PHYS 1511 Discussion Section: Week 13

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Review

Chapter 13: The transfer of heat

-Radiative Diffusion

-Net Radiative Power

Chapter 14: The Ideal Gas Law and Kinetic Theory

-Molecular Mass

-Mole (unit not facial blemish)

-Avogadro's Number

-The Ideal Gas Laws (Physics version, not chemistry)

-Charles & Boyles Laws

-Kinetic Theory of Gases

-Diffusion

Review (cont.)

Chapter 15: Thermodynamics

-Laws of Thermodynamics (0th - 3rd)

-Thermal Processes and work done on a thermal system

-Thermal processes using an Ideal gas

-Specific heat capacities

-Heat Engines

-Carnot Engine

-Refrigerators, Air Conditioners and Heat Pumps

-Entropy

Equations

Chapter 13:

$$Q = e\sigma T^4 At \qquad \text{(Radiation Heat Energy)} \tag{1}$$

$$P_{net} = e\sigma A(T^4 - T_o^4) \qquad \text{(Net Radiation Power)} \tag{2}$$

where

e - emissivity ($0 \leq e \leq 1$) where e =1 is blackbody (absorbs all light)

A - surface area

σ - Stefan-Boltzmann constant. (just a number to look up)

T_o - temperature of environment

Equations

Chapter 14:

$$n = \frac{N}{N_A} \qquad \text{(molecular mass)} \tag{3}$$

$$PV = nRT = NkT \qquad \text{(Ideal Gas Law)} \tag{4}$$

$$P_1 V_1 = P_2 V_2 \qquad \text{(Boyles Law)} \tag{5}$$

$$\frac{V_i}{T_i} = \frac{V_f}{T_f} \qquad \text{(Charles Law)} \tag{6}$$

$$U = \frac{3}{2} nRT \qquad \text{(Internal Potential Energy of Ideal Gas)} \tag{7}$$

$$\bar{KE} = \frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT \qquad \text{(Avg. Kinetic Energy } \textbf{per particle}\text{)} \tag{8}$$

$$m = \frac{DA(\Delta Concentration)t}{L} \qquad \text{(Diffusion)} \tag{9}$$

Equations

Chapter 15:
Specific Heat Capacities:

$$Q = nC\Delta T \qquad \text{(Heat Transfer)} \tag{10}$$

$$\gamma = \frac{C_P}{C_V} \qquad \text{(Gamma Constant)} \tag{11}$$

$$P_i V_i^{\gamma} = P_f V_f^{\gamma} \qquad \text{(Generalized Boyle)} \tag{12}$$

$$C_P = \frac{5}{2}R \qquad \text{(Specific Heat: Constant Pressure)} \tag{13}$$

$$C_V = \frac{3}{2}R \qquad \text{(Specific Heat: Constant Volume)} \tag{14}$$

Equations

$$W = P\Delta V \qquad \text{(Work done in static process)} \tag{15}$$

$$W = nRT\ln\left(\frac{V_f}{V_i}\right) \qquad \text{(Work done by Ideal Gas - isothermal)} \tag{16}$$

$$W = \frac{3}{2}nR(T_i - T_f) \qquad \text{(Work done by idea gas - adiabatic)} \tag{17}$$

$|Q_C| \Longrightarrow$ Rejected heat from system

$|Q_H| \Longrightarrow$ Input heat into system

$|W| \Longrightarrow$ Work done by the system

$T_C \Longrightarrow$ Colder temperature source

$T_H \Longrightarrow$ Hotter temperature source

<u>Engine:</u>

$$e = \frac{\text{Work Input}}{\text{Input Heat}} = \frac{|W|}{|Q_H|} \qquad \text{(engine efficiency)} \tag{18}$$

$$e = 1 - \frac{|Q_C|}{|Q_H|} \qquad \text{(e - in terms of rejected heat, } |Q_C|\text{)} \tag{19}$$

$$\frac{|Q_C|}{|Q_H|} = \frac{T_C}{T_H} \qquad \text{(Carnot Engine)} \tag{20}$$

Relevant Equations

$$\frac{|Q_C|}{|W|} = \text{refrigerator coefficient} \qquad \text{(refrigerator performance)} \tag{21}$$

$$\frac{|Q_H|}{|W|} = \text{heatpump coefficient} \qquad \text{(heatpump performance)} \tag{22}$$

$$\Delta S = \left(\frac{Q}{T}\right)_R \qquad \text{(Change in entropy for reversible process)} \tag{23}$$

$$W_{\text{Unavailable}} = T_0 \Delta S_{\text{universe}} \qquad \text{(irreversible process)} \tag{24}$$

Laws of Thermodynamics

$\mathbf{0}^{th}$ - Two systems are in thermal equilibrium if there is no net heat exchange between them when brought into thermal contact.

1st - When work, W, is done on a thermal system by added heat Q, a change in internal potential energy occurs (ΔU) where:

$$\Delta U = Q - W$$

2nd - Heat flows spontaneously from systems of higher temperature to lower temperature and never spontaneously the other way around.

3rd - It is fundamentally impossible to lower a substance to absolute zero ($T_K = 0K$) in a finite number of steps.

Question #1

Radiative Physics

The surface temperature of the sun is roughly $6000K$. The sun has a radius of 695,508 km and can be approximated as a perfect black body ($\Longrightarrow e =?$).

(a) What is the amount of energy radiated from the sun in 2 second?

(b) What is the amount of net power radiated from the sun if the surrounding space has a temperature of roughly $3^{\circ}K$?

(c) Compare (b) to the amount of energy released by all nuclear bombs by humans since 1996: $E = 2,135,000\text{TJ}$

$\sigma = 5.67 \times 10^{-8}\text{J}/(\text{s}m^2K^4\ )$
1 TerraJoule (TJ) $= 1 \times 10^{12}$
Surface area sphere: $4\pi r^2$

Question #2

Ideal Physics

A container holds 2.0 moles of gas. The total average kinetic energy of the gas molecules in the container is equal to the kinetic energy of an 8×10^{-3}kg bullet with a speed of 770 m/s. What is the temperature of the gas in Kelvin?

R = 8.31446261815324 J/(mol K)
$N_A = 6.022 \times 10^{23}\text{mol}^{-1}$
k = $1.38 \times 10^{-23} J/K$

Question #3

Tube Diffusion

A tube has a length of 0.015m and a cross-sectional area of $7.0 \times 10^{-4} m^2$. The tube is filled with a solution of sucrose in water. The diffusion constant of sucrose in water is $5.0 \times 10^{-10}\ m^2/s$. A difference in concentration of 3.0×10^{-3} kg$/m^3$ is maintained between the ends of the tube. How much time is required for the 8.0×10^{-13}kg of sucrose to be transported through the tube?

Question #4

Symbolic Physics

A monatomic ideal expands at a **constant pressure** supplied by an input energy Q. What percentage of the heat being supplied to the gas is used to increase the internal energy of the gas?

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Hint: 2nd Law of Thermodynamics and find particular ratio

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Symbolic Physics

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Hint: 2nd Law of Thermodynamics and find particular ratio
Hint Hint: When a gas undergoes a constant temperature change with added heat, the final temperature is less than the initial temperature

Question #5

Cooler than Physics

The wattage of a commercial ice maker is 225W and is the rate at which it does work. The ice maker operates just like a refrigerator or an air conditioner and has a coefficient of performance of 3.6. The water going into the unit has a temperature of $15.0^\circ C$, and the ice maker produces ice cubes at $0.0^\circ C$. Ignoring the work needed to keep stored ice from melting, find the maximum amount (in kg) of ice that the unit can produce in one day of continuous operation.

$c_w = 4180$ J/(kg K)
$L_f = 3.33 \times 10^5$J/kg (latent heat of fusion water)