Workshop 7: Dynamics

1 Getting Started

Make sure you have everything you need to complete this lab. To get started you will need the following:

- A LEGO Mindstorms EV3 brain brick.
- A computer with LEGO Mindstorms EV3 software application installed.
- A USB cable that connects the robot to your computer.
- Two motors.
- A ball.

2 Newton's Laws of Motion

In this workshop we will explore robot dynamics and basic Newtonian physics.

Newton's Laws describe how everyday objects move in response to forces. In robotics, we can use this to help our robots make predictions about how things in the environment will behave.

Newton's Laws of Motion are:

1. Every body remains at rest, or travels at constant speed in a straight line, unless a force acts on it.
2. The change of motion (i.e., momentum) of an object is proportional to the force.
3. To every action there is always an opposite and equal reaction.

Today, we'll see how we can use these to understand what happens when we throw something, like a ball.

3 Pitching Machine

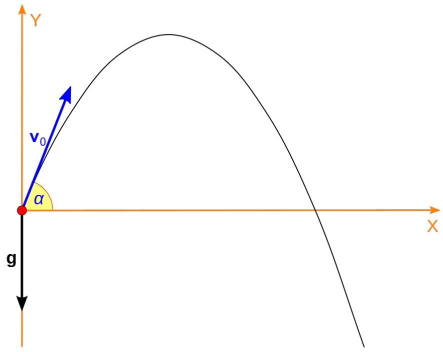
First, let's build a robot that can throw a ball. We'll base our design around pitching machines (used in sports training). After that, we'll make a very simple program to test if the robot works.

1. Open the website: http://nxtprograms.com/pitcher_and_batter/steps.html in your browser for the building instruction.
2. Open up the EV3 software, and start a new project. Name it something you will recognise (e.g., 'pitcher') and save it.
3. Use a **Motor Block** to program both wheels to run at a constant speed.
4. Next, take a ping pong ball, and set it on the pitching machine feeder.

   HINT: Slowly feed the ball to the wheels, and get ready to catch!

4 Projectile Motion

Newton's laws allow us to predict how the ball will move when it comes out of the machine.



The motion of the ball can actually be described as **projectile motion**. Projectile motion describes how an object moves when the only force that acts on the ball, is gravity. The force acts downward, causing a downward acceleration.

We will use the following **Kinematic Equations of Motion**:

Velocity equation:

$$v = u + at$$

where u is initial velocity, a is acceleration and t is time.

Displacement equation:

$$s = ut + \frac{1}{2}at^2$$

where s is displacement.

5 Throw the Ball from the Table into a Cup

First, let's look at the problem of throwing the ball from a table into a cup. For this, we'll launch the ball **horizontally**.

- Place the pitching machine onto the table, and place a cup onto the floor $50\,cm$ from the foot of the table. Launch the ball.

Did the ball make it into the cup? If it did, well done! (You were lucky!)

If not, let's use the equation of motion to improve our shot.

1. Calculate the **initial velocity** of the ball based on the rotation speed of the pitching wheels.

   HINT: You may need to measure some parts of your robot, such as the wheel diameter.

2. Measure the distance from the pitcher's release mechanism to the floor.
3. Can you use the equation above to work out the time it will take for the ball to hit the floor?

   HINT: Think about what forces are acting, and what is the acceleration of the ball.

4. Finally, using everything you calculated so far, can you figure out the distance that you should put the cup in order to get the ball to land in it?

   Remember, ask for help if you have any problems!

6 Challenge: Shooting the Ball at an Angle

For this challenge, we will start with both the robot *and* the cup on the floor. You will need to create a projectile motion at an given angle to *make a drop shot* to get the ball in the cup.

You might find the following equations useful for this:

Initial velocity vector:

$$\mathbf{u} = u_x \hat{\imath} + u_y \hat{\jmath}$$

Velocity in x:

$$u_x = \cos\alpha$$

Velocity in y:

$$u_y = \sin\alpha$$

where α is the angle.

Use these, with the equations above, to calculate:

- How much **time** the ball needs to complete its path.
- How **far** the ball will travel, and how **high** it will go.
- What **time** the ball will at the **highest point** of its motion!