MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.01T **Fall Term 2004**

Problem Set 12: Kinetic Theory; Mechanical Equivalent of Heat;

Available on-line November 19; Due: Friday December 3 at 4:00 p.m.

Please write your name, subject, lecture section, table, and the name of the recitation instructor on the top right corner of the first page of your homework solutions. Please place your solutions in your lecture section table box.

Nov 19 No Class

Problem Set 11: Due Tues Nov 23 at 4:00 pm.

Nov 22
Hour One: Kinetic Theory
Reading: YF 18.1-18.6

Hour Two: Problem Solving Session 18: Ideal Gas Law
Reading: YF 18.1-18.6

Nov 24
Hour One: Archimedes Principle
Reading: YF 14.1-14.3

Hour Two: Archimedes Principle PRS Contest

Nov 26 No Class
Problem Set 12: Due Fri Dec 3 at 4:00 pm.

Nov 29
Hour One: First Law of Thermodynamcics, Entropy, and Second Law of Thermodynamics

Hour Two: Problem Solving Session 19: Thermodynamics

Dec 1
Hour One: Temperature, Heat, and Heat Capacity
Reading: YF 18.4: YF 17.1-17.7

Hour Two: Experiment 10: Energy Transformations: Mechanical Equivalent of Heat
Reading: Experiment 10

Dec 3
Hour One: Problem Solving Session 20: First and Second Thermodynamics

Problem Set 13: Not graded. Recommended Final Review Discussed in class Dec 8

Dec 6
Hour One: Special Relativity: Space-Time, Causality and Simultaneity
Reading: YF: Chapter 37.1-37.4 p. 1403-1414

Hour Two: Problem Solving Session 21: Special Relativity: Time Dilation and Length Contraction

Dec 8
Hour One and Hour Two: Final Review

Final Exam Tuesday, December 14 9:00AM - 12:00 NOON

Problem 1: Isothermal Ideal Gas Atmosphere

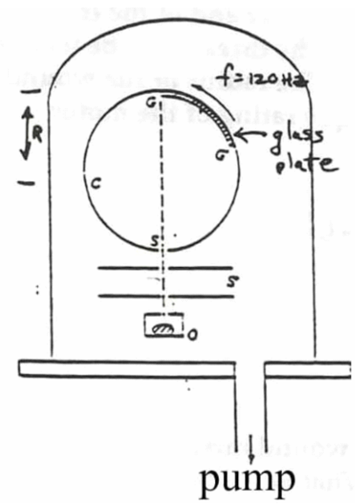
a) Find the root mean square (rms) speed of an oxygen molecule at T = 300K at sea level.

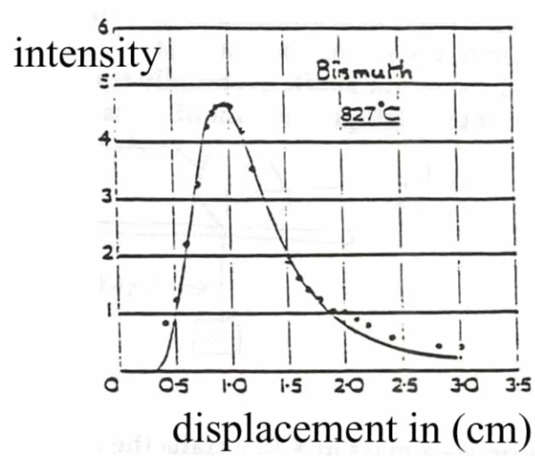
b) Find the root mean square z-component of the velocity of an oxygen molecule at T = 300K at sea level.

c) If a molecule with the above z-velocity were in a large evacuated container, to what maximum height H would it rise?

d) Find the rms z-component of velocity of a nitrogen molecule at T = 300K and height H assuming that the atmosphere extends that high (which it does)?

Problem 2: *Measuring Speeds of Gas Molecules* The actual speeds of atoms and molecules were first measured directly in 1930 by the following experiment. A beam of bismuth atoms, evaporated from an 'oven', passed through some defining slits in a hollow cylinder of radius $R = 4.7 \times 10^{-2}\ m$, rotating with frequency $f = 1.2 \times 10^{2}\ Hz$. The cylinder had a narrow slit cut in one side parallel to its axis. A glass plate was mounted opposite the slit in the cylinder. (See sketch). The fastest atoms would arrive at the leading edge of the plate and the slower atoms would distribute themselves further back along the plate. The following graph shows the results for Bismuth atoms at a temperature $T = 827\ ^{0}C$. In this problem we shall calculate the velocity of the Bismuth atoms at the maximum of the distribution curve. The Bismuth atoms have a molecular weight $M = 2.09 \times 10^{2}\ g/mole$.





a) What is the displacement backwards along the glass of the maximum of the curve?

b) What angle (in radians) does this correspond to?

c) How long does it take for the cylinder to rotate through this angle? (This corresponds to the time it takes the Bismuth atom to cross the diameter of the cylinder).

d) What is the velocity of these Bismuth atoms?

e) Using the equipartition theorem $v_{rms}^2 = 3RT/M$, where the universal gas constant $R = 8.31\, J/mole-K$, calculate the root mean square velocity of the Bismuth atoms. How does your answer compare to part d)?

Problem 3: Burning Calories

A racing bicyclist, traveling at an average speed of 25 mph, has a metabolic rate of

$$dE/dt = 1.36 \times 10^3 \text{ W}.$$

The average power output is

$$dW/dt = 3.0 \times 10^2 \text{ W}.$$

The person cycles for 4 hours and covers 100 miles. The person has mass $m = 60$ kg.

a) What is the average force that the person applies?

b) What is the ratio of power output to catabolic rate, $\varepsilon = \dfrac{dW/dt}{dE/dt}$?

c) How many kilocalories did the person burn up?

d) What rate did the cyclist generate heat?

e) What happens to this heat?

Problem 4: Experiment Mechanical Equivalent of Heat

This problem will be part of the experiment write-up (last page) and given out in class the day of the experiment.

Problem 5: Hand in the In-class problem Friday Dec 3 with your problem set.