PLASMA GLOBES
HOW DO THEY WORK?

TALES FROM STANFORD SOLAR
WE WORK AT THE STANFORD SOLAR CENTER, AND WE LOVE NASA!

WE ALSO LOVE TO EXPLORE... WANT TO JOIN US?
The clear glass orb is filled with a mixture of various noble gases with a high-voltage electrode in the center of the sphere. Plasma filaments extend from the inner electrode to the outer glass insulator. They are driven by high-frequency alternating current energy at approximately 35 kHz, 2–5 kV. This energy comes from a lower-voltage DC power supply usually connected to main power, and flows through a high-voltage transformer combined with a high-frequency electronic oscillator circuit which together output a high frequency and high voltage AC to the electrode. The radio-frequency energy is admitted into the larger space by capacitive coupling through the glass.

Wikipedia
OK. REMEMBER THAT ATOMS HAVE A NUCLEUS WITH ELECTRONS GOING AROUND IT?

AND THAT A GAS HAS NORMAL ATOMS BOUNCING AROUND IN IT

A GAS WHERE ELECTRONS HAVE BEEN KNOCKED OFF THEIR ATOMS IS CALLED A PLASMA.

HENCE THE NAME "PLASMA GLOBE".
Our sun, the stars, and most of the universe are a plasma.

It takes a lot of energy to break an electron off its atom.

OK, a gas is atoms. A plasma is atoms with some electrons knocked off by a lot of energy.

You got it!
SO THE GLOBE IS FILLED WITH PLASMA?

AH, NO. ONLY ITS TENDRILS ARE THE PLASMA.

THE REST IS ORDINARY GASES THAT HAPPEN TO GLOW WHEN THEY GET HOT.

THEY MIGHT BE NEON, ARGON, XENON, OR KRYPTON.

SOUNDS LIKE SOMETHING THAT COULD KILL SUPERMAN.

NO, THAT'S KRYPTONITE, AND IT'S MAKE-BELIEVE.

SHUCKS...
THE ELECTRODE IS POWERED BY SOME ELECTRONICS IN THE GLOBE BASE. IT IS A RADIO TRANSMITTER -- IT SENDS OUT RADIO WAVES.

SO WHAT MAKES THE TENDRILS?

SEE THAT THING IN THE MIDDLE? IT'S CALLED AN ELECTRODE.

SO IF I LISTEN TO THE GLOBE, I'LL HEAR MUSIC???

ARG...NO. IT DOESN'T SEND MUSIC, JUST RADIO WAVES, WHICH CARRY ENERGY.
I'm not quite sure what radio waves are....

Radio waves are electromagnetic radiation, which is energy -- like light from the sun, or energy from a hydrogen bomb, or X-rays. There are forms of energy our eyes cannot see. The types of light/energy include radio waves, microwaves, infrared, visible light, ultraviolet light, X-rays, and gamma rays.

The different types of light have different amounts of energy. Radio waves have the least, gamma rays the most.

Plasma globes use radio waves because they carry just enough energy to knock electrons off atoms to make the plasma. If plasma globes used X-rays or gamma rays, they would be very dangerous!

OK, I get that.
Radio wave energy

Since the radio wave energy is strong enough to knock electrons off the atoms in the gas...

...that makes the globe full of gas, electrons, and atoms missing electrons.

As the electrons and atoms dart around, they occasionally clump together.

As the clumps bounce around, they make it easier for other clumps to join them, making a streamer.

The radio wave energy also pushes the streamer, or tendril, towards the glass.
While the electrons are racing around in that plasma tendril, they sometimes knock other electrons off the gas atoms.

But the atoms want their electrons back, so they grab the closest one.

When a lost electron snaps back with a nucleus, energy is released.

Released energy

Just like energy is released when you let go of a stretched rubber band.

The little piece of energy, which is light, that is released is the color you see in the tendrils. You get different colors from the different gases.
So the glowing light comes from atoms recapturing lost electrons in a plasma!
IF THE ELECTRONS ARE RACING TOWARDS THE GLASS, CAN THEY GET THROUGH IT?

NOPE.

THEN DON'T THEY PILE UP AT THE GLASS?

WELL, AH, THERE'S A PART THAT I DIDN'T TELL YOU. THE ELECTRIC CURRENT COMES AND GOES, CHANGING DIRECTION, SO THAT PILEUPS HAPPEN ONLY FOR A TINY, TINY BIT OF TIME. WE CALL IT ALTERNATING CURRENT, AND IT HAPPENS REALLY, REALLY FAST.
Why do the tendrils go to your finger when you touch the globe?

The tendrils want to follow the electric field. It goes out of the glass in all directions, even though the electrons can’t. Normally, that electric field goes into the air. Electrons in the tendrils want to find atoms missing electrons (positively charged ions). There are more in your finger than in the air/gas around it, so the tendrils head in that direction!
That electric field is why you can light little neon bulbs and fluorescent tubes by holding them outside of the globe. They pick up the electric field there!

The electric field is also making electrons and atoms come and go in your finger, which is why your finger gets hot when you touch the globe!
The electrode in the center generates radio waves, which carry energy.

The energy knocks electrons off the gas atoms in the globe, making a plasma.

The atoms recapture lost electrons, and emit a bit of light in the process. Each gas makes a different color of light.

The electric field goes on outside the globe and can light little bulbs or be attracted to your finger.

YES!!!!!
AND ITS KINDA LIKE THE SUN.

THE SUN IS A PLASMA, LIKE THE STREAMERS IN THE GLOBE.

THE INSIDE OF THE SUN, ITS CORE, GENERATES ENERGY -- BUT BY CRUSHING ATOMS TOGETHER, NOT BY ELECTRICITY.

THE ENERGY FROM THE CORE RADIATES OUT IN ALL DIRECTIONS AND CAUSES ELECTRONS TO CRASH INTO EACH OTHER, LOSING ENERGY IN THE COLLISIONS, JUST LIKE THE PLASMA GLOBE.
The high-energy gamma rays emitted in the core get absorbed and re-emitted many, many times on their way out of the sun. Some of their energy is absorbed by the material, heating it up. So the energy of the photon gradually decreases on the way up from the hot interior to the less-hot surface.

Since the sun is so big, it takes the energy hundreds of thousands of years to work its way to the surface!

By that time, the gamma rays have lost enough energy to be emitted from the sun's surface as visible light.

Also, in the upper atmosphere the energy knocks electrons off atoms. When the atoms recapture the electrons, they make light just as in the plasma globe!
THE SUN HAS ‘TENDRILS’ TOO!

These are plasma tendrils, much like those in the globe. But these are a lot bigger. They loop down, rather than going straight up, cause they are pulled and held together by magnetic fields on the Sun.

Wow -- thanks, Camilla, for teaching me about plasma globes and the Sun!!!
Colours has trouble memorizing technical terms, so Camilla has tried not to use them. But if you really want to know, here are the terms:

**Glossary**

**Parts of an Atom**

- Neutron
- Proton
- Nucleus
- Electrons
The nucleus has 2 types of things - protons and neutrons.

In a normal atom, there are always the same number of electrons and protons, the blue things and the red things.

The blue things are electrons.

(We can ignore the grey neutrons because they don't have anything to do with plasmas or electric fields.)

The red things are protons.
The electrons and protons are attracted to each other like opposite poles of a magnet are.

This is called charge. By convention, we say that electrons have a negative (-) charge, and protons a positive (+) one. This charge is what holds atoms together!
If one of the electrons gets knocked off, like in a plasma, the atom becomes unbalanced: it has 2 pluses (+) and only 1 minus (-).

Electron getting knocked off

Now, like magnets, that atom is going to be attracted to electrons.

And the lost electron is going to be attracted to atoms with missing electrons.

Help!!!!

I need an electron!  
I need a nucleus!
Glossary

Electric Field

If an electric field is the pull/push attraction between electrons and protons, then how could it go outside the globe?

An electric field is like a magnetic field. They are a force and both can go through glass.

Electric Field

Magnetic Field

They look the same!

There are billions and billions of atoms and loose electrons both inside and outside the globe. The radio waves carry the electric field -- they are oscillating electric and magnetic fields moving through space, air, glass, etc.
Glossary: Ion, Charged Particle

Remember, the plus (+) of a proton and the minus (-) of an electron are called their charge.

If an atom has lost an electron, or an electron has lost a nucleus, they are called charged particles, or ions.
Glossary

Current, Alternating Current, Direct Current

When electrons are being pushed in an electric field, we call it **current.** It's much like the current that flows in water.

If the current is pushing only 1 direction, it's called **direct current.** Batteries work like this.

If the current is changing directions back and forth, it's called **alternating current.** This is used to avoid pile-ups of electrons at one end of the current and it's how electricity usually works.
**Glossary**

**Conductor**

Certain materials are easy for a current to go through. This means they are easy for electrons to move in. Other materials are hard for electrons and a current to move in. A material that is easy for a current or an electron is called a conductor.

Fingers are good conductors, so are metals, plasma, and even water.

Air is a bad conductor, as are glass and rubber.
An electrode is a place where electricity can leave (or enter) an object. In a plasma globe, the electrode is the center ball, and it launches energy and electrons into the globe.
GLOSSARY

PHOTON

Light comes in packets or chunks. The little piece of light emitted when an atom grabs back an electron is called a photon. Photons come in different sizes and colors, even colors that the human eye cannot detect.
Electromagnetic radiation is energy, or light, even light our eyes cannot see. The types include radio waves, microwaves, infrared, visible light, ultraviolet light, X-rays, and gamma rays.

The types of light differ by their amounts of energy. Radio waves have the least, gamma rays the most.

Light behaves like waves too. Radio waves have a long wavelength (and smallest amount of energy). Gamma rays have the shortest wavelength (and most energy).
Quick Summary

GAS + ENERGY = PLASMA

ELECTRONS GET KNOCKED OFF + ATOMS CAPTURE BACK THE ELECTRONS = LIGHT IS EMITTED!

AN ELECTRIC FIELD IS GENERATED BY THE ATTRACTION BETWEEN ELECTRONS AND PROTONS + THE ELECTRIC FIELD AFFECTS YOUR FINGER = PLASMA GLOBE
SOLAR RESOURCES

ABOUT NASA SOLAR MISSIONS:
- SOHO - http://sohowww.nascom.nasa.gov/

GREAT NASA ACTIVITIES:
- http://nasawave.length.org

FOR STUDENTS:
- THE STANFORD SOLAR CENTER HAS A LARGE COLLECTION OF ACTIVITIES, VIDEOS, AND IMAGES TO EXPLORE:
- FEATURES OF THE SUN -- A GREAT INTERACTIVE GAME WHERE YOU ARE A SOLAR SCIENTIST!
  - http://lasp.colorado.edu/home/education/k-12/project-spectra
- SPACE WEATHER CENTER
  LOTS OF GREAT GAMES AND FUN ACTIVITIES:
  - http://www.spaceweathercenter.org/activity_page/01/01.html

FOR TEACHERS:
- SDO FOR EDUCATORS
  ELEMENTARY AND SECONDARY LEARNING UNITS
  - http://sdotools.gsfc.nasa.gov/epo/educators/
- THE STANFORD SOLAR CENTER HAS A LARGE COLLECTION OF LESSONS, MOSTLY 4-12
- NOVA'S SUN LAB - GREAT LESSONS AND STUDENT ACTIVITIES
  - http://www.pbs.org/wgbh/nova/labs/lab/sun/
- OUR STAR THE SUN
  COLLECTION OF SUN-THEMED CLASSROOM RESOURCES FROM NASA’S SOLAR AND HELIOSPHERIC OBSERVATORY
  - http://sohowww.nascom.nasa.gov/classroom/classroom.html