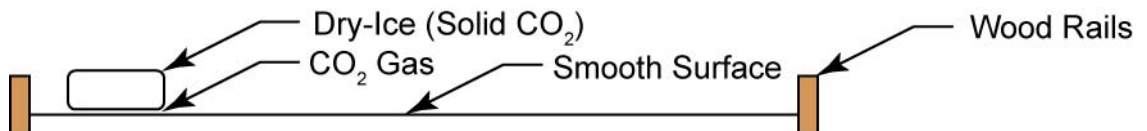


Cornerstone Electronics Technology and Robotics III
Moving and Maneuvering 1 Lab 1 – Newton’s First Law of Motion

- **Purpose:** The student will observe Newton’s First Law of motion using dry ice to simulate a “frictionless” object at rest and in motion.
- **Warning:** The main hazards and safety precautions for using dry ice are:
 - **HAZARD 1:** Extremely low temperature (-78°C) can cause freeze burns
SAFETY PRECAUTION 1: Wear gloves when handling dry ice or use tongs or spoon. NOTE: When performing demonstrations, wear gloves even when you are using tongs.
 - **HAZARD 2:** Expansion of carbon dioxide gas produced can generate high pressures in sealed airtight containers. **SAFETY PRECAUTION 2:** Store dry ice in non-airtight containers. Never store in airtight containers with screw caps.
 - **HAZARD 3:** Carbon dioxide gas produced is an asphyxiant in high concentrations. An asphyxiant is a gas or vapor that can displace or dilute air. Asphyxiants can cause unconsciousness and/or death if inhaled. **SAFETY PRECAUTION 3:** Use in large, well ventilated areas.
 CO_2 is heavy gas and will remain in low spots without assisted ventilation.
- **Apparatus and Materials:**
 - 1 – Level Smooth Surface with Containment Rails
 - 1 – Dry-Ice (Frozen CO_2)
 - Heavy Insulated Gloves
 - Area with Good Ventilation
- **Procedure:**
 - Dry ice has the feature of sublimation -- as it breaks down, it turns directly from a solid into carbon dioxide gas rather than a liquid. When a solid turns into a gas, it is called sublimation. Dry ice doesn’t evaporate, it sublimates.
 - Take a piece of dry-ice and place it on the smooth surface provided.
 - In the results, draw and label all of the forces acting on the dry-ice when it is at rest.
 - Now give the dry-ice a gentle but brief push across the smooth surface.
 - After the push, what does the dry-ice do? Record your observations.



Dry-Ice Set-up

- **Results:**

- Draw and label all of the forces acting on the dry-ice at rest.



- With the dry-ice at rest, explain what is happening in terms of Newton's First Law. Use labeled diagrams if appropriate. You will want to use some of the following words: force, gravity, balanced or unbalanced forces, or net force.

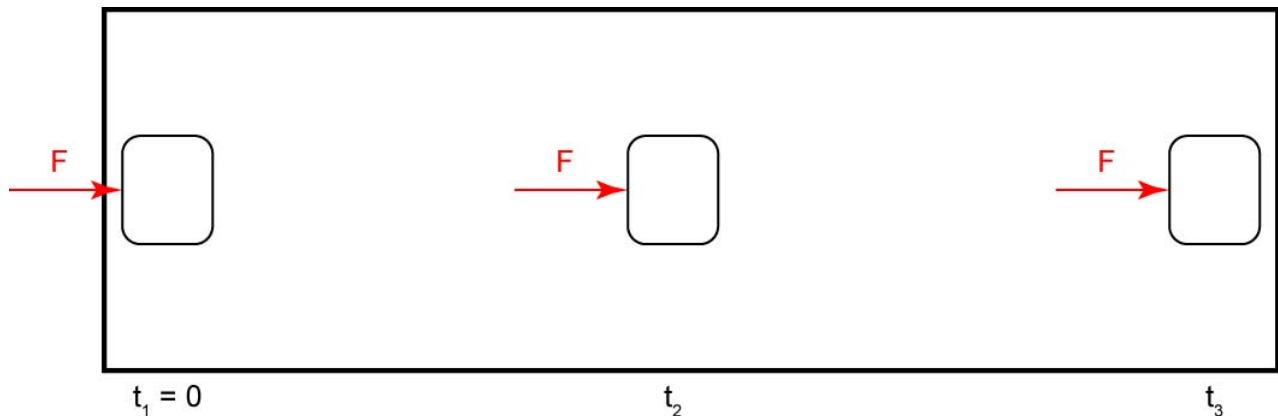
- After pushing the dry-ice, what happens?

- Again, explain your observations in terms of Newton's First Law.

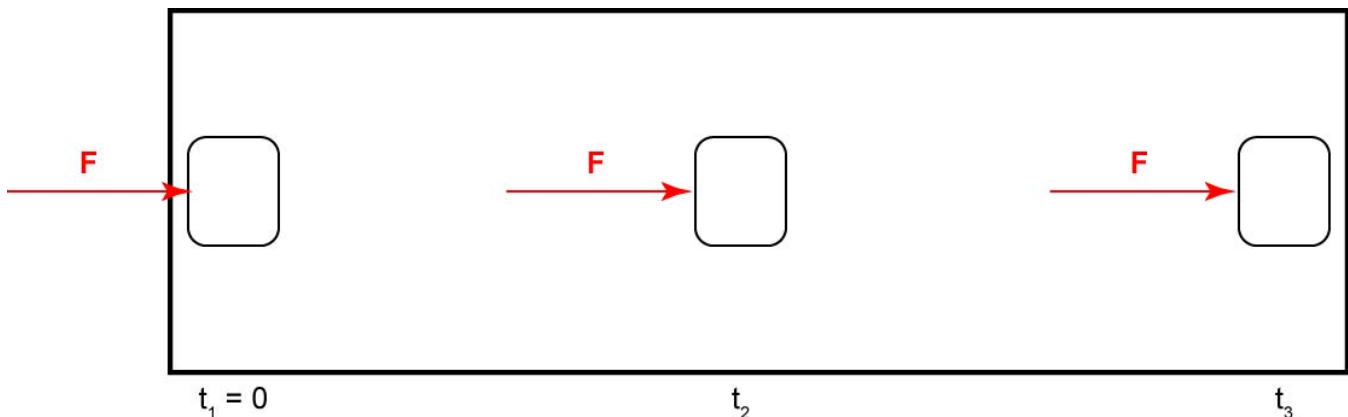
Cornerstone Electronics Technology and Robotics III

Moving and Maneuvering 1 Lab 2 – Newton’s Second Law of Motion

- **Purpose:** The student will observe Newton’s Second Law of motion using dry ice to simulate a “frictionless” object at rest and in motion.
- **Warning:** Review the hazards and safety precautions for using dry ice in Lab 1.
- **Apparatus and Materials:**
 - 1 – Level Smooth Surface with Containment Rails
 - 1 – Dry-Ice
 - Heavy Insulated Gloves
 - Area with Good Ventilation
- **Procedure and Results:**
 - Take a piece of dry-ice and place it on the smooth surface provided.
 - Apply a small constant force to the dry-ice and observe its velocity (its speed and direction) as it travels across the surface. Velocity is a vector quantity whose magnitude is a body's speed and whose direction is the body's direction of motion.
 - On the diagram below, draw a vector representing the relative velocities of the dry-ice at times t_1 , t_2 , and t_3 . The magnitudes of the velocities are only estimates.



- Now apply a larger constant force to the dry-ice.
- Draw the relative velocities at times t_1 , t_2 , and t_3 on the diagram below.



- **Conclusions:**

- When a force is applied to the “frictionless” dry-ice, did you observe acceleration?
- If there was acceleration, what was the evidence of the acceleration (review the definition of acceleration)?
- Again, if there was acceleration, what was its direction with respect to the applied force?
- When the force was increased in the second experiment, did the acceleration increase?
- When the applied force is constant, will the acceleration be constant? Remember $\mathbf{F} = m \times \mathbf{a}$.
- In our experiment, is the mass of the dry-ice a constant? Explain

Cornerstone Electronics Technology and Robotics III

Moving and Maneuvering 1 Lab 3 – Testing Prop Thrusts at Several Voltages

- **Purpose:** The students test the thrust of three different propellers using a homemade thrust test jig.

- **Apparatus and Materials:**
 - 3 – Different Propellers
 - 1 – 12 Volt DC Benchtop Power Supply
 - 1 – Mayfair ProLine Bilge Pump Model 2250 Motor (from Aftermarket Marine)
See: <http://www.amarket.com/imbp01.htm>
 - 1 – 5-Gallon Bucket of Water
 - 1 – Small Plastic Container
 - 1 – Clamp
 - 1 – Triple Beam Balance
 - Assortment of Lead Fishing Weights or Washers
 - 1 – Homemade Thrust Test Jig with Accessory Parts

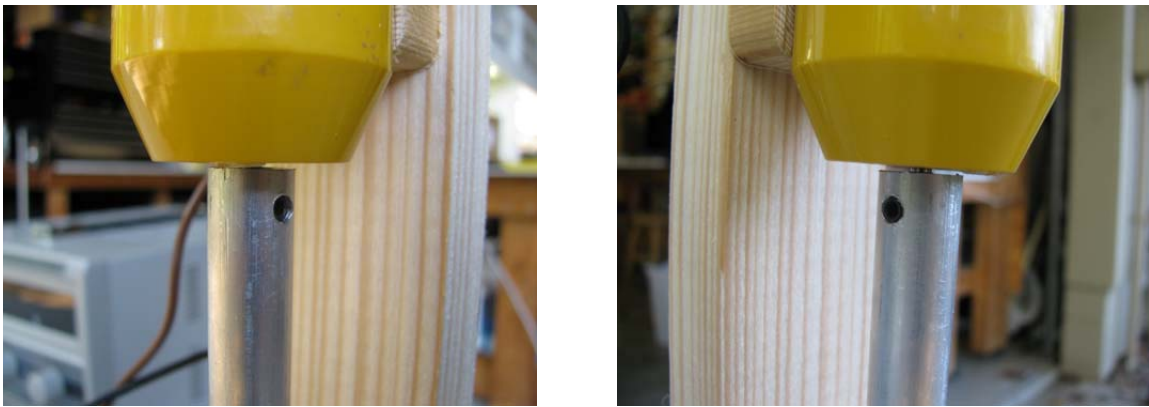
This thruster jig is built with a piece of 1 5/8" x 1/2" wood molding (from Lowe's) which has one end clamped to a work table and the other end is extended out from the table to provide a flexible cantilever. See the photo below. Pieces of wood molding thinner than 1/2" proved to be unstable when the motor was turned on.



A piece of 1 1/2" x 3/4" wood is attached to the end of the cantilever for motor mounting. Another piece is attached to help guide the end of the motor shaft (see photos above and on the next page).



It is difficult to attach the aluminum shaft onto the motor without introducing wobble. Use two set screws, one on either side of the shaft, to eliminate a significant portion of the wobble.



More ways to test thrust may be found in the textbook on page 671 or on the web at: <http://www.youtube.com/watch?v=Ca2Wlb6lR7g>

- **Procedure:**
 - Mount propeller #1 to the end of the motor shaft.
 - Clamp the cantilever to the table so the propeller is in the middle of the 5 gallon bucket.
 - Add a block of wood under the cantilever near the edge of the work table. See the photo below.



- Adjust the placement of the clamp so that the end of the cantilever is nearly horizontal.
- With the motor off, set up the metal angle or rod to line up with a mark on the vertical piece of wood as shown below. The thrust will be measured when the cantilever is brought back to this same vertical position by adding weights over the thruster to counter the force of the thruster.



- For our thruster, place a 5 amp fuse in line with the power supply.
- Connect the DC motor to the DC power supply to produce an upward thrust. Keep the power supply as close to the thruster as possible to minimize the voltage drop in the connecting wires. **Do not exceed the voltage rating of the motor (in our case, +12 volts).** Set the voltage at +12 volts.
- You may have to loosely guide the end of the shaft support with your fingers to avoid vibrations in the shaft.



- Add weights to the plastic container at the end of the cantilever until the metal angle lines up with the mark on the vertical piece of wood (see below).



- Measure the thrust by weighing the added weights and record the thrust, amperage and voltage for the test on a piece of scrap paper so you can average three tests. Convert grams-force to Newtons ($1 \text{ gf} = 0.00980665 \text{ N}$). See: <http://www.unitconversion.org/force/newtons-to-gram-forces-conversion.html>
- Perform the test three times and then record the average thrust, amperage, and voltage for the prop in the results.



- Plot your results on the graph provided.
- Repeat the test with two other props.



- **Results:**

- Prop #1:

Propeller #		Date:	
Voltage (V)	Current (A)	Thrust (N)	Power (W)
3 v			
6 v			
9 v			
12 v			

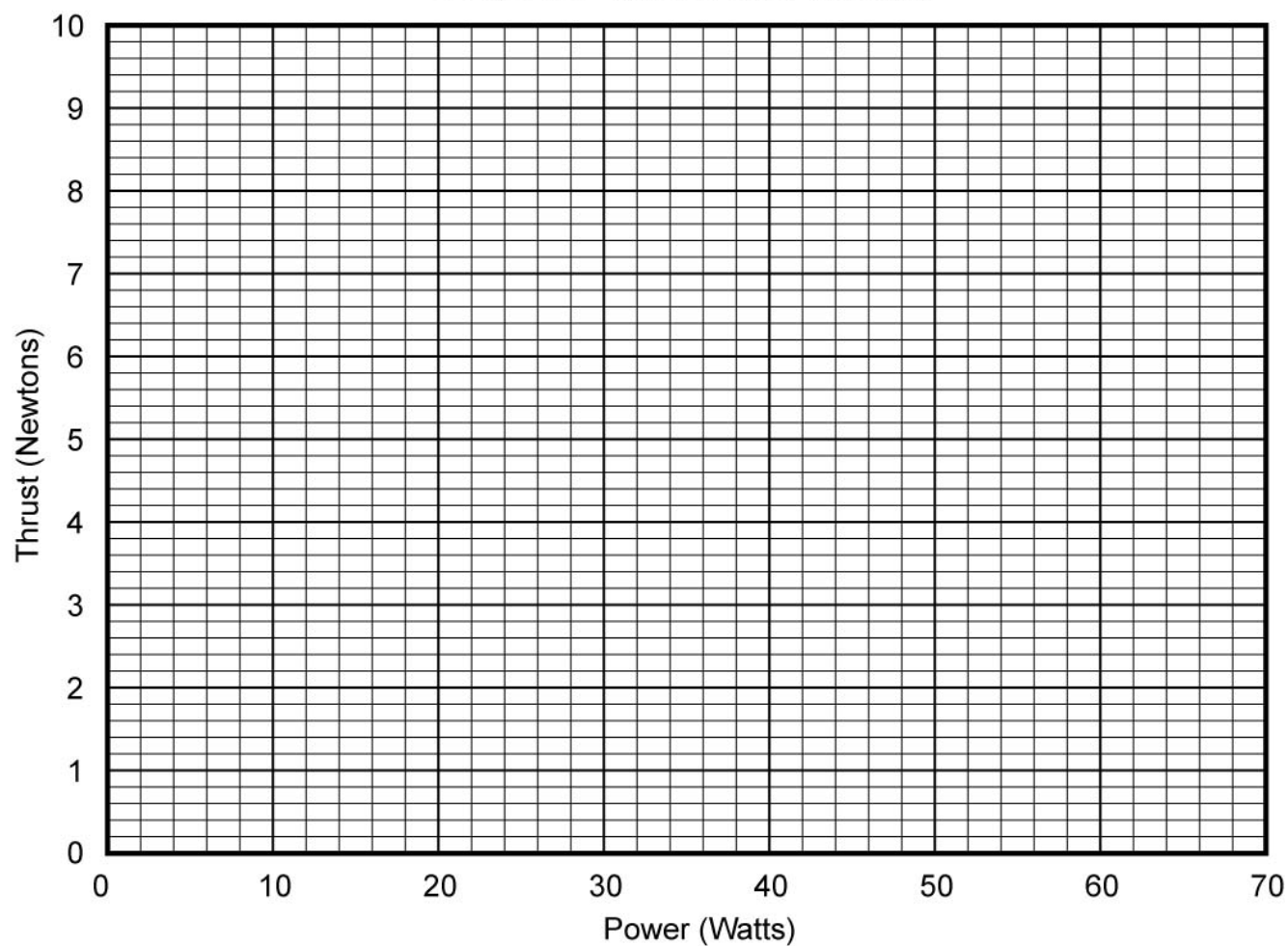
- Prop #2:

Propeller #		Date:	
Voltage (V)	Current (A)	Thrust (N)	Power (W)
3 v			
6 v			
9 v			
12 v			

- Prop #3:

Propeller #		Date:	
Voltage (V)	Current (A)	Thrust (N)	Power (W)
3 v			
6 v			
9 v			
12 v			

Propeller Thrust Test Results



- **Conclusions:**

- Which propeller was the most efficient at 12 volts (most thrust/watt)?

- If yo were going to use one of the three props o your ROV, which prop would be the first prop that you eliminated and why?

- Which of the remaining two propellers did you choose to select for your ROV and why?