1. (10 points) A particle of mass $M$ moves in the $xy$ plane. Its coordinates as a function of time are given by $x(t) = 2t^3; y(t) = 2t^2 - 3t$. (a) Find its angular momentum about the origin. (b) What force acts on it?

2. (20 points) (a) State the first law of thermodynamics. (b) Define isothermal, isobaric, isovolumetric, and adiabatic processes. (c) One mole of a monatomic ideal gas at temperature $T$ undergoes an isothermal expansion from volume $V$ to $2V$. Find the work done and the heat absorbed by the gas. Calculate the change in entropy of the gas.

3. (10 points) The wavefunction for a traveling wave on a string is

$$y(x,t) = 0.40 \sin(0.2\pi x - 0.6\pi t + 0.8)$$

where both $x$ and $y$ are in centimeters. Find (a) the amplitude, (b) the frequency, (c) the wavelength, (d) the wave speed, (e) the phase angle.

4. (15 points) Fig 1 shows a block of mass 4 kg suspended by a rope that passes over a pulley of mass 2 kg and radius 5 cm. The rope is connected to a spring whose stiffness constant is 80 N/m. (a) If the block is released from rest, what is the maximum extension of the spring? (b) What is the speed of the block after it has fallen 20 cm? Treat the pulley as a disk.

5. (10 points) A point charge $+Q$ is placed at the center of an uncharged spherical shell of inner radius $a$ and outer radius $b$. Find the electric field in the regions: $r < a$, $b > r > a$, $r > b$.

6. (15 points) A force varies as $F(x,y) = 3y^2i + 2xyj$. Perform the integration $\int F_x \, dx + \int F_y \, dy$ from $O$ to $B$ in Fig.2, along the following paths: (a) OA then AB; (b) OB. Does this function satisfy the criterion for being conservative?

7. (10 points) A flat rectangular loop and a long straight wire with current $I$ lie in the same plane, see Fig 3. (a) Determine the magnetic flux through the rectangular loop. (b) If the current in the wire varies according to $I = I_0 \cos(0.5t)$, what is the induced emf in the loop?

8. (10 points) A block of mass $m$ is placed on a block of mass $M$ as shown in Fig 4. The coefficient of kinetic friction for all surfaces is $\mu_k$. Ignore the mass of the pulley and the rope. For what value of the horizontal force $F$ will the blocks (a) move at constant speed, (b) accelerate at $a$. 

Fig 1

Fig 2

Fig 3

Fig 4