Multiple-choice questions (56 points; 8 points per question). For each of these seven questions, mark a clear “X” in the box next to the one best answer.

1. You double the mass of an oscillating mass-spring system while keeping the amplitude and spring constant the same. What effect does this have on the total mechanical energy of the system?

☐ A. The total mechanical energy becomes 4 times its previous value
☐ B. The total mechanical energy becomes twice its previous value
☐ C. The total mechanical energy becomes $\sqrt{2}$ times its previous value
☐ D. The total mechanical energy is unchanged
☐ E. The total mechanical energy becomes $1/\sqrt{2}$ times its previous value
☐ F. The total mechanical energy becomes 1/2 times its previous value
☐ G. The total mechanical energy becomes 1/4 times its previous value

2. A paint sprayer pumps air through a constriction in a 2.50-cm diameter pipe, as shown in the figure. The flow causes a pressure drop in the constricted area, so paint rises up the feed tube and enters the air stream. The speed of the air stream in the 2.50-cm diameter sections is 5.00 m/s. The density of the air is 1.29 kg/m$^3$, and the density of the paint is 1200 kg/m$^3$. We can treat the air and paint as incompressible ideal fluids. What is the maximum diameter of the constriction that will allow the sprayer to draw paint upward to the center of the constricted area?

☐ A. 0.260 cm
☐ B. 0.405 cm
☐ C. 0.807 cm
☐ D. 0.965 cm
☐ E. 0.122 cm
☐ F. 0.143 cm
☐ G. 0.244 cm

(MULTIPLE-CHOICE QUESTIONS CONTINUE ON THE NEXT PAGE)
3. A 70-g aluminum calorimeter contains 230 g of water. The calorimeter and water are at an equilibrium temperature of 20°C. A 190-g piece of metal, initially at 254°C, is added to the calorimeter. The final temperature at equilibrium is 32°C. Assume there is no external heat exchange. The specific heats of aluminum and water are 910 J/kg·K and 4190 J/kg·K, respectively. The specific heat of the metal is closest to:

- A. 190 J/kg·K.
- B. 220 J/kg·K.
- C. 250 J/kg·K.
- D. 270 J/kg·K.
- E. 290 J/kg·K.
- F. 320 J/kg·K.

4. You want to insert an aluminum rod, which at 20.0°C has a radius of 1.000200 cm, into a copper tube which has a radius of 1.000100 cm at 20.0°C. You decide to put both of them in the refrigerator. At what temperature will the rod just fit if both are cooled to the same temperature? The coefficient of thermal expansion for aluminum is $2.4 \times 10^{-5}$ K$^{-1}$, and that of copper is $1.7 \times 10^{-5}$ K$^{-1}$.

- A. 4.8°C
- B. 5.7°C
- C. 6.3°C
- D. 7.8°C
- E. 9.2°C
- F. 15°C

(MULTIPLE-CHOICE QUESTIONS CONTINUE ON THE NEXT PAGE)
5. Star #1 has a surface temperature of 6000 K (about the same as the Sun), while star #2 has a surface temperature of 3000 K. Star #2 radiates 256 times more energy per second than does star #1. Compared to the radius of star #1, the radius of star #2 is larger by a factor of

A. 2
B. 4
C. 8
D. 16
E. 32
F. 64
G. 128
H. 256
I. 512
J. 1024

6. This is a graph of displacement versus time for an object connected to an ideal spring and moving in simple harmonic motion. At which of the following times does the kinetic energy of the object have its maximum value?

A. \( T/8 \)
B. \( T/4 \)
C. \( 3T/8 \)
D. \( T/2 \)
E. \( 5T/8 \)
F. \( 3T/4 \)
G. \( 7T/8 \)
H. More than one of the above
I. None of the above

(MULTIPLE-CHOICE QUESTIONS CONTINUE ON THE NEXT PAGE)
7. An ideal massless spring with a spring constant of 2.00 N/m is attached to an object of 75.0 g. The system has a small amount of damping. If the amplitude of the oscillations decreases from 10.0 mm to 5.00 mm in 15.0 s, what is the magnitude of the damping constant $b$?

☐ A. 0.00693 kg/s
☐ B. 0.00762 kg/s
☐ C. 0.00857 kg/s
☐ D. 0.0100 kg/s
☐ E. 0.0139 kg/s
☐ F. 0.0152 kg/s
☐ G. 0.0171 kg/s
☐ H. 0.0200 kg/s
☐ I. 0.0462 kg/s
☐ J. 0.0924 kg/s
Problem (44 points)

A ball of mass $m$ is suspended from a very light string of length $L$ and is pulled to the left by a small angle $\theta$. The ball is then released. The ball swings without friction, and at the lowest part of its motion (when the string is vertical) it encounters an ideal massless spring of spring constant $k$ attached to the wall.

The ball compresses the spring, comes momentarily to rest, then is pushed back by the spring until the string is again vertical. The ball then loses contact with the spring, and the ball swings back to its original starting position. The motion then repeats.

(a) **Find the time for one complete cycle of this motion.** Assume that no energy is lost in the collision between ball and spring, and that once the ball hits the spring there is no effect due to the vertical movement of the ball. Your answer should involve no quantities other than $m$, $L$, $\theta$, $k$, and $g$. (It may or may not involve all of these quantities. You will lose points if you substitute a numerical value for $g$.)

For full credit, **show your work, simplify your answer, and draw a box around your final answer.**

(continued on next page)
Problem (continued)

(b) **Find the maximum distance that the spring is compressed during the motion.** Assume that no energy is lost in the collision between ball and spring, and that once the ball hits the spring there is no effect due to the vertical movement of the ball. Your answer should involve no quantities other than $m, L, \theta, k,$ and $g$. (It may or may not involve all of these quantities. You will lose points if you substitute a numerical value for $g$.)

For full credit, **show your work, simplify your answer, and draw a box around your final answer.**