Name:	
Class:	
Due Date:	

B.4 Thermodynamics

Additional HL Understandings

- The first law of thermodynamics, as given by $Q = \Delta U + W$, results from the Ο application of conservation of energy to a closed system and relates the internal energy of a system to the transfer of energy as heat and as work.
- The work done by or on a closed system as given by $W = P\Delta V$ when its boundaries are changed can be described in terms of pressure and changes of volume of the system.
- The change in internal energy, as given by $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}Nk_{\rm B}\Delta T$, of a system is related to the change of its temperature.
- \circ Entropy S is a thermodynamic quantity that relates to the degree of disorder of the particles in a system.
- Entropy can be determined in terms of macroscopic quantities such as thermal energy and temperature as given as $\Delta S = \frac{\Delta Q}{T}$ and also in terms of the properties of individual particles of the system as given by $S = k_B \ln \Omega$ where k_B is the Boltzmann constant and Ω is the number of possible microstates of the system.
- The second law of thermodynamics refers to the change in entropy of an isolated system and sets constraints on possible physical processes and on the overall evolution of the system.
- Processes in real isolated systems are almost always irreversible and consequently the entropy of a real isolated system always increases.
- The entropy of a non-isolated system can decrease locally, but this is compromised by an equal or greater increase of the entropy of the surroundings.
- Isovolumetric, isobaric, isothermal, and adiabatic processes are obtained by keeping one variable fixed.
- Adiabatic processes in monatomic ideal gases can be modeled by the equation as given by $PV^{\frac{5}{3}} = \text{constant}.$
- Cyclic gas processes are used to run heat engines.
- o A heat engine can respond to different cycles and is characterized by its efficiency as given by $\eta = \frac{\text{useful work}}{\text{input energy}}$

• The Carnot cycle sets a limit for the efficiency of a heat engine at the temperatures of its heat reservoirs as given by $\eta_{\text{carnot}} = 1 - \frac{T_{\text{c}}}{T_{\text{h}}}$.

Additional HL Equations

$$Q = \Delta U + W$$
$$W = P\Delta V$$
$$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}Nk_{B}\Delta T$$
$$\Delta S = \frac{\Delta Q}{T}$$
$$S = k_{B}\ln\Omega$$
$$PV^{\frac{5}{3}} = \text{constant}$$
$$\eta = \frac{\text{useful work}}{\text{input energy}}$$
$$\eta_{\text{carnot}} = 1 - \frac{T_{c}}{T_{h}}$$

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

- 1. Define thermodynamics.
- 2. Define a *closed system*.
- 3. Define an *isolated system*.
- 4. State the *first law of thermodynamics*.
- 5. Consider a system filled with an ideal gas and the equation for the law of conservation of energy $Q = \Delta U + W$.
 - a. Define ΔU . What is the meaning if $\Delta U > 0$ Joules? $\Delta U = 0$ Joules? $\Delta U < 0$ Joules?

b. Define *W*. What is the meaning if *W* > 0 Joules? *W* = 0 Joules? *W* < 0 Joules?

c. Define Q. What is the meaning if Q > 0 Joules? Q = 0 Joules? Q < 0 Joules?

6. Describe the equation $W = P\Delta V$.

- 7. Describe the equation $\Delta U = \frac{3}{2}Nk_{\rm B}\Delta T = \frac{3}{2}nR\Delta T$.
- 8. Define thermal equilibrium.
- 9. State the zeroth law of thermodynamics.
- 10. What does the area under a *pressure-volume curve* tell us?
 - a. Define *isothermal process*. Draw three *isothermal processes (isotherms)* on a *pressure vs. volume* graph.

b. Define *isobaric process*. Draw an *isobaric process* on a *pressure vs. volume graph*.

c. Define *isochoric/isovolumetric process*. Draw an *isochoric/isovolumetric* process on a *pressure vs. volume* diagram.

d. Define *adiabatic process*. Draw an *adiabatic process* on a *pressure vs. volume* graph.

11.Define entropy S. Units?

12.Describe the equation $\Delta S = \frac{\Delta Q}{T}$.

13. The change in entropy *S* of a system is defined as $\Delta S = \frac{\Delta Q}{T}$. a. What can we do to make ΔS positive?

b. What can we do to make ΔS negative?

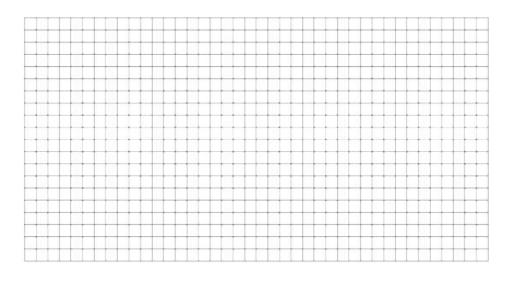
14.Describe the equation $S = k_{\rm B} \ln \Omega$.

15. State the second law of thermodynamics.

16. State the Clausius version of the second law of thermodynamics.

- 17. State the Kelvin version of the second law of thermodynamics.
- 18. State the *arrow of time* and *entropy* in terms of the *second law of thermodynamics*.
- 19. State the *third law of thermodynamics*.
- 20.Describe the equation $PV^{\frac{5}{3}} = \text{constant}$.
- 21.Define *heat engine* and *heat pump*.

22. Use a pencil! Carefully and clearly draw the *Carnot cycle*. Label the vertical axis and the horizontal axis. Label the adiabatic processes and isothermal processes.



23. In general the efficiency of an engine is $\eta = \frac{\text{useful work}}{\text{input energy}}$. For a *Carnot engine* $\eta_{\text{carnot}} = 1 - \frac{T_{\text{cold}}}{T_{\text{hot}}}$.

- a. Is the *Carnot cycle* a fast or slow process?
- b. Is the Carnot cycle realistic?
- c. Is the Carnot cycle efficient?