Projectile Motion Simulation

 No AI use

Time required: 120 minutes

Write a program to calculate the position of a projectile.

Assume that it has an initial height of $\mathbf{0}$, and neglect the air resistance for simplicity.

The projectile has an initial velocity $\boldsymbol{v_0}$ an angle of departure $\boldsymbol{\theta_0}$ and is subject to the gravity constant $\boldsymbol{g = 9.81\ m/s^2}$.

Time of Flight

The time-of-flight formula for a projectile launched with an initial velocity $\boldsymbol{v_0}$ at an angle $\boldsymbol{\theta_0}$ to the horizontal is given by:

$$\boldsymbol{T = \frac{2v_0 \sin \theta}{g}}$$

where:

- $\boldsymbol{T}$ is the time of flight,
- $\boldsymbol{v_0}$ is the initial velocity,
- $\boldsymbol{\theta_0}$ is the launch angle,
- $\boldsymbol{g}$ is the acceleration due to gravity (approximately 9.8 m/s29.8m/s2 on Earth).

Position of the Projectile

The position of the projectile is given by $\boldsymbol{x}$ and $\boldsymbol{y}$ coordinates, where the origin is the initial position of the projectile at time $\boldsymbol{t = 0}$. The total horizontal distance that the projectile travel is called its **range** (the point at which it hits the ground), and the highest peak (or vertical distance) is called its **apex**.

Equations for the trajectory can be given in terms of the time $\boldsymbol{t}$ or in terms of $\boldsymbol{x}$ and $\boldsymbol{y}$. The position of the projectile at any time is given by:

$$\boldsymbol{x = v_0 cos(\theta_0) t}$$

$$\boldsymbol{y = v_0 sin(\theta_0) t - \frac{1}{2} g t^2}$$

where:

- t is the time of flight,
- $\boldsymbol{v_0}$ is the initial velocity,
- $\boldsymbol{\theta_0}$ is the launch angle,
- $\boldsymbol{g}$ is the acceleration due to gravity (approximately 9.81 m/s on Earth).

Assignment

1. Get input from the user for:
    a. Initial velocity $\boldsymbol{v_0}$ in $\boldsymbol{m/s^2}$
    b. Angle of departure $\boldsymbol{\theta_0}$ in degrees

Describe the motion of the projectile by writing a script to answer the following:

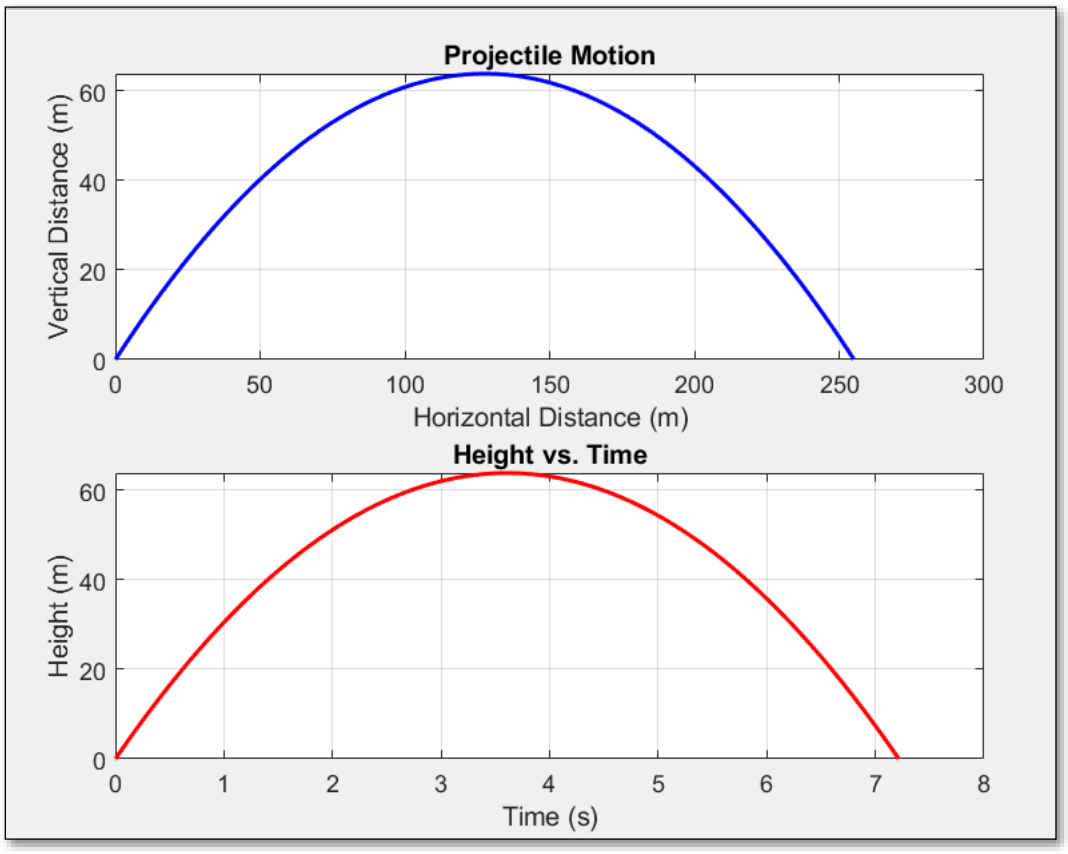
1. **Range**: The horizontal distance traveled by the projectile
2. **Time of flight**: The total time the projectile is in the air
3. **Time to apex**: The time it takes to reach maximum height
4. Round all results to 2 decimal places
5. Plot the position of the projectile at suitable $\boldsymbol{x}$ and $\boldsymbol{y}$ values.
    a. Create a time vector with 100 points from 0 to flight time
    b. Calculate horizontal position $\boldsymbol{x}$ at each time step
    c. Calculate vertical position $\boldsymbol{y}$
    d. The position equations come from the kinematic equations for projectile motion.

```
position = initial_position + initial_velocity × time + ½ × acceleration × time²
```

6. Plot height vs time.

Example run:

```
+---------------------------------------+
|     Projectile Motion Simulation      |
+---------------------------------------+
Enter an initial velocity (m/s): 50
Enter angle of departure (degrees): 45
+---------------------------------------+
Range of the projectile: 254.84 meters
 Time to reach the apex:   3.60 seconds
      Total flight time:   7.21 seconds
```



Challenges

- **Compare angles**: Plot the graphs of the projectile for different angles on the same graph.

- **Calculate energy**: Add calculations for kinetic and potential energy throughout the trajectory.
- **Add air resistance**: Modify the code to include drag forces.
- **Add animation**: Modify the code to show an animated projectile .
- **Include wind**: Add a horizontal force to simulate wind effects.
- **Different planets**: Change the calculation for different astronomical bodies.

Assignment Submission

1. Submit properly named and commented script files.
2. Attach a screenshot of the Command Window showing the successful execution of each script.
3. Attach all to the assignment in Blackboard.