Physics 1201 Review
September 2010

This is a collection of problems which covers the range of topics found in this course. Many of the problems have parts that deal with a single situation, while others have parts which are related to the same topic. Not all of these problems are necessarily representative of those found on the final examinations (some are longer or a bit more difficult), but they are indicative of the sorts of physical analysis and calculations you may be expected to carry out. Keep in mind that no list such as this one will cover everything you have studied in the course; you should be sure to review your lecture notes and homework thoroughly.

Many of the problems are based on those appearing in Fishbane, Gasiorowicz, and Thorton, Physics for Scientists and Engineers, 3\textsuperscript{rd} edition [FGT3] and Halliday, Resnick, and Walker, Fundamentals of Physics, 6\textsuperscript{th} edition [HRW6] and its Problem Supplement #1 [HRW6s]. Answers are provided following this list. A solution set is presented separately.

1. Estimate the amount of water that one person drinks in their lifetime. Suggest a body of water of comparable volume.
   Some population analysts estimate that about 300 billion people may have lived on Earth over historical time. What is the total amount of water that has been drunk by Humankind? If that water has been well mixed in the oceans to a depth of 100 meters, what fraction of that oceanic water have people used? How many molecules of water in the next liter you drink have been shared by another person?

2. The flow rate of liquid through a cylindrical tube was studied by G.H.L. Hagen, who experimentally derived a formula describing it in 1838. The relationship was formulated by J.-L.M. Poiseuille in 1840 and is known usually as Poiseuille’s Law (but also as the Hagen-Poiseuille Law). This equation relates the volume rate of flow through the tube, \( Q = \frac{dV}{dt} \), in terms of the radius of the tube, \( r \); the length of the tube, \( L \); the difference of pressure between the ends of the tube, \( \Delta P \); and the resistance of the liquid to flow, its viscosity, \( \eta \), which has units of (force \cdot time)/area. Use dimensional analysis to find the form of this Law, without its dimensionless numerical constants. You will need one piece of empirical information to resolve the relationship fully: doubling the length of the tube reduces the flow rate by one-half.

3. A freight train travelling at 135 km/hr rounds a bend. As the train enters a straightaway, the station ahead comes into view and the engineer abruptly notices that a passenger train is stopped on the same track the freight train is using; the end of that train is 3000 meters away. He immediately applies the brakes to avoid a collision. What deceleration must the brakes be able to provide in order to do so?
   In fact, these brakes can only achieve a deceleration of \( a_1 = -0.16 \text{ m/sec}^2 \). Meanwhile, at the station, the alert engineer of the passenger train spots the advancing freight and reckons that it will not be able to stop in time. Reacting quickly, she is able to get the passenger train accelerating just 30 seconds after the freight engineer applies his brakes. However, the passenger train is only able to accelerate at \( a_2 = 0.12 \text{ m/sec}^2 \).
   Has she successfully averted a collision between the trains? If so, what is the closest approach made between the ends of the trains, how fast are they moving at that moment, and how far from the station does that happen? If there is a collision, where does it occur and what is the relative speed of the trains at that moment?
   [based on HRW6 2-34, -38]
4. A hotel elevator can travel 78 meters along its shaft. On a long run, the car requires 5 seconds to accelerate its cruising speed and 8 seconds to decelerate to a stop. It is found that on a run covering the entire shaft, the car reaches the half-way point in a climb in 47.5% of the total travel time. How long does the trip take? What are the values of the two accelerations and the cruising speed? Suppose a Health-O-Meter scale were placed in the elevator and an adult of 800 N weight (as measured, say, in the hotel lobby) chose to weigh themselves while riding the elevator. What would the scale read during each phase of travel?

5. An adult and child decide to have a game of catch at a large park, but the largest suitable space is on a 15º slope. They stand 20 meters apart, as measured along the slope, with the child taking the uphill position. If both players choose a comfortable throwing angle of 30º relative to the slope, how fast much each person throw the ball to reach the other one? If each player uses this throwing angle and can throw as fast as 20 m/sec, how far along the slope would the ball land in each direction?

6. A 12 kg. ladder with legs 2.8 m. long can be opened out to stand up, with the arrangement secured by a tie-rod of length 0.9 m. located halfway up the legs. A worker weighing 900 N climbs the ladder to stand on a rung 2.3 m. measured along one leg from its foot. The floor is taken to be frictionless. What are the tension in the tie-rod and the forces on the ladder from the floor at each pair of its feet? Suppose the tie-rod has been damaged and replaced (improperly) by an equal length of material with a crushing strength of 200 N. What is the highest safe point measured along the legs to which this same worker may now climb? [based on HRW6 13-31]

7. 

a) A set of four uniform bricks (or blocks or books) of identical mass and length L are stacked so that they overhang one another as far as possible, yet still maintain static equilibrium (although not very stably). What are the respective distances of overhang (and how far does the end of the top brick extend beyond the end of the table)?

b) Now we rearrange the bricks into the new configuration shown (this illustrates the principle of the cantilever). For static equilibrium, find the distances marked.

[based on HRW6 13-24, 34]
8.  

a) What amount of force \( F \) must be applied horizontally at the axle of a bicycle wheel of radius \( R \) and mass \( M \) in order to raise it over a step of height \( h \)? (Treat the wheel as a uniform hoop.) Does the answer change if the wheel is replaced by a solid uniform disk of identical mass and radius?[based on HRW6 13-21, FGT3 10-70]

b) A ramp 1.5 meters long is set up to be inclined 22º to the horizontal. Three objects are placed at the top of this ramp and released simultaneously from rest. They are a thin-walled tube of diameter 8 cm., length 20 cm., and mass 0.38 kg.; a solid cylinder of diameter 5 cm., length 35 cm., and mass 4.6 kg.; and a solid sphere of diameter 15 cm. and mass 12.5 kg. All three objects have uniform densities and roll down the ramp without sliding. In what order do they arrive at the bottom of the ramp and how long does each one take to get there?

9.  

a) A common variation of the Atwood machine is to use a wedge and arrange the blocks and pulley so that each block slides on individual surfaces of the wedge. Here we have one block with mass \( m_1 = 1.8 \) kg. on the inclined surface 40º above the horizontal; the other block with mass \( m_2 = 3.0 \) kg moves on the other inclined surface. All of the surfaces are frictionless, as is the pulley. What angle \( \theta_2 \) above the horizontal must the second surface have in order for the system to be in static equilibrium?

b) Suppose now that the surfaces have a coefficient of static friction \( \mu_s = 0.38 \) and that \( \theta_2 = 32^\circ \); \( m_1 \) is unchanged. What range of masses may be used for \( m_2 \) so that the system remains in static equilibrium?

c) If we now choose to use masses of \( m_1 = 1.8 \) kg. and \( m_2 = 9.2 \) kg, and the surfaces of the inclines in part (b) have a coefficient of kinetic friction \( \mu_k = 0.26 \), what is the acceleration of the masses?[based on FGT3 5-13, -14, 10-50, -56, HRW6s 11-93]
10.

a) A block of mass \( m_1 = 0.7 \) kg. rests on top of a larger block of mass \( m_2 = 1.3 \) kg., which starts at rest on a frictionless tabletop. A massless cord is attached to \( m_2 \), which is used to apply a horizontal force of 6 N. If the contact between the two blocks is frictionless, what are the accelerations of each block?

b) If instead the coefficients of friction between the two blocks are \( \mu_s = 0.45 \) and \( \mu_k = 0.32 \), what are the accelerations of the blocks for the same 6 N applied force? What is the largest force that can be applied so that the two blocks move together? What are the accelerations of the blocks if the applied force is 10 N? [based on FGT3 5-36]

c) Using the blocks in part (b), we now attach a spring with constant \( k = 72 \) N/m to the lower block. What is the largest amplitude with which the blocks may oscillate so that they will continue to move together? [based on HRW6 16-16]

11.

a) The engine of a 900 kg. automobile is generating 95 kW of useful mechanical power in order to sustain its speed at 65 mph during interstate highway driving. If the coefficient of rolling friction is \( \mu = 0.025 \) and the car is on level pavement, how much power is being used to overcome air drag?

b) If the drag on the automobile is proportional to \( v^2 \), but the frictional force remains the same, what power must the engine supply to sustain the car at 80 mph?

c) If the engine is now held at this power level and the car is now taken up a 12% grade (a climb of 12 m. for every 100 m. traveled horizontally), at what speed would the car now move? Assume the rolling friction is essentially unchanged.

d) With the engine off and the gearing in neutral, at what speed would the car coast on a 12% downgrade? (Neglect internal friction in the transmission and wheels.) [based on HRW6 9-56, -57, -58, HRW6s 9-70]

12. This is admittedly a goulash problem in mechanics.

a) A block of mass \( m_1 = 0.100 \) kg. is initially held at rest in a spring launcher; the spring has constant \( k_1 = 100 \) N/m and is initially compressed by \( \Delta x = 11.0 \) cm. The launcher sits on a frictionless incline. It is located at a height \( H = 35 \) cm. above the bottom of a frictionless concave surface and is aimed at an angle \( \theta_1 = 25^\circ \) below the horizontal. (continued)
When this block is launched, it races down the curved ramp. At the bottom, it collides elastically with a second block of mass \( m_2 \). The second block now starts up the other incline. However, at a height \( h_1 = 2.5 \) cm. above the bottom, the incline ceases to be curved or frictionless: it is now straight and inclined \( \theta_2 = 9^\circ \) above the horizontal and has a coefficient of kinetic friction of \( \mu_k = 0.17 \). Upon ascending by an additional height \( h_2 = 5 \) cm., this block strikes a spring bumper with constant \( k_2 = 25 \) N/m, which brings the block momentarily to rest after being compressed by \( \Delta y = 5.0 \) cm.

Meanwhile, on the other side of this set-up, the first block has traveled back up its own ramp, where it just comes to rest momentarily as it reaches the spring launcher. What must the mass \( m_2 \) be?

b) On a second launch, we make one slight change by altering the compression \( \Delta x \) of the launcher spring. Now the second block travels up the rough incline and just comes to rest for an instant upon reaching the spring bumper, without compressing it. What is \( \Delta x \) this time?

13. a) An old-fashioned escapement clock (a “grandfather clock”) is regulated by the oscillation of a heavy pendulum set in motion. The pendulum is a long heavy shaft with a slot at the lower end, in which the position of a massive “bob” may be adjusted. For our particular clock, the shaft is essentially uniform in density and has a length \( L = 1.100 \) m. and mass \( m = 2.000 \) kg.; the bob is basically a uniform disk of radius \( r = 0.080 \) m. and mass \( M = 5.000 \) kg. (We will treat the pivot as being located just at the upper end of the shaft.) This physical pendulum should be adjusted so that its period is 2.000 seconds. (The escapement allows the clock gearing to advance at each half-oscillation.) How far is the center of the bob from the pivot point? Let us suppose that this clock is originally adjusted for a location at sea level on the Equator (where \( g_e = 9.78033 \) m/sec\(^2\)). [based on FGT3 13-64]

b) With the passing of the seasons, we find that, while the pendulum is adjusted correctly for the warmer months, with the arrival of cooler weather, the length of the shaft has contracted by 0.10%. How much time will our clock be off by after one week? In what way and by how much should the bob be adjusted? [based on HRW6s 16-71, -72, -90]

14. A block attached to a spring with constant \( k = 64 \) N/m is free to slide on a frictionless horizontal surface. At some particular instant, the displacement from equilibrium for the block is observed to be \( \Delta x = -0.37 \) m., the velocity is \( v = 2.64 \) m/sec, and the acceleration is \( a = 1.90 \) m/sec\(^2\). Find the angular frequency, \( \omega \), of the oscillation, and thus its period, \( T \). What is the mass of the block? Determine the amplitude of the oscillation, \( A \), and the phase angle, \( \phi \). Then write an equation describing \( \Delta x \) as a function of time. Calculate the total mechanical energy \( E \) for the spring-block system. [based on HRW6 16-19]
15. Consider two identical uniform spheres of radius $R$ and density $\rho$. A spherical cavity of diameter $R$ is carved out of each one, extending from the center of the sphere to its surface. For sphere A, this cavity is then filled with material of uniform density $3\rho$, while for sphere B, the cavity is left vacant.

a) Find the mass of each sphere in terms of $\rho$ and $R$.

b) Find the moment of inertia of each sphere about an axis through the center of the sphere and of the cavity, in terms of each sphere’s mass and $R$.

c) Find the moments of inertia about axes through the center of each sphere perpendicular to the axis described in part (b).

d) Determine the center of mass of each sphere.

e) Find the moments of inertia about axes parallel to those in part (c), but passing through the centers of mass.

[based on FGT3 9-35]

16. An old-fashioned phonograph turntable is set to spin at 45 rpm. A small plastic block of mass 18 gm. is located 6 cm. from the rotation axis.

a) If the block is to stay in place on the platter, what is the lowest value that the coefficient of static friction, $\mu_s$, between the block and the platter may have?

b) If the block were to be located at the rim of the platter, 15 cm. from the rotation axis, what minimum value for $\mu_s$ would now be required?

c) If this coefficient were instead $\mu_s = 0.23$, what would be the maximum distance from the rotation axis at which the block could remain on the platter without sliding?

d) Suppose the turntable is initially at rest. For the same level of static friction as in part (c), and with the block at the original distance of 6 cm. from the rotation axis, what is the shortest amount of time in which the platter could accelerate uniformly to its final angular speed of 45 rpm, without dislodging the block?

[based on HRW6 11-32]

17. A beaker of mass 95 gm., containing 1.36 kg. of water, is placed on a platform scale. A 840 gm. block of aluminum, with density 2.65 gm/cm$^3$, is suspended from a spring scale and is completely immersed in the water. What are the weight readings on each scale? Does it make a difference if an 840 gm. block of magnesium (density 1.74 gm/cm$^3$) is used instead? [based on FGTe 16-19]
b) A metal rod of 75 cm in length and mass of 2.8 kg. has a uniform cross-sectional area of 8.0 cm$^2$. However, as this rod is not uniformly dense, its center of mass is 25 cm from one end. The rod is suspended horizontally from cords fastened at each end and is completely immersed in water. Find the tension in each cord. (Note: the buoyancy force effectively acts at the center of the rod.)

Suppose the cord farther from the center of mass were removed. Where would the center of mass need to be so that the rod would maintain a level orientation?

[based on HRW6 15-37]

18. A research balloon is intended to lift 450 kg. of equipment (including the mass of the balloon itself) into the upper stratosphere. At the launch point of the ground, the density of air is 1.3 kg/m$^3$, while the density of helium is 0.18 kg/m$^3$. What mass of helium is required in order that the balloon and payload lift off from the ground with an initial acceleration of 0.05 m/sec$^2$? If STP conditions (1 atm. pressure, 20º C.) exist at the launch site, what volume of helium is used?

At the destination altitude of 40 km., the air temperature is -12º C. and the pressure is 0.29 kPa (NASA Earth Atmosphere Model). Assume no leakage of helium in flight, what is the volume of the balloon there?

19.

a) A filled container of water of height H has a circular hole of radius R punched through its bottom. As the water runs out, the stream narrows for a while before dynamical instabilities cause the stream to break up into spray. Where the stream is stable, find its radius, in terms of R, as a function of distance from the bottom of the container, y. At what point has the stream narrowed to 0.75R? [based on FGTe 16-26]

b) A storage drum of water with height H and cross-sectional area A sits on the floor of a warehouse. It is suddenly punctured through its side by a hole of area a at a height Y above the floor. Find an expression for the distance x away from the side of the drum where the stream of water lands. Also, find an expression for the rate at which this landing point moves. [based on HRW6 15-54]

20.

a) A student at a fast-food restaurant is drinking soda through a straw; the liquid in the cup has a depth D. If the student produces “suction” by reducing the pressure at the end of the straw in their mouth to 0.97 atm., how fast is the soda traveling when it enters their mouth? If the cross-sectional area of the straw is 0.25 cm$^2$, how fast can the student drink, in terms of volume rate of flow?
b) Consider a horizontal tube with cross-sectional area \( A \) which ends in a constriction with area \( a = A/9 \). If the pressure applied to the water at the wide end of the tube is \( p = 2.0 \) atm., what fluid velocity \( V \) through area \( A \) will cause the pressure at the mouth of the constriction to become \( p' = 0 \)? What is the water's velocity \( v \) through area \( a \)? If the diameter of the wide end is \( 0.30 \) cm., what is the volume flow rate through this tube? (Note: the drop of pressure to zero causes the liquid to spontaneously "explode" into vapor, in a process called cavitation; this is the principle behind such devices as atomizers and automobile carburetors.)

[based on HRW6 15-55, 56]

21.

a) A bubble of methane having a volume of \( 0.6 \) cm\(^3\) forms at the bottom of lake 22 meters deep, where the water temperature is \( 6^\circ \) C. It separates from its point of origin and rises to the surface, where the temperature is a balmy \( 32^\circ \) C. and the barometric pressure is \( 1027 \) kPa. Assume that the bubble is in thermal equilibrium with its surroundings at every point along the way; further assume that the water temperature changes linearly along that path. Find an expression for the volume of the bubble as a function of depth, \( y \). What is the bubble's volume when it is half-up? At the surface?

[based on FGT e 17-57]

b) An insulated cylinder is fitted with a gas-tight, moveable piston with surface area \( 140 \) cm\(^2\), which is subject to atmospheric pressure. When the gas in the chamber is heated from \( 15^\circ \) to \( 35^\circ \) C., it is found that a \( 10.0 \) kg. mass needs to be placed on top of the piston to restore it to its original position.

If the height of the chamber is initially \( 18.0 \) cm., how many moles of gas are in the cylinder? Now starting from the situation at \( 35^\circ \) C., find an expression for the height of the chamber as a function of temperature, with the same mass still atop the piston. What is the chamber's height at \( 45^\circ \) C.?

If the height of the chamber is to be kept constant, again starting from the situation at \( 35^\circ \) C., find an expression for the amount of mass which must be placed on the piston as a function of temperature. How much mass is required at \( 45^\circ \) C.?

[based on FGT e 17-56]
22.

a) Three cups (710 mL) of 12º C. water is poured into an electric blender and stirred by the rotating blades for 20 seconds. The three blades can be treated as paddles or rods with effective lengths of 2 cm. and masses of 3 gm. each; they spin at 800 rpm. The mechanical power delivered to the water is estimated by $P \approx 100 \cdot \omega^3$ (finding a more precise result is beyond the scope of this course). What is its final temperature of the water? Assume that the loss of heat from the water to its surroundings is negligible.

b) An old cartoon is found on a storeroom shelf which contains a block of some sort of alloy. The faded, handwritten label indicates that it is 64% copper and 36% [something else]; the rest of the writing has become illegible. It is found that the block has a mass of 96 gm. An insulated calorimeter with 240 gm. of water at 18.0º C. is prepared. The block is warmed to 72.0º C. and quickly placed into the water. The final equilibrium temperature in the calorimeter is measured at 20.0º C. Given that the specific heat of copper is 0.385 J/gm-K, what is the specific heat of the unknown alloy constituent? (It may be identifiable on this basis.)

c) A sheet of ice at -5º C. lies 1.0 cm. thick on a stretch of pavement in Minneapolis in January. The average intensity of sunlight at that time of year, in the hours around midday, is about 300 W/m² with a clear sky. If 60% of this energy goes into heating and melting the ice, how many hours would it take to remove this ice sheet, in the absence of other aids? The specific heat of ice is 0.49 cal/gm-K, the latent heat of fusion of water is 80 cal/gm-K, and the density of ice is 0.917 gm/cm³.

23.

a) Into an insulated container holding 685 gm. of water at 19º C. is placed 115 gm. of ice at -8º C. What is the entropy change in this system in attaining its equilibrium state?

If instead the quantity of ice were tossed into Lake Superior at a time when its surface temperature was 13º C., what would be the entropy change in the ice and lake in attaining thermal equilibrium? [based on HRW6 21-15, 16]

b) A gas-tight container has two chambers of identical volume separated by a gas-tight, removable partition. In one chamber, $n$ moles of oxygen are placed initially, while $n$ moles of nitrogen are placed in the other chamber; all of the gas is at the same temperature. The partition is suddenly removed and the two gases are free to intermingle. On reaching equilibrium, what is the entropy change in the container?

This procedure is repeated with $n$ moles of nitrogen in both chambers. What is the entropy change in the container on attaining equilibrium this time?

c) Twenty (20) six-sided dice are initially arranged in a row so that they all have identical orientations (for example, “6”-side facing up, “4”-side facing west). They are then jumbled into a state where no two dice have the same orientation (that is, if any two have the same side up, they have different sides facing west). What is the entropy change between the initial and final “states” of this set of dice?
For the thermodynamic cycle described in the graph above, fill in the two tables below. What is the thermodynamic efficiency of this cycle? What is its Carnot efficiency?

<table>
<thead>
<tr>
<th>Point</th>
<th>p (atm.)</th>
<th>V (L)</th>
<th>T (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>16</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>D</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process</th>
<th>ΔU (J)</th>
<th>W (J)</th>
<th>Q (J)</th>
<th>ΔS (J/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A → B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B → C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C → D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D → A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

totals for cycle
1. \( \sim 40,000 \) liters (small pond); \( \sim 1 \cdot 10^{13} \text{ m}^3 \); \( \sim 3 \cdot 10^4 \); \( \sim 1 \cdot 10^{22} \)

2. \( Q = \frac{r^4 \cdot \Delta P}{(\eta \cdot L)} \)

3. \(-0.234 \text{ m/sec}^2\); collision is averted: \( 37.5 \text{ m} .\), \( 14.0 \text{ m/sec} \), the end of the passenger train is \( 820 \text{ m} \) from where it started

4. 30 sec.; \( a_1 = 0.664 \text{ m/sec}^2 \), \( a_2 = -0.415 \text{ m/sec}^2 \); \( v = 3.32 \text{ m/sec} \)
   at \( a_1 \); \( 854 \text{ N} \); at \( v \); \( 800 \text{ N} \); at \( a_2 \); \( 766 \text{ N} \)

5. child throwing to adult: \( 13.76 \text{ m/sec} \), \( 42.2 \text{ m} \);
   adult throwing to child: \( 16.09 \text{ m/sec} \), \( 30.9 \text{ m} \)

6. tension in tie-rod: \( 271 \text{ N} \) in compression;
   normal force at rear feet: \( 589 \text{ N} \), at forward feet: \( 429 \text{ N} \), \( 1.65 \text{ m} \)

7. a) \( a_1 = (1/2)L \), \( a_2 = (1/4)L \)
   b) \( b_1 = (3/5)L \), \( b_2 = (1/2)L \), \( h = (25/24)L \)

8. a) \( F = \left( 2RH - h^2 \right)^{1/2} / (R-h) \) \cdot Mg, regardless of rotational inertia of wheel
   b) sphere: \( 1.070 \text{ sec} \), cylinder: \( 1.107 \text{ sec} \), tube: \( 1.278 \text{ sec} \)

9. a) \( 22.7^\circ \) b) \( 0.743 \text{ m}^2 \) c) \( 0.09 \text{ kg} \)

10. a) \( 30 \text{ sec} \), \( a_1 = 0.664 \text{ m/sec}^2 \), \( a_2 = 0.415 \text{ m/sec}^2 \);
    \( v = 3.32 \text{ m/sec} \)
    at \( a_1 \); \( 3.14 \text{ m/sec} \), \( 6.00 \text{ m/sec} \)

11. a) \( 88.6 \text{ kW} \) b) \( 171.6 \text{ kW} \) c) \( 33.0 \text{ m/sec} \) d) \( 15.2 \text{ m/sec} \)

12. a) \( m = 0.402 \text{ kg} \) b) \( \Delta x = 9.6 \text{ cm} \)

13. a) \( 1.0422 \text{ m} \) b) \( 306 \text{ sec} \), fast, lower bob by \( 1.2 \text{ mm} \)

14. \( \omega = 2.266 \text{ rad/sec} \), \( T = 2.77 \text{ sec} \), \( m = 12.5 \text{ kg} \), \( A = 1.18 \text{ m} \);
   \( \phi = -0.308 \text{ rad} \); \( \Delta x = 1.18 \sin(2.266 t - 0.308) \text{ m} \); \( E = 44.6 \text{ J} \)

15. a) \( M_A = (5/3)\pi R^3 \), \( M_B = (7/6)\pi R^3 \)
   b) \( (17/50)M_A R^2 \), \( (31/70)M_B R^2 \)
   c) \( (39/100)M_A R^2 \), \( (57/140)M_B R^2 \)
   d) A: \( R/10 \) from center of sphere toward dense sphere,
      B: \( R/14 \) from center of sphere away from cavity
   e) \( (19/50)M_A R^2 \), \( (197/490)M_B R^2 \)

16. a) \( 0.136 \) b) \( 0.339 \) c) \( 0.102 \text{ m} \) d) \( 0.155 \text{ sec} \)

17. a) aluminum block -- spring scale: \( 5.13 \text{ N} \), platform scale: \( 17.4 \text{ N} \);
    magnesium block -- spring scale: \( 3.50 \text{ N} \), platform scale: \( 19.0 \text{ N} \)
    b) \( T_{\text{rear}} = 15.4 \text{ N} \), \( T_{\text{far}} = 6.21 \text{ N} \), \( 0.080 \text{ m} \)

18. \( 72.8 \text{ kg} \); \( 408 \text{ m}^3 \); \( 134,400 \text{ m}^3 \)

19. a) \( r = R \cdot \left[ \frac{H}{(H+y)} \right]^{1/4} \) ; \( y = (175/81)H \)
   b) \( x = \left[ 2Y \cdot (H-Y) \right]^{1/2} \) ; \( dx/dt = -(a/A) \cdot (2gY)^{1/2} \)

20. a) \( 2.5 \text{ m/sec} ; 63 \text{ cm/sec} \) b) \( V = 2.25 \text{ m/sec} ; v = 20.3 \text{ m/sec} ; 15.9 \text{ cm/sec} \)
21. a) \( V = (0.6) \cdot \left( \frac{318,500}{102,700 + 9810 \cdot y} \right) \cdot \left( \frac{305.2 - \{13/11\} \cdot y}{279.2} \right) \) cm\(^3\);
    at \( y = 11 \) m., \( V = 0.950 \) cm\(^3\); at \( y = 0 \), \( V = 2.03 \) cm\(^3\);
    b) \( n = 0.107 \) moles; \( h = (18.0) \cdot \left( \frac{T}{308.2} \right) \) cm, 18.6 cm.
    \( M = 10 + \left[ 154.6 \cdot \left( \frac{T - 308.2}{308.2} \right) \right] \) kg, 15.0 kg.

22. a) 12.5° C.  
    b) 0.433 J/gm-K  
    c) 3.60 hours

23. a) \( \Delta S_{\text{water}} = -149.0 \) J/K, \( \Delta S_{\text{ice}} = +155.3 \) J/K, \( \Delta S_{\text{total}} = +6.3 \) J/K; \( \Delta S_{\text{total}} = +7.2 \) J/K
    b) \( \Delta S = 2nR \ln 2 \); \( \Delta S = 0 \)  
    c) \( \Delta S = k \ln(23!/4!) \approx 48.43 \) J/K

24.

<table>
<thead>
<tr>
<th>Point</th>
<th>( p ) (atm.)</th>
<th>( V ) (l)</th>
<th>( T ) (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>1.5</td>
<td>292.4</td>
</tr>
<tr>
<td>B</td>
<td>16</td>
<td>3.5</td>
<td>682.3</td>
</tr>
<tr>
<td>C</td>
<td>4.67</td>
<td>12</td>
<td>682.3</td>
</tr>
<tr>
<td>D</td>
<td>2.0</td>
<td>12</td>
<td>292.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process</th>
<th>( \Delta U ) (J)</th>
<th>( W ) (J)</th>
<th>( \Delta S ) (J/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A ( \rightarrow ) B</td>
<td>+4862</td>
<td>-3242</td>
<td>+8104</td>
</tr>
<tr>
<td>B ( \rightarrow ) C</td>
<td>0</td>
<td>-6990</td>
<td>+6990</td>
</tr>
<tr>
<td>C ( \rightarrow ) D</td>
<td>-4862</td>
<td>0</td>
<td>-4862</td>
</tr>
<tr>
<td>D ( \rightarrow ) A</td>
<td>0</td>
<td>+5055</td>
<td>-5055</td>
</tr>
</tbody>
</table>

totals for cycle: \( 0 \) \( -5177 \) \( +5177 \) 0

Carnot efficiency, \( \eta_c = 0.571 \), cycle efficiency, \( \eta = 0.343 \)

G. Ruffa -- revision 5/23/11