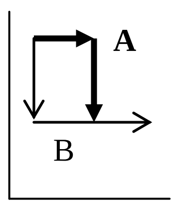
ANSWERS - AP Physics Multiple Choice Practice – Thermodynamics

	Solution	Answer
1.	$e_c = \frac{T_H - T_C}{T_H}$	C
2.	While *all* collisions are elastic and $K_{avg} \propto T$, the molecules move with a wide range of speeds represented by the Maxwellian distribution.	B
3.	For X⇨Y, the process is isobaric. Since the gas is expanding, W < 0 and since the temperature is increasing, $\Delta U > 0$ and $\Delta U = Q + W$ so Q > 0 (it is also true because process XY lies above an adiabatic expansion from point X)	C
4.	For Y⇨Z, the process is isochoric, which means no work is done (W = 0) and since the temperature is increasing, $\Delta U > 0$	C
5.	$PV \propto T$, or $P \propto T/V$ and if T × 2 then P × 2 and if V × 4 then P ÷ 4 so the net effect is P×2÷4	C
6.	James Joule did experiments on changing the temperature of water through various means, including by doing work on it.	C
7.	$PV \propto T$ so to triple the temperature, the product of P and V must be tripled	A
8.	Changes in internal energy are path independent on a pV diagram as it depends on the change in temperature, which is based on the beginning and end points of the path and not the path taken	C
9.	$K_{avg} \propto T$	D
10.	$H = \frac{kA\Delta T}{L}$	B
11.	by definition	D
12.	No work is done in an isochoric process, or a process where $\Delta V = 0$ (a vertical line on the pv graph)	A
13.	The temperature at any point is proportional to the product of P and V. Point A at temperature T_0 is at pressure × volume p_0V_0. Point C is at $3p_0 \times 3V_0 = 9T_0$ and point D is at $2p_0 \times 4V_0 = 8T_0$	C
14.	For the entire cycle, $\Delta U = 0$ and W = –8 J so $Q = \Delta U - W = +8$ J (8 J added). This means $Q_{AB} + Q_{BC} + Q_{CA} = +8$ J = +12 J + 0 J + Q_{CA} = +8 J	B
15.	Q = +275 J; W = + 125 J + (– 50 J) = +75 J; $\Delta U = Q + W$	C
16.	Q_H = 100 J and Q_C = 60 J; $e = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$	A
17.	Work is the area under the curve, the line bounding the greatest area indicates the most work done	A
18.	Temperature rises as you travel up and to the right on a pV diagram. Since processes 1, 2 and 3 are at the same volume, the highest point is at the highest temperature	A
19.	Q = +400 J; W = – 100 J; $\Delta U = Q + W$	C
20.	Isothermal means the temperature is constant. Points to the right or above are at higher temperatures.	B
21.	$P \propto T$ at constant volume. If T × 2, then P × 2. Since the mass and volume are unchanged, the density is unchanged as well	C

22.	If the collisions were inelastic, the gas would change its temperature by virtue of the collisions with no change in pressure or volume.	D
23.	related to average speed, $v_{rms} = \sqrt{\frac{3RT}{M}}$	C
24.	Being in thermal equilibrium means the objects are at the same temperature. Mass is irrelevant. The question describes the zeroth law of thermodynamics.	C
25.	Changes in internal energy are path independent on a pV diagram as it depends on the change in temperature, which is based on the beginning and end points of the path and not the path taken. Different paths, with different areas under them will do different amounts of work and hence, different amounts of heat exchanged.	A
26.	In linear expansion, every linear dimension of an object changes by the same fraction when heated or cooled.	D
27.	"rigid container" = constant volume. If the speed increases, the temperature will increase, and if the temperature increases at constant volume, the pressure will increase.	C
28.	$H = \frac{kA\Delta T}{L}$	D
29.	Q = –16 J; W = –32 J; $\Delta U = Q + W$	A
30.	Mass is independent of the state of a gas. ("color" will be addressed in a later topic, think about a yellow vs. blue flame or a "red hot" piece of metal)	E
31.	$P \propto nT/V$; if $n \times 3$ then $P \times 3$ and if $T \times 2$ then $P \times 2$, the net effect is $P \times 3 \times 2$	E
32.	Comfortable bath water should be slightly above room temperature. Room temperature is about 20ºC, or 293 K	D
33.	$e_c = \frac{T_H - T_C}{T_H}$ (use absolute temperatures)	D
34.	ΔU for each process is equal so $Q_{AC} + W_{AC} = Q_{ABC} + W_{ABC}$, or +30 J + (–20 J) = +25 J + W_{ABC}	C
35.	While temperatures are different on the Celsius and Kelvin scale, the temperature *intervals* are identical. 1ºC = 274 K, but 1 Cº = 1 K	D
36.	In any compression, work is done on the gas (W is +). Since the compression is isothermal, $\Delta U = 0$ so $Q = -W$ and heat leaves the gas.	A
37.	$\Delta U \propto \Delta T$	A
38.	$v_{rms} = \sqrt{\frac{3RT}{M}}$, if T is tripled, v is multiplied by $\sqrt{3}$	D
39.	A refrigerator should be less than room temperature, but above the freezing point of water (between 0ºC and 20ºC, or 273 K to 293 K)	D
40.	$e = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$	C
41.	1st law was first described by Clausius in 1850. (this will not be tested, but it's always good to have a reference for important laws)	B
42.	$K_{avg} \propto T$	C

43.	In linear expansion, every linear dimension of an object changes by the same fraction when heated or cooled.	A
44.	$K_{avg} \propto T$	D
45.	$P \propto n/V$ at constant temperature	A
46.	Since the container is insulated, no heat is exchanged (C is true), since there is no work done (no force required to expand), choice B is true. Since Q = 0 and W = 0, ΔU and $\Delta T = 0$ (A and E are true). While entropy change does have a heat component (and if Q = 0, the change in entropy may be incorrectly regarded as zero) it also has a volume component (how "spread out" the gas is)	D
47.	This question is a bit of a paradox as the energy form the fan giving the air kinetic energy is theoretically adding to the thermal energy of the air, But as the air lowers in temperature, this energy will dissipate into the walls and other outside areas of the room as thermal energy as well.	E
48.	$K_{avg} \propto T$	B
49.	Gas escaping form a pressurized cylinder is an example of an adiabatic process. While the gas rapidly does work (W < 0), ΔU is negative since heat does not have time to flow into the gas in a rapid expansion.	A
50.	In a Carnot cycle $\frac{Q_H}{Q_C} = \frac{T_H}{T_C}$ and in process AB, $\Delta U = 0$ and since $W_{AB} = -400$ J, $Q_{AB} = +400$ J and this is Q_H	E
51.	Since process A and B perform the same amount of work, they must have the same area under their respective lines. Since A does the work at a higher pressure, it does not have to move as far to the right as process B, which performs the work at a lower temperature. Since the end of process B lies farther to the right, it is at the higher temperature.	B



52.	At constant pressure $V \propto T$ (use absolute temperature)	B
53.	Metals are the best heat conductors and will conduct heat out of the hamburger quickly	A
54.	Consider the isothermal line as the "dividing line" between process that increase the temperature of the gas (above the isotherm) and process that lower the temperature of the gas (below the isotherm). A similar analysis can be done to identify heat added or removed from a gas by comparing a process to an adiabat drawn from the same point.	C
55.	$K_{avg} = 3/2\ k_BT$ (use absolute temperature)	C
56.	In linear expansion, every linear dimension of an object changes by the same fraction when heated or cooled. Since each side increases by 4%,the area increases by $(1.04)^2 = 1.08$	B
57.	$pV = nRT$ and $n = N/N_A$	D
58.	$K_{avg} \propto T$ (absolute)	E
59.	$Q_{abd} = +60\text{ J} + 20\text{ J} = +80$ J. W_{abd} = area, negative due to expansion = –24 J so $\Delta U = Q + W = +56$ J and $\Delta U_{abd} = \Delta U_{acd}$ and W_{acd} = area = –9 J so $Q_{acd} = \Delta U - W_{acd} = +56\text{ J} - (-9\text{ J})$	B

60. Since there is no area under the line (and no change in volume) W = 0. The temperature (and internal energy) decrease so Q cannot be zero (Q = ΔU – W) C

61. pV = nRT D

62. pressure is the collisions of the molecules of the gas against the container walls. Even though the speed of the molecules is unchanged (constant temperature), the smaller container will cause the molecules to strike the walls more frequently. B

63. Q = 0 in adiabatic processes (choices B and D). Q = ΔU – W. Choices A and C have the same ΔT and hence, same ΔU and since doubling the volume at constant pressure involves *negative* work, while doubling the pressure at constant volume does *no* work, ΔU – W is greater for the constant pressure process. (The constant temperature process has ΔU = 0 and less work than the constant pressure process) A

64. pV = nRT (watch those units!) C

65. by definition B

66. Isochoric cooling is a path straight down on a pV diagram (to lower pressures) A

67. Work = area under the curve on a *pV diagram*. In the convention stated, work is negative for any expansion. Be careful with the graph since it is a graph of pressure vs. *temperature*. We can find the work by using |W| = pΔV = nRΔT D

68. $e_C = \frac{T_H - T_C}{T_H}$ where $T_H \propto p_B V_B$ (the highest temperature) and $T_C \propto p_D V_D$ (the lowest temperature) gives $e_C = (6p_0V_0 - p_0V_0)/p_0V_0$ E

69. The heat input for this engine occurs during process D⇨A⇨B and the heat exhaust is B⇨C⇨D B
If P_0V_0 corresponds to temperature T_0, the temperatures at points A, B, C and D respectively are $3T_0$, $6T_0$, $2T_0$ and T_0. The change in temperature for each process is then AB = $+3T_0$, BC = $-4T_0$, CD = $-T_0$ and DA = $+2T_0$.
We also have $P_0V_0 = nRT_0$
For the isochoric process, where W = 0, Q = ΔU = 3/2 nRΔT
DA: $Q = 3/2\ nR(2T_0) = 3nRT_0$
BC: $Q = 3/2\ nR(-4T_0) = -6nRT_0$
For the isobaric processes, where W = –pΔV = –nRΔT,
Q = ΔU – W = 3/2 nRΔT + nRΔT = 5/2 nRΔT
AB: $Q = 5/2\ nR(3T_0) = 7.5nRT_0$
CD: $Q = 5/2\ nR(-T_0) = -2.5nRT_0$
Putting it all together gives us $Q_{input} = Q_{DA} + Q_{AB} = 10.5nRT_0$ and $Q_{exhaust} = -8.5nRT_0$

$$e = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H} = \frac{10.5nRT_0 - 8.5nRT_0}{10.5nRT_0} = \frac{2}{10.5} = \frac{4}{21}$$

70. $e = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$ E

71. Work = area enclosed by the parallelogram. Since the work done *on* the gas is negative for a clockwise cycle and they are asking for the work done *by* the gas, the answer will be positive. C

72. At constant volume ΔU = Q = 3/2 nRΔT where in an isochoric process nRΔT = ΔpV D
so Q = 3/2 ΔpV, or Δp = 2 × (+40 J)/(3 × 0.008 m^3)

73. $v_{rms} = \sqrt{\frac{3RT}{M}}$ Since hydrogen is 16 times lighter and $v_{rms} \propto \frac{1}{\sqrt{M}}$, $v_H = 4 \times v_O$ B

74. In a reversible (Carnot) engine $\frac{Q_H}{Q_C} = \frac{T_H}{T_C}$ (use absolute temperature) D

75. In a reversible (Carnot) engine $\frac{Q_H}{Q_C} = \frac{T_H}{T_C}$ C

76. $v_{rms} = \sqrt{\frac{3RT}{M}}$ since $M_O > M_H$ for them to have the same v_{rms} $T_O > T_H$ D

77. $e_c = \frac{T_H - T_C}{T_H}$ (use absolute temperature) B

78. $v_{rms} = \sqrt{\frac{3RT}{M}}$ if v_{rms} is doubled, then T is quadrupled. If T × 4 at constant volume, then p × 4 D

79. $Q_C = 3W$ and $Q_H = Q_C + W = 4W$. $e = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$ E

80. The "energy" lost or gained would be the sum of the work done on the gas and the net heat added to the gas, which is the change in internal energy of the gas. Since the gas returns to its original state, $\Delta U = 0$. A

81. $H = \frac{kA\Delta T}{L}$ A

82. An adiabatic expansion is shaped like an isotherm, but brings the gas to a lower temperature. C

83 $Q_{cycle} = Q_{12} + Q_{23} + Q_{31} = +60\text{ J} - 40\text{ J} + 0\text{ J} = +20\text{ J}$ E

$W_{cycle} = \Delta U_{cycle} - Q_{cycle} = 0\text{ J} - (+20\text{ J}) = -20\text{ J} = W_{12} + W_{23} + W_{31}$

where $W_{12} = -Q_{12}$ since $\Delta U_{12} = 0$ and $W_{23} = 0$

so we have $-20\text{ J} = -60\text{ J} + 0\text{ J} + W_{31}$ which gives $W_{31} = +40\text{ J}$

Process 3⇨1 is adiabatic so $\Delta U_{31} = W_{31}$