Biomedical Engineering Unit

Grade 5

Instructor's Guide to:

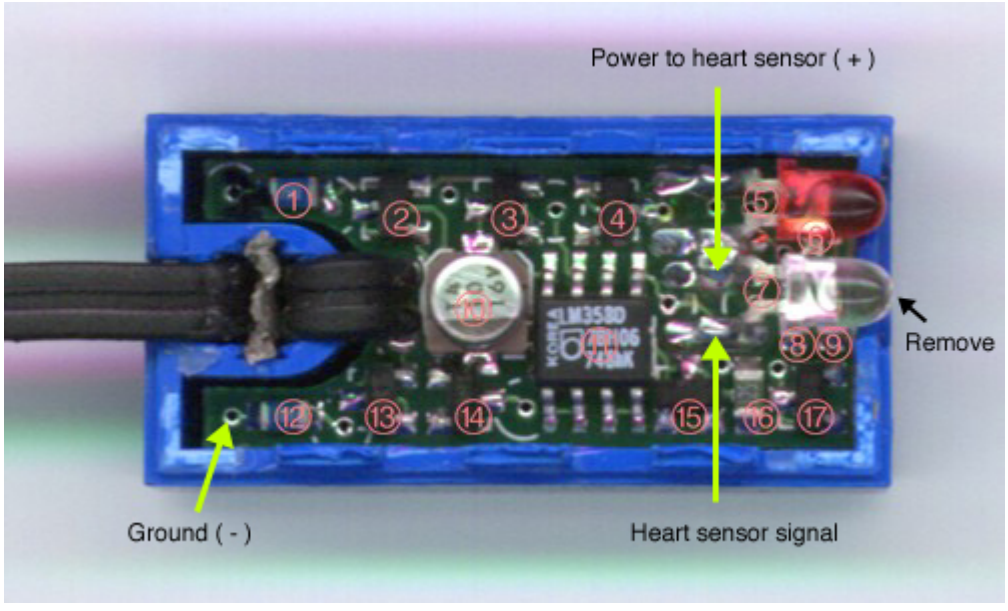
Heart Rate Monitor

This is a fun activity and a great opportunity for some hands-on learning. Even though the building is too dangerous for students to take part in, students participate in testing their own heart rates and graphing them. Depending on your students' level of understanding in ROBOLab™, you may also include them in the programming aspect of the activity.

Before taking on this project, instructors should know that it requires a permanent change to the LEGO™ light sensor, which is somewhat expensive. They are, however, usually less expensive than manufactured adapters. The building in this project should be done by the instructor for safety reasons. It is a relatively simple project to prepare for. You will need an RCX, a light sensor, a wire, three alligator leads (different colors, if possible), a chest-strap transmitter, a receiver with a serial connector, three leads, a soldering instrument, and the equipment necessary for your ROBOLab™ programming.

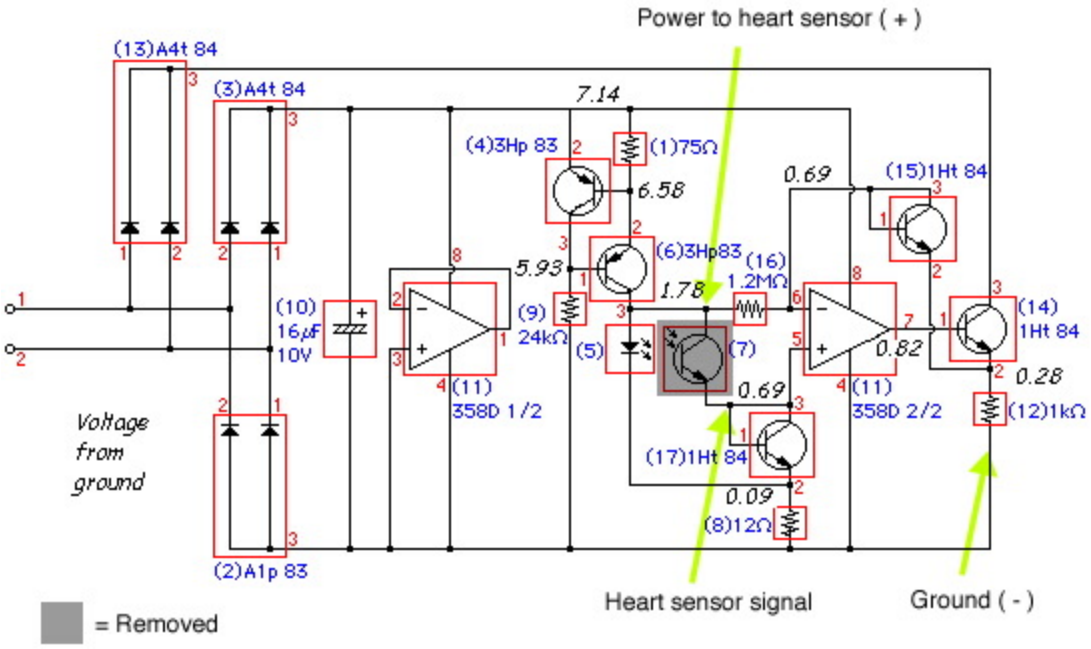
Building

To adapt your light sensor for this project, you must remove the plate on the bottom. This will take some force, but it can come off. When it is off, it should look like this:



(http://www.smm.org/heart/tools/heartsensor/instructions.html)

The green arrows point to your three soldering points for your three leads. After soldering on your leads, you should remove the light sensor (identified by the grey box). The picture that follows gives a detailed view of the light sensor.

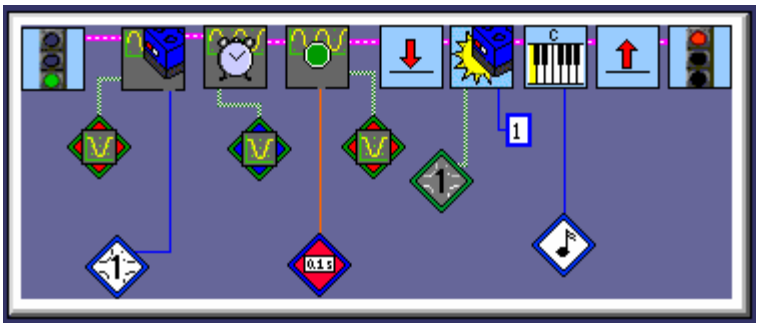


(http://www.smm.org/heart/tools/heartsensor/instructions.html)

When you have finished with your light sensor, attach your three alligator leads to the leads from the sensor. Then connect the alligator leads to the female serial adapter. Wire your light sensor to the RCX, and your building is done.

Programming

To program your monitor, go to Programming Level 5 of Investigator. You may wish to use the following:



This program tells the RCX to begin logging data from the light sensor in Port one for the red data set. It then initializes a timer to take data for the blue data set. It then starts the data logging for the item from the same data set (red), which is the light sensor and says to take samples every 0.1 seconds.

After those instructions, you should begin a jump loop by putting a land of any color into the program. After the land, you put in the actions that you would like to be repeated. In this case, you tell your light sensor in port one to wait for light at a cutoff brightness of one. When the brightness is one, you ask it to play a tone. Putting a jump afterward (the same color as your land) tells the program to repeat what is in between the land and jump.

Engineer: _____ Date:_____

Partner(s): _____ Class:_____

Heart Rate Monitor

Use your LEGO™ heart rate monitor and Investigator to see how your heart rate changes under different conditions.

Challenge

Wear the chest-strap from your pre-made LEGO™ heart rate monitor while you jog in place, while you jump rope, and at rest. Upload your readings on Investigator, and analyze the results.

Materials

The following materials will be used in this activity:

- LEGO™ RCX
- Adapted light sensor (performed by instructor)
- Wire
- Chest-strap Transmitter
- Receiver with a serial connector
- 3 alligator leads (different colors)
- Jump rope

Skills Learned

BME Physiologic Modeling, Simulation & Control, Investigator, Effect of physical activity on heart rate

Procedure

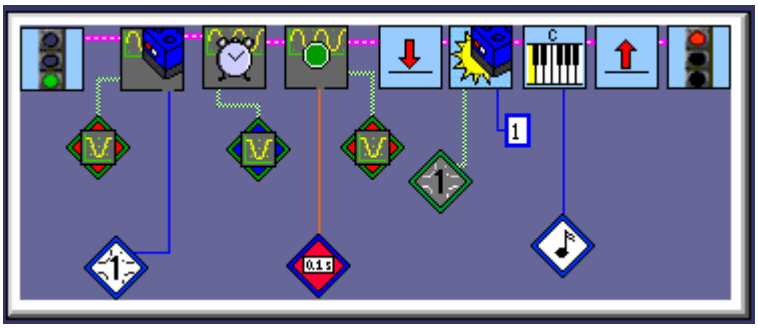
- Form a group for each monitor available.
- Group members will test one at a time, so determine an order.
- Each group member should recline and relax with the chest strap on for a test of heart rate at rest. Test for one minute, and save your data set as (name)rest.
- In the same order, each group member should wear the chest strap while jogging in place. Again test for one minute, and save your data set as (name)jog.

- In the same order, each group member should wear the chest strap while jumping rope. Again test for one minute, and save your data set as (name)jump.
- Assign each of your three data sets a color, and print a comparison graph. Attach it to this packet.
- Answer attached questions.

Extensions

1. Test students' heart rates under more conditions, such as holding their breath, reading aloud, drinking water, dancing, etc. – up to ten total data sets (there are only ten colors for data sets).

Sample Program



This program tells the RCX to begin logging data from the light sensor in Port one for the red data set. It then initializes a timer to take data for the blue data set. It then starts the data logging for the item from the same data set (red), which is the light sensor and says to take samples every 0.1 seconds.

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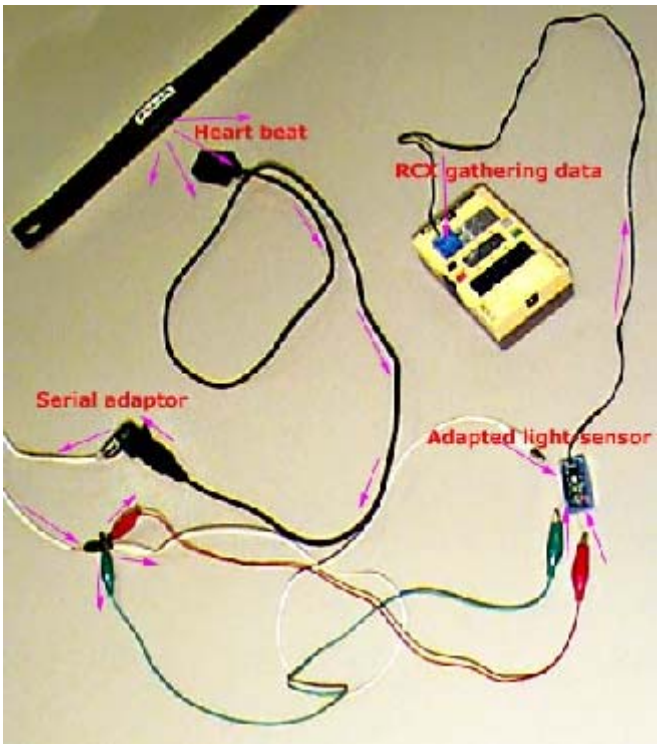
Sample Project



http://www.smm.org/heart/tools/heartsensor/top.html#circuit

Questions

1. Briefly explain your graph.

_____

_____

_____

_____

_____

_____

2. During which activity was your heart rate highest? Lowest?

_____

_____

_____

3. What do you think may be the reason for your answer to number 2?

_____

_____

_____

4. From your work, which do you think would produce a higher heart rate:
    - Sleeping *or* Dancing
    - Laughing *or* Talking
    - Watching a scary movie *or* Listening to soft Music

Instructor's Guide to:

Gait Analysis

This is a great project for students who are visual learners. It also encourages group work and communication without the need for competition.

Have your students break up into groups of four or five. Give each group enough letter paper, carbon paper and tape for them to make a runway three pieces wide and 3 meters (≈11 sheets) long. The letter paper should be taped down first and the carbon paper on top of that, white side up. Since this activity takes up a lot of the floor, some groups should work in the classroom and others in the hallway. If you do not have an assistant instructor, the most trust-worthy students should work in the hall, and you should check on their progress periodically.

If you would like this to be a short activity or if you have a low supply of carbon paper, assign each group a different pace: slow walk, brisk walk, jog, and run. For a larger class, you may even wish to add a skip or hop so that each group gets a different assignment.

Instruct groups to assign roles. One person should take on each of the following roles: walker, timer/measurer, range of motion measurer, and observer. In a group of five, there should be two observers. Below are the basic instructions for each position (more detailed instructions are in the procedure on the activity sheet.

> The timer signals the walker's start, and stops the clock when the walker reaches the finish line and determines the walker's pace and stride.
>
> The walker walks (or runs, etc.) on the timer's signal from a start line at the beginning of the runway to a finish line at the end.
>
> The range of motion measurer measures the walker's range in motion and relates it to the way he/she walks.*
>
> The observer watches how the walker's joints align and how his/her foot hits the floor.

Have the group members discuss their individual parts of the project when they are ready, and have them write a complete final analysis to encourage the communication aspect of engineering.

*The range of motion measurer will probably need the most help. This student will need to use a goniometer for his/her measurements. Instructions for using the goniometer can be simple. The student's measurements do not have to be precise. Instruct your students to do the following:

1. Line up the center of the goniometer's circle with the middle of the knee.
2. Have the walker fully extend his/her leg, and spread the sides of the goniometer to measure the angle of extension.
3. Have the walker fully flex his/her leg, and spread the sides of the goniometer to measure the angle of flexion.

Engineer: _____ Date:_____

Partner(s): _____ Class:_____

Gait Analysis

Take a closer look at the way you and your peers walk to see how the parts of your legs work together.

Challenge

In groups, observe and analyze the gait cycle of a peer and write a report on the sheet attached.

Materials

Goniometer, White Letter Paper, Masking Tape, Carbon Paper, Meter Stick, Stop-watch

Skills Learned

Range in Motion, Clinical Procedure, Observation, Body Systems

Procedure

Working in groups of four or five:

1. Assign a group member to each of the following tasks:
   - Walking
   - Timing/ Measurement
   - Range of Motion
   - Observing (Two members could do this)
2. The timer and observers should create a runway (dimensions: 3 sheets x 11 sheets) of plain letter paper. On top of this, lay carbon paper white side up for your walker to walk on. Skip to step 4.
3. While the runway is being made, the walker should have his/her range of motion measured. The person measuring the range of motion does so by using the goniometer. Look to number two under Tips for instructions on using the goniometer.
4. Put a piece of tape down on the carbon paper where it is over the letter paper to mark start and finish lines for timing purposes. When the tape is on the paper, write “START” and “FINISH” on it so that it will transfer through to the letter paper.
5. On the timer’s signal, the walker should start.

6. The observer should look to see how all the joints of the walker's leg line up and at how the foot hits the floor as a result.
7. The person measuring range of motion should watch to see how the joints that he/she measures move.
8. When the walker reaches the finish line, time should stop.
9. The measurer should measure the walker's stride.
10. The timer should count the number of steps taken to calculate the walker's pace. (Pace = number of steps/ time from start to finish)
11. The observer should look to the carbon paper to see how the foot struck the paper and incorporate that into the analysis.
12. All members should share their results and write up a final analysis on the sheet attached.

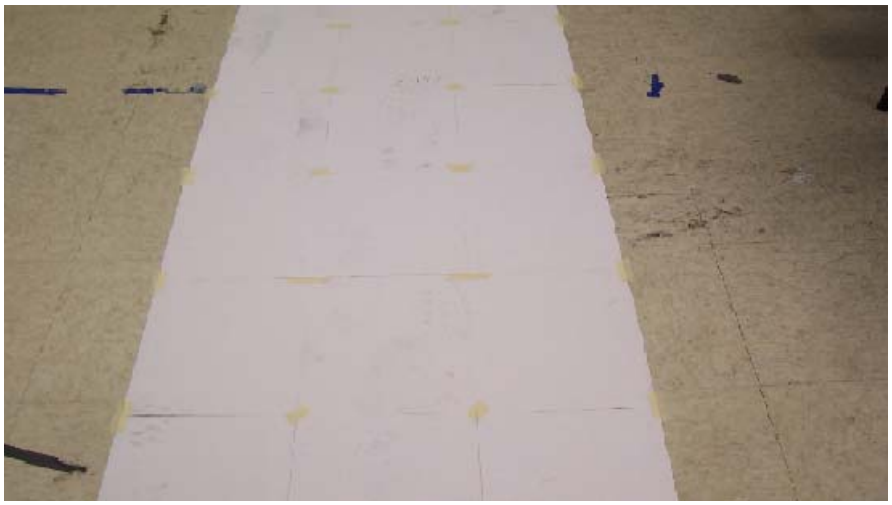
Tips

1. Make sure your steps are firm so that the carbon transfers over to the letter paper.
2. How to use a goniometer:
    - Line up the center of the circle with the middle of the knee (See picture in Sample Projects.).
    - Have the walker fully extend his/her leg, and spread the sides of the goniometer to measure the angle of extension.
    - Have the walker fully flex his/her leg, and spread the sides of the goniometer to measure the angle of flexion.

Extensions

1. Try walking at different paces and running, and compare your samples to each other.

Sample Projects

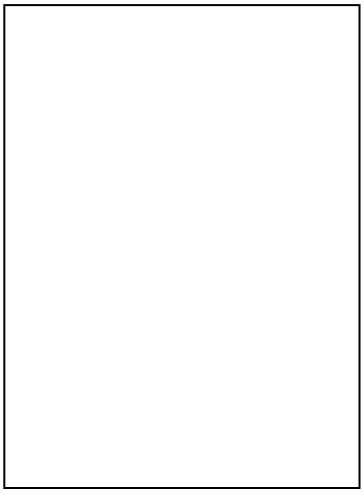


Questions

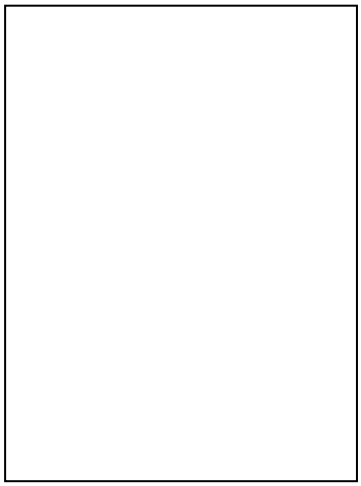
1. What were your measurements for your group's walker's Range of Motion?
   - Extension: _____
   - Flexion: _____

2. What were your walker's stats for:
   - Time from Start to Finish: _____
   - Distance (Start to Finish): _____
   - Number of Steps Taken: _____
   - Stride (Length of Step): _____
   - Speed (Distance/Time): _____

3. Draw your walker's alignment. Make three circles (hip, knee, and ankle), and connect them to each other to show the legs shape at different stages in gait.



(Striking Ground)



(Pushing Off)

4. From the marks on your runway, which part of the foot took the most force? The least?

_____

_____

_____

_____

5. How do you think the walker's range of motion affected his/ her gait?

_____

_____

_____

_____

_____

6. How do you think the walker's alignment affected his/her gait?

_____

_____

_____

_____

_____

Instructor's Guide to:

Prosthetic Leg

In this activity students will build an above the knee prosthetic leg using only the materials provided to them. This activity is very scientific and doesn't leave much room for creativity. It can be integrated into 5-12 grade students' studies of the human body, particularly the musculoskeletal system.

Because this activity involves a lot of sawing, students are especially responsible for their measurements and cannot complete their projects without the help of an instructor. To prepare for the activity, the instructor must purchase a wooden mannequin or another toy which would be easy to work with. At Tufts we used an 8.5" tall hardwood mannequin, which can be purchased at most art supply stores. This mannequin will be the amputee. A hack saw, a detail screw driver, and a metal rod 3mm in diameter will be needed in addition to the materials listed on the activity sheet.

Amputation

Since it would be dangerous to have students using hack saws, the amputations are totally in your control. Your amputations will take some time so make sure you plan in advance; if you have a large class, you may want to get some help in this part. It is also up to you how many students will be working on each mannequin. It is easier to prepare if students work in groups, but this will cause problems in the classroom since it only takes one student to do.

Because transfemoral amputations are more common in the real world than transtibial, this activity will be using a transfemoral amputee, but instructors are welcome to change this. Just know that a change would mean much less work in terms of the prosthetic since it will not involve the knee joint. A transtibial amputation, on the other hand, would be easier on the teacher since it is simple to break the lower leg off of many plastic figures or to disconnect the lower leg from the mannequin by unscrewing the knee.

For the transfemoral amputation it helps to draw a line where you will be making your cut. Make sure the cut is high enough that a knee would realistically fit in line with the opposite knee. When you have cut through all the wood, you must unscrew the hip to release the spring that runs down the thigh along with the severed leg. The entire limb will fall off at this time. To restore the top of the thigh, you must run a small rubber

band tightly down the middle. Screw the rubber band into the hip where the spring used to be, pull it tightly through the leg, and tie a knot. Fill in around the rubber band with Model Magic™, letting the knot sit outside. Use Krazy glue to secure the knot to the dry Model Magic™. If the wood is rough from your cut, you may wish to sand it down or to cover the end with a thin layer of Model Magic™.

Prosthetic by Part

Instructors should suggest that students work on the prosthetic limb by part. The suggested order would be as follows.

Knee

Check that students' knees are tight but still able to bend and do so smoothly.

Socket

The creation of the socket will be difficult for some students, particularly those with poor motor skills. Check that all students have the latex glove tightly over the leg before they start anything.

Help students to cut the glove to let the knot out and to glue the knee to the latex, and make sure everything is dry before allowing the students to continue. Encourage students to build from the top rather than the bottom and to use as little Model Magic as possible so that the socket doesn't come too far out from the leg. When they have finished, help students glue the ring to the outside of the Model Magic™ of the socket.

Lower Leg

Students must show their instructor their design drawn to scale and provide their measurements before they can build the lower leg. The instructor may need assistance in cutting the rod to the sizes specified by the students. Plan on having to cut all of the rods by the next class period. You should use a hack saw for the cutting, and it is best to clamp the rod to a table to keep it steady as you cut. Check at a local Home Depot – sometimes the workers there are willing to cut rods to size for you since they have the tools to do it easily. This could save you a lot of time.

Ankle

Your ankle doesn't have to move – many true prosthetics have stationary ankles. You may instruct students to use a bead as an ankle for the look of one or to create the ankle and foot as one out of extra model magic, or out of clay for something stronger. There is a lot of room for variations.

Foot

Have students mold a foot similar to the existing foot in size and shape. You may actually have them press their mannequins' feet into the clay and model it off of that.

Engineer: _____ Date:_____

Partner(s): _____ Class:_____

Prosthetic Leg

Jude is a transfemoral (above the knee) amputee who wants to walk on his own again. Make a prosthetic leg for him that he can put on and take off as he pleases.

Challenge

Make a prosthetic leg that is in line with the existing opposite leg for the figure you are given. The leg should have a socket that allows it to be put on and taken off with ease. Its knee should bend; students may also try to make its ankle roll for full range of motion.

Materials

The materials that you will use to create your prosthetic leg are the following:

- 8.5" tall Hardwood Mannequin
- Crayola Model Magic™
- Krazy Glue
- 2 Ring Terminals
- Nut
- Washer
- Bolt
- Latex Glove
- Rubber Band
- Ruler/ Tape Measure
- Scissors
- Engineering Paper
- Bead
- Metal Rod 3mm in Diameter

Skills Learned

Fitting, Measurement, Scale, Planning, Joints, Building

Safety

When using Krazy glue, do not touch the glue with your hands. If you must hold pieces together as the glue dries, use something between your hands and the glue (i.e. gloves, rag, etc,).

Procedure

- Connect two ring terminals using a bolt, a washer, and a nut. Make sure the fit is tight but that the joint moves smoothly. This is your knee.
- The most important part of your leg will be its socket. Your socket must fit snugly so that it will stay in place on the leg but not so snugly that it can not be removed when necessary. To make the perfect socket:
    - Cut off the pinkie of your latex glove, and fit it over the amputee's leg.
    - Pull it tightly and secure it using a rubber band. The rubber band should be high enough that it will not interfere with your mold without being so high that it cuts into the hip.
    - Cut the tip off just large enough that your knot from the end of the leg sticks out.
    - Using Krazy glue, attach the end of the ring terminal to the latex, making the knot sit inside. The glue should stick only to the latex and not to the leg. This is important.
    - When the glue has dried, begin putting on the Model Magic™ all around the leg and ring terminal to give a good transition from thigh to knee.
    - As it dries, Krazy glue the ring terminal to the Model Magic™.
    - Leave your socket to dry on the mannequin.
    - When it is dry (next class period to be sure), fold the top of the latex glove over the sides and remove the socket by tugging on the glove.
    - Try putting it on and taking it off to make sure you have a good fit.
- Measure the length that you will need cut for the lower leg, and make sure to consider the length that will fit into your ring terminal, and how much space you will need under it for the ankle and foot to fit. For this you should draw a diagram to scale on the engineering paper provided <u>IN PENCIL</u>. When you are confident in your measurement, submit it to your instructor who will cut the rod for you (by the next class period).
- When you have your rod to work with, cover one end very thinly with Model Magic™, Put some Krazy glue into the ring, and insert the rod into the ring. Let the glue dry.
- Have Jude step into some left over Model Magic™ or clay to get the size and shape of his foot. Make a foot for his new leg using this mold. To the top of the foot, for an ankle, connect a bead thet will fit around the end of Jude's lower leg.
- Make sure your new foot will fit onto Jude's leg and that both sides are even. When the foot is dry, glue the end of your rod into the bead, and make sure that the bead it strongly attached to the foot (this may need some glue). When the glue has dried, you will be done!

Extensions

1. Make your prosthetic function as a normal leg does (i.e. no hyperextension, no movements that are impossible for or would cause injury to humans).

Sample Projects