**Team and Team Number:** **Names:**

# SSSS Thermodynamics

# Division B Event

# By syo_astro

## Directions

*** Each part (e.g. a, b, etc or i, ii, etc) of a question is worth 1 point. Any question where the value changes will be noted. The test is 50 points and 25 minutes.**

*** The test involves questions relating to the physics of thermodynamics.**

***Use the sign convention that work done *by* the system means work, W, has a negative sign in the 1st law of thermodynamics.**

*** PLEASE: Remember to use correct units. A quantitative answer that is numerically correct without necessary units and/or significant figures is given a ½ point.**

*** Don't be afraid to guess (logically) for partial credit where possible, and read all parts of questions! Some parts may be easier and not require previous parts.**

*** Ties are broken by the total points from the following questions applied in order: 6, 1, 5, 4, 7, 14**

1. You are testing if a beaker of water is the right temperature for the build portion of Thermodynamics. You measure the water to be at a temperature of 303 K.
    a. What is this temperature in °C?
    b. You make the same test, but you want to check if your backup thermometer also works. This one only measures in °F. After waiting a long time, you find the temperature of the water is 66.2 °F. What is this temperature in °C?
    c. After waiting a long time, the water is essentially in what state, where the water exchanges no heat with its surroundings?
    d. If a granite rock was submerged in the water, after waiting a long enough time, what temperature would the rock have in °C?
    e. Which law of thermodynamics was used to establish the answers to the previous two parts?
    f. (2 pt) Which system in this question could be used as a thermometer: The granite rock, the cup of water, or the air in the room? Pick one and explain how it fulfills each condition of this law of thermodynamics.
2. Matching – On your answer sheet, write the roman numeral for the definition that most appropriately relates to a unit. Each correct is worth 0.5 pts.

| Unit | | Definition |
|---|---|---|
| a. Pascal | I. | The energy transferred to an object when 1 N of force acts on an object in the direction of its motion through a distance of 1 m. |
| b. Mole | II. | The amount of heat required to raise the temperature of 1 lb of water by 1° F. |
| c. Watt | III. | A unit of power. |
| d. Joule | IV. | The amount of heat required to raise 1 g of water 1° C. |
| e. Calorie | V. | The SI unit for an amount of substance. |
| f. BTU | VI. | A unit of pressure. |

3. How many calories are in a Calorie of food?
4. You put a bowl of water and a block of wood into a fridge.
    a. Which if either of the wood or water should have a lower temperature?
    b. Which of the wood or water, if either, should feel colder when you touch it?
    c. Which object has a higher specific heat? Which has the higher thermal conductivity?
    d. Based on this experiment, if you wanted to keep something warm would it better to submerge it in water or cover it in wood? Why (note high/low specific heat/conductivity)?
    e. Based on this experiment, if you wanted to more slowly heat something up, would it be better to submerge it in water or wrap it in wood? Why (note high/low specific heat/conductivity)?
5. You use an experimental metal for thermodynamics experiments. First you determine its specific heat by putting the metal on top of a flame such that it gets hot. The data from the experiment was Q = 10.0 J, m = 0.150 kg, and $\Delta T$ = 85.0 K.
    a. What is the specific heat, $c_p$, of this metal in J $kg^{-1}$ $K^{-1}$?
    b. (1.5 pt) For a fixed flame and thus amount of heat, would the specific heat change if 500.0 g was used instead for the experiment? Why or why not?

c. Only by specific heat, is this substance most similar to aluminum ($c_p$ = 0.9 J $kg^{-1}$ $K^{-1}$), bismuth ($c_p$ = 0.123 J $kg^{-1}$ $K^{-1}$), copper ($c_p$ = 0.386 J $kg^{-1}$ $K^{-1}$)?

d. You keep heating up the metal with a flame until it melts. You note from how hot the flame is and how long it burned that the metal received 68.4 kJ as it was melting. What is the latent heat of fusion for this metal in kJ/kg (assume the mass of the metal does not change)?

e. (1.5 pt) Based on your answers to the previous parts, is this substance likely to be a good or bad conductor of heat? Why or why not?

6. You want to engineer a system to help construction workers with lifting heavy metal beams. You try a piston filled with an ideal gas. To test what will be necessary, the piston is first lifted up by a person. It was measured that the gas goes from a temperature of 19 °C to 30 °C. The gas originally had a volume of 1.03 x $10^{-3}$ $m^3$.

   a. What is the new volume of the gas, in $m^3$?
   b. If there are 6.5 mols of gas, then what is the pressure of this gas, in Pa?
   c. How much work was done by the person, in J?
   d. This was slowly lifted at constant pressure. What is the name for this type of process?
   e. In an adiabatic process how much heat is added to the system, in J?
   f. If this were an adiabatic process, would the process take more or less work? Why? Explain using the $1^{st}$ law of thermodynamics in the following steps (i-iii are each worth 0.5 pt, while iv is worth 1.5 pts):
      i. What is the $1^{st}$ law of thermodynamics mathematically in terms of ΔU, Q, and W when heat Q goes **into** a system and work W is done **by** a system?
      ii. In an adiabatic process, what is the change in internal energy, ΔU, equal to in terms of any of Q (into the system) and W (by the system)?
      iii. With constant pressure, what is the change in internal energy, ΔU equal to in terms of any of Q (into the system) and W (by the system)?
      iv. In which case would more work be done for the same change in internal energy? Why does this make sense?
   g. If instead of the work done by the person, one could add heat due to combustion of oil. How much could be lifted? Show this by the steps:
      i. What is the term for a thermodynamic process that is maximally efficient?
      ii. Assuming this applies to the piston (it does not, but we could make a similar piston where it would), what is the efficiency for lifting the piston using the same conditions as when the person was lifting the piston?
      iii. Knowing the work put in from part b and the efficiency from the previous part, how much useful work can be done by using this piston, in J?
      iv. As a small test, you want to see if you could use the piston to lift a sofa. The work to lift an object is equal to m*g*h, where m is the mass of an object, g is a gravitational constant (equal to 10 $m/s^2$ on Earth), and h is the height an object is lifted. An average sofa is 150. kg. If it was lifted only 0.500 m, then how much work is done to lift the sofa, in J? Would it be possible to lift the sofa or metal beams with this piston?

7. It is well known that water freezes when its temperature is below 0 °C. In such a case, the entropy of water must *decrease*.

a. Which law of thermodynamics might make this statement seem questionable, stating that entropy of the universe always increases?
b. (1.5 pt) How can ice freeze spontaneously, meaning entropy decreases, while still letting this law of thermodynamics be valid?
c. (1.5 pt) Using this example, would it be possible to put a fan in front of ice, a freezer, or a fridge in order to continuously cool down a room? Why or why not (be sure to *explain* the relevant law of thermodynamics)?

8. Which law of thermodynamics states that the entropy of a system at absolute zero is equal to zero?
9. Who was the first to mathematically show the maximum efficiency of heat engines?
10. (0.5 pt) The SI unit of absolute temperature is named after which person?
11. From working on thermodynamics, who coined the term statistical mechanics and helped to establish the field of statistical mechanics?
12. In 1761, Joseph Black studied the melting of ice with calorimetry and introduced what term as a result?
13. What famous physicist studied Brownian motion and heat capacity after calling thermodynamics "the only physical theory of universal content which I am convinced will never be overthrown"?
14. Energy Transfer Matching – On your answer sheet, match the following examples to the form of energy transfer that is best demonstrated. Each correct answer is worth 0.5 pt. Answer with:
A) Conduction
B) Convection
C) Radiation

| Example |
|---|
| Blood circulation in a warm blooded animal |
| Sunlight |
| Popping popcorn in the microwave |
| Space Heater |
| The heat you feel from touching a smartphone |
| Solar Panels |
| Rubbing your hands together |

15. (2 pt) The following image shows a zebra imaged in infrared. Are the zebra's black stripes normally seen in visible light shown by the white or red stripes of the infrared image? Explain using knowledge of blackbody radiation.