Thermodynamics

- The study of laws of heat _____ and its relationship to _____

Systems have _____ energy due to the _____ and _____ of the _____ in it

- Heat can be _____ by the system
- Because of conservation of energy this changes the _____ energy of the system
- Heat is _____ when system _____ heat
- Heat is _____ when system _____ heat

Work can also change _____ energy of a system

- Work is _____ when it is done _____ the system
- Work is _____ when it is done _____ the system

1st Law of Thermodynamics

$$\Delta U = Q - W$$

- U = internal energy, Q = heat (positive when system gains Q), W = work (positive when system does W)

$$\text{For gasses } U = \frac{3}{2} NkT = \frac{3}{2} PV$$

While working on an assignment, Frank does 10000 J of work. In the process, his internal energy decreases by 20000 J. Find W, ΔU, and Q.
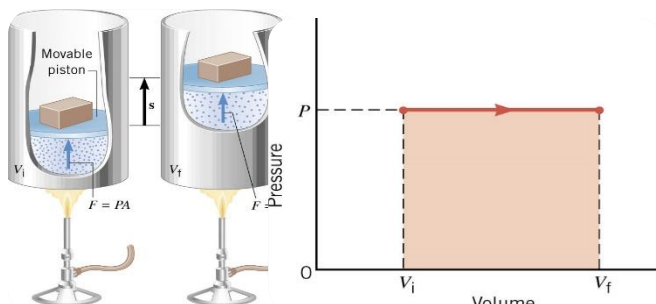
Four thermal processes

Each is quasi-static → _____ enough that _____ temperature and pressure

Isobaric

- Constant _____
- Frictionless piston where the pressure is determined by the weight of the piston (doesn't change)
- As the gas is heated, it expands and pushes the piston up
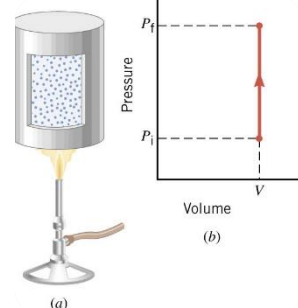
$$W = P\Delta V = P(V_f - V_i)$$
$$\Delta U = Q - P\Delta V$$

Isochoric

- Constant _____
- Since no change in volume no work is done

$$\Delta U = Q$$

Isothermal

- Constant _____
- Usually temperature of a gas decreases as it (PV=nRT) expands, so thermal energy is transferred into the gas from the environment
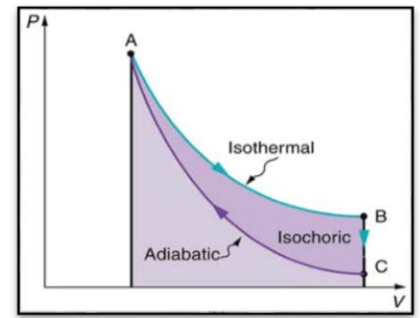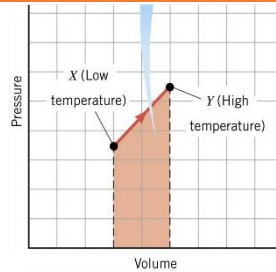
$$Q = W$$
$$\Delta U = 0$$

Adiabatic

- No heat _____

$$\Delta U = -W$$

- The area under a Pressure-Volume graph is the _____

- If the process goes in a _____, then the work done is the area _____ the loop on a PV graph

- Since the work can be _____ or _____, the processes can go _____ direction

- In theory it can be _____ reversed (return to previous state)

- There is always _____ so there is _____ completely reversible process

Homework

1. (a) Is it possible for the temperature of a substance to rise without heat flowing into it? (b) Does the temperature of a substance necessarily have to change because heat flows into or out of it? In each case, give your reasoning.

2. Suppose you want to heat a gas so that its temperature will be as high as possible. Would you heat it under conditions of constant pressure or constant volume?

3. How do heat transfer and internal energy differ? In particular, which can be stored as such in a system and which cannot?

4. The temperature of a rapidly expanding gas decreases. Explain why in terms of the first law of thermodynamics. (Hint: Consider whether the gas does work and whether heat transfer occurs rapidly into the gas through conduction.)

5. What is the change in internal energy of a car if you put 12.0 gal of gasoline into its tank? The energy content of gasoline is 1.3×10^8 J/gal. All other factors, such as the car's temperature, are constant. (OpenStax 15.1) **1.6×10^9 J**

6. How much heat transfer occurs from a system, if its internal energy decreased by 150 J while it was doing 30.0 J of work? (OpenStax 15.2) **120 J**

7. A system does 1.80×10^8 J of work while 7.50×10^8 J of heat transfer occurs to the environment. What is the change in internal energy of the system assuming no other changes (such as in temperature or by the addition of fuel)? (OpenStax 15.3) **-9.30×10^8 J**

8. What is the change in internal energy of a system which does 4.50×10^5 J of work while 3.00×10^6 J of heat transfer occurs into the system, and 8.00×10^6 J of heat transfer occurs to the environment? (OpenStax 15.4) **-5.45×10^6 J**

9. Suppose a woman does 500 J of work and 9500 J of heat transfer occurs into the environment in the process. (a) What is the decrease in her internal energy, assuming no change in temperature or consumption of food? (That is, there is no other energy transfer.) (b) What is her efficiency? (OpenStax 15.5) **-1.0×10^4 J, 5.00%**

10. A car tire contains 0.0380 m³ of air at a pressure of 2.20×10^5 N/m² (about 32 psi). How much more internal energy does this gas have than the same volume has at zero gauge pressure (which is equivalent to normal atmospheric pressure)? (OpenStax 15.10) **6.77×10^3 J**

11. A helium-filled toy balloon has a gauge pressure of 0.200 atm and a volume of 10.0 L. How much greater is the internal energy of the helium in the balloon than it would be at zero gauge pressure? (OpenStax 15.11) **300 J**

12. A hand-driven tire pump has a piston with a 2.50-cm diameter and a maximum stroke of 30.0 cm. (a) How much work do you do in one stroke if the average gauge pressure is 2.40×10^5 N/m² (about 35 psi)? (b) What average force do you exert on the piston, neglecting friction and gravitational force? (OpenStax 15.13) **35.3 J, 118 N**

13. Calculate the net work output of a heat engine following path ABCDA in the figure. (OpenStax 15.14) **4.5×10^3 J**

14. What is the net work output of a heat engine that follows path ABDA in the figure, with a straight line from B to D? Why is the work output less than for path ABCDA? (OpenStax 15.15) **2.4×10^3 J**