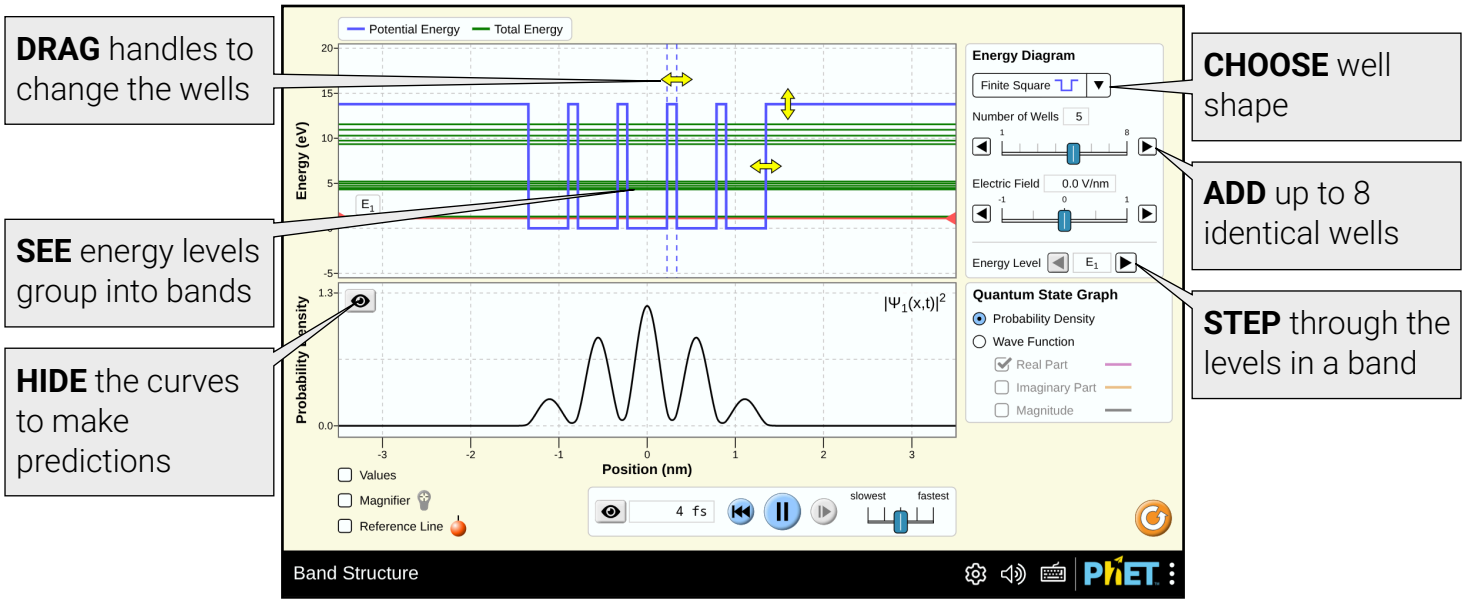
Band Structure

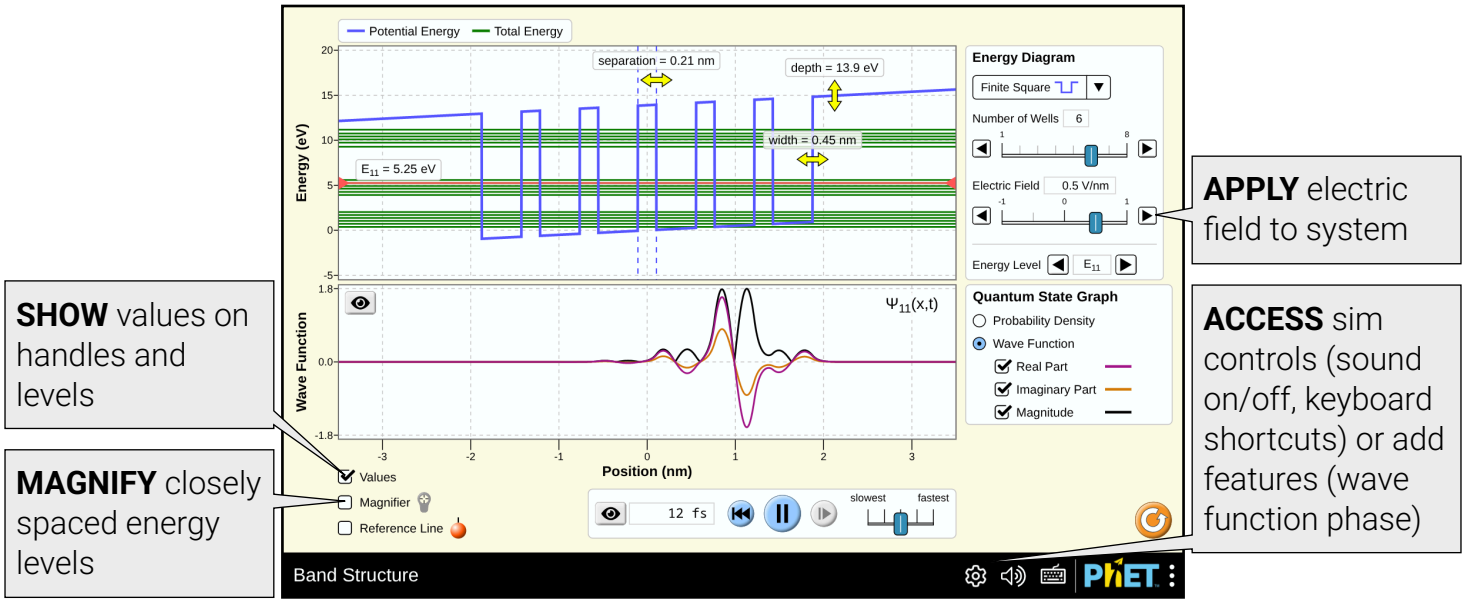
The ***Band Structure*** simulation allows students to explore how the number, separation, and shape of identical wells affect their energy levels and wave functions, and how an electric field changes them. It is part of the Quantum Bound States suite of simulations.

Band Structure Screen

Add identical wells to see energy levels group into bands.



Tilt the wells with an electric field and see how the energy levels and wave functions change.



Insights into Student Use

- Students may ask why time is running when the probability density of a single energy level never changes. Time runs to show that the real and imaginary parts still oscillate. The sim starts playing because some students who pause it never resume.
- Students often ask about the physical meaning of the imaginary part of the wave function, and rarely about the real part. Showing the real part, imaginary part, and magnitude together can help students see how they are related and that both parts are equally important.
- In interviews, students could not make sense of the phase-color representation without significant help. The Phase checkbox is hidden by default and can be added with Wave Function Phase in the Preferences menu. Use it with caution.

Complex Controls

- Click or tap an energy level in the Energy Diagram to select it. Hovering over a level highlights it and shows its label, plus its energy when Values is checked.
- The eye button in the Quantum State Graph hides the curves, so students can predict a wave function before revealing it. The eye button in the time controls hides the elapsed time.



- Check Magnifier to show a probe and a viewer that can be dragged separately. The viewer shows the area under the probe at 50×, which helps separate the closely spaced levels in a band.
- To see the wave function at t = 0 fs, as it appears in most textbooks, pause the sim and press the restart button.



Suggestions for Use

See all published activities for Band Structure.

- Use this sim to build a model of an electron in a solid by adding identical wells one at a time. Each single-well level becomes a band with one level for each well.
- Have students develop rules for how the separation, width, and depth of the wells change the widths of the bands and the gaps between them.

Sample Challenge Prompts

- How many energy levels are in each band? How does that number relate to the number of wells?
- How does the width of a band change as the wells move closer together?
- Select the lowest and highest levels of the lowest band. How do their wave functions differ?
- What happens to the gaps between bands as the wells get deeper or wider?
- Turn on the electric field. How do the energy levels in a band change, and where is the probability density of each state?

Sample Prediction Questions

- Predict how many levels the lowest band will have with 8 wells. Check your prediction with the Magnifier.
- Hide the curves with the eye button, then select the highest level of the lowest band. How many times will the wave function cross zero?
- Will Pöschl-Teller wells form bands the same way as Finite Square wells? Predict, then test.

Simulation Details

See this sim's Model Documentation for more details.

- Wave functions are normalized, so the area under the probability density is always 1.
- The ground state is E_1 for Finite Square wells and E_0 for Pöschl-Teller wells, so a phrase like "the third level" can be ambiguous.
- The sim finds the states with a numerical solver that holds the wave function at zero at the edges of the graph (±3.5 nm) and may respond more slowly on less powerful devices. With an electric field, only the states below the lower edge of the tilted barrier are shown.
- For Finite Square wells, separation is the distance between the walls of neighboring wells. Pöschl-Teller wells have a fixed width, and spacing is the distance between their centers.

Inclusive Features

See the simulation page for all supported inclusive features.

Alternative Input and Touchscreen Devices

- This simulation supports keyboard input for all handles, sliders, spinners, and tools. Home and End move a handle to its minimum or maximum value, and 0 moves the Reference Line to x = 0 nm. See the Keyboard Shortcuts dialog in the simulation for more information.

Sound and Sonification

- This simulation includes Basic Sounds, which provide audible confirmatory feedback to indicate successful interaction, such as when pressing a button or checking a checkbox.
- Handles and the Reference Line click as they move and play a boundary sound at the ends of their ranges.

Interactive Description (Core)

Core description is a subset of a fully described interactive experience.

- When the Reference Line has focus, press Space or Enter to hear the values of the plotted curves at its position.
- Teachers can access the Accessibility (A11y) View to see the descriptions available to screen reader users to decide if the sim's description meets their instructional needs. *Please note: A11y View is not intended for student use and will not provide a good experience for learners using screen reader software.*

Customization Options

Option 1: Use PhET Studio to configure a sim exactly how you want students to see it, save your preset, then send the preset link to your students. This is a premium product. Start a free trial today!

Option 2: Query parameters allow for customization of the simulation, and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, in Band Structure, if you want the sim to start paused (`isPlaying=false`) with sound muted (`audio=muted`) use:
https://phet.colorado.edu/sims/html/band-structure/latest/band-structure_all.html?isPlaying=false&audio=muted

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/band-structure/latest/band-structure_all.html?locale=es&isPlaying=false&audio=muted

⚙ Indicates this customization can be accessed from the Preferences menu within the simulation.

Query Parameter and Description	Example Links
`isPlaying` - when `false`, the sim starts paused at t = 0 fs, for courses that focus on stationary states. Default is `true`.	`isPlaying=false`
⚙ `phaseCheckboxVisible` - when `true`, adds a Phase checkbox for showing the phase of the wave function.	`phaseCheckboxVisible=true`
`interactiveHighlightsInitiallyEnabled` - opens the sim with interactive highlights enabled.	`interactiveHighlightsInitiallyEnabled`
⚙ `locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`audio` - if muted, audio is muted by default. If disabled, all audio is permanently turned off.	`audio=muted` `audio=disabled`
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`
`supportsPanAndZoom` - when `false`, disables panning and zooming using pinch-to-zoom or browser zoom controls. Default is `true`.	`supportsPanAndZoom=false`

Additional PhET Resources

See PhET's Inclusive Design page to learn more about each Inclusive Feature and how to use them with your students.
For more tips on using PhET sims with your students, see Teaching with PhET.
To learn more about ways to create and facilitate sim-based lessons, visit our free Virtual Workshops.