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Original Research Article

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MATLAB Simulation for Teaching Projectile Motion

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ABSTRACT. An approach for teaching projectile motion using MATLAB simulation was shared to the undergraduate and graduate level students. The main purpose of developing the code was to give students a better qualitative as well as quantitative understanding of the intricate factors (e.g., drag) influencing projectile motion, which are usually not discussed in standard texts. Yet another benefit of using such an approach is that the students become accustomed with some advanced features of MATLAB.

Keywords: Projectile; MATLAB simulation; Qualitative understanding; Quantitative understanding; Intricate factors.

INTRODUCTION

Some research studies reveal that students still find difficulties in grasping the concepts of projectile motion especially in a viscous medium.[1-4] Herein, we tried to reduce gap between concepts of projectile motion and the learning difficulties or misconceptions encountered by students. From the elementary physics, the projectile motion is known to occur when an object is thrown making some angle with the horizontal at certain initial velocity or dropped and move under the influence of gravity. It ought to be stressed that there is no effect of gravity on the horizontal motion of the object. The independence of the horizontal and vertical components of the motion of the object is often used to analyze projectile motion. It also accounts for the counterintuitive observation that an object thrown horizontally from ground takes the same time to fall to the ground as that when dropped from the same height.

MATERIALS AND METHODS

Our mathematical model for projectile motion is based on of the following set of differential equations (where symbols have their usual meanings):

$$\frac{dx}{dt} = v_x \quad (1)$$

$$\frac{dy}{dt} = v_y \quad (2)$$

$$\frac{dv_x}{dt} = \frac{1}{2} D\rho A v v_x \quad (3)$$

$$\frac{dv_y}{dt} = -mg - \frac{1}{2} D\rho A v v_y \quad (4)$$

To solve the above set of equations, a solver provided by the MATLAB named "ode45"5, is employed. This solver uses 4th and 5th order Runge-Kutta algorithms. The error is controlled by 'AbsTol' option. The solution is stable as depicted by the graphs shown in subsequent section. Since the method, 'ode45' is for non-stiff equations and it is a better solver5, so it is always the first choice for the ODE's solutions.

RESULTS AND DISCUSSION

Based on the obtained results, it was indicated that our MATLAB simulation of this work efficiently provided different options for analyzing the projectile motion as a benefit. Most striking features of our mathematical computer simulation was to provide eight types of graphical interface window which helps a deeper understanding of the concept and overcome the learning difficulties. As an example, Figs. 1a and 1b show a comparison of trajectory of projectile with and without drag.

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a)

b)

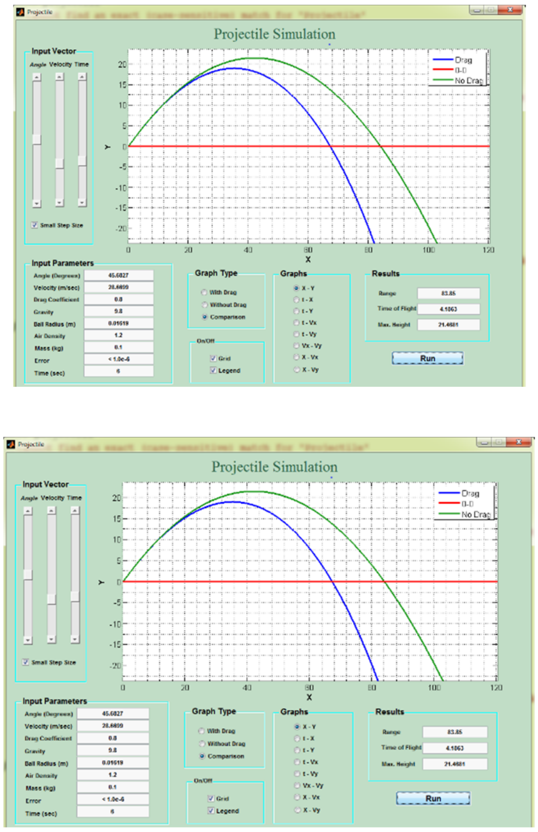

Fig. 1: (a) Comparison of trajectory of a projectile with drag, (b) Comparison of trajectory of projectile without drag.

It is quite easy for students to observe that how the drag changes the path of projectile. Changing the drag coefficients, the effect of resistive medium on the trajectory can be explained easily. The time dependence of the horizontal component of displacement is shown in Fig. 2. One can appreciate the obvious effect of presence/ absence of drag.

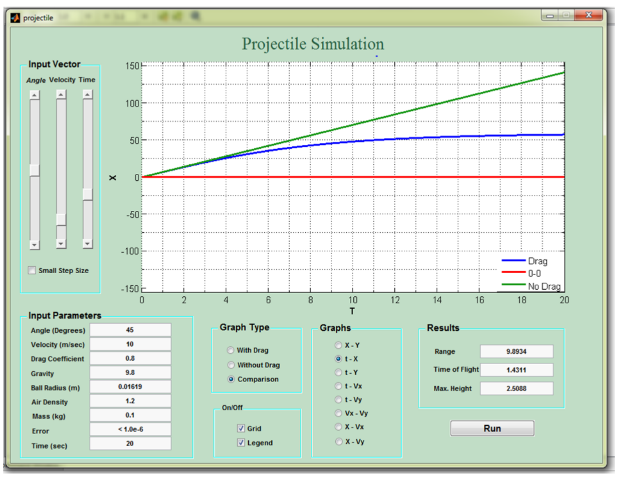

Fig. 2: Horizontal component of displacement in different intervals of time.

In order to show the dependence of the horizontal component of displacement on the horizontal and vertical components of velocity one can consider Fig. 3.

a)

b)

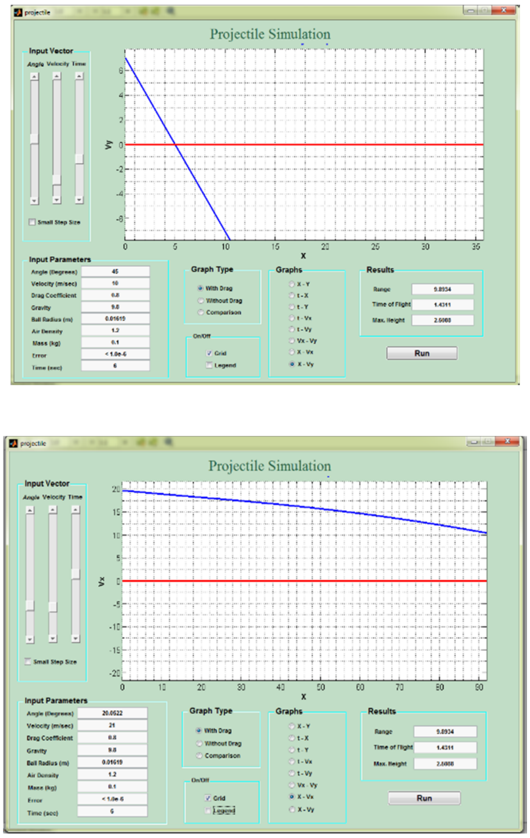

Fig. 3: (a) Vertical component and (b) horizontal component of velocity as a function of horizontal component of displacement.

The interdependence of the vertical and horizontal components of velocities in a resistive medium is shown in Fig. 4. It is interesting to note how the drag changes the horizontal component together with the vertical component. The figures here could help to visually compare the results.

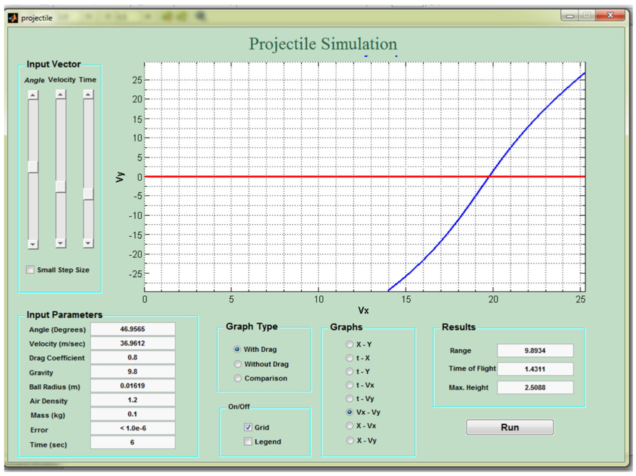

Fig. 4: Plot of the interdependence of vertical and horizontal components of velocities in a resistive medium.

In order to explain the time dependence of the horizontal and vertical components of velocity one could use Figs. 5a and 5b. The vertical component can have negative values as well in contrast to the horizontal component of velocity which is always positive.

a)

b)

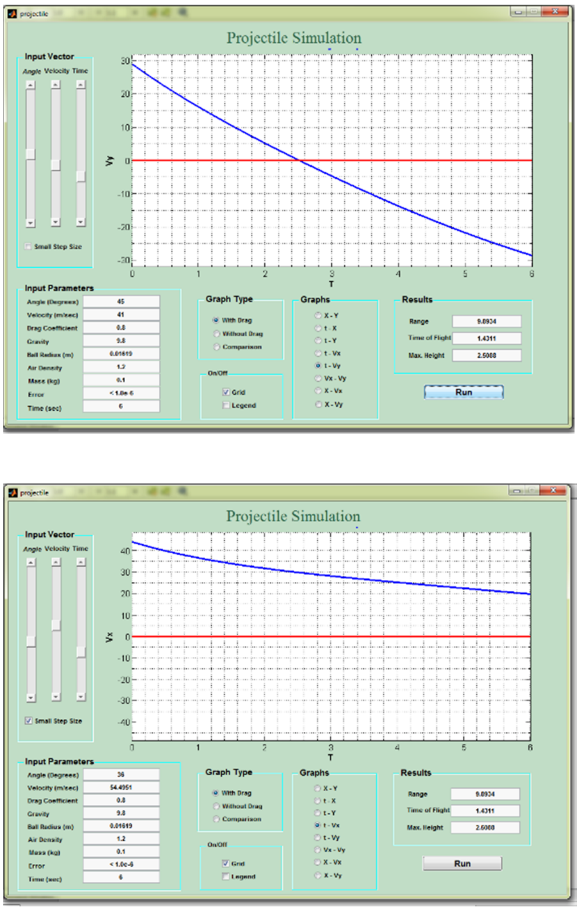

Fig. 5: Plots of (a) vertical component of velocity and (b) horizontal component of velocity as a function of time.

The time dependence of the vertical component of velocity can also be used to explain the idea of terminal velocity as depicted in Fig. 6.

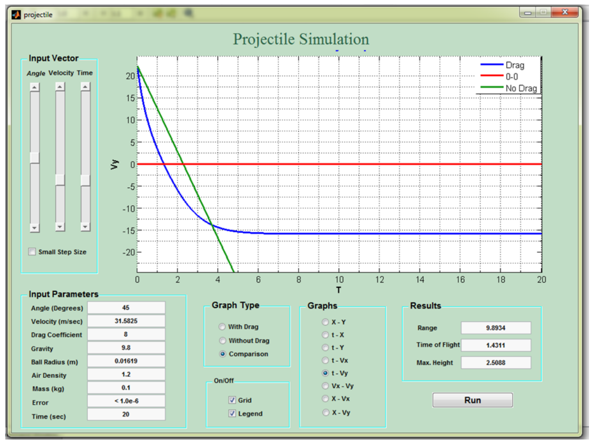

Fig. 6: Time dependence of the vertical component of velocity.

CONCLUSION

We presented MATLAB simulation for analyzing projectile motion with the view that students at the graduate and undergraduate levels could better understand the effect of resistive medium on such motion with error less than 10^{-6}. Slider and manual input parameters are used to obtain not only the benefit of displaying graphical interface window with fast changes in these input parameters and observed the value of respected parameters with high accuracy making the pedagogic significance of simulation high.

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