
2. Problem 2.32 of Marion and Thornton’s book.

3. Problem 2.9 of Marion and Thornton’s book. Assume that the resisting force is of the form \( F_r = -mkv \). After having completed points (a) and (b) in Problem 2.9:

   (c) Compare the times found in (a) and (b) analytically, and explain why the time in (b) is always smaller than the time in (a).

   (d) Take the limits \( k \to 0 \) and \( k \to \infty \) in the expression for the time obtained in (b) and explain your results.

4. A gun is fired straight up. Assuming that the air drag on the bullet varies quadratically with speed (i.e. \( F_r = -mkv^2 \) for a motion vertically upward or \( F_r = mkv^2 \) for a motion vertically downward, when you measure the vertical coordinate positive upward), show that the speed varies with height according to the equations:

   \[
   v^2 = (v_t^2 + v_0^2) e^{-2kx} - v_t^2 \quad \text{ (upward motion) ,}
   \]

   \[
   v^2 = v_t^2 - v_t^2 e^{2kx} \quad \text{ (downward motion) ,}
   \]

   where \( x \) is the vertical displacement, \( g \) is the gravitational acceleration, \( v_0 \) is the initial speed with which the bullet is fired, and \( v_t = \sqrt{g/k} \) is the terminal speed of the bullet. (Hints: in order to find the speed as a function of the position, i.e. \( v = v(x) \), observe that the equation of motion can also be written as:

   \[
   m\frac{dv}{dt} = m\frac{dv}{dx}\frac{dx}{dt} = m v\frac{dv}{dx} = F_{\text{net}} ,
   \]

   where \( F_{\text{net}} \) is the sum of all the forces acting on the bullet. Moreover, observe that the equation of motion is slightly different for the upward and the downward motions: since the retarding force is proportional to the square of the velocity, you need to carefully switch the sign of \( F_r \) when the bullet moves upward or downward.)

5. Use the result is Problem 4 to show that, when the bullet hits the ground on its return, the speed \( v_f \) will be given by

   \[
   v_f = \frac{v_t v_0}{\sqrt{v_t^2 + v_0^2}} ,
   \]

   where \( v_0 \) and \( v_t \) have been defined in Problem 4.