Course and Section_______ Names ___________________________

Date___________________ ___________________________

THERMODYNAMICS SIMULATION

Introduction

This simulation explores the heat Q in the case of a calorimeter and how the first law of thermodynamics applies to heat engines.

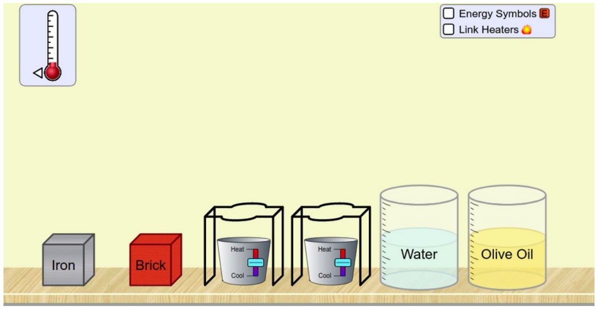
Submit your answers using Blackboard.

1 – Calorimetry

When two objects at different temperatures are in thermal contact they exchange heat, Q, until they reach the equilibrium temperature T_e. The amount of heat depends on the mass m, the change in temperature $\Delta T = (T - T_e)$ and the specific heat of the object, c, as follows,

$$Q = mc\,\Delta T$$

Open the simulation (https://phet.colorado.edu/en/simulation/energy-forms-and-changes) and select Intro



Here you will heat up a block and investigate how heat is exchanged with the liquid in a beaker.
On the top left corner there is a thermometer. The marks range from 25°C to 250°C, the initial room temperature is just above 25°C. You can select and use as many thermometers as needed.
1. What is the change in temperature between two marks on the thermometer ?
2. Put the beaker with water on the heater and increase the temperature until water vapor appears. Is the simulation consistent with vapor forming just before 100°C ?

Put the water back on the table and heat up the block of iron, then move it inside the water.
3. What happens to the temperature of iron?
4. What happens to the temperature of water?

Repeat: heat the iron <u>to the same</u> temperature of question 3 but now put it in the beaker with the olive oil.
5. How does the highest temperature reached by the olive oil compare to the highest temperature reached by the water in question 4?
6. Using the info in question 4 how does the specific heat of olive oil compare to the specific heat of water? (assume equal masses of the water and olive oil)

Assume a room temperature of 27°C, the volume of the water to be 2.5 L, and the initial temperature of the water to be 27°C. Heat up the iron block to 225°C and then put it into the beaker with water.
7. What is the equilibrium temperature? (use the value of the nearest mark)
8. Given specific heat of iron c_{Fe} = 0.46 J/g °C and water c_W = 4.18 J/g °C, find the mass of the block of iron.

Start over, put both the iron block and the brick on the two heaters. Click on *Link Heaters*. The brick is an alloy of unspecified metals.
9. Does the iron heat up faster?
10. Do the two blocks absorb an equal amount of heat per second?
11. Assume the two blocks are of equal mass, which has smaller specific heat?

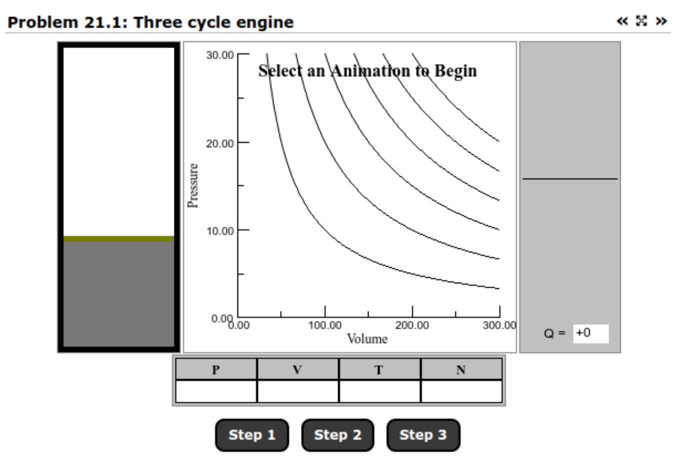
2 – Heat Engine

The first law of thermodynamics relates the change of the internal energy ΔU of a system (a gas inside a piston for example) to the amount of heat Q the system exchanges with the surrounding and the work W done on/by the system

$$\Delta U = Q - W \tag{1}$$

If Q is add to the system $Q > 0$, if Q is released by the system $Q < 0$. If work is done on the system $W < 0$, if W is done by the system $W > 0$.

Open the simulation (https://www.compadre.org/Physlets/thermodynamics/prob21_1.cfm)



In this simulation and for your calculations assume k_B = 1 J/K

For an ideal gas the change of internal energy is $\Delta U = \frac{3}{2} N k_B \Delta T$ (2)

In the case of an isothermal transformation of a gas inside a piston, the work done is

$$W = N k_B T \ln(V_f / V_i) \quad (3)$$

where V_f and V_i are the final and initial volumes.

By pressing Step 1, Step 2 and Step 3 the simulation shows the transformations of an ideal gas. Run each transformation in order. By looking at the variables displayed *P, V, T, N, Q*.

12. Which kind of transformation is Step 1?
13. Which kind of transformation is Step 2?
14. Which kind of transformation is Step 3?

NOTE: The simulation displays small gaps in the numerical values between steps for some variables. Treat those values as they were real measurements subjects to experimental errors. For example in step 2 for the final volume use V_f = 200, but for the initial volume use V_i = 201.67 since it is the final volume of step 1.

Using the equations (2) and (3) calculate ΔU and *W* for step 1 and 2. Report the value of *Q* given by the simulation (bottom right). Calculate again ΔU using equation (1) for step 1 and step 2. Needless to say, these values of ΔU for each steps 1 and step 2 must be the same. Use this information to check your calculations.
Be careful about using the correct signs of *Q* and *W*.

Step 1
15. ΔU
16. *W*
17. *Q*
18. $\Delta U = Q - W =$

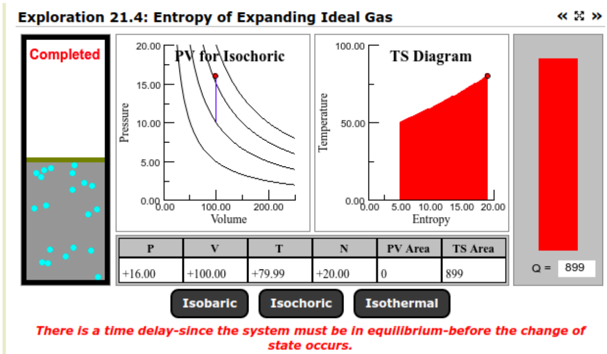
Step 2
19. ΔU
20. *W*
21. *Q*
22. $\Delta U = Q - W =$

Step 3
23. ΔU
24. *Q*
25. *W*

26. Calculate the net heat that was exchanged during one cycle $Q_{NET} = Q_1 + Q_2 + Q_3$.
27. Calculate the net work done by/on the system during one cycle $W_{NET} = W_1 + W_2 + W_3$.
28. Calculate the change of internal energy of the system during one cycle $\Delta U = Q_{NET} - W_{NET}$.

3 – Change in Entropy

Open the simulation (https://www.compadre.org/Physlets/thermodynamics/ex21_4.cfm)



In the case of a monatomic ideal gas which undergoes a thermodynamics transformation, it can be shown that its change of entropy is

$$\Delta S = N\left[\frac{3}{2}\ln\left(\frac{T_f}{T_i}\right) + \ln\left(\frac{V_f}{V_i}\right)\right]$$

where N is the number of molecules (in this simulation $k_B = 1$ J/K).
Use at least four significant figures to answer the following questions.

29. What is the change in entropy during isobaric process?
30. What is the change in entropy during isochoric process?
31. What is the change in entropy during isothermal process?
32. Does the entropy decrease in any of these processes?
33. Which process produces the most entropy?
34. Does the process in the question 34 also produce the most heat?