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UNIT I: Worksheet 3

1. An object is falling in the presence of air resistance $F_{air} = kv$, where the drag force is dependent on velocity and k is a experimentally determined constant. (This is accurate for objects moving at low speeds).
   a. Sketch a free-body diagram for the object dropped in the presence of air resistance, and write out the appropriate force summation equation.

   b. Use the summation equation to create a differential equation.

   c. Use the differential equation to sketch a velocity-time graph. (HINT: What is the velocity at t = 0? Using the summation equation, what is the acceleration at small velocities? At large velocities? What is the range for possible accelerations?)

   d. Separate the variables of the differential equation in (b) and integrate both sides to create an equation for velocity with respect to time. (HINT: $\int \frac{dx}{a-bx} = \frac{ln|a-bx|}{-b}$ via u-substitution)

2. Repeat Problem 1 for an object falling at high speed ($F_{air} = kv^2$). (HINT: $\int \frac{dx}{a^2 - x^2} = \frac{\tanh^{-1}\left(\frac{x}{a}\right)}{a}$ from integral tables)

3. The terminal speed of a sky diver in the extended position is 160 km/h. In the nosedive position, the terminal speed is 310 km/h. Assuming that C does not change from one position to the other, find the ratio of the effective cross-sectional area A in the slower position to that in the faster position.

4. Calculate the ratio of the drag force on a passenger jet flying with a speed of 1000 km/h at an altitude of 10 km to the drag force on a prop-driven transport flying at half the speed and half the altitude of the jet. At 10 km the density of air is 0.38 kg/m^3 and at 5.0 km it is 0.67 kg/m^3. Assume the airplanes have the same effective cross-sectional area and the same drag coefficient C.

5. A small rock moves in water and the force exerted on it by the water is $F = kv$. The terminal speed of the rock is measured and found to be 2.0 m/s. The rock is projected upward at an initial speed of 6.0 m/s. You can ignore the buoyancy force on the rock.
   a. In the absence of fluid resistance, how high will the rock rise and how long will it take to reach this maximum height?

   b. When the effects of fluid resistance are included, what are the answers to the questions in part (a)?