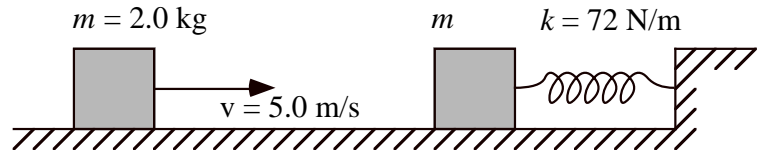


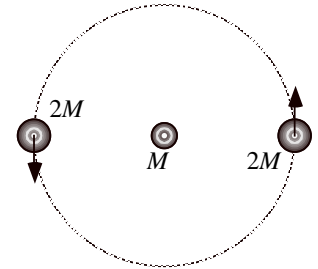
Name ! \_\_\_\_\_

**PLEASE READ THIS FIRST:** Work the problems on separate sheets of paper and staple *this* sheet to the front. Read each problem *carefully*. The credit you receive on each problem will depend *at least* as much on how you get your answer as on what answer you get. There is *no* need to be as “wordy” as I ask you to be on homework, but you must show your work or give at least a brief explanation for *every* answer. I give *no* credit for unsupported answers. I give partial credit for partially correct solutions, but *only* when I can figure out what you are doing, so be as clear as possible. Make *certain* that all numerical answers are given with a reasonable number of significant digits (when in doubt, three is usually a good compromise) and that you have included *appropriate* and *simplified* units. Check your answers for physical *reasonableness* whenever possible; I do deduct points for ridiculous answers that go unmentioned upon.

1. A 2.0 kg block slides along a frictionless surface at 5.0 m/s toward an identical block that is sitting at rest attached to a 72 N/m spring as shown at right. The first block strikes and *sticks to* the second and the combination oscillates thereafter.

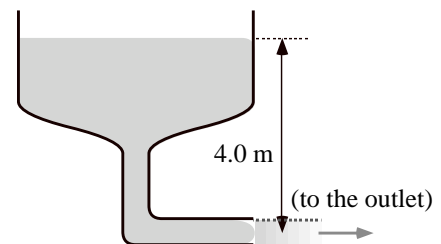


- [8 pts] How long a time does it take to complete one oscillation?
  - [8 pts] What is the maximum amount that the spring is ever compressed? [Hint: Momentum is conserved.]
  - [4 pts] How does the energy of the oscillating spring and combined block system compare to the kinetic energy of the first block before the collision? Explain!
2. Consider a system of three stars, two of which have mass  $2M$  and orbit about a motionless third star of mass  $M$  along the same circular path of radius  $R$  as shown at right.



- [8 pts] Find the *magnitude* of the *net* force on either of the two orbiting stars (in terms, of course, of the givens— $M$  and  $R$ .)
- [12 pts] Therefore, find the orbital period of either orbiting star (in terms of  $M$  and  $R$ .)

3. Water in a large vertical cylinder of diameter  $D$  is open to the air above and is draining out through a narrower pipe that has a diameter  $D/10$  as shown in the figure. The surface of the water in the large vertical pipe is descending at a speed of 12.0 cm/s. [Note: The outlet is *not* shown in the figure and may be higher or lower than the horizontal section of pipe.]



- [10 pts] What is the flow speed of the water in the narrower pipe? [Big hint: It *has* to speed up when the cross sectional area gets smaller.]
- [10 pts] What is the *gauge pressure* in the horizontal pipe, 4.0 m below the surface of the water in the vertical pipe? [Hints: Apply Bernoulli's principle between two *clearly* indicated points. Recall that gauge pressure is simply the *actual* pressure minus atmospheric pressure. The density of water is  $1.00 \times 10^3 \text{ kg/m}^3$ .]

EXTRA CREDIT [5 pts] The narrow pipe continues on to an open air outlet (not shown in the figure) without changing its diameter. Is the open air outlet at a higher or lower elevation than the horizontal section of pipe in the figure?

(over)

4. A diatomic ideal gas originally at pressure  $P_0$  and volume  $V_0$  is heated at constant volume until its pressure increases by a factor of 3. Next it is isothermally expanded until its pressure returns to  $P_0$ . Finally it is isobarically compressed to its initial volume.

- a) [4 pts] Show the process on a  $PV$  diagram.  
 b) [12 pts] Complete a simple table like that shown at right that gives the heat transfer to the gas, the work done by the gas, and the energy change of the gas for *each* of the three legs of this cycle. [All entries should be in terms of the “givens”— $P_0$  and  $V_0$ .]  
 c) [4 pts] What would be the “efficiency” of a heat engine based on this cycle?

leg	$Q$	$W$	$\Delta E$
1			
2			
3			

EXTRA CREDIT [5 pts] What is the maximum efficiency possible for a heat engine operating between the same temperature extremes that are found in this cycle?

5. Two isotropic sources (i.e., sources that emit equal power in all directions) oscillate in phase and emit sound of the same single frequency.  $S_1$  produces 10 W of acoustic power.

- a) [10 pts] How much power would  $S_2$  have to produce in order for it to sound just as loud at position  $P$  as  $S_1$  does?

An observer walking away from  $S_2$  hears a maximum intensity at point  $P$ . Then the intensity decreases for awhile and then rises again to *another* maximum as she approaches point  $Q$ .

- b) [10 pts] What is the wavelength of the sound?

EXTRA CREDIT [5 pts] How would your answer to part b have changed if I had said that the observer hears *minimum* intensities at both points  $P$  and  $Q$  **AND** would it have been *possible* to have *minimum* intensities at both points  $P$  and  $Q$ ? Explain very clearly why or why not!

