University of California, Berkeley Physics

7B Spring 2020 MidTerm Exam I

Thermodynamics and Electrical Force

Maximum score: 100 points

1. (15 points)

Helium atoms have a mass of 4u and oxygen molecules have a mass of 32u, where u is defined as an atomic mass unit ($u=1.660540\times10^{-27}$kg). Compare a gas of helium atoms to a gas of oxygen molecules.

(a) At what gas temperature T_E would the average translational kinetic energy of a helium atom be equal to that of an oxygen molecule in a gas of temperature 300 K?

(b) At what gas temperature T_{rms} would the root-mean-square (rms) speed of a helium atom be equal to that of an oxygen molecule in a gas at 300 K?

(c) What is the molar specific heat at constant volume (c_v) of oxygen molecules at 300K and at 3000K, respectively?

2. (25 points)

When a gas is taken from point a to point c along the curved path in the figure 1, the work done by the gas is W_{ac} = -32J and the heat added to the gas is Q_{ac} = -65J. Along path abc, the work done is W_{abc} = -54J.

(a) What is Q for path abc?

(b) If $P_c=0.5\times P_b$, what is W for path cda?

(c) What is Q for path cda?

(d) What is $E_{int,a} - E_{int,c}$?

(e) If $E_{int,d} - E_{int,c}=12$J, what is Q for path da?

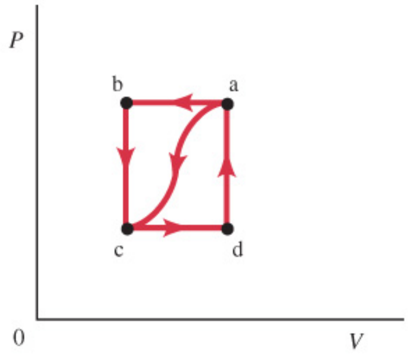

Fig. 1

3. (20 points)

A 400 g insulated aluminum cup at 80 °C is filled with 20 g of ice at 0 °C.

(a) Determine the final temperature of the mixture. The specific heats of water and aluminum are 4.2 J/g.K and 0.9 J/g.K, respectively. The heat of fusion of water is 333 J/g.
(b) Determine the total change in entropy as a result of the mixing process.

4. (20 points)

Four charges of magnitude +q are placed at the corners of a square whose sides have a length d. What is the magnitude of the total force exerted by the four charges on a charge Q located a distance b along a line perpendicular to the plane of the square and equidistant from the four charges?

5. (20 points)

An ideal heat pump is used to maintain the inside temperature of a house at Tin = 21 °C when the outside temperature is Tout. Assume that when it is operating, the heat pump does work at a rate of 1300 W. Also assume that the house loses heat via conduction through its walls and other surfaces at a rate given by (650W/°C)($T_{in}-T_{out}$).

(a) For what outside temperature would the heat pump have to operate at all times in order to maintain the house at an inside temperature of 21 °C?

(b) If the outside temperature is 9 °C, what percentage of the time does the heat pump have to operate in order to maintain the house at an inside temperature of 21 °C?

$$\Delta l = \alpha l_0 \Delta T$$

$$\Delta V = \beta V_0 \Delta T$$

$$PV = NkT = nRT$$

$$\frac{1}{2} m\overline{v^2} = \frac{3}{2} kT$$

$$E_{int} = \frac{d}{2} NkT$$

$$Q = mc\Delta T = nC\Delta T$$

$$Q = mL \text{ (For a phase transition)}$$

$$\Delta E_{\text{int}} = Q - W$$

$$dE_{\text{int}} = dQ - PdV$$

$$W = \int PdV$$

$$C_P - C_V = R = N_A k$$

$$PV^\gamma = \text{const. (For a reversible adiabatic process)}$$

$$\gamma = \frac{C_P}{C_V} = \frac{d+2}{d}$$

$$C_V = \frac{d}{2} R$$

$$\frac{dQ}{dt} = -kA\frac{dT}{dx}$$

$$e = \frac{W_{\text{net}}}{Q_{\text{in}}}$$

$$e_{\text{ideal}} = 1 - \frac{T_L}{T_H}$$

$$S = \int \frac{dQ}{T} \text{ (For reversible processes)}$$

$$dQ = TdS$$

$$\Delta S_{syst} + \Delta S_{env} > 0 \text{ (For irreversible processes)}$$

$$\oint dE = \oint dS = 0$$

	Q	W
Isobaric	$C_P n\Delta T$	$P\Delta V$
Isochoric	$C_V n\Delta T$	0
Isothermal	$nRT\ln\left(\frac{V_f}{V_0}\right)$	$nRT\ln\left(\frac{V_f}{V_0}\right)$
Adiabatic	0	$-\frac{d}{2}(P_f V_f - P_0 V_0)$

$$\vec{F} = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}\hat{r} = \frac{kQ_1 Q_2}{r^2}\hat{r}$$

$$\vec{F} = Q\vec{E}$$

$$d\vec{E} = \frac{dQ}{4\pi\epsilon_0 r^2}\hat{r} = \frac{k\,dQ}{r^2}\hat{r}$$

$$\int (1+x^2)^{-1/2} dx = \ln(x + \sqrt{1+x^2})$$

$$\int (1+x^2)^{-1} dx = \arctan(x)$$

$$\int (1+x^2)^{-3/2} dx = \frac{x}{\sqrt{1+x^2}}$$

$$\int \frac{x}{1+x^2} dx = \frac{1}{2}\ln(1+x^2)$$

$$\int \frac{1}{\cos(x)} dx = \ln\left(\left|\tan\left(\frac{x}{2} + \frac{\pi}{4}\right)\right|\right)$$

$$\int \frac{1}{\sin(x)} dx = \ln\left(\left|\tan\left(\frac{x}{2}\right)\right|\right)$$

$$\sin(x) \approx x$$

$$\cos(x) \approx 1 - \frac{x^2}{2}$$

$$e^x \approx 1 + x + \frac{x^2}{2}$$

$$(1+x)^\alpha \approx 1 + \alpha x + \frac{(\alpha-1)\alpha}{2} x^2$$

$$\ln(1+x) \approx x - \frac{x^2}{2}$$

$$\sin(2x) = 2\sin(x)\cos(x)$$

$$\cos(2x) = 2\cos^2(x) - 1$$

$$\sin(a+b) = \sin(a)\cos(b) + \cos(a)\sin(b)$$

$$\cos(a+b) = \cos(a)\cos(b) - \sin(a)\sin(b)$$

$$1 + \cot^2(x) = \csc^2(x)$$

$$1 + \tan^2(x) = \sec^2(x)$$