PH202 U2023 - Midterm 2 Solutions

Wednesday, February 14, 2024 1:26 PM

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NAME ONID

PH 202 MID TERM #2

Instructions:

Do not open the test until prompted to do so.

Read all the questions thoroughly and ask if you have any questions.

You have 40 minutes to complete the test.

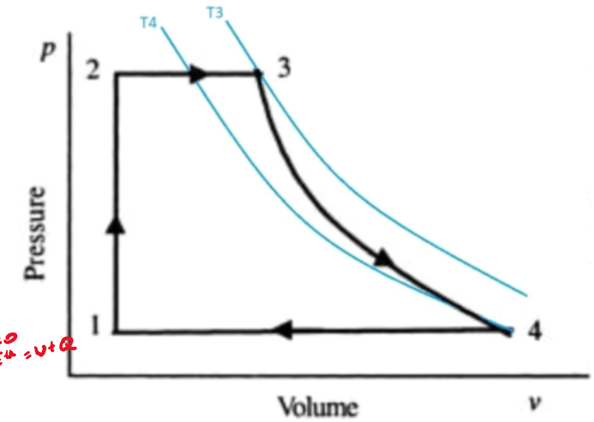
You may use:

- Up to 10 pages of notes of any kind
- A non-communicating calculator
- Your brain

Points break-down for each problem:

Question #1 +2	10 points
Question #3	20 points
Question #4	20 points
Total	50 points

1) An idealized Rankine cycle, shown in the figure to the right, consists of four processes. Read the below portions and select all the answers that are correct for this cycle.



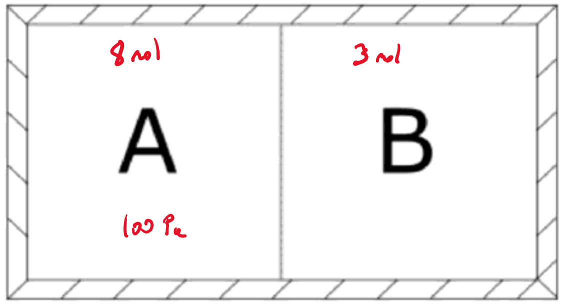
a. No work is done form 3 to 4
b. Positive work is done from 1 to 2
c. The process from 3 to 4 is isothermal
d. The process from 4 to 1 is isobaric
e. The process from 2 to 3 is isochoric
f. This process is a refrigerator
g. This process is a heat engine
h. The net work (done on the gas) from this process is negative
i. The net work from this process is positive
j. There is no heat transfer from 2 to 3
k. The heat transfer from 1 to 2 is positive $W=0$, $\Delta E_{th} = W + Q$
l. The heat transfer from 2 to 3 is positive
m. The heat transfer from 4 to 1 is positive
n. There is no change in thermal energy from 1 to 2 because no work is done.
o. Positive heat transfer is [illegible] thermal energy entering the system
p. Positive work is [illegible] work done by the system

← I don't like these as definitions, but (o) is true

2) While camping, two physics students start a fire to cook some food for dinner. After starting the fire, they have a cast iron skillet and several skewers to hold over the fire. The skillet is held over the fire and food is put inside. Also, food is placed on the skewers and held directly over the fire. Select all the below answers that are correct:

a) Food in the pan is heated by conduction as heat is transferred from the pan to the food that is touching the pan.
b) Food in the pan is heated by radiation from the fire, while the food on the skewers is not.
c) Both the skewers and the pan are heated by convection, which can be calculated by: $\frac{Q}{\Delta t} = \left(\frac{KA}{L}\right) \Delta T$
d) The heat transfer from radiation is highest from the fire because the temperature of the fire is significantly greater than anything else around the campsite
e) The fire is the only source of radiation heating
f) The molecules in the air around the fire are heated via convection ← partly, radiation too!
g) If given the temperature of the bottom and top of the pan, the thermal conductivity of the pan, the area of the pan, and the thickness, the students can calculate the conductive heat rate through the pan.

3) Two rigid boxes of equal volume are divided by a removable barrier and thermally isolated as shown in the diagram. These boxes are in thermal equilibrium together at 300K. There are 8 moles of gas in box A and 3 moles of gas in Box B. The pressure in Box A is 100 Pa.



(4 pts) What is the pressure of the gas in Box B?

$PV = nRT$ (P: $\uparrow \times 8/3$; V: same; n: $\uparrow \times \frac{8}{3}$; RT: same)

$P_B = \frac{3}{8} P_A = \frac{300}{8}\ Pa = \boxed{37.5\ Pa}$

(4 pts) How much thermal energy resides in the two boxes together?

$E^{th} = N \frac{3}{2} k_B T = \frac{3}{2} nRT = \frac{3}{2}(11)(8.314)(300) = 41{,}154.3\ J$

$Nk_B = nR$

$\boxed{E^{th} = 41{,}000\ J}$

The divider is now removed, allowing the particles to move freely around the space.

(4 pts) What is the temperature now that the gases have mixed?

300 K

(4 pts) What will happen to the arrangement of the gas particles in the box? Why? "configuarational drive to equilibrium"

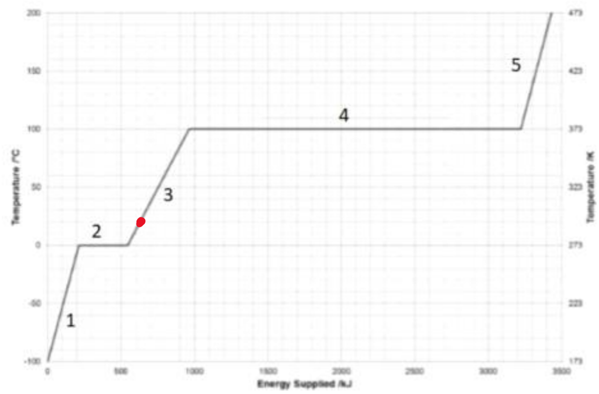
The gas particles will mix such that roughly equal parts of each will be on either side.

(gas will have ~uniform density over entire box)

(4 pts) What is the chance that the system will return to its original configuration? Why?

almost (essentially) zero. Each particle would need to have the correct $\vec{v}$ at the same time. There are $\sim 10^{24}$ particles $\Rightarrow \sim \frac{1}{10^{24}}$ chance $\cong 0$.

4) A 2 kg cube of Aluminum (specific heat = $0.9\frac{J}{gK}$) is heated up to 900K and placed in a bucket of water (specific heat = $4.182\frac{J}{gK}$) at 20 degrees Celsius. The below graph shows the temperature vs. energy for water.



(5 pts) Fill in the below table for the portions of this graph.

Section	Phase(s)	Heat transfer equation
1	solid water (Ice)	$Q = mc\Delta T$
2	freezing / melting ⇒ Ice + liquid	$Q = \pm m L_f$
3	liquid water	$Q = mc\Delta T$
4	vaporizing / condensing ⇒ liquid + vapor	$Q = \pm m L_v$
5	vapor (gas) (steam)	$Q = \Delta E^{th} = N\frac{3}{2}k_B \Delta T$

(4 pts) How much energy is required to raise the temperature of the water to the boiling point?

Q = about 300 kJ (reading from graph since m_{water} isn't given)

(4 pts) How much energy is required to boil all the water (L_v = 2260 kJ/kg)?

2,300,000 J (reading from graph)

(7 pts) What is the final temperature after the system reaches equilibrium?

boiling water ⇒ $Q = m_w L_v$

$2{,}300{,}000\ J = m_w (2{,}260{,}000 \frac{J}{kg})$

⇒ m_w = about 1 kg

⇒ $m_A c_A \Delta T_A = m_w c_w \Delta T_w$

$(2\,kg)(900 \frac{J}{kg\,K})(T_f - 900\,K) = (1\,kg)(4182 \frac{J}{kg\,K})(T_f - 293.15\,K)$

⇒ $T_f = 28.5\ K$