AP® PHYSICS B
2013 SCORING GUIDELINES

Question 5

10 points total **Distribution of points**

(a) 1 point

Use the equation for the change in internal energy (first law of thermodynamics)
$\Delta U = Q + W$
$\Delta U = (3200\ \text{J}) + (2100\ \text{J})$
For the correct answer, including units 1 point
$\Delta U = 5300\ \text{J}$

(b)

i. 2 points

For selecting "Decreases" 1 point
For a correct justification 1 point

Examples
Because work is done on the gas, W is positive. $W = -P\Delta V$, so ΔV must be negative and the volume decreases.
Because work is done on the gas, W is positive and the gas is compressed. If the gas is compressed, the volume decreases.

ii. 2 points

For selecting "Increases" 1 point
For a correct justification 1 point

Example
The internal energy increases (as shown in part (a)) and the temperature of an ideal gas increases as the internal energy increases.

iii. 2 points

For selecting "Increases" 1 point
For a correct justification 1 point

Example
From the ideal gas law, PV/T is constant. So if V decreases and T increases, P must increase.

Question 5 (continued)

Distribution of points

(c) 1 point

For stating the internal energy does not change
$\Delta U = 0$ 1 point

(d) 2 points

For selecting "Energy is transferred out of the gas" 1 point
For a correct justification 1 point

Example

$\Delta U = Q + W$ is zero for an ideal gas at constant temperature and W is positive since work is done on the gas. Therefore Q is negative, meaning energy is transferred out of the gas by heating.

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.

$\Delta U = Q + W$

$\Delta U = 3200\text{J} + 2100\text{J}$

$\Delta U = 5300\text{J}$

(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.

If work is done on the gas, it is being compressed by it's container during the process, thus decreasing in volume.

ii. Temperature

✓ Increases ___ Decreases ___ Remains the same

Justify your answer.

The gas' internal energy increased, thus it's temperature must have increased.

iii. Pressure

✓ Increases ___ Decreases ___ Remains the same

Justify your answer.

The work done to the gas caused it to decrease in volume, thus by $W = -P\Delta V$, the pressure must have increased in order to make up for that change.

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.

~~$\Delta U = Q + W$~~

~~$\Delta U = 0J + 1800J$~~

$\Delta T = 0$ thus,

$\Delta U = 0$

(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.

This is an isothermal process. As the gas is compressed, in order to maintain constant temperature it must transfer energy to the environment. This transfer is done through heating, this the environment around the gas will heat up by 1800 J.

GO ON TO THE NEXT PAGE.

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.

$\Delta u = W_{on} + Q_{into}$

$= 3200\,J + 2100\,J$

$\Delta u = 5300\,J$

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

i. Volume

___ Increases X Decreases ___ Remains the same

Justify your answer.

$W_{by} = p\Delta V$ $W_{on} = -p\Delta V$ $W_{on} = -W_{by}$

Because the work done on the gas is positive, then the change in volume of the gas must be negative

ii. Temperature

X Increases ___ Decreases ___ Remains the same

Justify your answer.

$\Delta u = \frac{3}{2}nR\Delta T$ Because the change in internal energy of the object is positive, then the change in temperature must be positive as well.

iii. Pressure

___ Increases ___ Decreases X Remains the same

Justify your answer.

Because work is done by the gas, the pressure must remain constant.

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.

$\Delta T = 0$

$\Delta u = \frac{3}{2} n r \Delta T$

$\Delta u = \frac{3}{2} n R (0)$

$\boxed{\Delta u = 0}$

(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.

X There is no energy transfer by heating.

Justify your answer.

The change in internal energy is zero because there is no change in temperature.

GO ON TO THE NEXT PAGE.

B5 C1

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. $\Delta U = Q + W$

$\Delta U = Q + W$

$\Delta U = 3200 + 2100$

$\Delta U = 5300$ Joules

(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

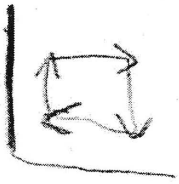
Justify your answer.

When energy is added to a gas by heating it up, it expands the gas given it a higher volume

ii. Temperature

✓ Increases ____ Decreases ____ Remains the same

Justify your answer.



If you increase the heat energy the temperature will increase

iii. Pressure

✓ Increases ____ Decreases ____ Remains the same

Justify your answer.

By increasing the volume of a gas in a container the pressure will increase also

GO ON TO THE NEXT PAGE.

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.

$\Delta U = Q + W$

$\Delta U = 0 + 1800$

$\Delta U = 1800$ Joules

(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.

When a gas is heated by its surrounding the temperature will increase which increase the internal energy of the gas so it is being transferred into the gas

AP® PHYSICS B
2013 SCORING COMMENTARY

Question 5

Overview

This question evaluated students' understanding of a system containing an ideal gas. This question required students to understand thermodynamics beyond a simple familiarity with equations, as they were asked to explain the interrelationships among work on the gas and temperature, pressure and volume of the gas. In the second portion of the question, temperature was held constant for the gas while work was done on it. This part required students to understand the relationships among temperature, internal energy, work, and heat.

Sample: B5-A
Score: 9

This is a well-organized response and almost earned full credit. Part (a) has the correct answer with units. Parts (b)(i), (b)(ii), and (d) have selected the correct choices and have acceptable justifications. Part (b)(iii) earned 1 point for correctly selecting "Increases" but the justification was insufficient (there is no mention of the dependency of pressure on temperature). Part (c) has a correct answer.

Sample: B5-B
Score: 6

Parts (a), (b)(i), (b)(ii), and (c) earned full credit. No credit was earned in parts (b)(iii) and (d) for selecting the wrong choices. (Note: the justifications for parts (b)(i), (b)(ii), (b)(iii), and (d) were not considered if the wrong answers were selected.)

Sample: B5-C
Score: 3

Full credit was earned in part (a). Credit was not earned in part (b)(i) because "Decreases" was not selected. One point was earned in part (b)(ii) for correctly selecting "Increases", but the justification was insufficient (the student needed to indicate that the total internal energy increases for temperature to necessarily increase). One point was earned in part (b)(iii) for correctly selecting "Increases", but the justification was insufficient (there is no mention of the dependency of pressure on temperature). No credit was earned in parts (c) and (d).