

## 1 Overview

There are multiple ways to pump a playground swing. For instance see this video <https://youtu.be/ZxBCYLfgTOY>. Here is a robot from my lab that pumps a swing from the standing position <https://youtu.be/mNHBRSlg1EM>. You will model, simulate, and analyze the pumping of the playground swing from the sitting position using MuJoCo. Here is a paper that describes modeling (optional read): *Wirkus, Stephen, Richard Rand, and Andy Ruina. "How to pump a swing." The College Mathematics Journal 29.4 (1998): 266.*

## 2 Pumping a swing from the sitting position

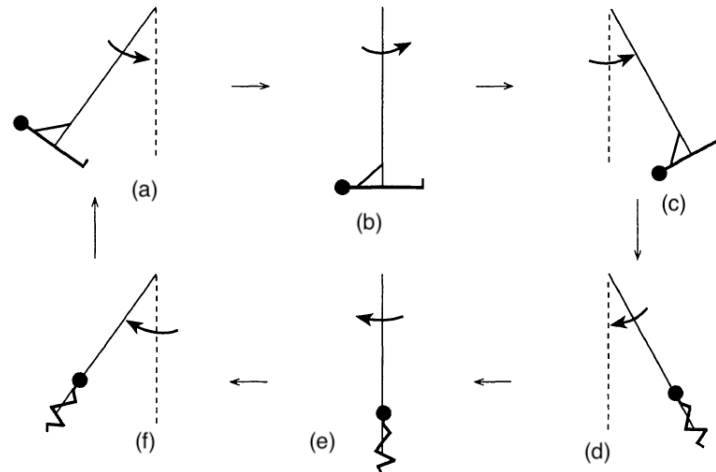


Figure 1: Pumping a swing from the sitting position

The strategy for pumping the swing is shown in Fig. 1. Here, the amplitude build is due to increase in angular momentum mainly due to the rotation of the body. The motion starts from the left extreme position with the rider in the horizontal position (a). When the rider reaches the extreme right position, she/he uprights the body effectively increasing the angular momentum (c). Thereafter, when the rider reaches the left extreme position, he/she orients the body horizontally again further increasing the angular momentum (f). This completes one swing.

Model for sitting pump

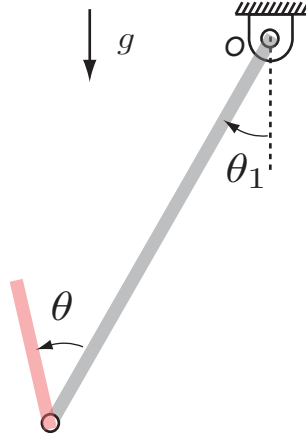


Figure 2: Modeling the sitting and standing pump in MuJoCo

### 3 Modeling, control, and analyses in MuJoCo

#### 3.1 Model

Figure 2 shows a possible model for the sitting pump. Each model has two links, link 1 is attached to the ground and link 2 attaches to the link 1. The motion of links 1 and 2 are described by the angles  $\theta_1$  and  $\theta_2$  respectively. You can choose suitable mass/inertia and link length parameters. I recommend making the link 2 mass substantially higher than link 1 (e.g., 5:1 or 10:1). I also suggest keeping the length of link 1 substantially higher than link 2 (e.g., 4:1 or 5:1). These are just suggestions, feel free to use your own judgement and intuition.

#### 3.2 Control

Based on the strategies explained in Sec. 2, program the 2nd joint to pump the swing. I recommend starting both the pendulum at the same angle  $\theta_1 = \theta_2 \neq 0$ . You could start the 2nd link at  $90^\circ$  as shown in the Fig. 1. I recommend using a proportional-derivative control of the position (i.e.,  $\theta_2$ ) and second link is not actuated. It is more important that the position controller has the desired pumping effect so you might have to tune the gains and set points accordingly.

#### 3.3 Submission

Submit the following. (1) Use either a visualization of the two pendulums side by side saved as a movie file graphs to demonstrate the main conclusion of the paper. 2) Send your folder(s) so I can run the code on my end.