Each problem will be graded on a scale of 0-4 points. You are asked to do any 8 of the problems.

Clearly indicate your choices, by listing here the two problems that you are not going to attempt:
a) _______ b) _______.

Show all your work on separate pages for each problem. Please use only one side of the paper to work the problems!
Collect your work together in numerical order (number each page) by problem when you finish, including your equation sheet at the end, use the envelope provided to store your work and the exam. Good luck!

Please confirm your student ID number: **Master.**

**DO NOT WRITE YOUR NAME!**

1. A particle moves in a plane according to
   \[ x = R \sin \omega t + \omega R t \]
   \[ y = R \cos \omega t + R. \]

   where \( \omega \) and \( R \) are constants. This curve, called a cycloid, is the path traced out by a point on the rim of a wheel that rolls without slipping along the \( x \) axis. (a) Sketch the path. (b) Calculate the instantaneous velocity and acceleration when the particle is at its maximum and minimum value of \( y \).

2. A 2.0-kg block is released from rest at the top of a 22° frictionless inclined plane of height 0.65 m. At the bottom of the plane it collides with and sticks to a block of mass 3.5 kg. The two blocks together slide a distance of 0.57m across a horizontal plane before coming to rest. What is the coefficient of friction of the horizontal surface?
3. A 1400-kg cannon, which fires a 70.0-kg shell with a muzzle speed (the speed along the length of the cannon, relative to the cannon) of 556 m/s, is set at an elevation angle of 39.0° above the horizontal. The cannon is mounted on frictionless rails, so that it recoils freely, (a) What is the speed of the shell with respect to the Earth? (b) At what angle with the ground is the shell projected? (Hint: The horizontal component of the momentum of the system remains unchanged as the gun is fired.)

4. A thin horizontal bar \(AB\) of negligible weight and length \(L\) is pinned with a frictionless pivot to a vertical wall at \(A\) and supported at \(B\) by a thin wire \(BC\) that makes an angle \(\theta\) with the horizontal. A weight \(W\) can be moved anywhere along the bar as defined by the distance \(x\) from the wall. (a) Find the tension \(T\) in the thin wire as a function of \(x\). (b) Find the horizontal and the vertical components of the force exerted on the bar by the pin at \(A\). (c) With \(W = 315\) N, \(L = 2.76\) m, and \(\theta = 32.0^\circ\), find the maximum distance \(x\) before the wire breaks if the wire can withstand a maximum tension of 520 N.

5. A small solid marble of mass \(m\) and radius \(r\) rolls without slipping along the loop-the-loop track shown in the figure, having been released from rest somewhere on the straight section of track. (a) From what minimum height above the bottom of the track must the marble be released in order that it just stays on the track at the top of the loop? (The radius of the loop-the-loop is \(R\); assume that \(R \gg r\).) (b) If the marble is released from height \(6R\) above the bottom of the track, what is the horizontal component of the force acting on it at point \(Q\)?

6. A satellite travels initially in an approximately circular orbit 640 km above the surface of the Earth; its mass is 220 kg, the radius of the earth is \(6.37 \times 10^6\) m. (a) Determine its speed. (b) Determine its period of revolution. (c) For various reasons the satellite loses mechanical energy at the (average) rate of \(1.40 \times 10^5\) J per orbital revolution. Adopting the reasonable approximation that the trajectory is a “circle of slowly diminishing radius,” determine the distance from the surface of the Earth, the speed, and the period of the satellite at the end of its 1500th orbital revolution. (d) What is the magnitude of the average retarding force? (e) Is angular momentum conserved?
7. An aluminum wire of length $L_1 = 60.0$ cm and of cross-sectional area $1.00 \times 10^{-2}$ cm$^2$ is connected to a steel wire of the same cross-sectional area. The compound wire, loaded with a block $m$ of mass 10.0 kg, is arranged as shown in the figure below so that the distance $L_2$ from the joint to the supporting pulley is 86.6 cm. Transverse waves are set up in the wire by using an external source of variable frequency. (a) Find the lowest frequency of excitation for which standing waves are observed such that the joint in the wire is a node. (b) What is the total number of nodes observed at this frequency, excluding the two at the ends of the wire? The density of aluminum is 2.60 g/cm$^3$ and that of steel is 7.8 g/cm$^3$.

8. Two trains on parallel tracks are traveling toward each other at 34.2 m/s relative to the ground. One train is blowing a whistle at 525 Hz. (a) What frequency will be heard on the other train in still air? (b) What frequency will be heard on the other train if the wind is blowing at 15.3 m/s parallel to the tracks and toward the whistle? (c) What frequency will be heard if the wind direction reverses?

9. A spaceship, at rest in a certain reference frame $S$, is given a speed increment of $0.500c$. It is then given a further $0.500c$ increment in this new frame, and this process is continued until its speed with respect to its original frame $S$ exceeds $0.999c$. How many increments does it require?

10. Two moles of a monatomic ideal gas are caused to go through the cycle shown in the figure. Process $bc$ is a reversible adiabatic expansion. Also, $p_b = 10.4$ atm, $V_b = 1.22$ m$^3$ and $V_c = 9.13$ m$^3$. Calculate (a) the heat added to the gas, (b) the heat leaving the gas, (c) the net work done by the gas, and (d) the efficiency of the cycle.