105 學年第一學期 普通物理 B 期末考試題

[Wolfson Ch. 15-19]   2017/01/10, ***19:30 – 21:00***

B

(i)答案卷第一張正面為封面。第一張正、反兩面<u>**不要寫任何答案**</u>。

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

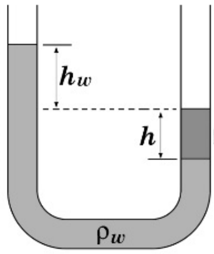
(iii)依計算題之題號順序在第二張<u>**反面**</u>以後寫下演算過程與答案，<u>**每題從新的一頁寫起**</u>。

$\sigma = 5.67\times10^{-8}$ W· m^{-2}·K^{-4}, water density = 10^3 kg· m^{-3}, $k = 1.38\times10^{-23}$ J/K, $R = 8.314$ J·K^{-1}·mol^{-1}.

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

• An iron tea kettle (水壺) with 1.0 kg water sits on a 1.0-kW stove burner. If it takes 5.9 min to bring the kettle and the water in it from 25 °C to the boiling point of water, the mass of iron kettle is 【1】kg. (specific heats for iron and water are 447 and 4190 J/kg·K, respectively.)

• A U-shaped tube, open at both ends, contains water (density ρ_w) and a quantity of fluid of density ρ. The fluid does not mix with water and occupies a length of *h* of the tube, as shown in right figure. The ratio ρ/ρ_w = 【2】.



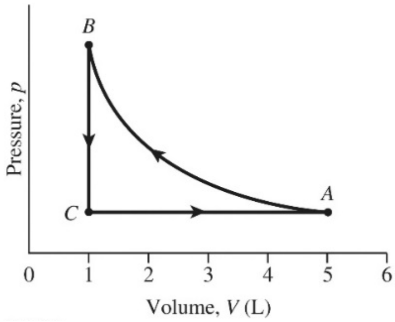
• A glass cup measures 12 cm high by 6.0 cm in diameter. Empty, it floats in water with one-third of its height submerged. How many 13-g rocks can be placed in the beaker before it sinks? 【3】

• The relationship of volume expansion coefficient β and temperature T for the ideal gas at constant pressure is $\beta\times T$ = 【4】.

• The thermal speed of a molecule is 515 m/s at 0 °C. At what temperature will the thermal speed be twice as large? 【5】K.

• In a malfunctioning nuclear power plant (故障的核電廠), cooling stops. The UO_2 fuel of 2.50×10^5 kg is continuously heated by the radioactive decay at the rate of 125 MW without cooling water. Once the melting point is reached, how long will it take for the UO_2 fuel to be melted completely? The heat of fusion of UO_2 is 259 kJ/kg. 【6】s.

• As shown in right figure, an ideal gas sample of γ = 1.4 undergoes the cyclic process ABCA, where AB is an isothermal process. The pressure at A is 60 kPa. The pressure at B is 【7】 kPa. The net work done on the gas for one cycle ABCA is 【8】J. If AB is an adiabatic process, the pressure at B is 【9】 kPa.



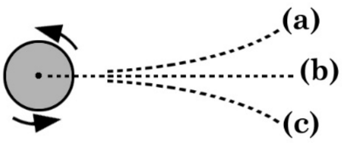
• The radiation energy from the Sun is absorbed by the Earth and is reradiated out from its entire surface area into space. The input power of the radiation to the Earth is $P_{sun} = 3010\times R_E^2$ (R_E is the Earth's radius). Assume the Earth is a perfect emitter (e = 1). When the P_{sun} is balanced with the power radiated by the Earth, the temperature of the Earth is 【10】 K. (The surface area of a sphere is $4\pi R^2$).

• A circular lake 1.0 km in diameter is 10 m deep. Solar energy is incident on the lake surface and raises its temperature to 30 °C. If the lake surface exchanges heat with deep cold water at a rate of heat conduction 1.2 MW, the temperature of the bottom water is 【11】 °C. (thermal conductivity of water is 0.61 W/m·K)

• A typical refrigerator (電冰箱) operates between −18 °C and 30 °C. Its maximum coefficient of performance (COP) is 【12】.The electric energy to freeze 1.0 kg of water at 0°C is 【13】kJ. The heat of fusion (熔化熱) for water is 334 kJ/kg.

• A gas mixture consists of 0.5 mol of oxygen (O_2) and 0.5 mol of helium (He). The molar specific heat of the mixture at constant volume is 【14】*R*.

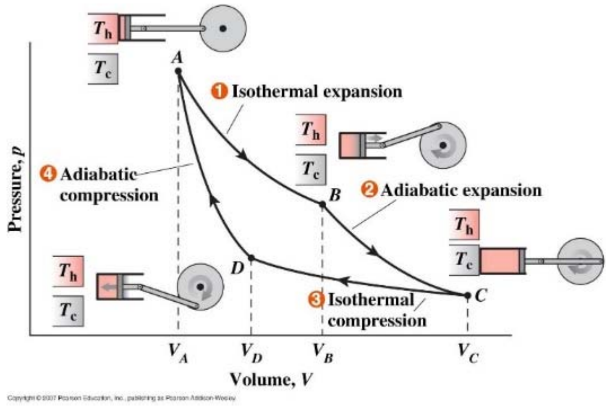
• We toss a ball to the right-hand side horizontally. If we ignore the gravitational attraction of the Earth and the ball has a spin as shown in the right figure, which path will the ball go? 【15】



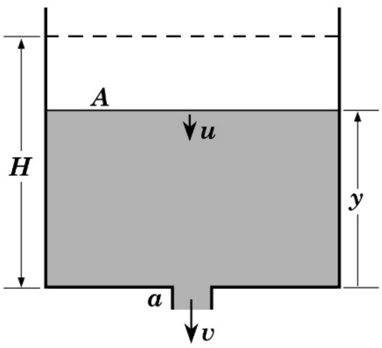
Part II Problems (10 points per problem)

1.
Consider two identical cups which contain 1.0 kg water each, initially at temperatures of T_1 = 100 °C and T_2 = 0 °C. Consider this thermal process: the two cups are brought into thermal contact. In order for them to reach equilibrium at T_f = 50 °C, a total amount of heat *Q* flows from the hot cup to the cold one. Assume that the specific heat of water is a constant 4.19 joule/gram °C.
Find (a) *Q*, (b) the change in entropy for the first cup ΔS_1 and (c) the second cup ΔS_2. (d) Find the sum of ΔS_1 and ΔS_2, and explain its meaning of its sign (positive or negative) in terms of the reversibility of this thermal process.

2.
The *pV* diagram for the Carnot engine is shown on the right.
(a) Find the heat Q_h adsorbed during AB, in term of T_h, V_B, V_A.
(b) Find the heat Q_c rejected during CD in term of T_c, V_C, V_D.
(c) Find the efficiency *e* of the Carnot engine.



3.
A large, open tank of cross-sectional area *A* is filled of water to height *H*. A small hole of area *a* is cut in the bottom of the tank. (a) Find the speed *v* of water emerging from the hole in terms of water depth *y* as shown in the figure. (b) Find the time it takes to drain all water from the tank. (*Hint*: *u* = – d*y*/d*t*)



Part I Answer Sheet

A【01】	300		B【01】	1.2
A【02】	243		B【02】	$1+\frac{h_w}{h}$
A【03】	571		B【03】	17
A【04】	5.31 (5.25 OK)		B【04】	$\beta T = 1$
A【05】	62.9 (63.6 OK)		B【05】	1092 K or 1090 K
A【06】	2		B【06】	518
A【07】	(a)		B【07】	300
A【08】	$\beta T = 1$		B【08】	243
A【09】	1092 K or 1090 K		B【09】	571
A【10】	518		B【10】	255
A【11】	255		B【11】	5 or 5.0
A【12】	5 or 5.0		B【12】	5.31 (5.25 OK)
A【13】	1.2		B【13】	62.9 (63.6 OK)
A【14】	$1+\frac{h_w}{h}$		B【14】	2
A【15】	17		B【15】	(a)

Part II Answer Sheet。

【A1=B3】

(a) Continuity eq.: $Au = av$ ……(1)

Bernoulli's eq.: $p_0+\frac{1}{2}\rho u^2+\rho g y = p_0+\frac{1}{2}\rho v^2, that\ \ is\ \ u^2+2gy=v^2 \ldots\ldots(2)$

From (1) and (2) $v=\sqrt{\frac{2gy}{1-\frac{a^2}{A^2}}}$ or $v=\sqrt{2gy}$ (because $A \gg a$ as mentioned in the question).

(b) From (1) $av = Au = A\cdot\left(-\frac{dy}{dt}\right), \therefore -\frac{dy}{dt}=\frac{a}{A}v=\sqrt{\frac{2gy}{\frac{A^2}{a^2}-1}} \rightarrow -\frac{dy}{\sqrt{y}}=\sqrt{\frac{2g}{\frac{A^2}{a^2}-1}}\cdot dt$

$$-\int_H^y \frac{dy}{\sqrt{y}}=\sqrt{\frac{2g}{\frac{A^2}{a^2}-1}}\cdot\int_0^t dt + constant. So\ \ 2\left(\sqrt{H}-\sqrt{y}\right)=t\sqrt{\frac{2g}{\frac{A^2}{a^2}-1}}+constant.\quad Since\ \ at\ \ t=0, y = H, \therefore\ \ constant = 0.$$

$When\ \ t=T, the\ \ drain\ \ time, y=0. \therefore T=\sqrt{\frac{2H}{g}\left(\frac{A^2}{a^2}-1\right)}$ or $T=\sqrt{\frac{2H}{g}\left(\frac{A^2}{a^2}\right)}$ (because $A \gg a$).

【A2=B1】

(a) $\Delta Q = \int_{T_1}^{T_f} dQ = \int_{T_1}^{T_f} m_1 c_1 dT = m_1 c_1 (T_f - T_1) = 1 \times 4190 \times (323 - 273) = 2.10 \times 10^4\ J$

(b) $\Delta S_1 = \int_{T_1}^{T_f} \frac{dQ_1}{T} = \int_{T_1}^{T_f} \frac{m_1 c_1 dT}{T} = m_1 c_1 \ln \frac{T_f}{T_1} = 1 \times 4190 \times (\ln \frac{323}{273}) = 704$ J/K

(c) $\Delta S_2 = \int_{T2}^{T_f} \frac{dQ_2}{T} = \int_{T2}^{T_f} \frac{m_2 c_2 dT}{T} = m_2 c_2 \ln \frac{T_f}{T_2} = 1 \times 4190 \times \ln \frac{323}{373} = -603$ J/K

(d) $\Delta S = \Delta S_1 + \Delta S_2 = 704 - 603 = 101$ J/K. The positive value means that the total entropy increases during this irreversible process. The result agrees with the 2nd law.

【A3=B2】

A→B (isothermal expansion $T_A = T_B = T_h$; $U = 0 = Q_h - W_{AB}$)

$$Q_H = W_{ab} = \int_{V_a}^{V_b} P dV = \int_{V_a}^{V_b} \frac{nRT_H}{V} dV = nRT_H \ln(\frac{V_b}{V_a})$$

C→D (isothermal compression $T_C = T_D$; $\Delta U = 0 = Q_C - W_{CD}$)

$$Q_C = W_{cd} = \int_{V_d}^{V_c} P dV = \int_{V_d}^{V_c} \frac{nRT_C}{V} dV = nRT_C \ln(\frac{V_c}{V_d})$$

B→C; D→Aadiabatic $PV^{\gamma} = (PV)V^{\gamma-1} = nR(TV^{\gamma-1}) = \text{constant}$

or $T_h V_B^{\gamma-1} = T_C V_C^{\gamma-1}$; $T_H V_A^{\gamma-1} = T_C V_D^{\gamma-1}$

$$efficiency \quad e = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H} = 1 - \frac{Q_C}{Q_H} = 1 - \frac{nRT_C \ln(\frac{V_c}{V_d})}{nRT_H \ln(\frac{V_b}{V_a})} = 1 - \frac{T_C}{T_H}$$