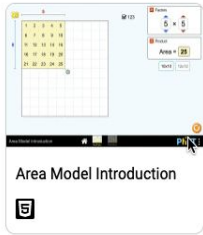
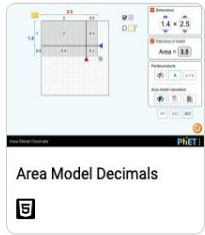
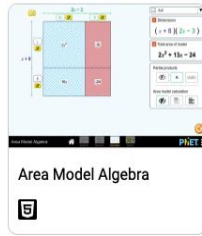
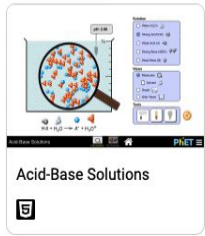
Research



Today: Over 190 simulations - all free



Activity #1: Explore a Sim!



Discuss:

What are your favorite features?

Benefits of Using PhET Simulations

INTERACTIVE VISUALIZATION: Foster visual, dynamic learning of scientific concepts.

COGNITION: Aids learning through scaffolding, reducing cognitive load.

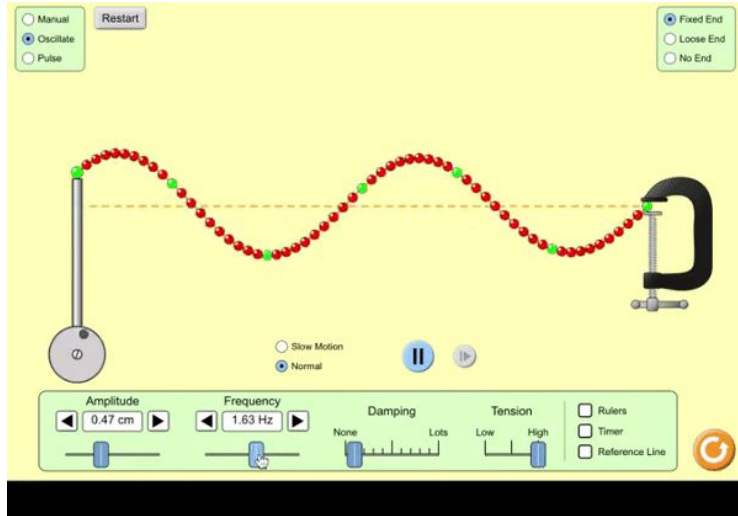
SELF-ASSESSMENT: Provide real time feedback with minimal explicit guidance.

REINFORCEMENT: Support multiple representations, pacing and self-directed learning.

AGENCY: Guides students without feeling guided.

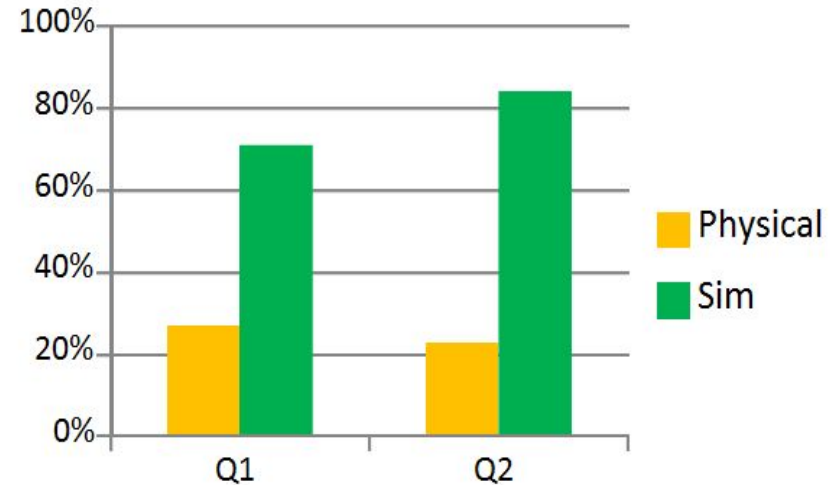
Sims are specifically designed to support students in constructing a robust conceptual understanding of math and science topics through exploration.

Evidence of increased learning



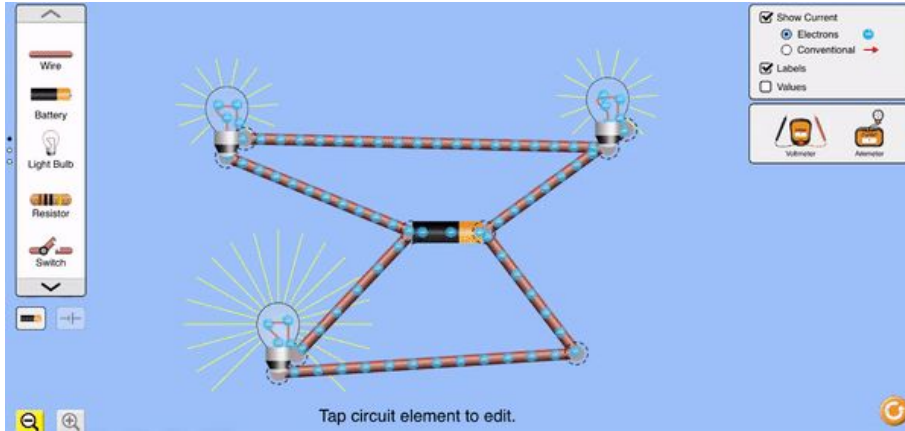
A greater percentage of students answer conceptual questions correctly when a sim is used in demos vs. physical equipment.

In-Class Questions

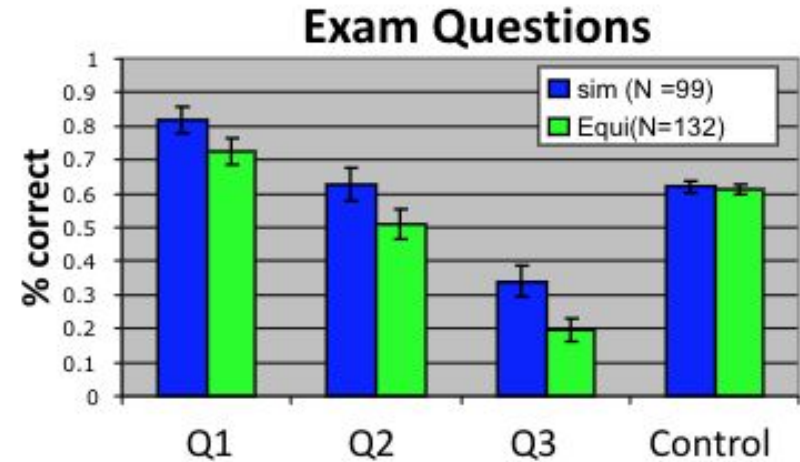


Perkins, K., et al. (2006). *Physics Teacher*, 44(18).

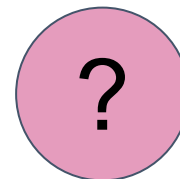
Evidence of increased learning



A greater percentage of students answer conceptual questions correctly when they do experiments with sim, followed by real equipment, compared with only using physical equipment.



Finkelstein, N., et al. (2005). *Physical Review Special Topics-Physics Education Research*, 1(1), 010103.



Discuss:

What science practices do you see students engaging in?

Moore et al. Chemistry Education Research and Practice, 14(3), 257-268, 2013.

Evidence of increased engagement

The power of 10 min of free exploration:
Molecular Polarity

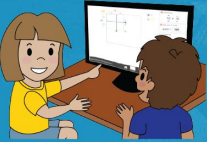
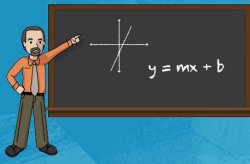
Analysis of 80 students working in groups:

- Explore 80% of all sim features across 3 screens
- Majority of talk about polarity

Topic	% of Utterances
Group Arrangement (Pre-Sim Use)	6%
Chemistry Concept - polarity	62%
Instructor-Student - polarity	2%
School - homework, lab	10%
Off-topic	20%

Moore et al. (2013). *Chemistry Education Research and Practice*, 14(3), 257-268, 2013.

Evidence of new classroom norms

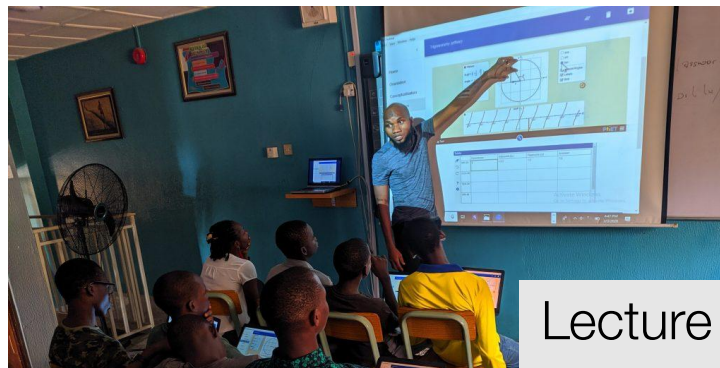
Sim Lessons	Non-Sim Lessons
<p>Exploring new mathematical ideas</p> <p>Inventing strategies</p> <p>Sharing own ideas</p>	<p>Practicing standard procedures</p> <p>Recalling facts</p> <p>Appealing to rules</p>
	

Atabas, S. et al. (2020). A tale of two sets of norms: Comparing opportunities for student agency in mathematics lessons with and without interactive simulations. *The Journal of Mathematical Behavior*, 58, 100761.

Flexible



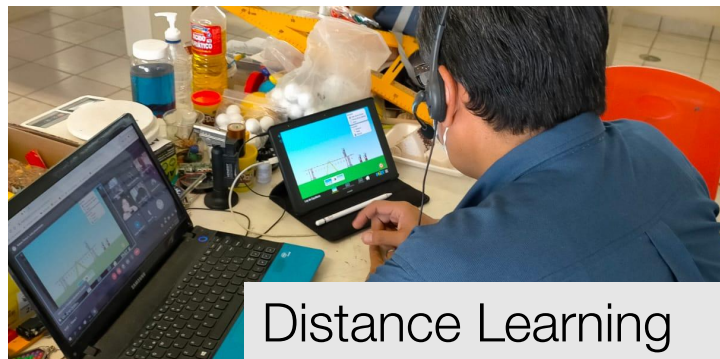
Pre-Lab



Lecture



Activity/Lab



Distance Learning

Sim Design: Open, flexible tools. Adaptable to your class.

The image shows the PhET Equality Explorer simulation interface. At the top, a text box displays the equation $3x - 1 = -x + 11$. Below it is a control panel with buttons for $+$, $-$, \times , \div , a coefficient input field set to 1, and a downward arrow button. To the right, another text box shows the solution $x = 3$ with a 'Snapshots' button below it. The central part of the interface features a balance scale with two pans. The left pan contains a blue square labeled $3x$ and a yellow circle labeled -1 . The right pan contains a blue square labeled $-x$ and a yellow circle labeled 11 . A green arrow points upwards from the center of the scale. At the bottom, there is a toolbar with buttons for x , $-x$, 1 , and -1 , a lock icon, and a circular arrow icon. The bottom-most bar contains the text 'Equality Explorer' and navigation icons for 'Basics', 'Numbers', 'Variables', 'Operations', and 'Solve It!', along with a speaker icon and the PhET logo.

INTUITIVE INTERFACE

PEDAGOGICALLY POWERFUL ACTIONS

MULTIPLE, ACCURATE, DYNAMIC REPRESENTATIONS

IMPLICIT SCAFFOLDING

Sim Design: Supports multiple learning goals.

CONTENT: Concepts, Models, Representations, Relationships

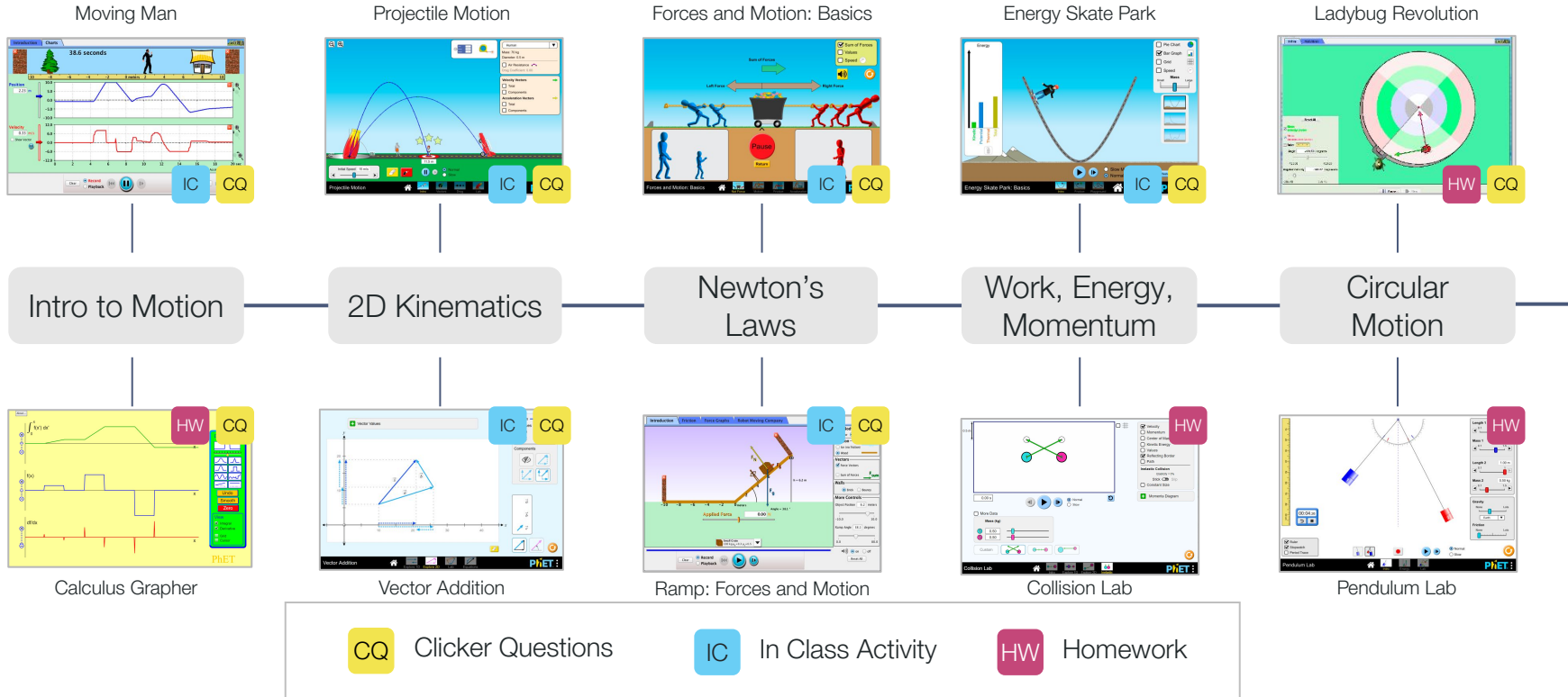
PROCESS: Explore, Question, Design, Predict, Data, Evidence, Reason

SOFT SKILLS: Argumentation, Collaboration, Planning, Reflection

HARD SKILLS: Lab techniques, Quantitative problem solving

AFFECTIVE: Enjoyable, Understandable, Relevant, Student Agency

Integrating PhET in Introductory Physics



Sims + Effective Pedagogies

- Whole-Class Inquiry
- Interactive Lecture Demonstrations
- Concept Questions w/Peer Instruction
- Challenge Prompts



Work through these workshops to learn about PhET's suggested pedagogical strategies, and optionally sign up to earn a certificate as part of our next facilitation cycle.

Math teachers with devices for every student may take the condensed [Teaching Math with PhET](#) workshop.



Introduction to PhET

Learn how to access and share PhET simulations with your students and explore the features that make PhET sims a powerful tool for science and mathematics teachers.

🕒 2 hours



Whole-Class Strategies

Learn strategies for how to use PhET in circumstances where you are presenting a simulation in front of the whole class using a projector, interactive whiteboard, or sharing your screen online.

🕒 3 hours



Math Activity Design

Learn strategies to create sim-based inquiry activity sheets for math classes where students have direct access to simulations on a singular or shared device.

🕒 5 hours



Science Activity Design

Learn strategies to create sim-based inquiry activity sheets for science classes where students have direct access to simulations on a singular or shared device.

🕒 5 hours

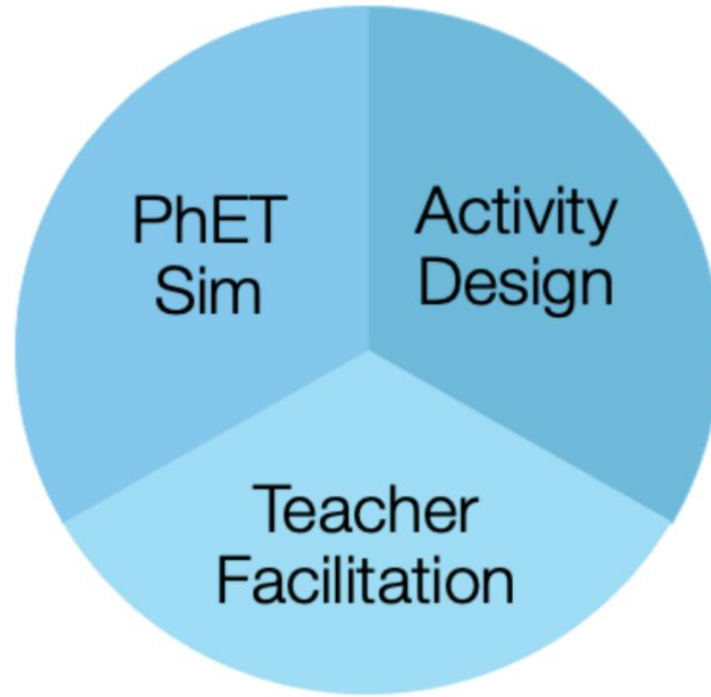


Facilitating PhET Simulation Use

Learn how to effectively design a learning sequence that makes use of PhET's simulations for mathematics and science

🕒 6 hours

Sim-based Learning



24

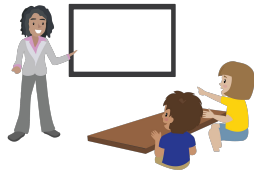
Teaching with PhET Sims

More
Teacher
Control

More
Student
Control



Lectures



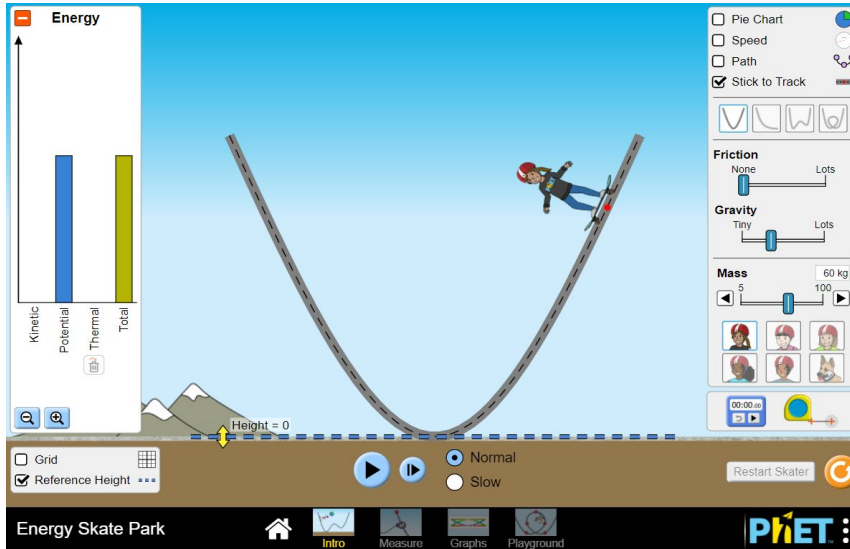
Interactive Lecture
Demonstrations
([see resources](#))

Concept Questions
([see resources](#))

Activities
& Labs



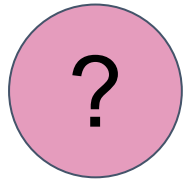
Whole Class: Concept Question w/Peer Instruction



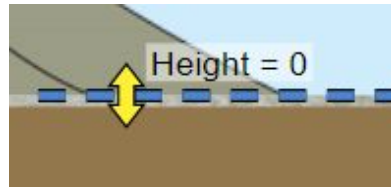
I move the reference height for zero of Potential Energy up to the **starting point** of the Skateboarder (skateboarder still starts from rest).

The total energy of the system is now:

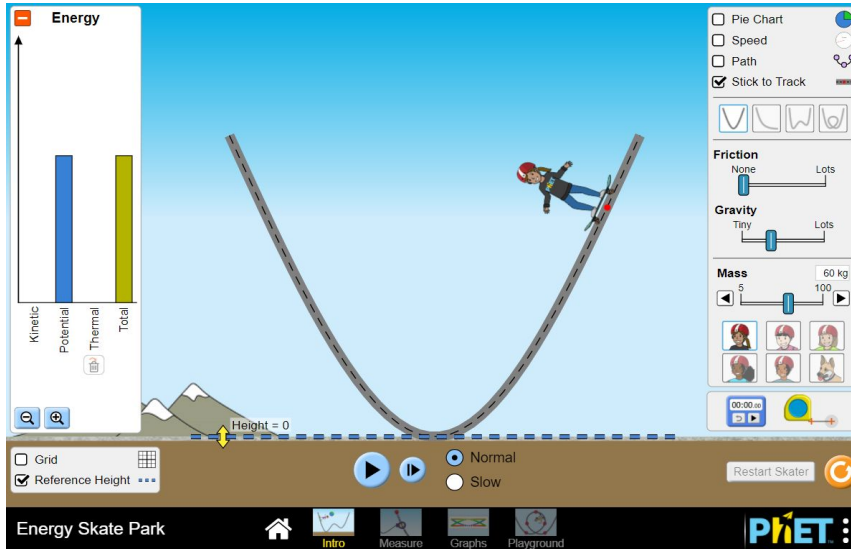
- A) Zero
- B) Positive
- C) Negative
- D) Depends on the position of the skateboarder



Poll



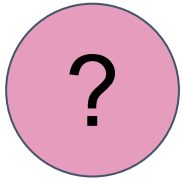
Whole Class: Concept Question w/Peer Instruction



I move the reference height for zero of Potential Energy up to the **starting point** of the Skateboarder (skateboarder still starts from rest).

The total energy of the system is now:

- A) Zero
- B) Positive
- C) Negative
- D) Depends on the position of the skateboarder



Discuss: What are some science practices students engage in while considering this question?

Activity #2: Write a Concept Question!

Write 1 or more concept questions for a simulation of your choice.

Be prepared to share your concept question.



Small Group/Ind.: Promoting Engaging and Inquiry

Top Tip #1:

Start with an “open explore” question.

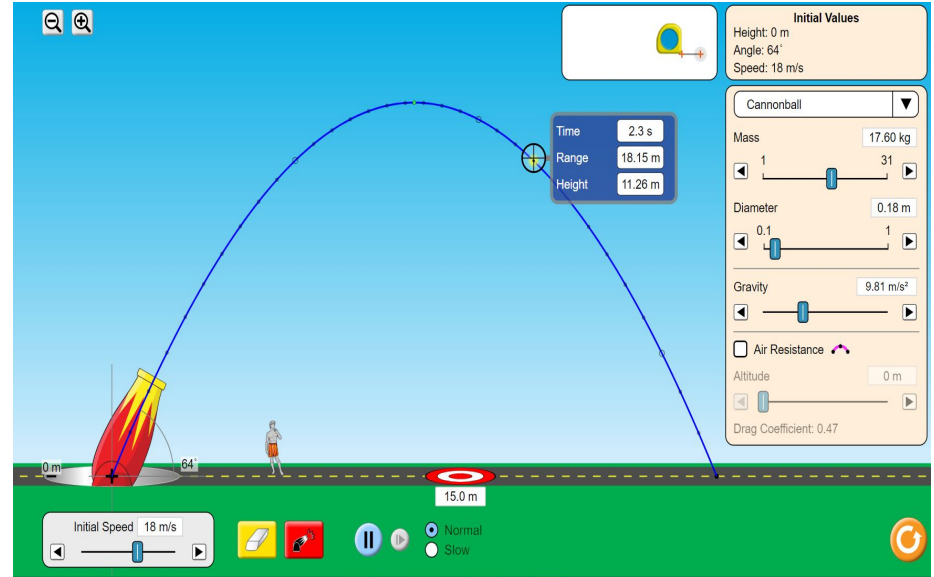
- Play with this simulation and develop your own ideas.
- Record a few discoveries you make.

The screenshot shows the 'Build an Atom' simulation for Helium. At the top left, a legend indicates: Protons (orange dots), Neutrons (grey dots), and Electrons (blue dots). The central part of the screen displays a 'Neutral Atom' of Helium with two protons and two neutrons in the nucleus, and two electrons in two shells. Below the atom are three bowls labeled 'Protons', 'Neutrons', and 'Electrons' containing the respective particles. To the right, there are three panels: 'Element' showing a periodic table with Helium (He) highlighted; 'Net Charge' showing a balance scale with a plus sign and a minus sign, currently set to 0; and 'Mass Number' showing a balance scale with the number 4. Below these panels is a 'Model' section with radio buttons for 'Orbits' (selected) and 'Cloud'. At the bottom right, there is a 'Show' section with checkboxes for 'Element' (checked), 'Neutral/Ion' (checked), and 'Stable/Unstable' (unchecked). The PhET logo is in the bottom right corner. The bottom of the screen has a navigation bar with icons for 'Build an Atom', 'Atom', 'Symbol', and 'Game'.

Small Group/Ind.: Promoting Engaging and Inquiry

Top Tip #2:

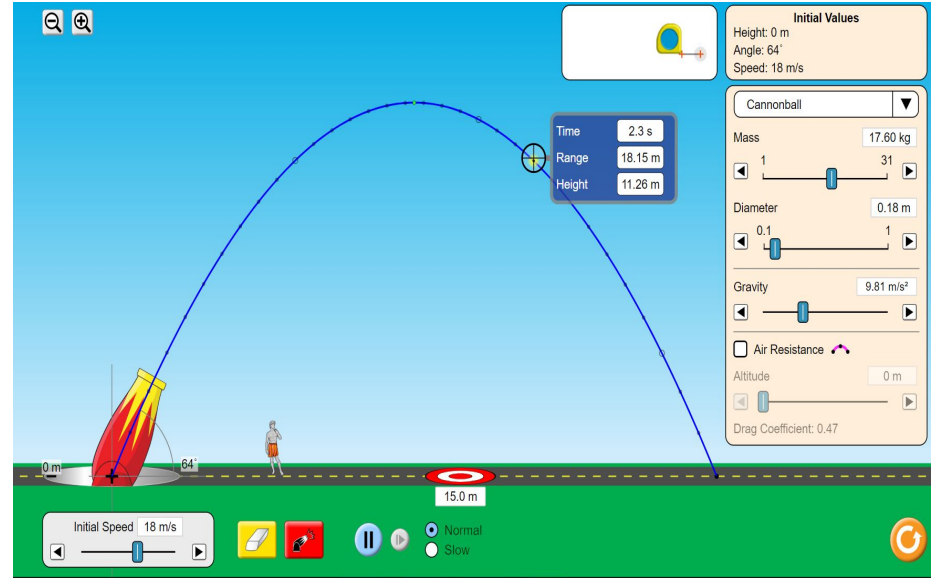
Use challenge prompts rather than direct specific instruction.



Small Group/Ind.: Promoting Engaging and Inquiry

Before: **Direct Instruction**

- Set the canon angle to 45 degrees.
- Measure distance for speeds of 5, 10, 15 m/s.
- Graph launch speed vs distance traveled

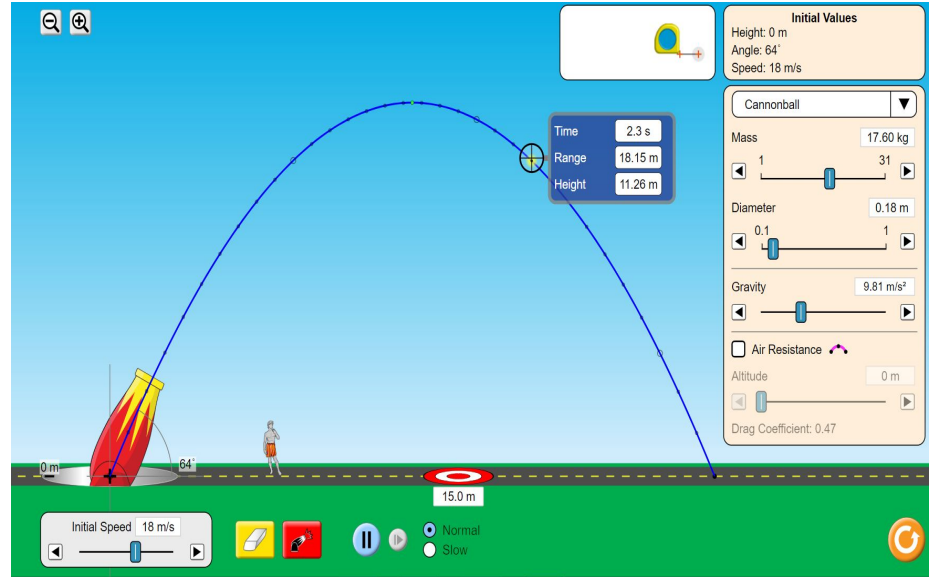


Challenge Prompts

Before: **Direct Instruction**

- Set the canon angle to 45 degrees.
- Measure distance for speeds of 5, 10, 15 m/s.
- Graph launch speed vs. distance traveled.

Rewrite as: **Challenge Prompt:**



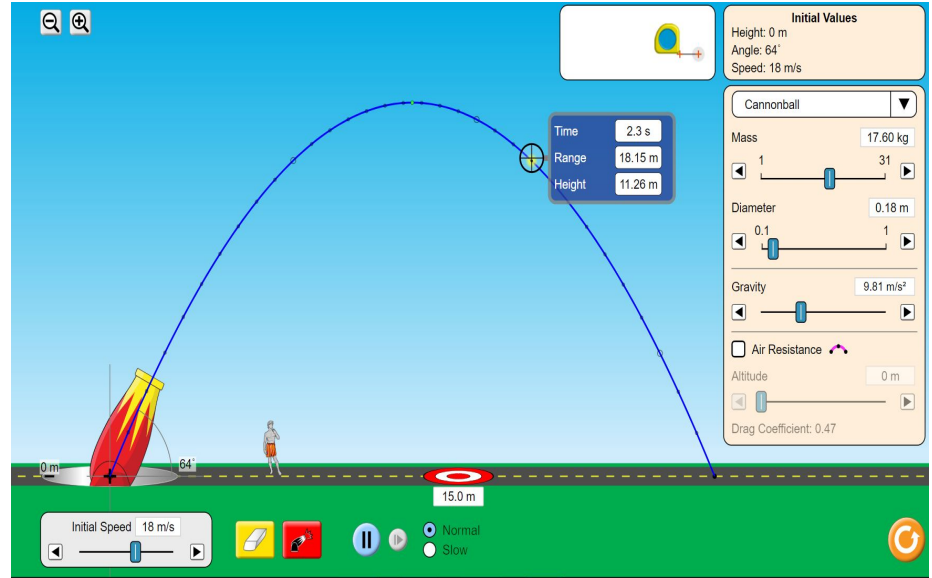
Challenge Prompts

Before: **Direct Instruction**

- Set the canon angle to 45 degrees.
- Measure distance for speeds of 5, 10, 15 m/s.
- Graph launch speed vs distance traveled

Rewrite as: **Challenge Prompt:**

What are all the ways to affect a projectile's horizontal landing distance?



Challenge Prompts

Find all the ways to... increase the force of gravity.

What's the largest... dipole moment you can make?

Create... an atom with a net charge of zero.

How can increase/decrease... the current?

Develop a procedure for... measuring the speed of the wave.

How do you know... if the spring constant is the same?

Activity #3: Challenge Prompts

Write 1 or more challenge prompts for a simulation of your choice.

Be prepared to share one of your challenge prompts



Example Activity

Masses and Springs

5-10 minutes of play – No instructions.

Challenge 1: Using data from the sim, make a graph that shows whether or not the springs obey Hooke's Law.

Challenge 2: What is the mass of the orange weight?

Challenge 3: Determine the spring constant in two different ways: with your graph from (1) and with the stopwatch.

The screenshot shows the PhET 'Masses and Springs' simulation interface. At the top, there are two sliders for 'Spring Constant 1' and 'Spring Constant 2', both set to a medium value. Below them are two vertical springs, labeled '1' and '2'. To the right is a control panel with checkboxes for 'Natural Length', 'Equilibrium Position', and 'Movable Line'. Below these are 'Gravity' settings, including a slider from 'None' to 'Lots' (set to 'Earth') and 'Damping = 0'. A stopwatch is visible in the bottom right of the control panel. In the center, a horizontal bar holds two masses, '1' and '2'. Below the bar is a shelf with five weights: a grey weight labeled '250 g', a grey weight labeled '100 g', a grey weight labeled '100 g', a pink weight labeled '?', a cyan weight labeled '?', and an orange weight labeled '?'. At the bottom of the interface is a navigation bar with icons for 'Home', 'Intro', 'Vectors', 'Energy', and 'Lab', along with the PhET logo.

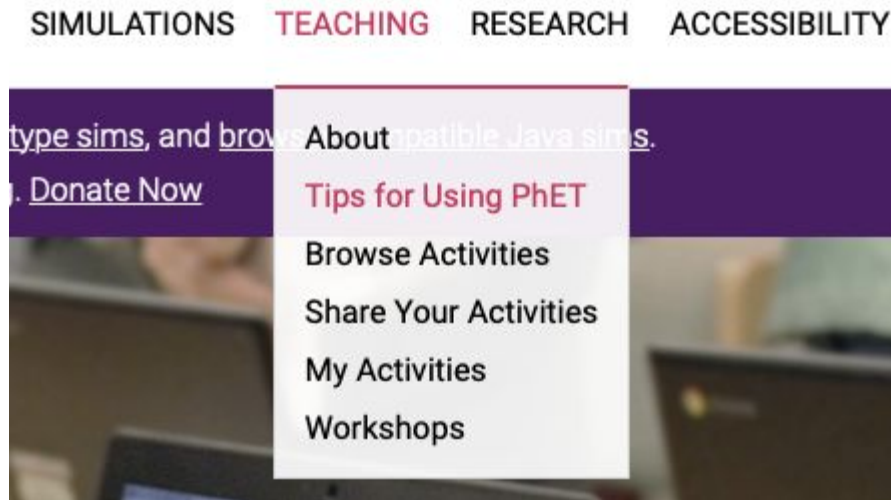
Find Teaching Resources

General tips for using PhET

Remote learning tips



Sim-specific resources

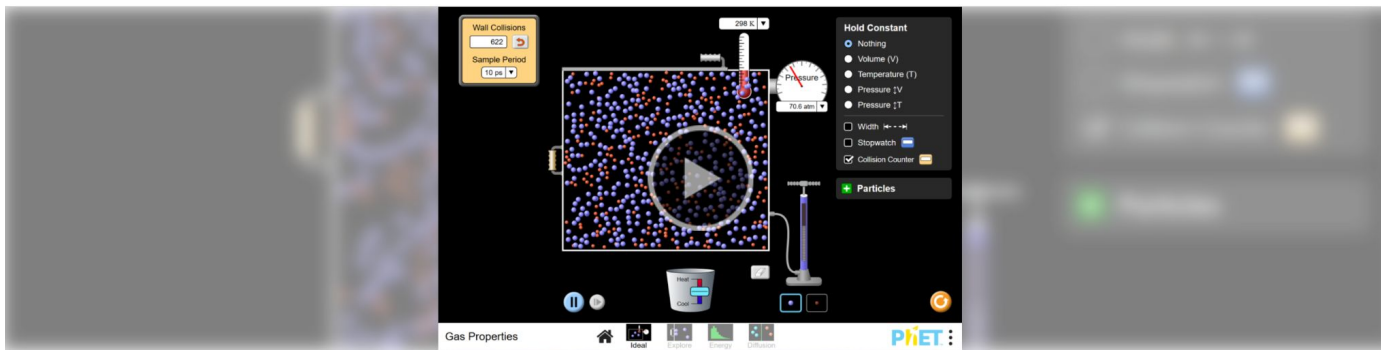
- Standards alignment
- Learning goals
- Teacher tips document
- Lessons and activity sheets
- Translated sims



Teacher Resources



[SIMULATIONS](#) [TEACHING](#) [RESEARCH](#) [ACCESS & INCLUSION](#) [DONATE](#)  



Gas Properties



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[Teaching Resources](#)

[Activities](#)

[Translations](#)

[Credits](#)



PhET is supported in part by



LEIFphysik



DFG



UNIVERSITÄT
KÖLN








Translations

Translated Sims

LANGUAGE	LANGUAGE (TRANSLATED)	NUMBER OF TRANSLATIONS
Afrikaans	Afrikaans	23
Albanian	shqip	171
Amharic	Amharic	90
Arabic	العربية	179
Arabic (Morocco)	العربية (المغرب)	1
Arabic (Saudi Arabia)	العربية (السعودية)	80
Armenian	Armenian	48
Azerbaijani	Azerbaijani	39
Bashkir	Bashkir	1
Basque	Euskara	217
Belarusian	беларускі	111
Bengali	Bengali	5
Bosnian	Bosanski	218
Bulgarian	български	66
Catalan	català	78

Accessibility Features

▼ Accessibility Features

-  Alternative Input (e.g., keyboard navigation) ⊕
-  Sound and Sonification ⊕
-  Interactive Description ⊕
-  Interactive Description on Mobile Devices ⊕
-  Pan and Zoom ⊕
-  Voicing ⊕
-  Prototype ⊕

Prototypes

Prototypes are only available in English but will be made translatable once published to the PhET website.

Caution: these simulations are not feature complete or fully tested, so you may find bugs or other issues. OneNote does not support embedding these prototypes.



[Circuit Construction Kit: AC](#)



[Density](#)



[Greenhouse Effect](#)

Offline Access

Offline Access

- ▶ **Desktop/Laptop Computer**
- ▶ **Chromebook**
- ▶ **iPad**



Q&A

Q&A and Thank you!

FIND PHET

Website: <https://phet.colorado.edu>

PhET iOS and Android Apps (\$0.99):

USE SIMS

In classroom, teacher PD, or curriculum

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Contribute lessons and activities

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