Smith's Key

A.P. Physics - B

# Unit 7 Test Review

## Thermal Physics: Chapters 13-15

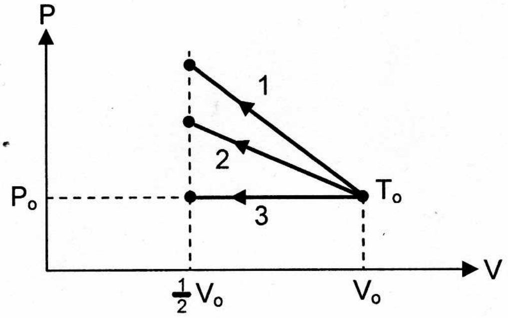
* In studying for your test, make sure to study this review sheet <u>along with your quizzes and homework assignments.</u>

**Multiple Choice Review:** On this portion of the test, you will not be allowed to use your calculator or AP formula sheet. (You may, however, use your AP table of information.) Approximate $g=10 m/s^2$ for simplicity of calculations. No partial credit will be given.

1. A certain quantity of an ideal gas initially at temperature $T_o$ , pressure $P_o$ , and volume $V_o$ is compressed to one-half its initial volume. As shown in the graph, the process may happen in several different manners, as represented by the three different lines on the graph. Which of the following is true of the final temperature of this gas?

   [✓ a.] It is greatest for process 1.
   b. It is greatest for process 2.
   c. It is greatest for process 3.
   d. It is the same for processes 1 and 2.
   e. It is the same for processes 1 and 3.

T is proportional to PV, so T is highest when PV is highest.



2. For the same graph as in problem #1, which of the following is true of the magnitude of the mechanical work done on the gas?

   [✓ a.] It is greatest for process 1.
   b. It is greatest for process 3.
   c. It is the same for processes 1 and 2.
   d. It is the same for processes 1 and 3.
   e. It is the same for all three processes.

W=Area under curve, and area under line 1 is greatest.

3. Which of the following will occur if the average speed of the gas molecules in a closed rigid container is increased? → So volume can't change, so speed directly impacts T, and P & T are directly related for constant volume. $(P_1/T_1 = P_2/T_2)$

   a. The density of the gas will decrease.
   b. The density of the gas will increase.
   c. The temperature of the gas will decrease.
   d. The pressure of the gas will decrease.
   [✓ e.] The pressure of the gas will increase.

Vol can't change! (a, b)

These would both go up. (c, d)

4. A gas with a fixed number of molecules does 32J of work on its surroundings, and 16J of heat are transferred from the gas to the surroundings. What happens to the internal energy of the gas?
   [✓ a.] It decreases by 48J.
   b. It decreases by 16J.
   c. It remains the same.
   d. It increases by 16J.
   e. It increases by 48J.

$$\Delta U = Q + W$$
$$= -16 - 32$$
$$= -48J$$

5. The absolute temperature of a sample of monatomic ideal gas is doubled at constant pressure. What effect, if any, does this have on the volume and density of the sample of gas?

| | Volume | Density |
|---|---|---|
| a. | Remains the same | Remains the same |
| b. | Remains the same | Doubles |
| c. | Doubles | Remains the same |
| [✓ d.] | Doubles | Is halved |
| e. | Is halved | Doubles |

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

If T ↑, V ↑.

And since $\rho = \frac{m}{V}$, if V ↑, ρ ↓.

6. A sample of an ideal gas is in a tank of constant volume. The sample absorbs heat energy so that its temperature changes from 300K to 600K. If $v_1$ is the average speed of the gas molecules before the absorption of heat and $v_2$ is their average speed after the absorption of heat, what is the ratio $v_2/v_1$?
   a. 1/2
   b. 1
   [✓ c.] $\sqrt{2}$
   d. 2
   e. 4

$V_{rms} = \sqrt{\frac{3RT}{M}}$ means that v is proportional to $\sqrt{T}$.

So if T doubles, v increases by $\sqrt{2}$.

7. If the pressure of an ideal gas held in a vessel is halved while its volume is quadrupled, the resulting temperature will be…
   a. half of its original value.
   b. the same as its original value.
   [✓ c.] twice its original value.
   d. one quarter of its original value.
   e. four times its original value.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(1)(1)}{T_1} = \frac{(\frac{1}{2})(4)}{T_2}$$

$$T_2 = 2T_1$$

$\Delta L = \alpha L_o \Delta T$ means that $\Delta L$ is proportional to both $L_o$ & $\Delta T$. If the first object is 10x as long, and experiences 2x the $\Delta T$, its $\Delta L$ will be 20x greater.

**8.** The temperature of a 5m-long object is increased by 20°C. The temperature of a second object, made of the same material as the first object but of length 50cm, is increased by 10°C. Which one of the following statements is true about the change in length experienced by the 5m-long object, compared to the change in length experienced by the 50cm-long object?

- **a.** The 5m-long object changes by 2 times as much as the other object.
- **b.** The 5m-long object changes by 10 times as much as the other object.
- [✓ **c.**] The 5m-long object changes by 20 times as much as the other object.
- **d.** The 5m-long object changes by 100 times as much as the other object.
- **e.** Both objects change length by the same amount.

**9.** An ideal monatomic gas is in a fixed container of size $0.3\text{m}^3$ at atmospheric pressure and temperature of 30°C. The number of moles present, in terms of the universal gas constant R, is closest to which of the following?

- [✓ **a.**] $\frac{100}{R}$ moles
- **b.** $\frac{1}{R}$ moles
- **c.** $\frac{90{,}000}{R}$ moles
- **d.** $\frac{1}{100R}$ moles
- **e.** $\frac{1}{1{,}000R}$ moles

$PV = nRT$

approx

$(100{,}000)(.3) = nR(300K)$

approx

$\frac{30{,}00\cancel{0}}{R30\cancel{0}} = n$

$\frac{300}{3R} = n$

**10.** During a certain thermodynamic process, a gas with a fixed number of molecules does 4000J of work on its surroundings, and its internal energy decreases from 7000J to 3000J. The process described is...

- **a.** an isothermal process.
- [✓ **b.**] an adiabatic process.
- **c.** an isovolumetric process.
- **d.** no special type of process.
- **e.** a physically impossible process.

$\Delta U = Q + W$

$-4000 = Q + -4000$

so $Q = 0$

**11.** What is the mass in kilograms of 4 moles of carbon dioxide gas ($CO_2$)? (The mass of one atom of carbon is 12u, and the mass of one oxygen atom is 16u.)

Mass of 1 mole of O atoms is 16g.

This just means that the mass of 1 mole of C atoms is 12g.

- **a.** 0.012kg
- **b.** 0.112kg
- [✓ **c.**] 0.176kg
- **d.** 12kg
- **e.** 176kg

Mass of 1 mole $CO_2 = 12 + 16(2) = 44g$

$4 \text{ moles} \left(\frac{.044 \text{ kg}}{1 \text{ mol}}\right) = .176 \text{ kg}$

**12.** Which of the following could be explained with the 2nd Law of Thermodynamics?

✓ The broken one is more disordered. → I. A broken coffee cup will never spontaneously reassemble itself.

II. Temperature of an ideal sample of gas is directly proportional to pressure and volume of the sample. } True, but because of ideal gas law.

✓ → III. Heat spontaneously flows from a hot object to a cold object, but not the reverse.

Spreading the energy out to more particles is more disordered.

a. I and II only

[✓ b.] I and III only

c. II and III only

d. I, II, and III

e. none of the above

**13.** What is the efficiency of a heat engine that absorbs 200J of heat per cycle and exhausts 150J of heat per cycle?

a. 15%

[✓ b.] 25%

c. 30%.

d. 50%

e. 75%

$W = 200 - 150 = 50$

$e = 50/200 = \frac{5}{20} = \frac{1}{4}$

**14.** Which method(s) of heat transfer require(s) particles of a medium to help transfer energy from one place to another?

✓ I. conduction → "Chain reaction" of particle vibrations, where neighboring particles bump each other

✓ II. convection → Faster-moving particles are actually moved to a new location, thereby transferring their E to the new location

Nope III. radiation ↓ E transferred through electromag waves (that can travel through space)

a. I only

b. II only

c. III only

[✓ d.] I and II only

e. I, II, and III

**Problem Review:** On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Partial credit will be given on these problems.

You won't actually need to convert Fahrenheit on the test.

**15.** In a closed cylinder there are 5 moles of nitrogen gas ($N_2$) at 143.7°F. What is the rms speed of the molecules in this container?

143.7°F = 335.2K

$$V_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.31)(335.2)}{.028}} = \boxed{546 \, m/s}$$

molar mass in kg ← 28g (from periodic table, ×2 because it's $N_2$.)

**16.** 40 kg of helium gas (He), at a pressure of 10atm, are held in a container at a constant volume and temperature. Another container at the same volume and temperature contains 27kg of fluorine gas ($F_2$). What is the pressure of the fluorine gas?

$$n_{He} = 40kg\left(\frac{1 \text{ mol}}{.004 \text{ kg}}\right)$$

$= 10,000$ moles

$$n_{F_2} = 27kg\left(\frac{1 \text{ mole}}{2 \times .019 \text{ kg}}\right) = 710.6 \text{ moles}$$

Since Vol & Temp are the same . . .

$$PV = nRT \longrightarrow \frac{P}{n} = \frac{RT}{V} \} \text{constant}$$

$$\text{so } \frac{P_1}{n_1} = \frac{P_2}{n_2} \rightarrow \frac{10}{10,000} = \frac{P_2}{710.6}$$

$$P_2 = \boxed{.71 atm}$$

**17.** A cylindrical brass sleeve is to be shrink-fitted over a brass shaft whose diameter is 3.212 cm at 10°C. The diameter of the sleeve is 3.196 cm at 10°C. To what temperature must the sleeve be heated before it will slip over the shaft.

It's like you need to increase the "length" of the circle from 3.196cm to 3.212cm.

$\Delta L = \alpha L_0 \Delta T$ ↙ would be given on the test

$$(.03212 - .03196) = (19E^{-6})(.03196)(\Delta T)$$

$$\Delta T = 263.5 \longrightarrow T_f = 10 + 263.5 = \boxed{273.5°C}$$

**18.** 80.0mL of water completely fills an aluminum container, when they are at 25.0°C. How much water spills out when it is heated to a temperature of 70°C?

Water:

$\Delta V = \beta V_0 \Delta T$

$\Delta V = (210E^{-6})(80)(70-25)$

$= .756$ mL

Aluminum:

$\Delta V = (75E^{-6})(80)(70-25)$

$= .27$ mL

Net Spilled $= .756 - .27$

$= \boxed{0.486 mL}$

**19.** Calculate the number of molecules per m$^3$ of gas at a temperature of 30°C and pressure of 5.1atm.

$PV = nRT$

$(5.1 \times 1.01E5)(V) = n(8.31)(303)$

This is more like what we actually focused on during class. → $204.6 \frac{\text{moles}}{m^3} = \frac{n}{V}$

$\rightarrow 204.6 \frac{\text{moles}}{m^3} \left(\frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mole}}\right) = \boxed{1.23E^{26} \frac{\text{molecules}}{m^3}}$

-or-

$PV = Nk_BT$

$(5.1 \times 1.01E5)(V) = N(1.38E^{-23})(303) \rightarrow \frac{N}{V} = \boxed{1.23E^{26} \frac{\text{molecules}}{m^3}}$

**20.** During a certain process, a fixed number of molecules of gas is compressed at a constant pressure of 4.2atm from 0.42m$^3$ to 0.35m$^3$. During the same process 35,000J of heat are transferred into the gas. Calculate the work done by the gas, and the change in internal energy of the gas.

$W_{on} = -P\Delta V$

$= -(4.2 \times 1.01E^5)(.35 - .42)$

$= +29,694J$ so $W_{by} \boxed{= -29,694 J}$

$\Delta U = Q + \overset{W_{on}}{W}$

$= 35,000 + 29,694$

$\boxed{= 64,694 J}$

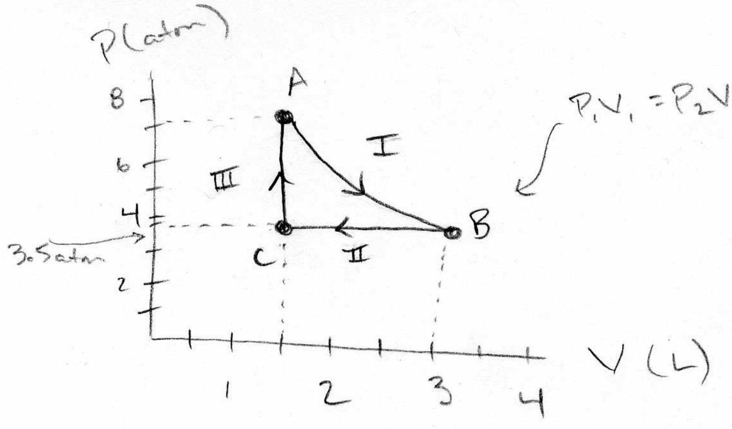
**21.** A 1.5L volume of air initially at 7.0atm of absolute pressure is allowed to expand isothermally until the volume doubles. The gas is then compressed isobarically until it reaches its initial volume. Finally, the gas undergoes an isovolumetric process to arrive back to its initial state.

**a.** Draw a PV diagram of the entire three-step cycle this gas undergoes.

**b.** Calculate the pressure of the gas after the first step of the cycle.

**c.** Calculate the work done by the gas during the third step of the cycle.

a)



$P_1V_1 = P_2V_2$ for Isothermal

b) $P_1V_1 = P_2V_2$

$7(1.5) = P_2(3) \longrightarrow P_2 \boxed{= 3.5 atm}$

c) $W = \text{area} = -P\Delta V = \boxed{0 J}$ (Isovol)

**22.** Calculate the efficiency of a Carnot engine operating between temperatures of 300°C and 420°C.

$$e_c = \frac{T_H - T_c}{T_H} = \frac{120}{(420+273)} = 0.173$$

$$= \boxed{17.3\%}$$

**23.** For the same engine as in problem #22, how much heat is exhausted per cycle, if 2500J of work are done per cycle?

$$e = \frac{W}{Q_H}$$

$$.173 = \frac{2500}{Q_H} \longrightarrow Q_H = 14,437.5\text{J}$$

$\uparrow$ Heat input

... so heat output...

$$Q_c = 14,437.5 - 2500$$

$$\boxed{11,937.5\text{J}}$$

**24.** A certain engine operates at 40% efficiency. At what rate must it exhaust heat, if it absorbs heat at a rate of 200W?

↑J/s

Every second...

$$0.4 = \frac{W}{200\text{J}}$$

$$W = 80\text{J}$$

So it must exhaust $200 - 80 = 120$J of heat per second.

So rate of exhaust $= 120\text{J/s}$

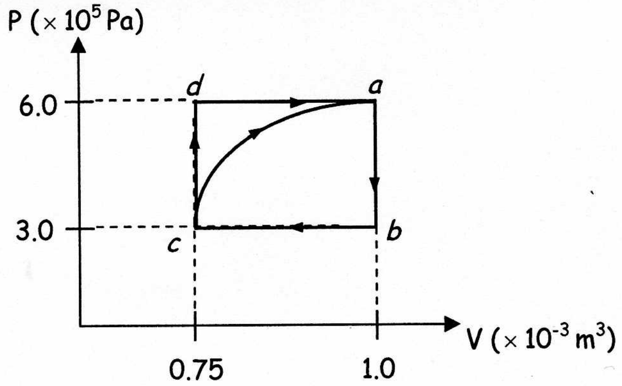
$$= \boxed{120\text{W}}$$

**25.** A certain aluminum rod is 95cm long and has a cross-sectional diameter of 4cm. What difference in temperatures between the two ends of the rod will cause heat to be conducted from one end to another at a rate of 230W? (The thermal conductivity of aluminum is 200J/sm°C.)

$$H = \frac{kA\Delta T}{L} \longrightarrow 230 = \frac{(200)(\pi \times .02^2)\Delta T}{.95}$$

$$\Delta T = \boxed{869.4°\text{C}}$$

## 26. Actual A.P. Physics B Free-Response Question (2003):



A cylinder with a movable piston contains 0.1 mole of a monatomic ideal gas. The gas, initially at state *a,* can be taken through either of two cycles, *abca* or *abcda,* as shown on the PV diagram above. The following information is known about this system

| | |
|---|---|
| $Q_{c\to a} = 685\text{J}$ along the curved path. | $U_a - U_b = 450\text{J}$ |
| $W_{c\to a} = -120\text{J}$ along the curved path | $W_{a\to b\to c} = 75\text{J}$ |

**a.** Calculate the temperature of the gas when it is at state *a.*

$PV = nRT \rightarrow (6E5)(1E^{-3}) = (.1)(8.31)T \rightarrow \boxed{T = 722K}$

**b.** Determine the change in internal energy, $U_a - U_c$, between states *a* and *c.*

$\Delta U_{C\to A} = Q_{C\to A} + W_{C\to A} = 685 - 120 = \boxed{565\text{J}}$

**c.** Calculate the work done by the gas in the process *cda.*

$W = \text{area}_1 + \text{area}_2 = 0 + (.25E^{-3})(6E^5) = 150\text{J}$ ← And since it's expanding, it's positive $W_{by}$.

**d.** i. Is heat added to or removed from the gas when the gas is taken along path *cda?* Explain your reasoning. $\boxed{+150\text{J}}$

$\Delta U_{C\to A} = 565\text{J}$ (from part B), regardless of the path. So...

$565 = Q - 150 \rightarrow Q = \boxed{+715\text{J}}$ So Heat is Added

ii. Calculate the amount of heat added or removed along the path *cda.*

$\boxed{+715\text{J}}$

**e.** After one complete cycle along the path *abca,* is the internal energy of the gas greater, less, or the same as before? Justify your answer.

Same because $\Delta U = 0$ for any complete cycle, due to the fact that Temp ends back at what it started.