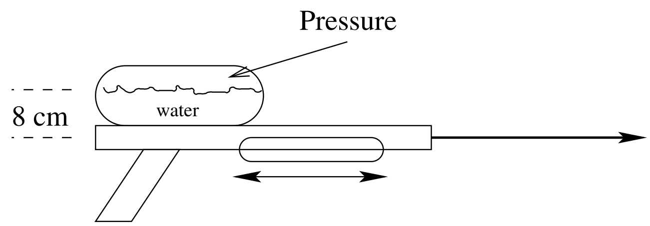
1. The Super Soaker water gun was a revolution in water gun technology. The pump handle is moved back and forth building up significant pressure in the water reservoir. The water is released by pulling a trigger and shoots for a significant distance. Assume that one can make an *absolute pressure* of 8 atmospheres in the reservoir. Find all the following:



   (a) What is the velocity at which the water leaves the gun?

   (b) If the water exits the gun through a hole with radius 1mm, what is the volume rate of flow ($\frac{m^3}{s}$)?

   (c) If the water gun is fired horizontally and held 1.2 meters above the ground, where does the water hit the ground?

   NOTE: The reservoir is a "tank" of water in which the water moves with negligible velocity..

2. You are given a rectangular Cu bar whose length is 80 cm and whose cross section is 1cm-by-1cm. You perform many experiments on this very same Cu bar. Answer all of the following (**NOTE:**: You will need to consult *many* tables from your book to get necessary constants).

   (a) What is the mass of the bar?

   (b) You apply equal but opposite forces (F=500 Newtons) to the ends of the bar in an attempt to stretch the bar. What is the new length of the bar?

   (c) You put the bar in a vacuum and it swells a tiny bit. What is the change in volume of the bar?

   (d) You apply a shear stress to the bar of 10^7 Pa. The forces are applies to the "long sides" of the bar (the 80x1 cm^2 faces). What is the deformation of the bar (x)?

   (e) How much force (applied as in part b) would be required to break the bar?

   (f) What is the apparent weight of the bar when it is under water?

   (g) If you raise the temperature of the bar from 20^o C to 30^o C, what is the change in its length?

   (h) Suppose that during the previous temperature rise, the bar were **FORCED** to remain at the original length. What is the "thermal stress" on the bar?

   (i) If you raise the temperature of the bar from 20^o C to 30^o C, what is the change in its volume?

   (j) How much heat was required to raise the temperature of the bar from 20^o C to 30^o C?

   (k) How much heat is required to take your Cu bar from room temp (20^o C) to its melting point?

   (l) How much heat is required to melt the bar (starting already at the temperature equal to the melting point)?

   (m) You place one end of your bar in ice water and the other end in boiling water. What is the rate at which heat flows through the bar?

   (n) Suppose your bar is inside a vacuum box and has a temperature of 500^o C.

      i. What is the rate at which heat flows off the bar into the vacuum (ignore any heat flows into the bar)?

      ii. Assuming that the walls of the vacuum box are at 20^o C, what is the rate at which heat enters the bar from the vacuum box?

      iii. What is the net rate of heat leaving the bar?
      NOTE: Assume an emissivity of $e = 1$ throughout this problem.

3. A collection of nitrogen gas molecules is at $P = 100,000\ Pa$, $T = 25^o\ C$, and is held in a box of Volume $V = 2\ m^3$. Answer all the following:

   (a) How many molecules are in the box?

   (b) What is the average Translational Kinetic Energy of one of these molecules?

   (c) What is the average velocity of one of these molecules?

   (d) What is the internal energy of the system?

   (e) How much heat is required to raise the temperature of the gas to 35^o C if the volume is not changed as the heat is added?

   (f) How much heat is required to raise the temperature of the gas to 35^o C if the volume is allowed to change in such a way that the pressure is not changed?

   (g) What is the change in internal energy of the gas during each of the two previous processes?

4. A warm summer day has a pressure of 100,000 Pa and a temperature of 300 K.

   (a) Find the number of moles per cubic meter of any ideal gas under these conditions.

   (b) Find the number of $\frac{kg}{m^3}$ of Nitrogen gas, N_2, under these conditions.

   (c) Find the number of $\frac{kg}{m^3}$ of Helium gas, He, under these conditions.

   (d) Determine the net force of a 1.5 m^3 Helium balloon in air (take the calculation for N_2 as a good approximation of air).

   (e) Determine the RMS velocity of the He atoms.

5. A 0.100 kg Cu cup contains 0.800 kg of water at 20^o C. 0.020 kg of ice whose temperature is -10^o C is dropped into the cup. Determine the final temperature of the system.

6. You travel in a spaceship to Mars. We will approximate your ship as a sphere of radius 10 meters and take its emissivity as 1.0.

(a) Assuming the surface of your ship is at the same 290 K as the interior, what is the rate at which the ship loses heat via radiation (in Watts)?

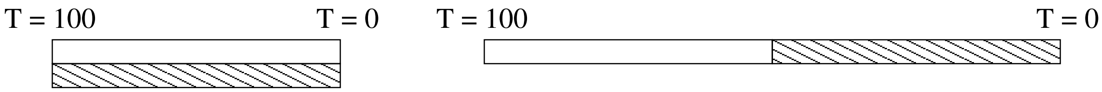
(b) The sun has a radius of 695,000,000 m and a surface temperature of roughly 5,800 K. How many $\frac{W}{m^2}$ are emitted from the sun's surface by radiation?

(c) Fortunately for you, you are much further than only 695,000 km from the center of the sun. You are 150 billion m from its center. How many $\frac{W}{m^2}$ is the sunlight intensity at your ship?

(d) How many Watts do you receive from the sun?

(e) Do you worry most about frying or freezing on your trip to Mars?

7. You have in your posession two rectangular bars. Each of these bars is 30 cm in length and has a square cross section of 2cm by 2 cm. The first bar is made of steel ($k = 40\frac{W}{m \cdot K}$) and the second is made of Alumunum ($k = 200\frac{W}{m \cdot K}$). You decide to do two experiments in heat transfer as shown in the figure below.



Experiment A

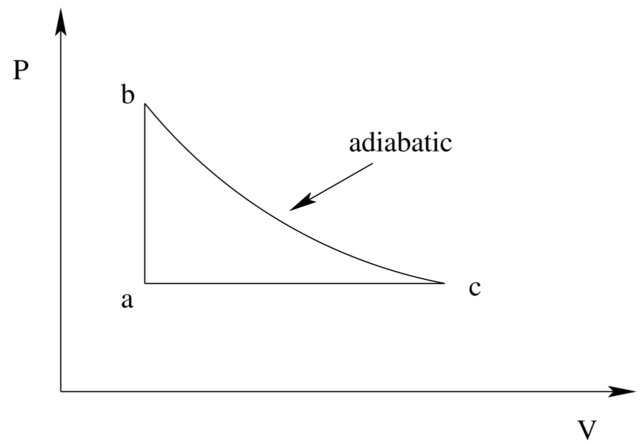
Experiment B

(a) Calculate the total heat transfer rate, H, for experiment A.

(b) Calculate the total heat transfer rate, H, for experiment B.

(c) Calculate the temperature at the place where the two bars connect in experiment B.

8. 2 moles of Nitrogen, N_2, gas are taken through the cycle shown in the figure below ($a \to b \to c$). At point a, the temperature is 300 K and the pressure is 100,000 Pa. During the process $a \to b$, the pressure of the system triples.



(a) Calculate and fill in the "state table" below:

	P	V	T
a			
b			
c			

(b) Calculate and fill in the "process table" below:

	W	Q	ΔU
a → b			
b → c			
c → a			
TOTAL			

(c) Calculate the heat from the hot reservoir, Q_H, and the heat to the cold reservoir, Q_C.

(d) Calculate the efficiency of your engine.

(e) Calculate the efficiency of a Carnot engine operating between the same two extremes of temperature.

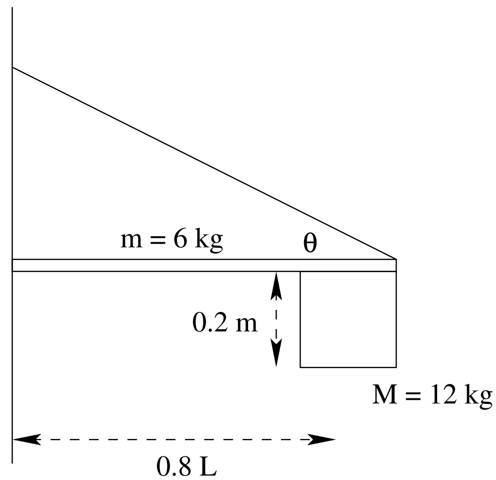
NOTE: A problem of this same type is guaranteed to appear on the final exam.

9. Most people hang their plants from a string or a chain (and some of them talk to the plants). You decide instead to hang your plant from a spring (k = 8 $\frac{N}{m}$) so that it can have fun oscillating up and down. After you hang your plant, you start it bouncing with an amplitude of 12 cm. You see that it oscillates with a frequency of 2 Hz.

   (a) What is the period of your plant?
   (b) What is ω?
   (c) What is the maximum velocity of the plant?
   (d) What is the maximum acceleration?
   (e) What is the velocity of the plant when its displacement from equilibrium is 4 cm?
   (f) What is the acceleration of the plant when its velocity is $\frac{1}{2}v_{max}$?
   (g) What amplitude of the oscillation would produce a maximum acceleration of 9.8 $\frac{m}{s^2}$?
   (h) How far is the spring stretched when the plant is at equilibrium?

   NOTE: When your plant's acceleration equals 9.8 $\frac{m}{s^2}$ downward your plant feels weightless. However, you need not worry about vomit since the plant has no stomach.

10. Now that you have your medical degree, you decide to "hang a shingle" in front of your home and begin your practice. In Chapter 12, I would have



asked you the following:

(a) What is the tension in the wire?

(b) What is the normal force from the wall?

(c) What is the upward force from the wall?

Now in Chapter 14 I will **instead** ask you different questions!! As shown, the length of the shingle is 20 cm. When a slight breeze blows, the shingle starts swinging with a small amplitude.

(a) What is the period of the motion of the shingle?

(b) If the maximum angle of the shingle is $\theta_{max} = 0.01 rad$, what is its maximum angular acceleration, α?

(c) What is the angular velocity, ω_v, when the angle of the shingle is $\theta = 0.005 rad$?

NOTE: Treat the shingle like a rod rotating about its end having a moment of inertia $I = \frac{1}{3} M L^3$.

11. An object oscillates according to the formula $x(t) = 0.12\cos(12t)$ where all numbers are in proper MKS units.

(a) What is the period of the motion?

(b) What is the maximum velocity of the motion?

(c) What is the velocity when x=0.10 meters?

(d) If this is the motion of a 0.100 kg mass on a spring, what is the spring constant?

12. A wave on a string is described by the equation $y(x,t) = 0.25\sin(3.14x + 450t)$, where all numbers are in proper MKS units.

(a) What is the frequency of the wave?

(b) What is the period of the wave?

(c) What is the wavelength of the wave?

(d) What is the velocity of the wave?

(e) What is the amplitude of the wave?

(f) Is the wave travelling in the positive or negative x direction?

(g) If the tension in the string is 100 N, what is the mass density, μ, of the string?

13. A flute should play an A (f=440 Hz) in its fundamantal mode.

    (a) Sketch the node pattern of the flute in its fundamantal mode.

    (b) What is the length of the flute's resonant cavity when sounding the A?

    (c) To sound "middle C" (f=262 Hz) the flute player closes holes on the flute making it longer. How long to sound middle C?

    (d) To sound a high A (f=880 Hz), the flute player cannot simply open more holes since the length will become too short? What do you do instead? Sketch the resulting node pattern.

14. The “A” string on a guitar is the second lowest string (E is the lowest). This one ideally plays an A (f=110 Hz) two octaves below the A from the previous problem. The length of the string is 0.648 meters and the tension is 100 N.

    (a) Sketch the node pattern when the string vibrates in its fundamental mode.

    (b) Find the mass per unit length, μ, of the string.

    (c) You wish to play a “C” (f=131 Hz) on this string. How do you accomplish this without changing the tension or μ of the string? Specify your answer as an exact numerical result.

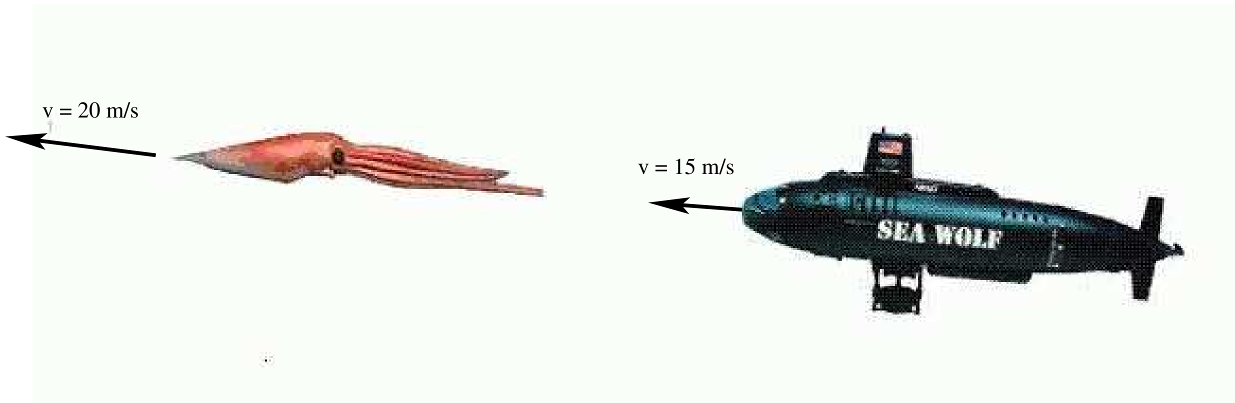
15. Two successive overtones of a closed organ pipe are 280 and 320 Hz.

   (a) What is the fundamental frequency?

   (b) WHat is the length of the organ pipe?

16. You are standing 10 meters away from a jet plane and the sound level of 140 dB is painful. Where should you stand to reduce the sound level to 120 dB?

17. Shown in the figure below is a submarine chasing a squid. Luckily for the squid he is moving faster. The submarine emits a sonar pulse with a frequency of 12,000 Hz. Using 1450 m/s as the speed of sound in water



find all the following:

(a) Frequency of sound heard by the squid.

(b) Frequency of sound heard by the sub reflecting off the squid.

(c) Beat frequency heard at the sub.