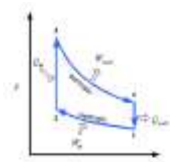
Thermodynamics…

First Law of Thermodynamics
Processes and p-V diagrams

P-V diagrams

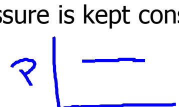
- A p-V diagram is essentially a graph that illustrates pressure as a function of a change in volume
- Work done on or by a system is related to the pressure and the volume, so these diagrams are useful for determining the amount of work that has been performed



- Sample p-V diagram showing a cycle of energy transformations in an "Otto" engine source: http://www.qrg.northwestern.edu/thermo/design-library/otto/otto.html

Isobaric Process

- **Isobaric**: the pressure is kept constant.
  →Graph example:



- In order for a volume change to occur without changing the pressure,
  - Temperature must change.
- **Work** performed must be equal to the area under the line (Isobar)

Isobaric Example

- 6.0 dm^3 of an ideal gas is at a pressure of 202.6 kPa. It is heated so that it expands at constant pressure until its volume is 12.0 dm^3. Find the work done by the gas.

$$W = p \cdot \Delta V \rightarrow W = (202.6 \text{ kPa}) \cdot (12.0 \text{ dm}^3\text{-}6.0\text{dm}^3)$$

$$W = (202.6 \text{ x } 10^3 \text{ Pa})(6.0 \text{ x } 10^{-3} \text{ m}^3)$$

$$= 1.216 \text{ x } 10^3 \text{ J}$$

$$= 1200 \text{ J}$$

Isochoric Process

- **Isochoric**: the volume is kept constant.
  →Graph example:
- Work done = _____
- So what happens?
  - Temperature and pressure can both change, so the thermal energy of the gas will change
  - (It either heats up or cools down…)
- Line on the graph is called an **isochore**

Example problem #2

- A thermal system containing a gas is taken around the cycle shown in the diagram.
- Starting at point A on the diagram, describe the cycle, and, calculate the work done by the system in the completion of the cycle

Answer, pt. 1

- From point A to point B is an isochoric process. The volume remains constant as the pressure increases as a result of the addition of thermal energy (heating the gas).
- $W_{A\rightarrow B}=0$ because there is no volume change

- From point B to point C, the volume increases while the pressure remains constant (an isobaric process)
- $W_{B\rightarrow C}$=area under the given isobar =
  $W=(6000)Pa\cdot(10-4)m^3= 3.6 \times 10^4$ J

Answer, pt. 2

- From point C to point D, the gas is cooled, keeping the volume the same and reducing the pressure.
- W = 0 because there is no volume change

- From point D back to point A, the volume is decreasing while the pressure remains constant.
- W = area under the curve = $P\cdot(V_2-V_1)$
  $W = (2000)Pa\cdot(4-10)m^3 = -1.2 \times 10^4$ J
- **Total work:**
  Net work = 3.6×10^4 J – 1.2×10^4 J = $\mathbf{2.4 \times 10^4}$ **J**

Note: if the cycle was repeated in the opposite direction, the work done would be **negative**

Isothermal Processes

- Both pressure and volume are varied, allowing the temperature of a system to remain constant
- Isothermal expansion or compression refer to the process in which a gas is expanded (or compressed) because of changes to pressure and volume while the temperature
- The line on a p-V diagram that shows an isothermal process is called an **isotherm**

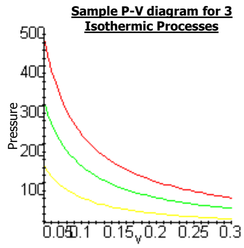
Isothermic Processes

- Remember: Pressure and volume are inversely related to each other when the temperature is a constant (Boyles' Law)
- If Red = T_1, Green = T_2, and Yellow = T_3, then:

$$T_1 > T_2 > T_3$$

- Remember,

$$pV = nRT$$

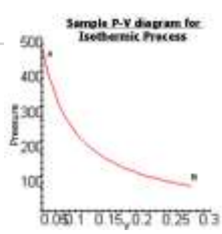


More on Isothermal Processes

- The following MUST occur if the temperature will remain constant while pressure and volume change:
  - It is assumed that the gas is held in a thin container with high thermal conductivity
    - This container must be in contact with a heat reservoir (such as a hot water bath)
  - The change in volume is completed SLOWLY, otherwise eddies will form in the gas, and hot spots will be produced, which would disrupt the gas' energy equilibrium.

Isothermic processes…more detail

- A sample of gas starts at point A, then a certain amount of heat (Q) is added, causing the system to move to point B
- Heat taken in causes gas to expand, and is equivalent to the mechanical work done by the gas
- No change in internal energy takes place (no change in temperature)
- Work done is equal to the area under the curve between points A and B…



$$W = R \cdot T \cdot \ln\left(\frac{V_2}{V_1}\right) = Q$$

Adiabatic Processes

- In an adiabatic expansion or contraction, no heat (Q) is allowed to flow in or out of the system.
- In an entire adiabatic process, Q = 0
- Conditions that must be met:
  - System must be extremely well **insulated**
  - Process must take place **rapidly** so that heat does not have time to leave the system

Adiabatic compressions…

- Work done on the gas causes an increase in its internal energy, causing an increase in temperature

$$\Delta U = Q - W$$

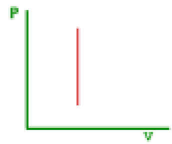
$$\text{remember, Q} = 0\text{...so,}$$

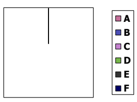
$$\Delta U = -W$$

- Quick review!
- Pull out your voters and get ready for some review questions. You can use any notes and your calculator.

The process shown in the diagram below is an...

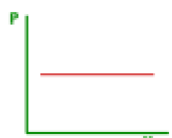
A. Isobaric process
B. Isochoric process
C. Isothermal process
D. Adiabatic process

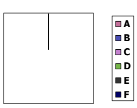




The process shown in the diagram below is an...

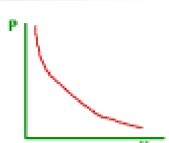
A. Isobaric process
B. Isochoric process
C. Isothermal process
D. Adiabatic process

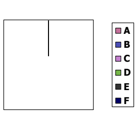




the process shown in the diagram below is an...

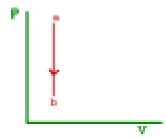
A. Isobaric process
B. Isochoric process
C. Isothermal process
D. Adiabatic process





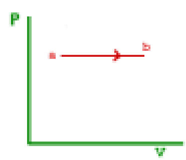
In the diagram below, the volume at point A is 200 L, and the pressure is 5 atm. At point B, the pressure is 1 atm. What is the work done?

A. 80,000,000 J
B. 400,000 J
C. 80,000 J
D. 0 J



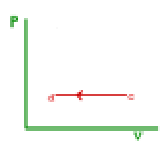
As shown below, the volume at point A is 200 L and the pressure is 5 atm. At point B, the volume is 400 L. What work was done?

A. 2x10^8 J
B. 1x10^8 J
C. 1x10^5 J
D. 0 J



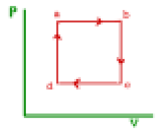
In the figure below, the volume at point "c" is 800 L and the pressure is 2 atm. The volume at "d" is 400 L. What is the work done?

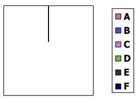
A. 8x10^7 J
B. -8x10^7 J
C. 8x10^4 J
D. -8x10^4 J



In the figure below, the volume at point "c" is 800 L and the pressure is 2 atm. The volume at "a" is 400 L and the pressure is 5 atm. What is the work done as the system goes through one complete cycle abcd?

A. 800000 J
B. 400000 J
C. 280000 J
D. 120000 J





In the figure below, the volume at point "c" is 800 L and the pressure is 2 atm. The volume at "a" is 400 L and the pressure is 5 atm. What heat is absorbed by the system in the square cycle illustrated?

A. 120000 J
B. 0 J
C. -120000 J
D. more information is needed