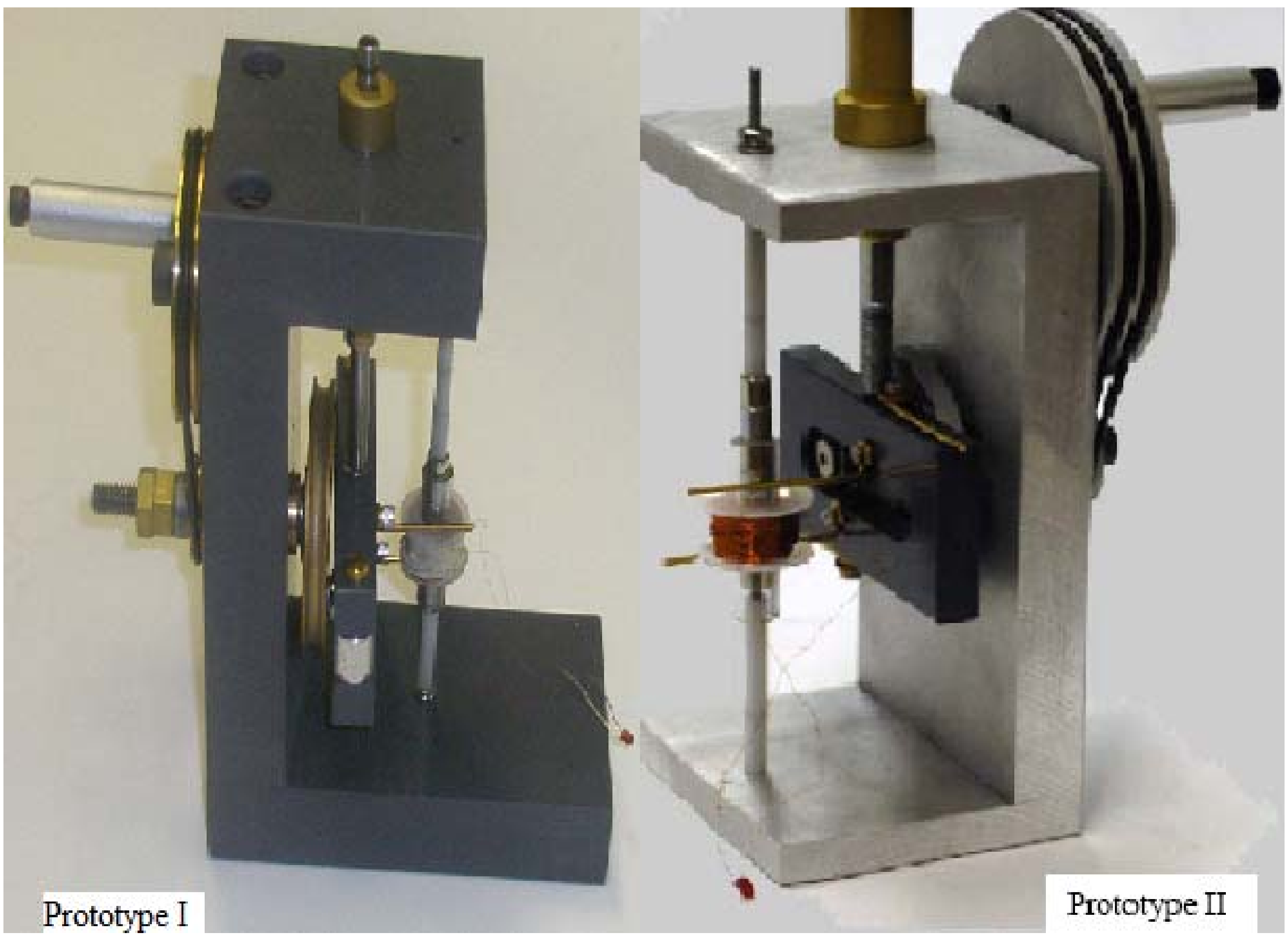
Permanent Magnetic Linear Generator Project Prototype

(This Material was Produced by Oregon State University's Energy Systems Group)

This Permanent Magnet Linear Generator (PMLG) prototype was developed as an example project for K-12 students interested in building a wave energy generator (with help from their teachers/parents). For this prototype, the linear motion of the waves is initially created using a rotary crank, and then mechanically converted to linear motion using a type of cam system. The primary linear generator components for this prototype are coils and magnets. By Faraday's law, when a conductor (e.g., the coil) experiences a changing magnetic field, voltage is induced in the conductor/coil. In this case, the rotary crank enables the linear motion of the coil (up and down) around the magnet assembly. Thus, the coil experiences a changing magnetic field, and since the conductor is a coil in a closed circuit, current flows and lights up an LED (light emitting diode). **The students are encouraged to build these project prototypes as a starting point, and then spring-board off these examples to create their own prototype ideas!**



Materials:

Note: The following items are examples of parts that you can use, however, we encourage you to substitute them with different parts of your own choosing.

S. No	Components	McMaster-Carr Item # http://www.mcmaster.com All items with #'s were purchased from McMaster-Carr	Attributes	Quantity
1	Shoulder screw guide-rod	91259a115	Shoulder screw (remove screw-head), used as guide-rod on PVC Motion converter. The thread size of the guide-rod 10-24.	1
2	Spacer for linear Motion converter	92510a745	.500" long stand- off used to create .500" center gap on motion converter assembly. (add washers if necessary to increase gap)	2
3	PVC	8747k118	PVC used for main body Cut to shape, bolt/glue together Cut to 3"X3", 3"X5", 3"X7"	1
4	Bronze sleeve bearing	6381k521	Used to guide drill bushing. Drill ¾"hole into lower part of Unit. This will enable you to connect the inside cam wheel to the small outside wheel.	1
5	Drill bushing	8492A157	Bushing fits inside of bronze sleeve bearing used to make transition between inside cam wheel and small outside wheel. It is also guiding the 5/16-18" threaded rod.	1
6	Shoulder screw	91259a617	Used as shaft for large crank wheel. Drill and tap hole into main body (5/16-18) to accommodate screw.	1
7	Copper Wire		Copper (enamel coating) 32 AWG	>50'
8	Shoulder screw	91259a533	Used as bearing shaft to hold two cam bearings in place.	

9	Magnet	NR0021-42NM (http://www.magnet4sale.com)	Ultra-High-Pull Neodymium ring magnet (0.25" dia, 0.25" Length)	4
10	Pulley (small out-side wheel)	6447k5	1" dia. pulley. Use 1/8 o-ring (Remove the bearing that comes with the pulley).	1
11	Pulley inside Cam wheel	647k11	Used for inside cam-wheel	1
12	Pulley crank-wheel	6447k11	2.5" dia. Use 1/8 "o-rings.	1
13	Flanged nut 5/16-18	90611a400	Press/Glue flanged nut in the hole of inside cam-wheel. Flange nut should face main base. (Trim/grind excess length)	1
14	Threaded rod 5/16-18	98750a045	Use threaded rod to connect inside cam-wheel to small pulley.	1
15	5/16-18 nuts	93827a219	Hex nuts used in conjunction with 5/16-18 treaded rod .	2
16	Sleeve bearing	6338k451	Guide bushing for ¼ dia. guide rod shoulder screw. Drill 3/8" hole into the top part of unit. Glue in place.	1
17	Belt/o-ring	o-ring can be purchased at mcmaster-carr	Determine length by using string. After mounting both small and large pulley (deduct about 30% of total length to allow for tension).	1
18	Bearing	57155k356	Bearing (2) used to create linear motion. Drill and tap (10-24) inside cam wheel to accommodate bearing shaft. Approx. 875" radial location of the hole will determine length of linear motion.	2
19	Tape	76275A11	General purpose, 0.5" wide. It is used to hold wires layer while winding the coil. It can also be used as general purpose tape (e.g temporary holding of different parts)	1 roll

20	Plastic cylinder	8532K11	Clear Extruded Acrylic Round Tube 3/8" OD, 1/4" ID, 6' Length	1
21	Plastic Washer	95630A245	PTTE Flat Washer,3/8” Screw Size, 0.82” OD, This is used to make winding coil easier.	2
22	PVC Motion converter	8660K33	Cut two pieces to 3.5” long. Drill two 3/16” holes at ends of upper part and 10-32 threaded holes at same location on lower part. Sandwich spacer in between. This item is used to let ½” dia. bearings produce linear motion.	1
23	Brass rod	8859k511	.063” rods cut to length and insert into .062” holes on face of motion Converting PVC.Alternative would be to create eye on end of rod and use 6-32 screws to hold rod in place.	2
24	Shoulder screw	91259A103	Used for crank handle. Drill and tap 10-24 hole near outside perimeter of crank wheel.	1
25	Standoff sleeve	92511A029	Use as second part of handle (sleeve).	

Primary Components:

A permanent magnet linear generator (PMLG) wave energy prototype can include:

1. **Buoy**
2. **Motion Converter**
3. **Magnet**
4. **Coil**

The buoy is the portion of the wave energy generator that moves up and down on the surface of the ocean. In this PMLG prototype, electricity is generated due to the relative motion of the buoy (coil) relative to the magnet assembly on the stationary shaft. For this particular prototype, a cranking device is used to create the initial motion (rotational motion), which is converted to linear (up-down) motion using a cam system.

Procedure:

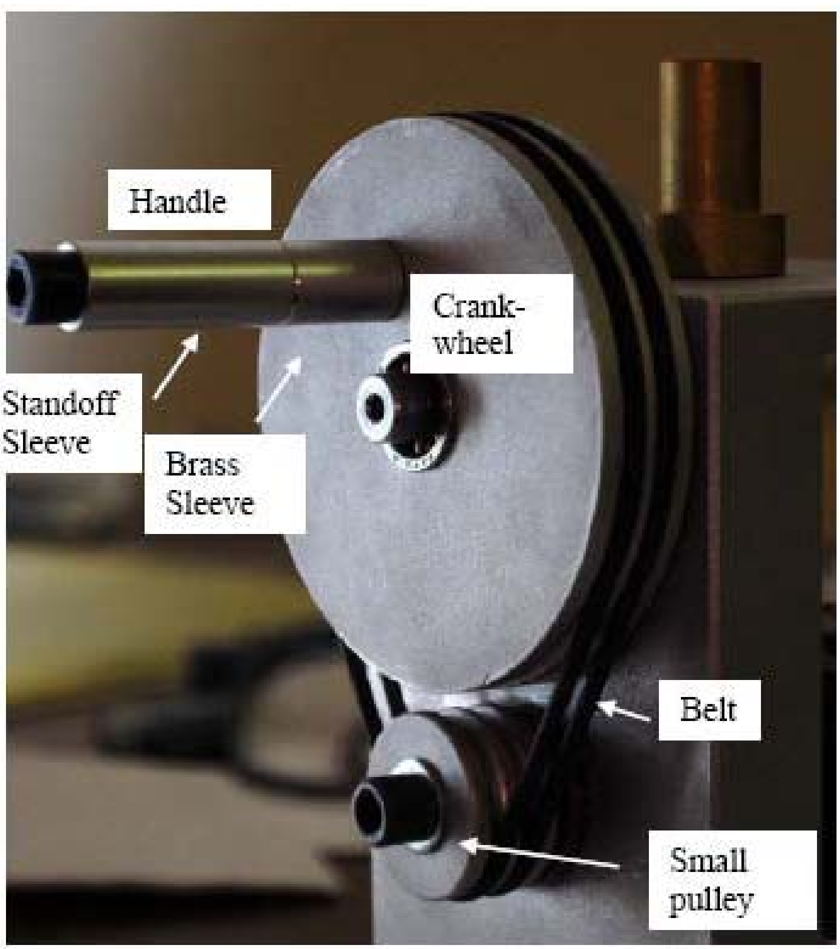


Figure 1. Cranking Device

Mechanical Frame:

Construct a box-like structure (5.5”x3”x3”), using wood, PVC or metal. Leave at least one side open. The frame in this example is made up of metal, and has three sides open.

Crank:

The cranking system consists of pulleys, belt/o-ring (or belts/o-rings), and a handle (Figure 1).

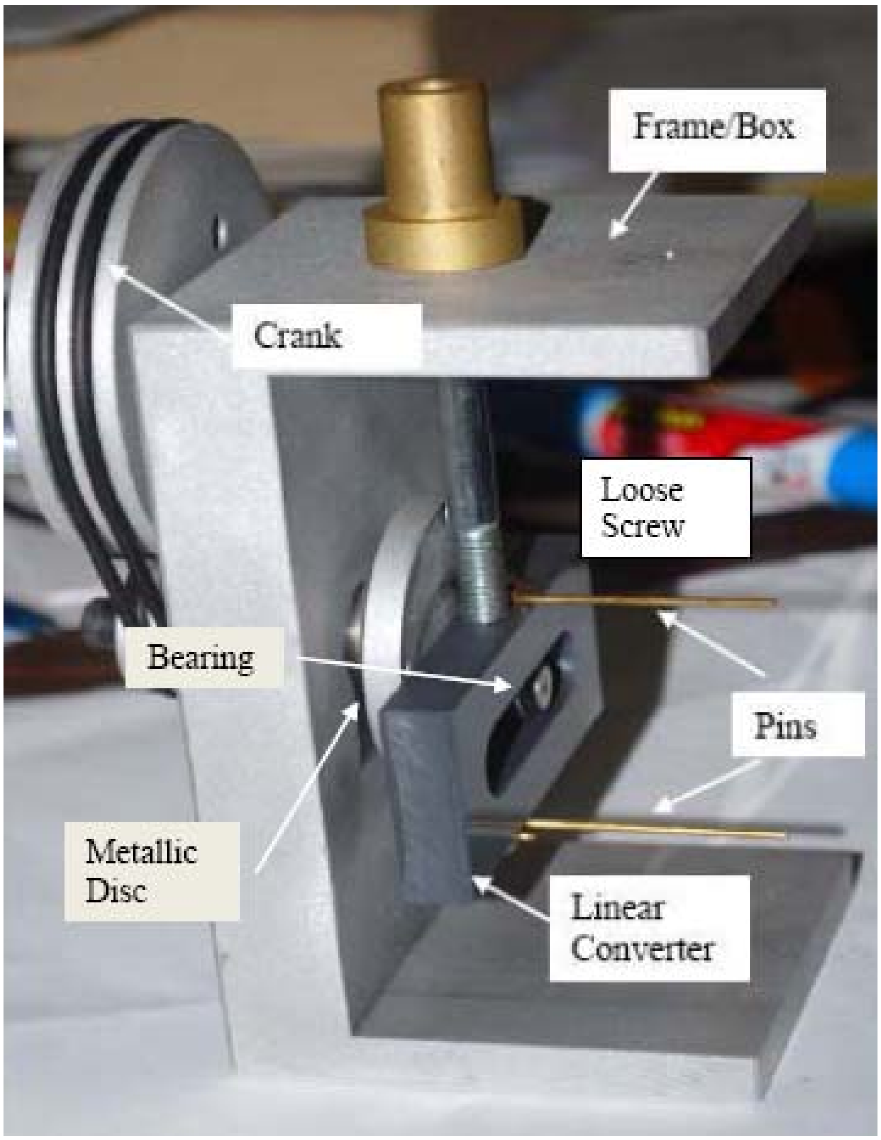


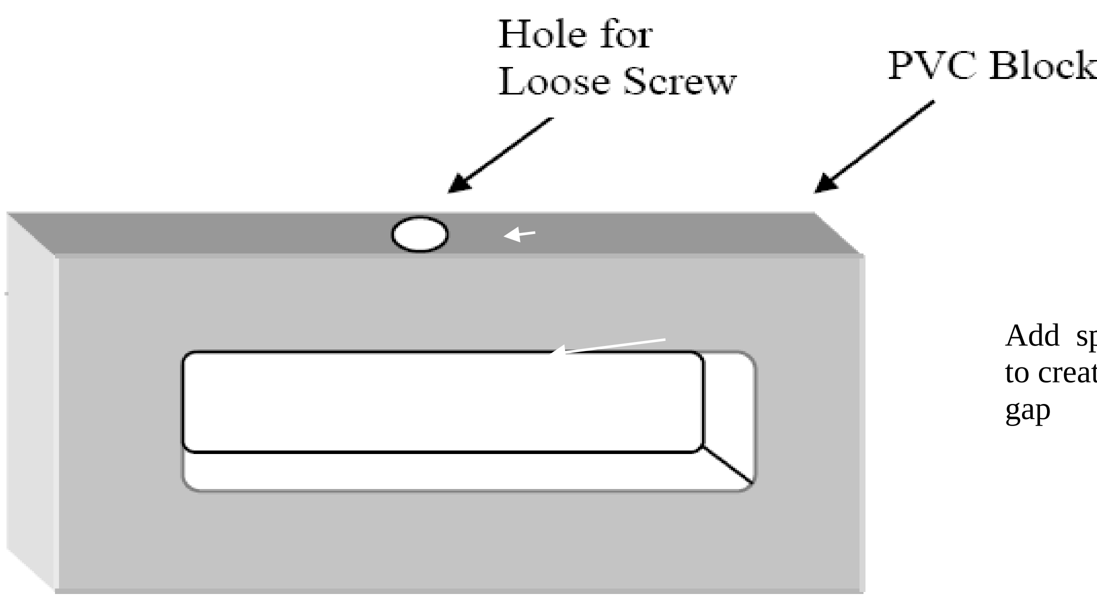
Figure 2. Frame with Cranking Device and Linear Motion Converter (a type of Cam system)

Pulley: You can either use a single grooved pulley or a double grooved pulley (both pulleys should have the same number of grooves). If you choose a double grooved pulley, you'll need two belts/o-rings. Note that using two belts/o-rings enables larger torque transmission.

Note: There is a handle on the larger pulley (Pulley 1). When the large pulley is cranked (rotated), the rotational motion is transferred to the small pulley through belts. Because of its small diameter, the smaller pulley (Pulley 2) rotates at a higher speed than the larger pulley. This enables higher linear velocities.

Belt/O-ring: To measure the length of the belt/O-ring, connect both pulleys with the thread or string (along the groove) .Choose the length of the belt/o-ring about 30% shorter than the length of the string (for an appropriately tight connection).

Linear Converter (A type of Cam system) (Figure 3)



Add spacers to create .500 gap

Figure 3. Linear Motion Converter (Cam)

Magnet & Coil

1. Use a long cylindrical magnet or long ring magnet (Outer diameter= 0.32", Length=1.5")

2. If you cannot find a long magnet, you can use 4 ring magnets (Figure 4 & Figure 5).

Hint:

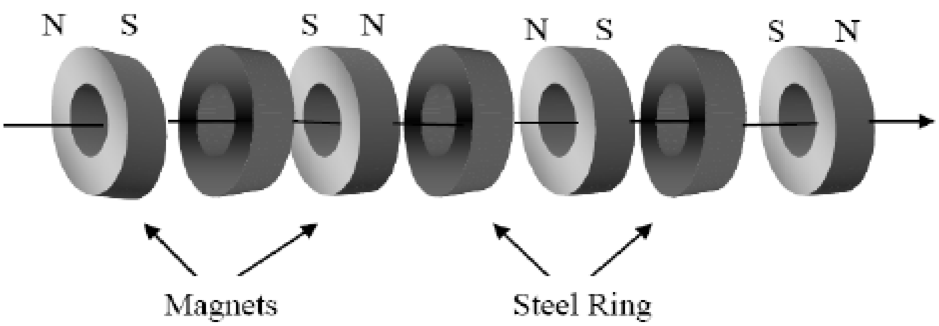


Figure 4. Magnet Arrangement

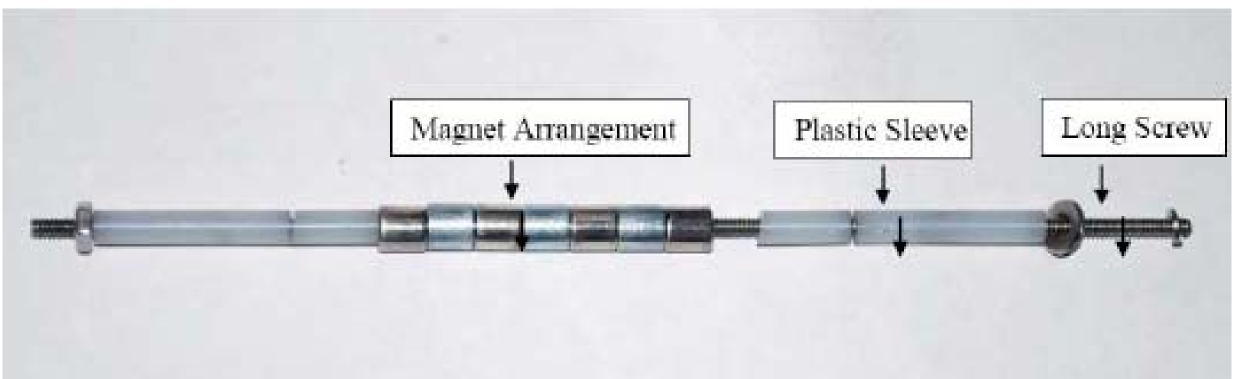


Figure 5. Magnet Arrangement on the machine

3. If the diameter of the magnet is other than specified above, adjust the diameter of the plastic cylinder accordingly.

4. Insert the magnets on the long screw. Also insert plastics tubes (diameter same as the magnet) on both sides of the magnet as shown in the figure.

Note: You can use a screw or a thin rod.

4. Wrap tape in a plastic cylinder along the length, sticky side out.

5. Wind the copper wire around the plastic cylinder/tube (0.5” width), leaving 0.5” space on both ends of the cylinder. Wind down until the coil is 1.6cm tall, then double back and wind back up to the top, and repeat until 1000 turns (wraps around the dowel) have been made.

Note: Start winding the coil so that approximately 12” of extra copper wire are coming off the coil (used to attach a diode). It helps to run the extra 12” towards the bottom of the coil so that it does not get in the way of the winding process.

Hint: Stick the end without the screw into an electric drill to spin the plastic tube while winding. If the copper wire came on a spool, it helps to assemble a rig that allows the spool to rotate freely while being unwound and fed to the coil. (leave another 12” coming off of the other end of the coil [i.e, cut the copper wire so that 12” are left after 1000 turns have been made]). Note: don’t worry about the exact number of turns.

6. Connect an LED (light emitting diode) to the ends of the coil (soldering it is effective for making a sound and permanent electrical contact.)

Note: Make sure to remove the enamel coating off the ends of the coil before attaching the LED (e.g., using sand paper).

Note: Since the voltage generated is very low, use a low voltage LED (e.g., less than 1V).

How it works?

When the system is cranked, Pulley 1 rotates (Figure 1). The rotational motion is transferred to Pulley 2 by the belt/o-ring. Since Pulley 2 has a smaller diameter than Pulley 1, it rotates faster, enabling higher linear velocities. Pulley 2 is connected to the disk on the opposite side of the wall. Thus, the metallic disk also rotates as does its bearing. The cam makes a certain radius while rotating (because it is not at the center). This enables linear motion (up and down). Two Pins are used to guide this linear motion of the coil (Figure 2). Thus, the coil moves up and down (over the magnet).

In this way, the coil experiences a changing magnetic field, and by Faraday’s law, when a conductor experiences a changing magnetic field, voltage is induced. Since the conductor is a coil in a closed circuit, current flows and the LED glows.

Note 1: The magnet mounted on the screw is stationary.

Note 2: The coil moves up and down, over the magnet. The movement is guided by two pins attached to the linear converter (cam).

Note 3: The linear converter (cam) is attached to a loose screw. The loose screw works only as a support. It should not be tightened on the frame. It should be free to move up and down.

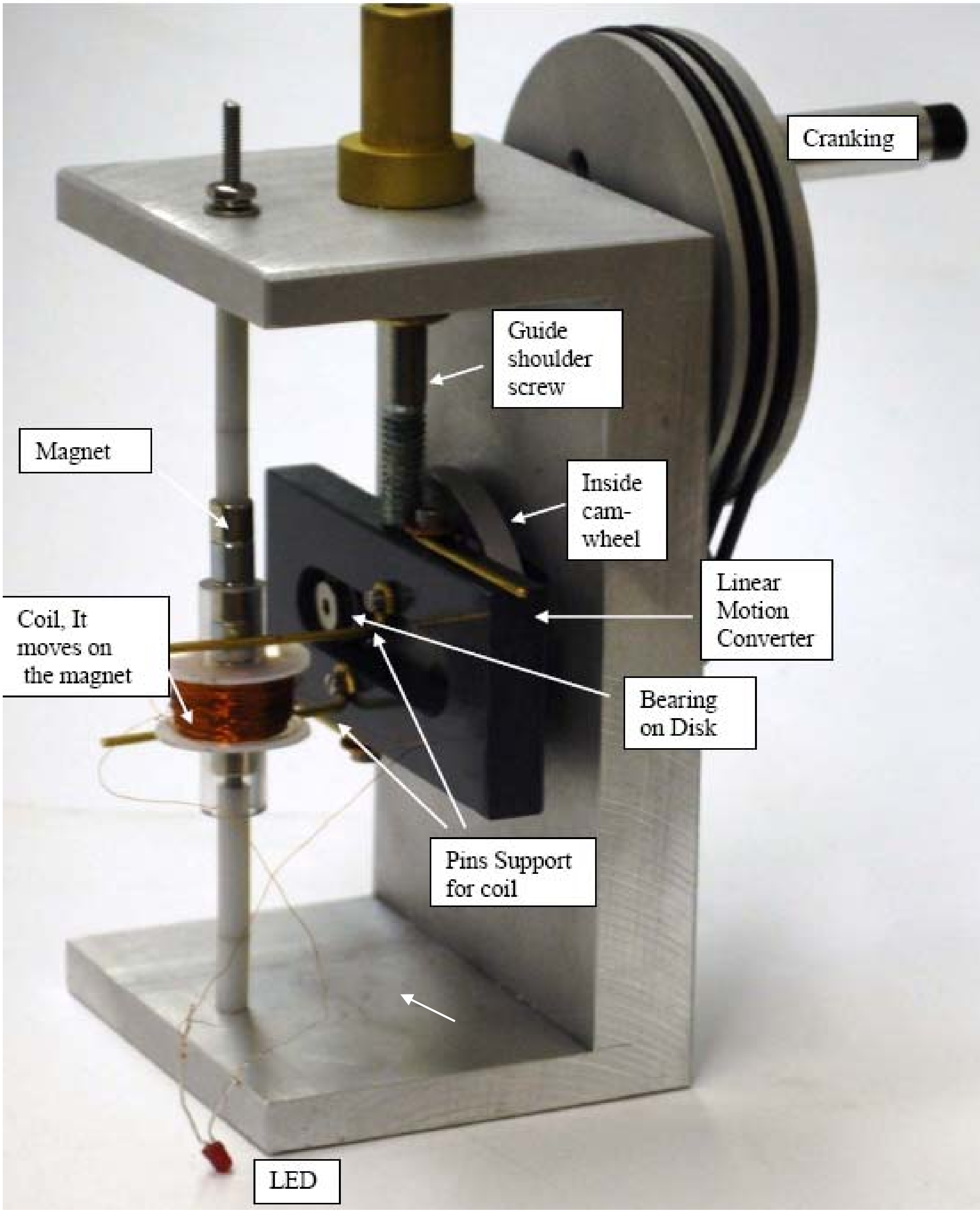


Figure 6. Figure of Complete System

Taking it a step further - What about using an Energy Storage System?

When you operate this device, you will see the LED "flicker". The flickering can be reduced (resulting in more continuous lighting of the LED) by using energy storage, such as a capacitor. You can use a capacitor in a circuit with a diode rectifier bridge (which converts ac voltage to dc), such as in the figure below.

Components:

1 Diode (Low voltage)-4
2 Capacitor (2000 microfared)-1
3 Breadboard -1
4 Wires- 18"

1. On the breadboard, mount the diodes, capacitor and LED as in the following figure (Figure 7).

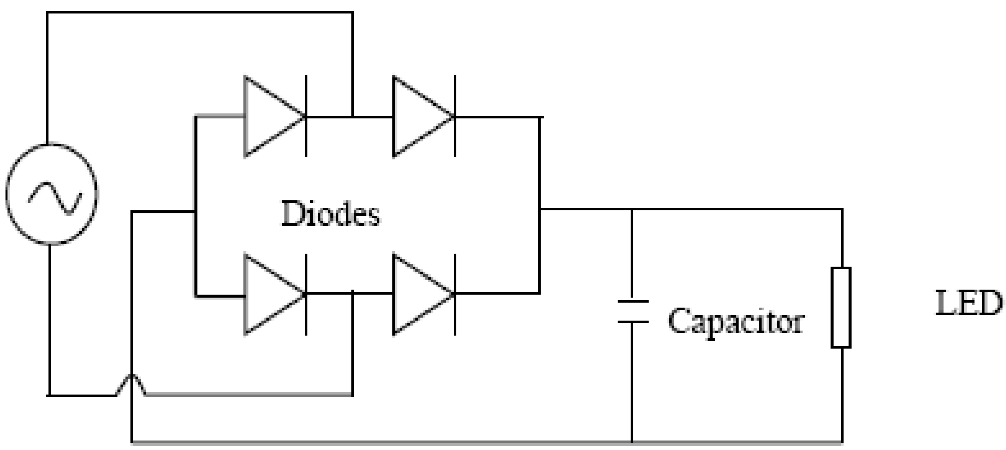


Figure 1. Energy Storage Example Circuit

Special Acknowledgement: The OSU Energy Systems Group would also like to acknowledge the prototype development efforts of Tim Donnelly!