1 Launching a Ball with a Flywheel

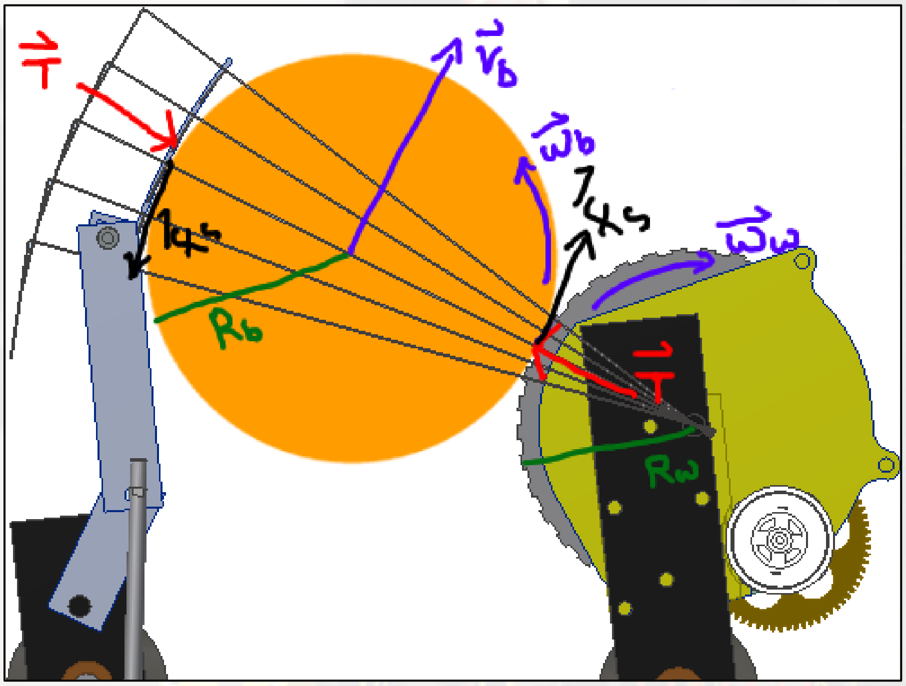

Figure 1: Free Body Diagram of the Launcher

In the process of designing our ball launcher, we made the assumption that the static friction between the ball and the launch wheel would be sufficient that the ball would not slip, so that we could model the system as an inelastic collision of a mass on a spinning flywheel.

Through conservation of momentum, we were able to calculate the relationship between the initial angular velocity of the wheel and the exit velocity of the ball, as is shown in the equations on the right. We then used this relationship to determine the angular speeds that the launcher wheel would have to achieve in order to launch the ball into the top hoop from the edge of the key.

We also determined through this calculation that almost the entirety of the energy needed to launch the ball came from the rotational kinetic energy of the wheel, and as a result we designed the wheel itself to fit the parameters we needed: it was milled from a solid block of aluminum.

After testing, we discovered that the friction of the bare surface was not sufficient to fulfill the initial assumption of static friction; we solved this problem by adding grooves into the wheel parallel to the axis of rotation. For more detail, see the friction test documentation.

$$\frac{I_w\omega_{wi}}{R_w} = \frac{I_w\omega_{wf}}{R_w} + m_bV_b + \frac{I_b\omega_{bf}}{R_b}$$

$$V_b = \frac{\omega_{wf}R_w}{2}$$

$$\omega_{bf}2R_b = \omega_{wf}R_w$$

$$\omega_{bf} = \frac{\omega_{wf}R_w}{2R_b} = \frac{2V_b}{R_w}\frac{R_w}{2R_b} = \frac{V_b}{R_b}$$

$$\frac{m_wV_{wi}}{2} = \frac{m_wV_{wf}}{2} + \left[m_bV_b + \tfrac{2}{5}m_bV_b\right]$$

$$\frac{m_wV_{wi}}{2} = m_wV_b + \left[\tfrac{7}{5}m_bV_b\right]$$

$$\frac{m_wV_{wi}}{2} = \left[m_w + \tfrac{7}{5}m_b\right]V_b$$

$$V_{wi} = 2V_b\frac{m_w + \tfrac{7}{5}m_b}{m_w}$$

2 Ball Recovery Time

One of the most crucial parameters for a ball launcher in Rebound Rumble is the total time it takes to launch all three balls which can be stored on the robot. Since the time it takes to launch an actual ball is essentially insignificant—less than a second—the key factor which determines this cycle time is the time it takes for the flywheel to return to its original speed.

The ball's kinetic energy after the launch is drawn from the rotational kinetic energy of the launch wheel, which serves as both the launch surface and a store of energy as a flywheel. Due to the conservation of energy, each launch causes the wheel to slow down to about 76.6% of its original speed, which needs to be made up by the input of energy from the motor.

As a result of this dependence, our motor (the Banebots RS-775 motor) was selected such that it would operate at about 70% of its rated power and speed without the load of the ball, such that there would be ample torque to spin the launcher back up to speed between launcher. Due to the placement of a hall-effect speed sensor on the launcher, the software is able to control the speed of the launch and thus launch all balls at the same initial velocity, and thus a repeatable trajectory.

3 Ball Kinematics

We were able to use forward kinematics to model the ball's trajectory given an initial launch speed and launch angle, assuming that there were no significant environmental factors affecting our ability to shoot.

Our calculations showed that we needed to launch the balls at about 22 ft/s to make the shot from the key without hitting the backboard, which works out to just about 2200 RPM.

Empirically, we need to launch at about 2250 RPM to get a consistent shot from the key; this results in an error of 2.2% and verifies our calculations, as well as the initial assumption of a completely inelastic collision and lack of slip following our modification to the launcher wheel.

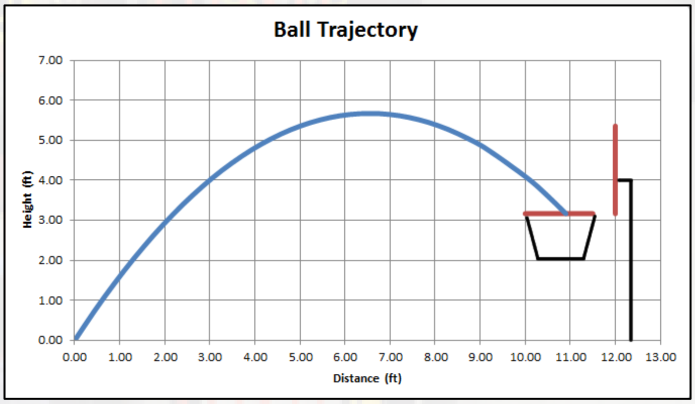

Figure 2: A direct shot through the hoop

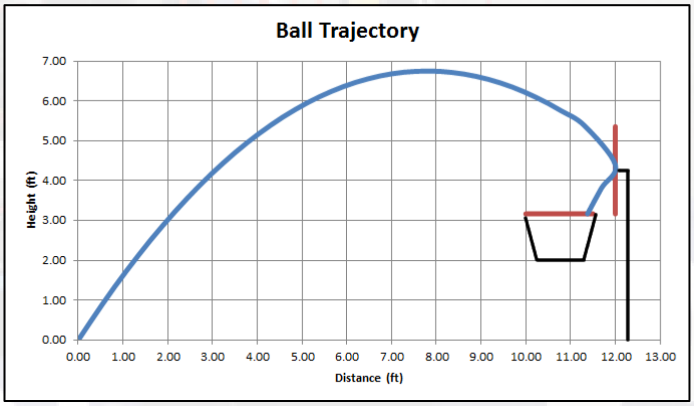

Figure 3: A shot bounced off the backboard