

## How to pump a swing?

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Modeling the pumping of a swing is a classical mathematical problem that appeals to the Newton's second law of motion. In the literature, pumping of a swing has been modeled in numerous ways. Elementary models assume that the rider of the swing is a point of mass whereas some advanced models consider the angular momentum of the rider in the course of pumping and assume that the rider's body-weight distribution is uniform from head to heels. Even if the existing models are adequate to explain the dynamical behavior of pumping a swing, there are various factors that need to be taken into consideration for precise modeling of the subtle movements of the rider during the course of pumping. For example, the person may rotate his arms, legs and his head during the upward and downward movements of the swing, especially at the highest and lowest positions of the swing. Furthermore, the weights of different parts of the body are different and their positioning during the motion of the swing may result in introducing new parameters to the model. In the model we proposed, the body-weight distribution of the person and the changes of angles of various parts of the body, especially legs and the upper part of the body above the waist, were taken into consideration. Moreover, the basic technique we used in establishing the dynamical system was considering the changes of the center of gravity of the rider at various stages of the motion of the swing. Numerical simulations using Matlab are carried out to draw phase trajectory diagrams and other important graphs of the motion of the swing. Many graphs are drawn changing some of the parameters and comparisons with the existing models were used to validate the new model. Moreover, the video images of actual pumping of a rider were used to investigate the accuracy of the model. The numerical simulations and comparisons revealed that the proposed model gives better approximations to the actual pumping of a swing.