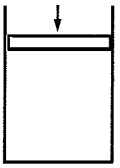
Thermal Physics

Thermal expansion: 1. A pair of eyeglass frames are made of epoxy plastic ($\alpha = 130 \times 10^{-6}\ °C^{-1}$). At room temperature (20° C) the frames have circular lens holes 2.8 cm in radius. To what temperature must the frames be heated in order to insert lenses 2.82 cm in radius?

2. An *Al* cup is filled to the brim with 500 mL of water at 10° C. If the temperature increases to 90° C, how much water will overflow? ($\beta_{Al} = 75 \times 10^{-6}\ 1/°C$, $\beta_{H20} = 210 \times 10^{-6}\ °C^{-1}$)



Ideal gas law: 3. 0.005 m^3 of a gas initially at STP is placed under a pressure of 3 atm (as shown on the right) so that its volume drops to 0.002 m^3. What is its final temperature?

4. Calculate the density (in kg/m^3) of nitrogen gas (molecular mass = 28 u) at STP using the ideal gas law.
5. A tire is filled with air at 10°C to a gauge pressure of 2.5 atm. If the tire reaches a temperature of 35°C, what fraction of the original air must be removed if the original pressure of 2.5 atm is to be maintained.
6. An ideal gas confined in a box of initial volume V. If the absolute temperature of the gas is tripled and the pressure of the gas is doubled, what would the volume of the gas be in the end?
7. The pressure in a helium gas cylinder is initially 20 atm. After many balloons have been blown up, the pressure has decreased to 7 atm. What fraction of the original gas is left in the tank?
8. Two ideal gases are held in two different containers A and B. a) A and B each holds two moles of gas. If B has twice the volume of A and 1/3 of the pressure of A, which container has a higher temperature?
   b) A holds 4 moles of gas and B holds 3 moles. If B has twice the volume of A and 1/3 the pressure of A, which container has a higher temperature?
9. An air bubble at the bottom of a lake 20 m deep has a volume of 0.8 cm^3. If the temperature at the bottom is 8 °C and at the top 24 °C, what is the volume of the bubble just before it reaches the surface?
10. A cylindrical container of cross-sectional area 0.01 m^2 is filled with nitrogen gas at the atmospheric pressure 1 atm at 17 °C. The container is closed and heated to 300 °C at the same volume. What is the force caused by the pressure difference on the top of the cylinder?

Kinetic theory: 11.What is the ave. translational KE of an O_2 molecule (molecular mass = 32u) at 40°C and 2 atm?

12. Find the total translational kinetic energy of 10 L of ideal gas at 3 atm.
13. Calculate the rms speed of carbon dioxide molecules (molecular mass = 44 u) at a temperature of 280K.
14. A gas is at 20 °C. To what temperature must it be cooled to halve its rms speed?
15. If an ideal gas is allowed to expand so that its volume is tripled while its pressure drops to 1/4 of its original pressure, a) by what factor does its temperature change? b) by what factor does its rms speed change?
16. The gases in two identical containers are at 2 atmosphere of pressure and 100°C. One contains helium gas (monatomic, atomic mass 4) and the other contains an equal number of moles of neon gas (monatomic, atomic mass 20). If 15 Joule of heat added to the neon gas increases its temperature a given amount, how much heat needs to be added to the helium gas to increase its temperature by the same amount?

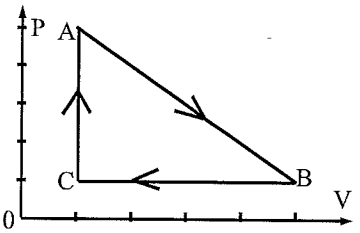
Heat: 17. A 2 oz. Snickers bar provides 266 Cal. How many joules does this bar provide?

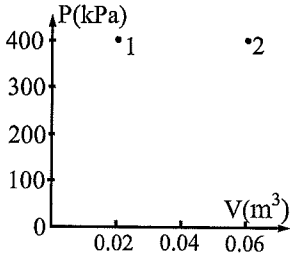
18. At time t=0, a pot filled with ice at −20°C is placed on a stove that provides heat at a constant rate. The ice melts and then is brought to a boil and continues to boil for a while. Plot a water temperature vs. time graph.

First law: 19. A system undergoes an adiabatic process and its internal energy decreases by 480 J. a) How much heat is exchanged with the system? b) How much work is done on or by the system? c) Does its temperature rise or fall?

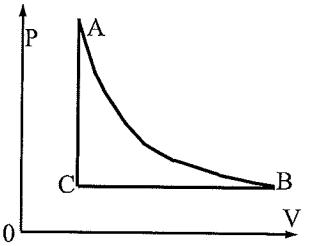
20. An ideal gas expands isothermally, performing 200 J of work in the process. Calculate a) the change in internal energy of the gas, and b) the heat absorbed during this expansion.
21. An ideal gas inside a container with rigid walls absorbs 90 J of heat. a) How much work was done by the gas? b) What was the change in internal energy of the gas during this process?
22. 0.02 m^3 of monatomic ideal gas initially at 500,000 Pa is allowed to expand isothermally until the pressure is 200,000 Pa. It is then compressed at constant pressure to its initial volume and lastly is brought back to its original pressure by heating at constant volume. a) What is the volume of the gas at the end of the isothermal process? b) Draw the process on a PV diagram. c) Find the change in internal energy, the work done by the gas, and the heat added to the gas for each of the 3 steps — isothermal, isobaric, and isochoric. d) Find the change in internal energy, the work done by the gas, and the heat added to the gas for the entire process.
23. Heat is added to an ideal gas, at a constant volume of 3 L, and the pressure and temperature are allowed to go up until the pressure reaches 4 atm. It is then cooled, at a constant pressure of 4 atm, from 3 L to 1.2 L when the temperature reaches its original value. a) Find the initial P. b) Draw the process on a PV-diagram. c) Calculate the total work done by the gas in the process, and d) the total heat flow into (or out of) the gas.
24. A thermodynamic system goes through the processes shown in the PV-diagram (on next page). Are the ΔU, Q and $W_{on\ gas}$ +, −, or zero in each of the following cases? a) Process A→B, b) process B→C, c) process C→A, d) process B→C→A, and e) process A→B→C→A.

If this thermodynamic system contains monatomic ideal gas, f) are the ΔU, Q and $W_{on\ gas}$ +, −, or zero for the process A→B→C. g) If the temperature at state B is T_B, calculate the temperature at state C in terms of T_B.



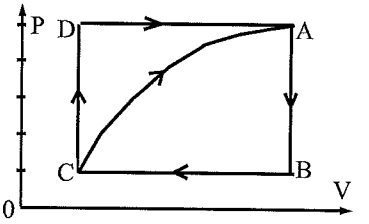


25. The PV diagram on the left shows two possible states of a system containing 5 moles of a monatomic ideal gas. $P_1 = P_2 = 400$ kPa, $V_1 = 0.02\ m^3$, $V_2 = 0.06\ m^3$. a) Draw the process which depicts an isobaric expansion from state 1 to state 2 and label this process (A). b) Find the work done by the gas and the change in internal energy of the gas in process (A). c) Draw the process which depicts an isothermal expansion from state 1 to the volume V_2 followed by an isochoric increase in temperature to state 2 and label this 2-step process (B). d) Find the change in internal energy of the gas for the 2-step process (B).



26. Gas in a chamber passes through the cycle ABCA as shown on the right. In the process AB, no heat is exchanged with the gas. In the process CA, 80 J of heat is added to the gas. For the complete cycle ABCA, the work done by the gas is 55 J. How much heat is added to or removed from the gas during process BC?

27. A cylinder with a movable piston contains a monatomic ideal gas. The information below refers to the PV-diagram on the right. $U_D - U_A = -75$ J, $W_{by\ gas B\to C} = -15$ J $Q_{C\to A} = 200$ J along the curved path, $W_{by\ gas C\to A} = 65$ J along the curved path. a) Determine the change in internal energy $U_C - U_A$. b) How much heat is added to or removed from the gas through the process ABC? c) How much work is done ON THE GAS in the process ABCDA? d) How much heat is added to or removed from the gas through the process CDA? e) How much heat is added to or removed from the gas through the process CD?



Heat engine: 28. A heat engine extracts 330 J from a hot reservoir, does work, then exhausts 190J into a cold reservoir. What is the efficiency of the heat engine?

29. The max. efficiency of a heat engine that operates between a firing chamber & an exhaust chamber is 40%. If the temp. in the firing chamber is 1500°C. What is the temp. in the exhaust chamber?

30. A Carnot engine performs work at the rate of 2000 W while using 5000 J per second. If the temperature of the exhaust is 200°C, what is the temperature of the heat source?