Name: ________________________________

Handout 8.1.1.1: Temperature Inquiry Activities

Any instrument used to measure temperature may be called a thermometer. In this class we will use mercury thermometers. These thermometers consist of a chamber or bulb of liquid with a long narrow tube. When the liquid inside becomes hotter, it expands and moves up the tube. When it becomes cooler, the liquid contracts and retreats down the tube. The level of the liquid in the narrow tube can therefore be used as a measure of the temperature. To measure the temperature of an object, we put the bulb inside the object and wait for the liquid to adjust to its new surroundings. We then read the level of liquid in the tube.

Investigation 1

In a thermometer, almost all of the liquid is in the bulb. The liquid rises in the narrow tube because the volume of the liquid increases; the liquid expands as it becomes warmer. Using a narrow tube makes it easier to observe the small changes in volume of the liquid in the bulb.

1. Examine a thermometer. Approximately how many times as wide as the narrow tube is the bulb?

2. The volume change of the liquid is the same in a narrow tube and a wide tube. Explain why it is easier to observe this change in volume using a narrow tube than using a wide tube.

In order to use a thermometer, we need to have marks along the narrow tube for reading the level of the liquid. But how can we decide where to put the marks and how to number them? In order to mark or calibrate a thermometer, it is helpful to be able to produce and recognize some standard temperatures.

Investigation 2

For this experiment, you will need about 75 mL of water. Place the water in a beaker and record the temperature.

1. Heat the beaker over a burner or hot plate and record the temperature of the water every 30 seconds. Do not let the thermometer rest on the bottom of the beaker; instead place the thermometer about halfway into the water and stir gently. Do not let the thermometer touch the sides of the beaker.

   Data –

Name: ______________________

2. Record the time when the water starts to boil vigorously. (Note: small bubbles of air come out of solution when water is heated. Do not mistake this for boiling, which involves larger bubbles.) Stop the experiment after the water has been boiling for at least three minutes.

3. Make a graph of the temperature versus time from your data. Indicate on the graph the time when the water began to boil.

4. Does the temperature of the water change in the same way before it starts to boil and after it has begun to boil? Explain how you can tell from your graph.

The temperature at which water boils is called its *boiling point.* As you observed in the preceding experiment, the boiling point of water is easy to identify. Similarly, it is easy to recognize when water is freezing. Water begins to freeze at a certain temperature and then remains at that temperature until all of the water has solidified. In addition, there is both water and ice present as the water is in the process of freezing or melting. On the *Celsius temperature scale*, the freezing point of water is 0°C and the boiling point is 100°C. On the *Fahrenheit temperature scale*, the freezing point of water is 32°F and the boiling point is 212°F.

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Discussion Questions

1. A block of wood and a block of aluminum have been sitting out for a while. How do their temperatures compare?
    a. The wood is hotter than the aluminum.
    b. The aluminum is hotter than the wood.
    c. Both are the same temperature.
    d. There is no way to know.
2. When you touch something, you are feeling
    a. The temperature of the object
    b. The thermal conductivity of the object
    c. Both the temperature and the thermal conductivity of the object.
3. You have 50g of water in a beaker, and the water is 24 degrees Celsius. If you divide the water into two beakers, with 25g in each beaker, what is the temperature of each one?
    a. 24 degrees C
    b. 12 degrees C
    c. 48 degrees C
    d. Some other temperature
4. Suppose a 60 g copper rod is heated so much that the temperature of the rod rises by 15 Celsius degrees. By how much does the temperature of one gram of the copper in the rod change?
    a. 4 degrees
    b. 15 degrees
    c. 0.25 degrees
    d. Some other temperature
    e. Cannot say
5. Which is larger, a Fahrenheit degree or a Celsius degree? That is, which is a larger temperature change: 1 Fahrenheit degree or 1 Celsius degree?
    a. Fahrenheit degree
    b. Celsius degree
    c. Both are the same

Name: ______________________________

Handout 8.1.1.2: Thermal Equilibrium and Expansion

Below is a picture of a joint located on the Congress Street Bridge in Troy, New York, United States.

CC-BY-SA-3.0/Matt H. Wade at Wikipedia

Questions –

1. Why do you think the bridge has joints like the one pictured above?

2. When do you think a joint like the one above would be useful?

Name: ______________________________

Handout 8.1.2.1: Gas Properties PhET Simulation

In this activity you'll use the *Gas Properties* PhET Simulation to explore and explain the relationships between energy, pressure, volume, temperature, particle mass, number, and speed.

This activity has 4 modules:

- Explore the Simulation
- Kinetic Energy and Speed
- Kinetic Molecular Theory of Gases
- Relationships between Gas Variables

Part I: Explore the Simulation

Take about five minutes to explore the sim.   Note at least two relationships that you observe and find interesting.

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Part II: Kinetic Energy and Speed

Sketch and compare the distributions for kinetic energy and speed at two different temperatures in the table below. Record your temperatures (T_1 and T_2), set Volume as a Constant Parameter, and use roughly the same number of particles for each experiment (aim for ~100-200). Use the T_2 temperature to examine a mixture of particles.

Tips:

T_1 = ________K *The Species Information and Energy Histograms tools will help.*

T_2 = ________K *The system is dynamic so the distributions will fluctuate.*

Sketch the average or most common distribution that you see.

	"Heavy" Particles Only	"Light" Particles Only	Heavy + Light Mixture
# of particles (~100-200)			
Kinetic Energy Distribution sketch for T_1			
Speed Distribution sketch for T_1			
Kinetic Energy Distribution sketch for T_2			
Speed Distribution sketch for T_2			

Name: ________________________

1. Compare the kinetic energy distributions for the heavy vs. light particles at the same temperature. Are these the same or different? What about the speed distributions?

2. Compare the kinetic energy distributions for the heavy vs. light particles at different temperatures. Are these the same or different? What about the speed distributions?

3. Compare the kinetic energy distributions for the mixture to those of the heavy-only and light-only gases at the same temperature. Are these the same or different? What about the speed distributions?

4. Summarize your observations about the relationships between molecular mass (heavy vs. light), kinetic energy, particle speed, and temperature.

Adapted from Chamberlain, Julia and Ingrid Ulbrich, PhET Program, "Gas Properties Modular Homework Activity," [Homework Handout]. CU-Boulder.

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Part III: Kinetic Molecular Theory (KMT) of Gases

Our fundamental understanding of "ideal" gases makes the following 4 assumptions.
Describe how each of these assumptions is (or is not!) represented in the simulation.

Assumption of KMT	Representation in Simulation
1. Gas particles are separated by relatively large distances.	
2. Gas molecules are constantly in random motion and undergo elastic collisions (like billiard balls) with each other and the walls of the container.	
3. Gas molecules are not attracted or repulsed by each other.	
4. The average kinetic energy of gas molecules in a sample is proportional to temperature (in K).	

Adapted from Chamberlain, Julia and Ingrid Ulbrich, PhET Program, "Gas Properties Modular Homework Activity," [Homework Handout]. CU-Boulder.

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Part IV: Relationships Between Gas Variables

Scientists in the late 1800's noted relationships between many of the state variables related to gases (pressure, volume, temperature), and the number of gas particles in the sample being studied. They knew that it was easier to study relationships if they varied only two parameters at a time and "fixed" (held constant) the others. Use the simulation to explore these relationships.

Variables	Constant Parameters	Relationship	Proportionality *(see hint below)*
pressure, volume			directly proportional or inversely proportional
volume, temperature			directly proportional or inversely proportional
volume, number of gas particles			directly proportional or inversely proportional

Hint: A pair of variables is *directly proportional* when they vary in the same way (one increases and the other also increases). A pair of variables is *inversely proportional* when they vary in opposite ways (one increases and the other decreases). Label each of your relationships in the table above as directly or inversely proportional.

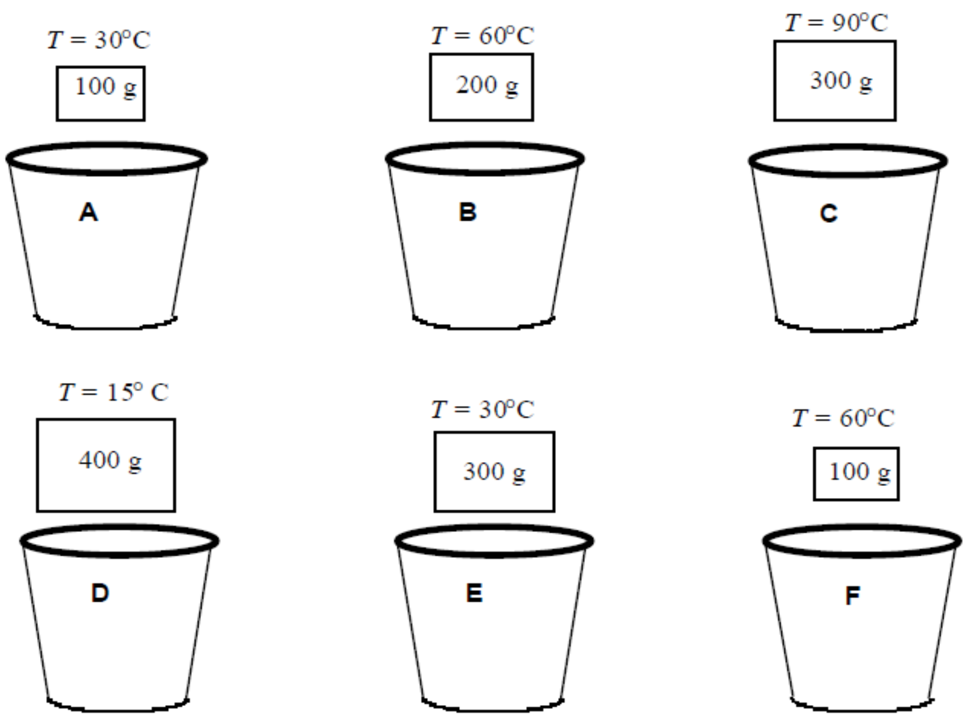
Adapted from Chamberlain, Julia and Ingrid Ulbrich, PhET Program, "Gas Properties Modular Homework Activity," [Homework Handout]. CU-Boulder.

Name: ______________________________

Handout 8.2.1.1: Quantitative and Conceptual Heat Practice

1. You have six Styrofoam cups containing the same amount of water at 20 °C. You also have six copper blocks whose masses and initial temperatures vary as shown below. One block goes into each cup. (Assume the mass of the water is between 500 g and 1000 g).

Rank these cups according to the maximum temperature of the water after the block is added.



Highest 1________ 2________ 3_______ 4________ 5________ 6________ Lowest

Or, all of the cups have the same maximum temperature. _______

Please carefully explain your reasoning.

Name: ______________________________

2. A student eats a dinner rated at 2000 (food) Calories. He wishes to do an equivalent amount of work in the gymnasium by lifting a 50 kg mass. How many times must he raise the mass to expend this amount of energy? Assume that he raises it a distance of 2 m each time and that he regains no energy when it is dropped to the floor. The acceleration due to gravity is 9.8 m/s^2 and 1 food Calorie is 10^3 calories.

3. A 100 kg student eats a 200 Calorie doughnut. To "burn it off," he decides to climb the steps of a tall building. How high would he have to climb to expend an equivalent amount of work?

4. A 5 g lead bullet traveling at 300 m/s is stopped by a large tree. If half the kinetic energy of the bullet is transformed into internal energy and remains with the bullet while the other half is transmitted to the tree, what is the increase in the temperature of the bullet? Assume the specific heat of lead is 128 J/kg°C.

5. A cup of coffee (140 g) cools from 75˚C down to comfortable room temperature 20˚C. How much energy does it release to the surroundings?

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6. Suppose during volleyball practice, you lost 2.0 lbs of water due to sweating. If all of this water evaporated, how much energy did the water absorb from your body? Express your answer in kJ. 2.2 lbs = 1.0 kg

7. A serving of Cheez-Its releases 130 kcal (1 kcal = 4184 J) when digested by your body. If this same amount of energy were transferred to 2.5 kg of water at 27˚C, what would the final temperature be?

Name: ______________________________

Handout 8.2.2.1: Phase Changes

Suppose you placed a beaker filled with water on a hot plate. You turned the hot plate on and left it on for some time and it begins to boil. What do you think the temperature vs time graph would look like for the water?
Draw your predicted graph here –

Experiment

Conduct the experiment with your partner. Collect data at increments of your choice. Sketch a graph of your findings –

a. What are the key features of your graph?

b. What do you think is the cause of these features?

c. Predict what you think the graph would look like for ice melting. Describe its features.

Name: ______________________________

Handout 8.2.2.4: Latent Heat Practice

Concept Practice

1. Why does blowing over hot soup cool the soup?

2. Why are icebergs often surrounded by fog?

3. Suppose a new liquid were discovered that is identical to water in every way except that it has a lower latent heat of fusion. Would it take a longer or shorter time to make ice out of this liquid in your freezer? Why?

4. A great amount of water vapor changes phase to become water in the clouds that form a thunderstorm. Does this release thermal energy or absorb it? Explain.

Quantitative Practice

5. Steam at 100°C is added to ice at 0°C. Find the temperature when the mass of steam is 10 g and the mass of ice is 50 g. The specific heat of water is 4186 J/kg°C, its latent heat of fusion is 3.33×10^5 J/kg and its heat of vaporization is 2.26×10^6 J/kg.

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6. In an insulated vessel, 250 g of ice at 0°C is added to 600 g of water at 18°C. How much ice remains when the system reaches equilibrium? Assume the heat of fusion of ice is 79.7 cal/g and its specific heat is 0.5 cal/g°C. The heat of vaporization of water is 540 cal/g and its specific heat is 1 cal/g°C.

Challenge Problem

7. When a lead bullet hits a large solid target at high speed, its entire kinetic energy is converted into heat. For simplicity, assume that all that heat is concentrated in the bullet rather than the target. If the bullet's initial temperature is 15°C, how fast would it have to move before the collision in order to have 30% of its mass melted after the collision? Lead has a melting temperature 327.3°C, a specific heat of 128 J/kg K and latent heat of fusion 24500 J/kg.

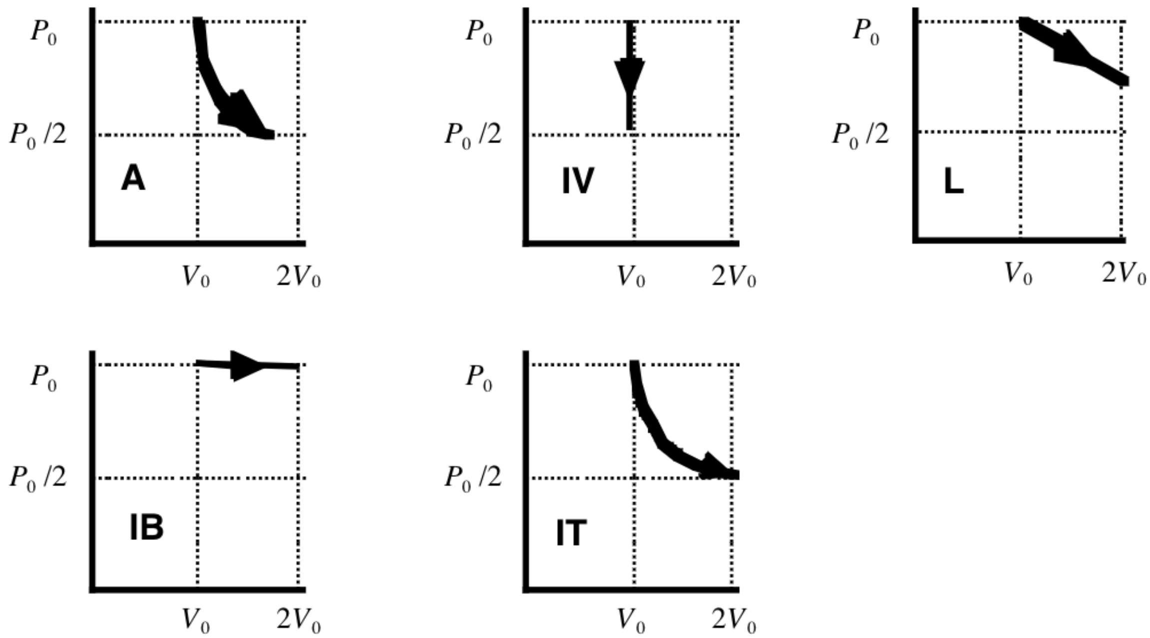
NAME: ______________________________

Handout 8.3.1.2.1: Thermal Processes (Part 1)

Five thermodynamic processes are illustrated below. All five processes are for the same ideal gas start if and the same initial pressure and temperature ($P_0$and T_0). Each of the five distinctly different processes results in different final equilibrium states. The labels on each of the diagrams are to be interpreted as follows:

A = adiabatic L = linear IT = isothermal
IV = isovolumetric IB = isobaric

Rank these processes from greatest to lease on the basis of the amount of work that is done by the gas. Positive work should be ranked higher than negative work.



Greatest Work 1______ 2______ 3______ 4______ 5_______ Least Work

Or, all of the diagrammed processes require the same amount of work done by the gas. ______

Or, there is no work done by the gas in any of these processes. _______

Please carefully explain your reasoning.

How sure were you of your ranking? (circle one)

Basically Guessed Sure Very Sure

1 2 3 4 5 6 7 8 9 10

110 J. Popp Ranking Task Exercises in Physics Properties of Matter, Heat-Thermodynamics, Waves

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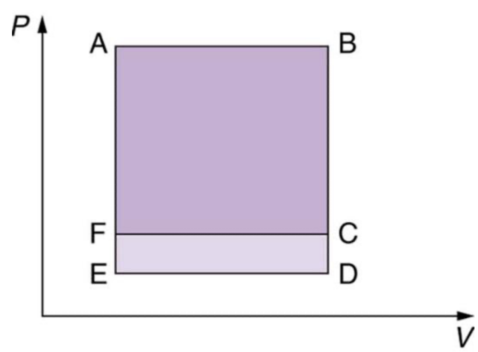
Handout 8.3.1.2.2: Thermal Processes (Part 2)

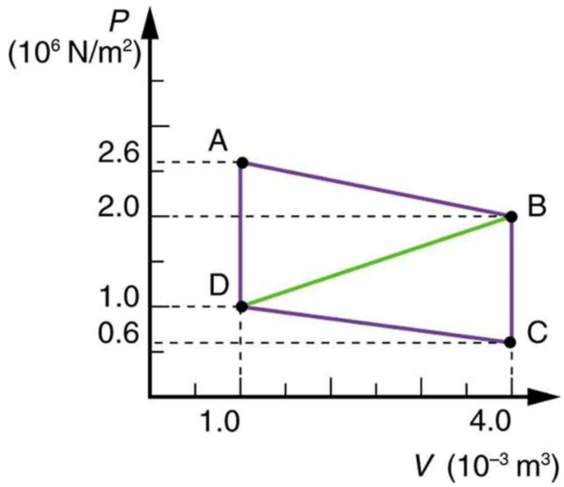
1. A great deal of effort, time and money has been spent in the quest for the so-called perpetual-motion machine, which is defined as a hypothetical machine that operates or produces useful work indefinitely and/or a hypothetical machine that produces more work or energy than it consumes. Explain, in terms of the first law of thermodynamics why or why not such a machine is likely to be constructed.

2. Which cyclical process represented by the two closed loops, ABCFA and ABDEA, on the PV diagram in the figure below produces the greatest net work? Is that process also the one with the smallest work input required to return it to point A? Explain your responses.



Name: ______________________________

3. Calculate the net work output of a heat engine following the path ABCDA in the figure below.

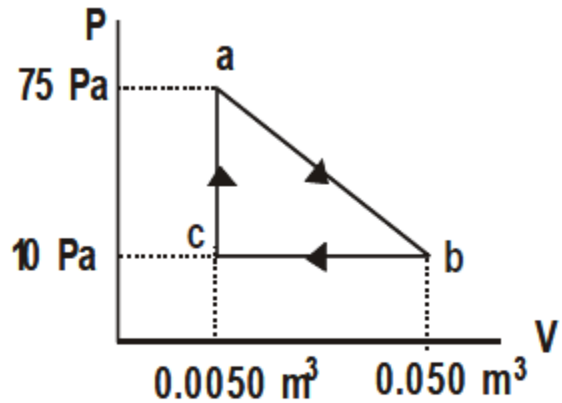


4. What is the net work output of a heat engine that follows path ABDA in the figure from Q3 with a straight line from B to D?

5. Why is the work output less than for path ABCDA?

Name: ________________________________

6. A gas undergoes a thermodynamic expansion process as shown. Process *ab* represents the output work, process *bc* represents input work, all three processes involve heat transfer.



a. What is the work accomplished along path *ca*?

b. What is the work along path *ab*?

c. What is the work along path *bc*?

d. What is the net work for the entire thermo cycle?

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Handout 8.3.2.1: Second Law of Thermodynamics and Engines

Visit the Carnot Cycle simulation site –
http://galileoandeinstein.phys.virginia.edu/more_stuff/Applets/carnot_cycle/carnot_cycle.html

Investigate what happens as the simulation plays.

1. What are the key features of the heat engine?

For the following questions support your answers with graphs, words, and sketches of the heat engine.

2. Describe what happens during isothermal expansion.

3. Describe what happens during adiabatic expansion.

4. Describe what happens during isothermal compression.

5. Describe what happens during adiabatic compression

Questions adapted from OpenStax, College Physics.

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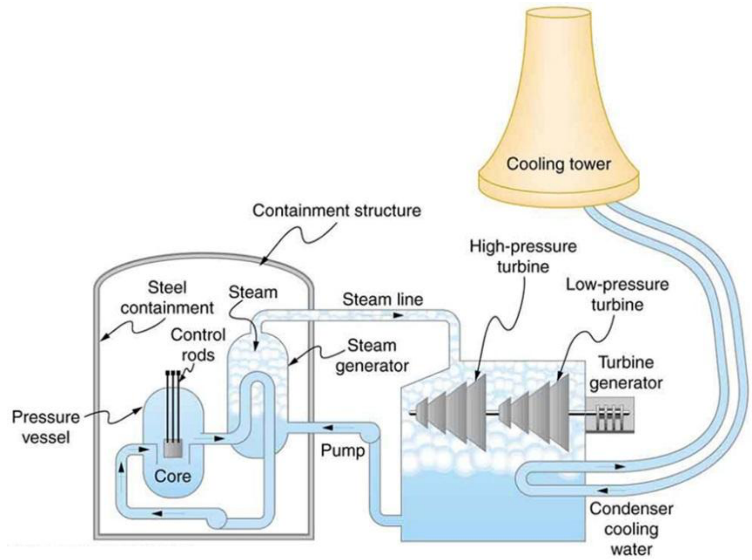
Additional Application Questions

6. A nuclear power reactor has pressurized water at 300°C. Heat transfer from water is a complex process (see figure below). Steam, produced in the steam generator, is used to drive the turbine-gneators. Eventually the steam is condensed to water at 27°C and then heated again to start the cycle over.



   a. Predict – what do you think the maximum efficiency for a heat engine operating between these two temperatures is?

   b. Calculate the maximum theoretical efficiency.

7. Suppose you want to design a steam engine that has heat transfer to the environment at 270°C and has a Carnot efficiency of 0.80.
   a. What temperature of steam must you use?

   b. Is this a reasonable temperature? Explain.

8. In your opinion, does the second law of thermodynamics alter the conservation of energy principle? Explain.

Questions adapted from OpenStax, College Physics.