
Environmental Sustainability
Clean Energy Sources

Unit 5

Electricity and Wind Turbines

We Use Electricity Every Day

Household Appliances

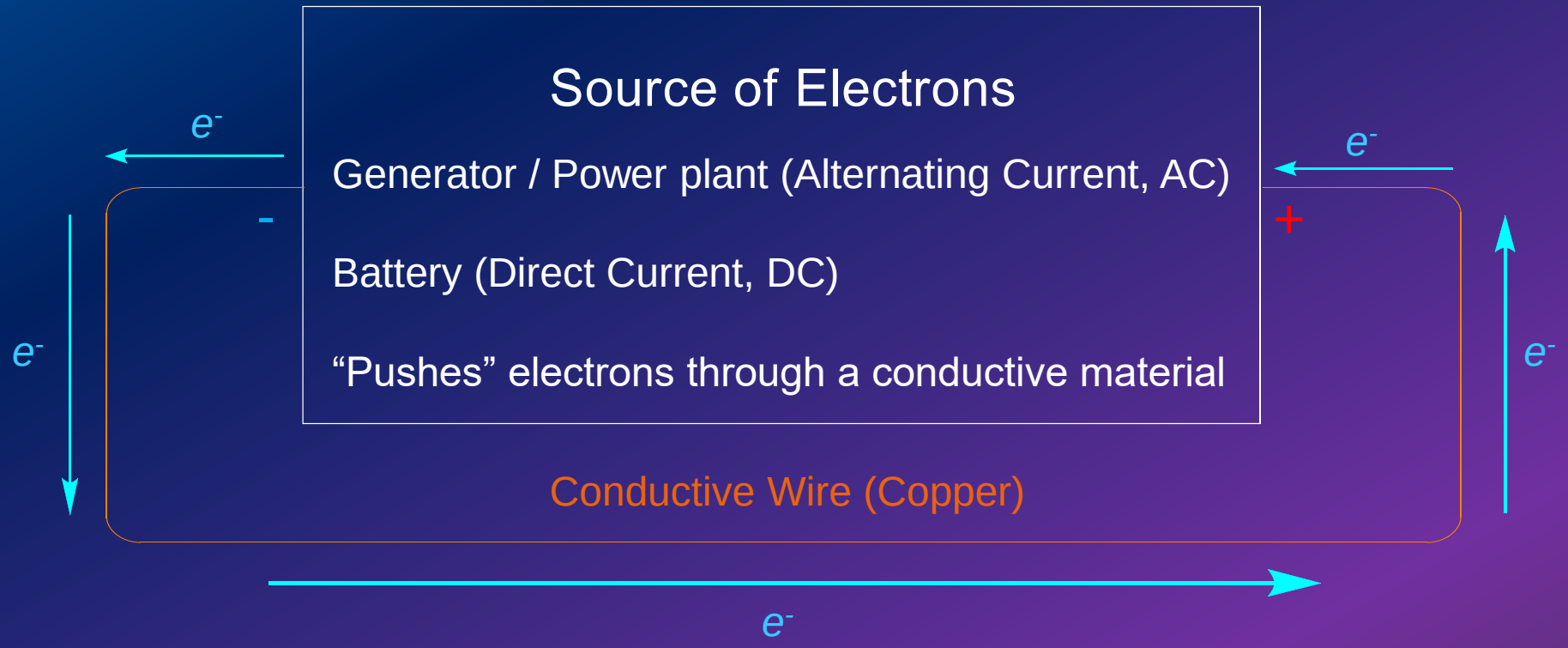
- Exhaust fan over the stove
- Electric blender
- Refrigerator
    - Compressor
    - Fan
    - Ice Machine
- Dryer
- Vacuum cleaner
- Fan for furnace / air conditioning

Driving

- Electric vehicles (EV's)
- Motors inside all cars
    - Fan for heater / air conditioning
    - Power windows
    - Power door locks
    - Power seats
    - Gauges

The Nature of Electricity

Electricity can be thought of as a “flow” of moving electrons



We get an electric *current* or a *circuit*!
Current creates *terminals* – a separation of charges
A *Voltage*

Electric Current – The Circuit Simplified

Voltage – the “pressure” that pushes electrons to move from the negative to positive terminal

Units of *volts* (V)
A typical household electrical outlet delivers 120 V

Amperage – Number of electrons moving through a circuit

Units of *amps*
1 amp means approximately 6.24×10^{18} electrons moving through the circuit per second

Resistance – Even the best conductor will “push back” on the moving electrons

Like friction – wind resistance on an airplane or friction of tires on the road
Units of *ohms* (Ω)

Quantifying Electricity Used

Electricity is energy!
Conventional unit = the Watt (W) or kilowatt (kW) 1 kW = 1000 W
Watts = (amps) x (voltage)

Example: Imagine that you plug a space heater into a wall outlet which delivers a voltage of 120 V. You measure the amount of current flowing from the wall outlet to the heater, and it comes out to 10 amps.

(10 amps) x (120 V) = 1200 Watts

This is what is meant if the heater is rated as a 1200 Watt (or 1.2 kW) device!

Example: How many amps are drawn by a 100 Watt light bulb if the lamp is plugged into a typical 120 V outlet?

(amps) = (watts) / (voltage) = (100 Watts) / (120 V) = 0.833 amps

Electricity Bills

Electricity bills typically are shown as a cost per **kilowatt–hour (kWh)**

One kWh is the amount of kW of electricity used in one hour

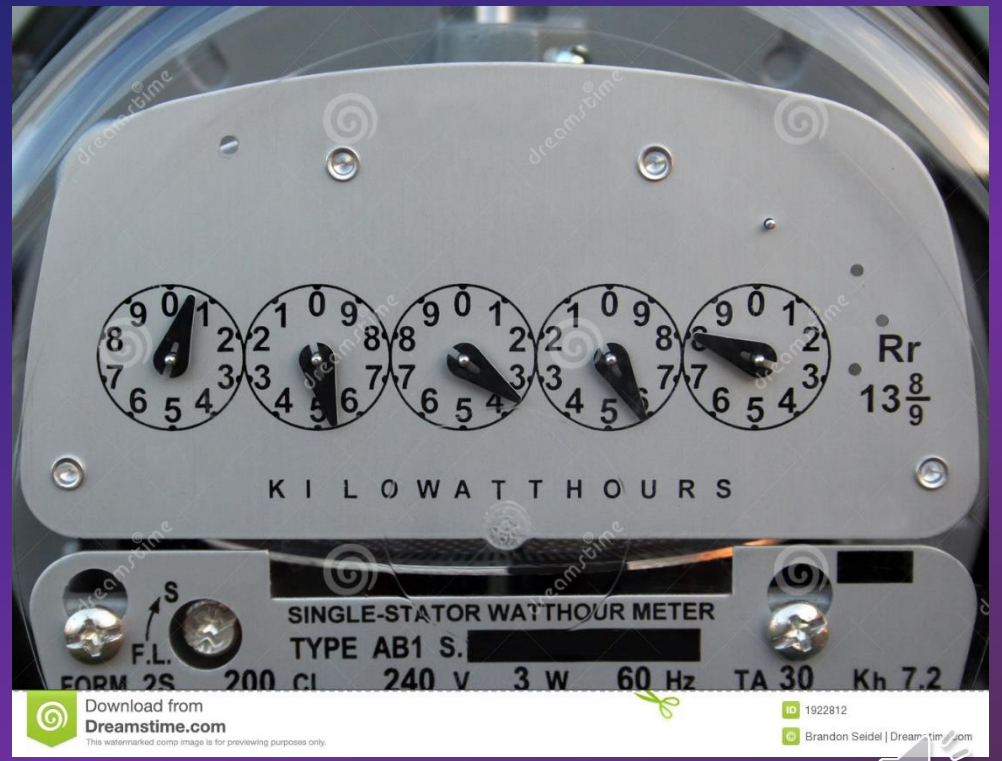
Monitored by the electric meter outside!

Example: Say you leave that 1200 Watt heater plugged in for a total of 12 hours during the day. Then, the amount of energy used is:

(1.200 kW) x (12 hours) = 14.4 kWh

If the electric company charges $0.44 per kWh, then you just spent

(14.4 kWh) x ($0.44 / kWh) = $6.34



Resistance

Why might a light bulb draw 100 W, yet a space heater might draw 1200 W?

- Household voltage is the same – 120 V
- Amperage must be different!
- Why?

Resistance

As electrons move through a circuit, they must “push their way” through what they are moving through

They are repelled by the electrons of the matter through which they are moving

- Opposite charges attract
- Like charges *repel*

Effect of Resistance on Amperage

Amperage – Number of electrons moving through a circuit

1 amp means approximately 6.24×10^{18} electrons moving through the circuit per second

Simply put, resistance slows down the progress of electrons through a circuit

Electrons must “push their way through”
Amperage is decreased

Ohm’s Law

(Current / Amperage) = (Voltage) / (Resistance)

$I = V/R$

Electrons in a Circuit are Resilliant

They *insist* on completing their journey about the current / circuit

“Pushing their way through” the resistance means that electrons do *work* on anything that gets in their way!

This is how electricity can power an electric appliance or even a car!

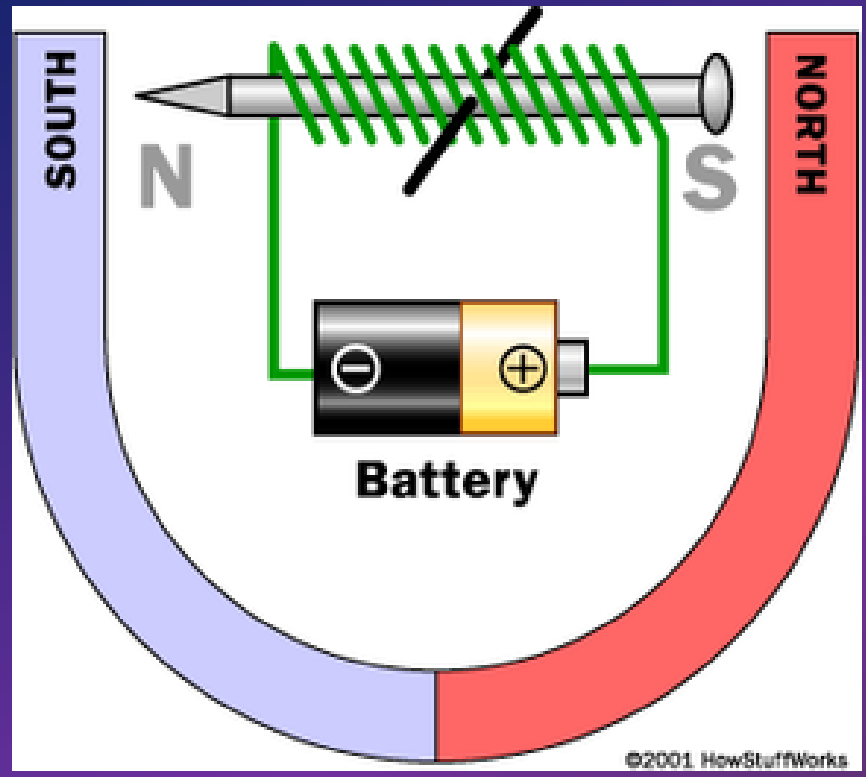
But…. *HOW* does it work?

Mass of an electron = 9.11×10^{-31} kg
Mass of an electric vehicle may be up to 2000 kg or more!

Electricity and Magnetism

Ever seen this science demonstration?

- Wrap a copper wire tightly around a small iron nail
- Connect the ends of the wire to opposite terminals of a battery
- Put the nail between the poles of a larger permanent magnet
- The nail orients itself in a specific direction



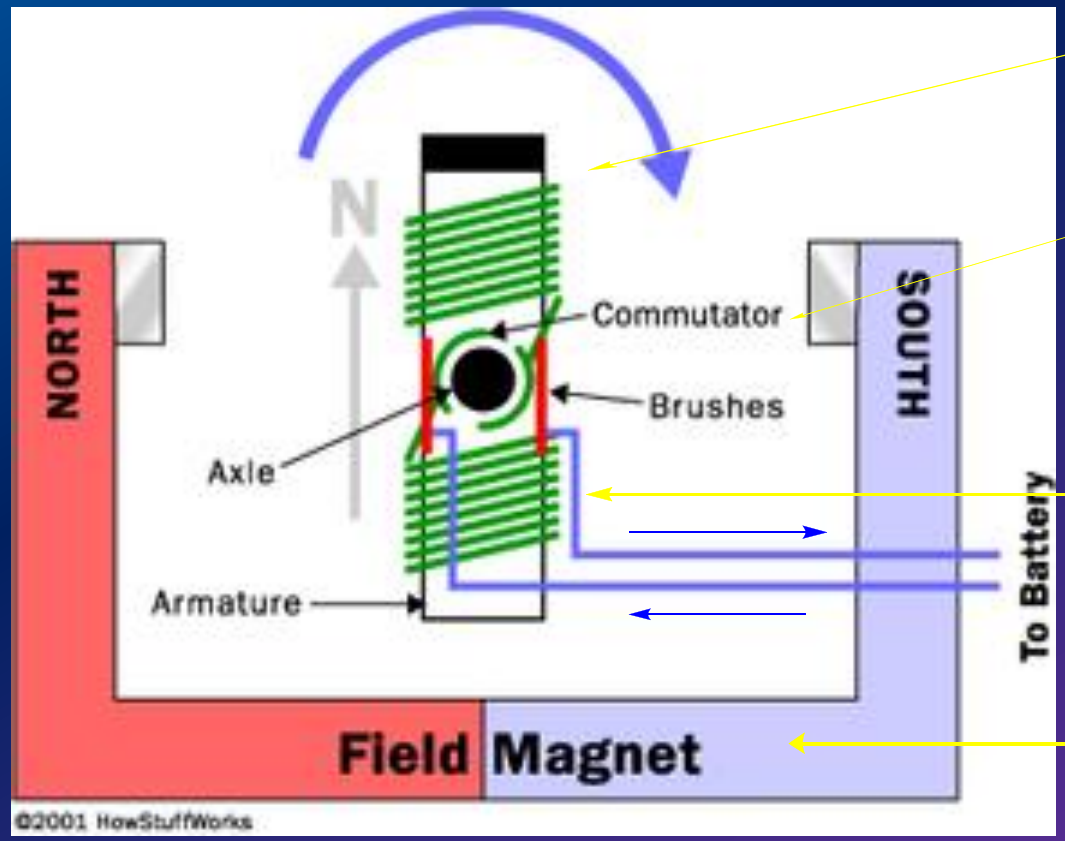
An Electromagnet!

- North “pole” of the nail attracted to the south “pole” of the magnet
- South “pole” of nail attracted to north “pole” of the magnet
- Opposites attract!

A rotating electric current creates a magnetic field
Electric fields and magnetic fields react with each other!

A DC Electric Motor

Basically, an electromagnet between the poles of a permanent magnet



Rotor then becomes an electromagnet
- North is repelled / “pushed” by north
- South is repelled / “pushed” by south

Commutator continually reverses / “flips” current direction
- Reverses the poles of the rotor
- Rotor continues to “spin”
- Creates mechanical work – turns the axle!

Conductive wire carries current around the rotor

Electric current from a battery / source of electricity

Stator – a permanent magnet

Where Does the Electricity Come From?

Energy cannot be created nor destroyed
Can be converted from one form to another
Most electricity still comes from large power plants

Coal burning plants

Nuclear power plants

What's the Problem?

Large Power Plants Produce Pollution

Coal burning plants

Release CO_2 gas to the atmosphere

$$C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)}$$

Other pollutants, if the combustion reaction is not efficient

Nuclear power plants

Produce toxic, radioactive waste

Has become safer in recent history

Alternative Cleaner Methods

Well… harnessing lightning directly isn't yet practical!

So… until we can, we need other sources

Solar panels convert light energy into electricity

The photoelectric effect produces direct current (DC)

Inverter converts DC to alternating current (AC)

Estimated to be only 32% efficient

The Nature of Electricity

Power plants (generators) produce electricity in the form of *alternating current* (AC)

- Direction of current flow reverses or *alternates*
  - 60 times per second in the U.S.
  - 50 times per second in Europe

Batteries, fuel cells and solar cells produce electricity in the form of *direct current* (DC)

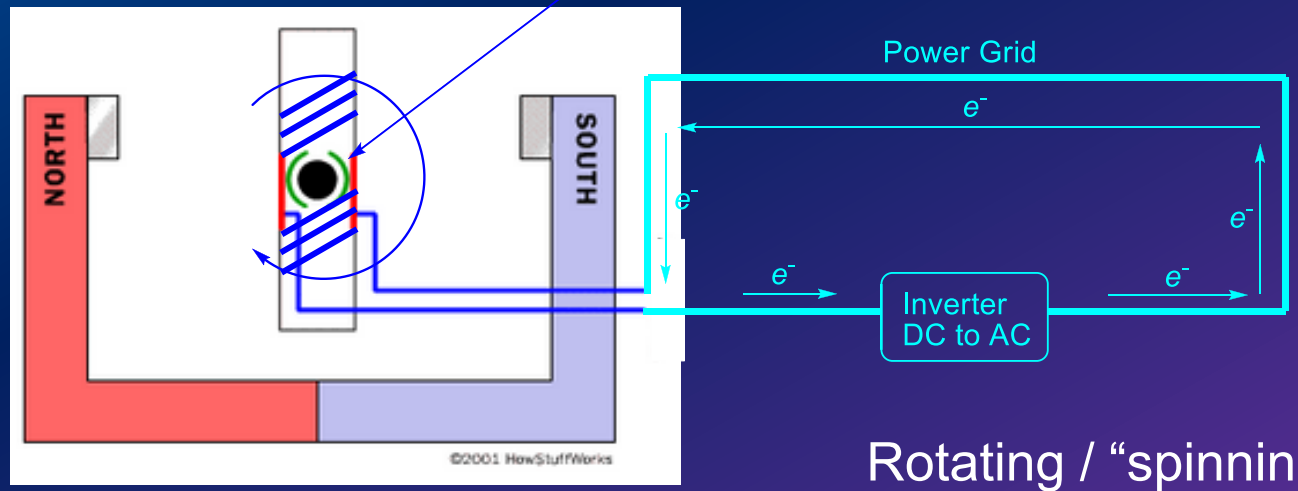
- Positive and negative terminals are always positive and negative – never change sign
- Current always flows in the same direction

An Electric Generator

Basically, the opposite of a DC motor

Need a force to rotate the axle!

Often, this is steam pushing on a “propeller”
Coal is burned to boil the water

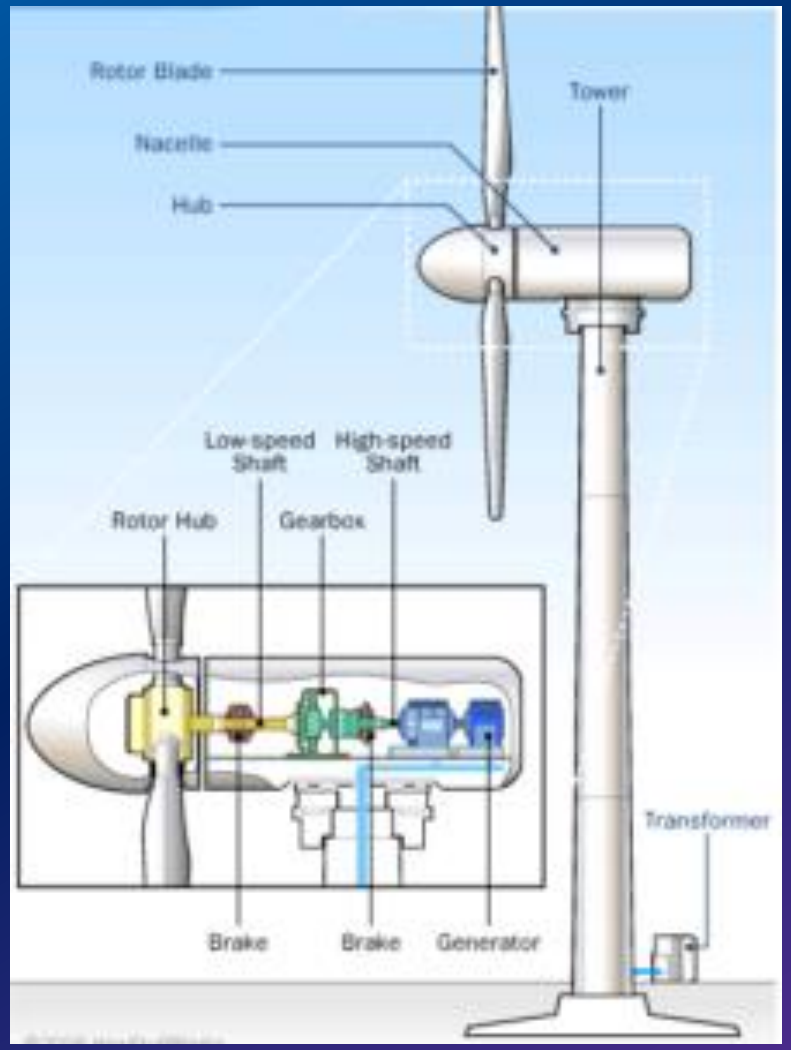


Rotating / “spinning” conductive wire between poles of a magnet
Produces electric current

Wind Turbines

Use wind as the force to rotate the coiled conductor!

Wind Turbines



Wind hits the rotor blades, causing them to spin

Hub is connected to an axle

Axle spins the conductor coils within the generator

Electric current then moves on to the transformer

Converts DC to AC

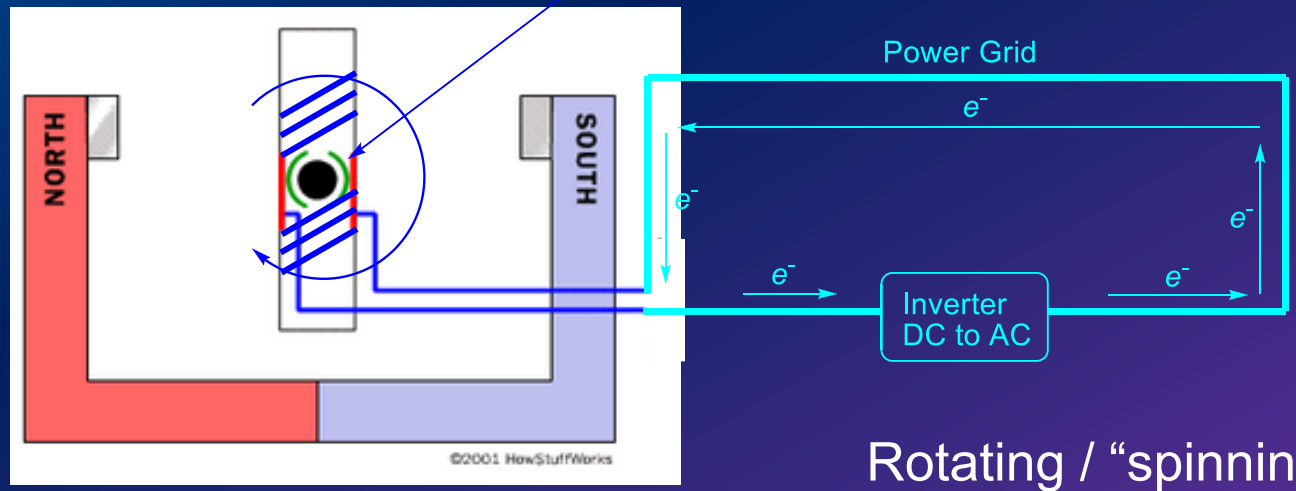
Then to the power grid!

An Electric Generator

Basically, the opposite of a DC motor

Need a force to rotate the axle

Wind hitting the turbine is the force!



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