Physical Constants

$\sigma = 5.6704 \times 10^{-8}\ \mathrm{W \cdot m^{-2} \cdot K^{-4}}$
$R = 8.3145\ \mathrm{J/(K \cdot mol)}$
$N_A = 6.0221 \times 10^{23}$
$k_B = 1.3806 \times 10^{-23}\ \mathrm{J/K}$
$1\ \mathrm{atm} = 1.01325 \times 10^5\ \mathrm{Pa}$
$g = 9.80\mathrm{m/s^2}$

Properties of H_2O

$L_v = 2256\ \mathrm{J/g}$
$c_w = 4.186\ \mathrm{J/(g \cdot K)}$
$L_f = 334\ \mathrm{J/g}$
$c_i = 2.09\ \mathrm{J/(g \cdot K)}$
$\rho_w = 1000\ \mathrm{kg/m^3}$
$\eta = 1 \times 10^{-3}\ \mathrm{N \cdot s/m^2}$

Circle the letter of the single best answer. Each question is worth 2 point

1. Two dams are identical in size and shape and the water levels at both are the same. One dam holds back a lake containing 1 million $\mathrm{m^3}$ of water while the other hold back a 4 million $\mathrm{m^3}$ lake. Which statement is correct concerning the total force on the dams?

   A. The dam with the larger lake has four the total force on it.
   B. The dam with the smaller lake has twice the total force on it.
   C. The dam with the larger lake has a slightly larger total force on it.
   D. None of the above.

2. A small obstruction plugs the exit from a bicycle tire pump. In a (failed) attempt to force the obstruction out, a force F_A is applied to the handle while a force F_B holds the obstruction in place. Compare these forces:

   A. $F_A > F_B$ by Pascal's principle
   B. $F_A = F_B$ by Newton's law
   C. $F_A < F_B$ because the obstruction is not moved

3. Two objects of the same mass are placed in water. Object A floats and Object B sinks. The greater buoyant force is on

   A. Object A
   B. Object B
   C. both are same

4. A wood box falls off a boat that is floating on a lake. The box floats. As a result, the level of the water in the lake

   A. rises
   B. falls
   C. is unchanged

5. Consider two glass capillary tubes; tube **A** has half the radius of tube **B**. Let F_A denote the total surface tension force pulling the water up tube **A** and F_B the total surface tension force pulling the water up tube **B**. Which of the following holds:

   A. $F_A > F_B$
   B. $F_A = F_B$
   C. $F_A < F_B$

6. A greenhouse has two identical rooms (same pressure, volume and temperature). One room simulates a jungle with high humidity; the other a desert with low humidity air. Compare the density of the air in the two rooms. (ρ_J denotes the air density in the jungle room; ρ_D denotes the air density in the desert room.)

   A. $\rho_J < \rho_D$
   B. $\rho_J = \rho_D$
   C. $\rho_J > \rho_D$

7. 10 liters of Argon at a pressure of 2 atm are in thermal equilibrium with 20 liters of Helium at a pressure of 1 atm. Which molecules have more kinetic energy, on average?

   A. Argon
   B. Helium
   C. they have the same average kinetic energy
   D. not possible to say; additional details required

8. Which molecules are moving faster, on average?

   A. Argon
   B. Helium
   C. they have the same average kinetic energy
   D. not possible to say; additional details required

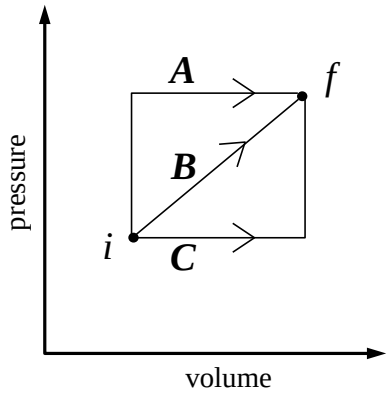
9. A quantity of an ideal gas is expanded to twice its initial volume. The process may be adiabatic, isothermal, or isobaric. Rank those three processes in order of the work done, least to greatest. (Hint: sketch a PV diagram)

   A. isobaric, isothermal, adiabatic
   B. adiabatic, isothermal, isobaric
   C. isobaric, adiabatic, isothermal
   D. isothermal, adiabatic, isobaric

10. Which one of the following statements best explains why convection does not occur in solids?

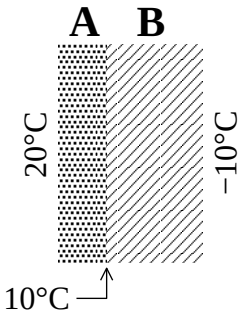
    A. Molecules in a solid are more closely spaced than in a gas.
    B. The molecules in a solid are not free to move throughout its volume.
    C. Molecules in a solid vibrate at a lower frequency than those of a liquid.
    D. Solids are less compressible than gases.

11. As shown in the diagram below, an ideal gas is taken reversibly from and initial state i to a final state f by three possible paths. Which path results in the greatest change in entropy?



    A. A
    B. B
    C. C
    D. they all have the same change in entropy

12. A wall of a house is insulated with two materials: 1 cm thick **A** and 2 cm thick **B**. In a steady state situation it is found that the temperature inside the house is 20°C, outside the house it's −10°C and at the interface between **A** & **B**, the temperature is 10°C. Which material has the greater thermal conductivity?



    A. A
    B. B
    C. they have the same thermal conductivity

The following questions are worth 12 pts each

Record your steps! (Grade based on method displayed not just numerical result)

13. You are driving to the top of Pikes Peak (altitude: 4302 m) from Colorado Springs (altitude: 1839 m) on a hot day (105°F). In Colorado Springs the barometric pressure is 90 kPa, the density of the air is 1 kg/m^3, and your tires show a gauge pressure of 30 psi.

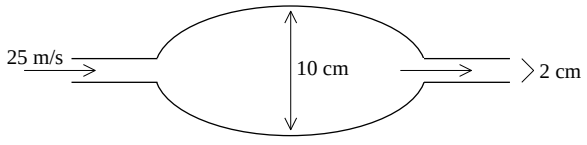
    A. What is the temperature in Colorado Springs in kelvin?

    B. Given that 90 kPa is about 13.05 psi, what is the absolute psi pressure in the tires at the top of Pikes Peak where the temperature is exactly freezing?

    C. Assuming the density of air is constant, what is the barometric pressure on top of Pikes Peak?

14. During an extended cold spell (temperature = −30°C) you decide to build an ice fortress with 1 kg ice bricks that, having been outside all this time, are also at −30°C. You accidentally spill 10 g of hot (T = 90°C) coffee on an ice brick; the coffee quickly freezes making a brown spot frozen onto the ice brick. If you assume that the brick was thermally isolated during the spill, what is the final temperature of the brick+frozen coffee?

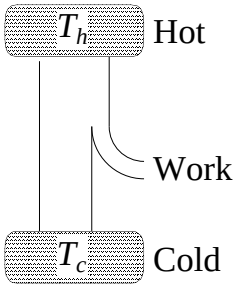
15. A horizontal hose with a normal diameter of 2 cm carries water at a pressure of 100 kPa moving at 25 m/s. At one spot the hose balloons out to a diameter of 10 cm. What is the pressure inside the enlarged region of the hose?



16. We have discussed two conceptual maps for a Carnot engine: (A) an abstract map that shows net energy flows to/from thermal reservoirs and (B) a more detailed P-V diagram of the working fluid. Select one of these maps and answer the corresponding questions. Use the following definitions:
Q_h = heat added to (+) or removed from (–) the hot ($T = T_h$) reservoir
Q_c = heat added to (+) or removed from (–) the cold ($T = T_c$) reservoir
Q = heat added to (+) or removed from (–) the working fluid of the machine itself
W = work done by the working fluid of the machine itself

A. i. For a Carnot engine report the signs of Q_h : , Q_c : , W :

ii. Add three arrows to the below left diagram showing the directions of the energy flows.



	hot	cold	fluid
ΔU			
ΔS			

iii. Enter in the above table (+,–,0) to denote the sign of the energy and entropy changes for the: hot reservoir, cold reservoir, and working fluid (for one complete cycle of the engine).

iv. Write down the formula for the total entropy change (i.e., including everything) in terms of the symbols defined above. What does the second law of thermodynamics say about this total entropy change in general? For a Carnot cycle what is the numerical value of this total entropy change?

B. i. Report which way the cycle turns for a Carnot engine by reporting the order the points are traversed. Put little arrows on the below plot to confirm your answer.

ii. Assume the working fluid is an ideal gas, and report in the below table the sign (+,–,0) of the corresponding quantity for each segment of the path (abcd).

path	ΔT	ΔU	ΔS	Q	W
a					
b					
c					
d