Physics 22 Practice Final - 3 hours
2 pages

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Write your answers in a blue book. Calculators and one page of notes allowed. No textbooks allowed. Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Make it clear what you think is known, and what is unknown and to be solved for. Except for extremely simple problems, derive symbolic answers, and then plug in numbers (if necessary) after a symbolic answer is available. For numerical work, take the acceleration of gravity near the earth to be $g = 10\,\mathrm{m/s^2}$ and the density of water $\rho_w = 10^3\,\mathrm{kg/m^3}$ and 1 atm $= 10^5\,\mathrm{Pa}$. **Put a box around your final answer... otherwise we may be confused about which answer you really mean, and you could lose credit.**

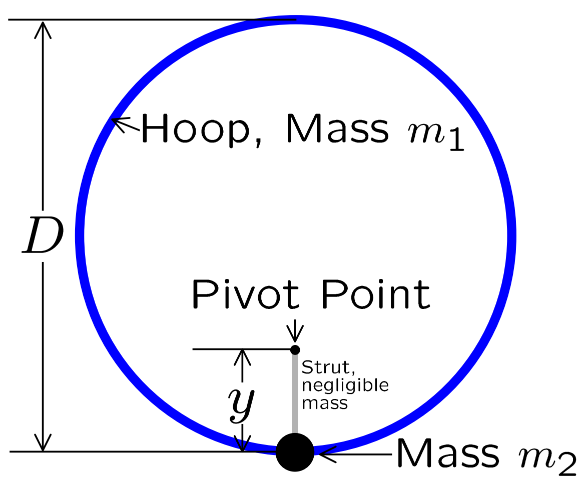

Figure 1: For use in problem 1.

1. A uniform hoop of mass m_1 and diameter D, as shown in Fig. 1, has a mass m_2 of negligible size attached. This system is made into a physical pendulum, by rigid attachment of a strut of length y and of negligible mass to the bottom of the hoop; the system pivots about the upper end of the strut, as shown in Fig. 1.

   (a) If y is too small, the orientation of the pendulum shown in Fig. 1 is not stable. Find the minimum value of y for the orientation to be stable, in terms of the given quantitites.

   (b) Determine the moment of inertia of the pendulum in terms of the given quantities.

   (c) Determine the period squared, that is, $T^2(y)$, of the pendulum as a function of the given quantities and the acceleration of gravity, g. Leave the distance of the center of mass of the pendulum from the the top of the bar, $y_{\rm cm}$, explicitly in your formula, without substituting for $y_{\rm cm}$ as a function the other quantities.

2. A 1/2 kg mass is on a spring in one dimension, and the circular natural frequency is $\omega_0 = 2\pi(1/\text{s})$. The damping force is $-b \times v$, where v is the velocity, and b is the coefficient of friction. What numerical value of b will cause the spring to be critically damped? Obtain a numerical result.

3. You have a hypo-squirt gun filled with water in outer space, where there is no gravity and no atmosphere. The hypo-squirt gun is a cylindrical piston with a tiny hole in the wall opposite the moving wall or plunger of the piston. The radius of the tiny hole is 0.05 cm, and the radius of the plunger is 5 cm. You push the plunger with a force of 500π N.

   (a) Draw a picture of the hypo-squirt gun.

   (b) What is the speed of the water as it exits the hole in the squirt gun, both symbolically and numerically?

4. A particular two moles of monatomic hydrogen atoms, which has a mass of 2 gm, is at a temperature of 600 K. Another mole of monatomic neon atoms, which has a mass of 20 gm, is also at a temperature of 600 K. Which gas has the larger internal energy? Which gas has the larger root-mean-squared velocity? Take the ideal gas constant to be $R = 8\text{J/K}$.

5. A gas-filled piston is run *backward* through a Carnot cycle. The low temperature, T_L, is the inside of a refrigerator. The high temperaturre, T_H, is the temperature of a kitchen. So, what happens in the reversed Carnot cycle is that a net work W is done on the gas in the piston, and heat Q_L is removed from the refrigerator at low temperature and then $-Q_H$ is deposited into the room at the high temperature. The figure of merit for a this situation is C, where

$$C = \frac{Q_L}{W} \, ,$$

   where c tells you how much heat removed you get per unit of work done.

   (a) Sketch the PV diagram, where the cycle starts at point d, the low volume point at T_L, and proceeds through c the high volume point at T_L, b the high volume point at T_H, a the low volume point at T_H, and then back to d.

   (b) Evaluate C in terms of the other quantities of this problem.

   (c) Which situation has a larger C: $\#1) T_L = 283\,\text{K}$ and $T_H = 293\,K$, or $\#2) T_L = 273\,\text{K}$ and $T_H = 293\,\text{K}$?

6. Consider a two shelf system, where $E_0 = mg|z| = 0.02\,\text{eV}$. An electron volt (eV) is a unit of energy equal to 1.6×10^{-19} Joules, and the eV is a unit appropriate for studying atoms and molecules. In these units, Boltzmann's constant is $k = 8.62 \times 10^{-5}\,\text{eV/K}$. There are $N = 10,000$ molecules in the two shelf system, and $N_\downarrow = 2,500$ are on the lower shelf. Determine, symbolically and numerically:

   (a) U, the internal energy of the system.

   (b) T, the temperature of the system.

   (c) σ, the dimensionless entropy of the system.