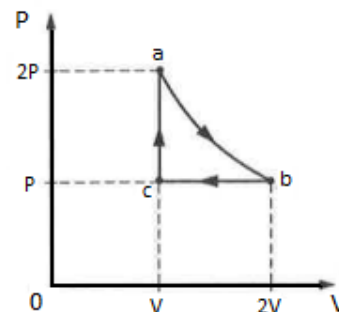


Thermal Physics Free Response

PSI AP Physics 2

1. One mole of ideal gas is initially at temperature T , volume $2V$, and pressure P , represented by point a on the graph shown above. The gas goes through the cycle from $a \rightarrow b \rightarrow c \rightarrow a$. Process ab is isothermal, process bc is isobaric, and process ca is isochoric.



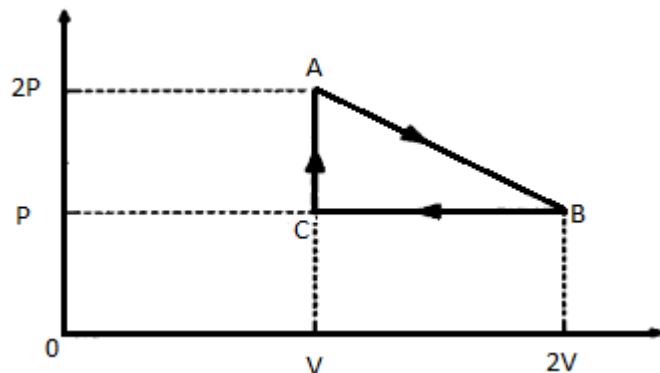
- a. What is the temperature at point c ?
- b. What is the total work being done on the gas as the process goes from point $b \rightarrow c \rightarrow a$? In a short coherent paragraph explain the difference between “work done” and “work by”, as well as why one answer would be positive and the other negative.
- c. Which of the processes result in heat being added to the gas? Explain your answer.
_____ ab _____ bc _____ ca

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2. One mole of ideal gas cycles from point $A \rightarrow B \rightarrow C$. Process BC is isobaric and process CA is isochoric.
- If the temperature of the gas at point A is T , what is the temperature of the gas at points B and C?
 - Is process AB isothermal? Explain your answer in a short coherent paragraph.
 - What is the work done by the gas during the cycle $A \rightarrow B \rightarrow C$?
 - How much heat is added to the gas in process BC? Express your answer with the given quantities as well as fundamental variables.

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3. One mole of a monatomic ideal gas goes through a cycle from point **a** → **b** → **c** → **a**. Process **ab** is isothermal, process **b** → **c** is isobaric, and process **c** → **a** is isochoric.



- a. Point **a** has a pressure of $2P$ and **b** has a pressure of P . Use this information along with the information above to sketch a PV diagram.

- b. What is the total work done by the gas along **b** → **c**?

- c. How much heat is removed from the gas between along **b** → **c** if the gas has a temperature of T at point **c**?

- d. What is the internal energy of the gas during process **AB**? Explain your answer.

- e. Is it possible for the work done by a gas to equal the work done on a gas? Why or why not? Explain your answer in terms of a PV graph.

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4. Two (2) moles of a monatomic ideal gas are placed in a cylindrical with a diameter of 20 cm with a piston at one end. The piston can move freely up and down without friction and has a diameter of 20 cm. A 50 kg weight is placed on the top of the piston. The initial temperature of the gas is 0°C .
- Calculate the gas pressure in the container.
 - Calculate the volume of the gas.
 - The gas is heated to a temperature of a 100°C at constant pressure. Calculate the new volume of the gas.
 - Calculate the amount of work done by the gas during its expansion.
 - Calculate the change in internal energy of the gas.
 - Calculate the amount of heat added to the gas.

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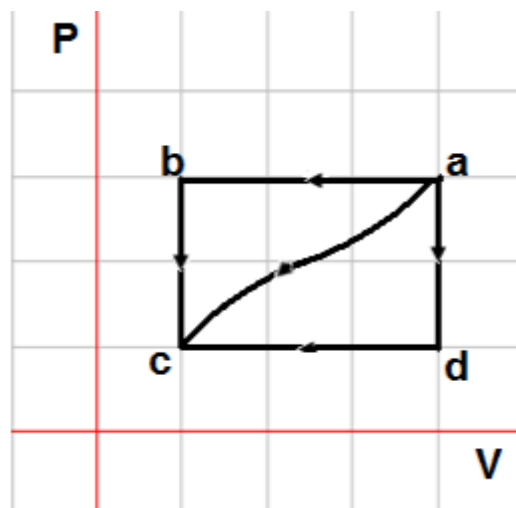
5. An ideal gas can be taken from state **a** to state **c** in three different paths: **a**→**b**→**c**, **a**→**d**→**c**, and curved path **a**→**c**. The pressure of the ideal gas at point **a** is three times the pressure at point **d**. Use the following information to answer all questions:

$$Q_{a \rightarrow c} = -120 \text{ J (curved path)}$$

$$W_{a \rightarrow c} = 75 \text{ J (curved path)}$$

$$W_{a \rightarrow d \rightarrow c} = 95 \text{ J}$$

$$U_a - U_d = 20 \text{ J}$$



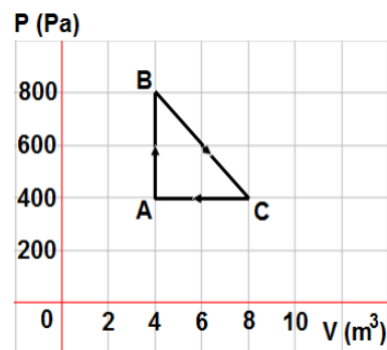
In the given information above we assume that work is done on the gas.

- Find the change in internal energy $U_a - U_c$.
- Find the heat added to the gas in the process **a**→**d**→**c**.
- Find the work done on the gas in the process **a**→**b**→**c**.

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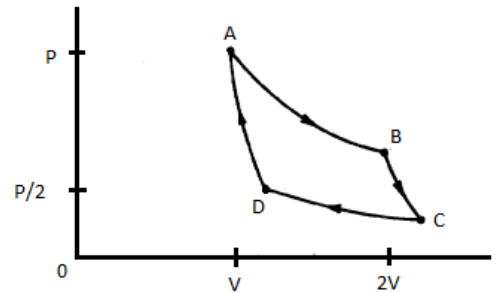
- d. Find the heat added to the gas in the process $a \rightarrow b \rightarrow c$.

6. One mole of an ideal gas is taken through a closed cycle $A \rightarrow B \rightarrow C \rightarrow A$. Use the information from the graph to answer the following questions:



- a. Find the temperature at point A.
- b. Is the net work done by the gas positive or negative? Explain.
- c. How much work is done by the gas?
- d. Is heat added to the gas or removed from the gas for the entire cycle? Explain.
- e. How much heat is added to the gas over the entire cycle?
- f. What is the change in internal energy for the entire cycle?

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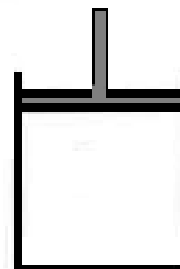


7. An engine will utilize the temperature difference between surface seawater and deep-sea water. The surface temperature is 20°C and the deep-sea temperature is 2°C .
- What is the ideal (Carnot) efficiency of this engine?
 - If the engine does 200 J of work, how much heat is given off to the surroundings per cycle?
 - Use the graph above to answer this question. Mark off each of the boxes in the table below with either a +, -, or 0 for Q and ΔT .

	Q	ΔT
AB		
BC		
CD		
DA		

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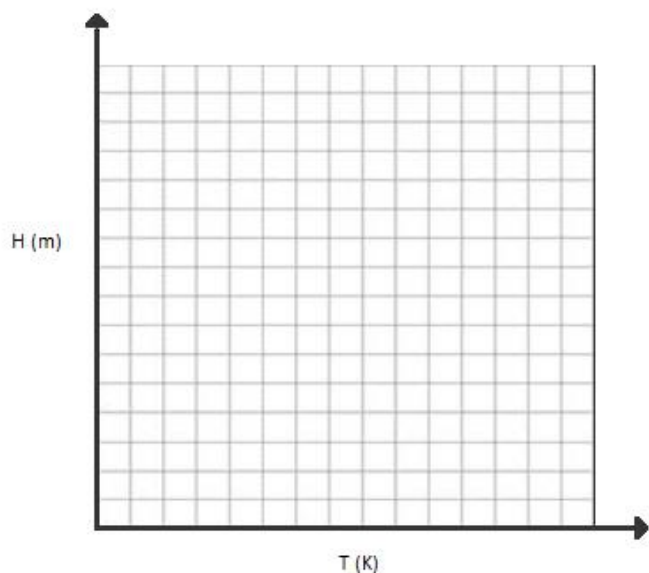
8. A cylinder (right) has a movable, frictionless piston with an area A . In an isobaric process, the gas in cylinder is heated and the piston is pushed upwards. Measurements are taken of the temperature T of the gas as well as the height h of the piston. Use the information in the table to find the number of moles n that the cylinder contains.



Height (m)	Temperature ($^{\circ}\text{C}$)
2.1	275
2.3	310
2.4	341
2.5	375

- a. Write an equation that can be used to solve for n using the given variables A , P , H , T , and other fundamental constants.
- b. The pressure is kept at 1 atm and the area of the piston is 1 m^2 . Create a graph using the data above that can be used to solve for n . Draw a best fit line through your points.

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- c. Find the number of moles n .
- d. James has been performing the above experiment in his physics class. His teacher tells him to find the work done by the gas during the process. He says that he should be using the equation $W=mgH$, and use the change in height for H and weigh the mass of the piston for m . Would this be correct? Explain why or why not in a coherent paragraph-length answer.
- e. Find the work done by the gas without using the equation $U=mgH$.

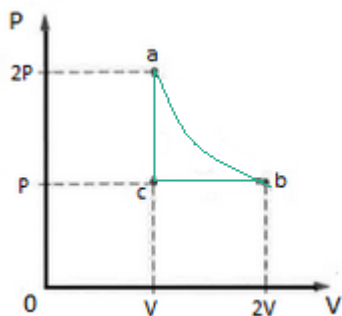
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Answer Key

- $T/2$
 - $W = +PV$. The work is positive by definition because energy is added to the gas as it is compressed by external forces. When work is done by a gas it expands, pushing out, and thus does mechanical work on the external environment.
 - Heat was added in processes ca and ab, but not in bc. In process ab, there is no change in temperature or internal energy, however, the gas expands and does work on its surroundings. Heat must have been added in order for the gas to do work. In process bc, there was no heat added to the gas. The gas's volume decreases while pressure stays constant, meaning its temperature is decreasing. The internal energy is decreasing as well. This means heat is being expelled from the gas, not added. Heat is being added to the gas in process ca. No work is being done by or on the gas, but the pressure increases while volume stays constant, resulting in a temperature increase.

- $T_B = T$; $T_C = T/2$
 - No, AB is not isothermal. While points A and B have the same temperature, not all points on line AB have the same temperature. In order for the line to be isothermal, the pressure and the volume of the gas must always multiply to the same number.
 - $W_{\text{gas}} = PV/2$
 - $\Delta U = Q + W$; $Q = \Delta U - W = \frac{3}{2}nR\Delta T - PV = \frac{3}{2}(PV - 2PV) - PV = -\frac{5}{2}PV$



- - $W = -PV$
 - $\Delta U = Q + W$; $Q = \Delta U - W = \frac{3}{2}nR(T - 2T) - PV = -\frac{3}{2}PV - PV = -\frac{5}{2}PV$ or $-\frac{5}{2}nRT$
 - $U = \frac{3}{2}nR(2T)$ (2T from part c)
 - No. Net work done on a gas is found by taking the area inside the path of the PV diagram. The only way this would be zero (work done on = work done by), is if the path was retraced. Then $\Delta T = 0$, $\Delta U = 0$, $Q = 0$.

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4. a) $P_{abs} = \frac{mg}{\pi r^2} + P_{atm} = \frac{50 \cdot 10}{3.14 \cdot 0.1^2} + 1 \cdot 10^5 = 1.16 \cdot 10^5 Pa$
 b) $V = \frac{nRT}{P} = \frac{2 \cdot 8.314 \cdot 273}{1.16 \cdot 10^5} = 0.039 m^3$
 c) $V = \frac{nRT}{P} = \frac{2 \cdot 8.314 \cdot 373}{1.16 \cdot 10^5} = 0.053 m^3$
 d) $W = -P\Delta V = -nR\Delta T = -2 \cdot 8.314 \cdot 100 = -1663 J$
 e) $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}W = 2495 J$
 f) $Q = \Delta U - W = 2495 J + 1663 J = 4158 J$

5. a) $\Delta U_{ac} = \Delta Q_{ac} + W_{ac} = -120 J + 75 J = -45 J$
 b) $\Delta Q_{adc} = \Delta U_{ac} - W_{adc} = -45 J - 95 J = -140 J$
 c) $W_{abc} = 3W_{adc} = 3 \cdot 95 = 285 J$ from graph
 d) $Q_{abc} = \Delta U_{ac} - W_{abc} = -45 - 285 J = -330 J$

6. a) $T = \frac{PV}{nR} = \frac{400 \cdot 4}{1 \cdot 8.314} = 192.4 K$
 b) positive $P\Delta V$ expansion is greater than $P\Delta V$ compression
 c) area of path = $\frac{1}{2}(800-400)(8-4) = 800 J$
 d) added, some converted to work, the remainder released
 e) 800 J
 f) $\Delta U=0$ over one cycle

7. a) $e = \frac{\Delta T}{T_{hot}} = \frac{18}{293} = 0.061$
 b) $e = \frac{W}{Q_H}; Q_H = \frac{W}{e}; Q_C = Q_H - W = W\left(\frac{1}{e} - 1\right) = 200\left(\frac{1}{0.061} - 1\right) = 3056 J$
 c)

	Q	ΔT
AB	+	0
BC	0	-
CD	-	0
DA	0	+

8. a) $PAh = nRT$
 b) $h = n\left(\frac{R}{PA}\right)T$ (find the slope of the best fit line h vs T : $\frac{\Delta h}{\Delta T} = n\left(\frac{R}{PA}\right) = 0.00394 m/K$)
 c) $n = \frac{PA \Delta h}{R \Delta T} = \frac{10^5}{8.314} \cdot 0.00394 = 47.4 moles$
 d) The mechanical work done by the gas is to lift the piston of weight mg a distance H . Hence work done by the gas is mgH
 e) $W = P\Delta V = PA\Delta H = 10^5 \cdot 1 \cdot 0.4 = 40,000 J$