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Project U Wash

The Battery Charging Hand-Powered Washing Machine

Role of the UWash

In third world countries, we need to increase the population's access to electricity by utilizing the energy put into washing laundry.

No Access to Electricity

One fifth of the world's population has no access to electricity and only a billion more have an unreliable supply.

Limited Water Supplies

884 million people in the world lack access to safe water supplies.

Washing Laundry is a Laborious Chore

This chore can consume 6 hours of a person's day for 3 to 5 days a week.

Energy Harvesting System

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Energy Conversion System for a Greener Planet

Energy Source

Energy Harvester

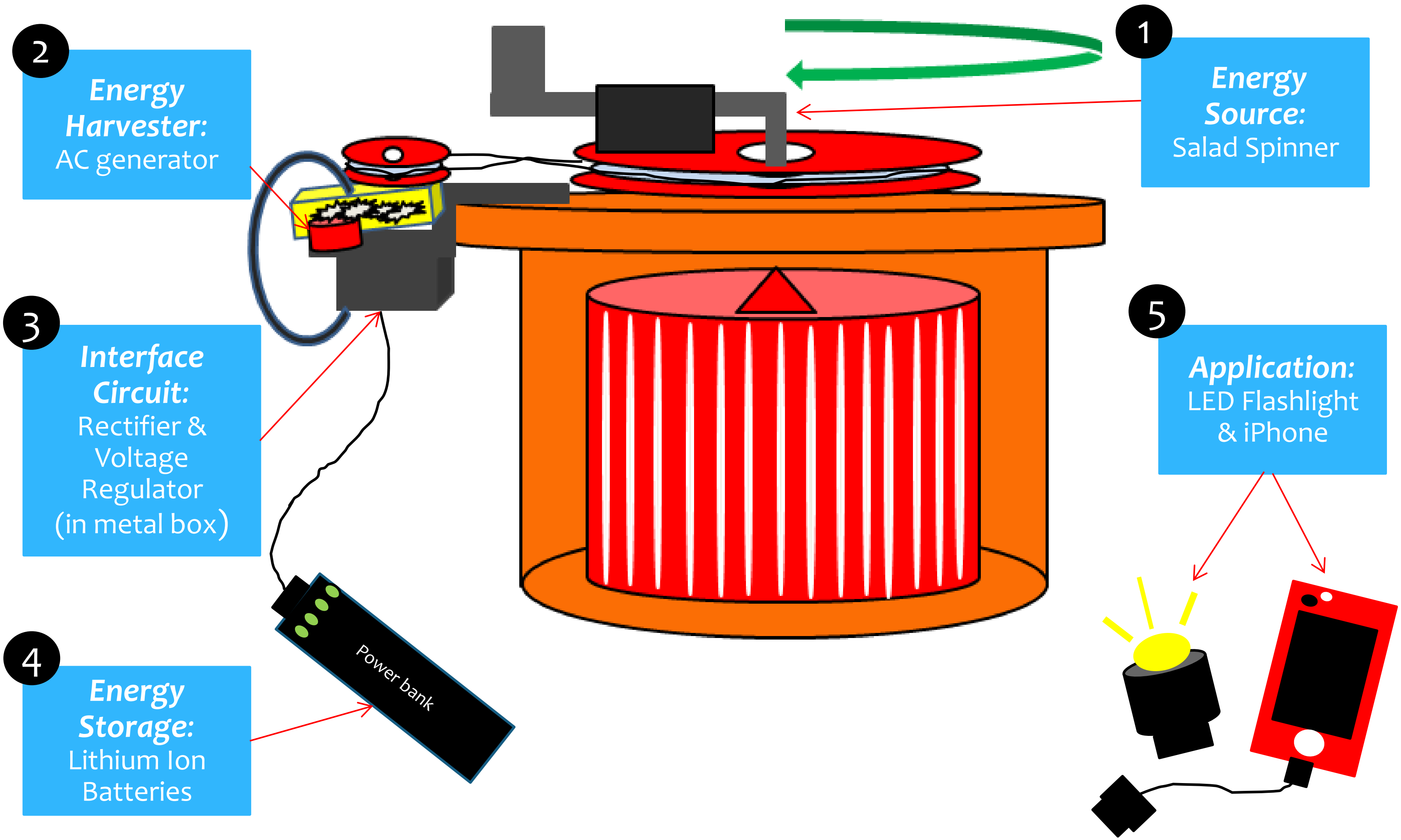
Energy Regulation Circuit

Energy Storage

Application

Store electrical energy while washing laundry

Rotate handle, spin AC motor, regulate & store output voltage



Application

Goal is to power a flashlight and an iPhone

Rechargeable Micro Flashlight

- Can provide *2 hours* of light after a full charge
- Energy Capacity: 0.3 Wh

Apple iPhone USB Data and Charge Cable

- Charges iPhone Battery
- Energy Capacity: 5.45 Wh

Charged by a 5V USB port

Energy Storage and Voltage Regulation

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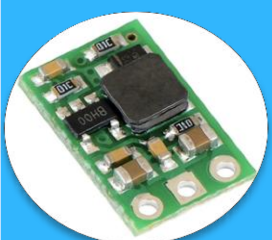
Supplying 5 V to flashlight and iPhone USB ports

Energy Regulation

Switch mode Voltage Regulator



- 80% efficient
- Takes in voltage and steps it up/down to 5V

Energy Storage

5V USB Charger & Power bank

- Composed of lithium ion rechargeable batteries
- Energy Capacity: 9.62 Wh

Application

Regulator and power bank chosen to charge flashlight & iPhone

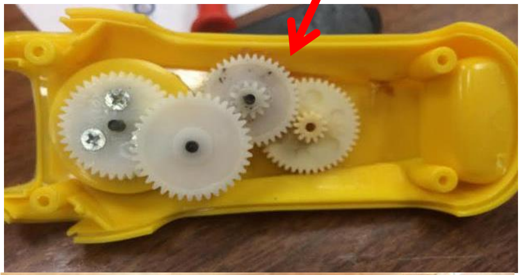
Choosing an Energy Harvester

ELECTROMAGNETIC ENERGY HARVESTERS				
Type:	Hub Dynamo	Bottle Dynamo	DC Motor	AC Motor
Visual:				
Output Voltage:	AC Voltage	AC Voltage	DC Voltage	AC Voltage
Product Ratings:	6V, 3W	6V, 3W	Varies with part	Varies with part
Efficiency:	72%	40%	75 - 80%	85 - 97%
Pros:	• Doesn't wear out as fast as bottle dynamos do	• Cheaper and smaller than hub dynamos	• Cheap & available in a variety of sizes	• Low maintenance & long life spans
Cons:	• Requires special attachment	• Noisy, slip in wet conditions	• Brushes wear out over time	• Can be more expensive and produce more audible noise than DC motors.

Testing~ AC Generator

Complete Hand Crank Flashlight

Overall 95:1 gear ratio



AC generator

Utilized a hand crank flashlight's AC generator

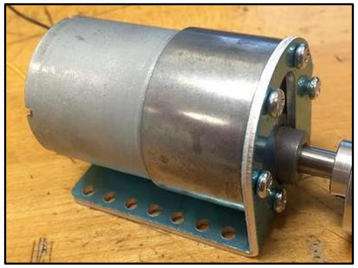
Energy Regulation Circuits

AC output voltage needs to be rectified, smoothed and boosted to 5V DC

AC Generator → Full Bridge Rectifier → Smoothing Capacitor → Voltage Regulator → Power bank

DC output voltage just needs to be boosted to 5V DC

DC Generator → Voltage Regulator → Power bank

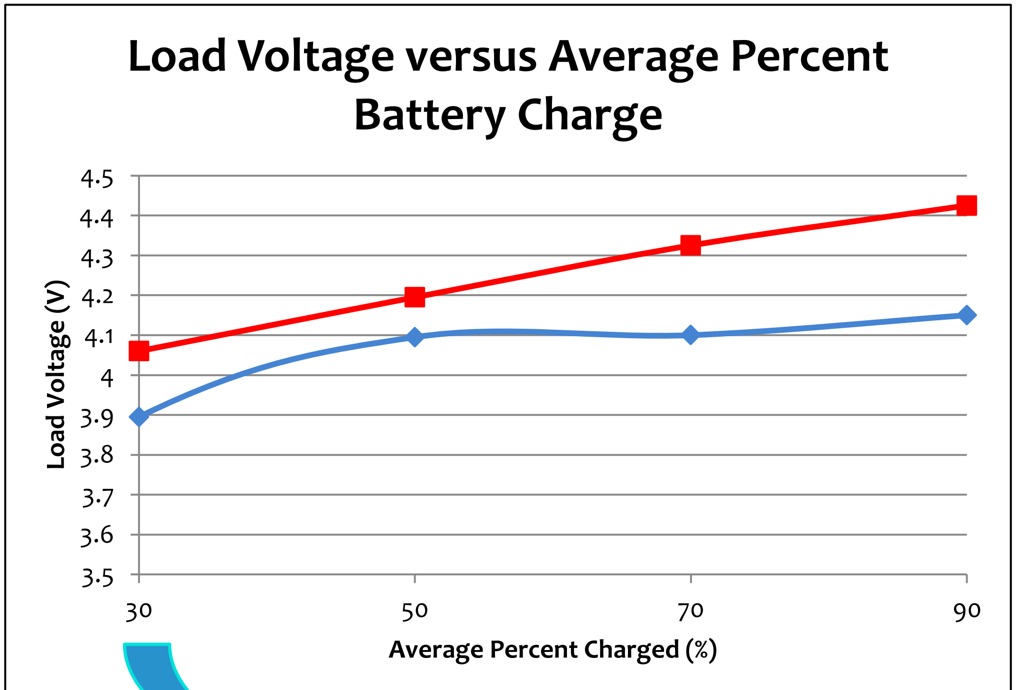


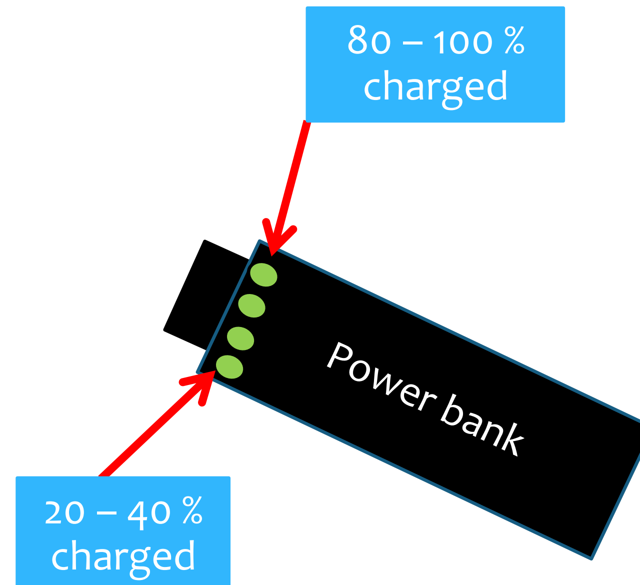
Load Voltage Using AC versus DC Generators

Key:

Gear Ratios

- DC Generator (180 * 19 = 3,420 RPM)
- AC Generator (120 * 94.6 =11,352 RPM)



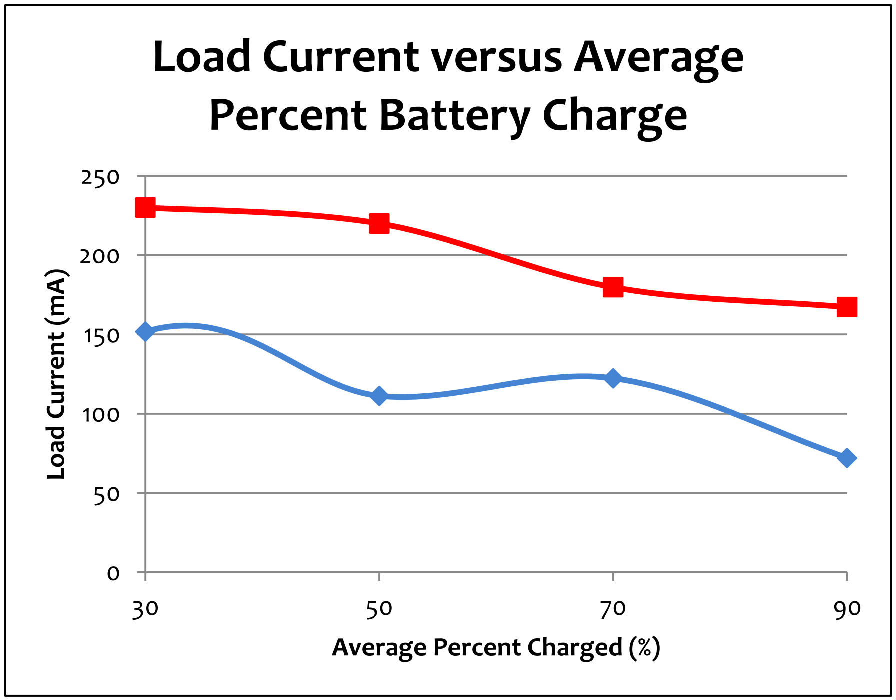


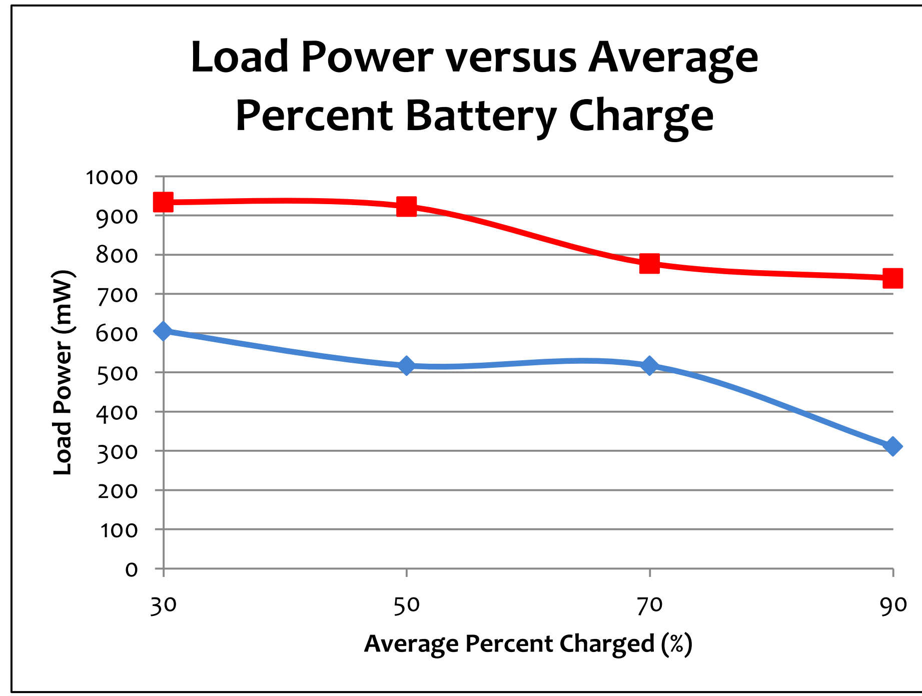
Average load voltage using the AC generator is always greater than the load voltage measured when using the DC generator

Load Current & Power Using AC versus DC Generators

Key:

- DC Generator (180 * 19 = 3,420 RPM)
- AC Generator (120 * 94.6 =11,352 RPM)





Load power & current are greatest when power bank is close to 0% charged

Energy Source and Harvester Choice

Cost, application & efficiency pointed towards an AC generator

Energy Source

Salad Spinner & Pulley System

- Pulley system we built provides a 5:1 gear ratio

Energy Harvester

AC Generator

- 8.2 – 9 V
- Comes from a hand crank flashlight
- Built in 95:1 gear ratio

Energy Regulation, Storage, Application

UWash is a success if it can fully charge the flashlight after a 1 hour use AND if over a 6 hour use it can charge an iPhone to at least 50%

Charging Results with hand crank

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How long it takes to charge the power bank (with hand crank flashlight)

Power Bank Percent Charged (%)	AC Motor
20 – 40	15 min.
40 – 60	2 hours 15 min.
60 – 80	4 hours 35 min.
80 – 100	7 hours 45 min.

How long power bank can keep flashlight on for

Power Bank Percent Charged (%)	Duration of time flashlight stays on for (hours)
20 – 40	2
40 – 60	5
60 – 80	10+
80 – 100	16+

Percent power bank can charge a dead iPhone to

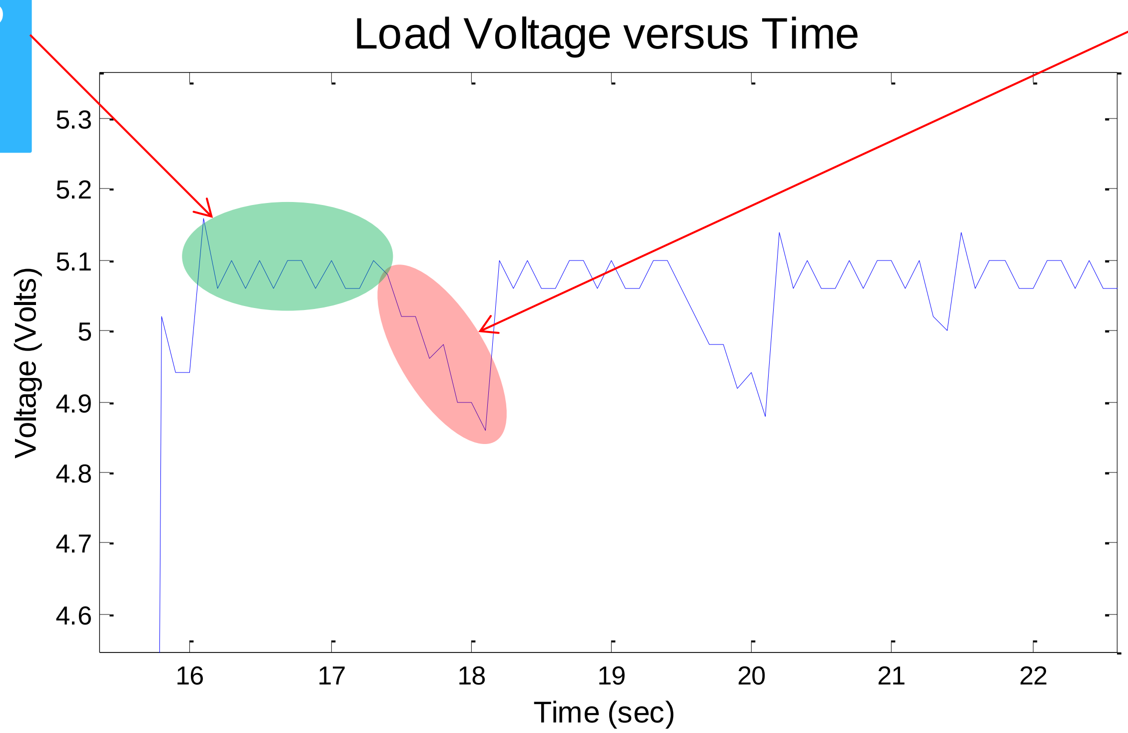
Power Bank Percent Charged (%)	Percent increase in iPhone Charge (%)
20 – 40	5
40 – 60	11
60 – 80	26
80 – 100	41

UWash is capable of fully charging the flashlight after a 1 hour use, but not capable of charging the iPhone to 50% after a 6 hour use

Considering Realistic RPM

Power Bank Battery at 0% Charge

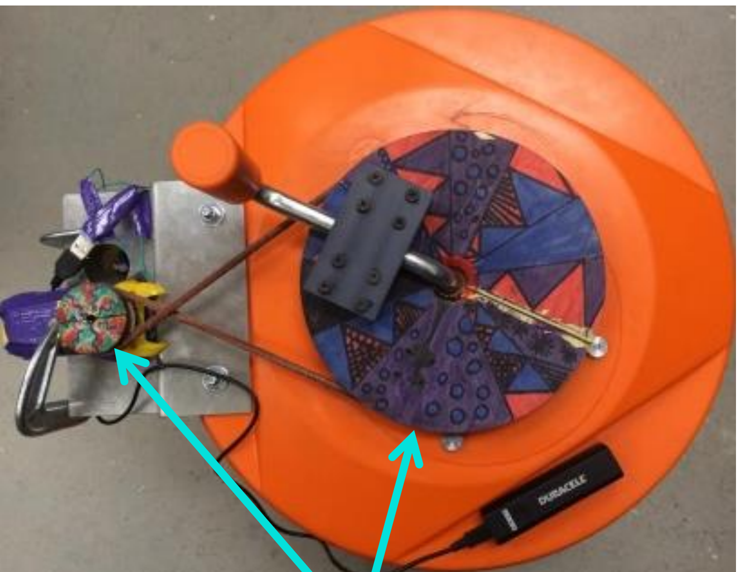
Corresponds to clockwise rotation



Corresponds to deceleration due to counter clockwise rotation change

Not all rotational motion will go into charging...

Final UWash Product



Final UWash Product Testing

After 15 minutes of UWash charging *with* laundry and water inside…

Duration of time flashlight stays on for (hours)
1

After 15 minutes of UWash charging *without* laundry and water inside…

Duration of time flashlight stays on for (hours)
1.5

Conclusions & Future Work

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Conclusions…

UWash is capable of fully charging flashlight after a 1 hour use but NOT capable of charging an iPhone to 50% after a 6 hour use

Possible UWash improvements…

- Replace pulley system with a chain and sprocket system
- Test additional AC generators to find the most efficient one
- Water proof all electrical components
- Create a new container for gear system & generator to sit more securely on platform

Thank you!

Types of Electric Motors

AC Motor	DC Motor
•Two main types: asynchronous and synchronous • Consists of an outside stationary stator with coils supplied with SC current to produce a rotating magnetic field & an inside rotor attached to the output shaft that's given torque by the rotating field •**PROS**: low cost, speed variation, high power factor, reliable operation •**CONS**: Inability to operate at low speeds, control complexity of AC drive, typically more expensive than DC motors for most horsepower ratings, noisy	•Two main types: brush & brushless • Brush DC motors: generates torque from DC power supplied to the motor by internal commutation, stationary magnets, & rotating electrical magnets • Brushless DC motors: use a rotating permanent magnet or soft magnetic core in the rotor, and stationary electrical magnets on the motor housing • **PROS**: Good speed control, easy to understand design, cheap • **CONS**: High maintenance, vulnerable to dust which decreases performance

Power Bank Indicator Translation

LED	Percent of Battery Charged (%)
4	80 – 100
3	60 – 80
2	40 - 60
1	20 - 40
1 (flashing)	< 20
0	0

How long it takes Computer to charge Power Bank

Power Bank Percent Charged (%)	Computer Port (reference)
20 – 40	10 min.
40 – 60	25 min.
60 – 80	2 hours
80 – 100	4 hours

Power Bank Ratings

Output : DC 5V ---1000 mA

Input : DC 5V ---1000 mA

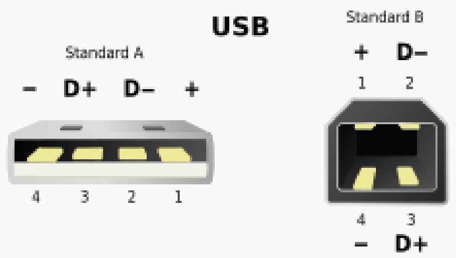
Capacity inside Li-ion battery : 3.7 V 2600 mAh

Energy Storage Capacity: 9.62 Wh

USB Ratings

Electrical	
Signal	5 volt DC
Max. voltage	5.00±0.25 V (pre-3.0); 5.00+0.25-0.55 V (USB 3.0)
Max. current	0.5–0.9 A (general); 5 A (charging devices)

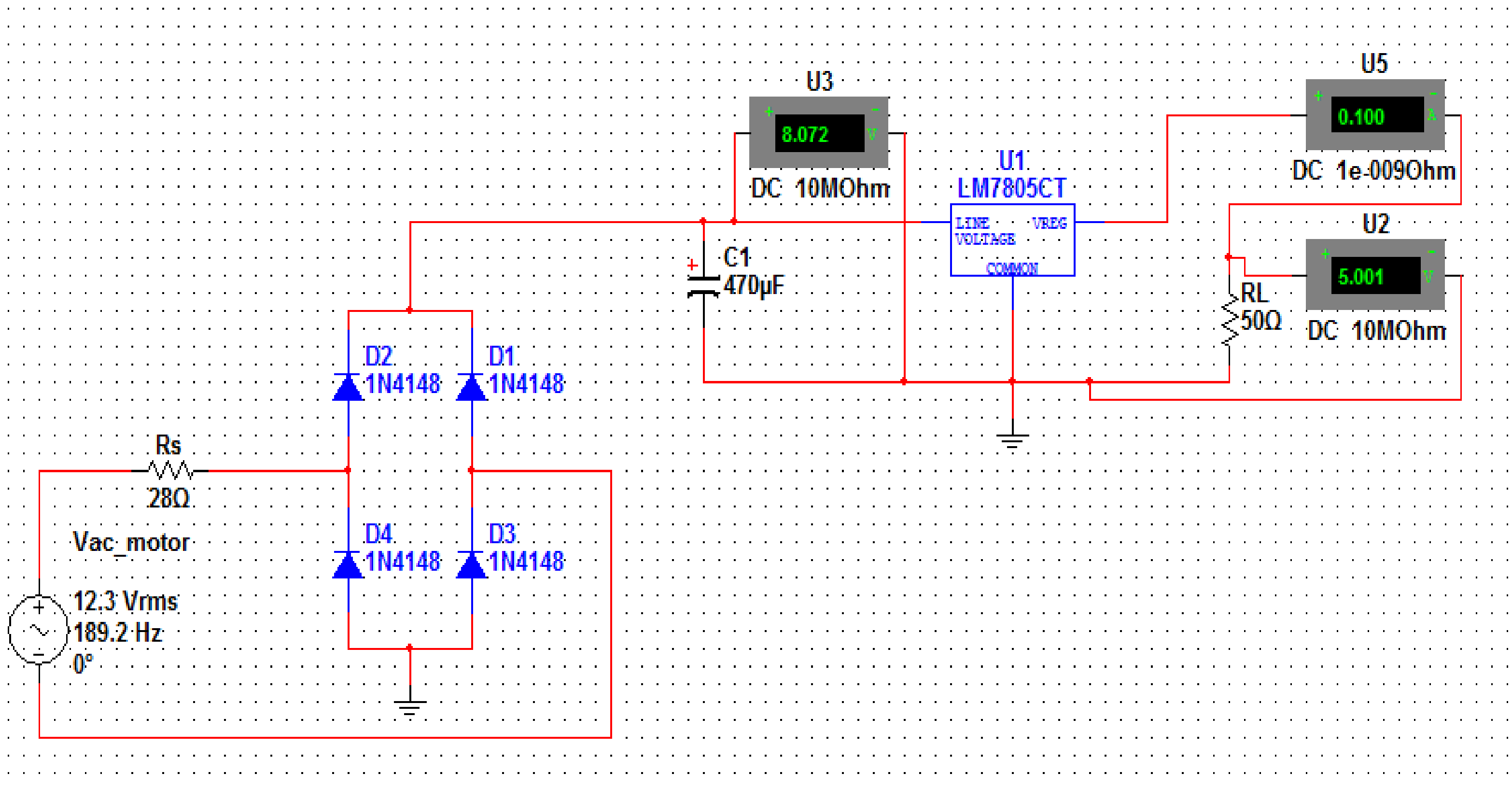
Pin out



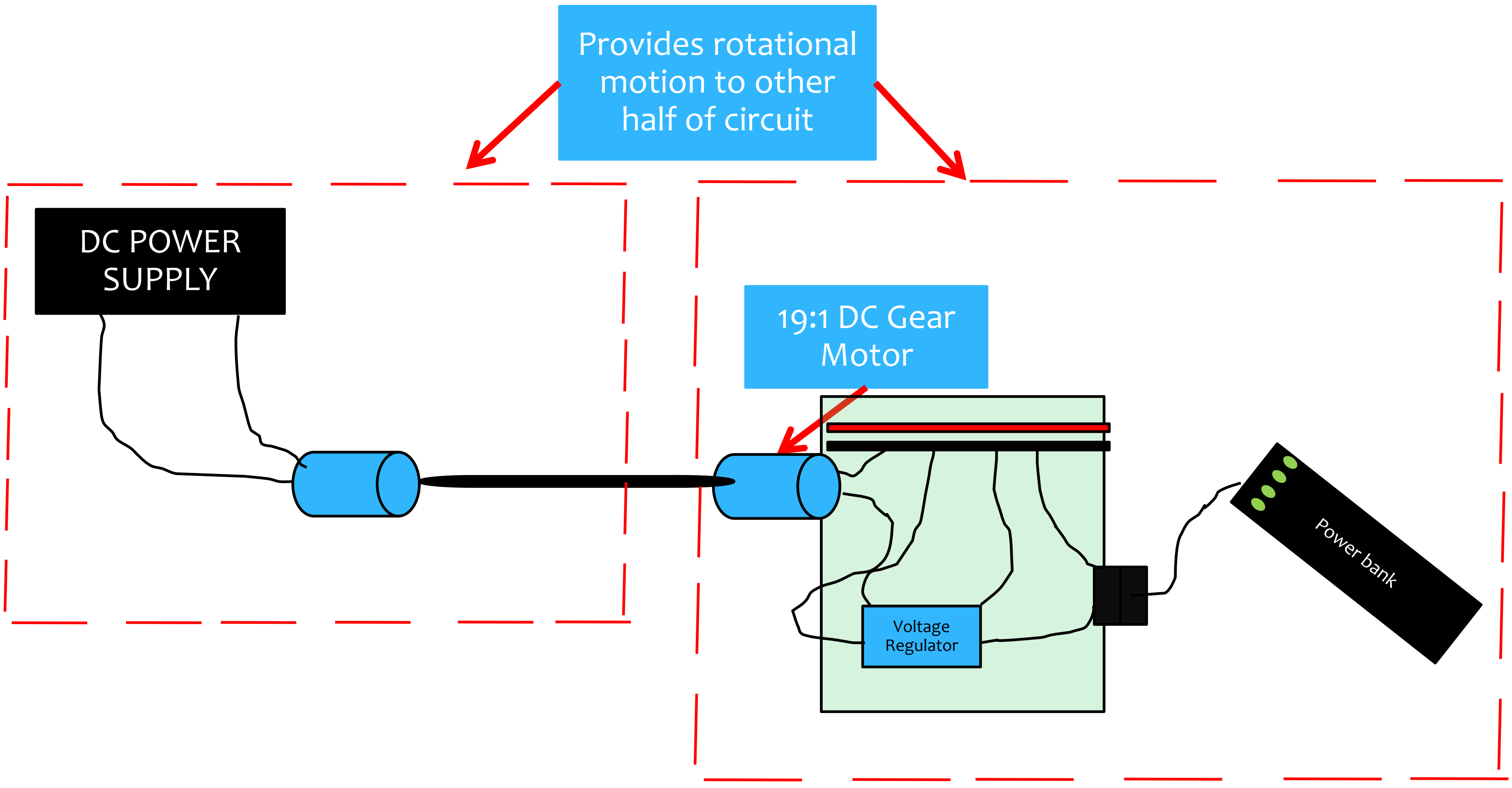
The standard USB A plug (left) and B plug (right)

Pin 1	V_{CC} (+5 V, red wire)
Pin 2	Data− (white wire)
Pin 3	Data+ (green wire)
Pin 4	Ground (black wire)

AC Generator Multisim Simulation

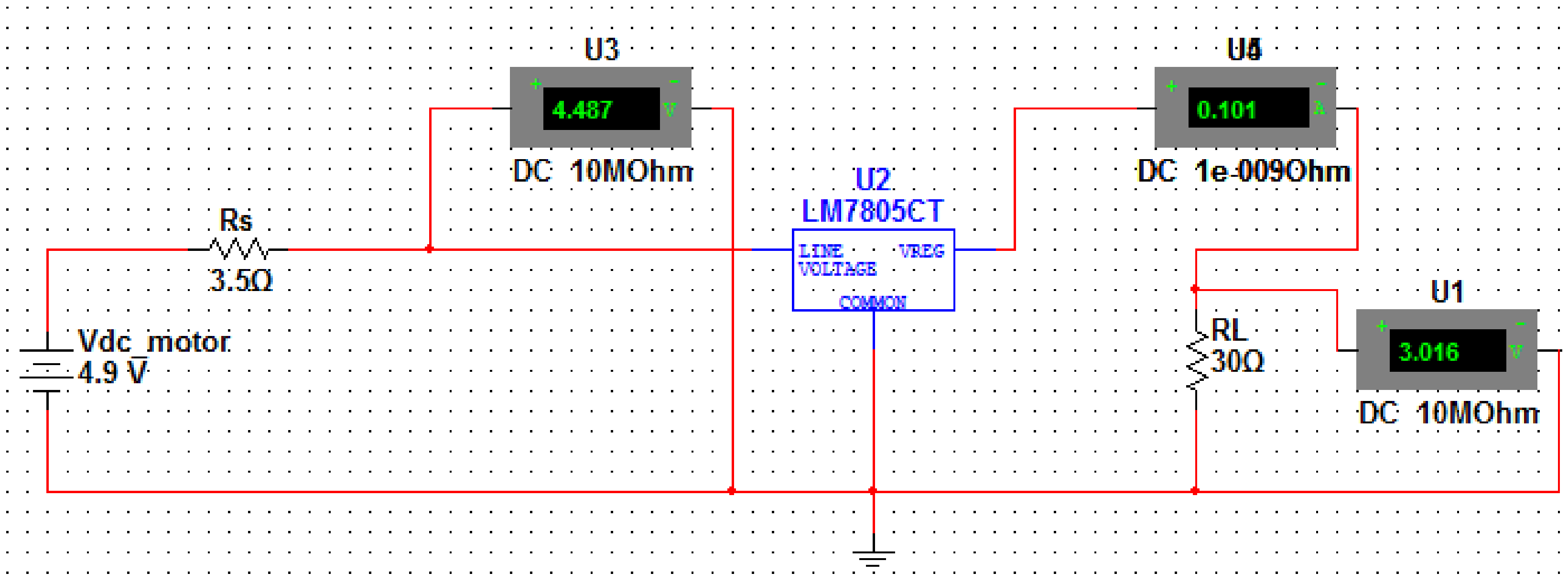


Testing~ DC Generator



Using a DC motor to drive a DC generator

DC Generator Multisim Simulation



Washing Machine Basics

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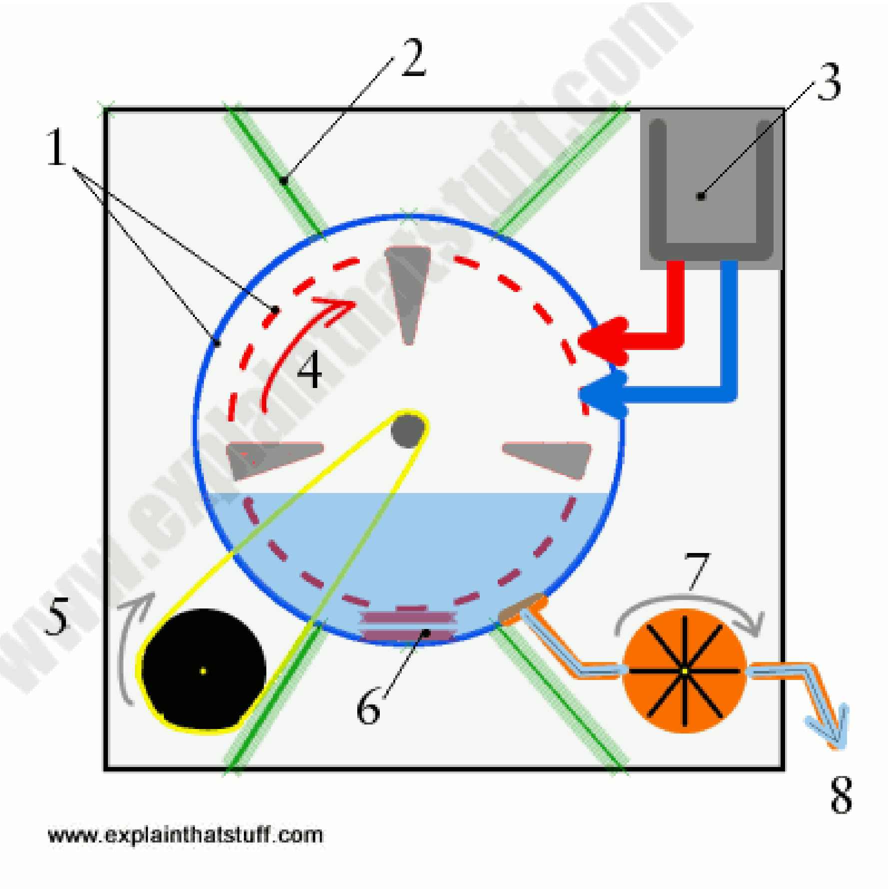
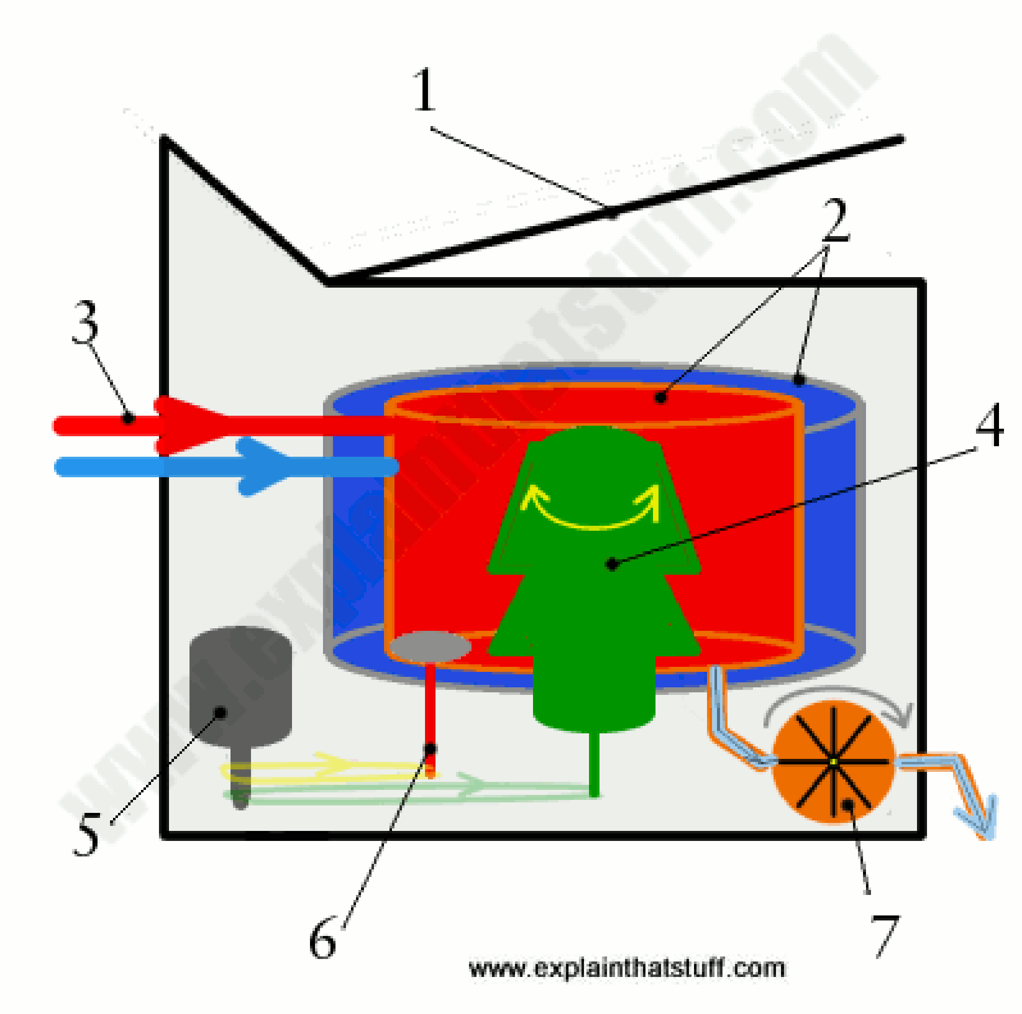
	Top Loading	Front Loading
Physical Description	➢ Lid on top ➢ Upright basket	➢ Door in front ➢ Side-ways mounted basket
Mechanics of washing clothes	➢ Uses paddles to move clothes around basket ➢ Paddles stir water while basket turns creating friction that loosens dirt from clothes	➢ Uses an agitator to move clothes around basket ➢ Agitator alternates direction on vertical axis, creating friction to loosen dirt from clothes
Pros	➢ Uses less water and detergent	➢ Uses more water and detergent
Cons	➢ Seal & lock at beginning of wash	➢ Can open lid anytime during wash

Front Load Washing



1) Fixed outer drum (blue) and fixed inner drum (red)
2) Springs to absorb vibrations of rotating drum
3) Detergent tray that allows hot and cold water to flow in
4) Inner drum: turns back and forth (grey paddles move clothes around)
5) Electric Motor that turns inner drum
6) Heating element to heat water
7) Pump to suck water away
8) Tube for water to drain

Top Load Washing



1) Lid to drop clothes into
2) Outer drum (blue) inner drum (red)
3) Hot and cold water pipes
4) Stationary agitator that turns around moving clothes through water
5) Electric motor that powers the agitator
6) Inner drum turned by the electric motor
7) Pump to drain water from the outer drum

How long we thought it would take to charge power bank

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Known Parameters:	Values:
Speed	2.5 km/hr
Radius of Handle Motion	8.5 in
RPM of driver pulley	30.72 RPM
RPM of DC motor pulley	92 RPM (~3X driver)
Output Power at 92 RPM	~0.5 Watts

These values show us that rotating the handle of the UWash at **~30 RPM for 1 hour** can generate about **0.5 watt hours** of energy

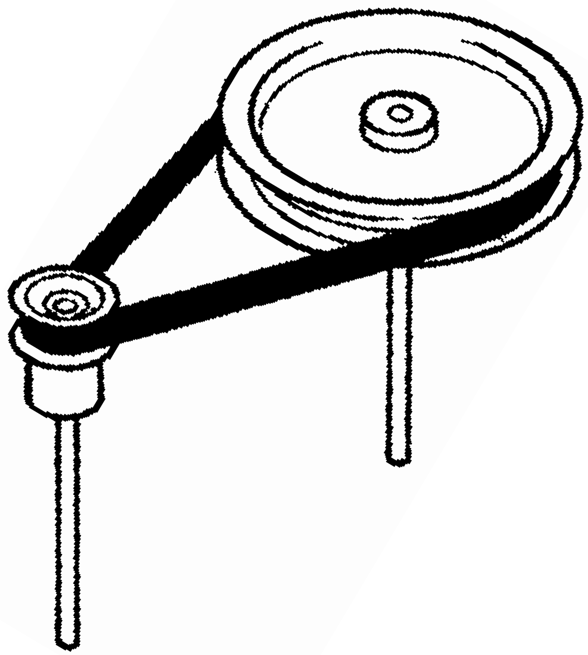
To fully charge the power bank (9.62 Wh) you would have to do a 1 hour wash at 30 RPM about 19 times… i.e 9.62 Wh / 0.5 Wh= 19

To fully charge the flashlight (0.3 Wh) you would need to do a 1 hour wash at 30 RPM about 1 time

To fully charge an iPhone (5.45 Wh) you would need to do a 1 hour wash at 30 RPM about 11 times

- This takes into account the 40% efficiency of a **bottle dynamo.**
- Taking into account the higher efficiency of DC motors we expect better results!

Pulley System



5.2 :1 Ratio

Ideally..30 RPM turns
DC generator ~ (19)*(5.2)*(30)= 2,964 Times
AC generator turns ~(94.6)*(5.2)*(30)= 14,757.6

AC Generator Test Result Data

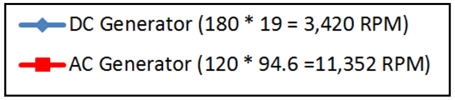
Charge (%)	R_{small} (Ω)	V_{in} reg (V)	V_{out} reg (V)	I_{in} reg (mA)	I_{load} reg (mA)	P_{in} (mW)	P_{load} (mW)	Efficiency (%)
20 - 40	0.08	2.845	4.06	449.375	230	1278.47	**933.8**	73.04
40 – 60	0.08	2.77	4.195	379	220	1049.83	**922.9**	87.91
60 - 80	0.08	2.775	4.325	337.5	179.75	936.563	**777.419**	83.01
80 - 100	0.08	2.83	4.425	324.375	167.25	917.981	**740.082**	80.62

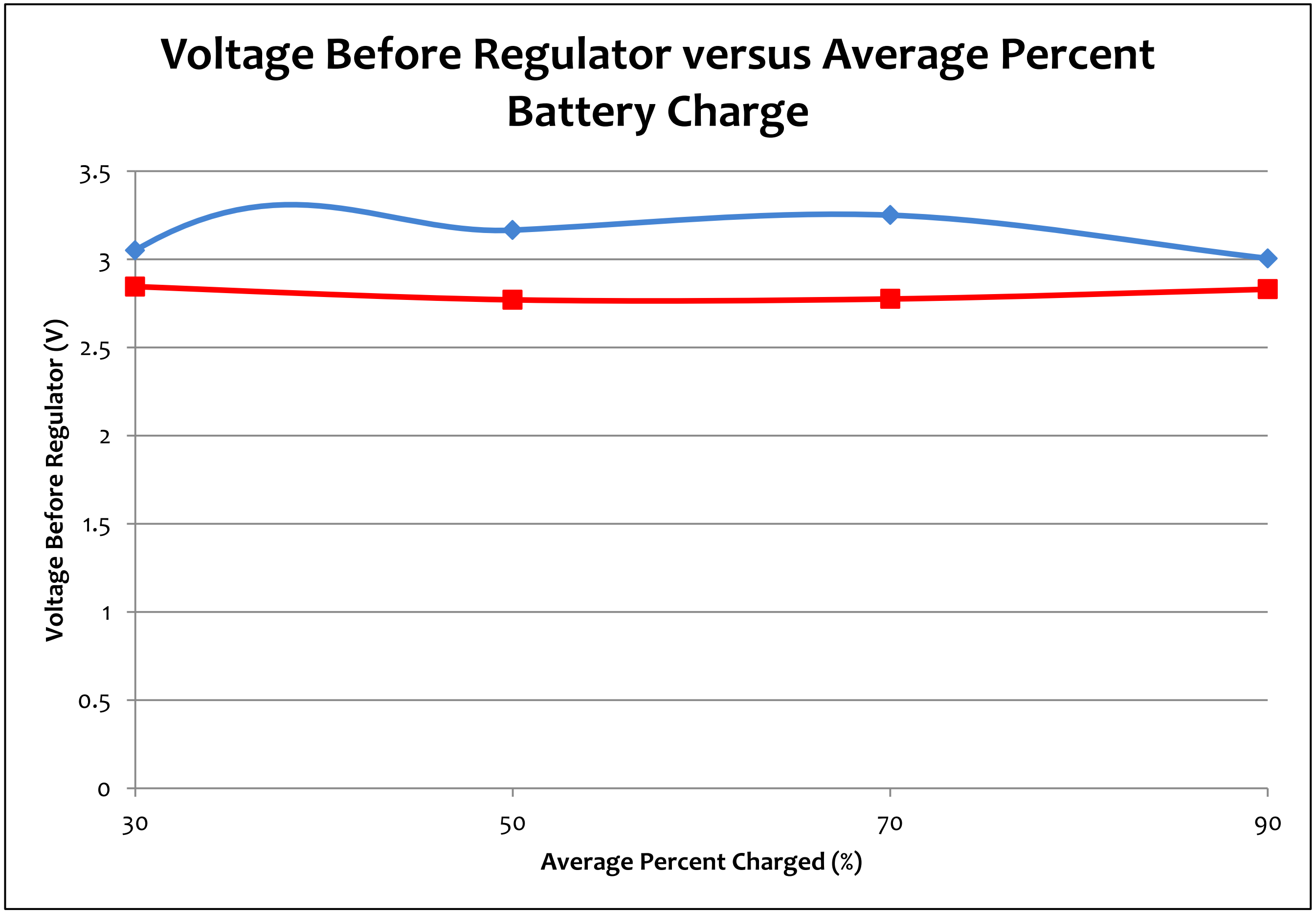
DC Generator Test Result Data

Charge (%)	R_{small} (Ω)	V_{in} reg (V)	V_{out} reg (V)	I_{in} reg (mA)	I_{out} reg (mA)	P_{in} (mW)	P_{out} (mW)	Efficiency (%)
20 - 40	0.08	3.05	3.99	259.375	151.75	791.094	605.483	76.54
40 – 60	0.08	3.165	4.65	185.125	111.25	579.591	517.313	89.26
60 - 80	0.08	3.25	4.225	197.125	122.375	640.656	517.034	80.70
80 - 100	0.08	3.005	4.31	294.875	72.125	886.099	310.859	35.08

Voltage before Regulator

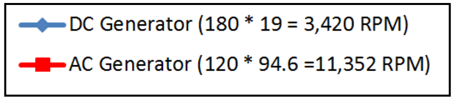
Key:

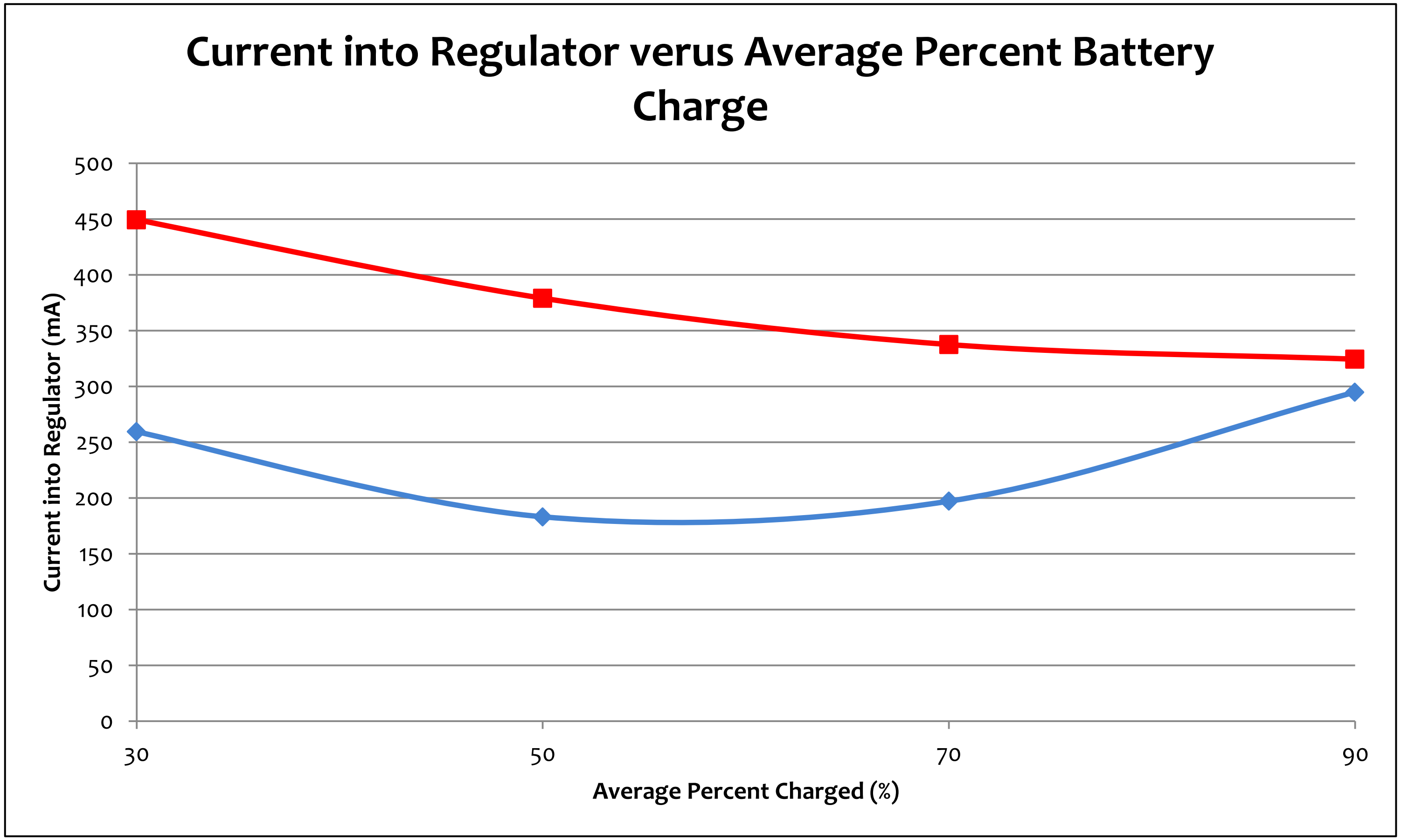




Current into Regualtor

Key:

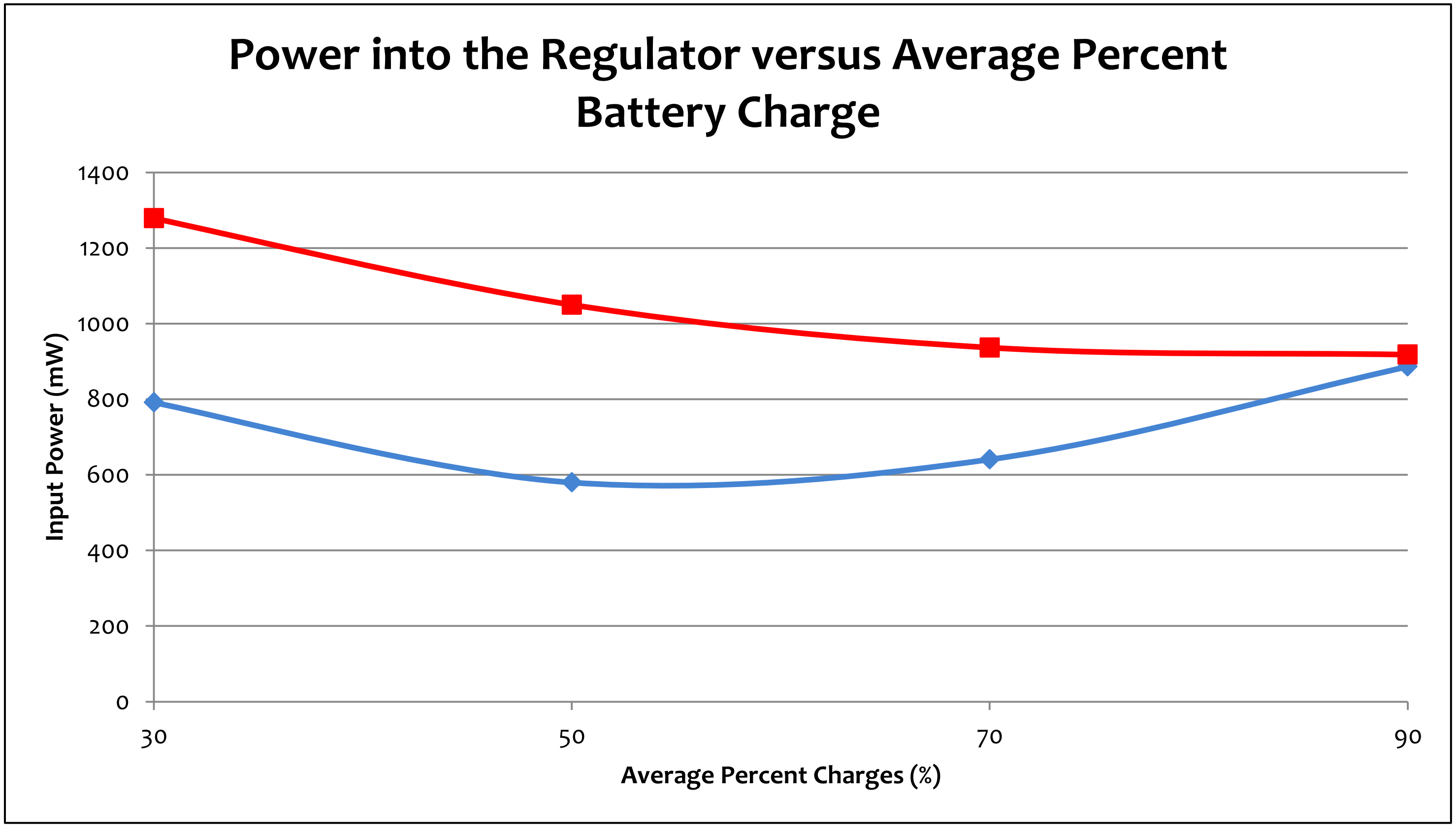




Input Power

Key:

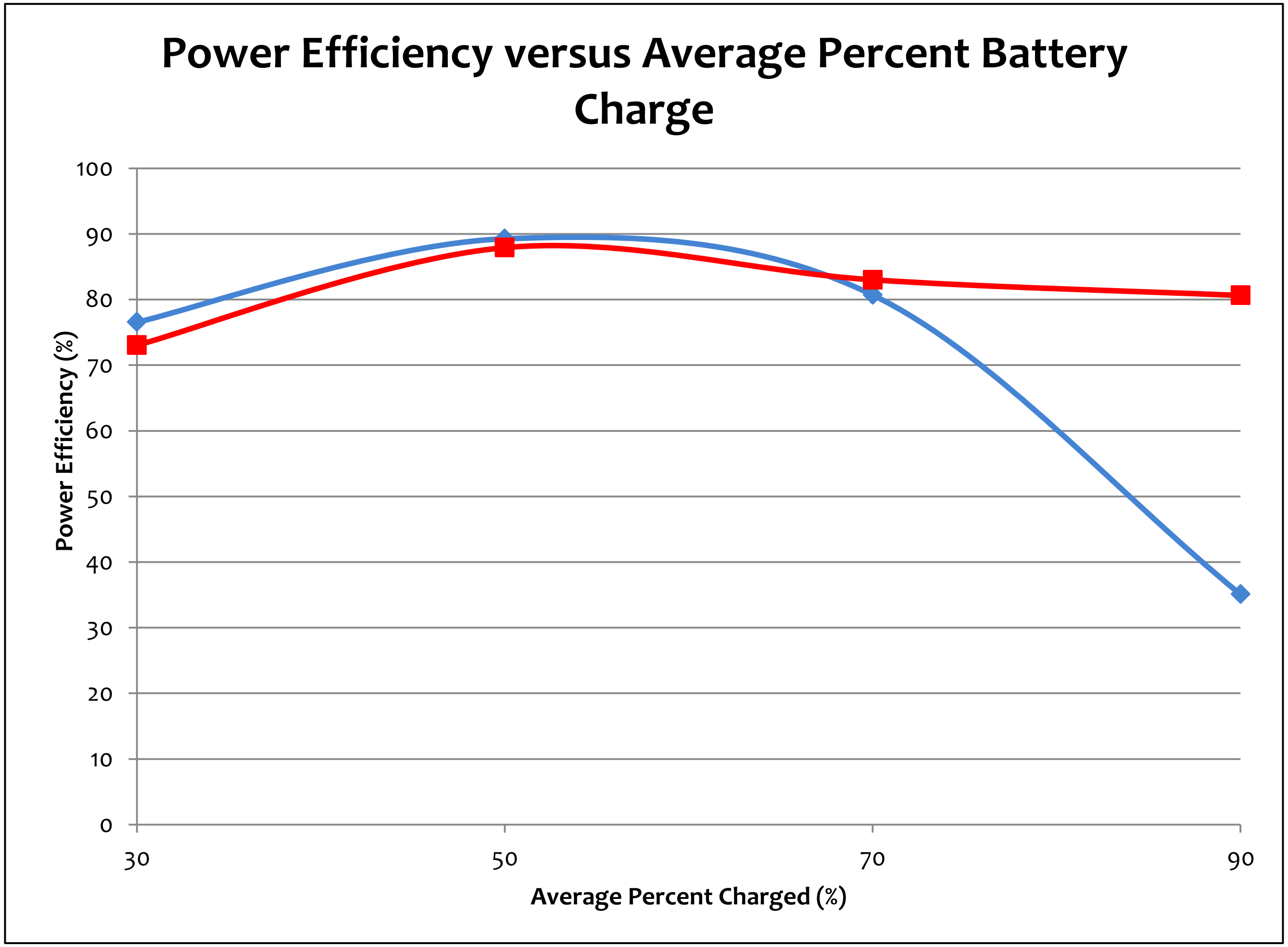
DC Generator (180 * 19 = 3,420 RPM)
AC Generator (120 * 94.6 =11,352 RPM)



Power Efficiency

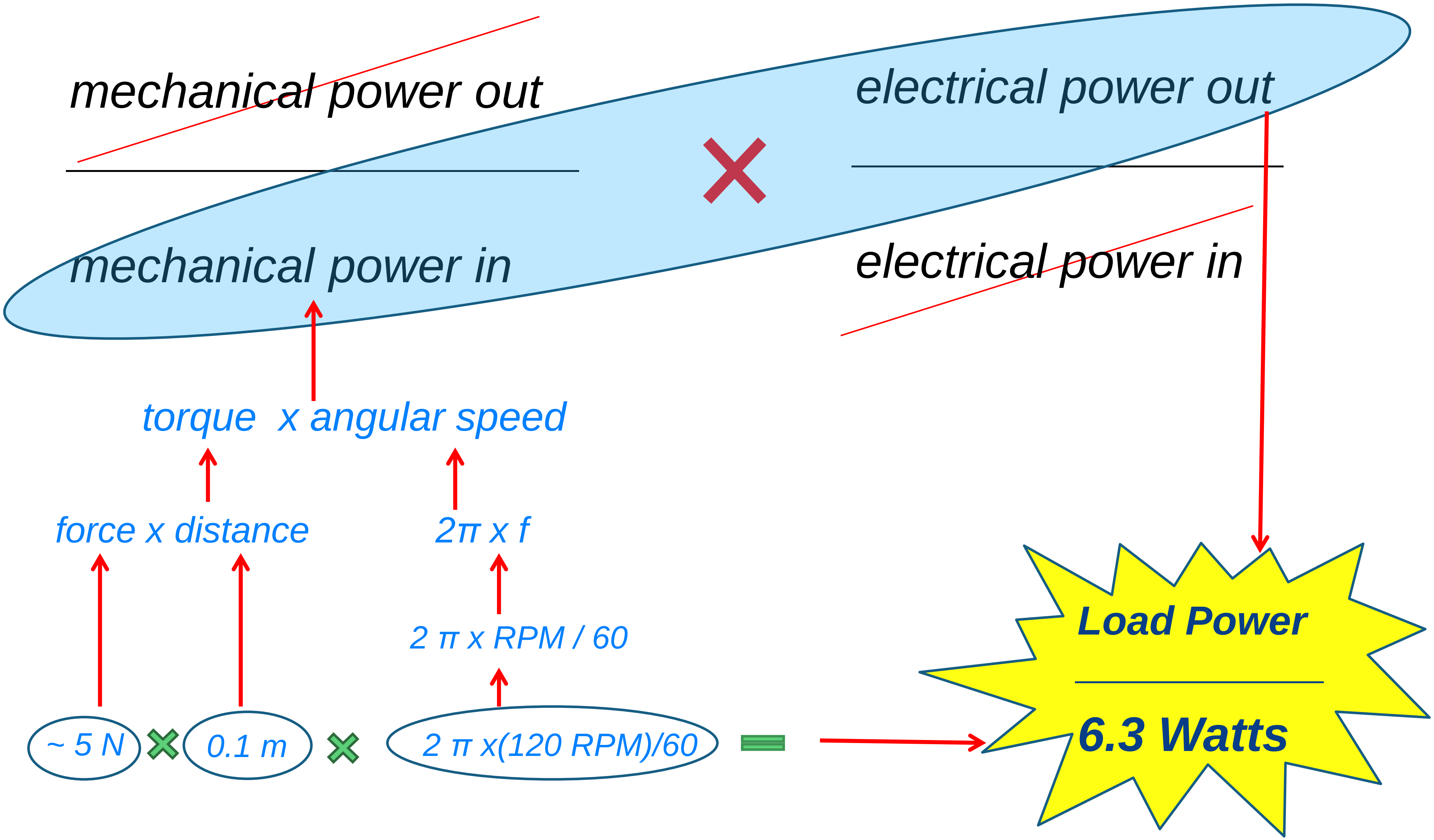
Key:

- DC Generator (180 * 19 = 3,420 RPM)
- AC Generator (120 * 94.6 =11,352 RPM)



Efficiency= (Pout/Pin) * 100)

Mechanical to Electrical Conversion Efficiency



Mechanical to Electrical Conversion Efficiency cont.

Average (%) Battery Charge	Mechanical : Electrical Conversion Efficiency (%)
30	14.8
50	14.6
70	12.3
90	11.8

Bibliography

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http://newobserveronline.com/wp-content/uploads/2013/04/pakistan-slum.jpg

http://www.technologystudent.com/gears1/chain1.htm

http://www.buysku.com/wholesale/iphone-4-usb-data-cable-with-1m-length-white.html

http://www.readymaderc.com/store/index.php?main_page=product_info&products_id=1472

http://www.officedepot.com/a/products/172802/Duracell-Portable-Power-Bank-With-2600mAh/

http://www.slideshare.net/fikakhamis/advantages-and-disadvatages-of-acdc-motor

http://www.urbancyclist.com/see-and-be-seen-a-guide-to-bike-lights

http://www.seeedstudio.com/wiki/Bicycle_Dynamo_With_Bracket_-_6V_3W

http://www.newegg.com/Product/Product.aspx?Item=9SIA2C50ZM3470