AP Physics Fall 2013/Spring 2014
Test 14 – Heat & Gas Laws

Name: Key

Multiple Choice	(Problems 1-10)	______	40 pts
Problem 11		______	7 pts
Problem 12		______	8 pts
Problem 13		______	10 pts
Problem 14		______	13 pts
Problem 15		______	12 pts
Problem 16		______	10 pts
Bonus		______	12 pts
Total		______	

Standard Properties of Water	**Constants**
Specific Heats ice = 2.09 J g^{-1} K^{-1} water = 4.184 J g^{-1} K^{-1} steam = 2.03 J g^{-1} K^{-1}	universal gas constant = 8.314 J mol^{-1} K^{-1} Boltzmann constant = 1.38×10^{-23} J K^{-1} Stefan-Boltzman = 5.67×10^{-8} W m^{-2} K^{-4} Avogadro's number = 6.022×10^{23} mol^{-1}
density of water = 1.00 g cm^{-1} density of ice = 0.9176 g cm^{-1}	
heat of fusion = 334 J g^{-1}	
heat of vaporization = 2260 J g^{-1}	

Name: ______________________________________

1. When a liquid freezes

A. the temperature of the substance decreases.

B. heat energy leaves the substance.

C. the temperature of the substance increases.

D. heat energy enters the substance.

2. The internal energy of an ideal gas depends on

A. its temperature.

B. its volume.

C. its pressure.

D. all of the above.

3. A chunk of ice (T = -20 °C) is added to a thermally insulated container of cold water (T=0 °C). What happens to the container?

A. The water cools down until thermal equilibrium is established.

B. Some of the water freezes and the chunk of ice gets larger.

C. The ice melts until thermal equilibrium is established.

D. non of the above.

4. By what primary heat transport mechanism does the Sun warm the Earth?

A. radiation

B. convection

C. conduction

D. all of the above in combination

5. A cup of water is scooped up from a swimming pool of water. Compare the temperature T and the internal energy U of the water, in both the cup and the swimming pool.

A. T_{pool} is equal to T_{cup}, and U_{pool} is greater than U_{cup}.

B. T_{pool} is less than T_{cup}, and the U is the same.

C. T_{pool} is equal to T_{cup}, and U_{pool} is less than U_{cup}.

D. T_{pool} is greater than T_{cup}, and the U is the same.

6. On a cold day, a piece of metal feels much colder to the touch than a piece of wood. This is due to the difference in which one of the following physical property?

A. latent heat

B. specific heat

C. density

D. thermal conductivity

7. Convert 14 K to °C

(A.) -259 °C

B. 46 °C

C. 25 °C

D. 287 °C

$T_c = T_K - 273°C = 14°C - 273°C = -259°C$

8. Express -40 °C in °F.

A. 4.4 °F

B. -54 °F

C. -72 °F

(D.) -40 °F

$T_F = \frac{9}{5}(T_c) + 32 = \frac{9}{5}(-40)°F + 32°F = -40°F$

9. A mole of diatomic oxygen molecules and a mole of diatomic nitrogen molecules at STP have

A. the same average molecular speeds. $v_{AV} \propto \frac{1}{\sqrt{m}}$

B. the same diffusion rates.

(C.) the same number of molecules.

D. all of the above.

10. If the absolute temperature of a radiator is doubled, by what factor does the radiating power change?

A. 8 **B.** 4 **C.** 2 **(D.)** 16

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 = (2)^4 = 16$$

7 pts **11.** What is the internal energy of a mono-atomic gas composed of $3.5\text{x}10^{23}$ atoms at 60 °C?

$$U = \frac{3}{2} NkT \quad (+3)$$

$$T = (60 + 273)\,K = 333\,K \quad (+1)$$

$$U = \frac{3}{2}(3.5\times10^{23})(1.38\times10^{-23}\,\frac{J}{K})(333\,K)$$

$$U \cong \boxed{2.41\,kJ}$$

(+2) #

(+1) appropriate units

8 pts **12.** Two liters of a perfect gas at 0 °C and 1 atm. If the gas is nitrogen, N_2, determine the number of moles.

The gas is at STP where $T = 273\,K$, $P = 1atm$

We know that 1mole occupies 22.4 ℓ. (+2)

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad (+3)$$

$$n_2 = \left(\frac{V_2}{V_1}\right) n_1$$

$$n_2 = \left(\frac{2\,\ell}{22.4\,\ell}\right)(1mole)$$

$$n_2 \cong \boxed{0.0893\,\ell}$$

← # (+2)

← units (+1)

10pts **13.** 1500 cm^3 of ideal gas at STP is cooled to -20 °C and put into a 1000 cm^3 container. What is the final pressure?

STP

(+1) $P_1 = 1\,atm$ (+1) $T_1 = 273\,K$ $V_1 = 1500\,cm^3$

$T_2 = 253\,K$ $V_2 = 1000\,cm^3$

(+1) ← Puts in Kelvin

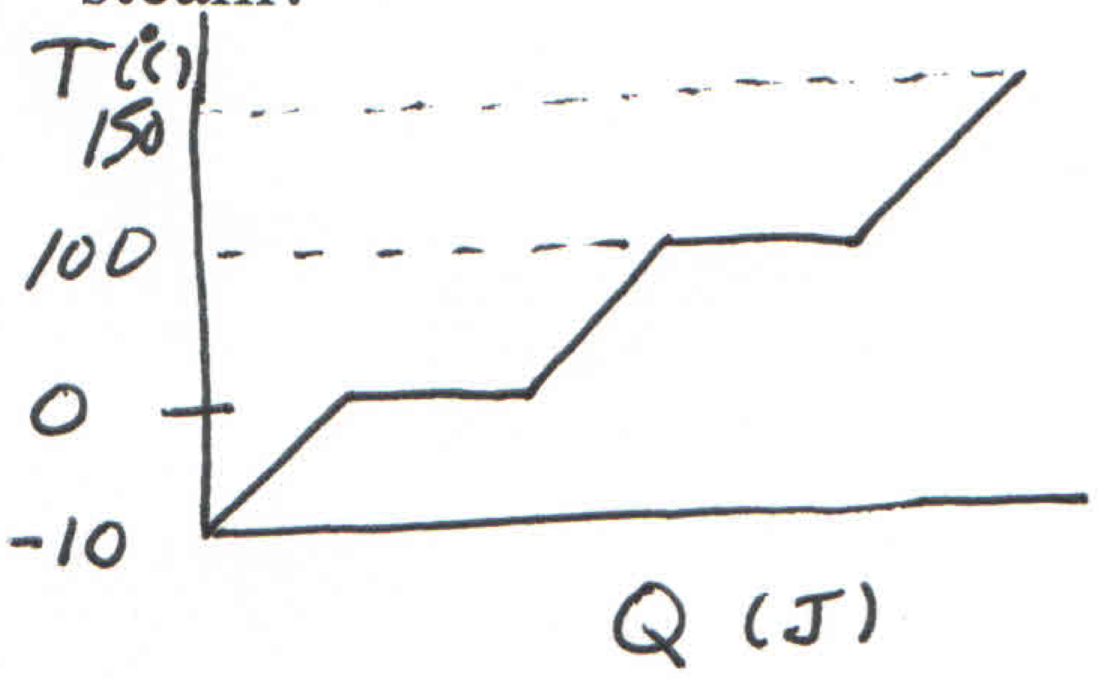
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$ (+3)

$$P_2 = \left(\frac{V_1}{V_2}\right)\left(\frac{T_2}{T_1}\right) P_1$$ (+1)

$$P_2 = \left(\frac{1500\,cm^3}{1000\,cm^3}\right)\left(\frac{253\,K}{273\,K}\right)(1\,atm)$$

$$P_2 \cong \boxed{1.39\,atm}$$ (+2) # (+1) units

13 pts **14.** How much heat is required to change 100 g of -10 °C ice to 150 °C steam?



a) Raise ice to 0°C

(+1) $Q_1 = m C_{ice} \Delta T_1$

$Q_1 = (100g)(2.09 \frac{J}{gK})(10 K) \cong 2.09 kJ$ (+1)

b) Convert ice to water

(+1) $Q_2 = m L_f$

$Q_2 = (100g)(334 \frac{J}{g}) \cong 33.4 kJ$ (+1)

c) Raise water to 100°C

(+1) $Q_3 = m C_{water} \Delta T_3$

$Q_3 = (100g)(4.184 \frac{J}{Kg})(100 K) \cong 41.84 kJ$ (+1)

d) Convert water to steam

(+1) $Q_4 = m L_v$

$Q_4 = (100g)(2260 \frac{J}{g}) \cong 226 kJ$ (+1)

e) Raise steam to 150°C

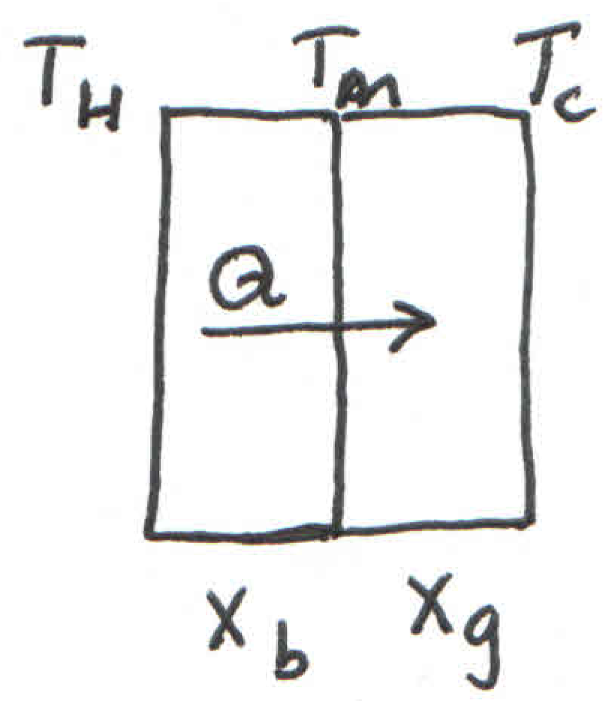
(+1) $Q_5 = m C_{steam} \Delta T_5$

$Q_5 = (100g)(2.03 \frac{J}{gK})(50 K) \cong 10.15 kJ$ (+1)

f) Add up all the Qs

(+1) $Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 \cong$ **313.5 kJ** — # (+1), (+1) units

12 pts **15.** A 3.0 cm thick brass plate (k = 105 W/K*m) is sealed to a glass sheet (k = 0.80 W/K*m), and both have the same area. The exposed face of the brass plate is 110 °C, while the exposed face of the glass is at 10 °C. How thick is the glass if the glass-brass interface is at 45 °C?



$T_H = 110\,°C$ $\quad T_c = 10\,°C$ $\quad T_m = 45\,°C$

$X_b = 3\,cm$ $\quad k_b = 105\,\frac{W}{K\cdot m}$ $\quad k_g = 0.8\,\frac{W}{K\cdot m}$

For the brass plate, the heat leaving is

(+1) $$\frac{Q}{t} = k_b A \frac{(T_H - T_m)}{X_b}$$ (+1)

For the glass, the heat entering is

(+1) $$\frac{Q}{t} = k_g A \frac{(T_m - T_c)}{X_g}$$ (+1)

(+3) connect heats

$$\Rightarrow \frac{k_b \not{A}(T_H - T_m)}{X_b} = k_g \not{A}\frac{(T_m - T_c)}{X_g}$$

(+2) $$X_g = \left(\frac{k_g}{k_b}\right)\left(\frac{T_m - T_c}{T_H - T_m}\right) X_b$$

$$X_g = \left(\frac{0.8\ W/km}{105\ W/km}\right)\left(\frac{45°c - 10°c}{110°c - 45°c}\right)(3.0\,cm)$$

$$X_g \cong \boxed{0.123\ mm}$$ — # (+2) — units (+1)

10 pts **16.** Determine the change in the volume of a block of cast iron 5.0 cm x10 cm x 6.0 cm, when the temperature changes from 15 °C to 47 °C. The coefficient of linear expansion for cast iron is 1.0×10^{-5} °C^{-1}.

(+1) $\beta = 3\alpha$

$\beta = 3(1.0 \times 10^{-5}\ °C^{-1}) = 3.0 \times 10^{-5}\ °C^{-1}$ (+1)

(+3) $\Delta V = \beta V \Delta T$

(+1)

$\Delta V = (3.0 \times 10^{-5}\ °C^{-1})(5.0\,cm \times 10\,cm \times 6.0\,cm)(47°C - 15°C)$

(+1)

$\Delta V = \boxed{0.288\ cm^3}$ — (+2) #

— (+1) units

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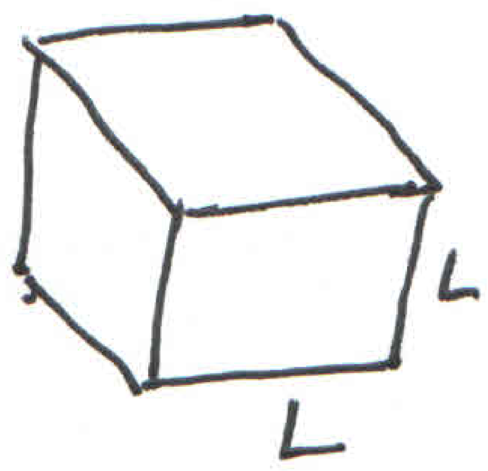
BONUS PROBLEMS

12 pts **1.** An aluminum cube with 3.5 cm sides is at a temperature of 600 °C. The properties of aluminum are provided in the table below. How much energy will be radiated by the cube in one hour?

thermal conductivity = 237 W m^{-1} K^{-1}	emissivity = 0.4
molar heat capacity = 24.2 J mol^{-1} K^{-1}	density = 2.70 g cm^{-3}
heat of fusion = 10.71 kJ mol^{-1}	molecular weight = 26.98 g
heat of vaporization = 294 kJ mol^{-1}	melting point = 660 °C



$$A = 6L^2 = 6(3.5\times10^{-2}\,m)^2 = 7.35\times10^{-3}\,m^2$$ (+1) (+1)

$$e = 0.4$$

$$T = (600 + 273)\,K = 873\,K$$ (+1) (+1)

(+2) $$P = eA\sigma T^4$$

$$P \cong (0.4)(7.35\times10^{-3}\,m^2)\left(5.67\times10^{-8}\,\frac{W}{m^2K^4}\right)(873\,K)^4$$

$$P \cong 97.27\,W$$ (+1)

$$E = Pt \cong \left(97.27\,\frac{J}{s}\right)(1\,hour)\left(\frac{3600\,s}{1\,hour}\right)$$ (+2) (+1)

$$E \cong \boxed{350.\,kJ}$$ (+1) # (+1) units