106 學年第一學期 普通物理 B 期末考試題

[Wolfson Ch. 15-19] 2018/1/9, ***8:20am – 09:50am***

B

(i)答案卷第一張正面為封面。第一張正、反兩面**不要寫任何答案**。

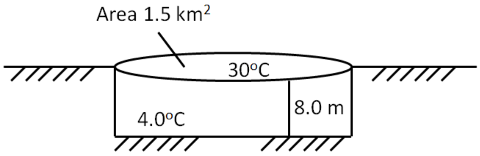
(ii)依空格號碼順序在第二張**正面**寫下所有填充題答案，不要寫計算過程。

(iii)依計算題之題號順序在第二張**反面**以後寫下演算過程與答案，**每題從新的一頁寫起**。

Constant: gravitational constant g = 9.81 m/s^2; ideal gas constant R = 8.31 J/K·mol; Specific heat: iron =447 J/kg*K; water = 4180 J/kg*K; ice = 2050 J/kg*K; Thermal conductivity: water = 0.61 W/m*K; Heat of fusion: L_f of water = 334 kJ/kg; Stefan-Boltzmann constant σ = 5.7*10^{-8} W/m^2*K^4

Part I. Filling the blank (5 points per blank)

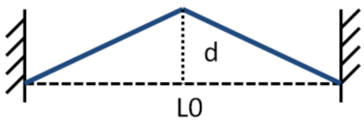
• A lake with a flat bottom and steep sides has surface area 1.5 km^2 and is 8.0 m deep. On a summer day, the surface water is at 30^{o}C and the bottom water at 4.0^{o}C. What's the rate of heat conduction through the lake?【1】W.



• At what water depth is the pressure two atmospheric pressure? 【2】m; What's the pressure at the bottom of the 11-km-deep Marianas Trench, the deepest point in the ocean? 【3】 Pa; Take atmospheric pressure as 101 kPa and the density of seawater as 1030 kg/m^3.

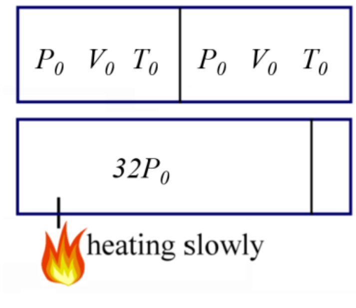
• A 1.0-kg iron tea kettle sits on a 2.2-kW stove burner. If it takes 5.9 mins to bring the kettle and the water in it from 21^{o}C to the boiling point, how much water is in the kettle?【4】kg.

• A rod of length L0 is clamped rigidly at both ends. Its temperature increases by ΔT. Due to thermal expansion, it cracks to form two straight pieces with equal length, as shown in the figure. Find an expression for the distance d shown in the figure, in terms of L0, ΔT, and the linear expansion coefficient α【5】.



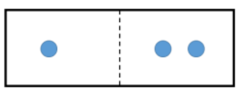
• A can of height h and cross-sectional area A0 is initially full of water. A small hole of area A1<< A0 is cut in the bottom of the can. Find an expression for the time it takes all the water to drain from the can. (Hint: Call the water depth y, use the continuity equation, and integrate)【6】.

• A chamber filled with monoatomic ideal gas (γ = 5/3) has insulating (絕熱的) walls and is divided into two parts by a frictionless insulating piston (活塞). Initially, the two parts have equal volumes V_0, equal temperatures T_0 and equal pressure P_0. A small heating bar is inserted on the left part and heat is supplied slowly to the gas on the left until its pressure reaches 32P_0. As a result, the right part will be compressed adiabatically to 32 P_0. In terms of V_0, and P_0, find (a) The final volume of the **right** part.【7】(b) The change of internal energy of the **left** part.【8】(hint: the change of internal energy $\Delta E_{int} = \frac{3}{2}nR\Delta T$)



• An air conditioner extract heat from the room at a rate of 5 kW, and delivers heat to the outside at a rate of 6 kW. If the electricity cost is 2 dollars/kW·h, what is the total cost if the AC runs for 5 hours【9】dollars.

• 3 atoms are confined in a box. Find the probability that 2 atoms are on the right side of the box as shown in the figure. There is no interaction between the atoms.【10】.



• The second law of thermodynamics leads us to conclude that【11】

(A) The total energy of the universe is constant.

(B) Disorder in the universe is increasing with the passage of time.

(C) It is theoretically impossible to convert work into heat with 100% efficiency.

(D) The total energy in the universe is increasing with time.

• 200 g of ice at -10°C is added to 1.0 kg of water at 15°C. When in thermal equilibrium, how much ice is left in the mixture?【12】g.

• Which one of the following statements is correct? 【13】

(A) When we add heat Q to 0°C ice, it melts (融化) and becomes 0°C water. During this process, its volume decreases. The change of internal energy, E_{int}(water) − E_{int}(ice), is less than the heat Q we added.

(B) At the same temperature, one mole of hydrogen molecules (H_2) has more kinetic energy (translational + rotational + vibrational) than that of one mole of helium atoms (He).

(C) Real gas is more like ideal gas at high temperature and high pressure.

(D) When the universe expands, its entropy does not change since it is an isolated system.

• The Sun radiates energy at the rate P=3.9x10^{26} W, and its radius is 7.0x10^{8} m. Treating the Sun as a blackbody (e=1). Find its surface temperature.【14】 K.

• What is the molar specific heat at constant volume C_v of an ideal gas consisting of 2 moles of O_2 and 3 moles of Ar at room temperature?【15】*R*.

Part II Problems (10 points per problem)

【1】A 1.00-kg copper block at 400 K is dropped into 1.00 kg of water at 300 K. The specific heat of copper is 386 J/kg·K and that of water is 4180 J/kg·K. (a) Find the final temperature when the two are in thermal equilibrium. (b) Find the entropy change for the copper and for the water.

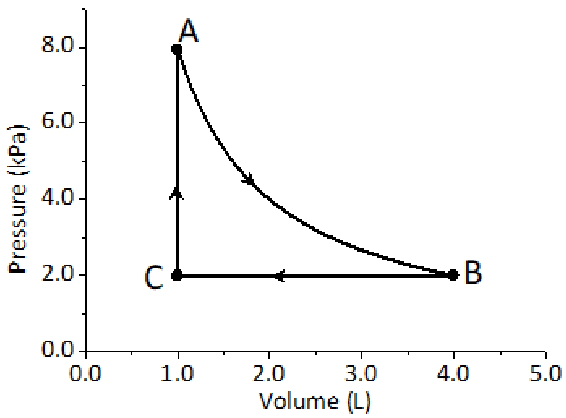
【2】 Based on four simplifying assumptions in kinetic theory of the ideal gas, and assume N molecules confined in a rectangular box with length L, please deduce following parameters:

(a) Average Force $\overline{F_i} = \frac{mv_{xi}^2}{L}$ due to the ith molecule by delivering momentum between collisions. v_{xi} is the velocity of the ith molecule along x direction.

(b) Pressure $p = \frac{mN}{V}\overline{v_x^2}$; m is the mass of one molecule; V is the volume of box; $\overline{v_x^2}$ is the average of the squares of all the x velocity components of the N molecules.

(c) In order to get PV = NkT; what is the average molecular speed $\bar{v}$ in terms of temperature T? k is Boltzmann's constant.

【3】Monoatomic ideal gas ($C_V = \frac{3}{2}R$) undergoes a cyclic process A → B → C → A in the *p*–*V* diagram as shown in the figure. Point A (*p* = 8.0 kPa, *V* = 1.0 L) initially has temperature 300 K. The gas undergoes an isothermal process to reach B (*V* = 4.0 L) and is then cooled at constant pressure to C (*V* = 1.0 L). (a) What is the temperature at C? (b) How much heat is absorbed during CA? (CA is a constant-volume process) (c) How much work is done to the gas during one cycle?



Part I Answer Sheet，Note: 有效位數錯誤者，扣1分。

A【01】	10		B【01】	-3.0×10^6
A【02】	110×10^6		B【02】	10
A【03】	$(A0/A1)(2h/g)^{1/2}$		B【03】	110×10^6
A【04】	-3.0×10^6		B【04】	2.3
A【05】	5.8×10^3		B【05】	$(L0/2)(2\alpha\Delta T+\alpha^2\Delta T^2)^{1/2}$
A【06】	2.3		B【06】	$(A0/A1)(2h/g)^{1/2}$
A【07】	24		B【07】	$(1/8)V_0$
A【08】	$(L0/2)(2\alpha\Delta T+\alpha^2\Delta T^2)^{1/2}$		B【08】	$(177/2)\ P_0V_0$ (177/2) nP_0V_0 gets 4 points.
A【09】	1.9		B【09】	10
A【10】	10		B【10】	3/8 or 0.375
A【11】	3/8 or 0.375		B【11】	B
A【12】	B		B【12】	24
A【13】	B		B【13】	B
A【14】	$(1/8)V_0$		B【14】	5.8×10^3
A【15】	$(177/2)\ P_0V_0$ (177/2) nP_0V_0 gets 4 points.		B【15】	1.9

Part II 有效位數錯誤扣 1 分。(One point is taken off for wrong significant figures.)

【A1 = B2】(a) : 3 points (b): 3 points, (c): 4 points

(a) $\overline{F_i} = \frac{\Delta p}{\Delta t} = \frac{2mv_{xi}}{2L/v_{xi}} = \frac{mv_{xi}^2}{L}$

(b) $p = \frac{\bar{F}}{A} = \frac{\sum \overline{F_i}}{A} = \frac{\sum mv_{xi}^2/L}{A} = \frac{mN}{AL}\frac{\sum v_{xi}^2}{N} = \frac{mN}{V}\overline{v_x^2}$

(c) $p = \frac{mN}{3V}\overline{v^2} = \frac{2}{3}N\left(\frac{1}{2}m\overline{v^2}\right) = NkT \rightarrow \frac{1}{2}m\overline{v^2} = \frac{3}{2}kT \rightarrow \bar{v} = \sqrt{3kT/m}$

【A2 = B3】(a) and (b): 3 points, (c): 4 points, AB and BC each account for 2 points.

(a) PV = nRT for BC. Since P is constant, T is proportional to V. T_C = 300/4 = 75 K

(b) $Q = \Delta E_{int} = nC_V\Delta T = n(3/2)R(T_A-T_C) = (3/2)(P_AV_A-P_CV_C) = (3/2)(8000*1.0*10^{-3}-2000*1.0*10^{-3}) = 9.0$ J

(c) AB: $W = \int -pdV = -nRT\int\frac{dV}{V} = -nR\times ln\left(\frac{V_B}{V_A}\right) = -nRT\times ln4 = -P_AV_A ln4 = -8\times ln4 = -11.1\,J$

BC: $W = \int -pdV = -2kPa(V_C - V_B) = -2000\times(-3.0\times10^{-3}) = 6.0\,J$

Total work = -11.1+6.0 = -5.1 J, the negative sign means the gas actually does positive work to the environment.

【A3 = B1】(a) 5 points (b) 3 points if only one of ΔS_{water} and ΔS_{copper} is correct, 5 points if both are correct.

(a) $T_{final} = \frac{m_1C_1T_1+m_2C_2T_2}{m_1C_1+m_2C_2} = \frac{1\times4180\times300+1\times386\times400}{1\times4180+1\times386} = 308.454\,K \cong 308\,K$

(b) $\Delta S_{copper} = \int_{400K}^{T_{final}}\frac{dQ}{T} = mc\int\frac{dT}{T} = mc\times ln\left(\frac{T_{final}}{400K}\right) = 1\times386\times\ln\left(\frac{308.454}{400}\right) = -100.32 \cong -100\frac{J}{K}$

If one use 308 K from (a), the answer becomes: $1\times386\times\ln\left(\frac{308}{400}\right) = -100.9 \cong -101\frac{J}{K}$ This is also OK.

$$\Delta S_{water} = \int_{300K}^{T_{final}}\frac{dQ}{T} = mc\int\frac{dT}{T} = mc\times ln\left(\frac{T_{final}}{300K}\right) = 1\times4180\times\ln\left(\frac{308.454}{300}\right) = 116.16 \cong 116\frac{J}{K}$$

If one use 308 K from (a), the answer becomes: $1\times4180\times\ln\left(\frac{308}{300}\right) = 110\frac{J}{K}$ This is also OK.

Student calculate the total entropy change, instead of water and copper respectively. It is also OK!