Early E. C.:	**/ 1**
Total HW Points Unit 2.C:	**/ 22**
Total Lab Points Unit 2.C:	**/ 26**
Unit 2.C Apps.:	**/ 5**
Late, Incomplete, No Work, No Units Fee?	Y / N

2.C.1 Problems – 1st Law of Thermodynamics
12.1-.2 of your book.

1. (2 Points) While playing in a tennis match, you lost 6.5 E 5 J of heat, and your internal energy also decreased by 1.2 E 6 J. How much work did you do in the match?

Possible 2.C.1 Pts.:	**2**
Late, Incomplete, No work, No Units Fee:	- 1 - 2
Final Score:	**/ 2**

2.C.2 Problems – Thermodynamic Processes
Section 12.3 of your book.

Possible 2.C.2 Pts.:	**6**
Late, Incomplete, No work, No Units Fee:	- 1 - 2 -3
Final Score:	**/ 6**

A quantity of ideal gas goes through an isothermal process and does 400.0 J of net work.

1. The internal energy of the gas is (1) higher than, (2) the same as, (3) less than when it started. Why?

2. Is a net amount of heat added or removed from the system, and how much is involved?

While doing 500. J of work, an ideal gas expands adiabatically to 1.5 times its initial volume.

3. The temperature of the gas (1) increases, (2) remains the same, (3) decreases. Explain.

4. What is the change in the internal energy of the gas?

An ideal gas is under an initial pressure of 2.45 E 4 Pa and occupies a volume of 0.20 m^3. The slow addition of 8.4 E 3 J of heat to this gas causes it to expand isobarically to a volume of 0.40 m^3.

5. How much work is done by the gas in the process?

6. Does the internal energy of the gas change in the previous problem? If so, then by how much?

Possible 2.C.3 Pts.:	6
Late, Incomplete, No work, No Units Fee:	- 1 - 2 -3
Final Score:	/ 6

2.C.3 Problems – Entropy
Section 12.4 of your book.

1. What is the change in entropy of mercury vapor (L_v = 2.7 E 5 J/kg) when 0.50 kg of it condenses to a liquid at its boiling point of 357 ^oC?

A process involves 1.0 kg of steam condensing to water at 100 ^oC.

2. The change in entropy of the steam (water) is (1) positive, (2) zero, (3) negative. Why?

3. What *is* the change in entropy of the steam in the previous problem?

4. In an isothermal expansion at 27.0 ^oC, an ideal gas does 60.0 J of work. What is the change in entropy of the gas?

An isolated system consists of two very large thermal reservoirs at constant temperatures of 100. ^oC and 0.0 ^oC. Assume the reservoirs made contact and 1000. J of energy transfer from the cold reservoir spontaneously (this is not physically possible, but assume that it does for this problem).

5. The total change in entropy of the isolated system (both reservoirs) would be (1) positive, (2) zero, (3) negative. Explain.

6. Calculate the total change in entropy of the isolated system.

Possible 2.C.4 Pts.:	7
Late, Incomplete, No work, No Units Fee:	- 1 - 2 -3
Final Score:	/ 7

2.C.4 Problems – Heat Engines
Section 12.5 of your book.

A gasoline engine has a thermal efficiency of 28%. If the engine absorbs 2000. J of heat per cycle,

1. What is the net work output per cycle?

2. For the previous problem, how much heat is exhausted per cycle?

3. An internal combustion engine with a thermal efficiency of 15.0% absorbs 1.75 E 5 J of heat from the hot reservoir. How much heat is lost by the engine in each cycle?

A gasoline engine burns fuel that puts 3.3 E 8 J of heat into the system per hour.

4. What is the energy input during a 2.0 h period?

5. If the engine delivers 25 kW of power during this time, what is its thermal efficiency?

A refrigerator with a C.O.P. of 2.2 removes 4.2 E 5 J of heat from its interior each cycle.

6. How much heat is exhausted each cycle?

7. What is the total work input (in joules) for 10 cycles?

Possible 2.C.5 Pts.:	6
Late, Incomplete, No work, No Units Fee:	- 1 - 2 -3
Final Score:	/ 6

2.C.5 Problems – The Carnot Cycle
Section 12.6 of your book.

1. A steam engine operates between 100. ^{o}C and 20.0 ^{o}C. What is the Carnot efficiency of the ideal engine that operates between these temperatures?

2. An engineer wants to run a heat engine with a Carnot efficiency of 40.0 % between a high-temperature reservoir at 300.0 °C and a low-temperature reservoir. What is the maximum Celsius temperature of the low-temperature reservoir?

A Carnot engine with an efficiency of 40.0% operates with a low-temperature reservoir at 40.0 °C and exhausts 1200 J of heat each cycle. For problems 3 and 4, what are:

3. the heat input per cycle,

4. the Celsius temperature of the high-temperature reservoir?

A Carnot engine takes in heat from a reservoir at 350 °C and has an efficiency of 35%. The exhaust temperature is not changed and the efficiency is increased to 40%.

5. The hot reservoir's temperature is (1) lower than, (2) equal to, (3) higher than 350 °C. Explain.

6. What is the new Celsius temperature of the hot reservoir?

AP Physics 2	Unit 2.C.1 Lab - The Cycle of a Steam Engine
Reminder: Update Table of Contents	Correction Credit: Half

Lab Overview:

Using a steam engine as a power source, you will explore thermodynamic relations within the First and Second Laws.

Materials:

1 – Old-School Model Steam Engine
Steam Engine Food (Pellets of hexamethylenetetramine)
Heat output = 30.0 MJ/kg
Massless Pulley
String
Set of Masses

Steam Engine Lab (2.C.1) Guide		
Table of Contents, Title/Date, Detailed Synopsis, Two Purposes		/ 2
Mission 1: Data Table	Labeled Well	/ 1
	Tidy	/ 1
	Fuel Info	/ 1
	Mass Info	/ 1
	Piston Info	/ 1
	State Variables	/ 1
Mission 2: Pressure vs. Volume Graph	Well Labeled Axes	/ 1
	Well Labeled Legs	/ 1
	Correct leg shapes	/ 1
Analysis 1: Average heat output.		/ 2
Analysis 2: Work done by engine.		/ 2
Analysis 3: Carnot Efficiency.		/ 2
Question 1: Sources of energy waste.		/ 3
Question 2: Graph Shape.		/ 2
Work Not Shown Fee:		-1 -2 -3
Late Lab Fee:		-5
Total:		**/ 22**

Mission 1 – Data Gathering

Gather data of a steam engine under power as it lifts a load upwards doing work. Such items will be fuel data, time duration of fuel source’s burning, pressure of steam engine at boiling, temperature of steam engine at boiling, mass lifted, distance lifted, time of lifting, piston volume data.

Mission 2: Pressure vs. Volume Graph

Make well labeled pressure vs volume graph of one complete cycle of the steam engine; from inlet of steam during expansion (Leg A), through closure of steam aperture to end of forward thrust (Leg B), through reverse thrust and outgassing (Leg C), through closure of exhaust port to point A of the cycle (Leg D), where fresh steam will enter the piston to start the next cycle.

This graph is designed to be conceptual, and not necessarily an accurate way of determining energy output by the steam engine.

Analysis: Show all your work for full credit. (2 Points Each).

1. What was the average amount of heat output by the fuel?

2. What was the work done by the steam engine?

3. What was the thermal Efficiency of the engine?

Questions. Rephrase and answer in complete sentences for full credit.

1. Identify four sources of energy loss in the steam engine system, describing how each divests energy from useful work into waste (4 points total).

2. What were deficiencies in your Pressure vs. Volume graph? In other words, what other data would you need to make it more representative of one cycle of the piston (2 points total)?

AP Physics 2	Unit 2.C - Thermodynamics				
Application Problems, AP Test Preparation Questions					
Presentation Points:	/ 5	Late Fee:	-2	Completion (Booklet Check)	/ 5

Your grade on this problem set will depend on the presentation you provide for your problem, and whether they are complete when you submit your Booklet at the end of the Unit.

1. A system does 45.0 J of work, and the energy input is 105 J. What is the change in internal energy?

2. A 1.0 kg amount of 100.0 ° water is placed around a cylinder of a cool, ideal gas, connected to a piston. As the water cools down to 55.0 °C, the gas in the cylinder heats up, pushing a piston so it lifts a 1.2 kg mass up (vertically) 0.25 m. How much work did the piston do? What's the thermal efficiency of this system?

3. A gas undergoes a process A-B along a straight line. At A the gas has a pressure of 75.0 kPa and a volume of 12.0 L. At B the pressure is 60.0 kPA and the volume is 20.0 L. The heat gained in this process is 600.0 J. The internal energy of the gas at A is 70.0 J. What is the internal energy of the gas at B?

A. 70.0 J B. 60.0 J C. 130. J D. 190. J E. 10.0 J

Unit 2.C Practice AP Multiple Choice Questions

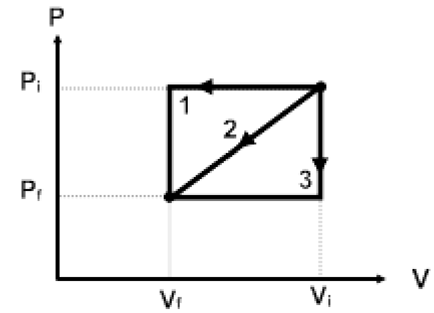
The following problems (multiple choice and free response) are designed to train you to take the AP Physics 1 test in the spring, and will be scored at the end of the Unit – based on completion and accuracy.

1. A container holds a mixture of two gases, CO_2 and H_2, in thermal equilibrium. Let K_C and K_H denote the average kinetic energy of a CO_2 molecule and an H_2 molecule, respectively. Given that a molecule of CO_2 has 22 times the mass of a molecule of H_2, the ratio of K_C/K_H is equal to:

   a. 1/22 b. $1/\sqrt{22}$ c. 1 d. $\sqrt{22}$ e. 22

2. If the temperature and volume of a sample of an ideal gas are both doubled, then the pressure
   a. decreases by a factor of 4
   b. decreases by a factor of 2
   c. increases by a factor of 2
   d. increases by a factor of 4
   e. remains unchanged

3. In three separate experiments, a gas is transformed from state P_i, V_i to state P_f, V_f along the paths (1, 2, and 3) illustrated in the figure:
The work done on the gas is
   a. greatest for path 1
   b. least for path 2
   c. the same for paths 1 and 3
   d. greatest for path 2
   e. the same for all three paths



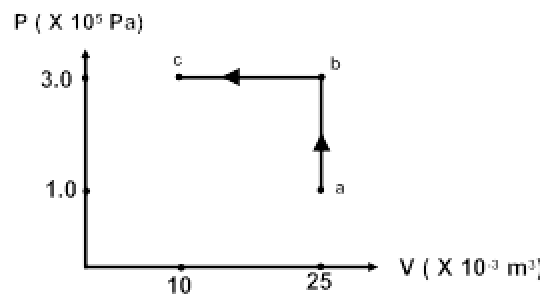
4. An ideal gas is compressed isothermally form 20 L to 10 L. During this process, 5 J of work is done to compress the gas. What is the change of internal energy for this gas?
   a. -10 J   b. -5 J   c. 0 J   d. 5 J   e. 10 J

5. An ideal gas is confined to a container whose volume is fixed. If the container holds n moles of gas, by what factor will the pressure increase if the absolute temperature is increased by a factor of 2?
   a. 2/(nR)   b. 2   c. 2nR   d. 2/n   e. 2/R

6. Two large glass containers of equal volue each hold 1 mole of gas. Container 1 is filled with hydrogen gas (2 g/mol), and Container 2 holds helium (4 g/mol). If the pressure of the gas in Container 1 equals the pressure of the gas in Container 2, which of the following is true?
   a. The temperature of the gas in Container 1 is lower than the temperature of the gas in Container 2.
   b. The temperature of the gas in Container 1 is greater than the temperature of the gas in Container 2.
   c. The value of R for the gas in Container 1 is ½ the value of R for the gas in Container 2.
   d. The rms speed of the gas molecules in Container 1 is lower than the rms speed of the gas molecules in Container 2.
   e. The rms speed of the gas molecules in Container 1 is greater than the rms speed of the gas molecules in Container 2.

7. Through a series of thermodynamic processes, the internal energy of a sample of a confined gas is increased by 560 J. If the net amount of work done on the sample by its surroundings is 320 J, how much heat was transferred between the gas and its environment?
   a. 240 J absorbed b. 240 J dissipated c. 880 J absorbed d. 880 J dissipated
   e. None of the above

8. What's the total work performed on the gas as it's transformed from state a to state c, along the path indicated?
   a. 1500 J b. 3000 J c. 4500 J
   d. 5000 J e. 9500 J

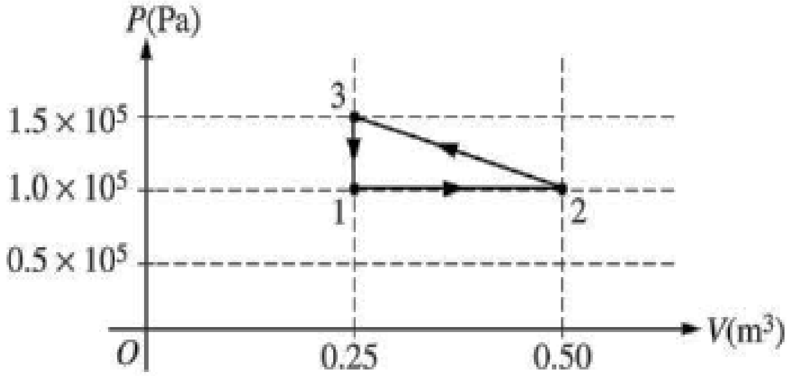


9. In one of the steps of the Carnot cycle, the gas undergoes an isothermal expansion. Which of the following statements is true concerning this step?
   a. No heat is exchanged between the gas and its surroundings, because the process is isothermal.
   b. The temperature decreases because the gas expands.
   c. This step violates the Second Law of Thermodynamics because all the heat absorbed is transformed into work.
   d. The internal energy of the gas remains constant.
   e. The internal energy of the gas decreases due to expansion.

10. What's the maximum possible efficiency for a heat engine operating between heat reservoirs whose temperatures are 800 °C and 200 °C?
    a. 25% b. 33% c. 50% d. 56% e. 75%

Unit 2.C Example AP Question – Free Response

AP Question 1



5. (10 points)

A cylinder with a movable frictionless piston contains an ideal gas that is initially in state 1 at 1×10^5 Pa, 373 K, and $0.25\ m^3$. The gas is taken through a reversible thermodynamic cycle as shown in the *PV* diagram above.

(a) Calculate the temperature of the gas when it is in the following states.

i. State 2

ii. State 3

(b) Calculate the net work done on the gas during the cycle.

(c) Was heat added to or removed from the gas during the cycle?

____ Added ____ Removed ____ Neither added nor removed

Justify your answer.

AP Question 2

5. (10 points)

In a certain process, 3200 J of energy is added to an ideal gas by heating. During the same process, 2100 J of work is done on the gas.

(a) Determine the change in the internal energy of the gas.

(b) Indicate whether each of the following properties of the gas increases, decreases, or remains the same during the process.

i. Volume

____ Increases ____ Decreases ____ Remains the same

Justify your answer.

ii. Temperature

____ Increases ____ Decreases ____ Remains the same

Justify your answer.

iii. Pressure

____ Increases ____ Decreases ____ Remains the same

Justify your answer.

Suppose that in a different process 1800 joules of work is done on the ideal gas at a constant temperature.

(c) Determine the change in internal energy of the gas during the process.

(d) Which of the following correctly describes the energy transfer by heating, if any, between the gas and its surroundings?

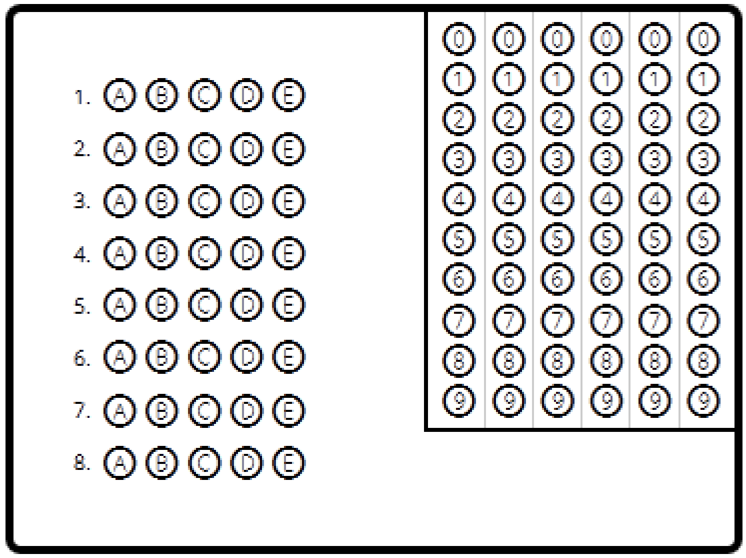
____ Energy is transferred into the gas. ____ Energy is transferred out of the gas.

____ There is no energy transfer by heating.

Justify your answer.

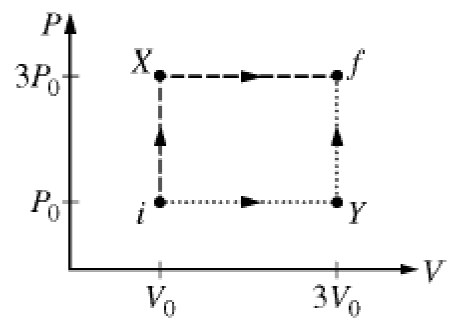
AP Physics 2	Unit 2.C Review - Thermodynamics						
Points:	**/ 14**	**Late or Incomplete Fee:**	**-2 -4 -6**	**Correction Credit:**		**Final Score:**	

Solve these problems here, THEN enter your responses in the bubble sheet provided.
Each question is worth two points.



1. What is the change in entropy of lead when 2.0 kg of molten lead solidifies? [L_f= 5.9 kcal/kg at 328°C].
A) 196 kcal/K B) -196 kcal/K
C) -1.96 E -2 kcal/K D) 1.96 E -2 kcal/K
E) 250 kcal/K

2. A container of ideal gas at STP (Standard Temperature and Pressure is 0°C and 1 atm) undergoes an isothermal expansion and its entropy changes by 3.66 J/K. How much work does it do?
A) 2.00 E 3 J B) 1.00 E 3 J C) 1.50 E 3 J D) 2.50 E 3 J E) 2.9 E 3 J



3. A sample of an ideal gas can be taken from state *i* to state *f* via two processes, as shown in the graph of pressure vs. volume. In on process the goes through state *X*, and in the other process the gas goes through state *Y*. Which of the following will be the same for both processes? **Select two answers.**
A) The sequence of events done to the gas to take it from state *i* to state *f*.
B) The temperature of the gas at the end of the process.
C) The work done on the gas.
D) The thermal energy transferred to the gas by heating. E) The change in the internal energy of the gas.

4. A refrigerator has a COP of 2.5. If it removes 7.7 MJ of heat in 25 minutes, what is the minimum power motor necessary to operate the refrigerator?
A) 1500 W B) 1025 W C) 2050 W D) 2700 W E) 3300 W

5. A refrigerator has a COP of 2.5. If it removes 7.7 MJ of heat in 25 minutes, what is its efficiency if it were a reversible engine?

A) 15.8 % B) 28.6 % C) 32.0 % D) 37.2 % E) 45.6 %

6. What is the maximum theoretical efficiency possible for an engine operating between 100°C and 400°C?

A) 44.6 % B) 35.6 % C) 48.9 % D) 40.1 % E) 38.2 %

7. A heat engine operating between 40°C and 380°C has an efficiency 60% of that of a Carnot engine operating between the same temperatures. If the engine absorbs heat at a rate of 60 kW, at what rate does it exhaust heat?

A) 22.8 kW B) 41.3 kW C) 35.6 kW D) 45.2 kW E) 17.8 kW

8. In a lab experiment, students place an increasing number of textbooks on top of a vertical syringe system filled with air. Each time a book is added, they allow the system to come to room temperature before measuring the new volume of the system. Assuming the air in the syringe to be ideal, which of the following best represents the expected graph of the volume of air as a function of book number?