蒋云翔 2022102330 CST

Physics CST (2023-24) Homework 4

Please send the completed file to my mailbox yy.1am@qq.com by November 11th, with using the filename format:

student_number-name-cst-hw4

Please answer the questions by filling on these sheets. Or alternatively, do the homework as usual by using papers, then take the pictures and paste them onto these question sheets.

0.22kg

1. How much mass of water vapour initially at 135°C is needed to warm 220 g of water in a 130-g glass container from 20.0°C to 65.0°C at thermal equilibrium? (Specific heats of water, steam and glass are 4.19×10^3, 2.01×10^3 and 837 J/kg · °C, respectively. The latent of vaporization of water is 2.26×10^6 J/kg.)

0.13kg

Sol: The water in container needs: $(65-20) \times 4.19 \times 10^3 \times 0.22 = 41481\,J$

The glass container needs: $(65-20) \times 837 \times 0.13 = 4896.45\,J$

The heat Q released = $2.26 \times 10^6 m\,J$

The water vapour will release: $(135-100) \times 2.01 \times 10^3 m + (100-65) \times 4.19 \times 10^3 m$

$= 2.17 \times 10^5 m\,J$

then we know: $2.26 \times 10^6 m + 2.17 \times 10^5 m = 41481 + 4896.45$

so: $m = 18.72\,g$

2. At a distance of 3.5 m from a source the sound level is 74 dB. How far away has the level dropped to 58 dB?

Sol: We know that intensity follows inverse square law:

$74-58 = 10\lg\frac{I_1}{I_2}$

$1.6 = \lg\frac{I_1}{I_2}$

$39.8 = \frac{I_1}{I_2}$

$(\frac{3.5}{x})^2 = \frac{1}{39.8}$

$x = 22.08$ m

3. How does the rate of heat transfer by conduction change of an object when the volume is decreased by half?

Sol: As for conduction: we know $P_c = \frac{k_c A}{L}(T_1 - T_2)$

k_c is a constant, and $(T_1 - T_2)$ is also a constant

we just need to consider A and L

Assume it is a cube.

when its volume is decreased by half

$(L')^3 = \frac{L^3}{2} \Rightarrow L' = \sqrt[3]{2}L$ $\quad \sqrt[3]{2}\cdot L'$

so: $A' = \cancel{(\sqrt[3]{2})^2}\cdot L'^2$ $\quad (\sqrt[3]{2})^2$

$P_c' = \frac{k_c A'}{L'}(T_1 - T_2) = \frac{2^{\frac{2}{3}}}{2}\cdot P_c \Rightarrow$ so its rate became $2^{\frac{2}{3}}$ times as before

v	$2v$	$4v$	$\frac{v}{2}$	$3v$
4	3	2	4	3

$\frac{76}{16}$ $\frac{19}{4}$

4. A box with volume V contains 16 particles with each of mass m having various speeds. Four have speed v; three have speed $2v$; two have speed $4v$; four have speed half v; the other three have speed $3v$. (a) Find the root-mean-square speed of the particles. (b) Use the ideal gas law to find the pressure inside the container.

Sol: (a) $\sqrt{\dfrac{4\cdot v^2+3\cdot(2v)^2+2\cdot(4v)^2+4\times(\frac{v}{2})^2+3\times(3v)^2}{16}}$

$= \frac{\sqrt{19}}{2}\cdot v$

(b) $PV=NKT \cdots ①$ $T=\frac{2}{3}\cdot\frac{\frac{1}{2}mv^2}{k} \cdots ②$

By ① ② we know: $P=\dfrac{19.33mv^2}{V}$

5. A box with 8 cells contains 2 different balls. The balls are allowed to sit on the same cell. What is the change of entropy if it is replaced by a box with only 4 cells?

Sol: The change of entropy is the final entropy minus the initial entropy

$\Delta S = S_f - S_i = k\ln S_f - k\ln S_i$

At initial state: it has ${}^8C_1\cdot{}^8C_1=64$ situations

At final state it has ${}^4C_1\,{}^4C_1=16$ situations

so $\Delta S = 1.38\times10^{-23}(\ln 16-\ln 64) = -1.91\times10^{-23}$ J/K

6. A box contains 10^{22} gas molecules, approximately, under normal room temperature and pressure. Approximate the change of entropy of the system if the volume of the box is double of the original. (For simplicity, assuming the molecules are distinguishable)

Sol: $\Delta S = S_f - S_i = nR\ln(\frac{V_f}{V_i})$

$V_f = 2V_i$

$n = 10^{22}\times\dfrac{1}{6.022\times10^{23}} = 0.017$ mol

so: $\Delta S = 0.017\times8.314\times\ln 2 = 0.098\ JK^{-1}$

7. Ultrasound that has a frequency of 2.44 MHz is sent toward blood in an artery that is moving away the source at 20.0 cm/s. Use the speed of sound in human tissue as 1550 m/s. (a) What frequency does the blood receive? (b) What frequency returns to the source? Take your results to 6 decimal places.

Sol: (a) Using doppler effect: $f = 2.44 \times 10^6 \times \frac{1550+0.2}{1550}$

$= 2.440315 \times 10^6$ HZ

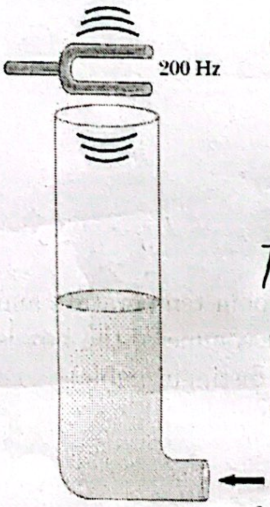
(b)

Also using doppler effect rules:

$f' = 2.44 \times 10^6 \times \frac{1550-0.2}{1550}$

$= 2.439685 \times 10^6$ Hz

8. Water is pumped into a long vertical cylinder at a rate of 24 cm^3/s. The radius of the cylinder is 5 cm, and at the open top of the cylinder is tuning fork vibrating with a frequency of 200 Hz. As the water rises, how much time elapses between any successive resonances at 20 °C?



Sol: The speed of sound wave:

$V_s = 343\sqrt{\frac{273+20}{273+24}} = 340.9$ m/s

The speed of water rising:

$V_r = \frac{\pi r^2}{24} = 3.27$ cm/s

The relative speed is: $V_R = V_s + V_r = 340.93$ m/s

So the time is: $\frac{200}{340.93} = 0.587$ s