

Unit 7 Test Review

Thermal Physics: Chapters 13-15

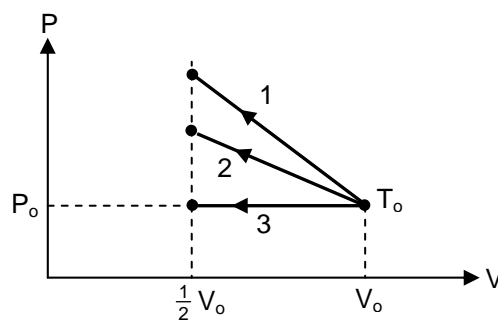
* In studying for your test, make sure to study this review sheet along with your quizzes and homework assignments.

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 $g=10\text{m/s}^2$ for simplicity of calculations.
No partial credit will be given.

1. A certain quantity of an ideal gas initially at temperature T_0 , pressure P_0 , and volume V_0 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?

- It is greatest for process 1.
- It is greatest for process 2.
- It is greatest for process 3.
- It is the same for processes 1 and 2.
- It is the same for processes 1 and 3.



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?
- It is greatest for process 1.
 - It is greatest for process 3.
 - It is the same for processes 1 and 2.
 - It is the same for processes 1 and 3.
 - It is the same for all three processes.
3. Which of the following will occur if the average speed of the gas molecules in a closed rigid container is increased?
- The density of the gas will decrease.
 - The density of the gas will increase.
 - The temperature of the gas will decrease.
 - The pressure of the gas will decrease.
 - The pressure of the gas will increase.

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?
- It decreases by 48J.
 - It decreases by 16J.
 - It remains the same.
 - It increases by 16J.
 - It increases by 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?
- | <u>Volume</u> | <u>Density</u> |
|---------------------|------------------|
| 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 |
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 ?
- 1/2
 - 1
 - $\sqrt{2}$
 - 2
 - 4
7. If the pressure of an ideal gas held in a vessel is halved while its volume is quadrupled, the resulting temperature will be...
- half of its original value.
 - the same as its original value.
 - twice its original value.
 - one quarter of its original value.
 - four times its original value.

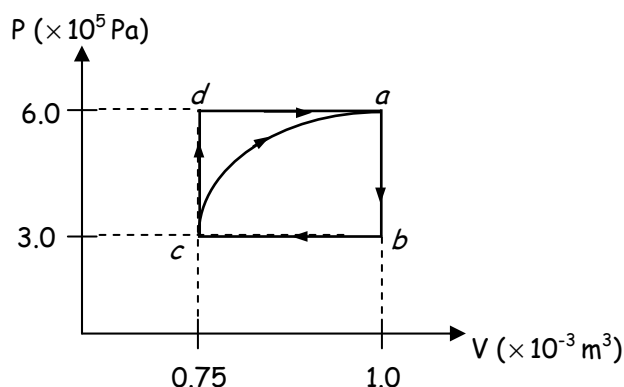
8. The temperature of a 5m-long object is increased by 20°C . The temperature of a second object, made of the same material as the first object but of length 50cm, is increased by 10°C . Which one of the following statements is true about the change in length experienced by the 5m-long object, compared to the change in length experienced by the 50cm-long object?
- The 5m-long object changes by 2 times as much as the other object.
 - The 5m-long object changes by 10 times as much as the other object.
 - The 5m-long object changes by 20 times as much as the other object.
 - The 5m-long object changes by 100 times as much as the other object.
 - Both objects change length by the same amount.
9. An ideal monatomic gas is in a fixed container of size 0.3m^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?
- $\frac{100}{R}$ moles
 - $\frac{1}{R}$ moles
 - $\frac{90,000}{R}$ moles
 - $\frac{1}{100R}$ moles
 - $\frac{1}{1,000R}$ moles
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...
- an isothermal process.
 - an adiabatic process.
 - an isovolumetric process.
 - no special type of process.
 - a physically impossible process.
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.)
- 0.012kg
 - 0.112kg
 - 0.176kg
 - 12kg
 - 176kg

12. Which of the following could be explained with the 2nd Law of Thermodynamics?
- 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.
 - III. Heat spontaneously flows from a hot object to a cold object, but not the reverse.
- 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%
14. Which method(s) of heat transfer require(s) particles of a medium to help transfer energy from one place to another?
- I. conduction
 - II. convection
 - III. radiation
- a. I only
 - b. II only
 - c. III only
 - d. I and II only
 - e. I, II, and III

19. Calculate the number of molecules per m^3 of gas at a temperature of 30°C and pressure of 5.1atm .
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 $35,000\text{J}$ of heat are transferred into the gas. Calculate the work done by the gas, and the change in internal energy of the gas.
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.
- Draw a PV diagram of the entire three-step cycle this gas undergoes.
 - Calculate the pressure of the gas after the first step of the cycle.
 - Calculate the work done by the gas during the third step of the cycle.

22. Calculate the efficiency of a Carnot engine operating between temperatures of 300°C and 420°C .
23. For the same engine as in problem #22, how much heat is exhausted per cycle, if 2500J of work are done per cycle?
24. A certain engine operates at 40% efficiency. At what rate must it exhaust heat, if it absorbs heat at a rate of 200W?
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 $200\text{J}/\text{sm}^{\circ}\text{C}$.)

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 $abcd$, as shown on the PV diagram above. The following information is known about this system

$$Q_{c \rightarrow a} = 685 \text{ J along the curved path.} \quad U_a - U_b = 450 \text{ J}$$

$$W_{c \rightarrow a} = -120 \text{ J along the curved path} \quad W_{a \rightarrow b \rightarrow c} = 75 \text{ J}$$

- a. Calculate the temperature of the gas when it is at state a .
- b. Determine the change in internal energy, $U_a - U_c$, between states a and c .
- c. Calculate the work done by the gas in the process cda .
- d.
 - i. Is heat added to or removed from the gas when the gas is taken along path cda ? Explain your reasoning.
 - ii. Calculate the amount of heat added or removed along the path cda .
- 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.

Answers:

1. a 2. a 3. e 4. a 5. d 6. c 7. c
 8. c 9. a 10. b 11. c 12. b 13. b 14. d

$$15. v_{\text{rms}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.31)(335.2)}{2(.014)}} = 546.3 \text{ m/s}$$

$$16. \frac{P_1}{n_1} = \frac{P_2}{n_2} \text{ leads to } \frac{10}{9992.5} = \frac{P_2}{710.6} \text{ leads to } P_2 = 0.71 \text{ atm}$$

where $n_1 = \frac{40,000 \text{ g}}{4.003 \text{ g/mol}}$ and $n_2 = \frac{27,000 \text{ g}}{2(18.998) \text{ g/mol}}$

$$17. \Delta L = L - L_0 = \alpha L_0 \Delta T \quad \text{so} \quad .03212 - .03196 = (19 \times 10^{-6})(.03196)(\Delta T)$$

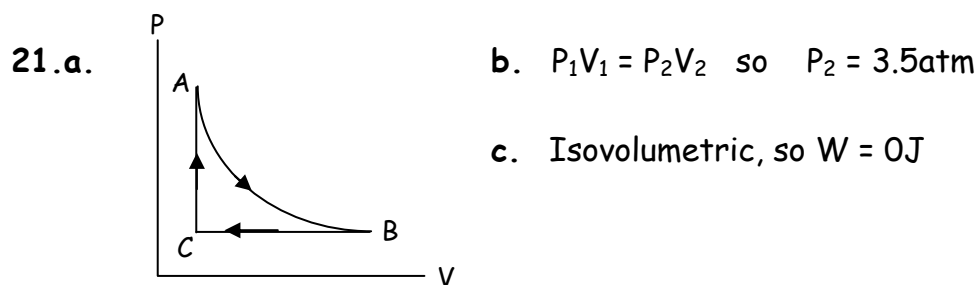
so $\Delta T = 263.5^\circ \text{C}$ and $T_f = 273.5^\circ \text{C}$

$$18. V_{\text{spilled}} = \Delta V_{\text{water}} - \Delta V_{\text{aluminum}} = (210 \text{E}^{-6})(80)(45) - (75 \text{E}^{-6})(80)(45) = 0.486 \text{ mL}$$

$$19. PV = Nk_B T \quad \text{so} \quad \frac{N}{V} = \frac{P}{k_B T} = \frac{(5.1)(1.013 \text{E}^5)}{(1.38 \text{E}^{-23})(303)} = 1.24 \text{E}^{26} \text{ molecules/m}^3$$

$$20. W_{\text{on}} = -P\Delta V = -(425,460)(.35 - .42) = +29,782 \text{ J} \quad \text{so} \quad W_{\text{by}} = -29,782 \text{ J}$$

$$\Delta U = Q + W_{\text{on}} = 35,000 + 29,782 = 64,782 \text{ J}$$



$$22. e = e = \frac{T_H - T_C}{T_H} = \frac{120}{693} = 17.3\%$$

$$23. 0.173 = \frac{2500}{Q_H} \quad \text{so} \quad Q_H = 14,450 \text{ J} \quad \text{and} \quad Q_C = 14,450 - 2500 = 11,950 \text{ J}$$

24. Even though it's a power problem, it can be easier to think of it in terms of what happens with energy every second. Each second, the engine absorbs 200J of heat, and then it does 80J of work. ($0.4 \times 200 = 80$)
So, each second $200 - 80 = 120$ J of heat are exhausted. This means that the rate of heat exhaust is $120\text{J/s} = 120\text{W}$.

25. $H = \frac{kA\Delta T}{L}$ leads to $230 = \frac{200(\pi \cdot 0.02^2)\Delta T}{0.95}$ leads to $\Delta T = 869.4^\circ\text{C}$

26.a. $PV = nRT$ so $T = \frac{PV}{nR} = \frac{(6\text{E}^5)(1\text{E}^{-3})}{(.1)(8.314)} = 721.7\text{K}$

b. $\Delta U_{C \rightarrow A} = Q_{C \rightarrow A} + W_{C \rightarrow A} = 685 - 120 = 565\text{J}$

c. $W_{\text{on}} = -P\Delta V = -(6\text{E}^5)(.25\text{E}^{-3}) = -150\text{J}$ so $W_{\text{by}} = +150\text{J}$

d.i. Heat is added during process *cda* because $\Delta U_{C \rightarrow A} = +565\text{J}$, but work on the gas during the same process is only -150J . So energy must have been added by heat, in order for the system to do work, but still increase in internal energy. (Note: ΔU is independent of the path taken.)

ii. $Q_{CDA} = \Delta U_{CDA} - W_{CDA} = 565 - (-150) = +715\text{J}$

e. Same as before, because it's a cyclic process.