Instructor Guide: Rules for Thermal Phenomena

What is this ACORN Physics Tutorial designed to do?

This worksheet is designed to **elicit common conceptual resources** for thinking about temperature and thermal energy, including:

- **Heat transfer is directional (from hot to cold).** For example, when students are discussing question I.A they might say something like this: "The two blocks end up the same temperature because the transfer of energy goes from high to low." Or, "the energy from the hot block transfers to the cold block."
- **An object's physical properties (mass and material) matter for thermal phenomena.** For example, when students are discussing question I.B they might say: "Greater mass requires more energy to be the same temperature." Or for 2.A, "Iron retains energy better, so the brick cooled down faster while the iron stayed hot."
- **Hotter objects have more energy.** A student might reason: "So we put heat (energy) in and the temperature will go up."
- **Energy is conserved.** Students may refer to energy transfers and transformations in their explanations of various thermal phenomena, or they may use the amount of energy initially in a system as a constraint that affects what can happen in the system.

This worksheet includes questions that elicit, refine, test, and/or build upon these ideas while at the same time leaving space for less-common ideas about temperature and thermal energy. In particular, this worksheet was designed to (I) designed to elicit and connect ideas like the ones above, (II) support students to further articulate and refine the resources elicited in part I, and (III) test and extend ideas to construct a qualitative model for thermal energy transfers and temperature changes.

What content learning goals might this worksheet support?

In general, ACORN Physics Tutorials are designed to support students in constructing their own models for physics concepts; the materials do not scaffold students toward a single, predetermined model. This worksheet guides students to construct a **qualitative** model for thermal energy transfers and temperature changes among objects in contact with each other.

Students will be able to:

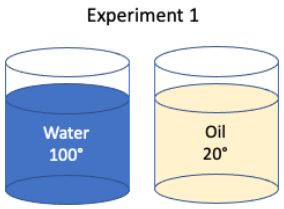
- Predict the direction of thermal energy transfer for objects in contact
- Define thermal equilibrium and predict the conditions under which it occurs
- Describe how mass, volume, and material influence thermal energy transfer.
- Distinguish thermal energy transfer from change in temperature.

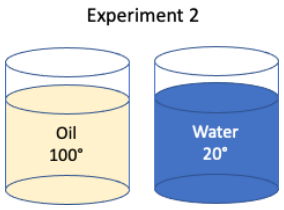
Example of student work:

Rule 1: Material matters: At room temperature, the block of iron has more energy than the block of brick, and the water has more energy than the olive oil.
Rule 2: Thermal energy tries to balance itself: when an object is being cooled, energy flows out from the object, and when an object is heated, energy goes from the heat source into the object.
Rule 3: The environment holds thermal energy as well: if an object is hotter than the environment, energy will flow from the object into the air, cooling the object down, and if the object is colder than the air, thermal energy will flow from the air into the object, heating it up.
Rule 4: Once an object starts boiling (changing into gas), it cannot get to a higher temperature.
Rule 5: Once the temperature stabilizes, objects in liquid share the same temperature as the liquid, even if they don't have the same amount of thermal energy.
Rule 6: If you want to cool something (or heat up) faster, make an object with much less or much more thermal energy touch it (e.g. hot metal in cold water)."

What questions can assess student progress toward these learning goals?

In experiment 1, 100g of olive oil at 100° C is poured into a beaker containing 100g of water at 20° C. After some time, the water and olive oil come to the same temperature and their temperatures stop changing. In experiment 2, the situation is reversed and 100g of water at 100° C is poured into a beaker containing 100g of olive oil at 20° C. After some time, the water and olive oil come to the same temperature and their temperatures stop changing.





Is the final temperature of the water and olive oil in experiment 1 *greater than, less than,* or *equal to* the final temperature of the water and olive oil in experiment 2? Explain your reasoning. If you need more information to make a prediction, describe what information you would need.

What resources, equipment, or experiments activities are good supplements to this worksheet?

- This worksheet pairs well with PhET's Energy Forms and Changes simulation. We recommend using the "intro" version and turning on "energy symbols." Students can use this simulation to qualitatively test predictions about temperature and thermal energy changes in various scenarios involving water, olive oil, iron, and brick. While this simulation is useful, there are significant limitations to what students can test with it (e.g., the simulation only allows one brick or iron cube, and the masses cannot be changed).
- Part III of this worksheet asks students to design and conduct an experiment to test their thinking. We recommend having the following equipment available to students:
    - Thermometer
    - Ice cubes
    - Hot water
    - Containers of various materials, masses and sizes, including a ceramic and metal container that can hold equal volumes and that have roughly equal masses.
    - Insulating box and/or cup.

What are specific strategies to help students with this worksheet?

- Keep track of questions that students express and suggest ways they can test their questions using equipment or simulations.
- Suggest thought experiments to clarify what a student is thinking or to resolve inconsistencies in their ideas.

What research has been done to develop and/or test this worksheet?

Learn more about the research involved in this worksheet here:
https://www.physport.org/curricula/ACORN/research#heatandtemperature