Worksheet: Rules for Thermal Phenomena

Name ______

The goal of this worksheet is for you and your partners to identify a set of "rules" that you can use to explain and predict macroscopic thermal phenomena. Because you've had a lot of experience with thermal phenomena over the course of your lifetime -- and you may even have learned about thermal physics in class -- you already know a lot about these phenomena. Here, we'll be asking you to identify and write down what you already know.

Use the box below to write down your "rules" as you're prompted throughout the worksheet.

My thermal physics rules

Here's an example of what you'll be doing in this worksheet: If I tap a light box that's sitting on the floor, I expect it to start sliding and then come to a stop. That expectation is informed by a set of rules that tell me how stuff behaves. For example, one rule is that things change their motion when there's a net force on them. Another rule is that friction tends to slow things down. Asking yourself, "How do I know this thing?," or "What is it that's informing my expectation here?," is what we're going to ask you to do again and again, except with thermal phenomena.

I. OBJECTS OF THE SAME MATERIAL

A. Consider the following scenario: Two identical metal blocks are sitting on a table. One is 100°C and one is 20°C. The blocks are placed in contact with one another and put into an insulated box. After several minutes, the blocks are the same temperature as one another.

i. Why does this happen? If your answer feels really simple to you -- like, "because it just does" -- try digging a little deeper to articulate why *that* simple thing happens. (For example, in the situation above with the light box, instead of saying "because things slow down," you could say "friction tends to slow things down" or "the box is rubbing against the floor, which slows it down.")

ii. Draw an energy tracking diagram that illustrates your idea. Your diagram should:

- Include "snapshots" of the important instants in time for this scenario.
- Include each object that is relevant
- Show units of energy explicitly, labeling each unit with a letter indicating the type of energy
- Be sure that energy is conserved! The number of energy units should be the same at all instants in your diagram.

iii. Is the final temperature of the blocks closer to 100°C, 20°C, 60°C, or something else? Explain your reasoning.

iv. What (perhaps unspoken) rules are you using to explain what happens? (A rule is something like "things change their motion when a net force acts on them" or "friction tends to slow things down.") **Write your rules in the box on the first page.**

B. Consider the following scenario: You have two cubes made of the same metal that have different mass (and volume). Each cube is heated to 100°C and then placed in identical volumes of room-temperature water in insulated cups. After several minutes, both cubes are the same temperature as the surrounding water. However, the water temperature is different in each cup: the water containing the larger cube has a higher temperature.

i. Why does this happen?

ii. Draw an energy tracking diagram that illustrates your idea.

iii. What rules are you using to explain why this happens? **Write your rules in the box on the first page.**

II. OBJECTS OF DIFFERENT MATERIALS

A. Consider the following scenario: A 100°C cube of iron with mass of 100g is placed into a beaker with 100 ml (100g) of 20°C water. After several minutes, the temperature of the iron and water have stopped changing and both are 28°C.

i. Explain this observation, and include an energy tracking diagram that illustrates this scenario.

ii. What rules are you using to explain why this happens? **Write your rules in the box on the first page.**

B. Consider the following scenario: A 100°C cube of iron with mass of 100g is placed into a beaker with 100g of 20°C olive oil. After several minutes, the temperature of the iron and oil have stopped changing and both are 35°C.
   i. Explain this observation, and include an energy tracking diagram that illustrates this scenario.

   ii. What rules are you using to explain why this happens? **Write your rules in the box on the first page.**

III. REFINING YOUR RULES

At this point, you should have a preliminary set of rules written down in your box.

Take a moment to **refine your preliminary set** by making your statements more precise, or by combining rules that may be special cases of a broader thing. (For example, if I were talking about forces and had written down, "Gravity changes the motion of objects," and, "Friction changes the motion of objects," I could combine those to say, "Forces change the motion of objects.")

Compare what's in your rule box with what's in your partners' rule boxes. (We know you've been working with them all along, but compare what you have actually written down.)

A. Do they have anything written down that you don't? If so, do you want to add what they have? Why or why not?

-

-

B. Did they word any of the same rules differently? If so, what's different about the wording, and are those differences meaningful, physics-wise, or just stylistic?

C. Do you have any unanswered questions about your rules or about what happens in the three scenarios above? **Record them in the rule box on the first page.**

IV. APPLYING YOUR RULES

Imagine you want to cool off some very hot soup in a small ceramic mug. Among your options are: (a) put it into a metal mug that is the same size as the ceramic mug; (b) pour in a bit of cold soup (just above 0°C); or (c) drop in a piece of ice at 0°C.

-

A. Use the rules you've written down to explain why each of these strategies would in fact cool down the soup. If you need to, add new rules you are using to explain each scenario. Draw a diagram to illustrate your thinking about each scenario.

   i. Metal mug:

   ii. Cold soup:

   iii. Ice:

B. Based on your explanations above, which of these methods do you think is likely to be fastest? What rules are you relying on to say so?

C. Design an experiment to test which of these methods is fastest, using the equipment you have at your disposal. (You may not have soup, but you could use water, for example.) Say why this is a good experiment for testing which is best.

   i. Conduct your experiment. What happened?

   ii. Does your experiment help you to identify any missing rules? If yes, what are they? If no, is there another experiment you could do to help you identify additional rules?

The point of this experiment is not to definitively answer the question, but to check whether your rules are accurate and useful in a new scenario – a preliminary test – and to identify any that may be missing.

CONCLUSION

You now have a refined (but still preliminary) set of rules for explaining and predicting thermal phenomena. When rules like these hold up again and again under experimental conditions, or when we can use existing rules or theoretical tools to verify them, they become part of a *model* for thermal phenomena. Most of the time, especially as we (and you) are learning about phenomena for the first time (or even the second or third), our models are *incomplete;* that's a sign that learning is happening! So identifying that what's in your box can't predict new things fully is a signal that you are still learning, which is exactly the right thing. For now, let's call what's in your box a preliminary, incomplete model for thermal phenomena that *you* can test or refine as you continue through your course.