Thermal Physics

Chapter 13-15 In-Class Example Problems

Thermal Expansion:

1. A certain gold bar has a length of 61cm at a temperature of 21°C. Determine its length at 100°C.

2. A steel automobile fuel tank is filled to the brim with 45L (12gal) of gasoline at 10°C. Immediately afterward, the vehicle is parked in the sunlight, where the temperature is 35°C. How much gasoline overflows from the tank as a result of the expansion?

Ideal Gas Law:

3. A storage tank at atmospheric pressure and temperature of 20°C contains 34.0g of oxygen gas (O_2). What is the volume of the tank?

4. 2L of gas, initially at STP, is placed under a pressure of 5atm, and it is noted that the volume of gas decreases to one-third its initial volume. What is the final temperature of the gas?

5. Calculate the number of molecules per m^3 in a container of oxygen gas at 3.2Pa and a temperature of 70°C.

Molecular View of Temperature:

6. 6 moles of oxygen gas (O_2) are confined in a constant-volume container at a temperature and pressure of 100°C and 5atm, respectively.

a. What is the average kinetic energy per molecule of the gas?

b. What is the total random kinetic energy of all the molecules of the gas?

c. What is the rms speed of the molecules of the gas?

1st Law of Thermodynamics:

7. 40J of heat is transferred to a sample of gas, while 35J of work are simultaneously done on the sample. Calculate the change in the sample's internal energy.

8. A system has a final internal energy of 36J, after undergoing a process where it loses 15J of energy by heat, and does 17J of work. What was the system's initial internal energy?

9. When $5.3E^5$J of heat is added to a gas enclosed in a cylinder fitted with a light frictionless piston maintained at atmospheric pressure, the volume is observed to increase from $1.9m^3$ to $4.1m^3$. Calculate the work done on the gas, and the change in internal energy of the gas.

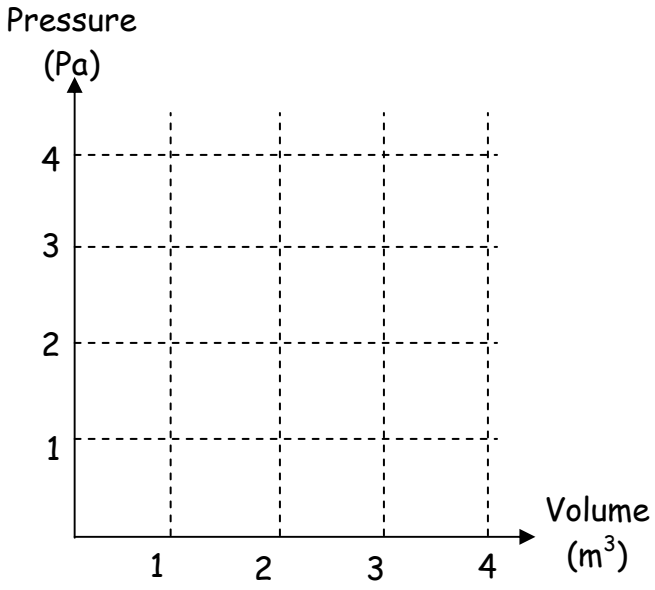
10. A sample of gas enclosed in container with a movable piston undergoes a thermodynamic process at a constant pressure of 3.1atm, during which its internal energy decreases by 720,000J. If 350,000J of heat is lost during this process, calculate the change in volume of the piston during the process.

P-V Diagrams:

11. A sample of 0.123 moles of gas has an initial volume of 1 cubic meter at an initial pressure of 4 Pascals.

a. Calculate the sample's initial temperature.

b. The sample undergoes an isothermal process as it expands to a final volume of 4 cubic meters. Sketch this process on the given graph.



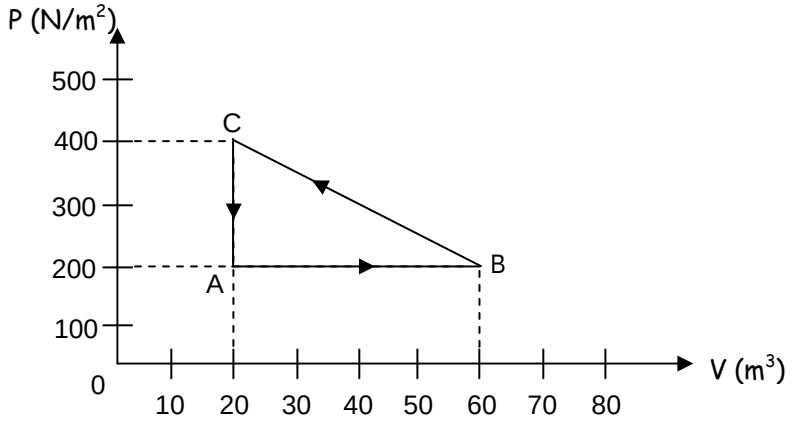
c. If 7.5J of heat were transferred to the sample during the previous process, calculate the work done on the gas during this same process.

d. The gas now undergoes an isobaric process as it decreases its volume to $1m^3$. Sketch this process on the graph, and calculate the work done on the gas during this process.

e. The gas now returns to its initial state by undergoing an isovolumetric process. Sketch this process on the graph, and calculate the work done on the gas during this process.

f. Calculate the following thermodynamic quantities for the gas during the entire cyclic process: $W_{on\ gas}$, ΔU, Q.

12. One mole of an ideal gas is taken around the cycle $A \rightarrow B \rightarrow C \rightarrow A$ as shown on the PV diagram.



a. Calculate the temperature of the gas at point A.

b. Calculate the net work done on the gas during one complete cycle.

c. Calculate the amount of heat added to or removed from the gas during the cycle.

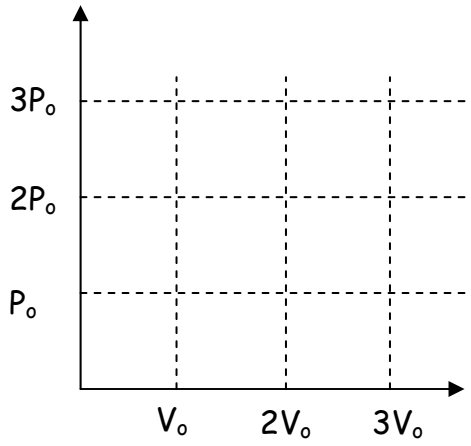
13. 1 mole of ideal gas is to be used as a working substance in a heat engine. Initially, the gas is at a pressure P_o and volume V_o. It then undergoes the following set of three processes:

I. $3PoV_o$ Joules of heat is added to the gas, as its pressure increases at constant volume to $3P_o$.

II. With the addition of $Q = 3.3PoV_o$ of heat, the gas is now allowed to expand isothermally to a volume of $3V_o$.

III. Then the gas is compressed at constant pressure back to its initial state.

Draw the PV diagram for this 3-part cycle, labeling each vertex with the appropriate temperature. Also calculate the work done during portion of the cycle.



2nd Law and Heat Engines:

14. Find the efficiency of an engine that introduces 5000J of heat during the combustion phase, and expels 3000J of heat at exhaust.

15. A certain Carnot engine absorbs 4000J of heat per cycle from a hot reservoir at 300°C, and the exhaust temperature is 120°C.

a. What is the efficiency of the engine?

b. How much work is done per cycle?

c. How much heat is expelled per cycle?

16. A heat engine operates in a Carnot cycle between 90°C and 350°C. If the engine absorbs 15,000J of heat per cycle from the heat reservoir, and each cycle lasts 0.2 seconds, what is the maximum power output of the engine?

17. A certain generator operates at 80% of its maximum theoretical (Carnot) efficiency between temperatures of 200°C and 300°C. The engine's output power is 400W. Calculate the rate of heat output.