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THE OPERATION DESERT STORM AND THE PATRIOT MISSILE DEFENSE SYSTEM [1] -TRAJECTORY MOTIONS IN THE AIR

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ABSTRACT

Contrary to the physics text book description of a high-speed trajectory motion of an object in the air, engineers have hard time on simulating the actual trajectory of a high-speed object in the air. There are various effects of air frictions such as vibrating motions, circular rotations and sideway swings, together with some additional non-linear effects on top of these.

KEYWORDS: projectile, trajectory, air friction; non-linear effects, butterfly effects

INTRODUCTION

In a college physics text book, any horizontally thrown objects travel in the x-direction as $x=v_0t$, where v_0 is an initial velocity in the x-direction and t is the time, and in the y-direction as $y=gt^2/2$, where g is the gravitational acceleration of $9.8m/s^2$.

These two equation can then be combined into a parabolic expression between y and x as follows (Tipler and Mosca, 2007); $y=g(x/v_0)^2/2=(g/v_0^2)x^2/2=Ax^2$, where $A=(g/v_0^2)/2$. However, a question can be raised why a pitched ball in a baseball game does not follow a typical parabolic trajectory as described in the standard college physics text book. Any baseball players ever participated in a game as a hitter witness a fact that a pitched baseball never follows a parabolic trajectory.

This obvious discrepancy is never explicitly discussed at least in a popular image of science. People simply believe in the text book description of a parabolic motion no matter how many times they observe an actual trajectory of motion in the air. This is in part due to the fact that we never fully understand all the effects of air frictions in a moving object.

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DRAG EQUATION

Understanding all those effects of air frictions in a moving object is far beyond the realm of a college physics text book. In fact, it is even beyond the realm of any professional engineering simulation project. Engineers barely start to understand those effects of air frictions, yet. Even the best computing facilities in the world may not be able to simulate a realistic trajectory of a pitched ball in an actual baseball game, which is thrown only 18 meters away from the position of a catcher.

In a simplistic way, the drag force caused by air friction can be quantified as a function of the speed, size and shape of an object together with the density of the surrounding air. This is known as the drag equation (Shapiro, 1961);

$$F_{drag} = \frac{1}{2}\rho v^2 C_D A$$

, where F_{drag} is the drag force, ρ is the density of the surrounding air, v is the velocity of the object relative to the fluid, A is the cross section of the object, and C_D is the dimensionless drag coefficient.

A moving object have a lower air pressure in an opposite side of a motion, which then drags the object. In a sense, the dragging effects of friction are larger in the opposite side of a moving object rather than in the fore side of it. This is somewhat contrary to the popular intuition about the friction. If the speed of a moving object becomes significant so that the air pressure behind becomes low enough to create a sort of quasi vacuum, then a whirling air flow from the fore side of the moving object to the quasi vacuum region becomes considerable. This whirling motion of air flow then in turn rotates the object in a circle or spiral pattern perpendicular to the motion. At this speed, due to the turbulent motion, the object's vibrations are destructive enough to threaten its own integrity. At the same time, the turbulent motion can also cause the object to swing sideway in a horizontal plane of the motion. This sideway swing motion resembles a leaf falling from the sky, showing a side-to-side motion of drifts toward the ground. Consequently, realistic trajectories of motions show all of these effects, i.e. vibrations, circular and spiral rotations and sideway swings. On top of these, some additional non-linear effects commonly known as "butterfly effects" will further complicate the actual trajectories of an object under air friction.

Even with the above drag equation, therefore, it is quite difficult to calculate an actual trajectory of a high-speed object with air friction, although some simulations have been attempted and even claimed to be quite successful. Despite these claims, however, high speed realistic trajectories are only obtainable from an actual observation or an experiment of fast-moving objects. Engineers always prefer actual experiments to computer-based simulations. They know they may not be able to simulate the actual high speed trajectory in the air, regardless some claims of successful simulations nowadays.

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CONCLUSION

Although people simply believe in the text book description of a trajectory motion, engineers are far from simulating the actual trajectory of a high-speed object in the air. This is due to the various effects of air frictions such as vibrating motions, circular rotations and sideway swings, together with some additional non-linear effects on top of these.

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