

THE AMAZING ECOCYCLE

or

MUSCLEWATT MANIA

or

HOW TO GET YOUR BODY IN SHAPE,
HELP SAVE THE PLANET,
AND HAVE FUN TINKERING,
ALL AT THE SAME TIME,
IN THE PRIVACY OF YOUR OWN HOME
(AND FOR ONE LOW PRICE)

by

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photographs courtesy of
Mandy HL Rhead

A ShareWords Publication

First Edition

(filled with errors and omissions, hopefully to be
corrected in future editions through reader feedback)

November, 1994

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1. PHILOSOPHY/PSYCHOLOGY/(THEOLOGY?) EDITORIAL

There seems to be a severe and dangerous imbalance in our industrial culture's relationship to the earth. One small manifestation of this imbalance can be seen in the concurrent use of "labor-saving" (usually energy-gobbling) devices and exercise equipment. It seems curious that we burn polluting and precious fuels to generate electricity which allows us to avoid using our muscles (i.e. to "save labor"), and then use our muscles to move about pieces of exercise machines which accomplish nothing other than providing resistance to the movements of our muscles. I am most acutely aware of this insanity when I find myself cruising the mall parking lot for a parking space 50 yards closer to the door to save myself having to walk that distance--when I have earlier in the day jogged around in circles going no place in particular for the exercise. It seems that there has to be a way, other than becoming a farmer or laborer, that those of us with desk jobs can get some exercise and also achieve greater balance between our bodies, our souls, and Mother Earth. One possibility is to convert a stationary bicycle from a brake pad grinding machine to an electricity generating machine.

2. A NOTE ABOUT HISTORY AS A LEAD-IN FOR A WORD FROM OUR SPONSOR (OPTIONAL)

I got to tinkering with my own exercycle for the reasons noted above, in combination with a life-long inclination toward tinkering with gadgets. In the course of procuring supplies and advice from Bill Simmons at Real Goods Trading Corporation I mentioned that I was trying to build a better exercycle/generator system. I said this with some trepidation, since I knew that Real Goods had a such a product in their catalog, so I imagined I might get some resentment that I was placing myself in a position of competing with them. Instead of resentment, the response I got was interest. Bill said that a lot of people called for advice about how to build their own small musclewatt (that term just came to me as I was typing this sentence) devices. He said that many of them could probably build their own such devices, better suited to their own particular needs than the one sold by Real Goods. He suggested that I might provide him with a write-up of whatever I had learned through my efforts, which he would in turn mail out to people who called him with inquiries about how to approach such a project. At this point I had to admit to myself (but not to Bill) that I really was feeling a little competitive and that in fact I had some vague fantasies of getting a patent and then getting rich. Bill's suggestion that I give

it away stood in sharp contrast to my millionaire fantasy, but seemed more consistent with the notion of living in balance and harmony with Mother Earth and my fellow creatures. After a few days of mulling things over I thought of the notion of computer shareware, in which somebody writes a program and distributes it without charge, with the understanding that those who choose to use the software would send its author a small fee.

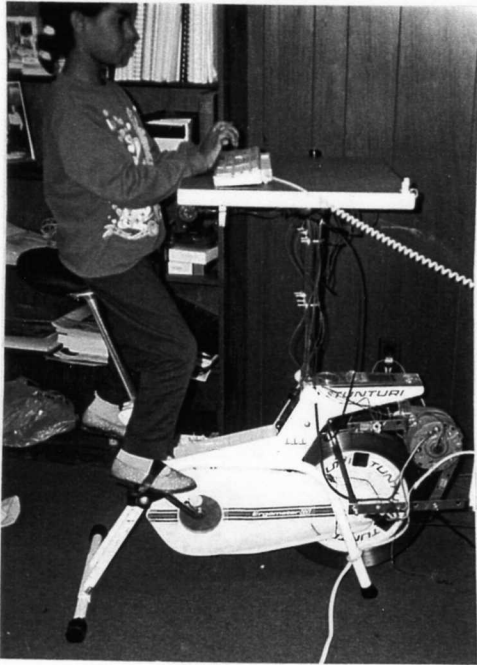
***** READ ME ***** READ ME *****

*
* 3. A WORD FROM OUR SPONSOR *
*
* Feel free to use the ideas contained herein and to *
* reproduce and distribute them. If you get a *
* fifth-generation photocopy which is hard to read, send *
* me \$3.00 (U.S.) and I will send you a new one. If you *
* decide to use the information presented here, I would *
* appreciate your sending me \$20 (more if you feel so *
* moved, less if that figure does not fit your economic *
* circumstances) at the address at the end of this *
* paragraph, in return for which I will put your name on *
* my mailing list for updates and will provide a *
* reasonable amount of advice over the phone. Send your *
* check to: *
*
* John Rhead *
* Suite 205 *
* 5560 Sterrett Place *
* Columbia, MD 21044 *
* (410) 997-5060. *
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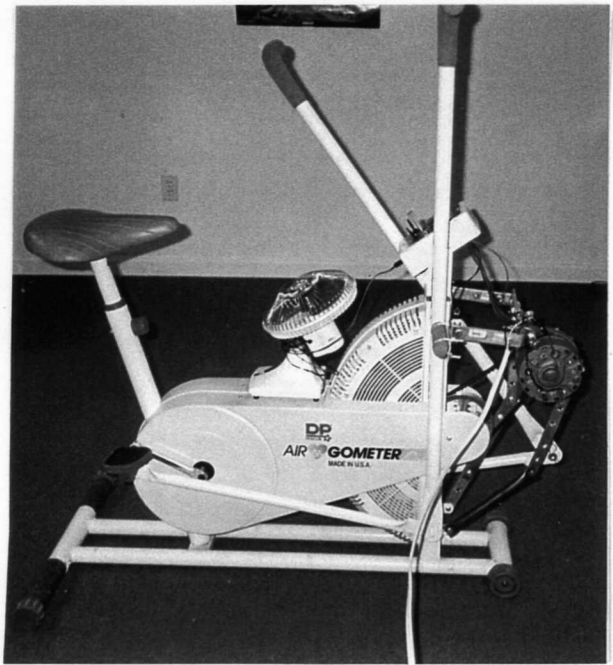
***** READ ME *****

3.5 HISTORICAL UPDATE

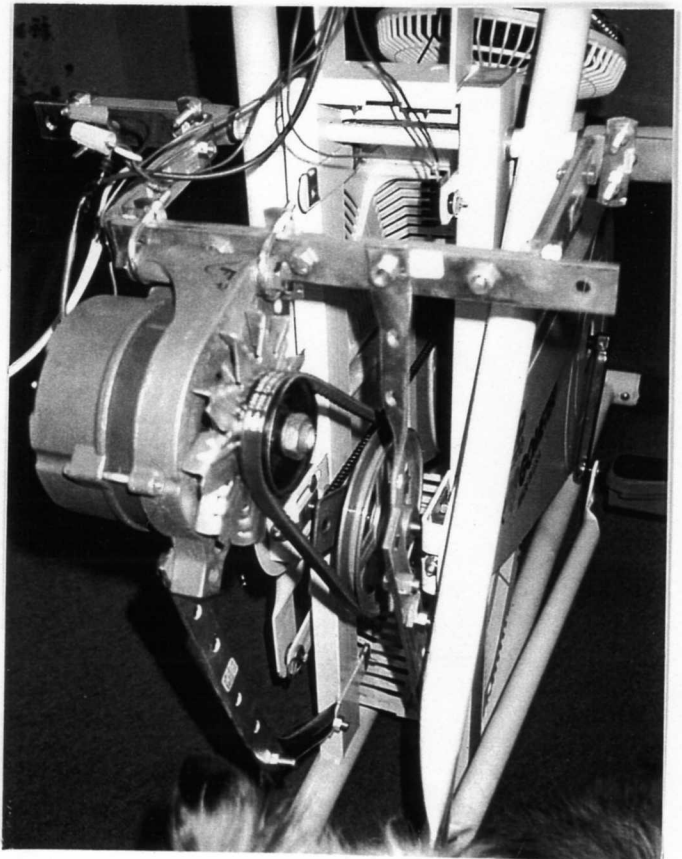
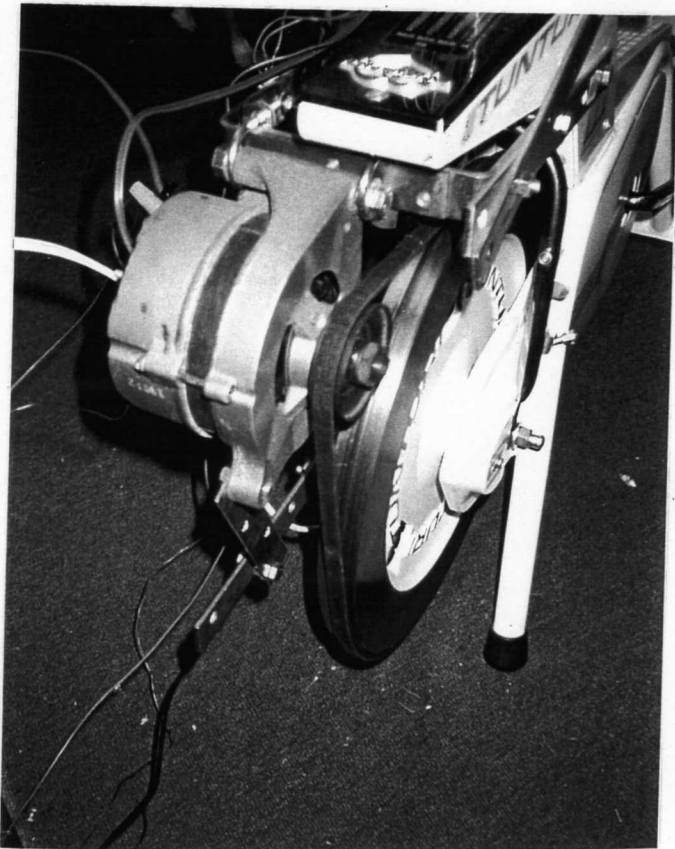
Since talking to Bill Simmons I have actually built up two exercycles. One is a Tunturi single action (i.e. you just pedal it, so your arms are free) and one is a DP dual action (i.e. you pump with you arms and legs both). The Tunturi has a small desktop mounted in place of the handlebars, which allows me to type on my computer, generate electricity, and sweat, all at the same time (as I am doing at this very moment). The DP gives the advantage of being able to increase the electrical output a bit, due to the added contribution of using one's arms, and to get a little upper body exercise in the bargain. The drawback is that you can't operate a keyboard while using it.



Tunturi single-action
with desktop



DP dual-action



4. WHY AN AUTOMOBILE ALTERNATOR?

There are at least three reasons to use an automobile alternator as a power source: availability/price, output capacity, and ease of output regulation (which in turn determines the required input effort--i.e. how hard and fast you have to pedal).

The most basic automobile alternator will put out at least 35 or 40 amps at 12-14 volts DC, which is more than enough. Anybody who could pedal hard enough to put out even 20 amps for as many seconds would be a world class athlete. If you get an alternator with output on the low end of the spectrum (say 40 amps), you may have to gear up your systems for a slightly higher rpm in order to get the output you need. Alternators are available from local auto parts stores, junkyards, and by mail order for under \$50.

Output regulation on an automotive alternator is accomplished by regulating output voltage, either by an internal regulator (i.e. built into the alternator and fixed at about 14 volts) or by an external regulator (also usually fixed at about 14 volts for most automotive applications). Either internally or externally regulated alternators can be used, but I have a strong preference for the external type, since it allows you to construct your own variable control circuit for output voltage. This allows you to select the output required for whatever you may be doing with the electricity, and, of at least equal importance, it allows you to select how hard and fast you are going to have to pedal. At any given moment the output you select will be a function of what you are doing with the output and how hard you want to work out, and it is nice to be able to regulate the output at will to match these parameters.

I have used a very garden variety Ford alternator (external regulator type) that has a 55 (or maybe 65--I'm not sure) amp output capacity and was used from 1968 up into the 80s sometime (very late 80s in pickup trucks, I am told). Any references to details of alternators in what follows will be assuming you are using something similar.

5. THE FIVE TECHNO-CHALLENGES (IF NOT NOBLE TRUTHS):

A. MOUNT IT: If you like hardware stores, or know how to weld, you will love this part. The idea is to find a way to mount your alternator so that it is fairly firmly attached to your exercise bike, is lined up with some kind of flywheel or pulley to drive the V-belt that will in turn drive the alternator, and has some mechanism to

fine tune the distance between the alternator pulley and the flywheel or pulley on the exercycle (so you can decrease this distance enough to mount or remove the V-belt and increase it enough to get the proper tension on the belt). I don't weld, but I love hardware stores, so I had a great time being creative with U-bolts, right-angle steel brackets, and flat steel strips of the same thickness (3/16") and width (a little over an inch) as the brackets. The right-angle brackets are about 6" long on each leg and the flat steel strips are a foot long. Both come with pre-drilled 3/8" holes every couple of inches, so a handful of 3/8" bolts about an inch long (with nuts) should be enough to get you in business. The computerized receipt from the hardware store calls these flat strips "12X1-1/8 ZINC MENDING PLATE" and the right-angle brackets are called "6X1-1/8 ZINC CORNER IRON."

U-bolts just wide enough to span very snugly (perhaps with a little omphh from the installer to spread them open just a bit) the width (a little over an inch) of the brackets and strips are very handy for mounting the alternator to the mounting frame you construct out of the brackets and strips, and perhaps for mounting the brackets and strips to tubular components of the frame of your exercycle. One side of the alternator has a hole about 4" long and 1/2" in diameter, through which you can run a 1/2" inch bolt that is about 5" long. If you put a nut on the end of the bolt and leave it loose enough that there is about a 1/4" gap at each end (i.e. a gap between the nut and the end of the hole in the alternator at one end, and a similar gap between the head of the bolt and the hole in the alternator at the other end), you can then put the rounded end of a U-bolt in each of these gaps. The legs of the U-bolt are then put around the width of one of the brackets or strips and, using the little flat plate that comes with the U-bolt, are bolted up to the bracket or strip. (After the U-bolts are tightened, you can tighten the nut on the 5" long 1/2" bolt that goes through the alternator, thereby closing the gaps where the U-bolts go around the 1/2" bolt and snugging the whole assembly--use washers on the 1/2" bolt on either side of each of the U-bolts if you feel the need.) In a similar fashion, the round end of the U-bolt can be put around a tubular part of the exercycle frame, thereby allowing you to bolt a bracket or strip to it.

B. SPIN IT: You need about 1000 RPM (presumably in the right direction, although I did accidentally get mine going backwards once, with no apparent damage) out of the alternator to get reasonable voltage. The correct

direction of spin can be inferred from the way the blades are pointing on the little fan just behind the pulley--they should be scooping air as it spins, which means it will be counterclockwise when you are facing the pulley end of the alternator. Incidentally, if you want to avoid wasting any energy pushing around air unnecessarily (the alternator won't need the cooling provided by the fan at the amount of output you will be creating), you can remove this fan. Just take off the nut on the end of the shaft, remove the pulley, remove and discard the fan, slip the pulley back on and bolt it back up.

My experience so far has been a V-belt can run from the pulley on the alternator around almost anything that is round and turns, in order to drive the alternator. My Tunturi exercycle has a lovely steel flywheel about an inch and a quarter wide with a small groove in the middle of the nice flat outside edge. I originally thought that the V-belt would just fit right in this groove. As it turns out, the inside edge of the V-belt is actually flat, and was too wide for the groove in the flywheel. As it further turns out, the flat inside edge of the V-belt rides just fine on the flat outside edge of the flywheel, so the groove in the flywheel is irrelevant.

One does need to calculate one's overall gear ratio as one sets up the drivetrain from the alternator. This is the ratio of number of revolutions of the alternator for each revolution of the pedals on the exercycle. It seems that about 20/1 is good for the single action (i.e. pedals only) bike. However, for the dual action (arms assisting the pedals through levers), something closer to 30/1 seems better; a ratio lower than 30/1 can require moving your arms pretty fast. These are pretty rough figures, so you may want to experiment with your own equipment and preferences before tightening all the bolts and welding everything up.

If you are very lucky, the overall gear ratio will be about right when you just slap a belt around the alternator pulley and whatever you have that spins on your exercise bike. However, if you aren't this lucky, you can start playing with the v-belt pulleys from the hardware store. They come in a range of sizes and can be adapted to whatever shaft you may be turning when you pedal your bike. You can also replace the pulley on the alternator to vary the overall gear ratio. There are some variations in pulleys for alternators available from shops that rebuild alternators, but the hardware store variety pulley is probably cheaper and adequate in most

cases. The trick in my experience so far is matching the hole in the center of the pulley with the output shaft of the alternator. The pulleys tend to come with a 1/2", 5/8" or 3/4" hole in the middle. The output shaft on my alternator seems to be just a tad over 5/8". You might be able to press a pulley with a 5/8" hole onto it, or you might have to bore (or file) out the pulley hole just a tad.

C. START IT: An alternator made for an external regulator will have will have an output post (usually labelled "B," "BAT" or "BATTERY") and a post that connects to the "field" part of the alternator (usually labelled "FIELD" or "F"). The output post does just what the name would imply; it puts out the electrical energy generated by the alternator. The regulation of the output voltage is accomplished by regulating the voltage input to the field post; higher input voltage to the field means higher output voltage. To get the whole thing started you need to prime the pump with a shot of 12 volts of DC to the field after the alternator is spinning. (Actually it is probably more gentle on the system to apply the 12 volts to the field just before the alternator is going to spin, and hold it on for a second or two until the alternator is up to speed and putting out voltage.) This is accomplished by having some kind of external power source, preferably a 12 volt battery. I say "preferably" because theoretically any power source that can provide a couple of amps at 12 volts DC should get you started. However, I have been warned that it is important to have a battery hooked up to the system to absorb power surges that might otherwise damage the alternator. This advice comes from guys who work on cars, so it may be a different story at the relatively low output levels generated by a person on an exercycle. However, I figure better safe than sorry, and a used battery from a junkyard is good enough for our purposes (if it has any life left in it at all) and is maybe a \$10 item. For a similar price you can get a new motorcycle battery from J.C. Whitney, although you will be on your own to find some acid to put in it after they mail it to you dry. The battery is connected (through a fuse--10 amps should be enough, and as close to the battery as possible so that a loose wire has minimal chance of flopping around and shorting to the battery inside the protective barrier of the fuse) to the alternator. The ground from the battery goes to the frame of the alternator (there are one or two posts on the alternator for this purpose, but any piece of metal that connects to the frame of the alternator is fine). The positive lead from the battery goes to the output terminal of the

alternator, but not directly. It goes through a diode first. One side of the diode connects directly to the output post of the alternator, and the other side of the diode connects to the lead coming from the battery, in such a way that current can flow from the alternator to the battery through the diode (for charging the battery when you are pedaling fast enough), but cannot flow from the battery back into the alternator. This is accomplished by making sure that the end of the diode with the little ring painted around it is connected to the battery lead, not the alternator. Such diodes are available from Radio Shack in a package of 4 for 2 or 3 dollars. (They call them rectifiers and rate them at 6 amps and 50 PIV under catalog number 276-1661). [Update: When I last visited a Radio Shack store they did not have the 6 amp model just mentioned. What they had instead was a package (catalog # 276-1141) with 2 "epoxy rectifiers," each rated at 3 amps. The good news is that you can wire these two together in parallel, which means connecting together the two leads from the ends with the rings of the two rectifiers and connecting together the two leads from the non-ringed ends of the two rectifiers. This whole unit then can function as a single 6-amp diode, and you won't have to buy more than you need in this single blister pack.] In order to prime the pump and get the alternator to begin making electricity, you need to give just a brief jolt of power to the field post. This is accomplished by running a wire from the junction where the battery lead joins the diode, through a pushbutton (good for 2 or 3 amps; Radio Shack catalog # 275-1556 is fine), and on over to the field post. Once you are ready to spin the alternator, you simply touch the pushbutton briefly to send a surge of power to the field and fire it up. In order to keep the whole thing running once you release the pushbutton, power will be directed from the output post to the field post by means of the voltage regulation circuit described in the next section.

D. CONTROL IT: The issues in constructing a control circuit are cost, ease of construction (including availability of parts), efficiency (i.e. you don't want to burn up too many precious watts in the regulator circuit), and function (i.e. that it works). Once you spin the alternator up and hit the start button, the voltage regulation circuit will take voltage from the output terminal of the alternator and deliver a certain reduced voltage to the field terminal. The voltage delivered to the field terminal will determine how much power the alternator will deliver as output at any given speed, and hence how hard and fast you have to pedal. It

appears that what works best is to have a voltage regulation circuit that provides the field terminal with a range from about 1.25 volts up to 6 volts. Below about 1.25 volts going to the field the alternator won't work at all, and above 6 volts input to the field it will be too hard to pedal. A good voltage regulator circuit which reliably allows you to dial in any voltage you want within that range is a true joy; it allows you almost infinite adjustment in how hard and how fast you want to pedal in order to deliver a given power output.

As it turns out, Radio Shack can sell you the components to make such a voltage regulator for just a few dollars. The heart of the system is a little solid state gadget called an LM317T (Radio Shack catalog # 276-1778). Along with this you need a 5000 ohm potentiometer (Radio Shack catalog # 271-1714), a heat sink (Radio Shack catalog # 276-1363) to keep the LM317T from overheating, and a 1000 ohm 1/4 watt resistor (they come five in a pack under Radio Shack catalog # 271-1321). Of unknown importance at this time is the little tube of white cream (which Radio Shack calls "Heatsink Compound" and will sell you under catalog #276-1372), which is supposed to be applied between the LM317T and the heat sink in order to make sure heat is transferred efficiently. It's probably good insurance, even though you will only need about 1% of the contents of the little tube. Finally you will need some wire to hook things up, and Radio Shack can provide this too; you get three small rolls (in different colors) of what they call "hookup wire" (18AWG stranded wire) under catalog # 278-1226. If you want to splurge you can also buy a control knob for the potentiometer. They come in different sizes and colors, and usually 2 to a blister pack, so you will end up with a spare.

Mechanical aspects of the LM317T: Using a solid state voltage regulator rather than just putting a big variable resistor (a rheostat) between the output and field posts of the alternator is a choice made primarily on the basis of efficiency; the solid state device will waste less power. The power wasted is in the form of heat which is given off as a byproduct of voltage regulation. Although the LM317T wastes less, it still does generate some heat. Hence the need for the heat sink. If the heat generated in the LM317T is not dissipated fast enough to keep it fairly cool, it will self destruct. I learned this the hard way by mounting one, with a heat sink, inside a small poorly-ventilated box. The heat was dissipated from the LM317T through the heat sink into the air inside the box, but that warm air was not carried out fast enough by convection, so the whole box heated up, the

heat sink could not longer dissipate heat fast enough, and kabloowie went the LM317T. The moral of this story would seem to be that one should mount the LM317T and its heat sink out in the open air, where convection can do its work and move the hot air away from it.

When mounting the LM317T, keep in mind the fact that its output goes not only to the little tab designated on the back of the package (one of three such tabs; the other two are for voltage input and voltage adjustment), but also to the larger metal ear of the LM317T. This is the part that has a hole in it for mounting the device. Since the output voltage goes to this ear as well as the tab, you can't just run a screw through the hole in the ear and mount it on any convenient metal surface. Once everything is bolted up, every convenient metal surface will probably be part of your ground circuit, so it you just bolt the LM317T to, say, the frame of your bike, you will be shorting its output to ground. Not productive. The solution is to mount the LM317T and its heat sink in such a way that it is electrically insulated from ground. A little creative use of garden hose washers, miscellaneous grommets, silicone silastic, and imagination should accomplish this. Something I have not yet tried, and hope somebody else will, would be to mount the LM317T and its heat sink right on the field post of the alternator. This would get around the need for creative insulation and would make a more direct contact for the current to flow (by cutting out the middleman, or in this case, the middlewire). The only significant question I see is whether or not one could drill out the mounting hole in the metal ear of the LM317T enough to accommodate the field post without damaging its delicate little electrical innards. Please let me know how it comes out if you try this.

Electrical aspects of the LM317T: There is a wiring diagram of sorts on the back of the blister pack in which the LM317T is sold. It shows two resistors (R1 and R2) and two capacitors (C1 and C2). The capacitors seem irrelevant in our situation and I have never used them. The first resistor, R1, is shown as a 240 ohm resistor. However, a 1000 ohm resistor should be used instead (Radio Shack catalog # 271-1321). This will limit the theoretical output of the regulator to 7.5 volts (in reality about 6 volts, according to my meter), which seems to be all you need. The second resistor, R2, is a variable resistor which goes from 0 up to 5000 ohms. It is also called a potentiometer and is sold under Radio Shack part # 271-1714.

You want to mount the potentiometer and the pushbutton (mentioned in the START IT section above) for starting the system in some place that is convenient to reach while you are pedaling. This will allow you to adjust how hard and fast you are pedaling. If you are using a dual action exercycle, you might want to even consider mounting these two controls near the end of one of the handlebar levers you are pumping with your arms, so that you can hit the start button and adjust the potentiometer without taking your hand off the lever. If you do this be sure to use fairly flexible (i.e. stranded) wire for the part where the wire goes from the moving lever to the stationary frame of the bike.

Now back to the wiring. Unless you get very creative with some kind of small clamps, it will require some soldering. Be particularly careful with the 3 little prongs coming out of the LM317T; if you get them too hot while soldering to them, it will destroy the LM317T. You can reduce this risk by clamping the prong, between the case of the LM317T and where you are soldering at the end of the prong, with a pair of pliers. (Radio Shack also sells a little gadget called a Mini Forceps, catalog number 64-1910, which will clamp onto the prong for this purpose.) This will keep some of the heat from reaching the case of the LM317T. It will also probably require more hands than most of us have, so you will probably need a friend to help at this point. Ideally, if you have not had experience soldering, you should get a friend who has. You need to run a wire from the output terminal of the alternator to the input (V_{in}) prong of the LM317T. Then you need a wire from the ADJ prong to the middle of the three connectors on the bottom of the potentiometer. Before you solder this connection, add to it one of the two leads coming out of the 1000 ohm resistor. Now solder it. The other end of that resistor needs to find its way to be connected to the wire you solder to the final prong of the LM317T (V_{out}), which in turn goes on down to the field post of the alternator. It can simply be spliced into the wire at some convenient point, or can be run on down to the field post with a wire of its own. One of the two remaining connectors on the back of the potentiometer needs to have a wire soldered to it and run to any good ground, which means any piece of metal which is electrically connected to the case of the alternator. This pretty much means any piece of metal which is part of the frame of the exercycle or of the mounting brackets for the alternator.

E. APPLY IT: Now that you are using your muscles to make electricity (musclewatts), what are you going to do with

