Physical Constants

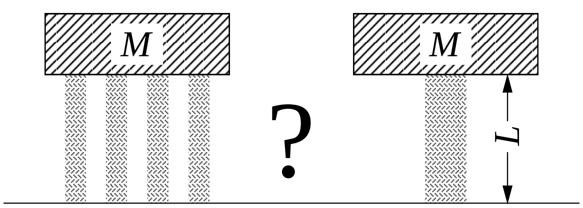
$\sigma = 5.6704 \times 10^{-8}\ \mathrm{W \cdot m^{-2} \cdot K^{-4}}$
$R = 8.3145\ \mathrm{J/(K \cdot mol)}$
$N_A = 6.0221 \times 10^{23}$
$k_B = 1.3807 \times 10^{-23}\ \mathrm{J/K}$
$1\ \mathrm{atm} = 1.0132 \times 10^5\ \mathrm{Pa}$
$g = 9.80 \mathrm{m/s^2}$

Properties of H_2O

$L_v = 2.26 \times 10^6\ \mathrm{J/kg}$
$c_w = 4186\ \mathrm{J/(kg \cdot K)}$
$L_f = 3.33 \times 10^5\ \mathrm{J/kg}$
$c_i = 2090\ \mathrm{J/(kg \cdot K)}$
$\rho_w = 1000\ \mathrm{kg/m^3}$
$\eta = 1 \times 10^{-3}\ \mathrm{N \cdot s/m^2}$

Circle the letter of the single best answer. Each question is worth 1 point

1. A particular mass (M) is to be supported by one or more matching vertical granite columns of a particular height (L). Safety standards specify the *stress* to be placed on such a granite column. (Of course, this specified stress is much less than the ultimate stress.) The cost of a column is directly proportional to its weight. Your job is to determine the number and radius of columns required. Which of the following considerations should influence your decision:

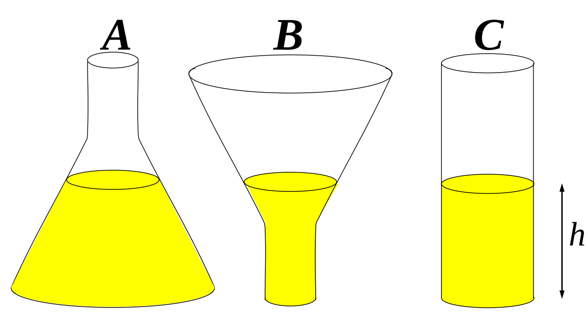


   A. When subjected to the specified stress, small-radius columns will compress more than large-radius columns.
   B. While the number of required columns depends on the selected radius, the total cost of the columns does not depend on the selected radius.
   C. With the specified stress, doubling the radius of a column will double the weight it can support.
   D. With the specified stress, the strain of a column depends on its length.

2. A steel plate has a hole drilled through it. The plate is put into a furnace and heated. What happens to the size of the inside diameter of the hole as the temperature increases?

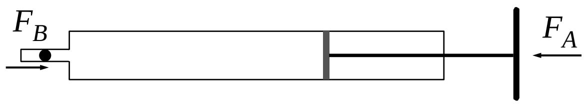
   A. increases
   B. decreases
   C. remains constant
   D. becomes elliptical

3. As shown below three different shape containers are filled with water to exactly the same water-level, h. (Of course, because of the different shapes the total amount of water differs.) Circle the letter of the container with the smallest pressure at its bottom.



   D. none of the above

4. 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:

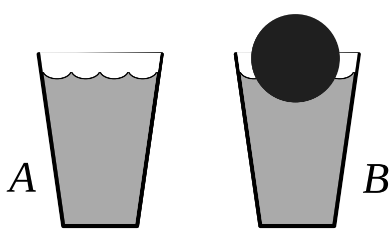


A. $F_A > F_B$ by Pascal's principle
B. $F_A = F_B$ by Newton's law
C. $F_A < F_B$ because the obstruction is not moved

5. An inverted drinking glass, filled with air, is placed mouth downward in the water. As it is pushed deeper, the air is increasingly compressed. How deep must the glass be pushed in order that the air will be compressed to half of its original volume?

A. about 1 meter
B. about 10 meters
C. about 100 meters
D. more than 200 meters

6. Two identical cups have exactly the same water level, but cup ***B*** has a plastic ball floating in it. (Of course ***B*** has less total water, since it has plastic in some places where ***A*** has water.) Which cup weighs more?



A. ***A***
B. ***B***
C. they weigh the same

7. Identical sized balls, one of iron and one of wood, are placed in water. The iron ball sinks; the wood ball floats. Compare the buoyant force on the balls. (B_W denotes the buoyant force the the floating wood ball; B_I denotes the buoyant force the the sunk iron ball.)

A. $B_W > B_I$
B. $B_W = B_I$
C. $B_W < B_I$

8. When you increase the temperature of honey it seems to flow faster, this is because:

A. the density of the honey decreases
B. the pressure on the honey increases
C. the tension on the honey is increased
D. the viscosity of the honey is reduced

9. 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. $F_A < F_B$

10. 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. $\rho_J > \rho_D$

11. Neon and helium are both monoatomic gases under 'normal' room conditions (say $P = 1$ atm, $T = 20°\text{C}$), but neon has a molecular weight about 5 times that of helium. Which would have more kinetic energy on average?

    A. Neon

    B. Helium

    C. they would have the same average kinetic energy

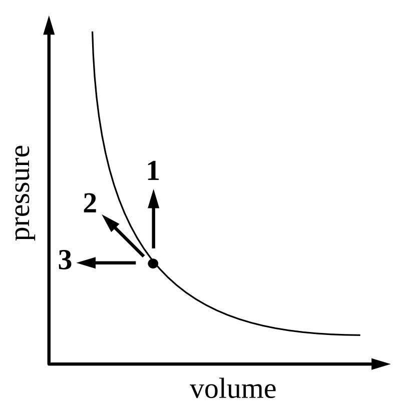
12. Three identical sealed rigid metal bottles contain different gases at the same temperature and pressure. One gas is monoatomic, another diatomic and the third is polyatomic. The temperature of all three is increased the same amount. The change in the internal energy of the gases is least for the:

    A. monoatomic gas

    B. diatomic gas

    C. polyatomic gas

13. The below figure shows (as a dot) the initial state of an ideal gas and an isotherm through that state. The gas is adiabatically compressed. Which labeled path could show this change?



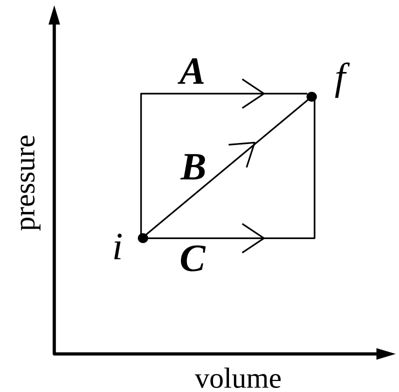
    A. 1

    B. 2

    C. 3

    D. none of the above

14. 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

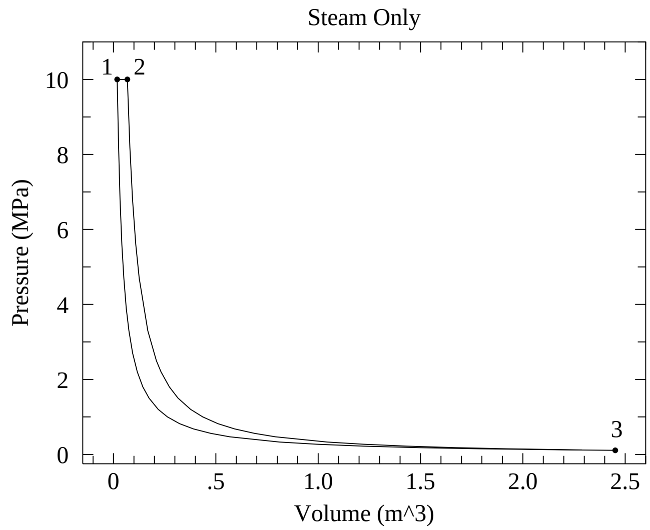
    D. they all have the same change in entropy

The following questions are worth 10 pts each

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

15. The following problem is based on "steam table" data—accurate values of V, T, U, S etc. for the real gas 'steam' rather then the mythical ideal gas. This problem is similar to the power plant cycle discussed in class, except here the steam is kept hot: no condensation and re-boiling.

- Initially, 1 kg of steam is just above its boiling point at a temperature of 311°C and pressure of 10 MPa (point 1).
- The steam is heated to 1200°C (point 2) isobarically.
- The high pressure steam is piped to a turbine where it expands adiabatically until the temperature returns to 311°C (point 3). This is the process that turns the generator.
- The resulting low pressure steam is isothermally compressed to return to its initial state.



point	Volume (m^3)	Pressure (MPa)	Temperature (°C)	U (kJ)	Entropy (kJ/K)
1	0.01803	10.	311	2545	5.6159
2	0.06789	10.	1200	4452	8.2124
3	2.45158	0.11	311	2828	8.2124

A. How much work does the steam <u>do</u> in the turbine?

B. How much work does the steam <u>do</u> in path $1 \to 2$?

C. How much heat is added to the steam in path $1 \to 2$?

D. How much heat is removed from the steam in path $3 \to 1$?

16. A 250 g block of aluminum is pulled from a container of liquid nitrogen ($T = -196°\text{C}$) and placed in 400 g of water which initially had a temperature of 20°C. The final state consists of everything at 0°C with 15 g of ice formed. Find the specific heat of the aluminum.

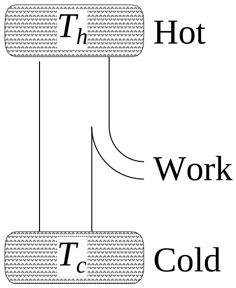
17. The Sagatagan is in the process of freezing over. The air temperature above the ice is $-20°\text{C}$; the water just below the 2 cm thick ice is at 0°C. How many grams of ice will form in one minute under 1 m^2 of ice as heat is conducted out of the water through the ice?
thermal conductivity of ice $= 2\ \text{J}/(\text{s}\cdot\text{m}\cdot{}^\circ\text{C})$

18. Water flowing at 0.2 m/s through a rubber tube of diameter 1 cm is used to model blood flow. An obstruction is introduced into a small section of the tube which reduces the tube diameter to .6 cm. (A) Calculate the flow speed through the tube section with the obstruction. (B) Calculate the pressure difference between: upstream of the obstruction and inside of the obstruction. (Which is greater: the pressure in the obstruction or the pressure upstream of the obstruction?)

19. We have discussed two conceptual maps for a Carnot refrigerator: (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 on the working fluid of the machine itself

A. i. For a Carnot refrigerator 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 refrigerator).

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 refrigerator by reporting the sequence that the points (1234) 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