Operator’s Manual

Muscle Recorder

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Important Safety Instructions:

If used properly, the Muscle Recorder generates the Force –Velocity curve for both muscle shortening and lengthening, in addition to the Length –Tension curve, for a variety of muscles at different stimulation levels. Prior to operating the device, it is essential to read this manual carefully in order to eliminate chances of injury. It is advised to follow the safety precautions listed below before operating this device.

- Keep saline solution away from electrical cords
- Clean the device after use
- Dispose of muscle in an appropriate manner
- Keep device away from young children
- Turn power off when not operating
Parts and Accessories:

- Lever arm

- Force Sensor
- Saline solution pump

- Weights
- Circuit Board
- LabVIEW program
Features:

The Muscle Recorder has the following capabilities and features:

- Uses LabVIEW, a state of the art virtual program by National Instruments
- Accommodates different muscle sizes
- Generates the Length-Tension graph based on the length of the muscle
- Calculates the velocity and then graphs the Force-Velocity curve for both shortening and lengthening
- Its lightweight frame makes it portable
- Allows the user to manually input information about the muscle being tested
- Automatically sprays the muscle according to a timer set by the user
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1 Introduction
1.1 General Overview of Device

The objective of the muscle recorder is to record the Force-Velocity and Length-Tension Relationship for a variety of muscles at various stimuli percentages. The Force-Velocity curve is recorded for both shortening and lengthening contractions of the muscle. Most devices used in other laboratories measure only the shortening (concentric contraction) of the muscle; therefore, this device is unique because it is also able to measure the lengthening (eccentric contraction) of the muscle. With the use of LabVIEW® program, the graphs showing the Force-Velocity (for both shortening and lengthening) and Length-Tension Relationships are acquired and displayed. This device will be implemented by the students in the Biomeasurements laboratory, and students will use the device in one of the experiments along with the LabVIEW® program. The aim is that students can understand the mechanics of muscle contractions analyzing muscle responses using the LabVIEW® program.

This section will provide the user with a top-down description of the various components of the muscle recorder. Pictures as well as descriptions are provided to make the user as comfortable as possible when first learning how to operate the device. In the next section (1.2), step by step instructions on how to use the device to test a muscle are included.
The entire device consists of a plastic enclosure containing a force sensor, weights, a lever arm, a saline reservoir and a saline pump. The muscle is attached to the lever by a fishing line; a tray that holds the weights is attached to the lever as well. In the back of the enclosure, there is the PCB board that houses the Hall Effect Sensor and voltage regulators. The bottom contains a saline reservoir, a pump and a vinyl tube pipe that sprays the muscle specimen with saline solution. With the help of National Instruments (NI) and the LabVIEW® software working together, the muscle will be stimulator through a pair of electrodes attached to the muscle, and the graphs showing the Force-Velocity (for both shortening and lengthening) and Length-Tension Relationships would be acquired and displayed after several trials for the experiment.

The device is a plastic enclosure that includes a lever arm, a saline solution compartment, a storage shelf and a PCB component section. It is made out of Plexiglas attached by methylene chloride, and the lever arm is a stainless steel rod. It was crylic Plexiglas that was ordered from Central Storage of the University of
Connecticut; the website was www.stores.uconn.edu, and the phone number was 860-486-3626. Plexiglas was ideal because it was light weight and cost effective. It is also durable and visually pleasing. The Plexiglas was cut into the sides of the enclosure then glued together using methylene chloride. The methylene chloride used was the type D37-1 produced by Fisher Chemical, lot number 902460 and FL-07-0290. In the image above, the doors of the enclosure as well as the shelf and the saline compartment are visible. The blue color is a protective cover, and the Plexiglas is colorless.

An important part of the device is LabVIEW. Our first step at building the program is one that reads the Hall Effect sensor output. The program was tested with the Hall Effect sensor, and it was determined to be functional. The final program, shown below, stimulated the muscle and reads the output of the force sensor, and turns on the motor in order to spray the pump when the muscle recorder is off. It also allows for the entering of data concerning the muscle.

This VI features a case structure with the following settings: run, spray and off. The following is the block diagram for the run position. This allows for the muscle stimulation and the reading of results. In the spray setting, a clock was added in order to run the pump for a designated time inserted by the user. The device doesn’t work while on the off position even though LabVIEW may be running.

Since there is a bug in the program that needs to be fixed, this is not the final version of the program. The final version will be included in the Final Presentation or in an updated report to be uploaded next week.
1.2 Step by Step Instructions

In order to use the device, turn the computer on and open LabVIEW. Then perform the following experiments or variations of them based on the instructor’s requirements.

**Testing required for the relationships**

- Obtain fresh muscle for experiments to be conducted
- Creation and design of a working Hall Effect sensor circuit
- Testing and calibration
- Measuring the rate of shortening and lengthening of muscle contraction under different loads
- The use of the lever arm for isometric conditions to reduce the force of gravity and the inertial force of the load at the muscle
- A variable for change in muscle length from the resting length
- To experiment when the muscle is first stretched to its optimal length to the start of the isotonic experiment
**Length-Tension:**

The relationship between muscle length and the maximum force is determined by varying the length at which the muscle is held during isometric twitch contractions. The steps are as follows:

- Set muscle at shortest physiological length
- Calibrate without any weight
- Deliver a single pulse at maximum stimulus
- Change to new length
- Stimulate and repeat as many times as necessary until the muscle’s longest physiological length is reached.
- Reset muscle to its shortest length
- Stimulate, then record tension

Below is an example of what the graph should look like:

![Graph showing the relationship between force and length](image)
**Force-Velocity:**

The force-velocity curve is obtained by stimulating the muscle with different load at the same stimulation level. Then the stimulation level set to a different constant and the experiment is run again.

- Stimulate muscle without any load
- Place a weight of five grams (5 g) on the lever arm then stimulate the muscle
- Increase the weight by five grams and stimulate the muscle
- Repeat the above process
- Measure height of the response at the peak for each recording in LabVIEW
- The time required for each peak of the contraction is measure in LabVIEW
- The velocity is calculated

Below is what the graph should look like:

![Figure 1: the force-velocity curve](image)
MAINTENANCE

Perform routine actions to keep the muscle recorder working, fixing electrical parts that become out of order or brake, and to prevent trouble from arising which would be a preventive maintenance. There are actions which have as an objective to retain the device in or restore it to, a state in which it can perform the required function. The actions should retain the device in a serviceable condition. There is work required to keep the device in such condition that it may be continuously used, at its original or designed capacity and efficiency for its intended purpose maintenance. There are several units to be considered for the muscle recorder device. There is electrical, software, material, and environmental maintenance needing to be performed in order to keep the device running.

ELECTRICAL MAINTENANCE

The main electrical components of the muscle recorder include the Hall Effect sensor, voltage regulators, transistor, a force transducer, a DC water pump, and are fixed in the PCB board. Some of the electrical parts do not require individual electrical maintenance but proper handling is required for proper function and durability.

1. Hall Effect sensor

- Care should be taken because the little piece is relatively sensitive to static electricity and magnetized items.

- Also its legs are brittle and care should be taken when trying to connect it or soldering into the PCB board.

2. The force transducer and the sensor

- Must be properly calibrated before each test and recording.

- Calibration helps to produce better measurements.

3. The 12V DC water pump

- Has a long life brushless motor.

- Ideal for continuous duty applications, it has a
durable magnetic rotor, therefore is has very low maintenance.

- To prevent little debris to get stuck in the motor through the fluid inlet, a little mesh can be placed in the inlet.

- The water pump can be raised off the bottom of the reservoir to keep it away from particles found in the fluid of the reservoir.

- The pump’s tubing should be connected properly to prevent leakage of the fluid.

4. The PCB Board

- Mechanically supports and electrically connects the electronic components using conductive pathways from copper sheets laminated onto a non-conductive substrate.
- Must be properly used in order to guarantee its function.
- The component leads are electrically and mechanically fixed to the board with a molten metal solder.

- Areas that should not be soldered to may be covered with a polymer solder resist (solder mask) coating. The solder resist prevents solder from bridging between conductors and thereby creating short circuits.

- Solder resist also provides some protection from the environment.

- When boards fail to work, it might need to be de-soldered to replace failed components.

- There is a coat which is applied to the board by dipping or spraying after the components have been soldered. The coat prevents corrosion and leakage currents or shorting due to condensation.

- PCB boards are static sensitive, and therefore must be placed in antistatic bags during transport.
- When handling these boards, the user must be earthed;
failure to do this might transmit an accumulated static charge through the board, damaging or destroying it.

-Even bare boards are sometimes static sensitive. It is quite possible to blow an etch off the board (or change its characteristics) with a static charge.

In general:

• Do not expose the components or the PCB board to static electricity.

• The electrical components connected the PCB board are very sensitive and one could possibly damage them.

• Keep electrical leads clean.

• Keep the electrical components in a dust free environment.

• The electrical components should not be exposed to high temperature since it may cause damage to the device.

• In the same manner they should not be exposed to extreme cold temperatures.

• Components should be used and placed in room temperature.

• Prevent water and humidity from coming into direct contact with the PCB board and its components.

• Make sure components do not come in contact in the PCB board.

• Fried components need to be re-checked and replaced.

Most of these problems will be avoided in the muscle recorder set up because there will be a small enclosure within the muscle recorder enclosure. This small enclosure will protect the PCB board and its components because as the rest of box it is made out of Plexiglas. Additionally there is a top shelf used for placing electronic parts to prevent any fluid splashing them when hydrating the muscle.
SOFTWARE MAINTENANCE

The software used to control all of the aspects of the muscle recorder device is the LabView® program.

• For proper use one has to make sure that all the output wires are connected properly to the BNC board, otherwise the LabView® program will not be able to receive the information from the components.

• The BNC board must be properly connected to the PXI box in order to work.

• Special attention should be paid to the values that the software is giving to prevent strange or wrong readings coming to the Excel sheet. For example be careful with the conversion between scientific notation and number values.

• The user should constantly monitor connections, the written program in LabView®, check for errors, values, parameters, and variables, in order to prevent problems or confusing data.

• The pins in the BNC board should be handled gently and connected properly.

• Prevent any spillage on top or nearby its connections.

• Need to control the timing between the acquisition and generation modulus, to know which acquisition sample should correspond to which generation sample.

• Calibration is required between each experiment.
PLEXIGLAS (ACRYLIC) MAINTENANCE

Plexiglas is an acrylic, very versatile material having great impact strength yet it is light weight with exceptional optical quality. It is easy to work with as it can be sawed, drilled, routed, glued, painted, and decorated. Although tough and practical to work, with certain measures should be taken into account when working with Plexiglas.

• Buy the acrylic making sure that it has not been sitting stored for a long time.

• Before building the acrylic enclosure, the user must be aware of the maintenance steps to build and obtain a strong and durable enclosure for the muscle recorder.

• Once the Plexiglas is cut into pieces it should be filed to obtain smooth edges, helping to obtain a better contact between pieces for a stronger bond.

• Sanding can also help prevent snapping or breaking of edges.

• The pieces are glued using Methylene chloride (dichloromethane). Re-application of the chemical compound can be applied to keep the box from becoming weak.

• Plexiglas measuring 0.635 cm (¼ of an inch) in thickness is ideal for the building of the muscle recorder enclosure. If thinner than 0.635 cm, the material becomes flimsy and brakes easily.

• It is easy to drill, but the user should try to drill holes in the acrylic before gluing pieces together.

• Otherwise should be done slowly and well supported on top of wood to prevent cracks around the hole.

• When cleaning it, consider a clean soft terry cloth towel or cheese cloth.
• Do not use paper towels. Paper towel fibers are to coarse and will scratch the surface of the Plexiglas.

• Try to leave the protective peeling plastic to protect the enclosure from scratches.

• The enclosure should be cleaned periodically to remove any dirt, dust, or residue from the fluid.

• The cleaning of the enclosure is facilitated by the usage of the reservoir acrylic box by removing it from the enclosure and washing it with fresh water.

• The muscle recorder should be handled with care, since as any other acrylic material, it can brake with any excessive force or bang.

• This material is very resistant to water, but extreme temperatures; both hot and cold will wear it down and make it lose its properties.

• Heavy objects should not be placed on the top shelf as it could fall down.

• A lot of weight on the lever can loosen the bottom shelf requiring extra chemical to glue it again.

• The user should handle the enclosure’s door with manner to prevent the braking or loosing of them.

• If the screws that hold the lever arm come in contact with water, it is necessary to clean them to prevent corrosion.

• In the same manner, the brass hinges will need to be cleaned if they come into contact with any kind of fluid.

• Remaining pieces of Plexiglas should be stored in a room temperature place, preventing other object from scratching its surface, and maintaining it from being under heavy objects.
ENVIRONMENTAL MAINTENANCE

There are several factors in the environment that can contribute to the malfunction, breakdown, and even failure of the muscle recorder device.

Corrosion
• It can affect connections between cables, in the PCB board, PXI box, force transducer, and the screws holding the lever arm.

• As stated before, a small enclosure will enclose the PCB board and its components.

• Periodic cleaning of the cables, board, and box should be done.

• Careful attention to the screws and nuts holding the lever arm, as well as the brass hinges holding the enclosure’s doors.

• The lever arm itself is made out of stainless steel, but once again, it should be dried after each experiment.

Fluid
• The fluid used in the experiment for the recording of the muscle is saline solution.

• The salt in the fluid can cause problems if coming into contact with any electric component.

• Try to keep the spray of the pump away from the main components, also trying to minimize splashing of fluid.

• The water pump should work just fine with the saline solution, but it would be proper to rinse it after each experiment with fresh water to help it last longer.
• The Plexiglas is water resistant; therefore there is no problem of having the saline solution coming into contact with it for extended periods of time.

• Proper cleaning of the Plexiglas with fresh water after each experiment is necessary.

Moisture
• Compared to water, moisture is harder to prevent it from coming into contact with all the components.

• Make sure there is a constant check for moisture around the main components.

• The PCB board enclosure should be checked to prevent moisture coming in contact with electrical components.

Temperature
• Avoid exposing the muscle recorder to extreme temperatures.

• Very hot temperatures can cause slight deformation of the Plexiglas (weaker properties).

• It can also damage electrical components in the PCB board.

• Hot temperatures damage the muscle to be tested.

• Very cold temperatures can also influence the durability and effectiveness of electronic components.

• Under colder temperatures than normal, the muscle might change properties (muscle contraction time).

• Room temperature is ideal for the muscle recorder and the set up of the experiments.
Storage

• Muscle recorder should be stored in a room temperature place.

• It is should be moisture free.

• Prevent dust from getting into difficult sites in the entire enclosure and the PCB board.

• Do not leave the device near the end of a table, because any sudden movement can make it fall down.

• All components should be inside the enclosure when the experiments conclude after it has been properly cleaned.

• It should be carried with both hands, since the entire Plexiglas enclosure is rather heavy.

MECHANICAL MAINTENANCE

Several parts of the muscle recorder device must be kept in good condition, and they should have the proper maintenance in order perform its purpose. The user should keep in mind that mechanical maintenance involves planning, reviewing, and evaluating the entire device installation, construction, modifications that it might need, and repairing any malfunctioning component.

Muscle

• In order to obtain the relationship curves, an animal muscle is required.
• The muscle selected for this experiment is the frog’s gastrocnemius.
• The frog can be euthanized by the physical method of cervical dislocation, or pitching.
• Humane care of animals using mechanisms to minimize pain and suffering must be maintained.
• Those using animals need to be aware that disease prevention is not simple, but involves a variety of complex considerations.
• Need to complete the IACUC (Institutional Animal Care and
Use Committee) protocol, with the most recent information.

- Complete the University of Connecticut Occupational Health and Safety Program for Animals Handlers Personnel Form, with all of the user’s updated vaccines.
- The user needs to familiarize with all of the details of its use and maintenance.
- All factors responsible for variation within and between experiments must be defined and controlled.
- Environmental factors can affect research animals and thereby confuse research results as well.
- Relaxing effect on the skeletal muscle is important to obtain good results.
- During the experiment, the muscle needs to be kept fresh by applying good amounts of saline solution.
- The temperature in which the muscle is exposed to is also important, the cooler the temperature, the fresher the muscle will stay.
- Maintenance of the environment in which the frog is euthanized should be kept in hygienic conditions.
- Proper cleaning of the site should be maintained.
- Ask about the proper disposal of the animal and the muscle used to prevent spread of disease, improper disposal, or diffusion of odors.

Needles
- Percutaneous electrical nerve stimulation is done through needles injected in the frog muscle.
- Electrodes kept in good conditions deliver good muscle stimulation.
- Each needle should be subjected to being disinfected prior to each experiment.
- They require low maintenance as they are surgical stainless steel concentric needles.
- Store the electrodes in a well sealed package where they are not under pressure.
- Prevent any kind of bending or breakage, otherwise replacement will be necessary.
- Proper connection between the concentric electrodes and the BNC cable is required to send the stimuli.
• Good mechanical maintenance can be provided by the user by always checking soldering connections and re-solder if required.

Lever arm

• The lever arm is surgical stainless steel requiring low maintenance as it will not be corroded by the saline solution or humidity.
• Check the magnet, proper positioning and attachment in the lever arm.
• The lever arm design works when the attachment to the enclosure is precise and strong.
• Always make sure that the screws and the nuts are well tight to maintain the lever arm in the desired horizontal position.
• The pin made out of the screws, and nuts should be cleaned and dried to prevent any type of corrosion.
• Keep the lever arm free of any stress caused by tension, leaving the lever in a downward position after tests, and leaving no weights hanging on it.
• Obtain and test the quality of the nylon before each experiment.
• Hooks used in the attachment of the muscle should be cleaned after each experiment to keep them in good condition.
Technical Description:

This project designed a muscle stimulator in order to stimulate a frog’s gastrocnemius muscle, record its outputs digitally, and then output all that information to a graph. The graph will be self-generated by the program recording and taking all the data together. The software integrating all the data collected will be LabVIEW, a product of National Instruments.

The most basic challenge in design of our system was creating a circuit board which was suitable to the needs of this project. The circuit board was not as complex initially as it was redesigned to be. The circuit board at this point is not a PCB board, but is rather a proto-typed proto board. This is as well functioning as a finalized PCB board, so it is still sufficient to run the project off, though a finalized PCB board would have been preferable.

The design began with the figure presented below:
This circuit board was an extremely primitive design. It only had one function, and that was to make the Hall Effect sensor work. The Hall Effect sensor was researched by our group to have a very complex circuit associated with it. According to a master’s thesis published by Meraj Khan the Hall Effect sensor had a circuit design diagrammed below, and we hoped to re-create that exact circuit in the figure above.

Unfortunately, information we had at the time was incomplete about the sensor, and we were uninformed as to the best mode of operation. As it turns out, the above information tells about the inner workings of a Hall Effect sensor, and is not really pertinent to the purposes of this design project. The actual setup for a Hall Effect sensor circuit it turns out is much simpler then these previous designs indicate.

**Hall Effect Sensor:**

The Hall Effect sensor is a 3-prong device that has to be wired up according to diagram in order to have a meaningful working output. This is one drawing available
from Digikey’s website. Digikey is the manufacturer of the Hall Effect sensor which we have chosen to purchase.

Digikey’s available online information was fairly conflicting in what it provided as a guide to proper configuration for optimal output of their device. The diagram shown just above indicates that the left terminal is voltage, the middle terminal is ground, and the right terminal is output. The following alternate diagram was available in the same data sheet document which provided the preceding information.

This was misleading for the group as it indicated that instead of having the right terminal as an output, it was having the middle terminal as an output. After configuring one of our two Hall Effect sensors in this manner, we got a reading from it that was 0 voltage. We asked Dave Price what the problem could be with our circuit, and he immediately asked to see the data sheet. When he was shown this diagram, he indicated that sometimes manufacturers of parts put out confusing diagrams aimed for the employees in the company’s usage, and not necessarily for customers who use the product. He indicated that this could have been a message for electrical engineers within their company manufacturing the product, and not for clients who were using it. Additionally, he added we continue to search the same document and possibly find another configurations diagram. Upon doing so, this image was stumbled upon:
The main significance of this image is not the constant and values which it portrays, but the configuration diagram which is more user friendly then it lets on. This case indicates that the left lead is a positive terminal, the middle lead a negative terminal, and the right lead an output terminal. The right lead as a positive terminal would have a 5 Volt lead connected to it since this is the livewire lead, and the device runs off 5 Volts DC input. The negative symbol on the middle lead is not one which we would have used, since our standard of writing a 0V terminal is ground. The negative lead simply signifies that this terminal must be connected to the local ground. The local ground in this case is the ground which is shown on the power supply. Finally, the only terminal left uncoordinated is the output terminal. This terminal provides the service from the function of the Hall Effect sensor. The sensor transforms the input voltage, and sends a readout value through this terminal. This is the hot wire which we seek value from. The output of this lead is connected to a DAQ which is to be output directly into LabVIEW. Equations must be setup in LabVIEW so that it takes this voltage value from the sensor and then converts it to a useful value of length. This length will then be the y-coordinate of our length versus tension curve.

The way the Hall Effect sensor records a change in length is a pretty brilliant harnessing of a phenomena observed when an electric current is passed through a magnetic field. If there was no magnetic field present,
then the Hall Effect sensor would have a constant proportional effect on it's output reading. Under magnetic field quantity $B = 0$, the Hall Effect sensor acts as a voltage transformer, with a simple equation defining its inputs and outputs. That equation is shown below.

$$V_o = (1/2) V_{in}$$

Upon influence of a magnetic field, the result of the equation $V_o$ varies dramatically. Because of this, if the sensor were held in a fixed position, and then a magnet were placed in motion, the sensor would output different values of voltage depending on how far away the magnet generating the magnetic field was. The relationship between these two would be terrific if it were linear, but unfortunately, that is not the case. Because of this, a relationship between the two must be determined, and this could be done by taking a regression. Because the relationship was determined to be nonlinear, the next step would be choosing what type of regression would be best to suit the data. The next rung up on the power of equations ladder is the quadratic equation, but how much could the result of a quadratic regression be trusted? Because of this issue, it was necessary to evaluate how close the $R^2$ value of the number is. The closer that value is to 1, the more valid the regression would be. Ultimately, the equation must fit the form of $y = mx + b$ since it is a linear relationship we seek. Therefore, squaring the resulting data in a LabVIEW program, and then multiplying it by a constant would be sufficient to determine what value is needed for that program. The data values we took are shown below. In this case, the x value represents a change in length, and the y value represents the output voltage. This leads to a slope of change in y divided by change in x which will have units Volts per unit length. Length will be measured in meters, and Volts will be measured as so.

**Force Transducer:**

An additional part to the measurement instrumentation of this design project was the force transducer. Force is an integral element to this experiment. There are forces generated by gravity which act upon the apparatus at all times. Also, the main studied element in this experiment, the muscle itself, generates a force when it contracts. This force needs to be measured, and the only suitable
measuring instrument to do this would be a force transducer. The force transducer will continuously record the force which it is imposed upon, and then output an electronic voltage as a result. This means that it operates in a similar manner to the Hall Effect sensor. That sensor, observes a change in magnetic field, and then has its amplifier outlet a different voltage. This sensor, observes a change in forces applied onto it, and outputs a different voltage. They are analogous in the meaning that they both respond to outside stresses, and output different voltages as a response to their environmental influence.

Sensitivity is the most important parameter when selecting a force transducer. Many industrial projects require a force transducer to measure the colossal forces generated in a large metal machine operation. Others are the size of large cumbersome machines because their functions are on such a great scale that in order to generate readings in a high magnitude, the machine must be built large. Our physical constrictions of our plastic box and small quantity of force generated necessitate a need for a small force transducer, and one that has been engineered to deliver results which are not of great magnitude, but are great in terms of quality of accuracy. Therefore, when selecting a force transducer for the purposes of this design project, it was more advantageous to select one which was made for student research purposes rather than commercial sales objectives. Because of this, we marketed first toward devices which are made by student supply companies before searching product made by Digikey or other commercial suppliers. The order of the force measured by those devices were much greater than the values which we seeked.

The force generated by the muscle was calculated in a non-conventional way. The group had observed from the PNB department how much force is generated in the frog gastrocnemius muscle, but the way force was recorded in that department was in grams. It is difficult to accurately gauge what a force measured in grams truly represents, but we believe that this means how much force the muscle would be applying under acceleration due to the gravity since the muscle is operating here on earth. This leads to calculation based on a simply Newtonian mechanics equation, and will lead to the ultimate values for the forces sought. Instead of calculating every equivalent value for force along the
curve, it made more sense to solve for the hi and lo values of the data set, as this will indicate the range of which the force will operate at. This can be done by this equation:

\[ F = \frac{(mg)}{1000} \text{ (g in grams)} \]

In this equation, \( F \) is the force generated, \( m \) is the recorded mass value, and \( g \) is acceleration due to the gravity. The quantity on the right is divided by 1000 because the mass is measured to be in grams, and the standard unit of mass for measuring force is kilogram. Multiplying by the constant of \((1/1000)\) converts the units of mass from grams to kilograms. The minimum value for this study was 0g which equals 0 Newtons. The maximum value shown was at about 750 grams, which converts to 7.35 Newtons. Now that the order of the target force developed is known, a force transducer may be selected which appropriately matches this quantity.

The transducer which we ultimately selected is produced by Pasco. Their company specializes in research devices made for students, and they again fulfilled that objective with this device. Its model number is PS-2104 and it is titled the Pasco PassPort. The price of the said device is roughly $108.00. It is shown below.
A nice feature of the above design is the USB cord which sticks out the back of the device. This is the port in which the output of the device is read out upon. It supplies the value from the device from the sensor to the computer, allowing for real time updates in the force being developed within the muscle. The specifications of the device are available below:

Sensor Range: ±50 Newtons (N)
Accuracy: 1 %
Resolution: 0.03 Newtons (N)
Max. Sample Rate: 1,000 samples per second
Default Sample Rate: 10 samples per second
Over-limit Protection: Prevents damage from forces greater than 50 N
ZERO Button: Tares the output to zero Newtons before each use.

**Pump:**

Our pump design was a continuously improving setup that began primitively. Our original design did not have a lot of foresight to expect all the future problems it brought along. This also contributed to future delays farther down the road. The pump we originally bought ran off of 120 Volts AC power. What this implied is that it needed its own individual power cord which connected to the wall. This further meant that a separate wire with a voltage transformer would be needed to plug in to our PCB board, which would ultimately mean that for operation, the device would need 2 plugs connected into the live wire 120 V AC outlet in a wall socket. This was an engineering practice which we chose to improve upon. The way we would do this was create a PCB hub which every voltage needed was supplied off of. By modifying the approach to this, it also implied that the pump design which we previously had was to be insufficient. Rather than use a pump which ran off of 120 V AC, we needed to make a pump which operated sufficiently off of some DC Voltage which was less than or equal to 12 V DC. The reason it would have to be less than or equal to that arbitrary 12 Volt value is because this same board would have 5 volt and 8 volt voltage regulators which would drop the 12 volt input to a 5 and 8 volt output respectively. If it had to drop from a higher voltage then the regulator could malfunction. 12 Volts or less was also an ideal voltage because the constrictions for our pump are
small. A water pump is generally designed for fountain purposes, or to move water through a pool, or for various other industrial applications. Therefore, the pumps manufactured for these purposes are relatively much larger than the 30 cm x 80 cm restrictions on the size of our box. In order to be practical, the pump which we purchased had to be the appropriate size so that it fit in the box, and spat water in a manageable quantity. A manageable quantity and volume of water would shoot water at about a height of 10-15 cm more than the height of the spout of the pump. Combined with the size restriction due to the constraints of our plexiglass box, this led to 2 simultaneous specifications our selected pump had to adhere to.

This small pump shown above is ideal for the purposes of this experiment. It incorporates everything from the physical restrictions we have to the small scale function which we are looking for. The specifications of this exact pump are shown below.
The above values indicate the exact specifics for the pump which we need. The most important is the 12V DC value which the pump is said to run off. Furthermore it offers a value of 120 miliamperes, which is an extremely weak current. This is ideal for our device since we only have one power cord entering the PCB board. What this implies is that all the voltages will be wired up in parallel from there, so that 12 Volts can go to the three distinct sources. The three distinct sources are the Hall Effect sensor, force transducer, and pump. Regulating voltage is simple since voltage can just be dropped by voltage regulators. The challenging aspect of this setup is managing current throughout the device. The reason this becomes difficult is because when setups are wired in
parallel, as we have designed, current splits up. Therefore, if there is a fixed amount of current with quantity “I” entering the system, then if the summation of needed currents is greater than “I”, enough current would not be sent to the different components of the device. The AC to DC adapter we currently have has a setting of 12 V output with 1.5 amperes maximum loading current. This implies that the pump will absorb less than 10% of the maximum output of the device, leaving 90% of the remaining current to be divided amongst the other parts respectfully. This circuit is described below.

**PCB Board:**

The PCB Board will ultimately be designed once the protoboard for this system is completely finished. The current design of the protoboard is shown below.
The board incorporates two input terminals, where the first input terminal is the local ground, and the second input terminal is the live 12 Volt wire. These leads then run to a bus which is placed on the left of the protoboard. Every terminal connected to these two buses are thus wired to ground and to the live 12 Volt lead. The outputs then get augmented as are necessary. In the top set of electrical circuitry, the 12 volt and ground leads are
wired to an 8 Volt regulator, as to send the proper voltage to the force transducer. The 8 Volt lead yellow wire could then be clipped onto the force transducer in order to run it properly. The middle set of circuitry features a 5 volt regulator which connects to the Hall Effect sensor. The third set of wires has no voltage regulator, because it shall be clipped to the 12 Volt DC pump.

A diagram of a simplified version of the working circuit is shown below:

![Diagram of a simplified version of the working circuit.](image)
Most of the above material describes the electronic components which are active within the design of our project. This covers much of the material we designed this semester, but does not cover the entire projects technical elements. The project had many physical aspects to it as well which contributed to its completion. Primarily, the box for the design had to be built. The box was made out of a plexiglass material which was purchased from the University of Connecticut Depot Department. The plexiglass had to be purchased from there rather than a commercial warehouse because of quality issues. The quality of plexiglass improves when it is purchased new, and decreases when it sits on shelves for periods of time. This implies that if we bought it from a commercial warehouse supplier we would not be getting the best quality product, but that if we bought it fresh from a supplier who would build the item when we ordered it, that it would assure the best quality for our product. The plexiglass which we have chosen to work with is $\frac{1}{4}$ inch thick, (0.635 cm) and has been cut into different dimensions for the height width and thickness of the box. The height of the box is 60 cm tall,
and this is the tallest dimension out of any in the box setup. We designed the box this way so that it stands sturdy while up right. The box could be thought of to have its components stacked on top of each other so that it can hold upright while all the elements of the box are inside. The box has a much different look to it then we initially planned out. It was initially more of a square design, but what we learned was that the components which were placed into our design were all taller than they were longer, and therefore, the box had to be adjusted similarly. A diagram of the old box design is shown above. The new box design is much more ideal and shows the progress that came about while designing this project. The other dimensions of the current box are 30 cm width and 20 cm thickness.

**Shelves:**

The box is not just composed of walls, but also has shelves in various places for different purposes. There is a shelf on the top of the box which leaves a space of 6.75 cm in the vertical direction. This is there to separate electrical components from the water which would be splashing around below. Additionally there is a lower reservoir shelf which was designed to house excess Ringer’s solution which would then be delivered to the pump so that it can be dispersed to wherever it is needed. Initially, it was idealized that this would just be a sloped reservoir, which would lead into the pump, fill it, and then redistribute the solution. In practicality, this was insufficient for our purposes, and what it led to was us needing some alternative method to supplying liquid to the pump. To do that, we created a box with an open top, which lies inside the apparatus. The pump then sits inside this liquid filled box which it can then acquire the solution from. This acts as the modified version of our previous sloped reservoir.

**Sensor Arm:**

An arm was created for the Hall Effect sensor, and this was placed next to the lever arm. The sensor arm was initially made as a means of holding the Hall Effect sensor, but this was found to be fairly impractical. The sensor arm would have a slightly different function, but it would still be placed in the same spot. Until we were better familiarized with how the PCB board would function,
we anticipated that we could place the sensor wherever we choose and would put other electrical components accordingly. Unfortunately, the sensor would have to be mounted directly into the PCB board and therefore it would need to be placed at an exact orientation so that it would be within the magnetic field of the magnet. Also, this implied that the sensor must be on one of the sides of the PCB, so that it is the closest spot to the magnet while still connected to the electronics which supply it voltage and current. Because it could not be separate from the device, the sensor arm changed from a sensor arm to a PCB board arm. Its complete function is to house the PCB board, and give it a position to rest upon. Furthermore, it also meant that the arm needs a covering, because the board must be protected from the moist surrounding environment. Exposure to water can quickly damage the sensitive electronic components which are supported by the board, so there must be non-vulnerable protection for this component.

Lever:

The lever for this device had to meet certain qualifications to be usable for the purposes of this experiment. This lever would have to endure continuous exposure to salt solution in the form of Ringer’s solution, and would thus have to be durable over the long haul. Therefore, it could not be a simple generic allot of steel since that would rust fairly quickly. Rather than that, the lever must be made to a type of metal which will not rust over time. One option for metal to meet this criteria is if it is made out of normal metal with a coating of paint on it. Paint functions as a protective material for metal, as it provides a protective coating which liquid and air cannot penetrate. The problem which our group has been trying to prevent is air mixing with our steel rod lever. If air mixes in with steel in a liquid environment, the three elements combine to make iron oxide, commonly known as rust. Therefore, it became an engineering challenge to design a rod which will not rust over time when exposed to these elements. Finally, we came to a practical decision to how to handle this problem.

Upon review of our design with Dr. John Enderle, we decided that the best approach to making a non-rustable lever was to build the lever exclusively out of stainless steel. Stainless steel has the ability to never become rusty. Additionally, it is not particularly dense steel, so
it would serve perfect as to have a force of the muscle
applied onto it since it can move some appreciable amount
with. Also, since this will be used for medical procedures,
it made most sense to apply surgical stainless steel, as
oppose to ordinary stainless steel. What this meant is that
of all the available stainless steel alloys, we had to pick
stainless steel 3.2, which is surgical stainless steel.

**Magnet:**

The magnet for this experiment had a terribly
important function. The magnet had the responsibility of
applying a magnetic field about the Hall Effect sensor. As
described above, the Hall Effect sensor has the job of
detecting a change in length by detecting how far away the
center of a magnetic field is. Therefore, selection of a
practical magnetic source is crucial to the success of the
operation of this device. One idea initially tested is
running a current through a coiled wire. Based on the
number of turns in the coil, this would generate a known
magnetic field. Unfortunately, the device became determined
to be too difficult to apply and a different source for
magnetism was required. Because of this, our approach
became to use a magnet which was based out of some
ferromagnetic material. Ferromagnetic materials are simply
iron based metals that naturally have been blessed with
magnetic properties. The intensity of the magnet would not
have to be much, since it would just require some response
from a relatively sensitive Hall Effect sensor. In order to
test if a magnetic field were to be strong enough, then it
would have to be placed near the Hall Effect sensor, and
moved around to see if it illicits some type of measurable
response. This is the method we used to test this
particular magnet from working.

The magnet was mounted by a welding operation. The
spot which was chosen for it was a necessity since it had
to be on the lever. Because the magnet’s orientation must
correspond with a length of change, it had to be in a fixed
position on the lever. What this means is that the magnet’s
change in position must correspond to a desired change in
length. Our method of doing so can be best understood by
idealizing the magnet as a point along the line of the
lever. Because when the muscle contracts it changes the
position of the lever, the entire lever swings down in one
uniform motion. Therefore, at a certain point along the
lever, for any amount of torque provided by the muscle, the lever can be expected to rotate at a proportional angle. This angle theta then is related to the amount of change in position of the exact point on the lever where the magnet is. Therefore, by welding the magnet onto the lever, it relates to a change in position on the lever, which relates to the change in angle of the lever, which is ultimately tied back to how much change in length of the muscle occurred.

**Muscle properties:**

The muscle in action during the conduction of this experiment shall be the frog gastrocnemius muscle. This muscle is ideal for this experiment because of it’s size and weight. The size of the frog gastrocnemius muscle is about 2 to 4 centimeters, thus making it perfect for the size of the space in the diagrammed box shown below. The muscle would go in the lower right corner.

Additionally to having the ideal size, the amount of contraction it can cause will be good for the setup which corresponds with our device. The contraction could not be more than one centimeter in length, and therefore will move the lever approximately about half a centimeter on maximum displacement. The reduction in length occurs because the magnet is placed between the fulcrum of the lever and the location of attachment of the muscle. However, as relatively minor as this change may be, it will still cause an appreciable change in the voltage output of the Hall Effect sensor. Therefore, it is ideal for the setup which we have developed for this experimental design. The Hall Effect sensor is accurate up to 3 hundredths of one volt, thus allowing for minor changes resulting in large quantities of feedback.

**Loading Lever weights:**

Another aspect to the design of this project is loading up the lever properly. The lever will fall to the right if it is simply loaded with a muscle contracting on it, thus making for a force system at equilibrium. In an idealized situation, when at equilibrium, the lever should be at rest. What determines if the lever is at rest are the forces and torques which act upon the lever. In this case, there are only two forces which will act upon the lever.
These two forces are the force of the loading weights, and the force of the contracting muscle. The loading weights are a gravitational force, and the muscle shall behave as a tensile force. There is an additional force which is the weight of the lever which is evenly distributed throughout the lever, but for simplification of the solution process, this extraneous force will be assumed to be zero. The setup becomes much more difficult to understand and incorporate if the lever is assumed to be something else. In order for this 2 force system to be at equilibrium, the main concern isn’t the forces acting in equality but rather the torques which they apply. Torque relates to force with an equation

\[ \tau = F \times d \]

In the above equation, \( \tau \) represents torque, \( F \) equals force, and \( d \) equals the distance from the force being applied to the fulcrum of the lever. What this allows us to do is gain mechanical advantage by manipulating the distance the force is to the point of interest. The value in this is that the torque causes rotation upon the lever. Therefore, if the torques are equal and opposite, then the net rotation of the lever will be zero. In otherwords, the lever will remain at rest. From there on, when the muscle contracts, the lever will begin to slightly swing, though it will stay very close to its initial position. Therefore, equilibrium will not be reached exactly, but the apparatus will stay stable as it operates.

The design of the loading weights is ideal to match up with the geometrical shape of our lever system. The weights load up in a stack formation, one resting on top of the other. The weights have holes through the middle so they can each be comfortably attached to the metal hook shown below. The weights are made out of brass, though what is only relevant is the quantities of their mass and weight, not their density or material. Shown are the hook and weights separate, and then an image of how they stack on top of each other.

**LabVIEW:**

Labview is an integrated computer software program. Labview is the command center for all the electronic inputs and outputs for our device. Created by National Instruments, it is a program which connects computer
commands by using wires to communicate from function to function rather than the classical method of mathematical equations. Because of its more user friendly software design, Labview is ideal for the purposes of this senior design project. Additionally, by use of an instrument called a Digital Acquisition Device, shorthand noted as a DAQ, LabVIEW has the capability to send out voltage signals generated by its software, and receive voltage signals to be read and given meaning by its software. In order to operate correctly, LabVIEW must send out voltage signals and take in voltage values only through a DAQ. The DAQ provided with Labview software has multiple input and output terminals, which is helpful in our situation since we will be sending out multiple signals from the computer and also receiving multiple signals through the computer. The signal which we are using is normal voltage, which is not any sort of advanced digital signal. Therefore, for our purposes, the only terminals which shall be utilized are the analog input and output terminals.

The LabVIEW program we have designed has four separate elements to it, all held together by their own individual do-while loop. One operation is the 5 Volt stimulator. This is a system designed to send out a 5 Volt pulse which will be connected to an electrode which will then send out a 5 Volt pulse through an analog output through the DAQ. Once in the DAQ, it will run through the connector provided by the DAQ in LabVIEW. This connector is wired to black and red leads, where red is live wire and black is ground wire. Because of this, it will be connected to our stimulator which also has a black ground lead and a red live lead. The stimulator is simply a metal rod which will deliver live voltage to the muscle. An additional part of the LabVIEW virtual instrument we designed is the sensor readers. There are two sensors which output voltages as their readings, and these were described above. These two sensors are the Hall Effect sensor and the force transducer. Both output voltages, which through input terminals on the DAQ, are read through LabVIEW. Once in LabVIEW, these two voltages are then converted from values in volt to values in length and force respectively. Finally, they are put into graphs of length versus tension and force versus velocity. The ultimate goal of this design project is to generate those two curves, and LabVIEW is the actual instrument to finalize this product. The fourth function for which a virtual instrument was created in LabVIEW was to control the rate at which the pump operates. By sending out a
controlled signal at a fixed pulse rate, the pump will operate upon our command. LabVIEW, when set to a value by us, can control how moist the muscle remains by demanding when the pump apparatus operates. An image of these block diagrams is offered below.
Troubleshooting is a form of problem solving. It is a systematic search for the source of a problem so that it can be solved. Troubleshooting is often a process of elimination - eliminating potential causes of a problem. In general, it is the identification or diagnosis of "trouble" in a system. The problem is initially described as symptoms of malfunction and troubleshooting is the process of determining the causes of these symptoms.

During continuous operation of this device, problems with functioning may arise. The design was formed with this in mind, and access is available to fix most problems. Additionally, care was taken to select supplies which would be user friendly under long term usage. Amongst these advances were choosing plexiglass instead of metal steel to build the box out of. The purpose for this is to avoid corrosion of the steel over time by preventing the formation of iron oxide, commonly referred to as rust.
Pump:

The pump is enclosed in a reservoir to continuously supply liquid solution to the device. The solution which is best to supply for this particular purpose is Ringer’s solution which will keep the muscle viable and fresh. One possible source of error is thus in the transfer of liquid from the pump to the tube shown above. The clamp may become loose over time, or may wear down because it is made of steel. The steel of the clamp is vulnerable to prolonged exposure to salt solution as it could turn to iron oxide and rust. If this happens, replace the clamp with any other. The time expectancy for this to occur is approximately 1 year. Therefore, before the device is
prepared for use by a new semester, it is an intelligent idea for general upkeep to replace the clamp. A close up of the clamp is shown below.

Additionally, a problem which could be faced while interacting with the pump is failure to produce solution out of the spout at the top of the pump. This could occur with either a weak stream of liquid being propelled by the device, or by the device altogether not expelling any product. First the electric connections of the pump should be double checked. The pump has 2 wire leads that exit the back of it. There is a yellow wire, which needs to be supplied a 12V supply of voltage, and a black wire which needs a ground supply. Therefore, the most common situation which would lead to the failure of the pump to operate would be a faulty connection to these two leads of the voltages involved. A diagram of where the connection is established is added below.
In the diagram above the clip on the left has the yellow lead connected to it. The clip on the right has the black lead connected to it. The leads are connected the plastic box by black electric tape. Therefore, if this tape were to become loose, the entire lead setup could lose its strength and durability. Also, because of the strain these clips apply to the leads, they could weaken the strength of the cord at this junction. If the clips are reattached and the pump still fails, voltage continuity at this junction should be checked.

Additionally, a weak or inconsistent stream could be caused by lack of surrounding fluid. In order to operate properly, the tube on the pump perpendicular to the spout must be completely submerged in liquid. For clarity purposes, this inlet tube is shown below.
In addition to the possible faults with the pump listed above, there are other elements of the device which are subject to needing repair over time. Amongst these devices, one is the force transducer. The largest problem that this element faces is the dislodging of its circuit elements over time. The pin for the force transducer is a primary candidate for displacement during operation because of the pins stability within the protoboard. The pins with the 8-pin DIN connector are not designed to naturally merge with the inserts of the protoboard. Therefore, the connection is operational but it is fairly loose. Additionally, the pin has its own output cords exiting it from underneath. The reason for this is the design of the pin has its output cords oriented anti-parallel to its input pins, and has a clip placed beyond the insertion of the cords into the pin. The output is thus wired as shown in the diagram below.
The input voltages enter the device on the right side of the screen, and the connection occurs on the right side of the image shown. Then, the connecting cables exit the pin from underneath the device and come out to the connecting clips, one of which is shown in the upper left hand corner of the photograph. Again, this connection is not an ideal method for checking the device, so if the force transducer experiences trouble operationally with its output, then this should be the first spot to check for corrections.

The force transducer is an element designed to read a target force which is applied to its hook. What this means is that there is a measurement device for force which is
not regularly going to be neutralized. The transducer must be in static equilibrium in order to give an accurate reading. For this reason, it must be placed in a supported state. The transducer is oriented in the box so that it is resting on the bottom floor of the plexiglass, and further supported by being taped onto the sloped reservoir. The force which is constantly acting on it, gravity, is balanced by the contact force directed up the page applied by the box. Because these two forces are force pairs, they are equal and opposite. The equilibrium of the device is shown in the free-body diagram below.

Electric Circuit Board:

Though much effort was placed into making the circuit board as well made as possible, it is still subject to failure during prolonged use over time. Amongst one area where damage could occur over time is the relay switch.
The relay switch is composed of 6 clips on the upside of the device. These six clips all have wires soldered on as clips. Therefore, they may become subject to failure as time passes with the device. The connection may weaken as the clips provide constant force on the wires they are attached to as time wears on.

Also, another trouble spot for the electronic circuitry is the bus along the top of the strip. The electronic voltage strip on the north side of the device has the responsibility of holding all three voltage clips, and then supplying these three voltages to the rest of the device. Shown underneath this paragraph is the diagram of the three voltage clips. One of these clips is the ground.
voltage, another is a 12 volt source, and the third a negative 12 Volt source.

These clips can become faulty over time, and need to be checked to make sure they are still connected properly. The way to test for continuity at this junction is to simply turn the power supply on and place a voltmeter onto the clips and test for continuity. The importance of testing this as a primary source of error is because these clips control the entire system, and therefore if they are faulty, so is the rest of the protoboard. Additionally, the bottom of this image includes the bus terminal connections. These terminals connect the voltage sources to the rest of the device through bus terminals. Therefore, these are equally important to the proper voltage distribution across the circuit board. An image of these connections is shown below.
There are three connections illustrated in the above diagram. The first is the black ground on the left side coming from the ground left into the top bus terminal. From there the ground voltage is sent to the left hand side of the protoboard. The live wire of 12V is shipped from the entry clip to the 3\textsuperscript{rd} top bus terminal. From here the voltage is sent to the 2\textsuperscript{nd} bus on the left hand side of the protoboard. As the semester went along, the group became more and more comfortable attaching electronic components to the circuit board. Because of this, future parts were added on with a much simpler process than parts that were added on to the board early in the semester. An example of this is the connection from clip 3 to the middle bus in the diagram. Rather than being sent from the clip to a top terminal bus and then to a parallel terminal bus, the voltage is sent directly from the clip to the bus. This improves the efficiency of the design by allowing less overall room for error. In order to test if these circuit elements are working properly, a voltmeter must be wired in parallel to these elements of the circuit and then tested for continuity.

**Lever Arm:**

The lever arm is responsible for transferring the force generated by the muscle to a tangible change in length. The lever moves as much as the muscle commands it to by the length of its contraction. To gain mechanical
advantage, the lever fulcrum is placed near the loading force of the device, and the muscle connection is at the opposite end at a greater distance from the pin which acts as the fulcrum. This is shown in the lever setup below. In the diagram below no muscle is attached, but a fish hook is placed representing the tensile contraction of the muscle.

If the weights of the lever disconnect from the device, replace them near the orientation the above figure indicates. Also, if question is raised as to where the muscle is supposed to be attached, simply refer to the diagram above and place the hook with the muscle onto the lever.
The lever arm also has another function as it swings in conjunction with contraction of the muscle. This is the process of having its magnet rotate about the Hall Effect sensor to provide a reading for the change in length taking place at the east end of the lever. This means that the Hall Effect sensor must always be near the magnet, in close enough proximity to experience the effect of the sensor. Proper setup is shown below.

In the diagram above, the magnet is placed directly above the Hall Effect sensor. The sensor is attached to all the black tape on the underside of the magnet. The distance between the two is about 5 millimeters. A proximity which is significantly greater than this will be incapable of transmitting a magnetic field of great enough strength to
Illicit an appropriate response from the Hall Effect sensor. The pin holding it in place with washers to keep it still is shown below. In case the pin becomes dislodged or the washer is removed from the pin, just replace it as diagrammed here.
Pump

**Problem:** Low flow from pump  
**Possible cause:** Blockage, or clogging.  
**How to fix it:** check input area from clogging or blockage, also check hose for blockages.

**Problem:** No flow from pump.  
**Possible cause:** Power supply is off, pump is clogged.  
**How to fix it:** check power supply is on, disconnect pump to be cleaned, and then connect again.

Enclosure

**Problem:** Enclosure feels fragile or bends.  
**Possible cause:** Breaking apart.  
**How to fix it:** Apply more Dichloromethane to each side of the enclosure.

**Problem:** Doors brake, or fall down.  
**Possible cause:** Damaged hinges, or bad plexiglass.  
**How to fix it:** Replace for new and bigger hinges. Replace doors withthicker plexiglass. File edges of doors in a very detailed manner to prevent cracks.

**Problem:** Shelves brake.  
**Possible cause:** Not enough glue.  
**How to fix it:** Apply more chemical to the shelves, let dry for 20 min and apply again.

**Problem:** Fluid leakage in the reservoir.  
**Possible cause:** Not enough glue.  
**How to fix it:** Wash and dry completely. Apply more chemical to the reservoir, let dry for 20 min and apply again.

Lever arm

**Problem:** Loose magnet.  
**Possible cause:** More glue is needed.  
**How to fix it:** Apply more Gorilla glue to the magnet in the original position.

**Problem:** Lever moving side to side.
Possible cause: Spacer not working.
How to fix it: Cut new piece of plastic tube to place in the side of the lever to prevent its motion.

Problem: Loose lever arm.
Possible cause: Unfasten parts.
How to fix it: Fasten screws and nuts tightly.

Problem: Loose lever arm.
Possible cause: Holes are too big.
How to fix it: Drill holes again to the enclosure making them slightly bigger than the diameter of the screws.
The following list states a few problems that the user may encounter while operating this device using LabView. It is by no means inclusive. Moreover, due to certain difficulties encountered with LabView, the program as is may not be completely functional, and the lab instructor’s help should be sought.

**Problem:** LabView is not running.

**Solution:**

a) Make sure the National Instruments PXI-1031 is turned on.
If it is off, then the computer must be shut down. The device - National Instruments PXI-1031- should be turned on while the computer is off. After that is on, the computer may be turned on again.
b) Change the Enum setting from “off” to “spray” or “run” after you run the program. That could be done either from the front panel by pressing the up or down arrows, or from the block diagram by selecting the appropriate setting from the drop down menu. The default “off” position features no DAQ’s or any other LabView commands.

*Problem:* There is an error and the DAQ won’t collect data.  
*Solution:*  
Place a case structure around the “write data to spreadsheet file” and set it to false. A popup will then appear and ask the user to choose a place for the data to be written. A text file would be the best choice.

*Problem:* The saline solution pump will not turn on.  
*Solution:* Manipulate the settings of the timer shown below.
Problem: The graphs not accurate.
Solution:
a) Make sure the force sensor is “zeroed” correctly. In reality the force sensor doesn’t need calibration; a voltage change of 160 millivolts translates to a one Newton change in force. The force sensor should, however, be attached securely to the set up in order to prevent its movement that may result in incorrect data acquisition.

b) The muscle should be fresh and properly hydrated. A muscle that isn’t recently obtained may be less receptive to the experiment and may not flex and extend to its fullest ability.

c) Add the correct muscle equations as determined in your lab. Incorrect constants and formulas will definitely be major sources of error. The following is a list of formulas that may be considered:

Newtonian mechanics equations:

Eq. 1) \( F_{net} = ma \)

Eq. 2) \( F_{net} = \sum F \)

Eq. 3) \( F_{net} = F_{sensor} + F_{Lever} + F_{Masses} - F_{Muscle} \)

Eq. 4) \( W = U + K \)

Miscellaneous Equations:

Eq. 5) \( V = lwh \)

Eq. 6) \( \sigma = (L_f - L_o) / L_o \)

Eq. 7) \( F = 0.16V \)