Project: Ballistics Testing

In this project, you will investigate the effects a drag force has on a bullet. The setup involves guns with different sized bullets and muzzle velocities fired downward into a tank of water. My police investigators use this type of ballistics tank to recover bullets from guns without damaging the bullet itself. The only difference is that there is a maximum muzzle velocity allowed (typically ~1100 ft/s) and that the bullets are fired downward at a shallow angle (~20^{o}) into the tank instead of straight down. In this project, we will assume that there is NO restriction to the speed of a bullet and that the bullets are infinitely rigid (*meaning they will never lose their shape*).

In this project, we will assume that the drag force is proportional to v^2 and has the form:

$$\mathbf{F}_r(v) = \frac{1}{2} c_w \rho A v^2 \left(-\hat{\mathbf{v}}\right) \qquad \textbf{Drag Force}$$

(*In reality, as the bullet speed approaches* 0 *m/s, the drag force becomes proportional to v , not* v^2)

* In this project, we will also assume that the muzzle velocity is the initial velocity that the bullet has as it enters the water.

(*In reality, our results will over estimate the actual results because we will not be accounting for the energy loss of the bullets as they enter the water. In addition, the force of impact at really high speeds causes the bullets to break apart!*)

Procedure:

On separate sheets of paper,

a) Draw a force diagram of the system

b) Find an expression for v(t)

c) Find an expression for x(v)

Constants:

ρ (*water*) = .9982 g/cm^3

c_w (*bullet*) = .295

Hints: Use the chain rule on $\frac{dv}{dt}$ to get a $\frac{dv}{dx}$ term before integrating.

USE MATHCAD!!!

Let $\alpha = \frac{c_w A \rho}{2m}$ to help simply your calculations and expressions.

Assume the cross-sectional area (A) of a bullet is that of a circle.

d) Complete the following table using your formulas derived in parts (b) and (c).

Bullet Type	**Radius**	**Mass**	**Muzzle Velocity (v_o)**	**α (m^{-1})**	**Stopping time (*s*)**	**Stopping distance (*ft*)**
9 mm	0.464 *cm*	8 *g*	1160 *ft/s* (353.8 *m/s*)			
.223 rifle	0.278 *cm*	3.6 *g*	2500 *ft/s* (762.5 *m/s*)			
.30 M1 Garand	0.391 *cm*	9.7 *g*	2800 *ft/s* (854 *m/s*)			
.50 cal rifle	0.649 *cm*	46.7 *g*	3000 *ft/s* (915 *m/s*)			

e) Graph $x(v_o)$ for each bullet on a single plot over the range 0 to 1200 m/s.

f) On the popular show Mythbusters (aired on the Discovery Channel), they performed some ballistic tests to determine the depth a person could be under the water and be safe from someone firing a gun at them (Episode – Bullet Proof Water). I have approximated the data for the penetrating depth for each bullet in the table below.

Bullet Type	**Approx. Penetrating Depth**
9 mm	9 ft
.223 rifle	3 ft
.30 M1 Garand	2.5 ft
.50 cal rifle	2 ft

* Graph the mythbusters data on the same plot that you produced in step (e) and estimate how much energy is being lost (in percent) at the surface of the water by each bullet.

Recall: $E = \frac{1}{2}mv^2$ and $E_i(air) = E_f(water) + E_{loss}$

g) Use the energy loss expression to estimate the more realistic speed of the bullet as it enters the water.

Bullet Type	**Our assumed initial speed (ft/s)**	**Estimated initial speed (ft/s)**
9 mm	1160 *ft/s*	
.223 rifle	2500 *ft/s*	
.30 M1 Garand	2800 *ft/s*	
.50 cal rifle	3000 *ft/s*	

* Where do you think the lost energy goes?