DC SOURCES OF ELECTRICITY

Subject Name: Electrical Fundamentals

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Battery

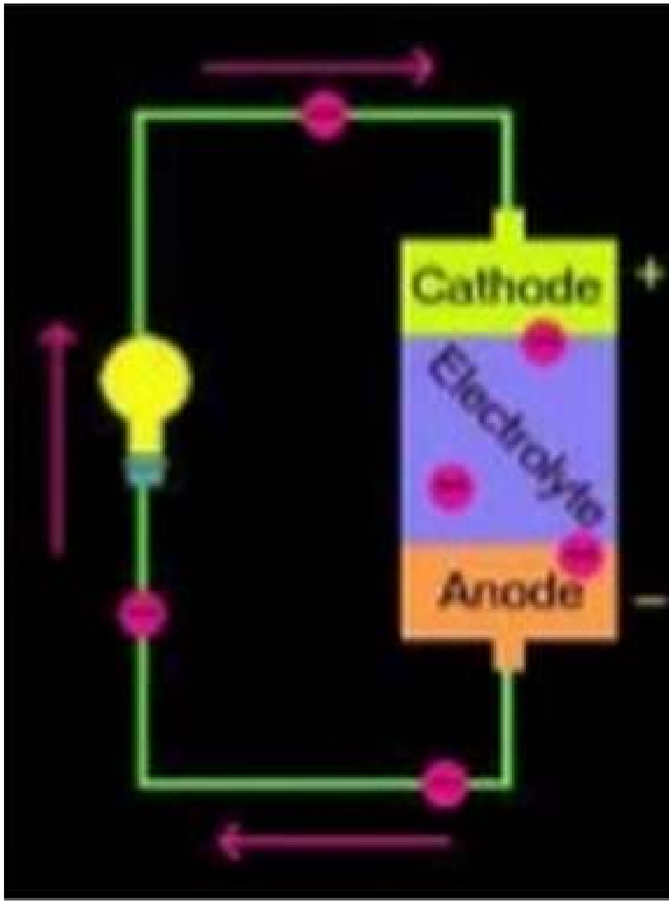
Convert stored chemical energy into electrical energy

Reaction between chemicals take place

Consisting of electrochemical cells

Contains

- Electrodes
- Electrolyte



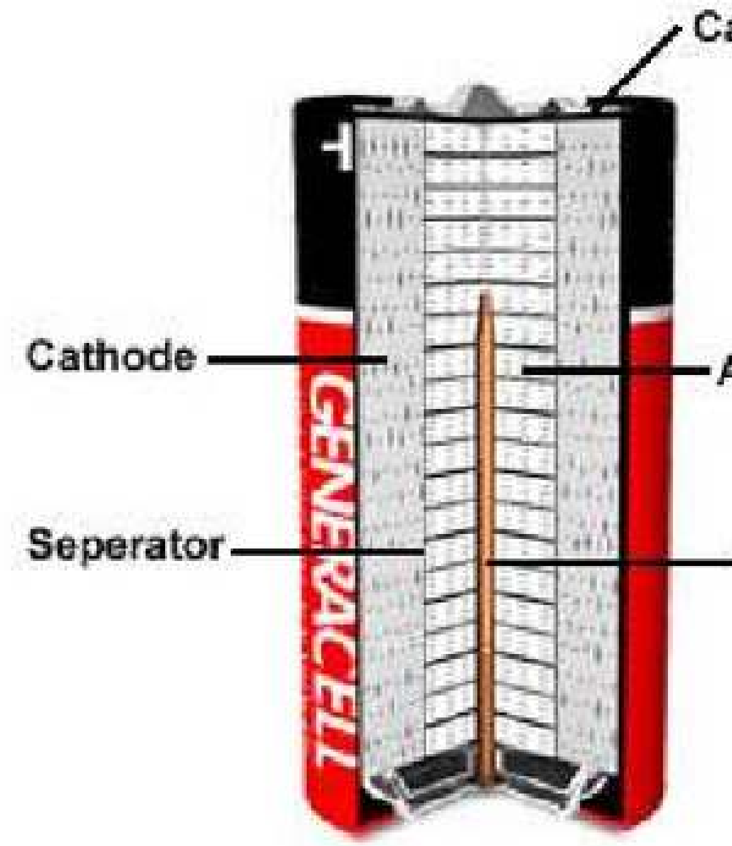
Battery Overview

Battery has metal or plastic case

Inside case are cathode, anode, electrolytes

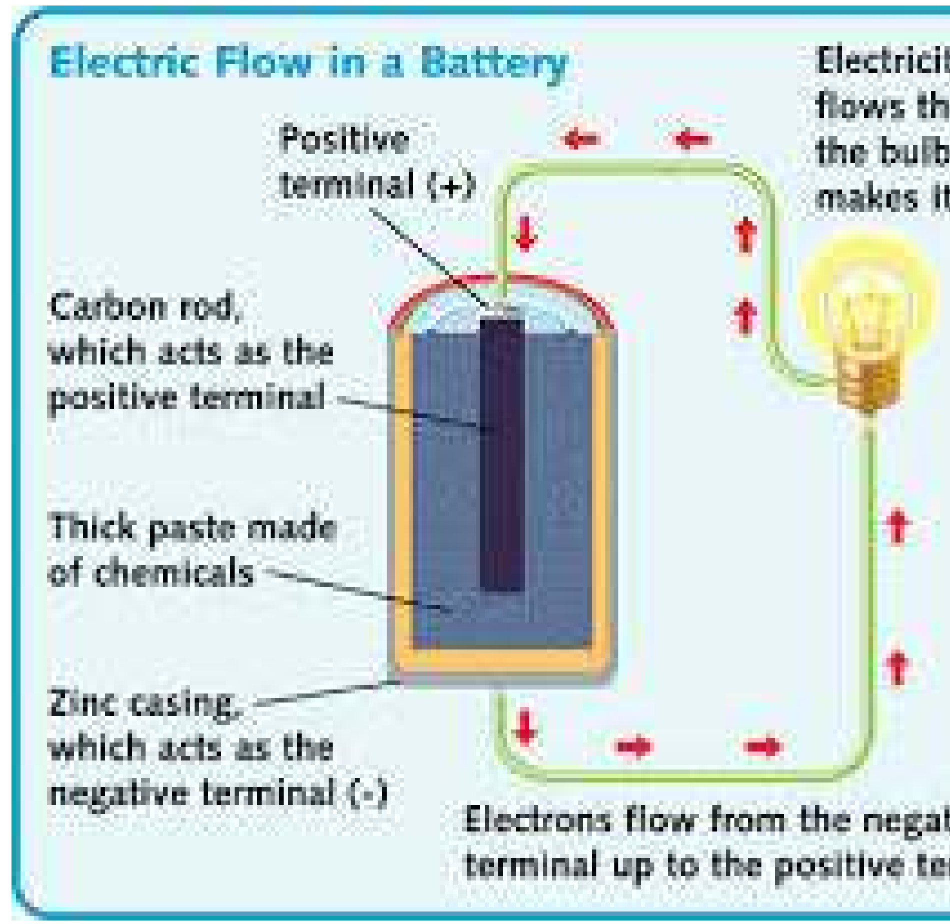
Separator creates barrier between cathode and anode

Current collector brass pin in middle of cell conducts electricity to outside circuit



Primary Cell

- ne use (non-rechargeable/disposable)
- nemical reaction used, can not be versed
- sed when long periods of storage are quired
- wer discharge rate than secondary atteries
- se:
  - smoke detectors, flashlights, remote controls



Alkaline Cell

Alkaline batteries name came from the electrolyte in an alkane

Anode: zinc powder form

Cathode: manganese dioxide

Electrolyte: potassium hydroxide

The half-reactions are:

$Zn_{(s)} + 2OH^{-}_{(aq)} \rightarrow ZnO_{(s)} + H_2O_{(l)} + 2e^{-}$ [e° = -1.28 V]

$2MnO_{2(s)} + H_2O_{(l)} + 2e^{-} \rightarrow Mn_2O_{3(s)} + 2OH^{-}_{(aq)}$ [e° = 0.15 V]

Overall reaction:

$Zn_{(s)} + 2MnO_{2(s)} \rightarrow ZnO_{(s)} + Mn_2O_{3(s)}$ [e° = 1.43 V]

Zinc-Carbon Cell

Anode: zinc metal body (Zn)

Cathode: manganese dioxide (MnO_2)

Electrolyte: paste of zinc chloride and ammonium chloride dissolved i water

The half-reactions are:

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ [e° = -0.763 V]

$2NH_4^+(aq) + 2MnO_2(s) + 2e^- \rightarrow Mn_2O_3(s) + H_2O(l) + 2NH_3(aq) + 2Cl^-$ [e° = 0.50 V]

Overall reaction:

$Zn(s) + 2MnO_2(s) + 2NH_4Cl(aq) \rightarrow Mn_2O_3(s) + Zn(NH_3)_2Cl_2\ (aq) + H_2O(l)$ [e° = 1.3

Primary Cell

kaline Battery

inc powered, basic electrolyte

igher energy density

unctioning with a more stable chemistry

helf-life: 8 years because of zinc powder

ong lifetime both on the shelf and better erformance

an power all devices high and low drains

se:

Digital camera, game console, remotes

Zinc-Carbon Battery

- Zinc body, acidic electrolyte
- Case is part of the anode
- Zinc casing slowly eaten away by the a electrolyte
- Cheaper then Alkaline
- Shelf-life: 1-3 years because of metal
- Intended for low-drain devices
- Use:

  Kid toys, radios, alarm clocks

Secondary Cells

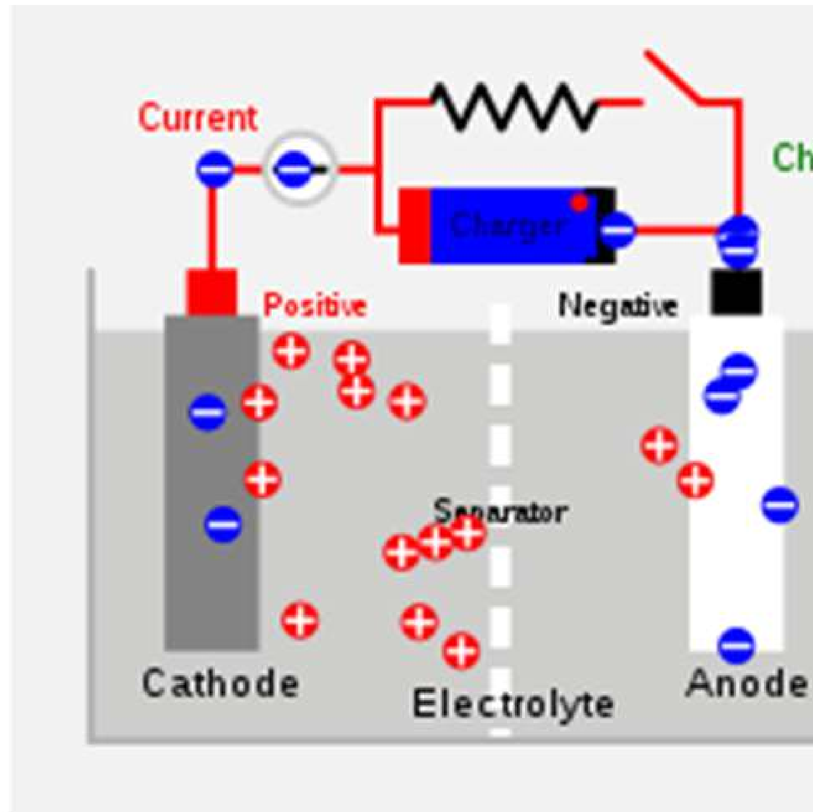
Rechargeable batteries

Reaction can be readily reversed

Similar to primary cells except redox reaction can be reversed

Recharging:

- Electrodes undergo the opposite process than discharging
- Cathode is oxidized and produces electrons
- Electrons absorbed by anode



Nickel-Cadmium Cell

Anode: Cadmium hydroxide, $Cd(OH)_2$

Cathode: Nickel hydroxide, $Ni(OH)_2$

Electrolyte: Potassium hydroxide, KOH

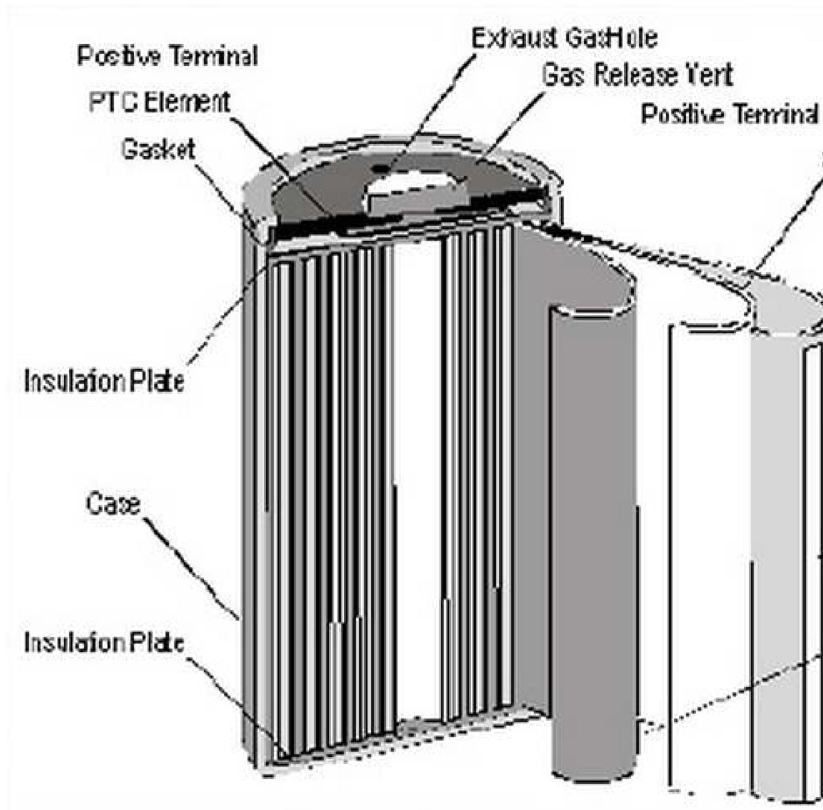
The half-reactions are:

$Cd + 2OH^- \rightarrow Cd(OH)_2 + 2e^-$

$2NiO(OH) + Cd + 2e^- \rightarrow 2Ni(OH)_2 + 2OH^-$

Overall reaction:

$2NiO(OH) + Cd + 2H_2O \rightarrow 2Ni(OH)_2 + Cd(OH)_2$



Nickel-Cadmium Cell

Maintain a steady voltage of 1.2v per cell until completely depleted

Have ability to deliver full power output until end of cycle

Have consistent powerful delivery throughout the entire application

Very low internal resistance

Lower voltage per cell

Nickel-Cadmium Cell

Advantages:

- This chemistry is reliable
- Operate in a range of temperatures
- Tolerates abuse well and performs well after long periods of storage

Disadvantages:

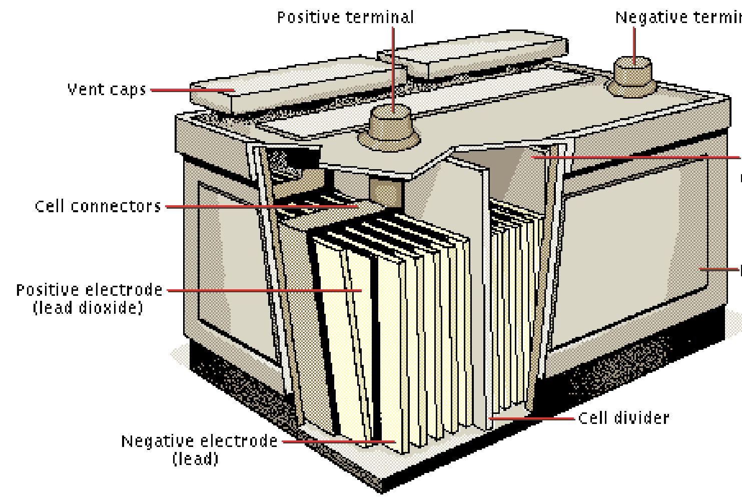
- It is three to five times more expensive than lead-acid
- Its materials are toxic and the recycling infrastructure for larger nickel-cadmium batteries is very limited

Lead-Acid Cell

Anode: Porous lead

Cathode: Lead-dioxide

Electrolyte: Sulfuric acid, 6 molar H_2SO_4



Discharging
(+) electrode: PbO2(s) + 4H+(aq) + SO42-(aq) + 2e- → PbSO4(s) + 2H2
(-) electrode: Pb(s) + SO42-(aq) → PbSO4(s) + 2e-

During charging
(+) electrode: PbSO4(s) + 2H2O(l) → PbO2(s) + 4H+(aq) + SO42-(aq) +
(-) electrode: PbSO4(s) + 2e- → Pb(s) + SO42-(aq)

Lead-Acid Cell

- The lead-acid cells in automobile batteries are wet cells
- Deliver short burst of high power, to start the engine
- Battery supplies power to the starter and ignition system to start the engine
- Battery acts as a voltage stabilizer in the electrical system
- Supplies the extra power necessary when the vehicle's electrical load exceeds the supply from the charging system

Lead-Acid Cell

Advantages:

- Batteries of all shapes and sizes, available in
- Maintenance-free products and mass-produced
- Best value for power and energy per kilowatt-hour
- Have the longest life cycle and a large environmental advantage
- Ninety-seven percent of the lead is recycled and reused in new batteries

Disadvantages:

- Lead is heavier compared to alternative elements
- Certain efficiencies in current conductors and other advances continue to improve on the power density of a lead-acid battery's design

Lithium-Ion Cell

Anode: Graphite

Cathode: Lithium manganese dioxide

Electrolyte: mixture of lithium salts

Lithium ion battery half cell reactions

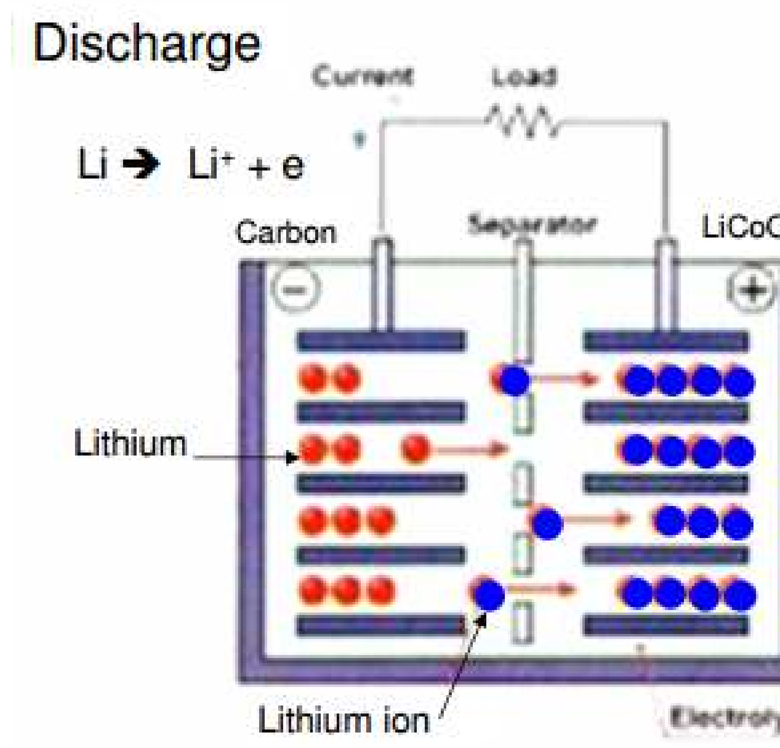
$CoO_2 + Li^+ + e^- \leftrightarrow LiCoO_2$ $E^o = 1V$

$Li^+ + C_6 + e^- \leftrightarrow LiC6$ $E^o \sim -3V$

Overall reaction during discharge

$CoO_2 + LiC_6 \leftrightarrow LiCoO_2 + C_6$

$E_{oc} = E^+ - E^- = 1 - (-3.01) = 4V$



Lithium-Ion cell

- Ideal material
  - Low density, lithium is light
  - High reduction potential
  - Largest energy density for weight
- Li-based cells are most compact ways of storing electrical energy
- Lower in energy density than lithium metal, lithium-ion is safe
- Energy density is twice of the standard nickel-cadmium
- No memory and no scheduled cycling is required to prolong battery life

Lithium-Ion cell

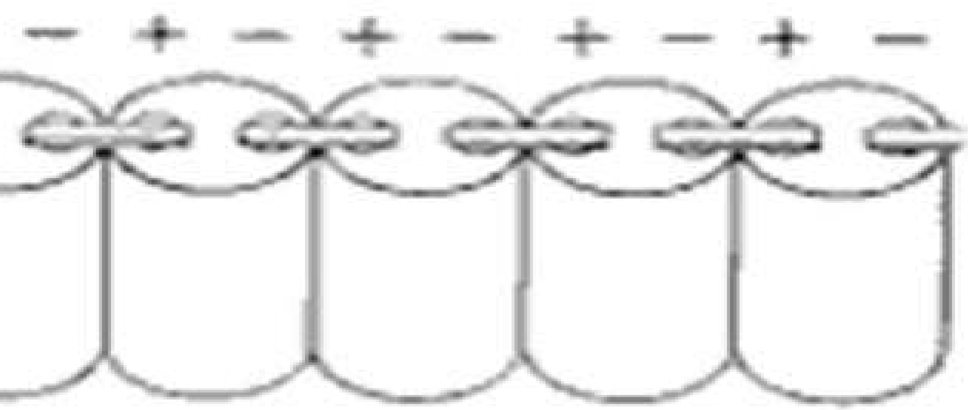
Advantages:

- It has a high specific energy (number of hours of operation for a given weight
- Huge success for mobile applications such as phones and notebook computers

Disadvantages:

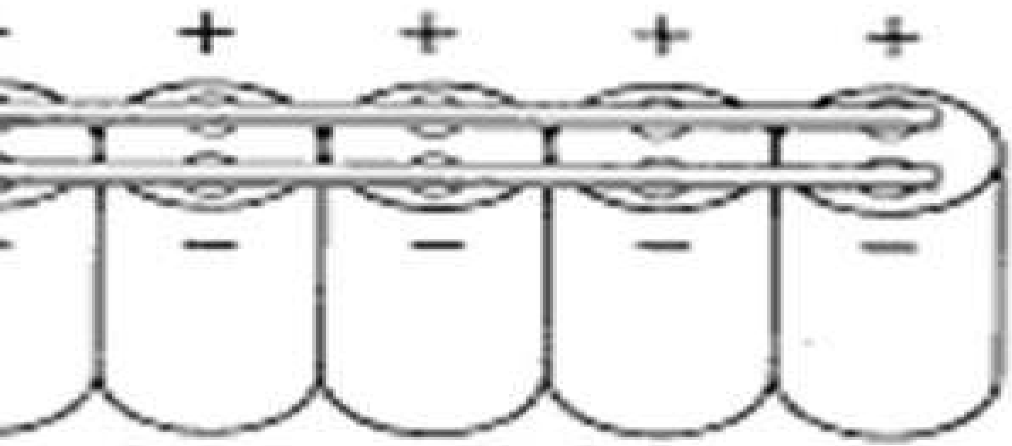
- Cost differential
  - Not as apparent with small batteries (phones and computers)
  - Automotive batteries are larger, cost becomes more significant
- Cell temperature is monitored to prevent temperature extremes
- No established system for recycling large lithium-ion batteries

Series Connected Batteries



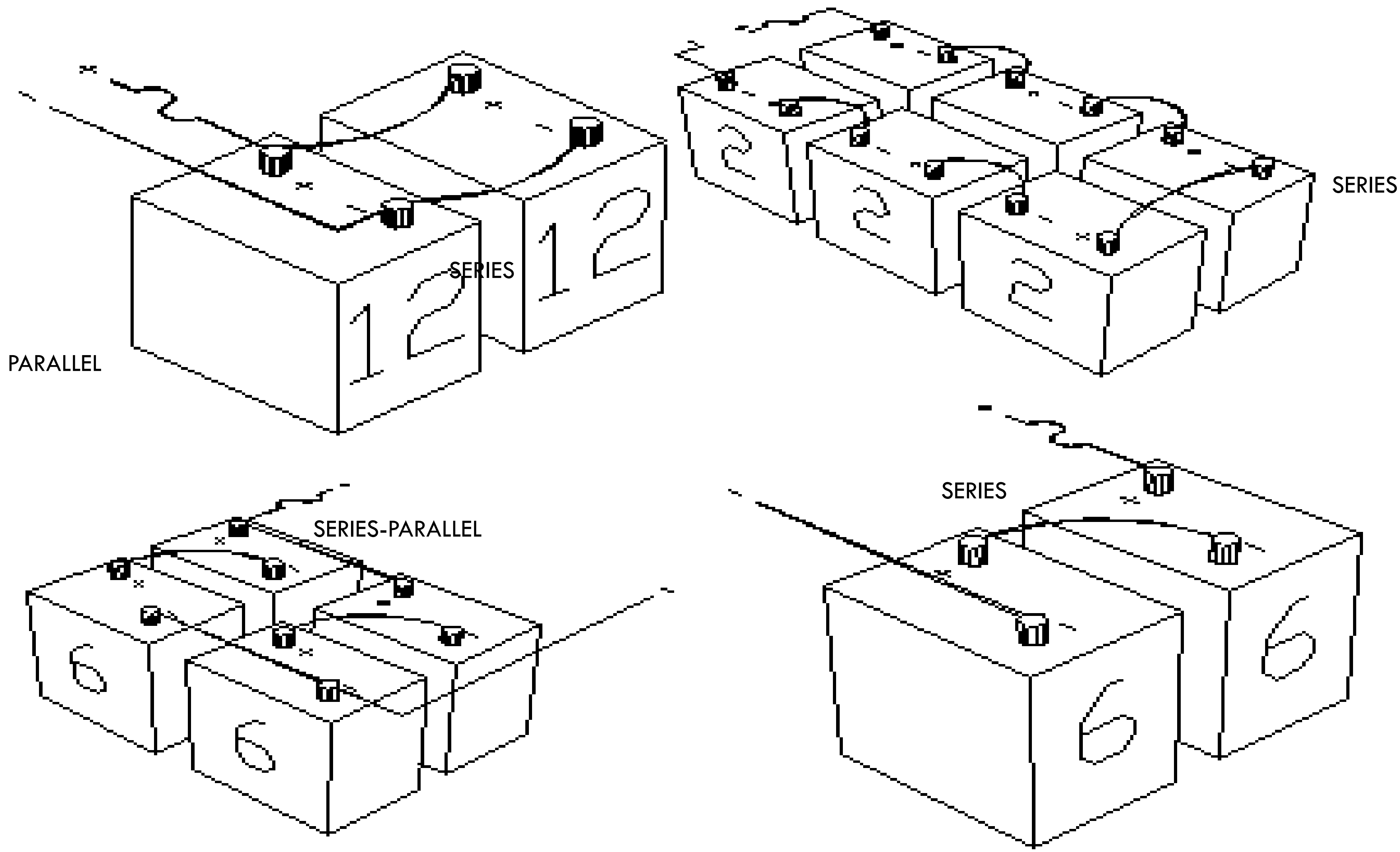
- Positive terminal of one cell i connected to the negative terminal of the next, is called series connected battery.
- The voltage of this type of battery is the sum of a individual cell voltages.

Parallel Connected Batteries



- Connect the negative termin
  from one cell to the negative
  the next cell
- Connect the positive termina
  to the positive terminal, is
  parallel connected.
- Voltage remains constant an
  the current is cumulative.

Series-Parallel Connections



Comparison of various batteries

ar	Lead acid cell	Nickel-Iron cell	Nickel-cadmium cell
plate	Lead peroxide (PbO_2)	Nickel hydroxide $Ni(OH)_3$	Nickel hydroxide
e plate	Lead (Pb)	Iron (Fe)	Cadmium (Cd)
yte	Sulphuric acid H_2SO_4	Potassium hydroxide KOH	Potassium hydroxide KO
f	2.0 V/cell	1.2 V / cell	1.2 V / cell
resist.	Low	High	Low
ency	90 – 95 %	70 - 80 %	70 - 80 %
ciency	72 – 80 %	55 – 60 %	55 – 60 %
city	Discharge rate & Temp	Only on temperature	Only on temperature
	Less expensive	Twice the lead acid cell	Twice the lead acid cel
	1250 charges and discharges	About 8 to 10 years	Very long life
	Moderate	Light	More heavy
trength	Poor	Good	Good

Comparison of primary and secondary cells

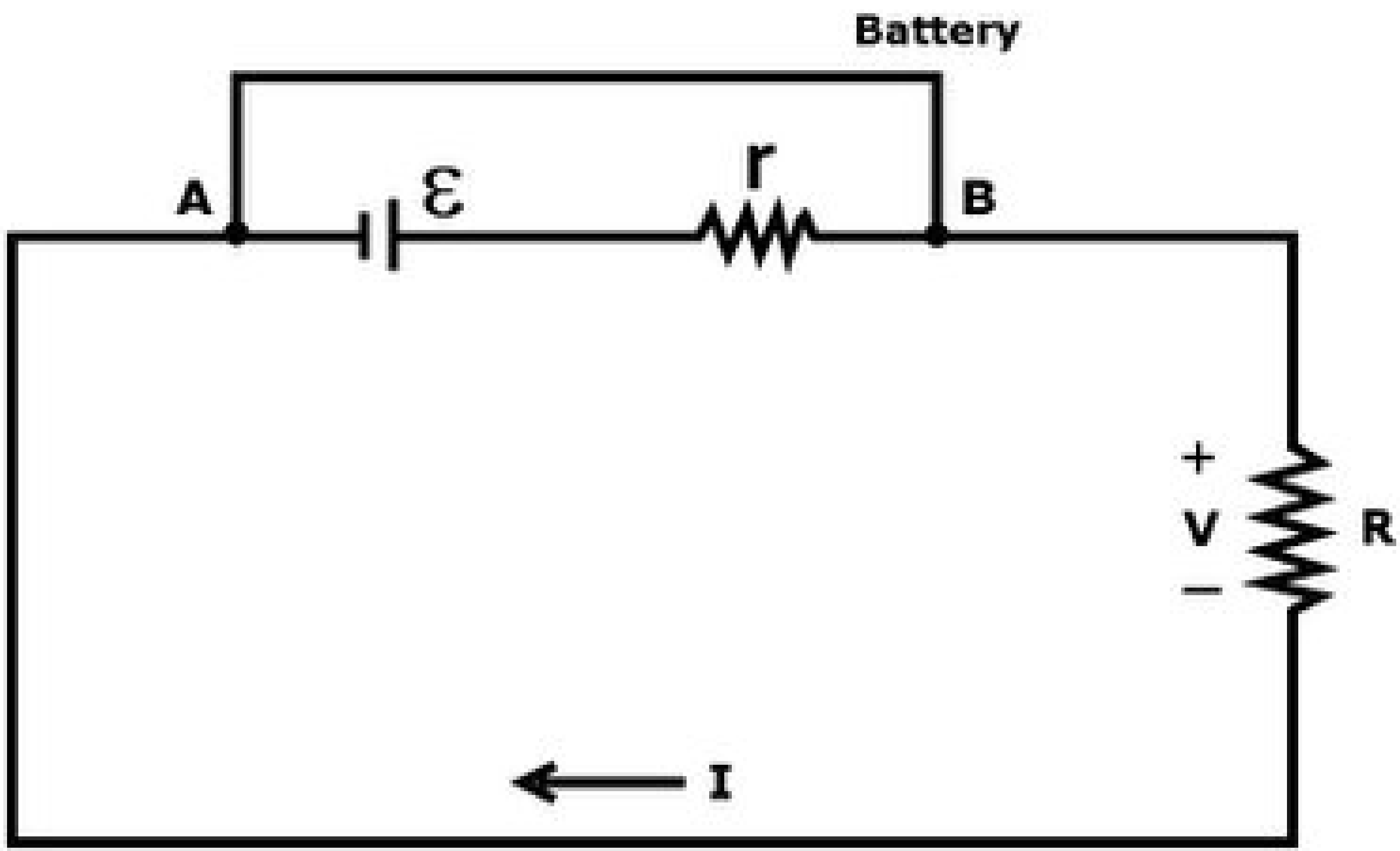
rimary cells	Secondary cells
lectrical energy is directly obtained from chemical nergy	Electrical energy is present in the cell in the from of chemical energy and then converted to electrical energy
hemical actions are irreversible	Chemical actions are reversible
ell is completely replaced when it goes down	Cell is recharged back when it goes down
ow Efficiency	Efficiency is high
apacity is low	Higher Capacity
ess cost	High initial cost
lo maintenance required	Frequent charging and other maintenance is requir
g. Dry cell, mercury cell, zinc-chloride cell	E.g. Nickel- iron, lead acid and nickel- cadmium

nternal Resistance & It's effect on a battery

Batteries are constructed from materials that possess non-zer resistivities. The internal resistance of a component arises fron structural imperfections or irregularities. The seemingly imperceptibl resistances of all the components add up to a total resistance of finite, perceptible magnitude.

No crystal structure is *perfect.* Even a metal tends to possess som resistance due to various factors, such as impurities or the collision o electrons in the bulk of a conductor due to randomized heating. On can conclude that no *real* battery is a *pure* voltage source.

Connection diagram of Battery with Internal Resistance(r)



$r+V$

$=0$

$\frac{\varepsilon}{r}$

drop across the load **R**. Also, the maximum current that can be drawn from a battery is now reduced due to this internal resistance.

ge drop across the load **R**. Also, the maximum current that can be drawn from a battery is now reduced due to this internal resistance.

- This voltage is formally known as electromotive force. It supplies th force that plunges the electrons into motion. If we connect a external resistance **R,** a load, in series to complete this circuit, b Ohm’s law, we find:

$$\frac{\varepsilon - V}{r} = I$$

or, $$\boxed{\varepsilon = Ir + V}$$

When $V=0$

$$I(0) = \frac{\varepsilon}{r}$$

Here **V** is the voltage drop across the load **R**. Also, the maximun current that can be drawn from a battery is now reduced due to thi internal resistance.

If the value of **I > I(0),** then the value of V becomes negative, whicl implies a *negative* R. This is essentially impossible. One can conclud that if this circuit is short-circuited by directly connecting the tw terminals with a wire, the maximum current that will be drawn is nov limited to **I(0).**

$$\mathcal{E} = Ir + V$$

$$= Ir + IR$$

$$= I(r + R)$$

or,

$$I = \frac{\mathcal{E}}{r + R}$$

$$P_{\mathcal{E}} = I\mathcal{E} = \frac{\mathcal{E}^2}{(r + R)} \quad \text{---------}(1)$$

$$P_r = I^2 r = \frac{\mathcal{E}^2 r}{(r + R)^2} \quad \text{---------}(2)$$

$$P_R = I^2 R = \frac{\mathcal{E}^2 R}{(r + R)^2} \quad \text{---------}(3)$$

Thus, from (1),(2) and (3)

$$\boxed{P_{\mathcal{E}} = P_r + P_R}$$

Rating of battery

<u>pere-hour rating:</u>

AH- battery can supply 12Amp for 10 hours

10 Amp for 12 hours

6Amp for 20 hours

indicates the capacity of battery to supply a certain amount of curr
certain number of hours

Rating of battery

att-hour rating:

0AH- battery can supply 12Amp for 10 hours

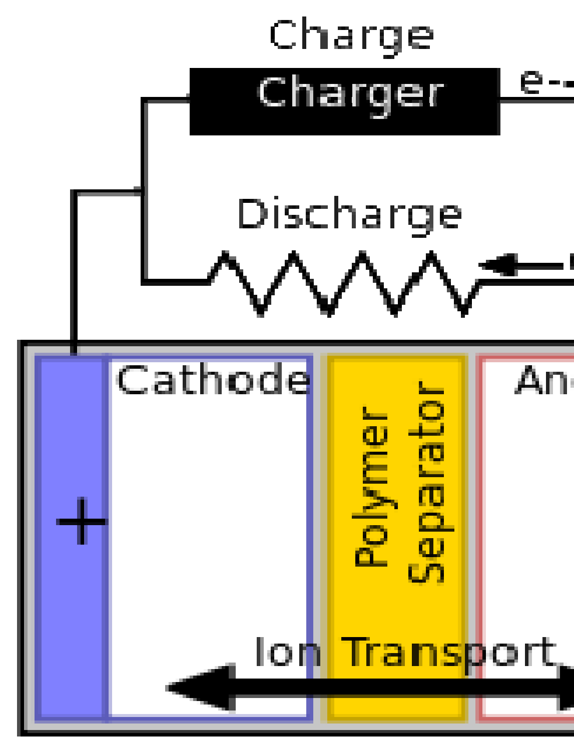
average discharging voltage is 2V then watt hour rating

H=120*2=240WH

e WH rating is given by the product of AH rating and the aver scharge voltage of the battery.

parator is a permeable membrane placed between a battery's anode and c
ain function of a separator is to keep the two electrodes apart to
al short circuits while also allowing the transport of ionic charge carriers
to close the circuit during the passage of current in an electrochemical cell.

rators are critical components in electrolyte batteries. A separator generally s of a polymeric membrane forming a porous layer. It must be chemically electrochemically stable with regard to ctrolyte and electrode materials and mechanically enough to withstand the high tension during construction. They are important to batteries e their structure and properties considerably the battery performance, including the batteries and power densities, cycle life, and safety



PROPERTIES

ical stability

e separator material must be chemically stable against the electrolyte and e
terials under the strongly reactive environments when the battery is fully charged.

ness

battery separator must be thin to facilitate the battery's energy and power den
parator that is too thin can compromise mechanical strength and safety. Thickness s
iform to support many charging cycles. 25.4μm-(1.0mil) is generally the standard w

ty

e separator must have sufficient pore density to hold liquid electrolyte that enable
ove between the electrodes.

size

re size must be smaller than the particle size of the electrode components, inclu
ive materials and conducting additives. Ideally the pores should be uniformly di
ile also having a tortuous structure.

anical strength

e separator must be strong enough to withstand the tension of the winding operatio ttery assembly. Mechanical strength is typically defined in terms of the tensile str th the machine (winding) direction and the transverse direction, in terms of tear re d puncture strength.

bility

e electrolyte must fill the entire battery assembly, requiring the separator to "we th the electrolyte. Furthermore, the electrolyte should be able to permanently parator, preserving the cycle life.

nal stability

e separator must remain stable over a wide temperature range without curling or pu ying completely flat.

nal shutdown

parators in lithium-ion batteries must offer the ability to shut down at a temperature wer than that at which thermal runaway occurs, while retaining its mechanical prope

BATTERY CHARGING METHODS

onstant Voltage. ...

onstant Current. ...

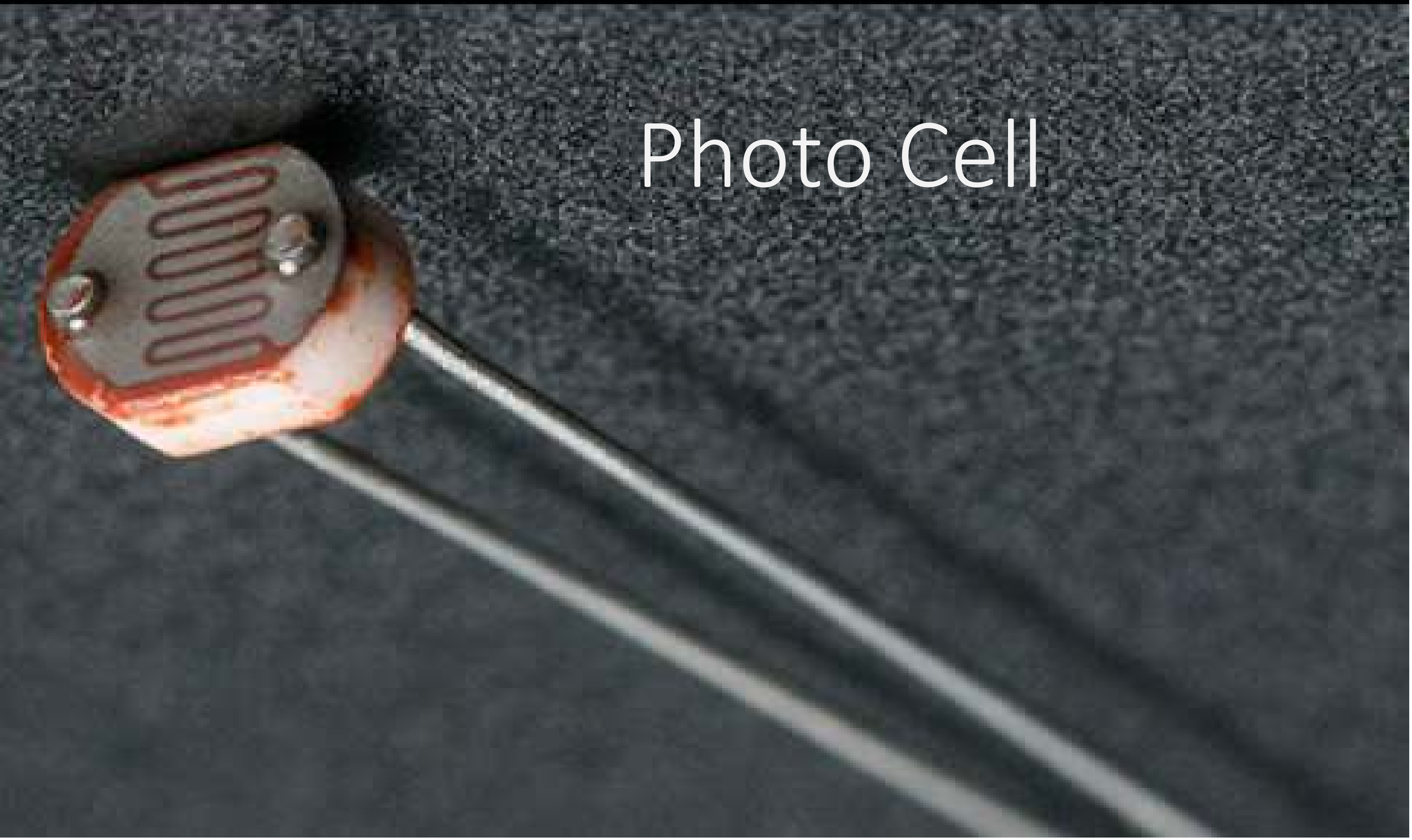
rickle **Charge**. ...

nt Voltage : A constant voltage charger is basically a DC power supply whic
t form may consist of a step down transformer from the mains with a rectifier to
voltage to charge the battery. Such simple designs are often found in cheap car
s. The lead-acid cells used for cars and backup power systems typically use c
chargers. In addition, lithium-ion cells often use constant voltage systems, althou
are more complex with added circuitry to protect both the batteries and the user saf

nt Current: Constant current chargers vary the voltage they apply to the ba
n a constant current flow, switching off when the voltage reaches the level of a full
sign is usually used for nickel-cadmium and nickel-metal hydride cells or batteries.

charge :Trickle charging is designed to compensate for the self discharge of the
ous charge. Long term constant current charging for standby use. The charge rat
ng to the frequency of discharge. Not suitable for some battery chemistries, e.g. Ni
, which are susceptible to damage from overcharging. In some applications the ch
d to switch to trickle charging when the battery is fully charged.

Photo Cell



OPERATION OF PHOTO CELLS

cells are sensors that allow you to detect light. They are small, inexpensive, low
use and don‘twear out.

at reason they often appear in toys, gadgets and appliances.

are often referred to as CdS cells (they are made of Cadmium-Sulfide), light-de
s (LDR), and photo resistors.

cells are basically a resistor that changes its resistive value (in ohms Ω) depending

ght is shining onto the squiggly face.

are very low cost, easy to get in many sizes and specifications, but are very innacur

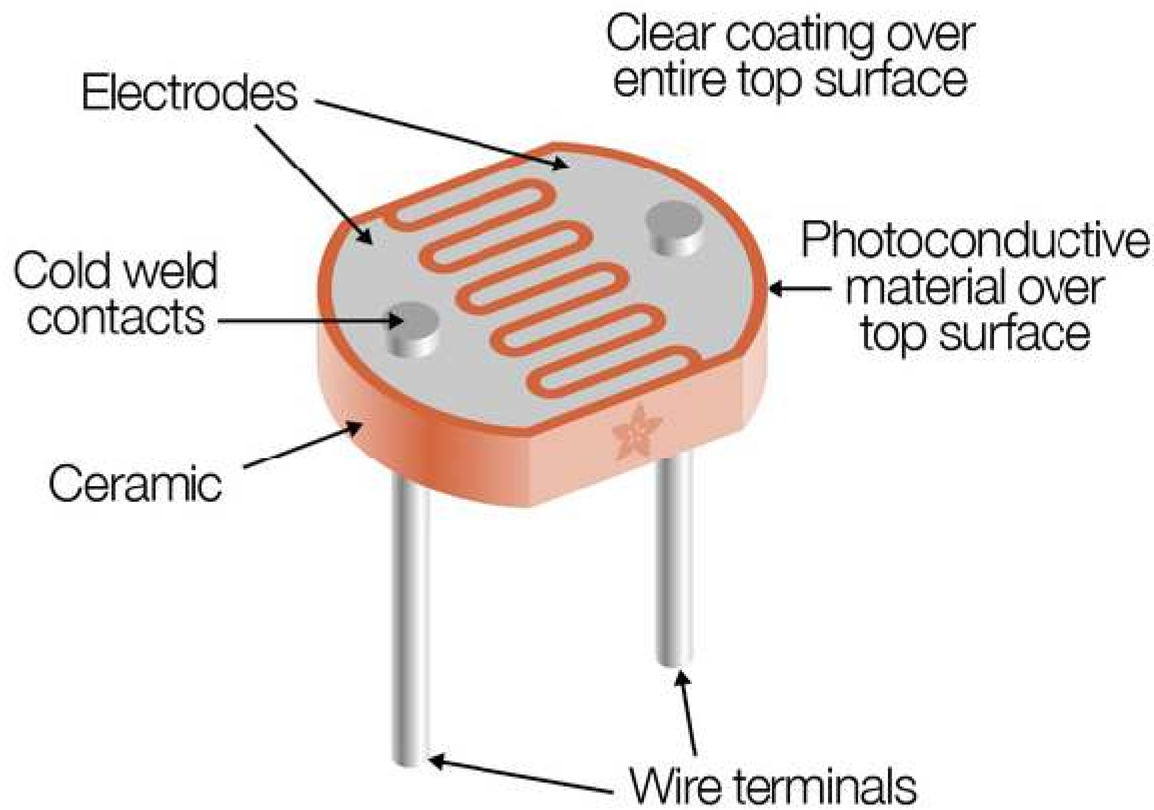
photocell sensor will act a little differently than the other, even if they are from t

he variations can be really large, 50% or higher!

his reason, they shouldn't be used to try to determine precise light levels in

dela.

d, you can expect to only be able to determine basic light changes.


Clear coating over entire top surface
Electrodes
Cold weld contacts
Photoconductive material over top surface
Ceramic
Wire terminals