Advanced Programming – Mid-Term Exam. **Spring 2023**

Question 1 –

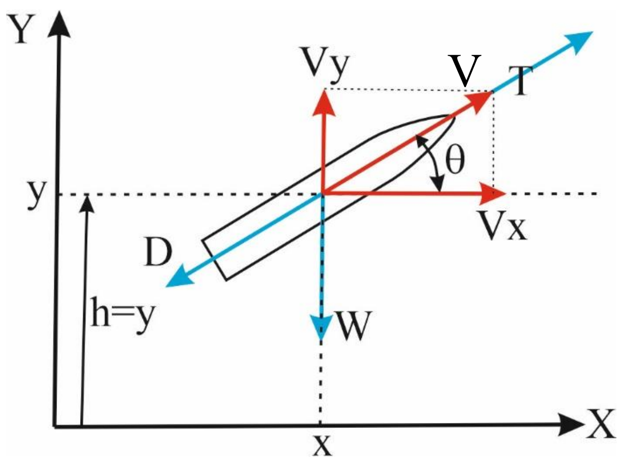
- Make a class for simulation of the flight of rockets (The equations for simulation are presented)
- The characteristics of a sample rocket is given but the class should be general and can be used easily for simulating other rockets
    - Use the class and run the simulation for the following initial conditions:

$$V_0 = 10\frac{m}{s} \qquad \theta_0 = 45°$$

Create the following output files:

- Trajectory.dat -
  This file includes three columns: t, x, y
- Velocity.dat -
  This file includes three columns: t, Vx, Vy

Model:



To simulate the rocket, integrate x, y, V_x, V_y using the following equations:

$$\frac{dx}{dt} = V_x$$
$$\frac{dy}{dt} = V_y$$
$$\frac{dV_x}{dt} = \frac{F_x}{m(t)}$$
$$\frac{dV_y}{dt} = \frac{F_y}{m(t)}$$

The integration should be stopped until the rocket hits the earth (y=0). Note

$$V = \sqrt{V_x^2 + V_y^2} \qquad V_x = V * \cos\theta \qquad V_z = V * \sin\theta \qquad \theta = \tan^{-1}\frac{V_y}{V_x}$$

For calculating Fx and Fy and m(t) **in each integration step** use the following procedure:

1- Calculate Air Density (ρ) using these equations:

$$\mathrm{T_a(h)} = 15 - 0.00649\mathrm{h}$$

$$\mathrm{P_a(h)} = 101.29 * \left(\frac{\mathrm{T_a(h)} + 273.1}{288.08}\right)^{5.256}$$

$$\rho(h) = \frac{\mathrm{P_a(h)}}{0.2869 * (T_a(\mathrm{h}) + 273.1)}$$

$\mathrm{T_a}$ is air temperature, $\mathrm{P_a}$ is air pressure and h is the instantaneous height of the rocket ($h = y(t)$).

2- Calculate the Drag force of the rocket using the following equation:

$$D = \frac{1}{2}\rho(h) * V^2 * S * C_D$$

Where, $C_D = 0.4$ is the drag coefficient, and $S = 0.008$ is the reference area.

3- Calculate Thrust using the following equation:

$$T = \begin{cases} I_{sp} * g * \dfrac{m_p}{t_b} & t < t_b \\ 0 & t > t_b \end{cases}$$

Where $I_{sp} = 220$, $g = 9.81, m_p = 3$ is the propellant mass and $t_b = 0.1$ is the burn time

4- Calculate θ using

$$\theta = \tan^{-1}\frac{V_y}{V_x}$$

5- Calculate mass using the following equation

$$m(t) = \begin{cases} m_0 - \left(\dfrac{m_p}{t_b} * t\right) & t < t_b \\ m(t) = m_0 - m_p & t > t_b \end{cases}$$

Where $m_0 = 8$ is the initial mass, $m_p = 3$ is the propellant mass and $t_b = 0.1$ is the burn time

Calculate Forces in x and y direction using following equations:

$$F_x = (T - D) * \cos(\theta)$$

$$F_y = (T - D)\sin\theta - m(t) * g$$