Be sure to write down answers with units in SI wherever unit is needed.
*You must provide answers to **all three boldfaced problems** and two problems of your choice from the remainder. Extra credit up to 10% of the total will be given to any additional problems answered beyond the required five. There are a total of two pages of problems, front and back. Be sure not to miss them.*

1. **A particle's motion is described by its position at any given time t.**
   a. **Write down the definition of displacement, average velocity, and acceleration of an object moving in two dimension.**
   b. **Derive the instantaneous velocity in terms of time and acceleration.**
   c. **Derive the position in terms of time, velocity, and acceleration.**

2. A projectile is fired from the origin at t=0 with a velocity v_i, at an angle θ_i,;
   a. Show that the path of projectile motion is a parabola under the influence of earth's gravitational acceleration, g.
   b. Find the maximum height and the time it takes for the projectile to reach at the maximum height at any initial angle θ_i,.
   c. Find the maximum range at any initial angle θ_i, and the angle that gives maximum range for any projectile
   d. Express this motion vectorially.

3. A hockey puck on a frozen pond is given an initial speed of 20.0m/s. The puck always remains on the ice and slides 115m before coming to rest.
   a. Draw a free-body diagram for this motion and write down the components of all the forces involved in this motion.
   b. Determine the coefficient of kinetic friction (m_k) between the puck and ice. Remember that the force of friction is proportional to normal force.

4. **Show that the acceleration measured in the stationary frame of reference (S) is the same as the one measured in a frame of reference (S') moving at a constant velocity. Explain what this means.**

5. **Drag force of air to an object moving with speed v is expressed as:** $R = \frac{1}{2} DrAv^2$

   where D is the drag coefficient, r **is the density of air, and A is the largest cross section area of the object.**
   a. **Write down the dimension of D,** r, **A, and v, then show that R has the dimension of force.**
   b. **Draw a free-body diagram of a ball of mass m falling in the gravitational field and find the terminal speed of this object.**
   c. **Explain how the terminal speed depends on the size of the ball.**
   d. **Consider a pitcher throwing a ball of mass 200g at a speed 160km/sec. Find the resistive force on the ball. The mass of the air is 2.0mg in 1 cm^3. The diameter of the ball is 7.4 cm. The gravitational acceleration is 9.80m/s^2.**

More problems on the back.

6. A hailstone of mass 0.480 g falls through the air and experiences a net force given by $F = -mg + Cv^2$ where $C = 2.50 \times 10^{-5} kg/m$.
   a. Compute the terminal speed of the hailstone.
   b. Use Euler's method of numerical analysis to find the speed and position of the hailstone at 0.2 s intervals for a total of 1 second, taking the initial speed to be 0.

7. Gravitational force between two objects with mass m_1 and m_2 is given by Newton's law of gravitation; $F = G\frac{m_1 m_2}{r^2}$ where $G = 6.673 \times 10^{-11} N \cdot m^2 / kg$ is the gravitational constant, and r is the distance between the two objects.
   a. Consider a satellite of mass m moving in a circular orbit around the earth at a constant speed v and at an altitude h. above the Earth's surface. Determine the speed of the satellite in terms of G, h, and Earth's radius R_E. The radial acceleration is given as $a_r = \frac{v^2}{r}$
   b. Compute the speed and the time for a complete circular motion around the Earth for a satellite at an altitude of 1000 km, circling the Earth. The radius of the Earth is $R_E = 6.37 \times 10^3 km$ and its mass is $M_E = 5.98 \times 10^{24} kg$.

More problems on the back.