

# Interactive Simulations for Active Learning

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: [physicslens.com](http://physicslens.com)

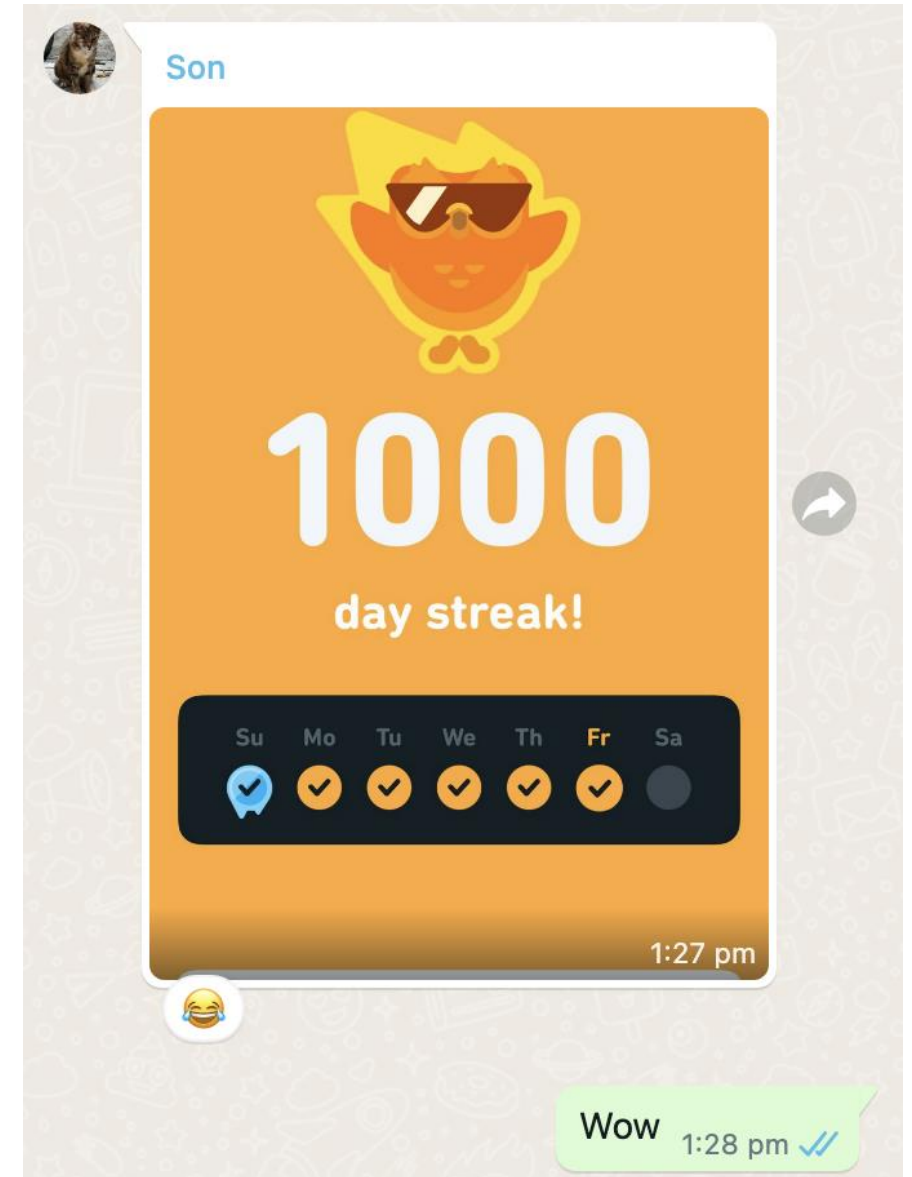
Download this deck of slides at the website above

# Content

- Integrating Interactive Simulations
- Creating Interactive Simulations
  - GeoGebra
  - GenAI
- Sample Learning Experiences
  - Sim + Custom AI Bot + ShortAnsFA

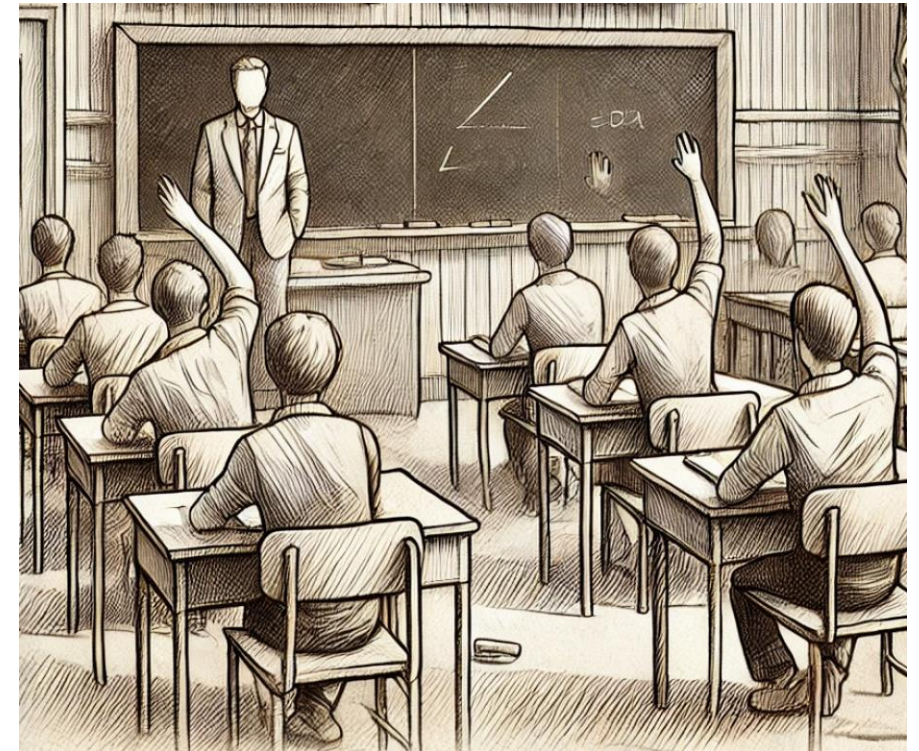
# What engages our students?

- Gamification features:
  - Streaks and daily goals
  - Experience points and leaderboards
- Adaptive algorithm tailored to individual proficiency levels
- Interactive exercises
- Instant feedback



# Definitions

- Engagement: observable behaviors and attitudes that reflect a student's active participation in the learning process, the manifestation of motivation through active involvement
  - behavioral aspects : attendance and participation
  - emotional aspects : interest and enthusiasm
  - cognitive aspects : investment in learning and self-regulation
- Simulation: a program that contains a model of a system or a process



# Effects of using computer simulations

Primary author	Subject	Cognitive topic	Interventions	Results/ Conclusions	Effect size (Cohen's d)
Gibbons et al (2004)	Biology	Chromosome analysis; Bioinformatics	Virtual approach vs. real approach	Decreased study time; increases assessment scores	2.36
Zacharia (2007)	Physics	Electrical circuits	Laboratory with simulation vs. laboratory without simulation	Better conceptual understanding	0.70
Trey and Khan (2008)	Chemistry	Le Châtelier's Principle	Computer simulation with dynamic analogy vs. computer simulation without dynamic analogy	Enhanced learning of unobservable phenomena in science	1.45

Rutten, N., Van Joolingen, W. R., & Van Der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & education*, 58(1), 136-153.

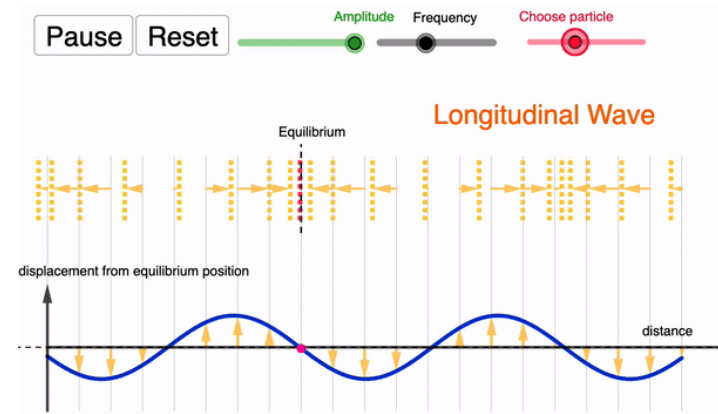
# Simulations Increase Motivation

<b>How Simulations Support</b>	<b>SDT Component</b>
<ul style="list-style-type: none"><li>• Allows self-directed exploration and personalised learning</li></ul>	Autonomy
<ul style="list-style-type: none"><li>• Provides real-time feedback</li><li>• Mastery through iterative practice</li><li>• Promotes critical thinking</li></ul>	Competence
<ul style="list-style-type: none"><li>• Relate to real world applications</li><li>• Foster collaboration</li></ul>	Relatedness

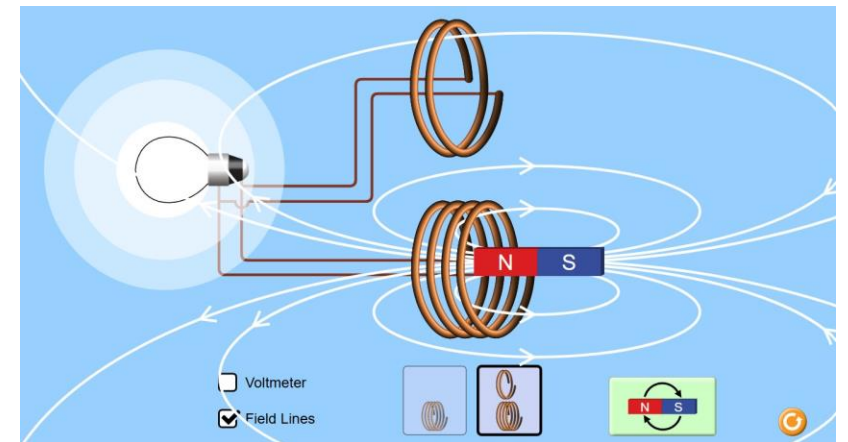
# Types of Interactive Simulations

- **Concept Visualisation**

- To help students understand and visualize abstract or hard-to-observe physics concepts and phenomena.
- e.g. electric field visualization, wave behavior, microscopic views of particle collisions or thermodynamics.



<https://www.geogebra.org/m/kq3e2qjk>



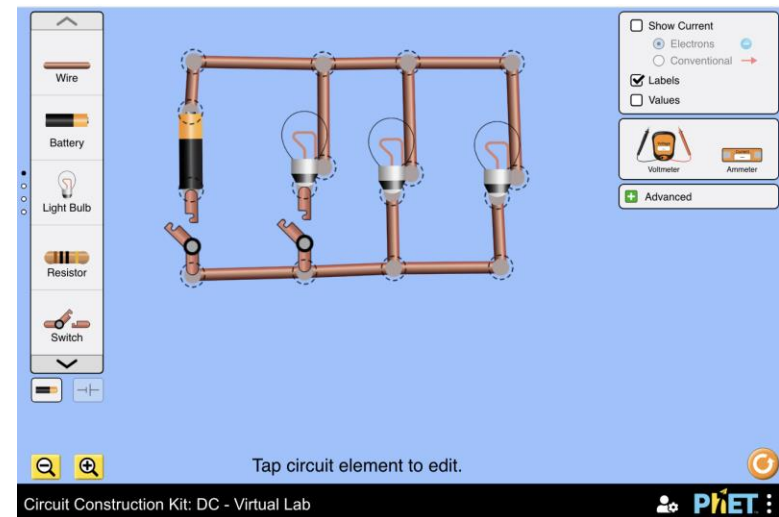
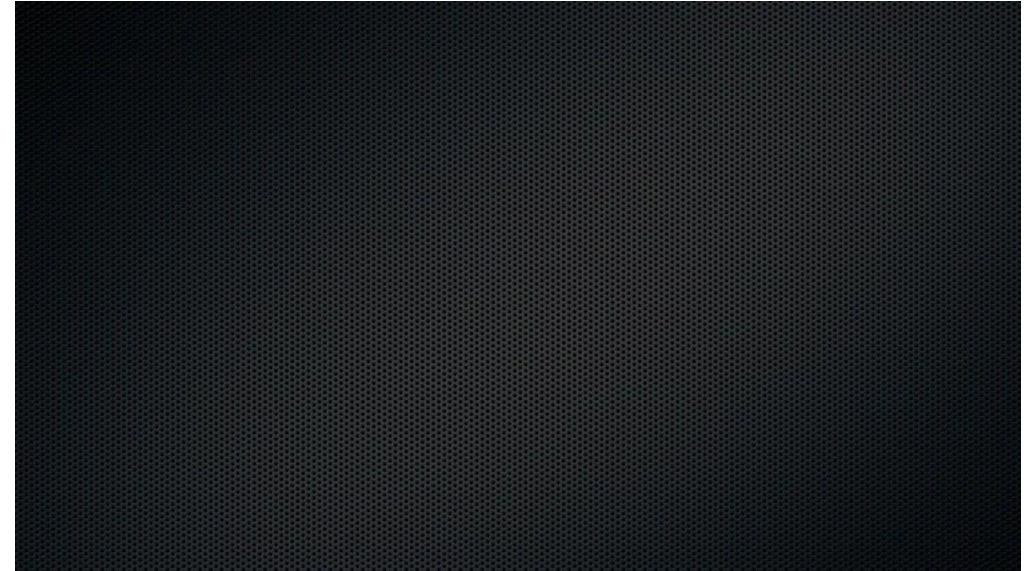
# Types of Interactive Simulations

- **Concept Visualisation**

- To help students understand and visualize abstract or hard-to-observe physics concepts and phenomena.
- e.g. electric field visualization, wave behavior, microscopic views of particle collisions or thermodynamics.

- **Exploratory Laboratory**

- To recreate the experience of a physics lab (often under ideal conditions) or provide structured problems for students to apply physics principles and solve
- e.g. virtual circuits, bridge force distribution with adjustable loads, collision carts.



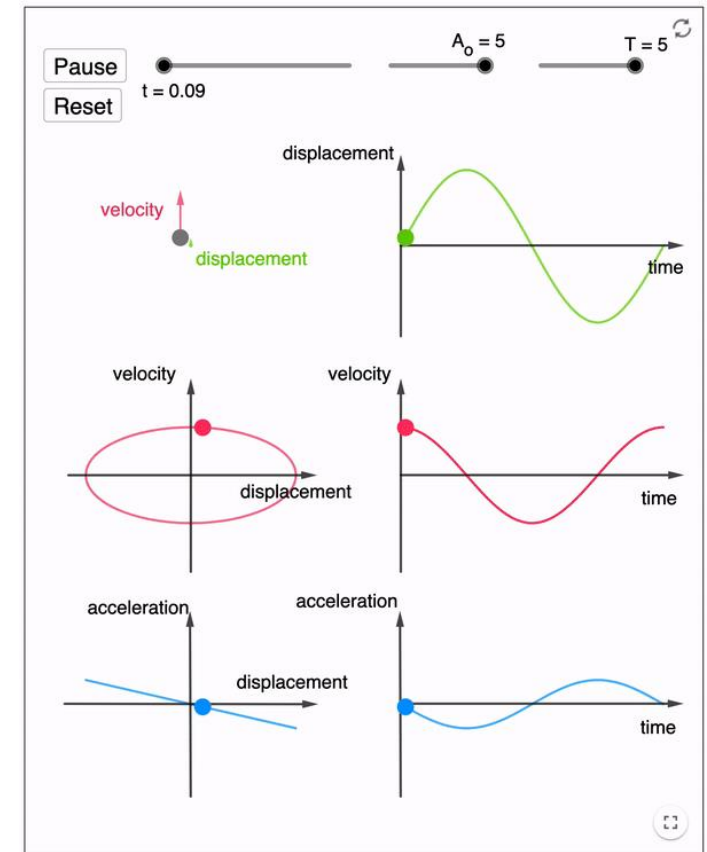
# Commonly used simulation libraries



Sometimes I just can't find the simulation I want...

# Factors promoting engaged exploration with simulations

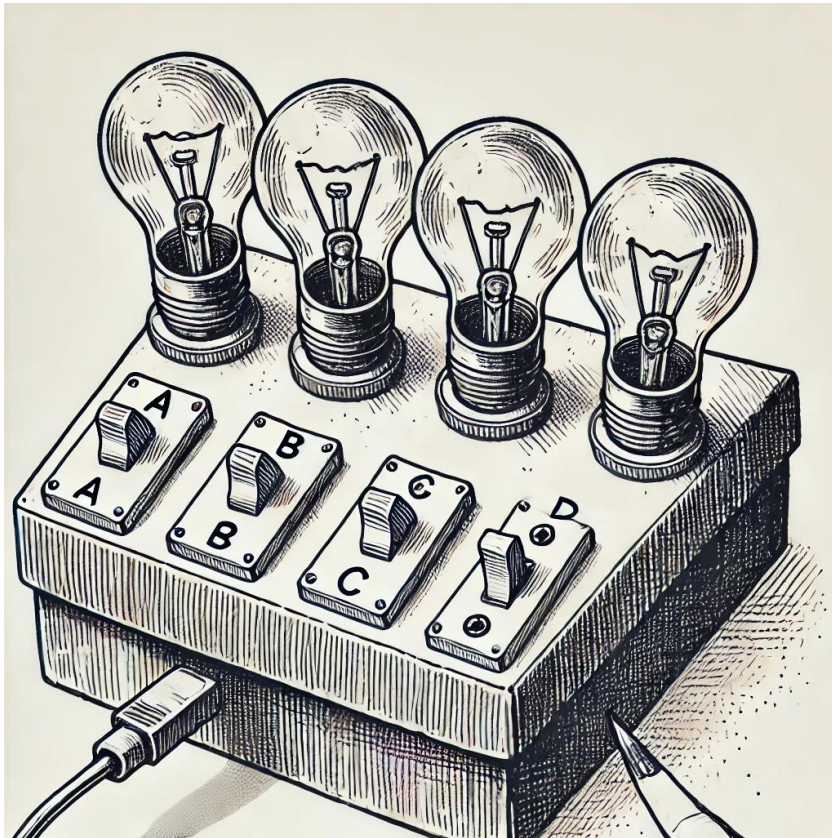
- 1) **High Interactivity:** Real-time feedback and user control over variables allow students to explore actively and make immediate observations.
- 2) **Affordances:** Features within the simulation, such as adjustable parameters and measurement tools, encourage students to take productive actions relevant to learning goals.
- 3) **Constraints:** Limitations within the simulation restrict students from unproductive or overly complex actions, focusing exploration on essential concepts.
- 4) **Multiple Representations:** Simulations provide various visual representations that aid students in drawing connections across concepts and phenomena.
- 5) **Implicit Scaffolding:** The design implicitly guides students' exploration by balancing ease of use with challenge, helping them focus on the relevant aspects of the phenomena.
- 6) **Encouragement of Independent Inquiry:** Open-ended questions prompt students to explore freely rather than follow a rigid sequence, allowing them to ask and answer their own questions.



<https://for.edu.sg/shm>

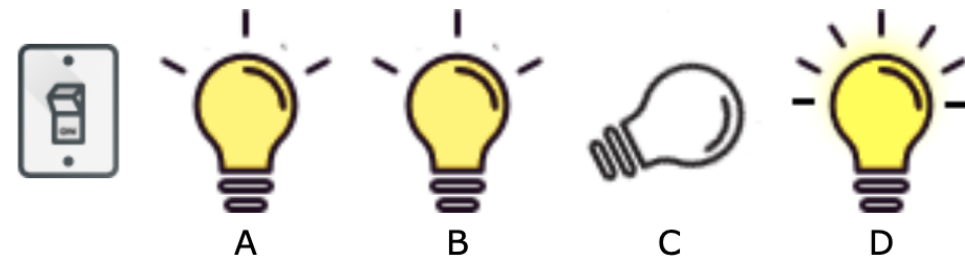
# Presenting investigative problems

When simulations are better than actual setups



## Bulbs in Unknown Circuit 3

Click on the switch to turn the power on.  
Click on a bulb to remove or connect it from the circuit.



Legend:



bulb is lit



bulb is not lit



bulb is removed from socket

[Home](#)

[Series](#)

[Parallel](#)

[Unknown](#)  
1

[Unknown](#)  
2

[Unknown](#)  
3

<https://for.edu.sg/lightbox>

# Presenting problems to solve

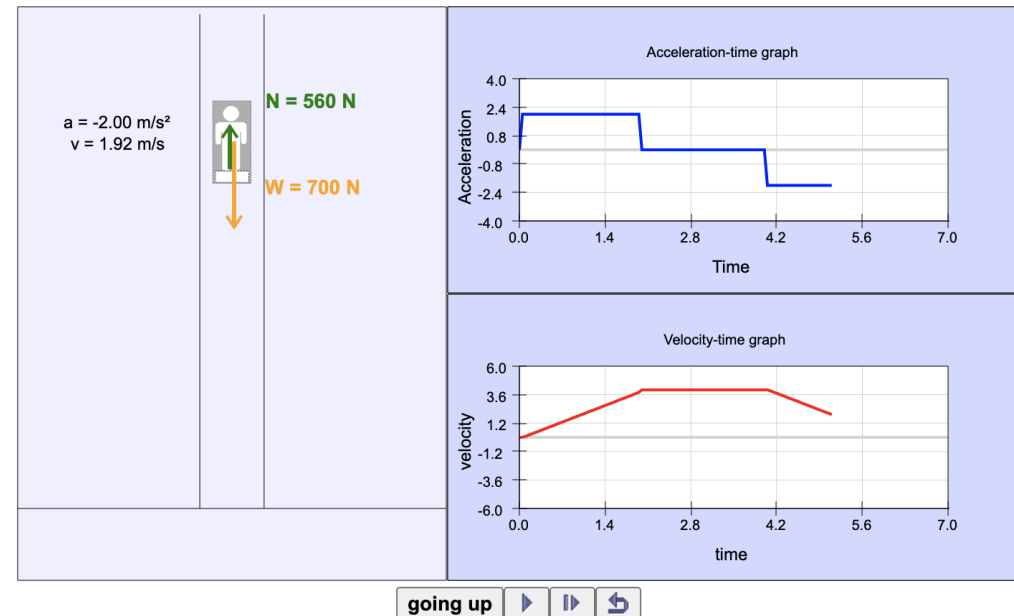
Using a blend of real-life video demo and simulation



Have you ever felt lighter or heavier inside a moving elevator? The video above shows how the reading on a weighing scale with a man standing on it varies as the elevator is moving. The simulation below demonstrates how the forces on the man varies with acceleration and velocity.

Can you explain why the reading on the weighing scale fluctuates?

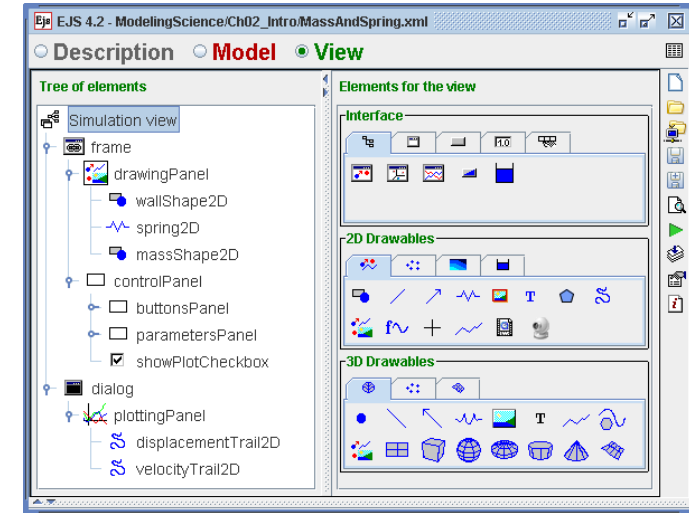
Can you determine whether the elevator is on its way up or down?



<https://for.edu.sg/elevator>

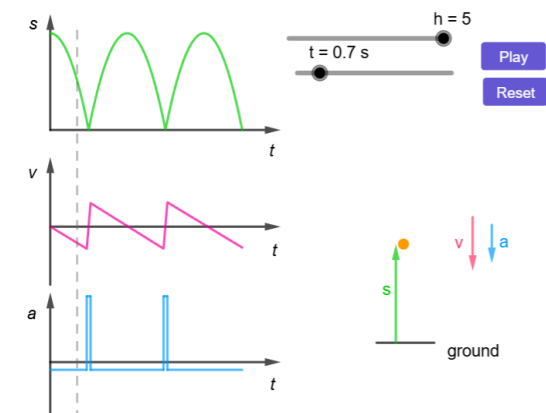
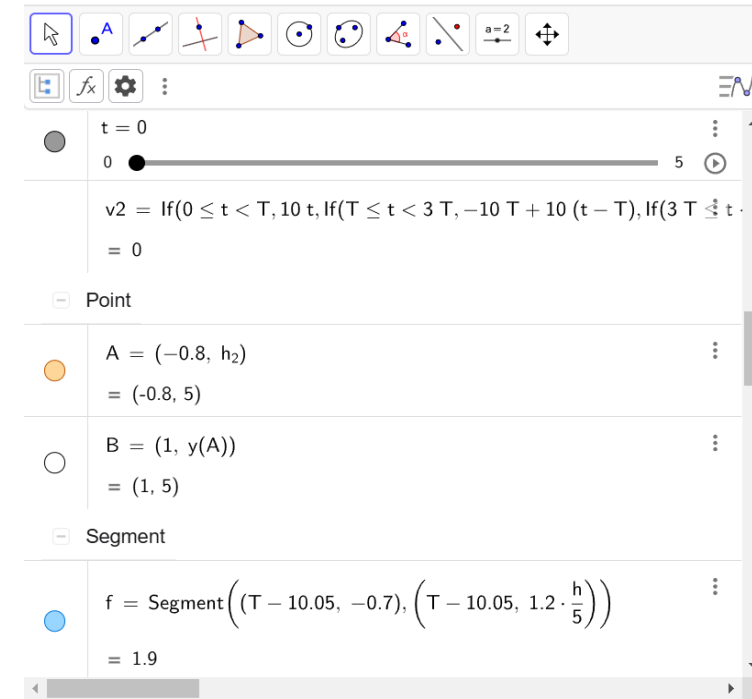
# Accessible Tools for Simulation App Designers

- **Easy JavaScript Simulations (EJS)** – A modeling tool using JavaScript, allowing educators to build customizable, interactive simulations with minimal coding.
- **Scratch** – A block-based visual programming platform, ideal for beginners and younger learners.
- **GeoGebra** – A dynamic mathematics software that enables interactive visualizations and simulations in geometry, algebra, calculus, and other math concepts.
- **AI-generated simulations** – Generative AI (e.g. ChatGPT, Claude, Copilot) that create codes for simulations based on input criteria



# GeoGebra - a Math tool for Science simulations

- "No coding" needed. Just Math.
- Two dots define a line / vector / circle
- X and Y coordinates can be expressed as a function of another variable, e.g. time
- Additional features:
  - Checkbox or button to hide/show an object or start the time
  - Sliders to change variables.
  - Codes to display points for games
- Step by step guide at <https://for.edu.sg/ggbphysics>



# AI-generated interactive simulations

- AI generated javascript + html using prompts without programming skills.
- Prompt as though you are telling a programmer what to design, e.g. describe the interactions with sliders or buttons
- Test and debug using prompts too
- Deployed by sending the files or uploading into SLS or hosting online
- Sample prompts at <https://for.edu.sg/apps>
- Step by step guide at <https://for.edu.sg/aisim>



*Input:*

Make a html5 and javascript simulation of a longitudinal wave with a series of particles in continuous oscillation about their equilibrium positions, similar to this image. Use sliders to change the magnitude of the oscillations.



To create a HTML5 and JavaScript simulation of a longitudinal wave similar to the image you provided, you can follow these steps. The idea is to have a series of particles oscillating horizontally around their equilibrium positions, with sliders allowing the user to control the amplitude of the oscillations.

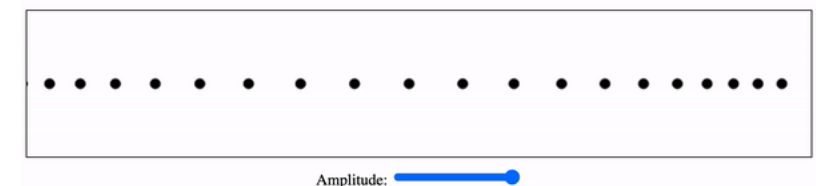
Here's an example code to get you started:

**HTML:**

```
html Copy code  
  
<!DOCTYPE html>  
<html lang="en">  
<head>  
  <meta charset="UTF-8">  
  <meta name="viewport" content="width=device-width, initial-scale=1.0">  
<title>Longitudinal Wave Simulation</title>
```

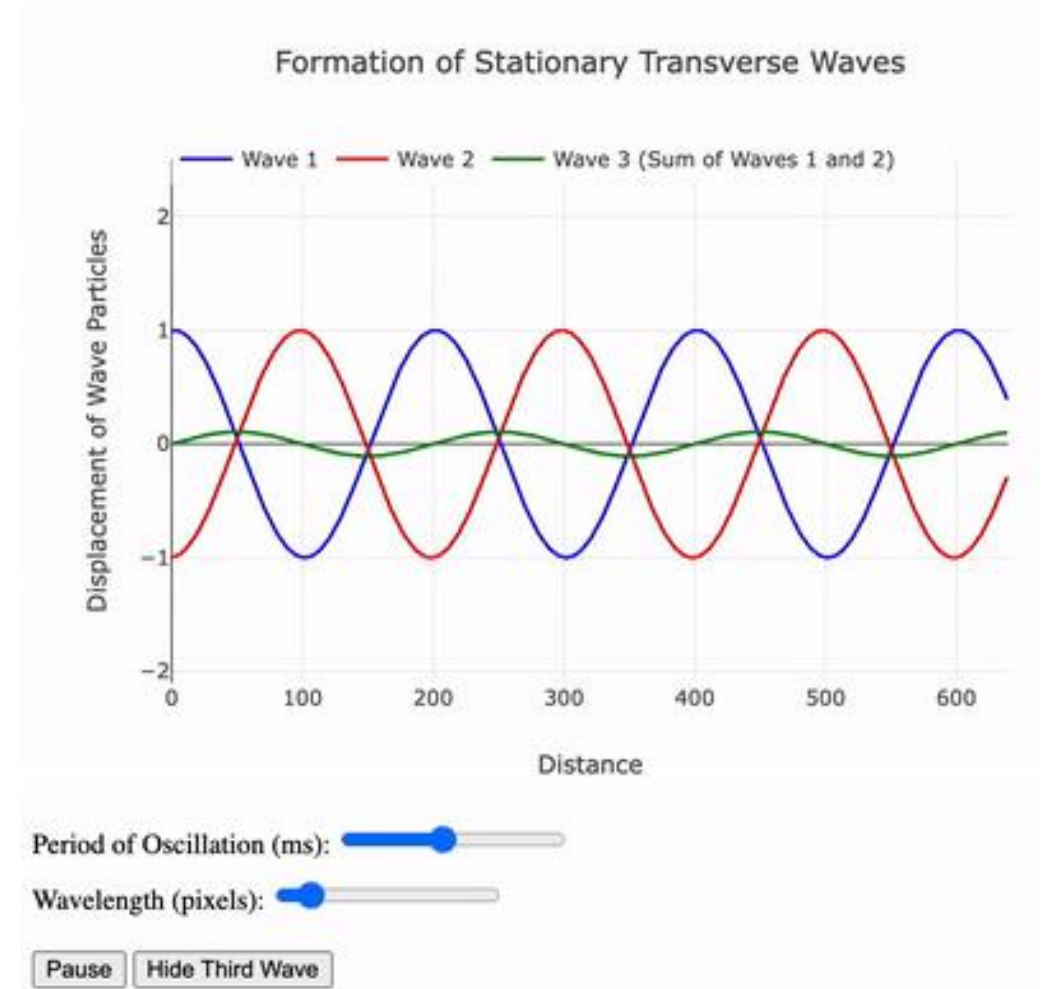
*Output:*

**Longitudinal Wave Simulation**



# Guided inquiry with interactive simulations

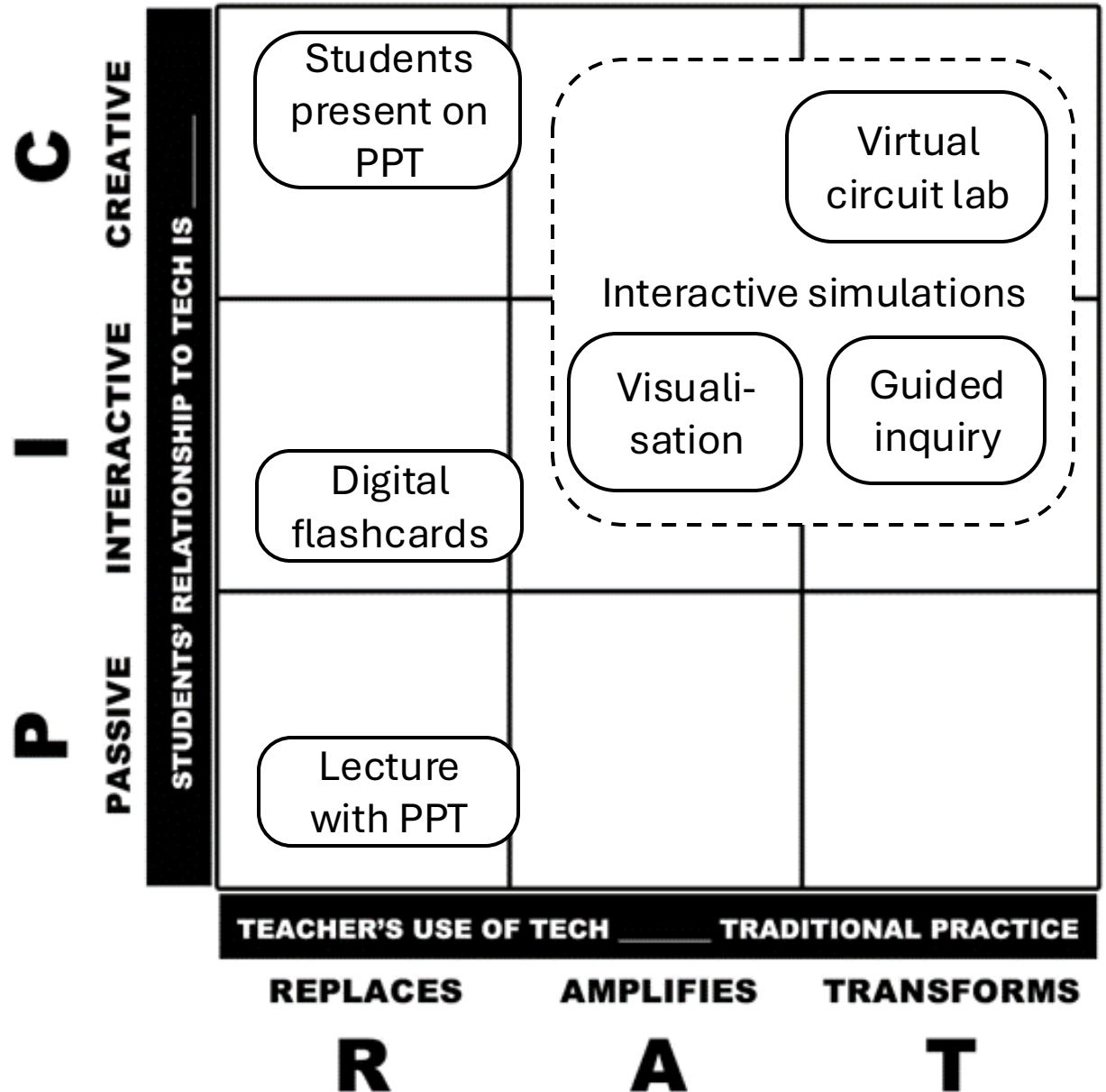
- State Learning Objectives – helps focus their inquiry
- Scaffold Inquiry Process – use prompts such as POE
- Promote Exploration – allow students to manipulate variables
- Facilitate Peer Discussion – sharing of insights, questioning each other and building knowledge together
- Check for Understanding or Self-Assessment



# Meaningful use of tech

- Is student's use of tech  
Passive/Interactive/Creative?
- Is teacher's use of tech  
Replacing/Amplifying/  
Transforming traditional  
practice?

Kimmons, R., Graham, C. R., & West, R. E. (2020). T  
PICRAT model for technology integration in teacher  
preparation. *Contemporary Issues in Technology and  
Teacher Education*, 20(1), 176-198.



# Learning experience : Kinetic Particle Model of Matter

***Activate  
Learning***

Guided inquiry  
with **simulation**

***Promote  
Thinking and  
Discussion***

**Custom AI bot** to  
engage in  
discussion

***Check for  
Understanding***

AI-generated  
feedback using  
**SLS Feedback  
Assistant**

<https://vle.learning.moe.edu.sg/community-gallery/lesson/view/b582192d-1d30-488a-a846-93c34d69da85/cover> (Section C of this module)

# Learning Experience : Kinetic Particle Model of Matter

- Embedded in Student Learning Space for home-based learning
- Success criteria : use the kinetic model of matter to describe the effect of temperature on gas pressure
- Exploration with button and slider:
  - Click on the **play** button to observe the behaviour of the particles and the pressure gauge.
  - Gradually **change** the temperature and observe the behaviour of the particles and how the pressure changes.

Exploration

© Content in the frame is from an external source

# Learning Experience : Kinetic Particle Model of Matter

- Providing instant personalised help during asynchronous home-based learning
- Scaffolding questions asked using a custom AI chatbot (embedded Schoolai.com)
- System prompt given to custom bot constrains discussion to the problem

How does increasing the temperature of the gas affect the pressure?

Explain how increase in temperature of a gas affects the pressure.



**S** Welcome! Let's dive into how temperature affects the pressure of a gas using the kinetic particle model.

To start, can you explain what happens to the kinetic energy of gas molecules when the temperature increases?

Speak



**S** KE should increase

**S** Great! Now, if the kinetic energy of the gas molecules increases, what do you think happens to the frequency of their collisions with the walls of the container?

Send a message



Chat can make mistakes. Check important info.

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# Setting up and monitoring a custom AI bot

Space Creator

## Title & Prompt:

Give your space a title and prompt the AI to create the desired experience.

### Title \*

Explain how increase in temperature of a gas affects the pressure.

### AI Prompt

You are a Socratic tutor whose role is to use guiding questions to help user explain how changing the temperature of a gas affects the pressure using the kinetic particle model of matter.

#### Success criteria:

1. User should relate an increase in temperature of a gas to an increase in the average kinetic energy of the molecules.
2. The increase in kinetic energy (KE) leads to two outcomes: an increase in frequency of collisions with each other and the walls of the container, and an increase in the average force exerted during each collision.
3. This results in an increase in pressure as pressure = force per unit area.

Make reference to the notes attached. Do not go beyond the scope of the notes.

### Standards ⓘ

+ Add a standard

📄 2024 IP4 Physics Topic17 Kinetic Model of Matter Notes (T).pdf

schoolai

Launchpad Spaces Tools Assistants

🔌 👤 🚀 Launch a Space

## Explain how increase in temperature of a gas affects the pressure.

Started Jul 12, 10:06am

+ Add tag

📄 Invite ⏸ Pause ⏹ End ⋮

129 Participants

🔍 Search names and chats

A-Z

👤 Groups

📄

🔄

Gas Guru 43/129

Suggested Grade A

NAME	😊 HEADLINE
[redacted] <i>the average force exerted during the ...</i>	😊 Demonstrating strong understanding of collision dynamics. ...
[redacted] <i>The force exerted by the molecules o...</i>	😊 Outstanding understanding of gas behavior and pressure dynamics! ...
[redacted] <i>which electron shell has the highest a...</i>	😊 Engaged in particle physics; exploring quantum concepts actively. ...
[redacted] <i>more force is exerted on the walls</i>	😊 Excellent understanding of gas behavior and kinetic theory! ...
[redacted] <i>no</i>	😊 Great understanding of gas behavior and kinetic energy! ...
[redacted] <i>Amount of force exerted divided by t...</i>	😊 Student demonstrates strong understanding of pressure concepts. ...

- 🔍 [redacted]  
The student expressed the idea that kinetic energy converts to thermal energy, indicating a misunderstanding of kinetic energy's role in temperature changes.
- 😊 [redacted]  
Student expressed frustration with the repeated focus on gas pressure and showed a strong interest in discussing astrophysics instead.
- 👤 [redacted]  
Student expressed a desire to learn about becoming an astrophysicist instead of discussing the assigned topic on gas pressure.
- 🌟 [redacted]  
The student demonstrated a strong understanding of how temperature affects gas pressure using the kinetic particle model. They successfully connected the concept to real-world applications like car tires.
- 💡 [redacted]  
The student provided a detailed and accurate explanation of how

# Learning Experience : Kinetic Particle Model of Matter

- Checking for Understanding using SLS Short Answer Feedback Assistant (ShortAnsFA)
- ShortAnsFA uses mark scheme input by teacher to provide feedback and assign a mark (option)
- Students to raise questions on feedback if any

How does increasing the temperature of a gas affect its pressure?

 **FEEDBACK ASSISTANT**

Short Answer Feedback Assistant will provide marks and feedback for this question



Short Answer Feedback Assistant uses generative AI. Please check that feedback and marks are accurate and appropriate.


In the context of the kinetic particle model of matter, increasing the temperature of a gas leads to an increase in the average kinetic energy of the gas molecules. This causes the molecules to move faster, resulting in more frequent and forceful collisions with each other and the container walls. These increased collisions lead to a higher pressure within the gas.

[Read Less](#)

# Learning Experience: Kinetic Particle Model of Matter

- AI provides feedback
- AI awards mark (optional)


Suggested Answer | Feedback | Teacher Comments

 **Suggested Answer**

(1 mark) An increase in temperature of a gas to an increase in the average kinetic energy of the molecules.  
The increase in kinetic energy (KE) leads to two outcomes:  
(1 mark) an increase in frequency of collisions with each other and the walls of the container, and  
(1 mark) an increase in the average force exerted during each collision.  
(1 mark) This results in an increase in pressure as pressure = force per unit area.

[Read Less](#)

Suggested Answer | Feedback | **Teacher Comments**

 **Teacher Comments**

**Short Answer Feedback Assistant**

16 Jul 2024 09:05 PM

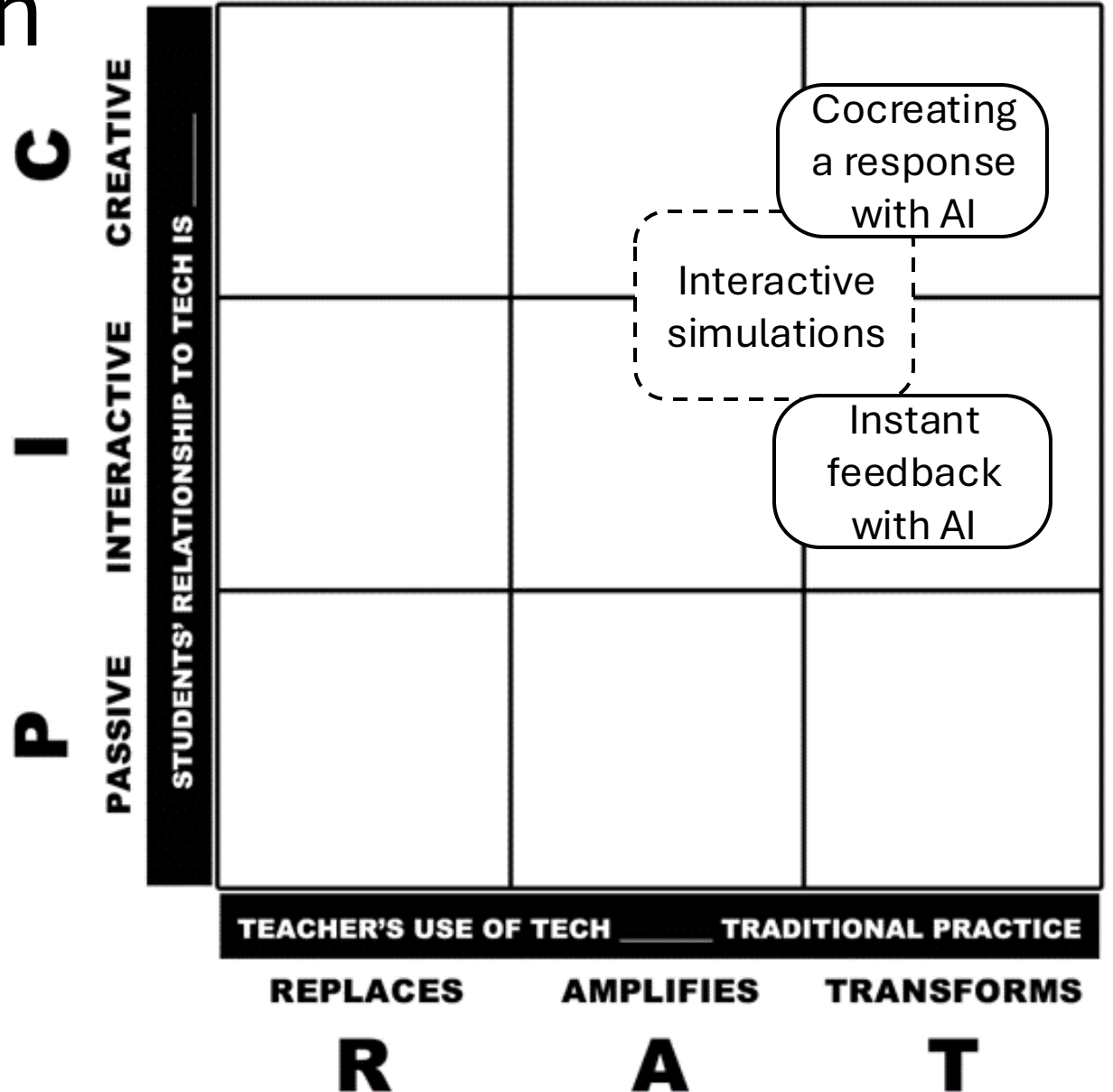
Your response correctly explains how increasing the temperature of a gas affects its pressure. You mentioned that increasing the temperature leads to an increase in the average kinetic energy of the gas molecules, which is accurate. You also correctly noted that this causes the molecules to move faster, resulting in more frequent and forceful collisions with each other and the container walls, leading to a higher pressure. However, you missed the specific mention of 'pressure = force per unit area'. Overall, well done!

[Read Less](#)

[+ ADD](#)

# Meaningful use of tech

- Is student's use of tech  
Passive/Interactive/Creative?
- Is teacher's use of tech  
Replacing/Amplifying/  
Transforming traditional  
practice?



# Another Learning Experience: Radioactivity

***Activate  
Learning***

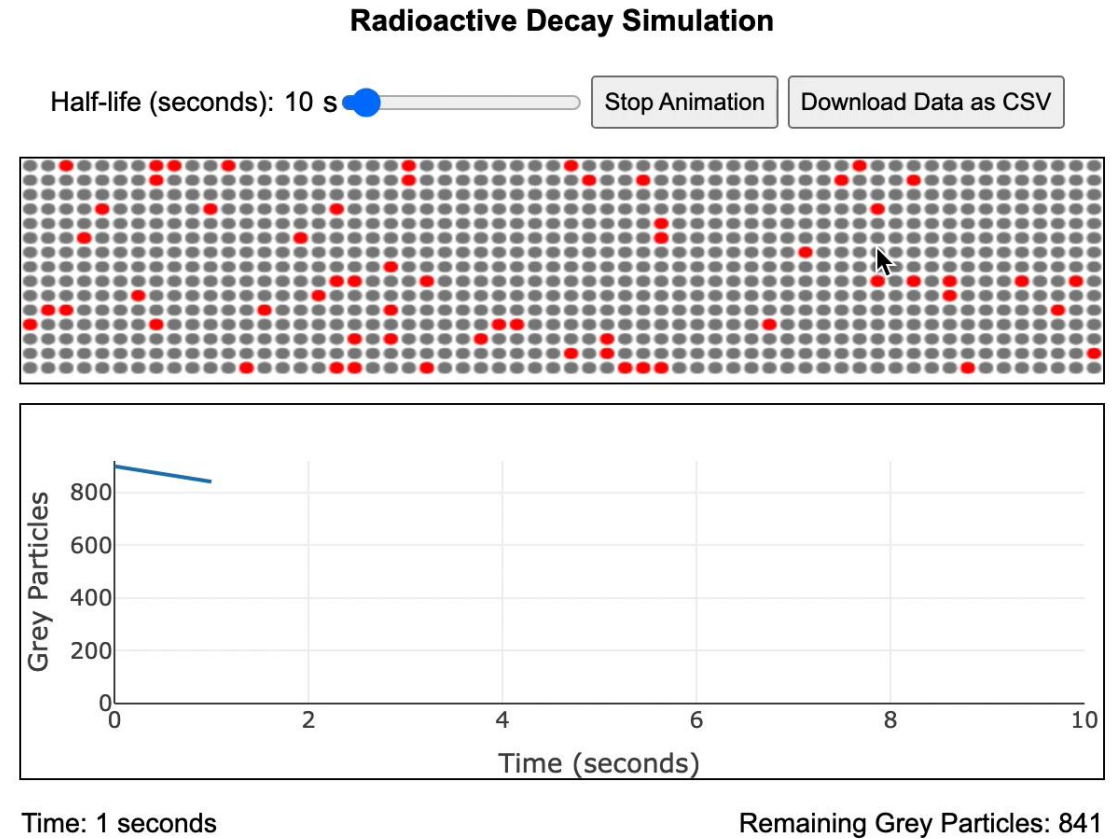
Guided inquiry  
with **simulation**

***Check for  
Understanding***

Using **MCQ**  
**Quiz**

# Another Learning Experience: Radioactivity

- Implemented as a Home-Based-Learning (HBL) package
- Objective: Understanding half-life through decay curves and data in tables



# Another sample activity : Radioactivity

- Scaffolding through:
  - Suggesting initial settings
  - Pointing out what to observe.
  - Giving hint
- Providing instant feedback through MCQ quiz

Q1

Setting the half-life of the grey particles in the simulation at 20 seconds, how many particles do you expect there to be after 10 seconds if there are 900 particles in the beginning?

HINT 1

Fraction of radioactive sample left after time  $t = \left(\frac{1}{2}\right)^{t/20}$ .

Between 400 and 500

Between 600 and 700

Between 700 and 800

Between 800 and 900

**Feedback**

The number of particles after time  $t$  can be calculated using the formula for exponential decay:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/20}$$

where  $N_0$  is the original number of undecayed particles.

Substitute the values:

$$\frac{N}{900} = \left(\frac{1}{2}\right)^{10/20}$$
$$N \approx 900 \times 0.707 \approx 636$$

unsolicited

# Student Feedback

Dear Mr Tan,

Thank you for sharing with us your PASSION for physics :) It is truly inspiring to see a teacher like you putting so much effort to teach us the different concepts using various CREATIVE methods such as through your small applets websites and your FUN<sup>3</sup> activities! I can really see the effort you put in and I am genuinely very grateful to have a teacher who cares so much about his students' growth! ♥ I hope you know

HAPPY TEACHER DAY MR TAN!! I'm genuinely so grateful to have you as my CT & physics tutor bc of the dedication you have for teaching us is CRAZY. Your stimulation and hula hoop and Fleming's Hand are so helpful in helping me understand those complex topics I've never heard of bt,

you're really passionate for it :) I'm sorry that I'm not the best student but thank you for being patient and kind with me. I'll work hard for Eoys. Thank you for using cool ways to teach us like bringing props and applets! I appreciate you as my teacher and CT. :)

Happy teacher's day Mr Tan. ~

Thank you for teaching us physics and going the extra length to demonstrate the physics principles through cool simulations and gadgets, which makes learning physics more interesting! Thank you for also

“Thank you for also making content much more **interactive** and **digestible** with your amazing coding skills to curate simulations for us to visualize, using AI chatbots to understand and explore new concepts and even putting up free learning materials on your website and youtube. All these have aided me so much in understanding and allowed me to **explore further about physics in my free time**”

Thank you for also making content much more interactive & digestible with your amazing coding skills to curate simulations for us to visualize, using AI chatbots to understand & explore new concepts, & even putting up free learning materials on your website & youtube. - All these have aided me so much in understanding & allowed me to explore further about physics in my free time 😊