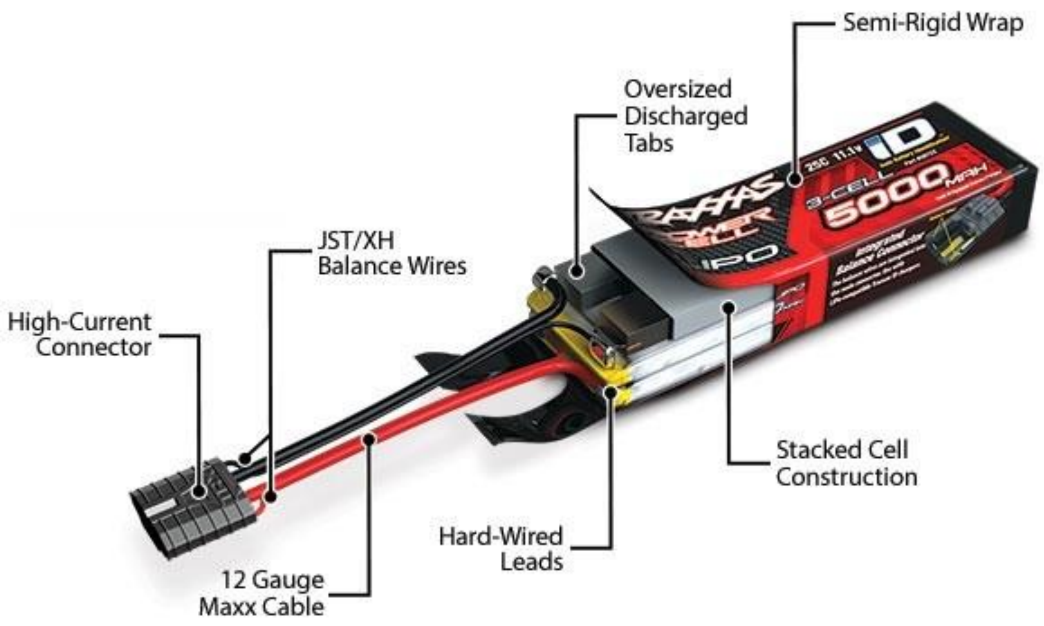
POWER SYSTEM MANAGEMENT

Battery is a collection of one or more cells, storing electrical energy for powering electrical devices.



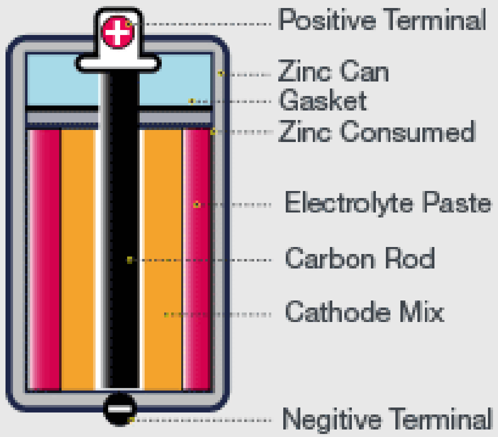
The _Cell_ This basic electrochemical unit handles the actual storage of energy in a battery.

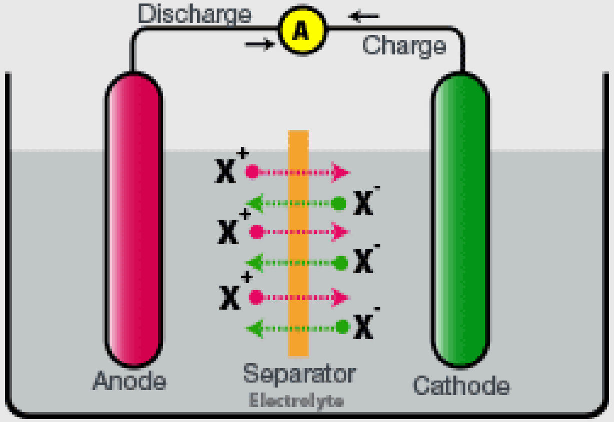
3 main components: two electrodes and an electrolyte.

Overall, the cells in a battery provide the necessary voltage and current levels.

DIFFERENCE BETWEEN PRIMARY CELL AND SECONDARY CELL

BYJU'S
The Learning App





PRIMARY CELL

A PRIMARY CELL IS A BATTERY THAT IS DESIGNED TO BE USED ONCE AND DISCARDED, AND NOT RECHARGED WITH ELECTRICITY AND REUSED LIKE A SECONDARY CELL IN GENERAL, THE ELECTROCHEMICAL REACTION OCCURRING IN THE CELL IS NOT REVERSIBLE, RENDERING THE CELL UNRECHARGEABLE.

SECONDARY CELL

A SECONDARY CELL IS A TYPE OF ELECTRICAL BATTERY WHICH CAN BE CHARGED, DISCHARGED INTO A LOAD, AND RECHARGED MANY TIMES, AS OPPOSED TO A DISPOSABLE OR PRIMARY BATTERY, WHICH IS SUPPLIED FULLY CHARGED AND DISCARDED AFTER USE.

Difference Between Primary Cell and Secondary Cell

Primary Cell	Secondary Cell
Have high energy density and slow in discharge and easy to use	They are smaller energy density
There are no fluids in the cells hence it is also called as dry cells	There are made up of wet cells (flooded and liquid cells) and molten salt (liquid cells with different composition)
It has high internal resistance	It has a low internal resistance
It has an irreversible chemical reaction	It has a reversible chemical reaction
Its design is smaller and lighter	Its design is more complex and heavier
Its initial cost is cheap	Its initial cost is high

common primary battery chemistries

Battery Type	***Characteristics***	***Applications***
Alkaline ($Zn/Alkaline/MnO_2$)	Very popular, moderate cost, high performance	Most popular primary batteries
Magnesium (Mg/MnO_2)	High capacity, long shelf life	Military and aircraft Radios
Mercury (Zn/HgO)	Very high capacity, long shelf life	Medical (hearing aids, pacemakers), photography
Lithium/Solid Cathode	High energy density, low temp performance, long shelf life	Replacement for button and cylindrical cells
Lithium/Soluble Cathode	High energy density, good performance, wide temp range	Wide range of applications with a capacity between 1 – 10,000 Ah
Lithium/Solid Electrolyte	Low power, extremely long shelf life	Memory circuits, medical electronics
Silver/Zinc (Zn/Ag_2O)	Highest capacity, costly, flat discharge	Hearing aids, photography, pagers
Zinc – Carbon	Common, low cost, variety of sizes	Radios, toys, instruments

Common secondary battery chemistries

Battery	Specific energy (W h kg^{-1})	Peak power (W kg^{-1})	Status
Lead–acid	35–50	150–400	Widely used; cheapest available
Nickel–iron	50–60	80–150	Low electrical efficiency; high self-discharge
Nickel–cadmium	40–60	80–150	Commercially available, but costly; recycling issues with toxic cadmium
Nickel–metal-hydride	60–80	200–300	Available in small-to-medium sizes; used in hybrid electric vehicles; costly
Nickel–zinc	70–100	170–260	Short cycle life
Zinc–bromine	70–85	90–110	Chemical reactivity of bromine to cell components; safety; development almost ceased
Zinc–air	100–200	80–100	Mechanically rechargeable only; development almost ceased
Vanadium redox	20–30	110	At demonstration stage for stationary energy storage
Sodium–sulfur	150–240	230	Development almost ceased
Sodium–nickel-chloride	90–120	130–160	Battery electric vehicle applications
Lithium-ion	100–220	200–1,000	Commercially available in small sizes; careful control of recharging required; various systems according to electrode and electrolyte materials employed

Common secondary battery characteristics

Specifications	Lead Acid	NiCd	NiMH	Li-ion[1]		
				Cobalt	Manganese	Phosphate
Specific energy (Wh/kg)	30–50	45–80	60–120	150–250	100–150	90–120
Internal resistance	Very Low	Very low	Low	Moderate	Low	Very low
Cycle life[2] (80% DoD)	200–300	1,000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Charge time[4]	8–16h	1–2h	2–4h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Moderate	Low	Low. No trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	1.2V[6]	1.2V[6]	3.6V[7]	3.7V[7]	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	1.00V		2.50–3.00V		2.50V
Peak load current Best result	5C[8] 0.2C	20C 1C	5C 0.5C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C (32 to 113°F)		0 to 45°C[9] (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 65°C (–4 to 149°F)		–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months[10] (toping chg.)	Full discharge every 90 days when in full use		Maintenance-free		
Safety requirements	Thermally stable	Thermally stable, fuse protection		Protection circuit mandatory[11]		
In use since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very high	Very high	Low	Low		
Coulombic efficiency[12]	~90%	~70% slow charge ~90% fast charge		99%		
Cost	Low	Moderate		High[13]		

Battery Life Calculation

Battery Life = Capacity / Consumption * (1- Discharge Safety)

- **Capacity** is the capacity of your battery, measured in ampere hours. You can usually find this value printed on your battery.
- **Consumption** is the average current draw of your electronic device, expressed in amperes. (If you want to learn more about the electric current, make sure to check out the Ohm's law calculator!)
- **Discharge safety** is the percentage of your battery capacity that is never used. For example, if you use a LiPo battery to fly a drone, you should never discharge it below 20% - otherwise, it can be damaged. Our battery life calculator assumes a default discharge safety of 20%, but feel free to change it as you wish.

How to calculate amp hours?

Let's assume you want to find out the capacity of your battery, knowing its voltage and the energy stored in it.

1. Note down the voltage. In this example, we will take a standard 12V battery.
2. Choose the amount of energy stored in the battery. Let's say it's 26.4 Wh.
3. Input these numbers into their respective fields of the battery amp hour calculator. It uses the formula mentioned above:

`E = V * Q`

`Q = E / V = 26.4 / 12 = 2.2 Ah`

4. The battery capacity is equal to 2.2 Ah.

How long will a battery last: sleep mode

Now, let's imagine you are building an IoT device that spends most of the time in sleep mode. You'll probably want to calculate how long will a battery last in such a case. All you have to do is open the advanced mode to find out!

In the advanced mode, you can adjust the following additional parameters:

- **Awake time** is simply the time that your device is not sleeping during one operational cycle - for example, 2 seconds.
- **Consumption in sleep mode** is the average consumption of your device in sleep mode, measured in amperes. This value is probably much lower than the consumption in awake mode.
- **Sleep time** is the time that your device spends sleeping during one operation cycle.

Based on the parameters listed above, the battery life calculator finds the average consumption according to the equation

`average consumption = (consumption1 * time1 + consumption2 * time2) / (time1 + time2)`

where index `1` describes the awake mode, and index `2` the sleep mode.

After determining the average consumption, our calculator substitutes for the regular battery life formula to figure out the runtime of your battery.

Having Sleep Mode in any device is certainly a benefit towards battery life.

How to calculate how much battery capacity you need.

1) Calculate the consumption

If the current drawn is x amps, the time is T hours then the capacity C in amp-hours is

$$C = xT$$

For example, if your pump is drawing 120 mA and you want it to run for 24 hours

C = 0.12 Amps * 24 hours = 2.88 amp hours

2) Consider the life cycle of the battery

$$C' = C/0.8$$

For the example above

$C' = 2.88\ AH / 0.8 = 3.6\ AH$

3) Consider the rate of discharge depending on the type of battery

Due to Peukart effect. A big effect in alkaline, carbon zinc, zinc-air and lead acid batteries

For example, if your portable guitar amplifier is drawing a steady 20 amps and you want it to last 1 hour you would start out with Step 1:

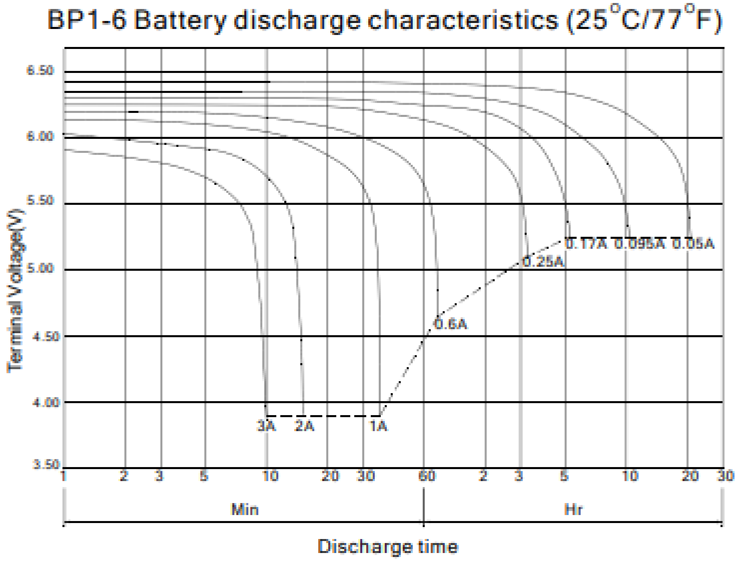
C=20 amps * 1 hour = 20 AH

Then proceed to Step 2

C' = 20 AH / 0.8 = 25 AH

Then take the high rate into account

C''=25 /.5 = 50 AH



Example for battery discharge rate

4) What if you don’t have a constant load? The obvious thing to do is the thing to do. Figure out an average power drawn. Consider a repetitive cycle where each cycle is 1 hour. It consists of 20 amps for 1 second followed by 0.1 amps for the rest of the hour. The average current would be calculated as follows.

$20*1/3600 + 0.1(3599)/3600 = 0.1044$ amps average current.

(3600 is the number of seconds in an hour).

In other words, figure out how many amps is drawn on average and use steps 1 and 2. Step 3 is very difficult to predict in the case where you have small periods of high current. The news is good, a steady draw of 1C will lower the capacity much more than short 1C pulses followed by a rest period. So if the average current drawn is about a 20 hour rate, then you will get closer to the capacity predicted by a 20 hour rate, even though you are drawing it in high current pulses. Actual test data is hard to come by without doing the test yourself.

Convert watts to amps

For example, say you want to run a 250 watt 110VAC light bulb from an inverter for 5 hours.
Watt-hours = watts * hours = 250 watts * 5 hours = 1250 watt hours

Account for the efficiency of the inverter, say 85%

Watt-hours = watts * hours / efficiency = 1250 / 0.85 = 1470 watt-hours

Since watts = amps * volts divide the watt hours by the voltage of the battery to get amp-hours of battery storage

Amp-hours (at 12 volts) = watt-hours / 12 volts = 1470 / 12 = 122.5 amp-hours.
If you are using a different voltage battery the amp-hours will change by dividing it by the battery voltage you are using.

Wireless Charging AGV -Magic Power For Autonomous Mobile Robots

Wireless charging is a trending topic in the **AGV and AMR industry**. More and more Automated Guided Vehicle (AGV) suppliers are slowly incorporating this technology into their robots.

What is AGV wireless charging?

With an **inductive wireless charging system** AGVs and AMRs can perform contactless battery opportunity charging.

The system counts on a **stationary active fixed coil** on the floor on on a wall and on a **mobile passive coil on the mobile robot**.

The active coil generates a magnetic field that induces an alternated current in the mobile coil. This current is used to charge the mobile robot battery.

The main AGV and AMR Wireless Charging Systems manufacturers are:

Manufacturer	Description	Available Power (W)
B&PLUS	While many companies are new entrants to the development of wireless power supply technology, we have more than 30 years of experience in developing and manufacturing wireless power supply devices. Rising above the competition, B&PLUS JAPAN provides wireless power transfer (WPT) technologies with wide power range solutions and options for signal transmission.	600 W
DAIHEN	Through the combination between the electric energy specialists DAIHEN and the patented coil technology of Electricity, D-Broad allows for an charging area that is unchallenged in its width. It allows for wireless charging with a maximum gap of 40mm for power receiving & transmission, while the AGV can be stopped with a gap up to 10mm. D-Broad has a charging success rate of 100% (a charging failure = stoppage of the AGV). Until now, a charging failure complaint has not been registered from any of our customers.	Up to 4 kW
DELTA	Delta Energy Systems (Germany) GmbH is the world's leading producer of power supplies for the top names in industrial, medical and consumer electronics devices. We offer innovative wireless battery charging systems for AGV and Forklift applications. No more expensive connectors and cables to replace. Safe, highly reliable, programmable charging for any battery type with CANBus communication and over 93% effi ciency.	From 1 KW up to 30 KW
IN2POWER	In2Power specialises in maximizing the use of time. By optimizing charging opportunities with cutting-edge wireless technology, we are able to create more efficient movements, within the same time frame, compared to traditional charging systems.	1.5/2.5kW (M-SERIES) output <40A 16kW (L-SERIES) in two versions: <250A (18-60VDC) <125A (60-120VDC) It is possible to arrange parallel / multiple application to increase outputs.
WIBOTIC	WiBotic core technology was developed by co-founders, Ben Waters (CEO) and Professor Joshua Smith, at the University of Washington in Seattle. Now headquartered near the UW, the company continues to benefit from a rich pool of technical and managerial talent in one of the country's fastest growing markets. Whether you're landing drones on rooftops, deploying mobile robots across wide areas, attempting to re-power AUVs at depth, or need to reliably power industrial automation equipment, WiBotic offers a wireless charging solution that keeps you moving forward.	Up to 300 W
Wiferion efficient wireless power	Wiferion develops and sells energy systems for mobile robotics applications. Our inductive charging system in combination with standardized battery modules, the company offers scalable and modular energy systems. Wiferion's battery modules were optimized for use along with wireless etaLINK chargers. In the system network, Wiferion implements optimal charging processes and can thus ensure the best possible and economical use of the energy storage system.	3kW 12 kW

Mobile Robots Battery Charging Solution

1 Opportunity Charge

Opportunity charging, for mobile robots, permits batteries to be charged several times during its working hours. The autonomous mobile robot or AGV goes to defined charging stations and performs charging while waiting for a new mission to be delivered. If the battery balance is properly calculated, the vehicle could never need a change of battery.

2 Battery Swap

Well, it's pretty simple. The mobile robot works with a single battery until it is fully drained that need to be swapped with a fully charged one. Battery swapping can be done manually or automatically as needed or on a schedule.

How does Wireless Charging for AMR and AGV work?

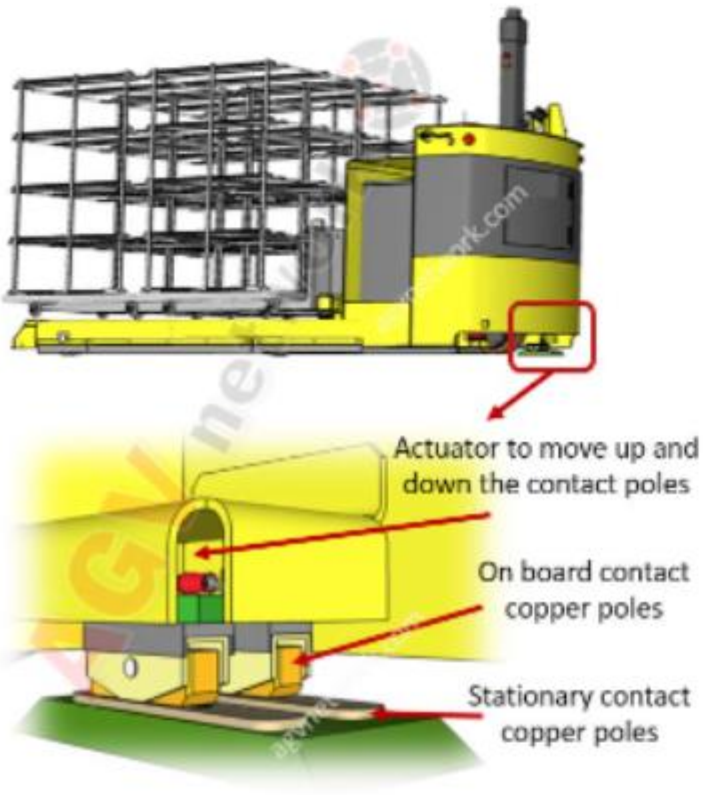
As explained, the opportunity charging can be performed with the classical “**contact charging**” electrodes or with the latest **“inductive contactless charging**”.

So, what is the difference between them? The point is pretty self-explanatory:

- In the “contact” charging there’s is a **physical connection between the charging poles**

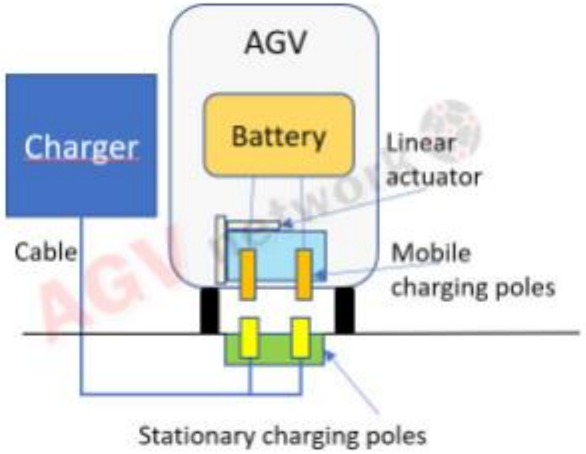
- In the “wireless” charging the power transfer is done **without any physical contact**

AGV and AMR contact charging system

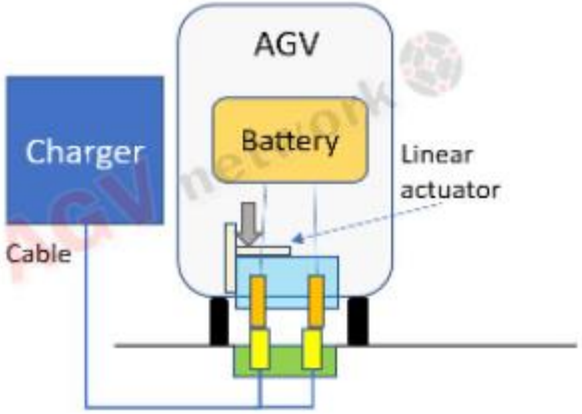


AGV with contact charging poles

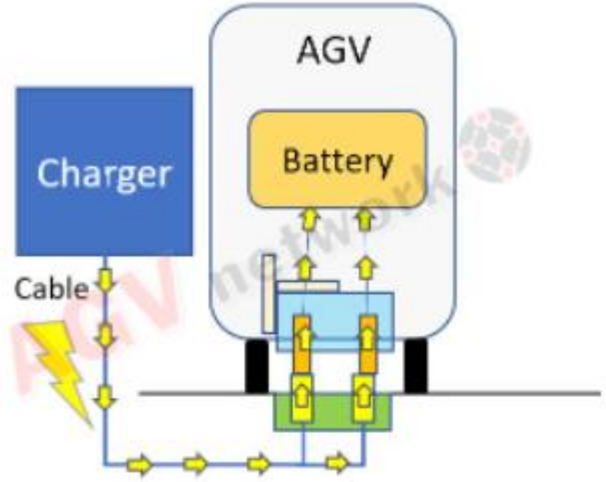
Typical contact charging poles



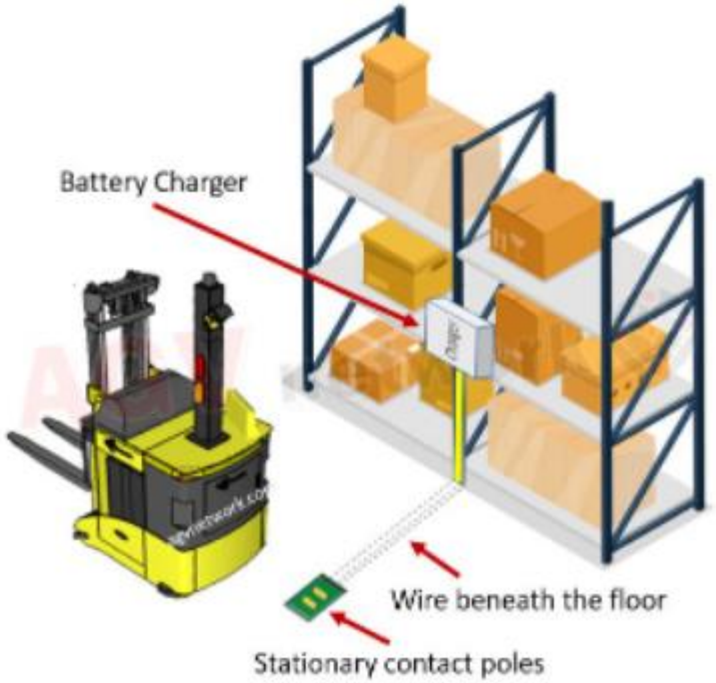
The agv with the onboard charging poles arrives to the charging station. The charging station is composed by the stationary contact poles and the charger.



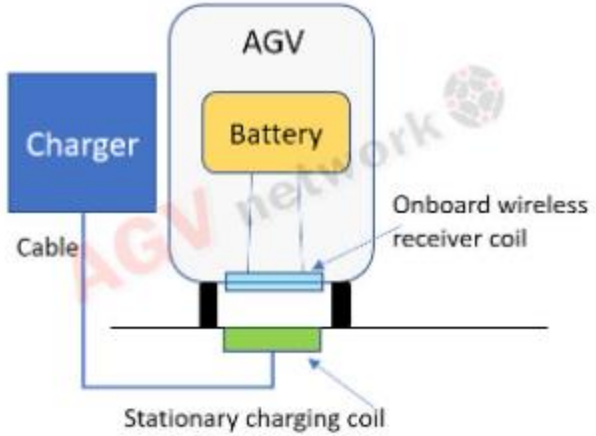
The AGV moves down the contact poles, in general, tanks to a linear actuator.



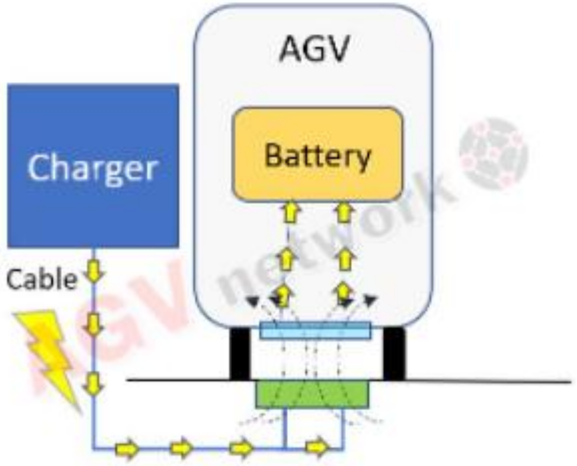
The poles (onboard and stationary) touch. The charger verifies the voltage differential and starts the charging cycle.



AGV and AMR wireless charging system



The agv with the onboard charging "coil" arrives to the charging station. The charging station is composed by the "stationary coil" and the charger.

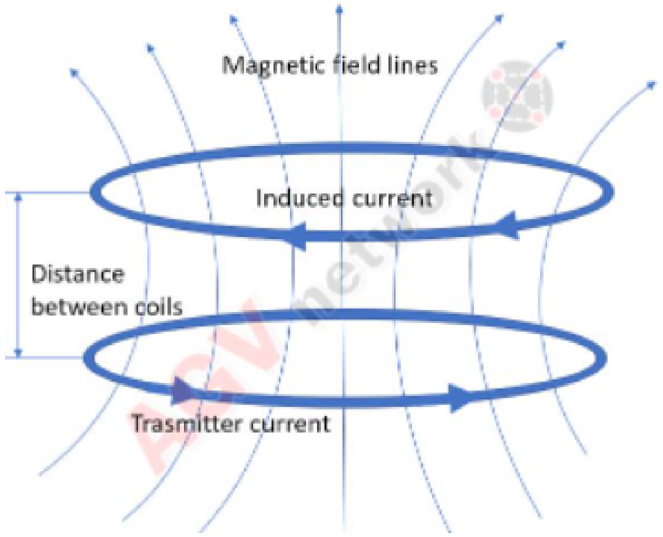


As soon as the onboard coil and the stationary coil overlap, the power is **"magically" transferred without any contact** thanks to the inductive principle.

What is wireless inductive charging technology?

The concept of wireless charging is simple: a magnetic loop antenna (copper coil) is used to create an oscillating magnetic field, which can create a current in one or more receiver antennas (receiver coils).

The “induces” word opens the doors to the **Inductive Power Transmission.**



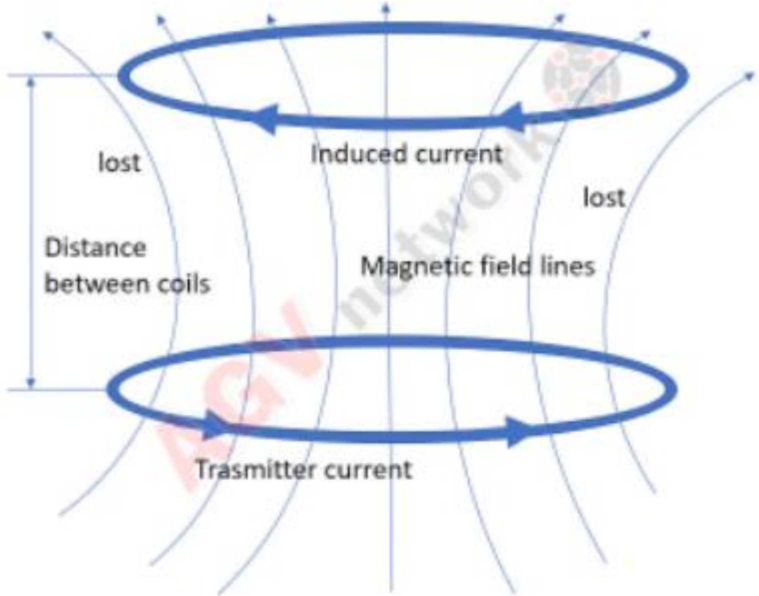
Tesla demonstrated that an alternating current in a wire coil generated an alternating magnetic field, which, in turn, induced an alternating current in a proximity secondary coil.

By attaching a load to the secondary coil, the induced alternating current can, for example, charge a battery.

Under optimum conditions the process is efficient and facilitates easy charging.

Nevertheless, there are two factors that inherently influence the application performance related to **Mobile Robots.**

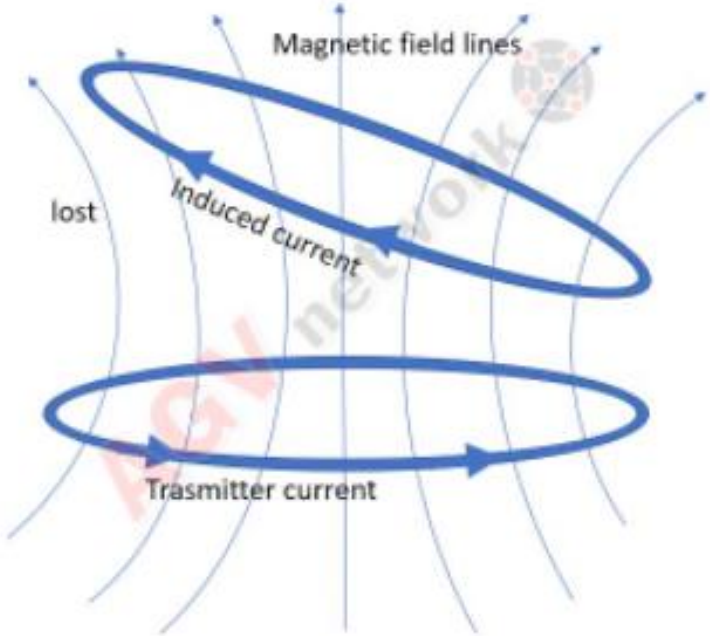
- The distance gap between the two coils. The flux drops rapidly with distance between the coils. It means that the closer the coils are, the more power transfer is achieved.



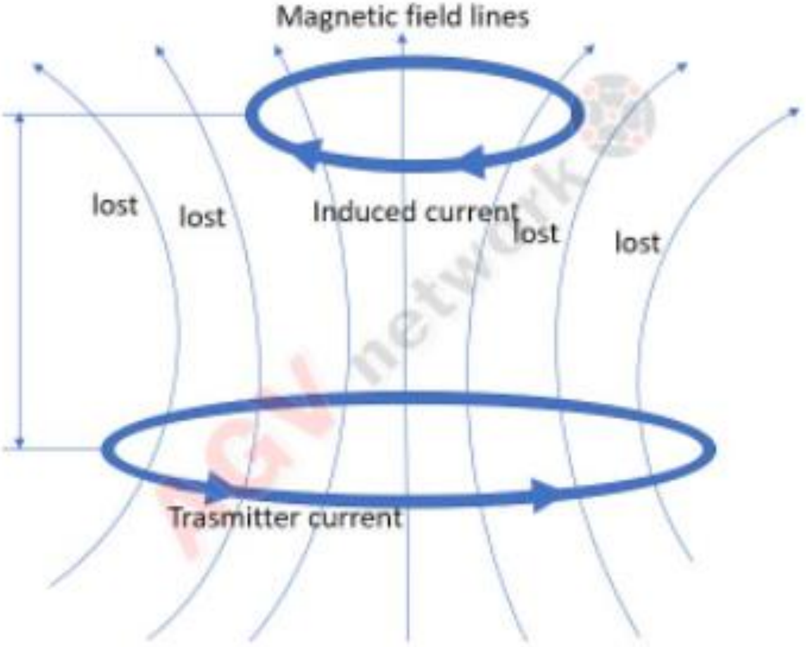
- Consequently, the secondary coil must be placed as close as possible to the primary to intercept the most flux.

The amount of energy that the secondary coil captures is proportional to the cross section that faces the magnetic field. The cross section depends on:

The alignment (parallelism) of the two coils.



The dimension of the coils



What are the advantages to Wireless Charging For AGV and AMR Robots?

High Efficiency 93%-95%

Full Power Of High-Energy Streams Immediately After Start

No Wear And Tear Or Maintenance As There Are No Contacts Involved

High Mobile Robot Positioning Tolerance Compared To Contacts And Omnidirectional Charging

One single wireless charging system can supply power to different vehicles and batteries

Intelligent data transfer during wireless charging

What Is The Main Disadvantage to Wireless Charging For AGVs And AMRs?

EXPENSIVE $$$$$