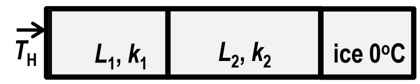
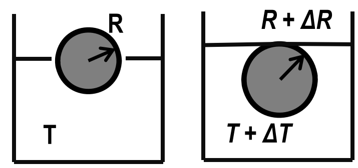
In each problem express your answer in terms of known variables listed for that problem; not all variables need to be used
Show your work, box your answers, check units.

Problem 1(total: 20 points)
The known variables are M , L_F T_H T_C K_1 K_2 L_1 L_2 A
Consider a heat source at temperature T_H and a mass of ice M at temperature T_C = 0C. Heat is conducted from the heat source to the ice through two heat conducting rods with thermal coefficients K_1 and K_2 , of lengths L_1 L_2 , and of cross section area A as shown. The latent heat coefficient for the ice is L_F
The system is insulated meaning that the only heat flow is from the heat source to the ice.



- What is the temperature at the junction of the two rods
- What is the time t needed for the ice to completely melt into water at 0C?

Problem 2 (total: 20 points) The known variables are: R β_S ρ_S T ΔT
Consider a sphere of radius R and density ρ_S and of coefficient of volume expansion for the sphere is β_S. At temperature T the sphere floats in a liquid; it is half submerged. At temperature $T + \Delta T$ the sphere has neutral buoyancy in the same liquid (on the verge of sinking).



- What is the coefficient of volume expansion β_L for the liquid?

Problem 3 (total: 20 points) The known variables are T_C, T_H M_W c_W M_S c_S
At a camp fire high in the sierra you are roasting marshmallows using a metal skewer of mass M_S and of specific heat c_S. The skewer is at temperature T_H. You dip the skewer in a pan filled with a mass M_W of water (specific heat c_W) at temperature T_C until the skewer and the water reach thermal equilibrium (ignore the water container in this problem and assume there is no water evaporation).

- What is the thermal equilibrium temperature, T_F?
- What is the change in entropy of the skewer ΔS_S
- What is the change in entropy of the water ΔS_W.
- What is the total change in entropy ΔS_{TOT} for the system (water +skewer).
- Quoting a thermodynamic law, explain and deduce the sign of ΔS_{TOT}

Problem 4 (total: 20 points) The known variables are V_A V_B P_A n γ ($\gamma = C_P/C_V$) R (ideal gas constant)
All final answers must be in terms of these variables.
Recall that $W_{ADIABATIC} = P_iV_i^{\gamma} * 1/(1-\gamma) * [V^{1-\gamma} - V_i^{1-\gamma}\} = 1/(1-\gamma) * [\, (PV-PiVi)$

Consider a closed cycle A-B-C (in that order) for a heat engine operating with n moles of an ideal gas.
A-B: adiabatic expansion starting at volume V_A and pressure P_A and ending at volume $V_{B\,=}\ 2V_A$
B-C: isothermal expansion from volume V_B back to volume V_A
C-A: isochoric with pressure increasing back to P_A

- Draw a PV diagram showing all three heat processes; clearly label the axes with V_A V_B P_A P_B
- For each segment AB, BC, CA, describe whether there is heat flowing in the system, out of the system, or no heat flow
- For each segment AB, BC, CA, describe whether there is work done by the system (positive), on the system (negative), or no work done.
- Find the points in the points in the closed cycle with the highest and lowest temperatures T_H and T_C
- Find the Carnot efficiency e_C of a Carnot engine working with heat sources at T_H and T_C
- Find the efficiency of the heat engine e

Problem 5 (total: 20 points): The known variables are: Q_1 Q_2 Q_3 a k [$k = 1/(4\,\pi\,\varepsilon_o)$ is the proportionality constant in Coulomb's law]
Two charges have opposite signs. +Q_1 is at the origin. and -Q_2 is at position a >0 on the x-axis (Q_1 > Q_2 and are both positive quantities).
- What is the position P>0 on the x-axis where the electric field is zero?

Now consider a third charge Q_3 positioned at P; since the electric field at P is zero and since the electric field is the force per unit charge, the net force by Q_1 and Q_2 acting on charge Q_3 will also be zero.

- Is the force exerted by Q_3 on Q_2 also zero? If yes state why if not what is that force?
- Is the force exerted by Q_3 on Q_1 also zero? If yes state why if not what is that force?
- Hard → [10 pts for that part]: What additional conditions on Q_1 , Q_2 , Q_3 are necessary so that the force exerted by any two charges on the third one is zero?