

Training for Educators

Entanglement

Secondary Level
Ages 12-18

Purpose of the lab

- The purpose of this lab kit is to introduce quantum entanglement through activities and experiments. Students will think about how entangled particles that are in superposition can then be measured to understand information about both particles instantly, no matter how far apart they are. This will be demonstrated analogously with balls using “measuring” by feeling and with a game.
- The main takeaways are:
 - Superposition means that an object can exist in multiple states at once.
 - Entangled objects are linked such that knowing something about one of them gives information about the other instantly.
 - Measurement of a system forces the objects to be in definite states.

Summary of experiments



There are 2 activities and one design challenge.

Supplies list

- Identical cups
- Two types of balls that have very different weights (like metal and plastic)
- Marker
- Fabric (as a blindfold)
- Coins with two clear sides (labelled heads and tails)
- Tangled game pieces (game cards, game boards, printed scorecards)
- Scale (optional)

Safety considerations

Before the students begin the laboratory, please take into consideration the following safety concerns:

- If moving to different locations or behind a divider, especially when blindfolded, be mindful of obstacles to prevent accidents.

Setting up your space

- Gather your supplies and separate by experiment(s) on your table.
- These are our recommendations:
 - Each student should have a pencil or pen.

Groups of 2-4 students can be given the following supplies:

- 2 identical cups
- 2 balls of very different weights
- Fabric (as a blindfold)
- 2 identical coins with a heads/tails
- Tangled game pieces
 - Two gameboards
 - Two scoresheets
 - One set of game cards

The class can share the following supplies:

- Markers
- Scale (optional)

Part I. "Measuring" by feeling

- Set-up:
 - Each group of 2-4 students gets 2 cups, two types of balls that have very different weights, and fabric for blindfold.
- Procedure:
 - Blindfolded students should guess which of the two balls is in the cup they are holding, as well as in the cup they are not holding.
- Results:
 - Students will see that by making a "measurement" on the ball in the cup they are holding, they can know which ball is in the other cup (as long as they make the correct guess first).

The takeaway is the "entangled" balls are being used to demonstrate superposition, and by "measuring" one ball by feel, you instantly know something about the other ball.

Part II. Tangled!

- Set-up:
 - Each group (2-4 students) will need coins (with clearly labelled heads/tails), game cards, game boards, and printed scorecards for the Tangled! game.
- Procedure:
 - Students will play the Tangled! game with different rounds (non-entangled, entangled - must match, entangled - must anti-match).
- Results
 - Students should see values in non-entangled and entangled rounds not correlated and correlated, respectively.

The takeaway is that the “entangled” coins will be correlated (knowing information about one gives you information instantly about the other).

Part II. Tangled!

- Teachers can watch a video demonstration of the Tangled game here (American Physical Society):
 - https://www.youtube.com/watch?v=o_Mhr-0xF0U

Design challenge

Students are asked to design a device that uses entanglement and superposition to do something useful. For the purposes of this challenge, you can also imagine that quantum mechanical behavior like entanglement and superposition extends to large objects around you (like balloons, cups, balls, etc.).

- Questions to ask the students (encourage creativity)
 - What could entanglement and superposition be useful for in the real world? You can consider real world applications or imaginary ones in which entanglement and superposition extend to large objects around you. Be creative and think broadly.
 - What will you use entanglement and superposition for in your device? Is your device a real-world or imaginary-world device?
 - How will your device meet a need in your life or in your community?
 - What kinds of materials will you need to create your device?