PHYSICS-2112 Fall 2019 **Exam 1** **September 24, 2019**

Last Name (print)___ _KEY_____________ ***First*** Name (print)________________________

Signature ______________________________ LSU ID No. _____________________________

DEPARTMENTAL POLICY STATES THAT ANY AND ALL NONAPPROVED ELECTRONIC DEVICES MUST BE TURNED OFF AND IN YOUR BAG AT THE FRONT OF THE ROOM. NO STUDENT MAY LEAVE THE ROOM DURING THE EXAM FOR ANY REASON – ONCE A STUDENT EXITS THE ROOM HIS/HER EXAM IS OVER.

Circle one:

C. Deibel	(Sec. 1; MWF 9:30 am)
M. Wilde	(Sec. 2; MWF 12:30 pm)
P. Sprunger	(Sec. 3; TTh 9:00 am)

Have your LSU ID ready when you turn in your paper.

You may only use an ordinary scientific or graphing calculator. *You may not use a cell phone, smart phone, or tablet application as your calculator.*

Examine your paper to be sure it is complete and legible. There should be 12 multiple choice questions and 2 free-response problems, totaling 100 points. There are 6 pages, including the cover sheet.

For the multiple choice questions, bubble in the correct answer on your scantron for each question. There is room on the exam for scratch work or calculations, but that work will not be checked or graded. Partial credit may be awarded on multiple choice questions, but this partial credit will be based on the answers that you have bubbled in on the scantron and NOT on your scratch work on the exam itself.

For the free-response problems, show all relevant work in the space provided. Without supporting work, even a correct answer will receive little or no credit. Partial credit will be awarded as warranted.

If your work for a problem is somewhere other than the space provided for that part of the problem, you must indicate where your work is located. *E.g.*, if you need more room for your solution, then you may write on the back of the page. Be sure to add a note to this effect; otherwise, anything on the back of the paper will be regarded as scratch work and will not be checked or graded.

Be sure that numerical answers appear with appropriate **SI units**. Points will be deducted for missing, incorrect, or "silly" units. If the final answer is, in fact, a dimensionless quantity, please write the numerical result followed by the word dimensionless.

You will have 60 minutes to complete this examination.

Question #1 (no points)

Bubble in the answer choice corresponding to your class section number.

A. Sec. 1; MWF 9:30 am (Deibel)
B. Sec. 2; MWF 12:30 pm (Wilde)
C. Sec. 3; TTh 9:00 am (Sprunger)

Question #2 (no points)

Your version of the test is A. Bubble in answer **A** on your scantron.

Question #3 (5 points)

A circular disk of aluminum has an area of 10.000 cm^2 at 20.00°C. What is the area when the temperature of the disk is raised to 330.00 °C. The linear expansion coefficient of aluminum is 23.00 × 10^{-6} /°C

A. 10.152 cm^2
B. 10.076 cm^2
C. 10.228 cm^2
D. 10.143 cm^2
E. 10.052 cm^2

Linear Expansion → Area expansion

$$A \cong A_0(1+2\alpha\Delta T) = \pi r^2 = \pi\left[r_0(1+\alpha\Delta T)\right]^2$$

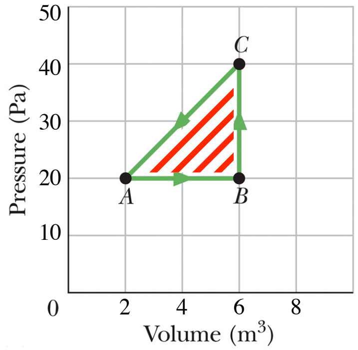
$$= (10.000\text{ cm}^2)\left(1+2(23\times10^{-6}/^\circ\text{C})(330^\circ\text{C} - 20^\circ\text{C})\right)$$

$$= 10.143\text{ cm}^2$$

Question #4 (5 points)

A gas within a closed chamber undergoes the cycle as shown in the *p*-*V* diagram. Calculate the net energy added to the system as heat during one complete cycle.

A. 40 J
B. 20 J
C. 0 J
D. – 20 J
E. – 40 J



1st Law & Definition of work done

1st Law: $\Delta E_{int} = Q - W_{by}$

For a complete cycle, $\Delta E_{int,cycle} = 0$, so $Q_{net} = W_{by}$

$$Q_{net} = W_{by} = \oint p\,dV = \left[\begin{array}{c}\text{area inside curve}\\ \text{ccw}\rightarrow\text{negative}\end{array}\right] = -\ 40\text{ J}$$

Question #5 (5 points)

The pressure of a monatomic ideal gas is doubled, while its volume is reduced by a factor of four. What is the ratio of the new rms speed of the atoms to the initial rms speed?

A. 0.500
B. 0.707
C. 1.414
D. 2.000
E. 1.000

RMS speed of gas molecules and ideal gas law

Knowing $v_{rms} \propto \sqrt{T}$ & $pV = nRT$:

If $p_{new} = 2p_{old}$ & $V_{new} = \frac{1}{4}V_{old}$, then

$$v_{rms,new} \propto \sqrt{T_{new}} \propto \sqrt{(p_{new})(V_{new})} \propto \sqrt{(2p_{old})(\tfrac{1}{4}V_{old})}$$

$$\propto \sqrt{(2)(\tfrac{1}{4})T_{old}} \propto \left(\sqrt{(\tfrac{1}{2})}\right)v_{rms,old}$$

$$\text{so}\quad \frac{v_{rms,new}}{v_{rms,old}} = \left(\sqrt{(\tfrac{1}{2})}\right) = 0.707$$

Question #6 (5 points)

Complete the following statement: The term *heat* most accurately describes

A. the internal energy of an object.
B. the flow of energy due to a temperature difference.
C. a measure of how hot an object is.
D. the molecular motion inside of an object.
E. the absolute temperature of an object.

From book: “Heat Q is energy that is transferred between a system and its environment because of a temperature difference between them”

Question #7 (5 points)

Complete the following statement: The internal energy of an ideal monatomic gas is

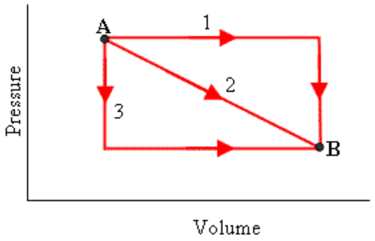
A. dependent on both the pressure and the temperature of the gas.
B. a constant that is independent of pressure, volume or temperature.
C. proportional to the pressure and inversely proportional to the volume of the gas.
D. independent of the number of moles of the gas.
E. proportional to the Kelvin temperature of the gas.

From book (Eqn 19-38): $E_{int,monatomic} = 3/2nRT$
“The internal energy E_{int} of an ideal gas is a function of the gas temperature *only*; it does not depend on any other variable”

Question #8 (5 points)

The pressure-volume graph shows three paths in which a gas expands from an initial state A to a final state B. Rank the paths according to the heat *Q* added to the gas, largest to smallest.

A. 1 = 2 = 3
B. 1, 2, 3
C. 2, 1, 3
D. 3, 2, 1
E. 1 = 3, 2



1st Law & Definition of work done

1st Law: $\Delta E_{\text{int}} = Q - W_{by}$ or $Q = \Delta E_{\text{int}} + W_{by}$

From the area under each curve, we know : $W_1 > W_2 > W_3$.

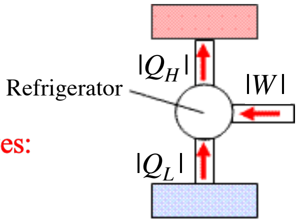
Also, the internal energy is a state function or $\Delta E_{\text{int}} = E_f - E_i$, so $\Delta E_{\text{int,1}} = \Delta E_{\text{int,2}} = \Delta E_{\text{int,}}$

Together we then know $Q_1 > Q_2 > Q_3$ or a ranking of 1, 2, 3

Question #9 (5 points)

A refrigerator uses W = 100 J of work to remove Q_L = 700 J of heat from its interior. The heat delivered to the room containing the refrigerator is _______, and the coefficient of performance (K) of the refrigerator is _______.

A. Q_H = 600 J, K = 1/7
B. Q_H = 800 J, K = 8
C. Q_H = 800 J, K = 7
D. Q_H = 600 J, K = 7
E. Q_H = 500 J, K = 4



Entropy in the Real World: Refrigerators

For any ideal refrigerator, the 1st of thermodynamics gives:

$$|W| = |Q_H| - |Q_L| \rightarrow |Q_H| = |W| + |Q_L|$$

So here, $|Q_H| = |100\text{ J}| + |700\text{ J}| = 800\text{ J}$ &

Coefficient of performance, $K = \frac{|Q_L|}{|W|} = \frac{|700\text{ J}|}{|100\text{ J}|} = 7$

Question #10 (5 points)

A Carnot engine has an efficiency of 45%. It operates between constant-temperature reservoirs differing in temperature by 165 C°. In kelvins, what is the temperature of the hot reservoir?

A. 530 K
B. 370 K
C. 200 K
D. 300 K
E. 465 K

Entropy in the Real World: Engines → Carnot Engines

For any ideal engine, the 1st of thermodynamics gives:

$$\varepsilon = \frac{|W|}{|Q_H|} = \frac{|Q_H| - |Q_L|}{|Q_H|} \text{ for Carnot engine } \varepsilon_C = \frac{|T_H| - |T_L|}{|T_H|}$$

Here, $\left(|T_H| - |T_L|\right) = \Delta T_C = 165\ ^{\circ}\text{C} = 165\ \text{K}$ & $\varepsilon_C = 0.45$, so

$$|T_H| = \frac{|T_H| - |T_L|}{\varepsilon_C} = \frac{165\ \text{K}}{.45} = 367\ \text{K} \cong 370\ \text{K}$$

Question #11 (5 points)

A fixed amount of ideal gas is compressed adiabatically. Which entry in the table below correctly indicates the sign of the work done by the gas, the change in the internal energy, and the heat exchanged with the environment?

	Work done	*Change in internal energy*	*Heat exchanged*
A.	positive	negative	zero
B.	negative	zero	positive
C.	negative	negative	zero
D.	positive	positive	zero
E.	negative	positive	zero

1st Law & Definition of work done & Adiabatic processes

1st Law: $\Delta E_{\text{int}} = Q - W_{by}$ & by definition $Q = 0$ for an adiabatic process.

For a compression, $V_f < V_i$, so $W_{by} = \int^{V_f} p\,dV < 0$ $\left(\text{or } W_{by} \text{ is negative}\right)$ & thus, $\Delta E_{\text{int}} = -W_{by}$, or ΔE_{int} is positive.

Question #12 (5 points)

When 20.9 J was added as heat to a particular ideal gas, the volume of the gas changed from 50 cm^3 to 100 cm^3 ($10^6\ \text{cm}^3 = 1\ \text{m}^3$) while the pressure remained at 1.00 atm (1 atm = 1.01×10^5 Pa). If the quantity present was 2.00×10^{-3} mol, find the molar specific heat at *constant pressure*, C_P?

A. 20.8 J/mole/K
B. 4.14 J/mole/K
C. 18.4 J/mole/K
D. 34.4 J/mole/K
E. 12.5 J/mole/K

Molar Specific Heat of an Ideal gas

In this case, we have heat (Q) added during gas expansion at constant pressure ($p_i = p_f = p_0$).

Knowing $pV = nRT$ & $Q = nC_p\Delta T$

$$\text{or } C_p = \frac{Q}{n\Delta T} = \frac{Q}{n\left(\frac{p_f V_f}{nR} - \frac{p_i V_i}{nR}\right)} = \frac{QR}{p_0\left(V_f - V_i\right)}$$

$$C_p = \frac{(20.9\ \text{J})(8.31\ \text{J/mole/K})\left(\frac{10^6\ \text{cm}^3}{1\ \text{m}^3}\right)}{(1.01\times 10^5\ \text{Pa})\left((100\ \text{cm}^3) - (50\ \text{cm}^3)\right)}$$

$= 34.4$ J/mole/K (e.g. methane at 255 K)

Problem #1 (21 points) – Show your work! (Circle your final answers)

A 150 g zinc bowl contains 200 g of water, both at 20°C. A 250 g cylinder of copper at a high temperature is dropped into the bowl causing the water to boil and 5.0 g of the water turns to steam. The final temperature of the bowl-water-cylinder system is 100°C. Neglect any energy transfers with the environment. The specific heat of both copper and zinc is 390 J/kg•°C *(answers to three sig figs)*

a) (5 points) How much energy is transferred to the water as heat in order to increase the temperature of the water?

Absorption of Heat: *ΔT*

In this case, we have heat (Q) added to raise the temperature of the water from 20 ˚C → 100 ˚C.

$$Q_{\Delta T,H_2O} = m_{H_2O}c_{H_2O}\Delta T = (0.20\text{ kg})(4187\text{ J/kg/K})\left(T_f - T_i\right) = (0.20\text{ kg})(4187\text{ J/kg/K})\left(100\text{ ˚C} - 20\text{ ˚C}\right)$$
$$= 67.0\text{ kJ}$$

b) (5 points) How much energy is transferred as heat to convert the 5 g of water to steam?

Absorption of Heat: *phase change*

In this case, we have heat (Q) added to convert 5g of H_2O from water to steam at 100 ˚C.

$$Q_{phase,boil} = +m_{H_20\rightarrow steam}L_{fus} \;=\; +(0.005\text{ kg})(2256\text{ kJ/kg}) \quad \left[\textit{positive}!\right]$$
$$= 11.28\text{ kJ}$$

c) (4 points) How much thermal energy is transferred to the zinc bowl?

Absorption of Heat: *ΔT*

In this case, we have heat (Q) added to raise the temperature of the zinc from 20 ˚C → 100 ˚C.

$$Q_{\Delta T,Zn} = m_{Zn}c_{Zn}\Delta T = (0.15\text{ kg})(390\text{ J/kg/K})\left(T_f - T_i\right) = (0.15\text{ kg})(390\text{ J/kg/K})\left(100\text{ ˚C} - 20\text{ ˚C}\right)$$
$$= 4.68\text{ kJ}$$

d) (7 points) What was the initial temperature of the copper cylinder?

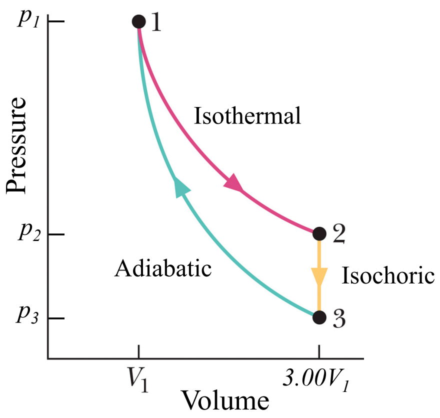
Heat exchange

If we neglect "any energy transfers with the enviroment", we know that the sum of total heat exchanged is zero, or

$$0 = \sum_{processes} Q_i = Q_{\Delta T,H_2O} + Q_{phase,boil} + Q_{\Delta T,Zn} + Q_{\Delta T,Cu}\ ,$$

where $Q_{\Delta T,Cu}$ is the heat released lowering the temperature of the Cu from $T_{i,Cu} \rightarrow 100$ ˚C. So we have,

$$Q_{\Delta T,H_2O} + Q_{phase,boil} + Q_{\Delta T,Zn} = -Q_{\Delta T,Cu} = -m_{Cu}c_{Cu}(T_f - T_i)$$
$$\left(67.0\text{ kJ} + 11.28\text{ kJ} + 4.68\text{ kJ}\right) = -(0.25\text{ kg})(390\text{ J/kg/K})\left(100\text{ ˚C} - T_{i,Cu}\right)$$
$$851\text{ ˚C} = T_{i,Cu} - 100\text{ ˚C}$$
$$T_{i,Cu} = 951\text{ ˚C} = 1224\text{ K}$$



Problem #2 (29 points) – Show your work! (Circle your final answers)
One mole of an ideal monatomic gas passes through the reversible cycle shown in the P-V diagram. At **point 1** in the cycle, $P_1 = 1.52\times10^5$ Pa (1.5 atm) and V_1 = .025 m^3. Also $V_2 = V_3 = 3.00V_1 = 0.075$ m^3. *(answers to three sig figs)*

a) (6 points) What is the temperature at all three points in the cycle (T_1, T_2, & T_3)?

We're given that this is a monatomic ideal gas ($\Rightarrow c_V = \frac{3}{2}R, c_p = \frac{5}{2}R,$ & $\gamma = \frac{5}{3}$), there's 1 mole, and that $p_1 = 1.52\times10^5$ Pa and $V_1 = 0.025$ m^3.

a) For T_1, use the ideal gas law $\Rightarrow T_1 = \dfrac{p_1V_1}{nR} = \dfrac{(1.52\times10^5\text{ Pa})(0.025\text{ m}^3)}{(1.0\text{ mole})(8.31\text{ J/mole/K})} = 457\text{ K}$

b) For T_2, since $1\rightarrow2$ is an isotherm $\Rightarrow T_2 = T_1 = 457$ K $\left[\text{or } \left(p_1V_1 = p_2V_2\right)_{isotherm} : p_2 = 0.507\times10^5\text{ Pa and } V_2 = 0.075\text{ m}^3\right]$

c) For T_3, since $3\rightarrow1$ is an adiabat $\Rightarrow T_1V_1^{\gamma-1} = T_3V_3^{\gamma-1} \Rightarrow T_3 = T_1\left(\dfrac{V_1}{V_3}\right)^{\gamma-1} = (457\text{ K})\left(\dfrac{0.025\text{ m}^3}{0.075\text{ m}^3}\right)^{5/3-1} = 220\text{ K}$

b) (3 points) What is the net entropy change during one full cycle?

$\Delta S_{cycle,rev}$ = 0 J/K (state quantity of reversible cycle is zero – independent of path)

c) (6 points) Find the change in entropy during each process. (ΔS_{12}, ΔS_{23}, & ΔS_{31})?
d)

For any reversible gas process, we know $\Delta S \equiv \displaystyle\int \frac{dQ}{T} = nR\ln\frac{V_f}{V_i} + nC_V\ln\frac{T_f}{T_i}$

a) For $\Delta S_{3\rightarrow1,adiabat} = 0$ J/K $\left[\text{from } Q_{adiabat} = 0\right]$

b) For $\Delta S_{1\rightarrow2,isotherm} = nR\ln\dfrac{3V_1}{V_1} + nC_V\ln\dfrac{T_1}{T_1} = (1.0\text{ mole})(8.31\text{ J/mole/K})\ln(3) + 0 = +9.13\text{ J/K}$

c) For $\Delta S_{2\rightarrow3,isochoric} = nR\ln\dfrac{3V_1}{3V_1} + nC_V\ln\dfrac{T_3}{T_2} = 0 + (1.0\text{ mole})(\dfrac{3}{2}\bullet8.31\text{ J/mole/K})\ln\left(\dfrac{220\text{ K}}{457\text{ K}}\right) = -9.13\text{ J/K}$

[note that since $\Delta S_{3\rightarrow1,adiabat} = \Delta S_{cycle,rev} = 0$, that we know that b) and c) have to be equal and opposite]

e) (7 points) Find the heat transferred during each process (Q_{12}, Q_{23}, & Q_{31})?

Calculate Q for each process (isothermal, isochoric, and adiabatic):

a) For $Q_{1\rightarrow2,isotherm} = W_{isotherm} = nRT\ln\dfrac{V_f}{V_1} = (1.0\text{ mole})(8.31\text{ J/mole/K})(457\text{ K})\ln(3) = +4.17\text{ kJ (absorbed)}$

c) For $Q_{2\rightarrow3,isochoric} = nC_V\Delta T = nC_V\left(T_3 - T_2\right) = (1.0\text{ mole})(\dfrac{3}{2}\bullet8.31\text{ J/mole/K})\left(220\text{ K - }457\text{ K}\right) = -2.96\text{ kJ (released)}$

c) For $Q_{3\rightarrow1,adiabat} = 0$ K $\left[\text{definition of adiabatic process}\right]$

f) (4 points) the *net* work done during one full cycle?

For a cyclic, reversible process $\Rightarrow \Delta E_{\text{int},cycle} = 0$. From 1st law $\left(\Delta E_{\text{int},cycle} = Q_{net} - W_{net} = 0\right)$, we have for the cycle $W_{net} = Q_{net}$.

Here $Q_{net} = Q_{1\rightarrow2,isotherm} + Q_{2\rightarrow3,isochoric} + Q_{3\rightarrow1,adiabat} = \left(+4.17\text{ kJ}\right) + \left(-2.96\text{ J/K}\right) + \left(0\right) = 1.22\text{ kJ}$

So, $W_{net} = Q_{net} = 1.22$ J

g) (3 points) What is the net internal energy change during one full cycle?

$\Delta E_{int,\,cycle}$ = 0 J (state quantity of reversible cycle is zero – independent of path)