A Mechanical Model of a Hydrofoiling Bee

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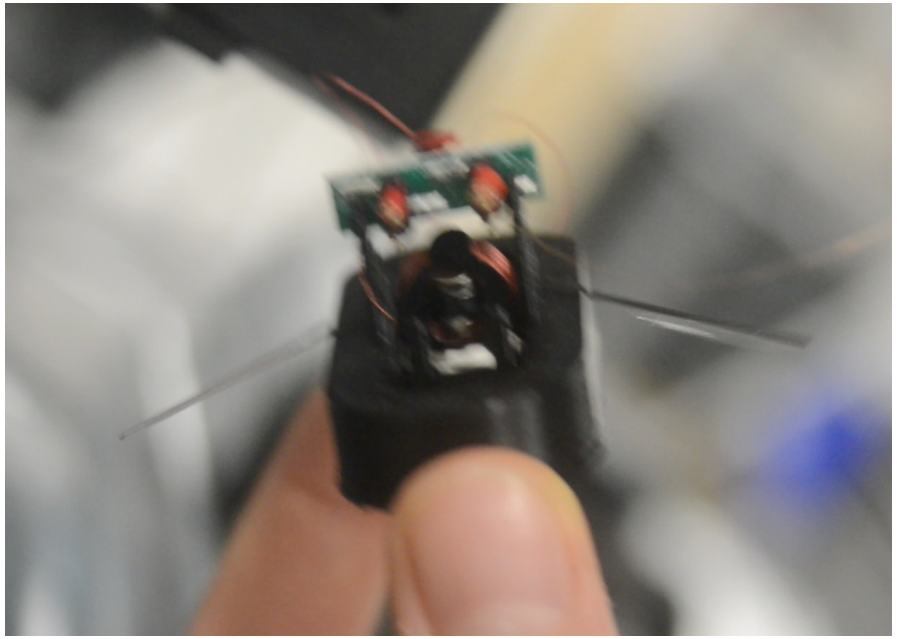
Presented by: Lena Wu

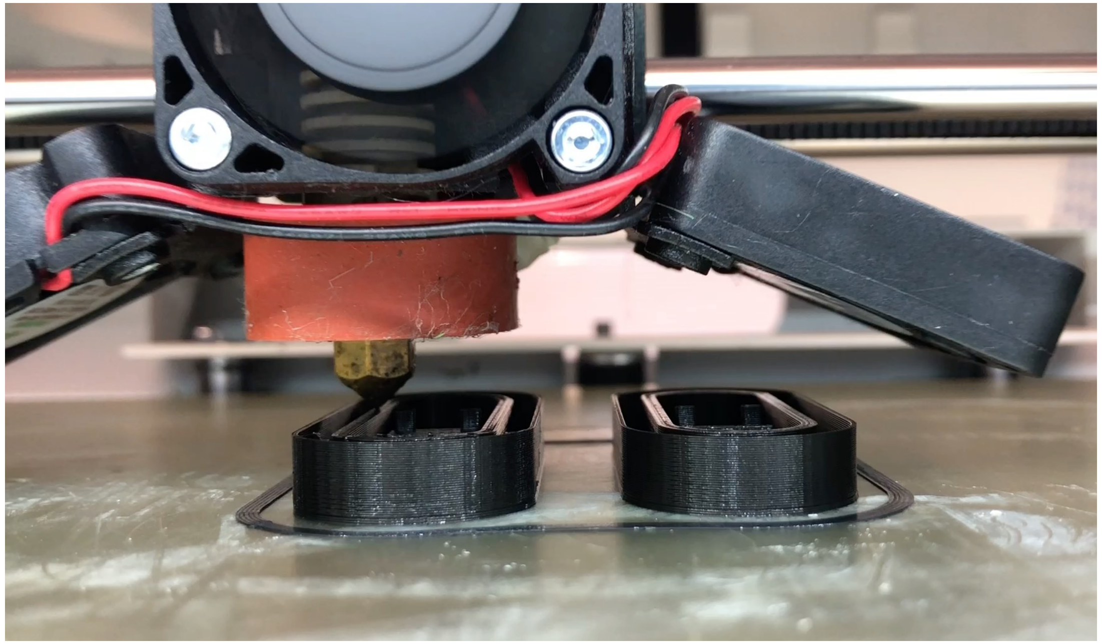


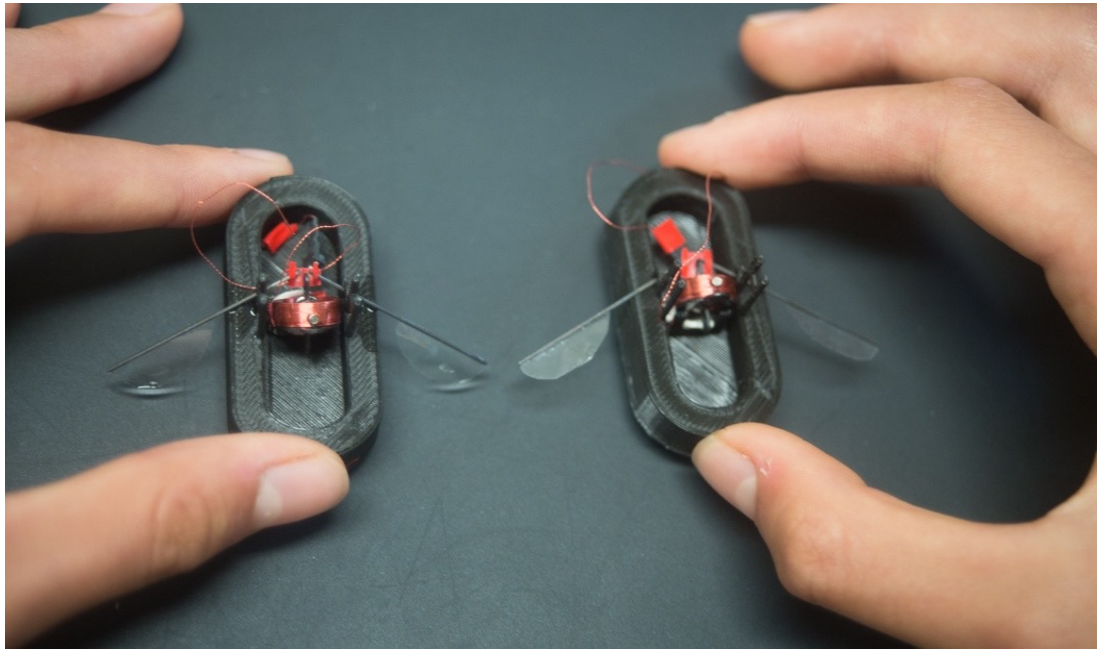
Background

- Honeybee’s often get trapped in water when collecting water
- Bee’s wings stick to the water, and as they vibrate their wings, they create waves that will push them to shore
- Can’t control the frequency and amplitude of a real honeybee

What I Did

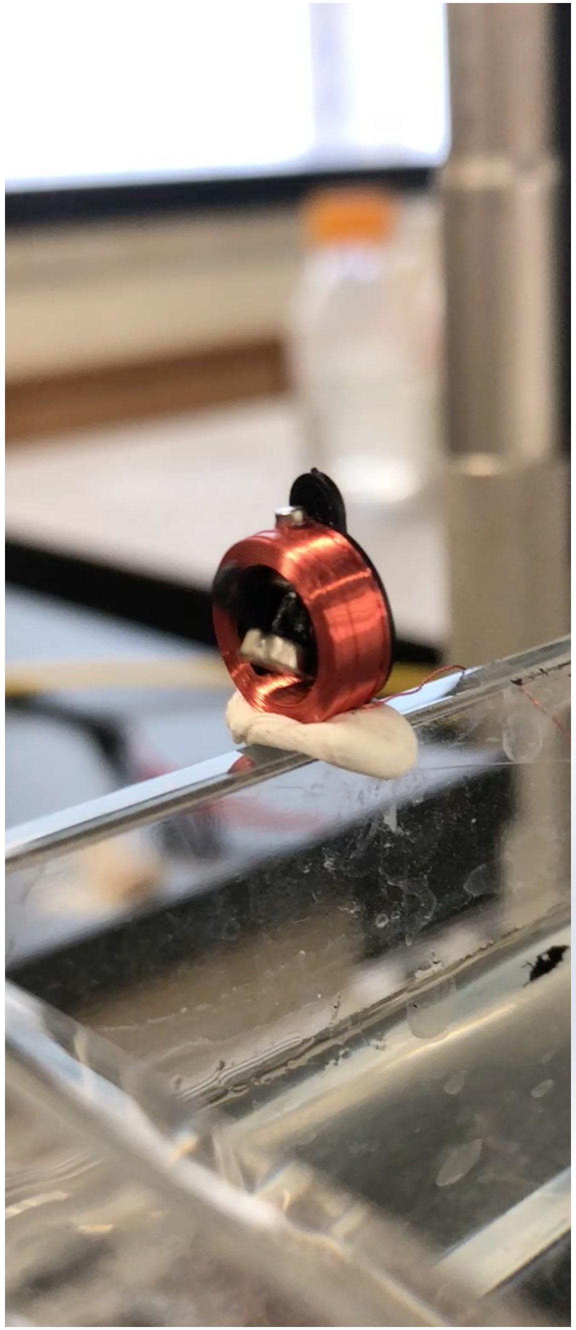
- Designed and built a mechanical model of a surface swimming bee
- Used a high-speed camera to take videos of two mechanical models
  - One with a straight wing motion
  - One with a tilted wing motion
- Analyzed the data and compared the efficiency and velocity between the two models

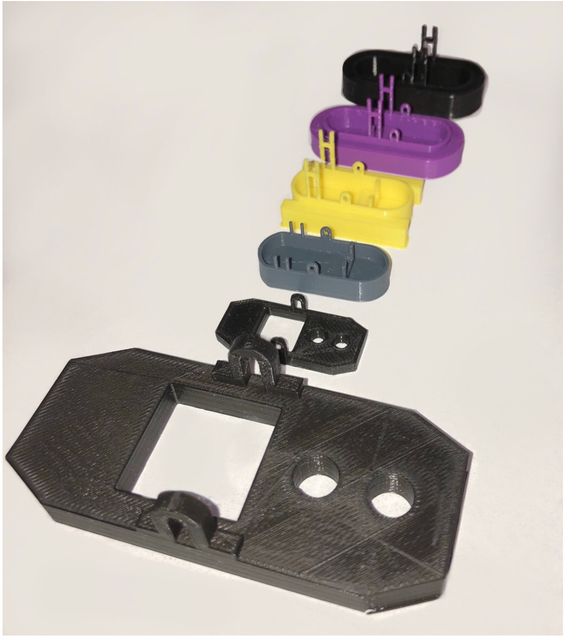


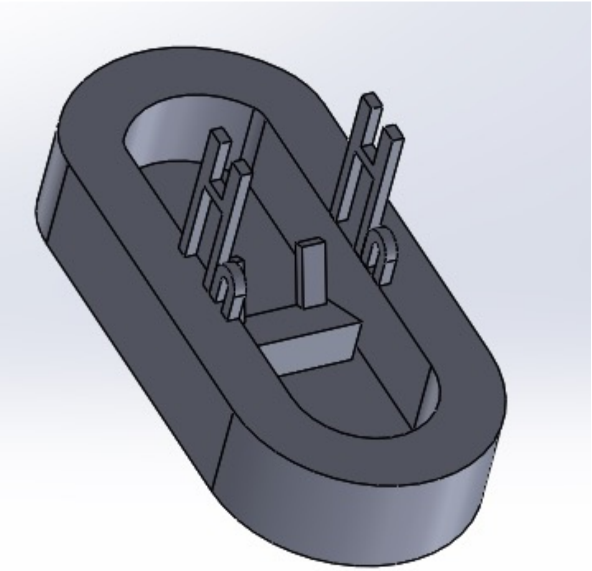


Design Process

- Designed the model around the oscillating electromagnetic actuator
- Created individual parts and assemblies in SolidWorks
- 3D Printed the model in the Tech Lab
- Continuously improved design until getting a working model

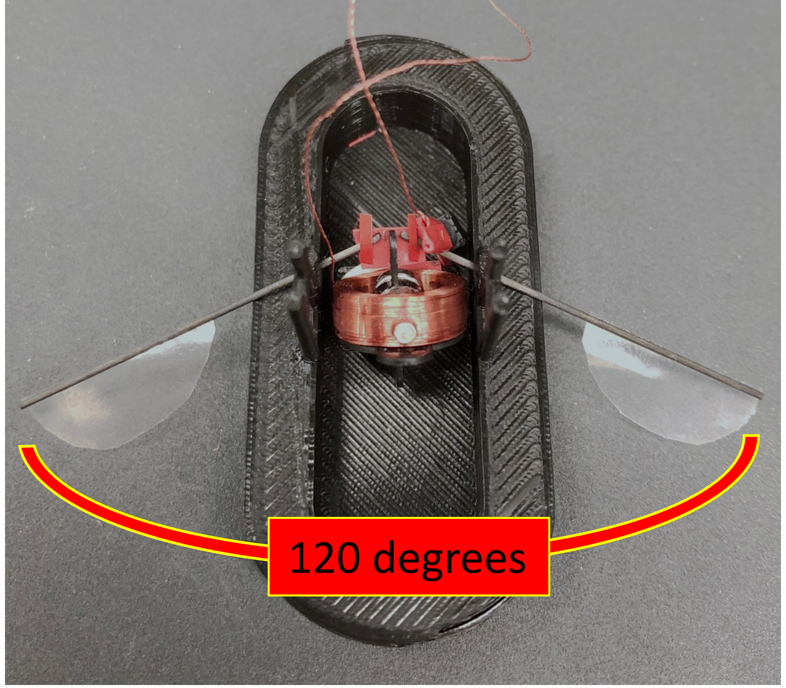






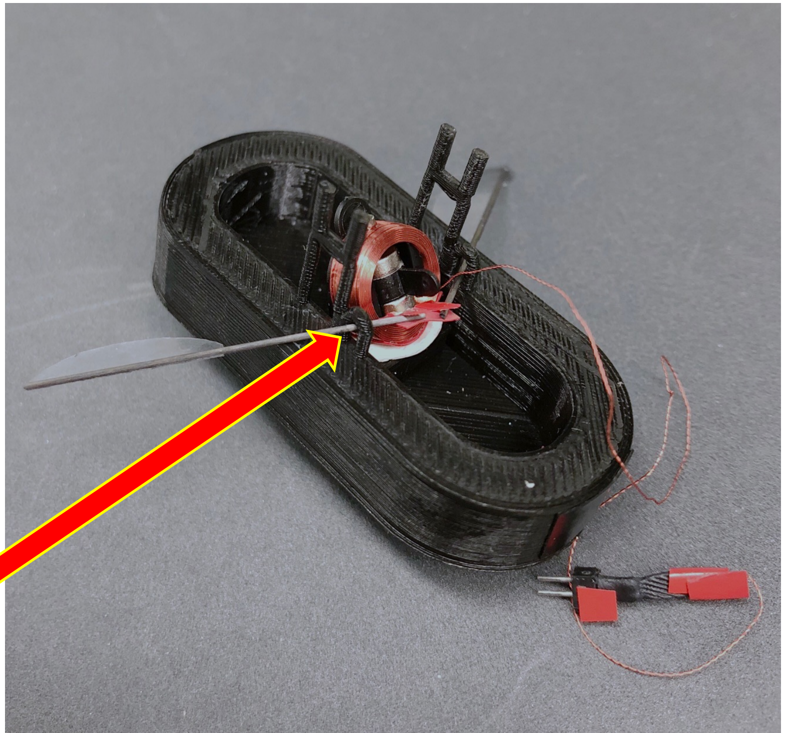
Design and Parameters

- Wings attached to actuator with flexible tape, and go through two levers
- Hollow walls for buoyancy
- What you can change:
  - Wings shape, length, and angle
  - Frequency, amplitude, offset
  - Sine, square, triangle wave



	Mechanical model	Real bee
Body length	45mm	12mm
Wing length	25mm	9.7mm
Weight	5.4 grams	.1 grams

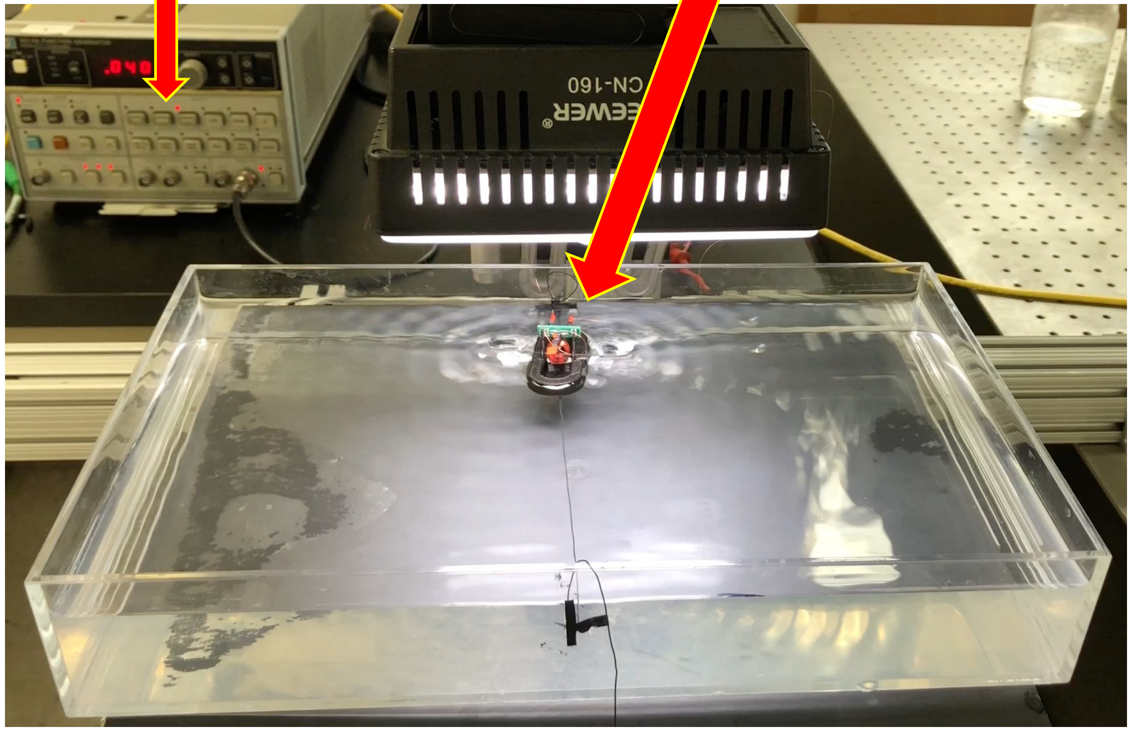
lever



The Setup

Function generator

String



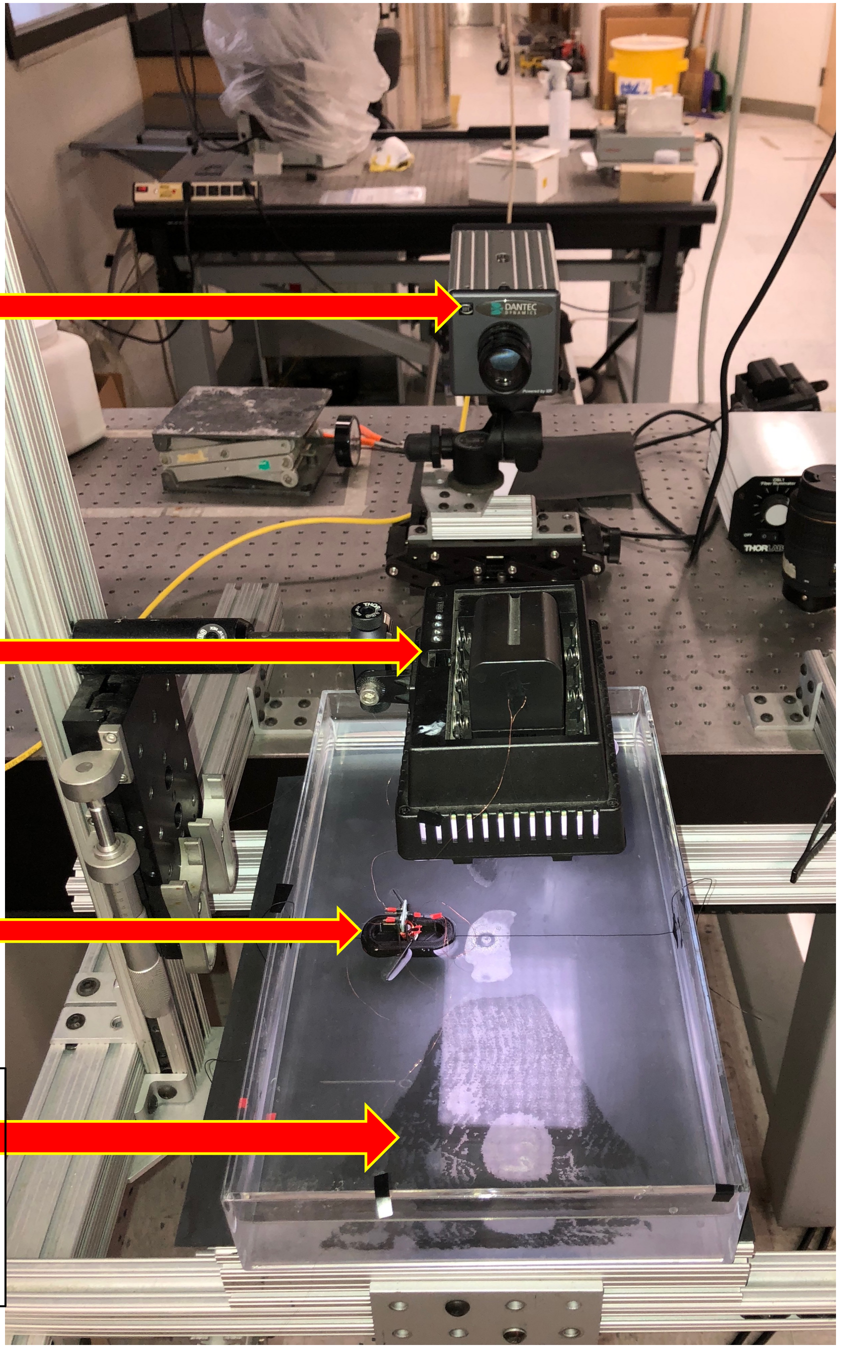
High-speed camera (NanoSense MkIII)

Light Source

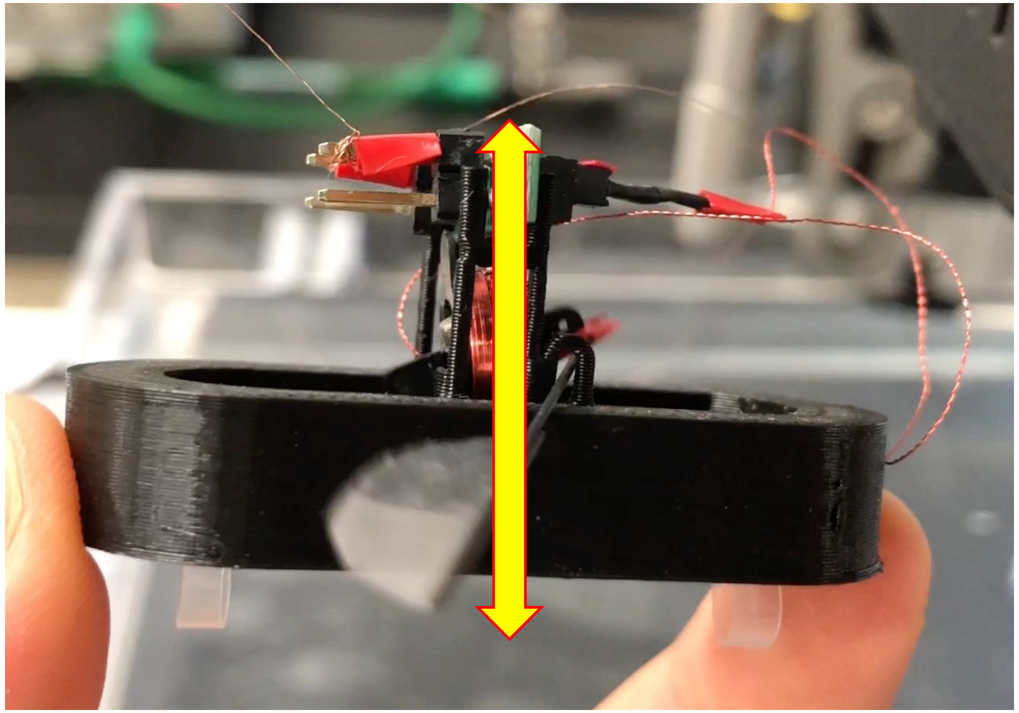
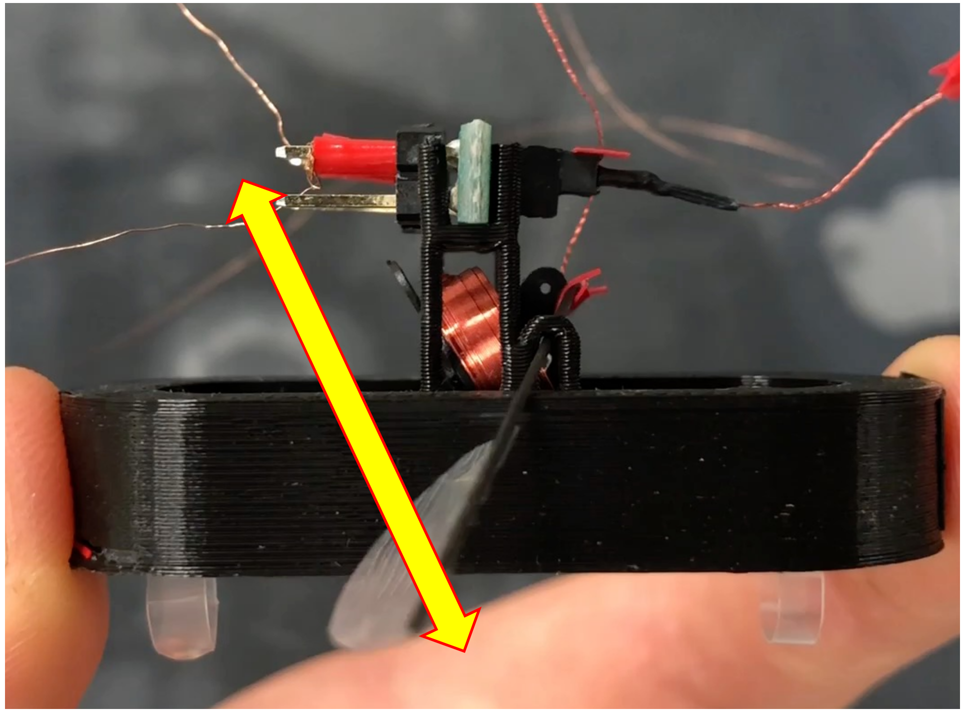
Mechanical bee

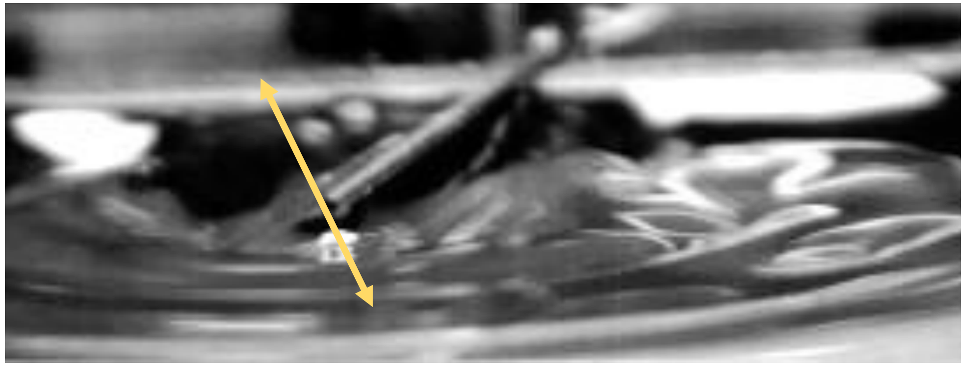
Water tank

- 1.5” deep water
- 8” x 13” tank

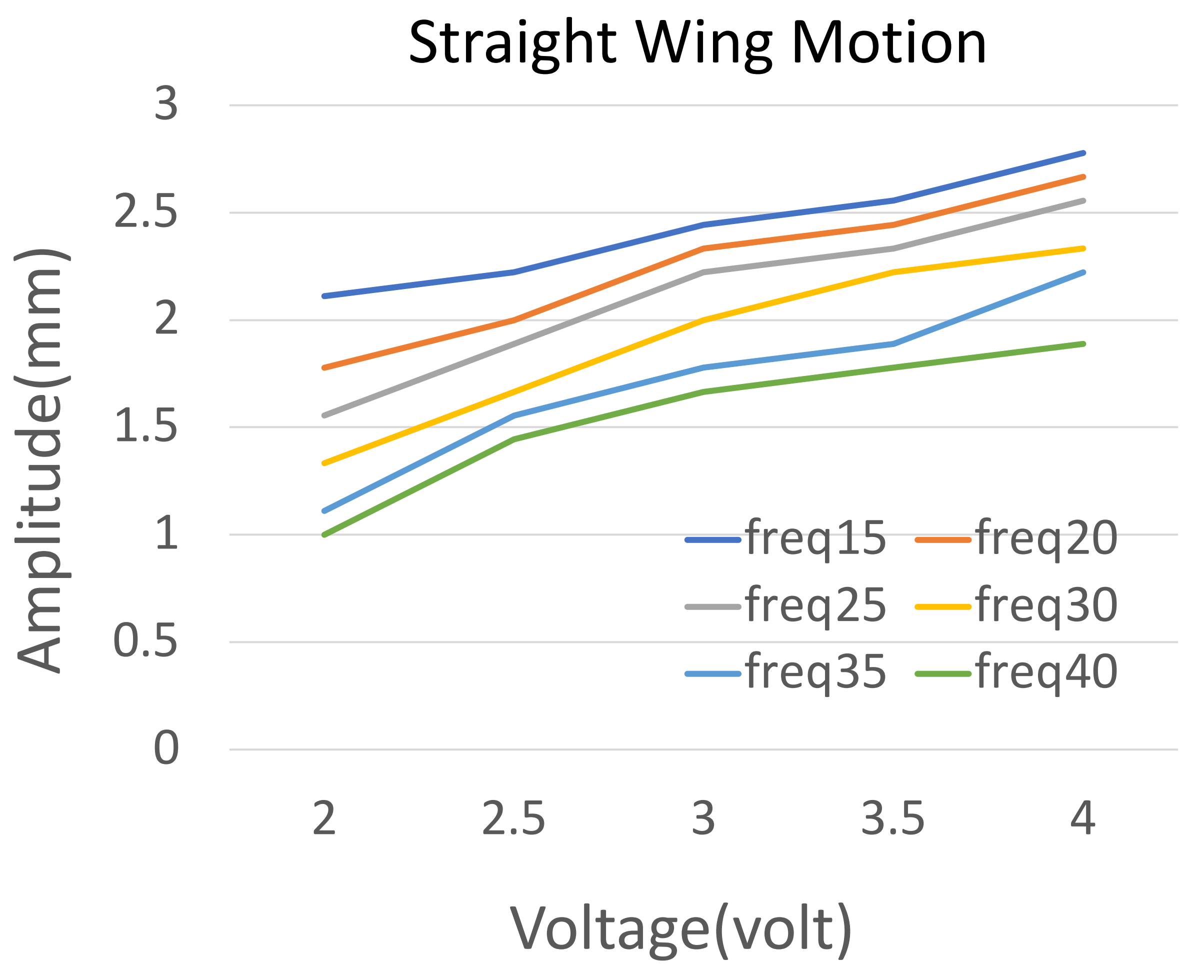


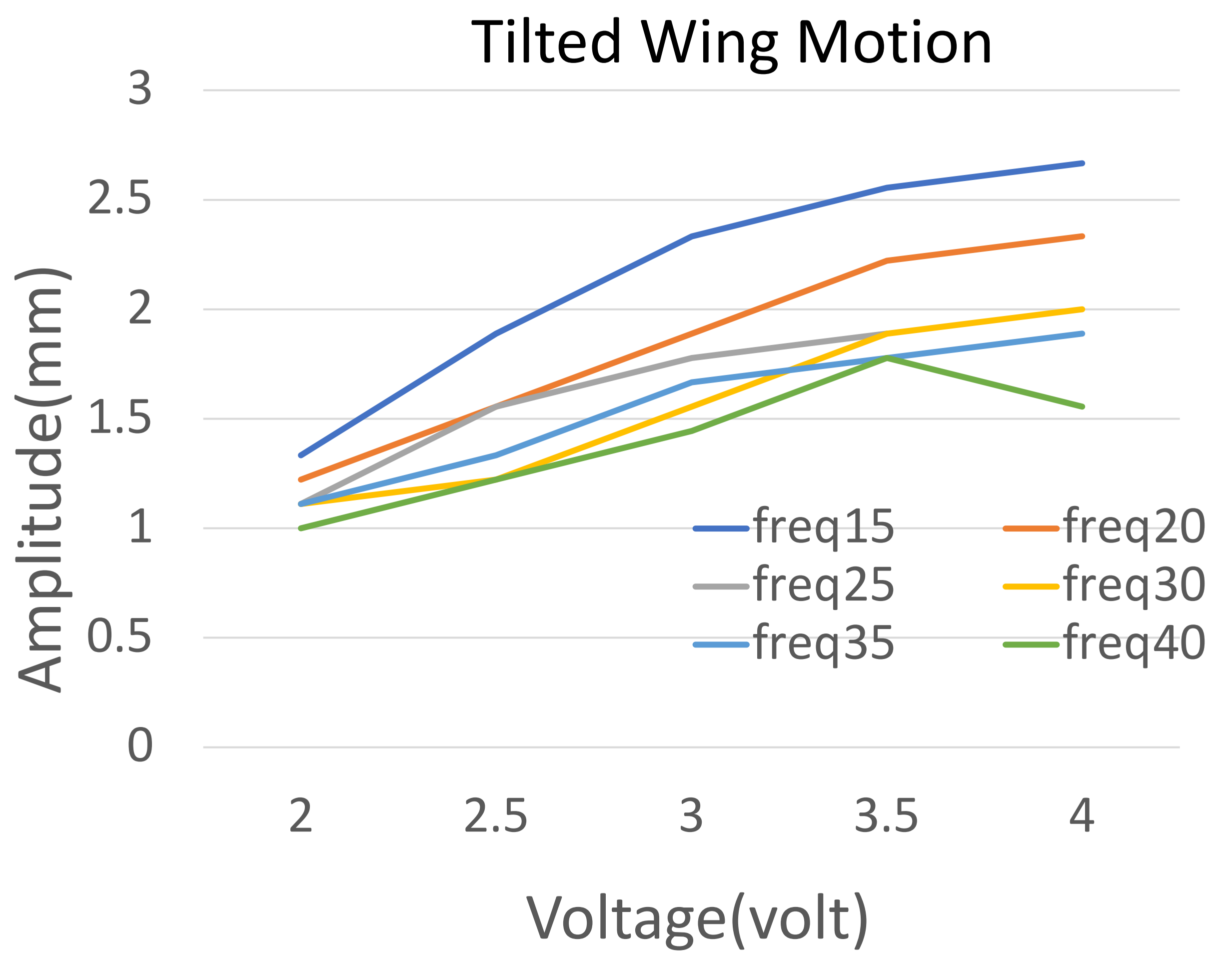
Tilted Versus Straight Wing Motion



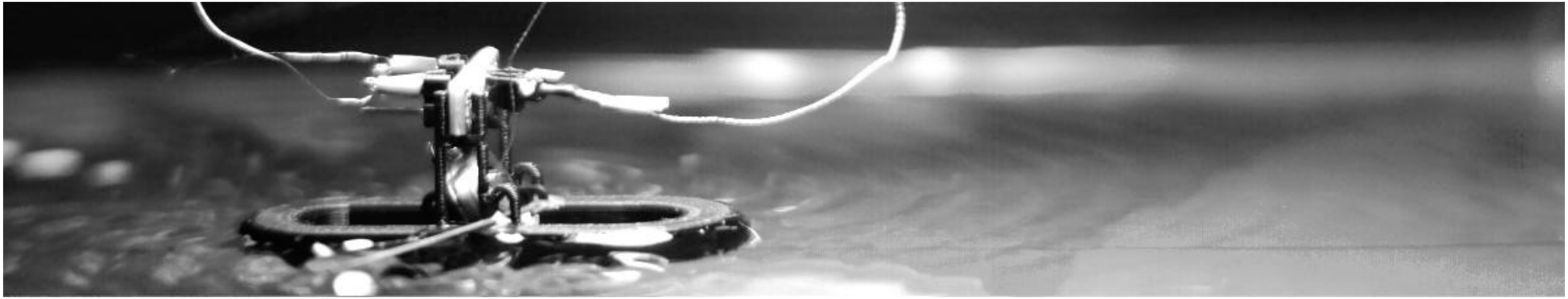
Calibration: Amplitude of the Wing Tip vs Voltage



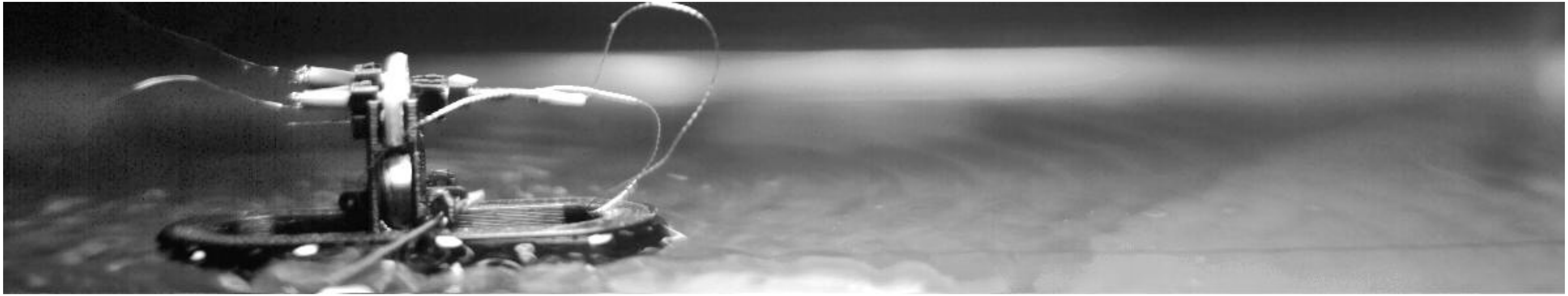


Comparing Velocities (30Hz, 4 volts)

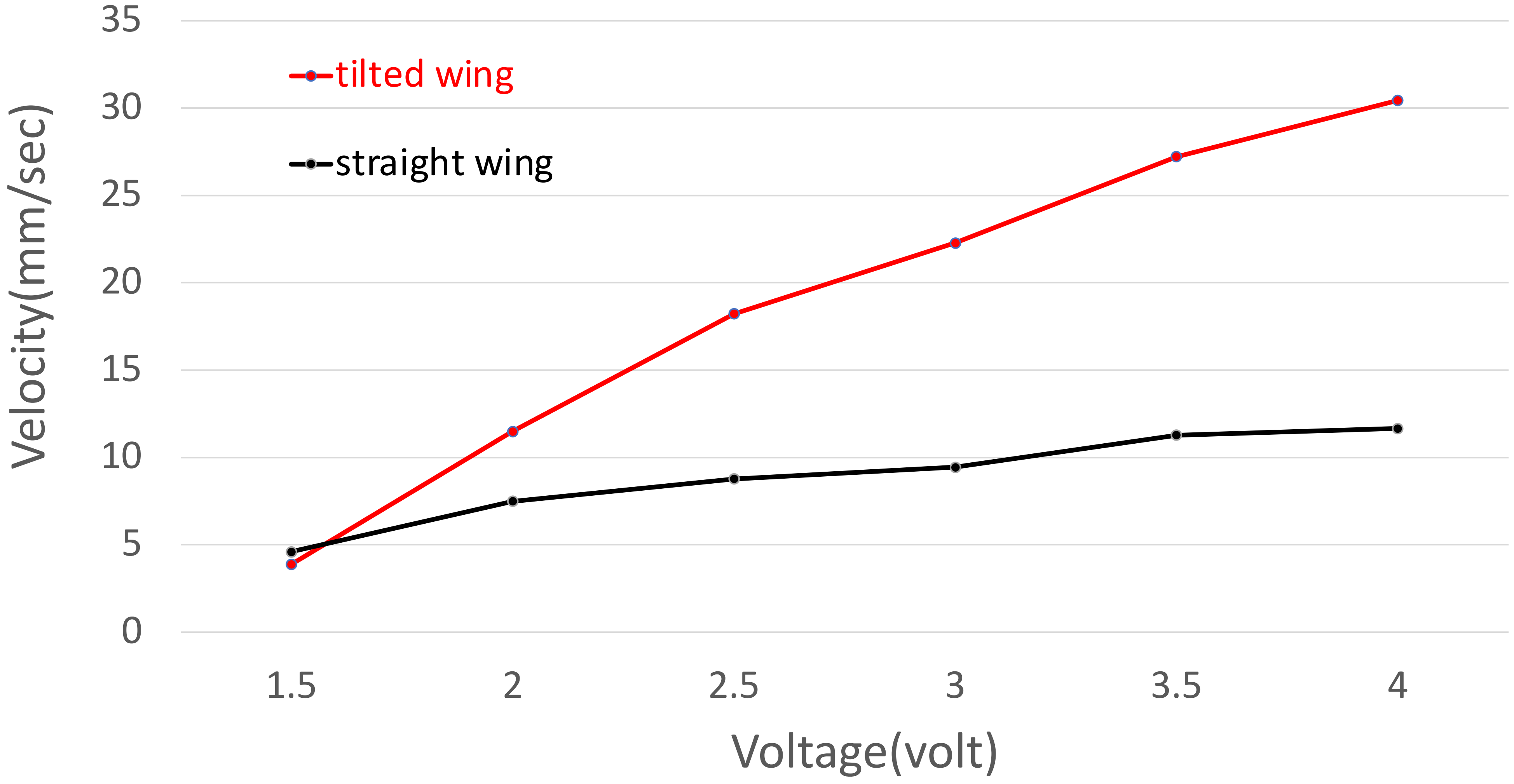
Tilted Wing Motion



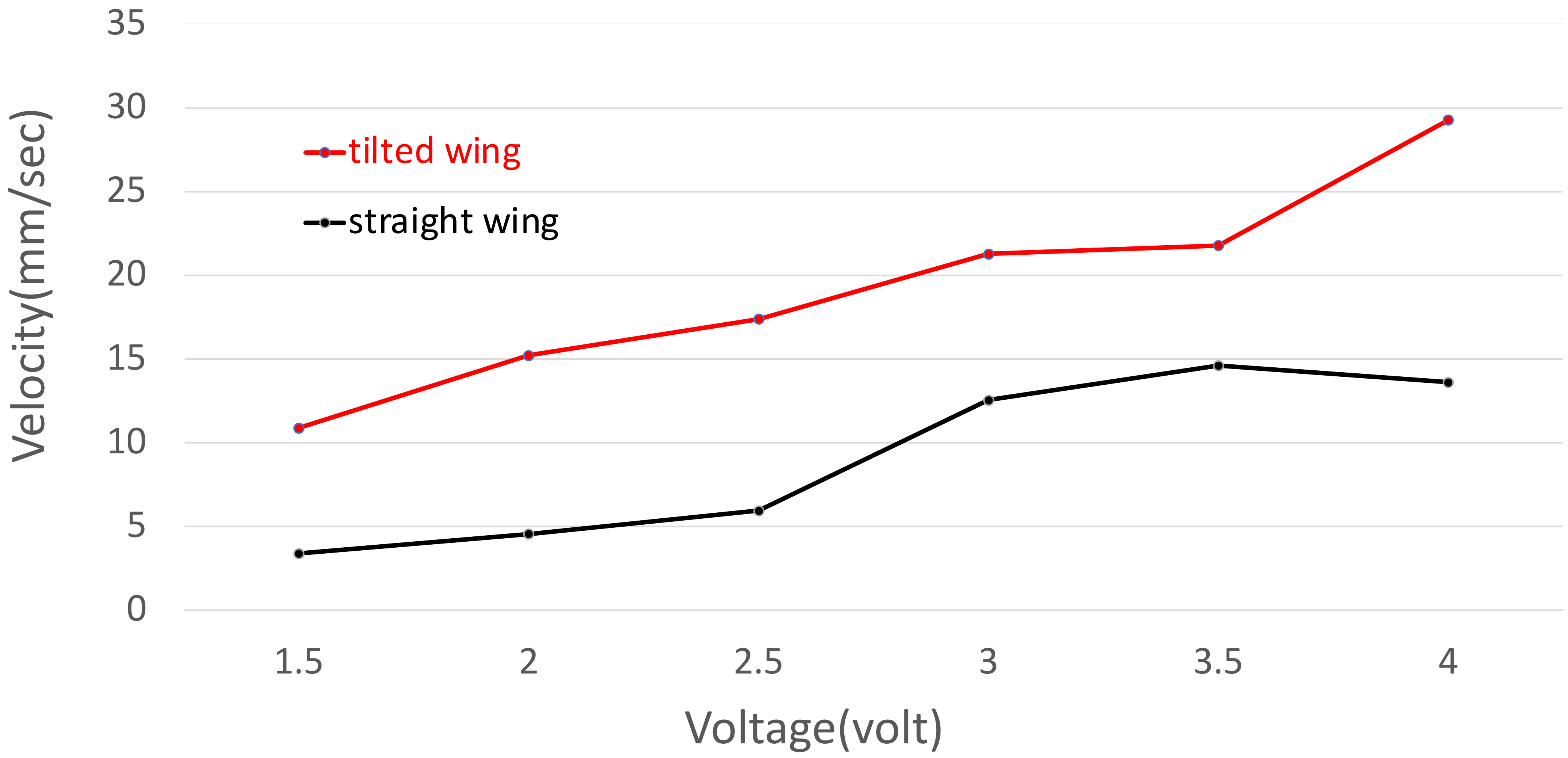
Straight Wing Motion



30 Hz : Tilted Wing Motion is Faster



45 Hz : Tilted Wing Motion is Faster

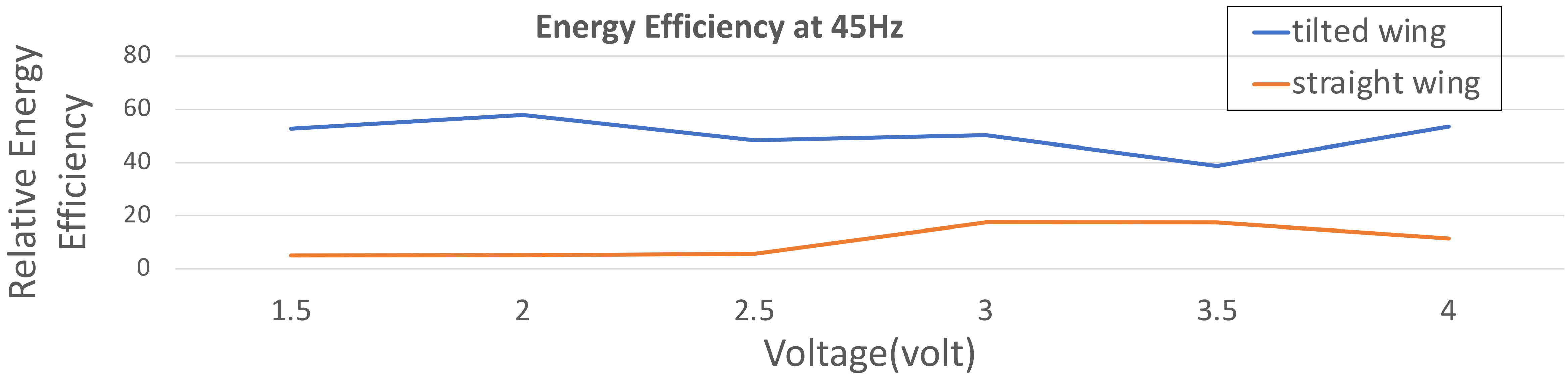


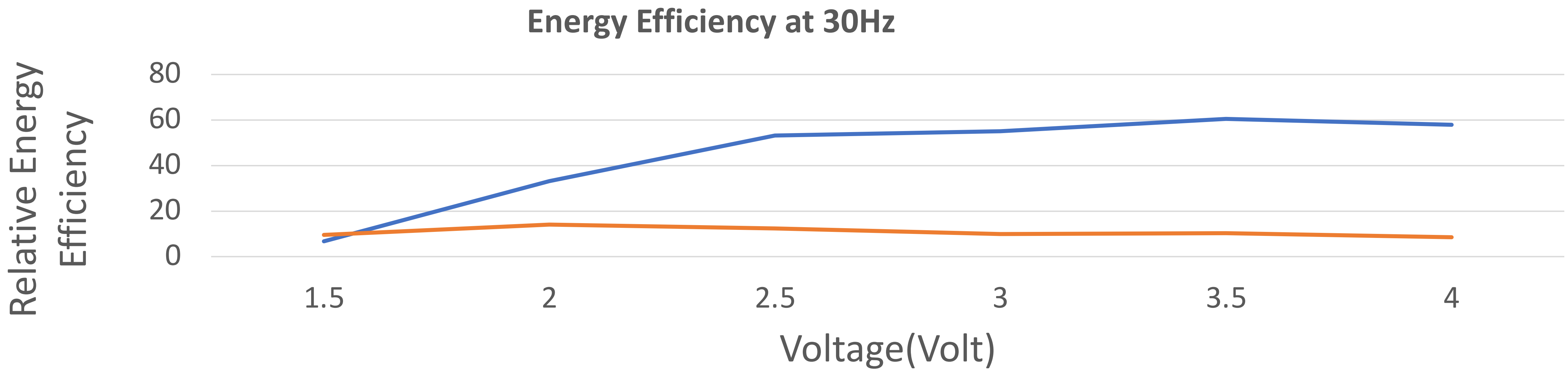
Efficiency

Efficiency: how much energy is used to maintain the swimming speed

$$\text{Efficiency} = \frac{E_{output}}{E_{input}} = \frac{\frac{1}{2}mv^2}{\frac{V^2}{Rf}} \propto \frac{v^2}{V^2}$$

Tilted Wing Motion is More Energy Efficient





Conclusion

- Having a simple up/down wing motion is less efficient and slower then a tilted wing motion
- A real bee’s motion is similar to the tilted wing motion, showing that the bees may have chosen the movement that maximizes efficiency and speed

Further Studies

- Optimize efficiency
  - Change parameters to create the most efficient bee using the mechanical model
  - Which wing motion, wing angle, wing length, wing shape, etc with results in the most efficient movement?
- Direction of movement
  - At higher frequencies, with the wing at a certain angle the mechanical bee will move backwards

What I learned

- Bees
- How to use
  - SolidWorks
  - 3D printer
  - High-speed camera
  - Analyze data using ImageJ
  - Excel

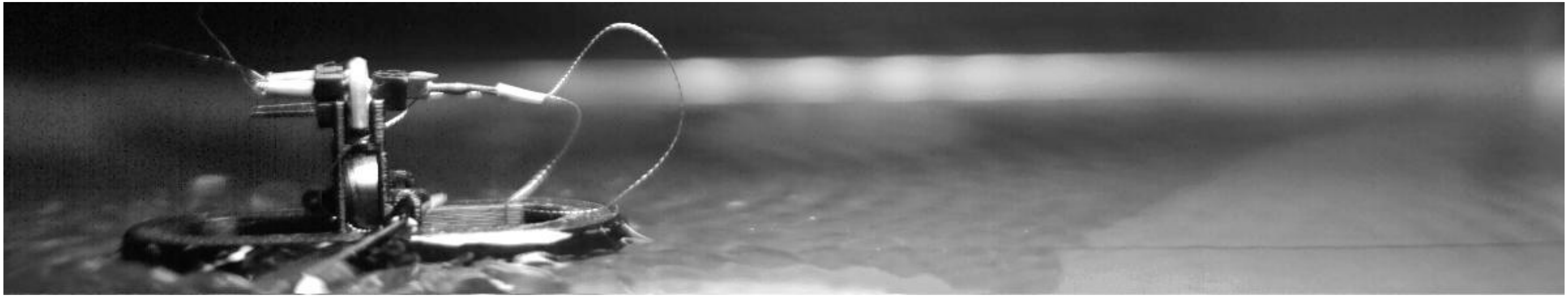
Thank You!!

- Chris Roh
- Morteza Gharib
- And everyone else in the lab!

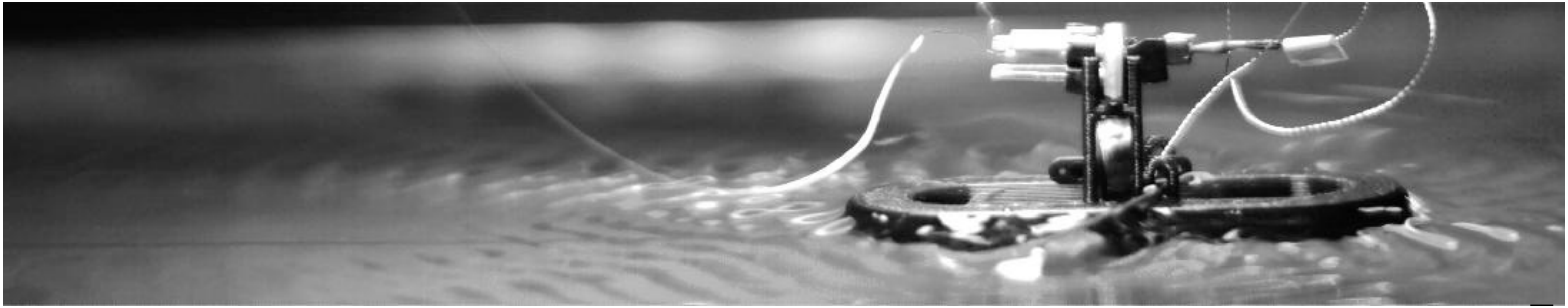
Direction of Movement

At 45Hz, amplitude of 3Volts

- Wing tilted 20 degrees



- Wing tilted -20 degrees



Efficiency of Mechanical Model

The mechanical model is not efficient:

example: With tilted wing motion at 45Hz and 2volts

$$\eta = \frac{\frac{1}{2}(.0054)(.0152)}{\frac{2^2}{(63)(45)}} = .0299$$