General Notes About 2009 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point and a student's solution contains the application of that equation to the problem, but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 4

15 points total | **Distribution of points**

(a) 2 points

For a correct expression for the pressure due to the weight of the piston — 1 point
For including atmospheric pressure — 1 point
$P = P_{atm} + (mg/A)$

Notes:
The second point was also awarded for stating the assumption that the cylinder is in a vacuum.
A numeric value for atmospheric pressure instead of a variable in the equation was acceptable.

(b) 2 points

For combining resistors in parallel — 1 point

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_0} + \frac{1}{R_0} + \frac{1}{R_0} = \frac{3}{R_0}$$

For the correct answer — 1 point
$R_{eq} = R_0/3$

(c) 3 points

For correctly relating the change in internal energy of the gas to the energy provided by the circuit — 1 point
$\Delta U = P_{cir}t$
For a correct relationship for the power delivered by the circuit in terms of voltage difference and resistance — 1 point

$$P_{cir} = \mathcal{E}^2/R_{eq}$$

$$\Delta U = \left(\mathcal{E}^2 \Big/ \frac{R_0}{3}\right)t$$

For the correct answer — 1 point
$\Delta U = 3\mathcal{E}^2 t/R_0$

Question 4 (continued)

Distribution of points

(d) 3 points

For indicating that the temperature decreases — 1 point

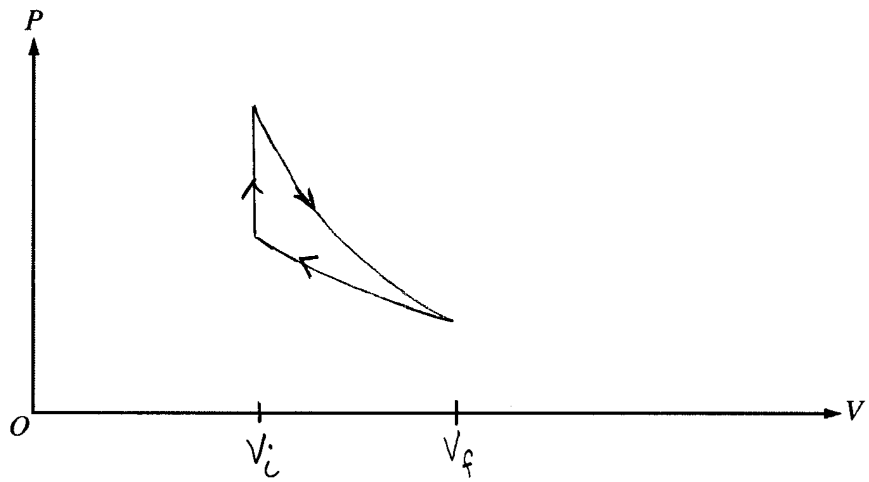
Justifying using the first law of thermodynamics: $\Delta U = Q + W$

For indicating that $Q = 0$ (the definition of an adiabatic process) — 1 point

For indicating that negative work is done on the piston, so applying the first law gives a net loss of energy in the gas and thus the internal energy decreases — 1 point

Since the internal energy is proportional to temperature, the temperature must also decrease.

(e) 5 points



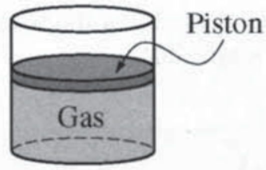
For a vertical straight segment — 1 point

One point for each curved segment from one end of the straight line to a point at a lower pressure and higher volume — 2 points

(Only the segments were scored. Presence or correctness of arrowheads was not considered.)

For correctly labeling V_i — 1 point

For correctly labeling V_f — 1 point



4. (15 points)

The cylinder shown above has an open top, and gas is held inside it by a piston of mass m and area A. The gas is insulated from its surroundings and is initially in equilibrium at volume V_i. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Determine the absolute pressure P_i of the gas at equilibrium.

$$P_i = P_g + P_{atm} = \frac{F}{A} + P_{atm} = \frac{mg}{A} + P_{atm}$$

The gas is heated by a circuit that contains three resistors, each of known resistance R_0, connected in parallel to a power source of emf $\mathcal{E}$. The piston is held fixed so that the gas remains at constant volume while being heated for a period of time t.

(b) Determine the resistance of the circuit.

$$R = \frac{R_0}{3}$$

(c) Calculate the change in internal energy of the gas.

$$Q = I^2 R t = \frac{\mathcal{E}^2}{R} t = \frac{3\mathcal{E}^2 t}{R_0}$$

$$W = 0$$

$$\therefore \Delta U = W + Q = \frac{3\mathcal{E}^2 t}{R_0}$$

After the time t, the circuit is disconnected. The piston is then released and the gas is allowed to expand adiabatically until it reaches volume V_f.

(d) Indicate below whether the temperature increases, decreases, or remains the same during this process.

_____ Increases ✓ Decreases _____ Remains the same

Justify your answer.

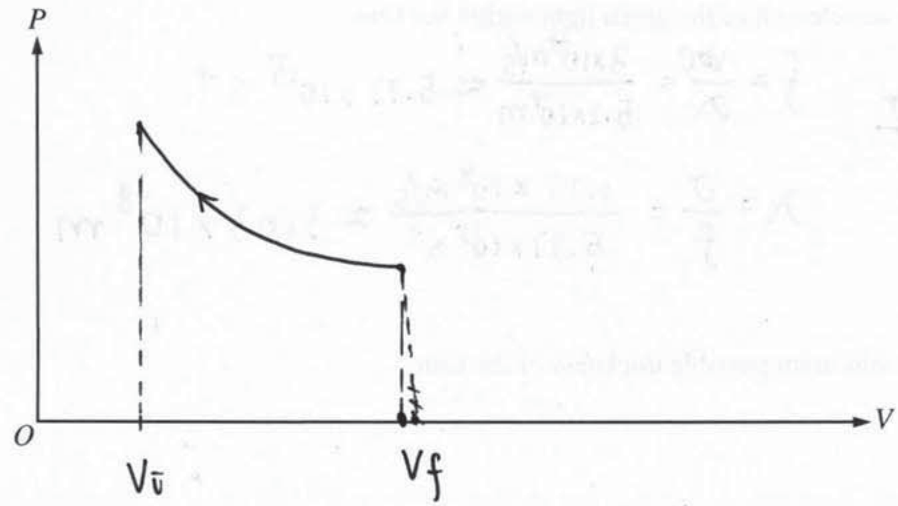
Since ~~Because~~ ~~it~~ the gas expand adiabatically, $Q = 0$.

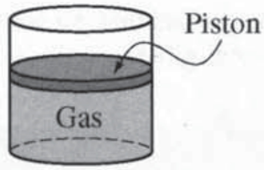
Volume increase, the system does work to ~~the~~ its envirorment,

thus $W = -pV$

$\Delta U = Q + W = -pV$

(e) The gas is then compressed isothermally to its original pressure and volume. On the axes below, draw a PV diagram for the complete cycle described in this question, labeling V_i and V_f on the volume axis.





4. (15 points)

The cylinder shown above has an open top, and gas is held inside it by a piston of mass m and area A. The gas is insulated from its surroundings and is initially in equilibrium at volume V_i. Express all algebraic answers in terms of the given quantities and fundamental constants.

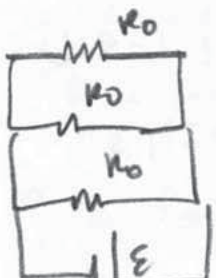
(a) Determine the absolute pressure P_i of the gas at equilibrium.

$P_i = P_{atm} + P_{piston}$ $P = F/A$ ($F \to mg$)

$P_i = 1.0\times10^5 + \frac{9.8m}{A}$

The gas is heated by a circuit that contains three resistors, each of known resistance R_0, connected in parallel to a power source of emf $\mathcal{E}$. The piston is held fixed so that the gas remains at constant volume while being heated for a period of time t.

(b) Determine the resistance of the circuit.



$\frac{1}{R_T} = \frac{1}{R_0} + \frac{1}{R_0} + \frac{1}{R_0} = \frac{3}{R_0}$

$R_T = \frac{R_0}{3}$

(c) Calculate the change in internal energy of the gas.

$\Delta U = Q + W$

$\Delta U = Q - P\Delta V$

$\Delta V = 0$ since V is constant

$\Delta U = Q = \frac{3\mathcal{E}^2}{R_0}$ J

$V = IR$ $I = \frac{\mathcal{E}}{(\frac{R_0}{3})} = \frac{3\mathcal{E}}{R_0}$

$P = IV = \mathcal{E} \cdot \frac{3\mathcal{E}}{R_0}$

$= \frac{3\mathcal{E}^2}{R_0}$

After the time t, the circuit is disconnected. The piston is then released and the gas is allowed to expand adiabatically until it reaches volume V_f.

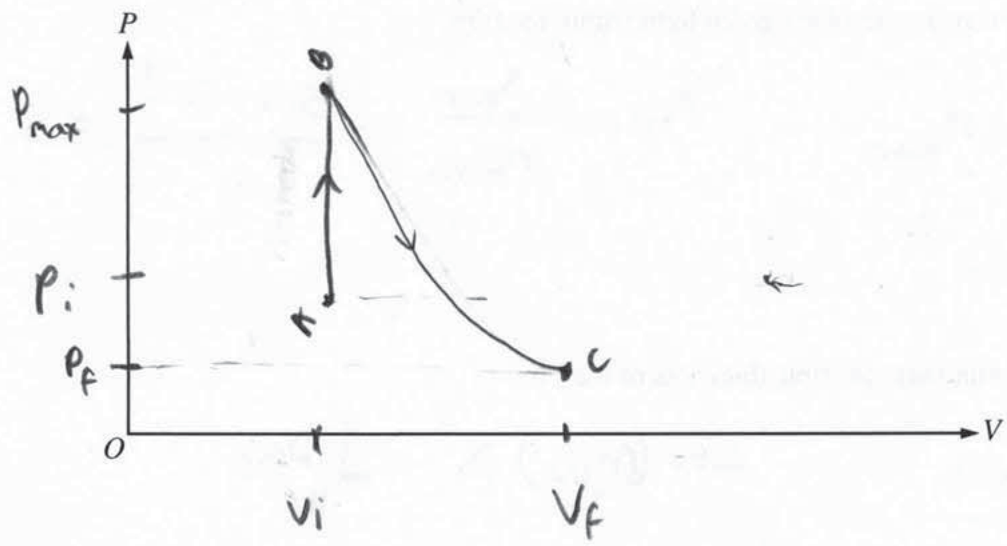
(d) Indicate below whether the temperature increases, decreases, or remains the same during this process.

_____ Increases _____ Decreases ✓ Remains the same

Justify your answer.

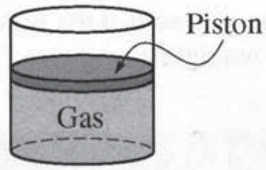
PV = nRT
constant
∴ → volume will increase
→ pressure will decrease
will balance each other out

(e) The gas is then compressed isothermally to its original pressure and volume. On the axes below, draw a PV diagram for the complete cycle described in this question, labeling V_i and V_f on the volume axis.



A-B : constant volume.
Being heated for a period of time t.

B-C : circuit disconnected → volume decreasing until Vf
pressure decreasing



4. (15 points)

The cylinder shown above has an open top, and gas is held inside it by a piston of mass m and area A. The gas is insulated from its surroundings and is initially in equilibrium at volume V_i. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Determine the absolute pressure P_i of the gas at equilibrium.

$P = \frac{F}{A}$

$P_i = \frac{mg}{A}$

The gas is heated by a circuit that contains three resistors, each of known resistance R_0, connected in parallel to a power source of emf $\mathcal{E}$. The piston is held fixed so that the gas remains at constant volume while being heated for a period of time t.

(b) Determine the resistance of the circuit.

$\mathcal{E} = Blv$ $\quad V = IR$

$= BlI3R_0$

$R_0 = \frac{\mathcal{E}}{3BIl}$

(c) Calculate the change in internal energy of the gas.

$U = \frac{3}{2}nRT$

$= \frac{3}{2}PV$

V : constant $\quad Q = CV$

$\therefore \Delta U = \frac{3}{2}\Delta P$

After the time t, the circuit is disconnected. The piston is then released and the gas is allowed to expand adiabatically until it reaches volume V_f.

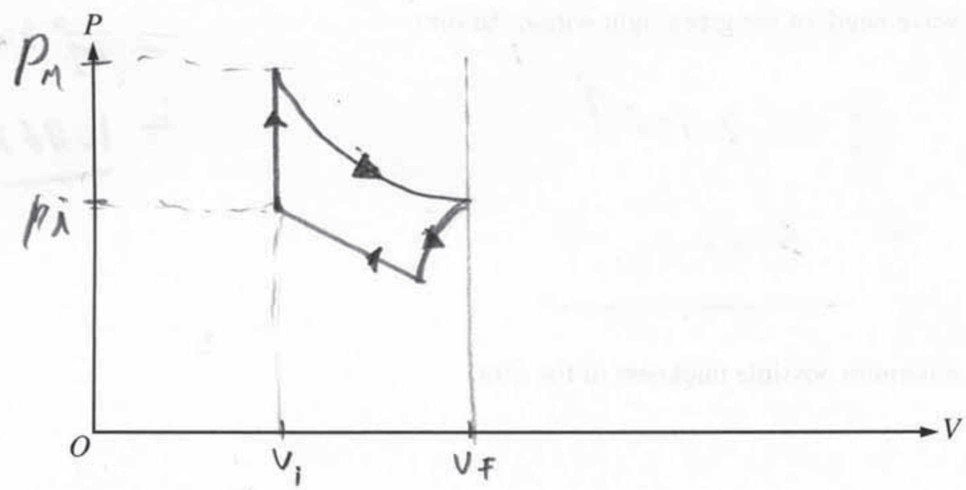
(d) Indicate below whether the temperature increases, decreases, or remains the same during this process.

_____ Increases _____ Decreases __✓__ Remains the same

Justify your answer.

because the gas is expanded adiabatically.

(e) The gas is then compressed isothermally to its original pressure and volume. On the axes below, draw a PV diagram for the complete cycle described in this question, labeling V_i and V_f on the volume axis.



Question 4

Sample: B-4A
Score: 12

Parts (a) and (b) earned 2 points each, and part (c) earned 3 points. Part (d) lost 1 point because there is no explicit connection made between the changes in temperature and internal energy. Part (e) is missing two segments and lost 2 points.

Sample: B-4B
Score: 9

Parts (a) and (b) earned 2 points each. Part (c) earned 1 point for the correct expression for power. Part (d) earned no points, and part (e) lost 1 point for the missing segment.

Sample: B-4C
Score: 5

Part (a) is missing atmospheric pressure and earned only 1 point. The next three parts earned no points. Part (e) lost 1 point for the incorrectly drawn segment.