AREN 2110 http://ceae.colorado.edu/~silverst/aren2110/

Concept Inventory

We are collecting information about this concept inventory. It is very important that we get accurate information, so please take this inventory without the use of books, notes or any other aid. How you perform on this test will not affect your grade. We are not asking for your name and you can feel confident that we will respect your confidentiality.

Thank you for your assistance with this project!

1. **Gender**

_____male
_____female

2. **Ethnicity**

______White
______African American
______American Indian
______Hispanic/Latino
______Asian/Pacific Islander
______Multiracial
______Other (please specify)
____

2. **Major**

_____chemical engineering

_____mechanical engineering

_____electrical engineering

_____computer engineering

_____ environmental engineering

_____civil engineering

_____architectural engineering

_____other (please identify)

____

3. **Year in school;**

______freshman

______sophomore

______junior

______senior

4. **Current GPA**

______3.50 - 4.00

______3.00 - 3.49

______2.50 - 2.99

______2.00 - 2.49

______below 2.00

5. Write "A" for any of the following courses that you have already taken, and "C" if you are currently enrolled in the course

_______thermodynamics

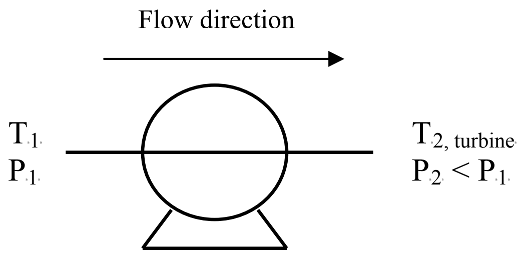
_______fluid dynamics

_______heat transfer

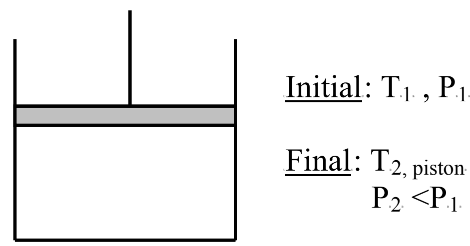
Question 1

Two frictionless, adiabatic devices operate using air at the conditions shown below. The inlet conditions for the turbine (T_1, P_1) are the same as the initial conditions for the piston and the outlet pressure exiting the turbine (P_2) is the same as the final pressure in the piston.

<u>Note</u>: a turbine is a device that converts energy from a fluid into mechanical work



frictionless, adiabatic turbine



frictionless, adiabatic piston

Under these conditions, which device will produce more mechanical work per unit mass of air?

a. Turbine produces more work because energy from the temperature drop and the pressure drop are both converted to work

b. Piston produces more work because energy from the temperature drop and the pressure drop are both converted to work

c. Turbine and piston produce the same amount of work because the initial and final air conditions (temperature and pressure) are the same.

d. The device that produces more work can't be determined until P_2 is known.

Question 2

A beaker of still water sits on a lab bench. An engineering student adds one drop of blue dye to the water and stirs the beaker contents.

Eventually, the dye will be uniformly distributed throughout the water and no further change in the distribution of dye will be observed. At this point, we can say that:

a. Water and dye are in equilibrium and the system is at steady-state.

b. Water and dye are in equilibrium but the system is <u>not</u> at steady-state.

c. Water and dye are <u>not</u> in equilibrium but the system is at steady-state.

d. Water and dye are <u>not</u> in equilibrium and the system is <u>not</u> at steady-state.

because:

e. The net movement of dye in water is zero and there is no liquid flow into or out of the beaker.

f. The net movement of dye in water is zero and all conditions in the beaker (for example, temperature, pressure, volume, concentration) are not changing with time.

g. Diffusion is taking place at the water-dye interface so the system can never come to equilibrium.

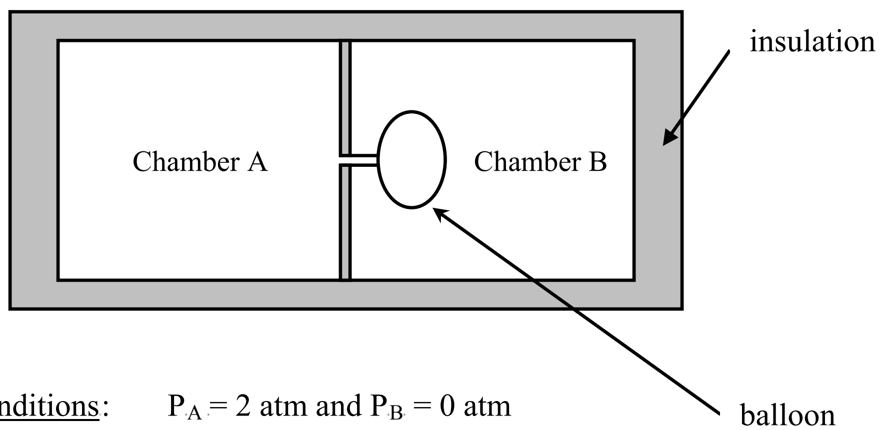
h. Equilibrium and steady-state are related – you can't have one without the other.

Question 3

As shown below, an insulated, rigid vessel is divided into 2 chambers, “A” and “B.” The divider contains a small hole where a balloon is firmly attached so that the balloon pressure is the same as the pressure in chamber A.

An engineering student uses this apparatus to conduct an experiment using an ideal gas by slowly increasing the pressure in chamber A. Initially, both chambers and the balloon are at a pressure of 0 atmospheres (a perfect vacuum). The student then slowly introduces ideal gas to chamber A until the pressure reaches 2 atmospheres.

Suddenly the balloon bursts and allows gas from chamber A to quickly enter chamber B through the small hole in the divider.



<u>Initial conditions</u>: $P_A = 2$ atm and $P_B = 0$ atm
(when balloon bursts)

<u>Final conditions</u>: $P_A = P_B$

What happens to the temperature of the gas in the container (including both chambers) during the process of expanding gas into chamber B after the balloon bursts?

(You may assume that the gas temperature in chamber A is very close to the gas temperature in Chamber B during the process.)

a. gas temperature decreases since the gas will cool when rapidly expanded through a small hole

b. gas temperature increases because work will occur in chamber B when pressure increases

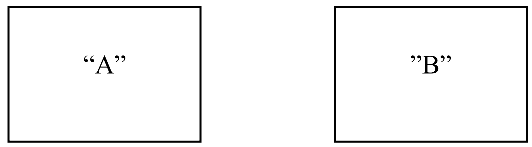
c. gas temperature remains constant because expansion of an ideal gas through a small hole does not affect temperature

d. gas temperature increases since friction caused by gas expansion through a small hole will generate increased heat

Question 4

Identical rigid vessels contain two different ideal gases as shown below. Vessel 1 contains pure gas “A” while vessel 2 contains pure gas “B.”

The molecular weight of “A” is twice that of “B.”



Vessel 1 Vessel 2

If the pressures in vessels 1 and 2 are equal ($P_1 = P_2$) and gas temperatures in vessels 1 and 2 are equal ($T_1 = T_2$), what can be said about the molar densities (gmoles/volume) of gas in the two vessels if both gases can be assumed ideal?

a. Both have the same molar density since temperature, pressure, and volume are the same.

b. The molar density in vessel 1 is <u>twice</u> the density in vessel 2 because the molecular weight of gas “A” is twice that of gas “B.”

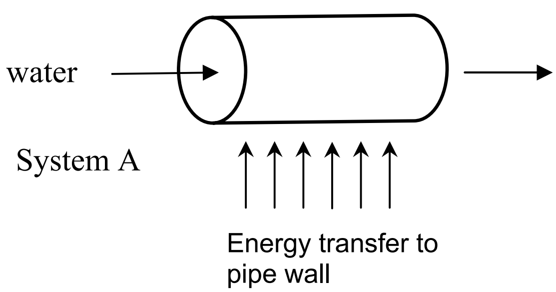
c. The molar density in vessel 1 is <u>half</u> the density in vessel 2 because the molecular weight of gas “A” is twice that of gas “B.”

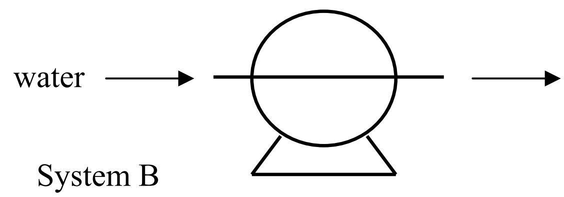
d. Nothing can be said about molar density because the volume of the vessels is not specified.

e. The molar density of the two gases can never be equal since the molecular weights of “A” and “B” are different.

Question 5

As shown below, two streams of water are flowing at steady-state through circular pipes. In pipe A, thermal energy is added to the water by raising the temperature of the pipe wall. In pipe B, a pump is installed which increases the pressure of the water.





<u>System A</u>: temperature increases
pressure is constant (ignore very small frictional pressure drop in the pipe)

<u>System B</u>: pressure increases
temperature is constant (ignore very small frictional heating in the pump)

Which of the following statements correctly describes how the pipe and pump change the enthalpy and internal energy in the flowing water?

a. systems A and B both increase enthalpy and internal energy

b. system A increases internal energy but not enthalpy; system B increases enthalpy but not internal energy

c. system A increases both enthalpy and internal energy; system B increases enthalpy but not internal energy

d. system A increases both enthalpy and internal energy; System B doesn't increase either internal energy or enthalpy

because:

e. internal energy and enthalpy are closely related so that if one increases, so does the other

f. internal energy is a function of both temperature and pressure for most liquids

g. enthalpy can increase with increases in either temperature or pressure

h. no energy change occurs if the temperature remains constant

Question 6

Gaseous hydrogen (H_2) and oxygen (O_2) are mixed in a 2:1 molar proportion (2 moles of H_2 per mole of O_2) in a rigid, constant volume tank at temperature T_1 and pressure P_1. A spark in the tank causes <u>all</u> of the H_2 and O_2 to form gaseous water according to the following reaction:

$$2H_2 + O_2 \rightarrow 2H_2O$$

After the reaction is completed, the tank contents are cooled back to the original temperature T_1.

You may assume that H_2, O_2, and gaseous H_2O all behave as ideal gases.

If none of the water condenses during the experiment, what can you say about the final pressure of the tank contents?

a. P_2 cannot be determined since it's impossible to cool the system back to T_1 without condensing some of the water vapor

b. $P_2 = P_1$ since pressure is inversely proportional to temperature according to the ideal gas law

c. P_2 is somewhat less than P_1 but the exact difference cannot be estimated without knowing how much the temperature increased during the reaction

d. $P_2 = 2/3\ P_1$ since the number of moles decreased by 1/3 during the reaction

Again assuming none of the water condenses during the experiment, what can you say about the final molar density (moles/volume) of the tank contents?

e. the molar density doesn't change since mass can't be created nor destroyed during the reaction and the tank volume is constant

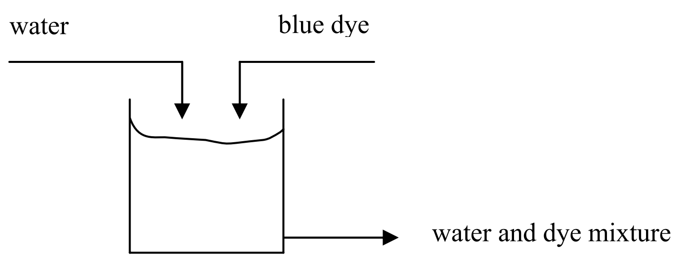
f. the molar density increases since water molecules are larger than H_2 or O_2 molecules

g. the molar density decreases by 1/3 since the number of moles decreases in the reaction by 1/3

h. the molar density cannot be determined since it is not directly related to pressure if a chemical reaction occurs

Question 7

Water and blue dye are individually and steadily added to a beaker as shown below. The water/dye mixture is steadily removed from the beaker so that the liquid level in the beaker remains constant. The beaker contents are well stirred so that the distribution of dye in the beaker is uniform (same dye concentration at all locations in the water).



The water and dye flowrates are constant and the total flowrate is 1 liter/minute.

The beaker has a volume of 1 liter so the average time that water and dye spend in the beaker is 1 minute. If the time required for water and dye to come to equilibrium is 2 minutes, what can we say about the water and dye in the beaker?

a. Water and dye are in equilibrium and the system is at steady-state.

b. Water and dye are in equilibrium but the system is <u>not</u> at steady-state.

c. Water and dye are <u>not</u> in equilibrium but the system is at steady-state.

d. Water and dye are <u>not</u> in equilibrium and the system is <u>not</u> at steady-state.

because:

e. The ratio of dye to water is constant throughout the beaker and the liquid flowrate is constant.

f. The water and dye don't have enough time to come to equilibrium but all conditions in the beaker (for example, temperature, pressure, volume, concentration) are not changing with time.

g. The water and dye don't have time to come to equilibrium in the beaker and therefore the system can never be at steady-state.

h. Equilibrium and steady-state are related – you can't have one without the other.

Question 8

You have access to two sources of energy that can be used to turn a steam turbine (a device that converts thermal energy into mechanical work):

- 1000 KJ of energy stored as superheated steam at 400 ^{O}C and 20 bar
- 1000 KJ of energy stored as superheated steam at 600 ^{O}C and 20 bar

Which of these two energy sources can be converted into more mechanical work per unit mass of steam?

a. 400 ^{O}C steam

b. 600 ^{O}C steam

c. both will give the same amount of work

d. can't decide with the information given

because:

e. steam at different temperatures can't exist at the same pressure so turbine performance is not known

f. turbine will extract the same amount of energy from both steam sources since performance is only a function of mechanical design

g. turbine will extract more energy from higher temperature steam source because hotter steam provides a larger temperature difference between energy source and waste energy rejection

h. turbine will extract more energy from lower temperature steam source because colder steam is easier to process mechanically

i. amount of energy in each steam source is the same

Question 9

Table salt is slowly added to a beaker of water that is being stirred. Initially, all the salt dissolves in the water. As more salt is added, the water eventually becomes saturated with salt and some solid salt remains undissolved. Once solid salt is observed in the bottom of the beaker, no additional salt is added to the beaker.

Assuming the beaker contents are still well stirred, we can say that:

a. Salty water and solid salt are in equilibrium and the beaker system is at steady-state
b. Salty water and solid salt are in equilibrium but the beaker system is <u>not</u> at steady-state
c. Salty water and solid salt are <u>not</u> in equilibrium but the beaker system is at steady-state.
d. Salty water and solid salt are <u>not</u> in equilibrium and the beaker system is <u>not</u> at steady-state.

because:

e. salt is always being dissolved on a molecular level so the system can never come to equilibrium

f. equilibrium and steady-state are related – you can’t have one without the other

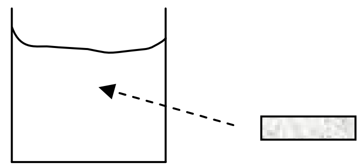
g. maximum amount of salt is dissolved (so net dissolution rate is zero) and conditions in the beaker (temperature, pressure, composition) are not changing with time

h. once the water is saturated, salt dissolution stops so system can’t be at steady-state

Question 10

A small piece of metal at a temperature of 75 ^{O}C is placed into an insulated beaker of water at a temperature of 25 ^{O}C as shown below. The masses of water and metal are equal.

After a long period of time, how would the temperatures of the water and metal bar be related assuming that no significant energy loss occurs through the beaker walls?



water at 25 ^{O}C metal bar at 75 ^{O}C

a. Since the mass of water and metal are the same, the system will end up at 50 ^{O}C (the average of the two starting temperatures).

b. The temperatures of the metal bar and water will be the same and will end up somewhere between 25 ^{O}C and 75 ^{O}C depending upon the heat capacity of the metal and water.

c. The temperatures of the metal bar and water will be the same and will end up somewhere between 25 ^{O}C and 75 ^{O}C depending upon the thermal conductivity of the metal and water.

d. The metal bar will always remain slightly hotter than the water because metal stores energy better than water does.

Question 11

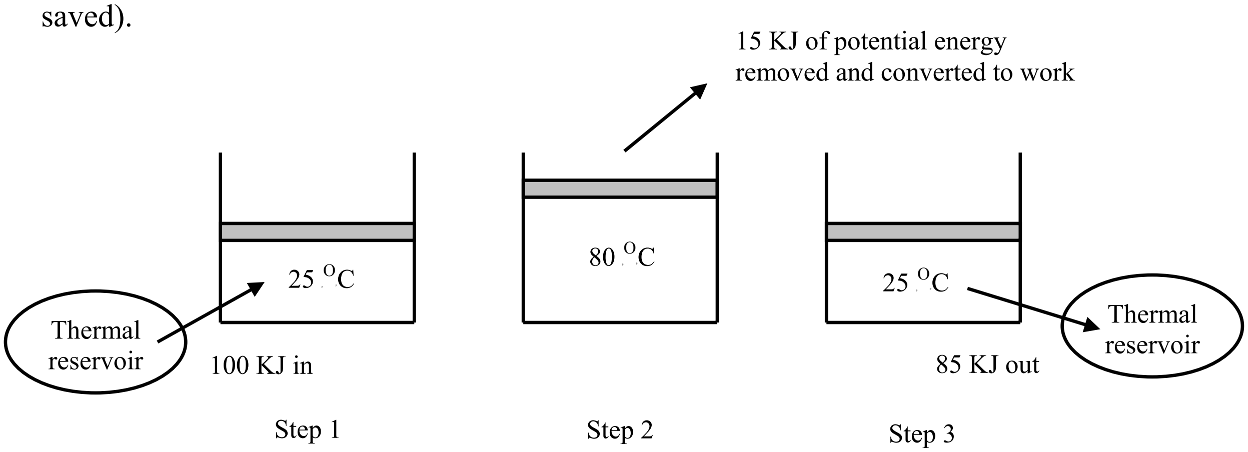
A student proposes a method for completely converting thermal energy to mechanical work. It consists of the following three steps involving a cylinder and a frictionless piston that moves up and down in the cylinder:

Step 1 – gas at 25 ^{O}C is contained in the cylinder and supports the piston; 100 KJ of energy is added to the gas from a thermal reservoir

Step 2 – the added energy increases the gas temperature to 80 ^{O}C and expands the piston to a higher position; the increase in piston potential energy is 15 KJ which is converted to work and removed from the system

Step 3 – excess thermal energy is returned to the same thermal reservoir, which causes the gas temperature to drop back to 25 ^{O}C and the piston to return to its original position

The net result of this process is that 15 KJ of thermal energy has been converted to work with no net loss of thermal energy (all unused thermal energy is returned to the thermal reservoir and saved).



What would you say to the student who proposed this process?

a. the process will not work because energy at 25 ^{O}C cannot be returned to the higher temperature thermal reservoir in step 3

b. the process will work if the piston is truly frictionless and the none of the transferred heat is lost to the atmosphere

c. the process will work because energy is conserved in the system

d. the process may work, but only if more details are known about the heat transfer rates in steps 1 and 3