Students can learn much at expo-type events by interacting directly with the presenters at their booths. We've assembled some key questions students can use to help their learning and that teachers can use as one metric of student-professional interaction. The following questions are arranged by booth owner and can be supplemented by the teacher.

Contemporary Physics Education Project (CPEP)
Sam Lightner (lightner@westminster.edu)
Cherie Harper (gsphysics@live.com)

Of the three types of energy-releasing reactions (chemical, fission, fusion) which one releases the most energy per kg of fuel?

Answer: fusion

List three naturally occurring plasmas that exist in space beyond the Earth's atmosphere.

Answer: solar corona, solar core, solar wind, nebula, interstellar space

In the fusion simulation done at the booth, what specific nuclei do the large and small bottle tops represent?

Answer: Large = Tritium (T, Triton), Small = deuterium (D, Deuteron)

General Atomics
Rick Lee (rick.lee@gat.com)

What is gaseous plasma and why is it referred to as the 4th state of matter?

Answer: Gaseous plasma, or just plasma, is ionized gas. An ionized gas is produced when one or more electrons are removed from an atom or molecule of gas. This removal of electrons results in separating the positively charged ions and negatively charged electrons. The path of travel of each of these charged particles can be influenced using electric and magnetic fields. Examples of plasma include: lightning, sparks, the discharge inside of a fluorescent tube, the aurora borealis (or Australis), the sun and other stars, and discharges inside high-temperature magnetically confining tokamaks. While plasma was present in the universe before solids, liquids, and gases, it wasn't characterized as the 4th state of matter until well after the establishment of solids, liquids, and gases as the (first) three states of matter.

What is the most abundant element in the universe and through what process is this element incorporated into heavier elements?

Answer: Hydrogen (single proton in nucleus, single electron outside of nucleus) is the most abundant element in the universe. Most of the hydrogen present today was formed more than 13 billion years ago, just after the Big Bang. Hydrogen is incorporated into heavier elements through fusion processes inside massive stars within the massive star's relatively short 10M year life. Fusion is the process of bringing nuclei together to form another nucleus; the fusion process will lead to energy released if the reacting nuclei are less massive than (or about equal in mass to) iron (Fe), cobalt (Co) or nickel (Ni). Neutron capture processes are responsible for producing elements heavier than Fe, Ni, or Co, and require energy. Neutron capture processes occur once a star explodes in a supernova (collapse and subsequent explosion) event due to the a small buildup of iron at its core and will continue over a very brief period measured in minutes!

How is the electricity generated that comes into your home?

Answer: Depending on the region of the country you live in, electricity production may start with coal, oil, natural gas (methane), fission, solar power, or hydroelectric processes. In general, a turbine (a set of closely spaced fan blades) is spun which, in turn, spins an electrical generator. One can spin the turbine using steam produced from heated water or by falling water, thereby producing electricity from the connected generator. There is a large distribution system made of wires, cables, poles, transformers, and more that allow electricity to be brought to your home.

Suppose oil production peaked (maxed out) in 15 years. How old will you be? How will your reliance on oil be changed in 15 years?

Answer: A 15-year-old student will be 30 years old. Gasoline availability (more $$) may be less than seen today or at least more expensive. Electricity will still be produced using oil, but that, too, may become more expensive. Cosmetics, plastics, pharmaceuticals, and all other organic chemistry-based products will become more expensive as the raw material, oil, becomes increasingly scarce. Your children will probably rely on oil for (a guess) about 20% of the electricity production. Hopefully, more energy dependence on truly long-term methods, such as fusion, will be realized.

The Laboratory for Laser Energetics (University of Rochester)

Reuben Epstein (reps@lle.rochester.edu)

What do the letters in the name LASER stand for?

*Answer: **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation.*

What amount of seawater contains an amount of fusion energy equivalent to the energy in the world's oil reserve? In other words, what volume of seawater, in cubic kilometers, would this be?

Answer: One cubic kilometer

What kind of rocket is used to compress fusion fuel to high density?

Answer: The rocket is a spherical rocket, compressing the spherical fuel volume to a greatly reduced volume. The rocket is also a laser-driven rocket, where the laser heats the outer surface of the fuel capsule. This causes the outer surface to vaporize and expand rapidly, creating the rocket thrust

Lawrence Livermore National Laboratory

Steve Allen (allens@fusion.gat.com)

How do radio waves, visible light, and X-rays differ as components of the electromagnetic spectrum?

Answer: Each has its own unique wavelength and frequency.

Why do astronomers use radio, visible light and X-ray telescopes to collect data about the sun and other stars?

Answer: The universe contains numerous types of stars that emit energy at different parts of the electromagnetic spectrum.

What COLOR is common to the plasmas that we see on earth (like the tokamak) and in the sky (like the Orion Nebula)?

Answer: Red

MIT Plasma Science and Fusion Center

Paul Rivenberg (rivenberg@psfc.mit.edu)

Name at least four examples of plasmas.

Answer: Sun, stars, aurora borealis; lightning and electric arcs; fluorescent light bulbs; fusion experiments; neon signs.

Why are magnets used to confine plasmas in some fusion experiments?

Answer:
Fusion plasmas are so hot that they will melt anything they touch. Obviously it would be difficult to contain such a hot plasma in any device. But because plasmas are made of electrically charged particles they respond to magnetic fields. In a fusion experiment, magnets are used to push the plasma away from the inner walls of the fusion experiment (i.e., the vacuum vessel). This only works because the plasma is made of ions and electrons, which are electrically charged. You can't push on a gas with magnets since a gas is made of neutral atoms

Name two ways plasmas could be used to help people.

Answers: A) Plasmas from fluorescent lights allow people in buildings to see what they're doing when it is dark outside. Fluorescent lights also use less than half as much power to produce the same amount of visible light as incandescent light bulbs, so they save people money.

B) Plasmas can be used to process solid wastes or chemical spills in soil, destroying toxic compounds or converting them into safer forms. At the Hanford site in Washington State, which the Department of Energy describes as "the world's largest environmental cleanup project," plasma was used to target and destroy carbon tetrachloride pumped from the soil.

C) Although fusion energy is not yet a reality, scientists expect that energy produced from fusion plasmas will one day create less radioactive waste than nuclear fission and less carbon dioxide than fossil-based fuels.

D) The sun is a burning plasma that supplies the earth with almost all of its energy. It makes it possible for plants to grow through photosynthesis

Princeton Plasma Physics Laboratory
Deedee Ortiz (mortiz@pppl.gov)

What is the difference between a gas and a plasma?

Answer: A plasma is a hot gas that can conduct electricity and is effected by magnetic fields.

Name a naturally-occurring plasma and a human-produced plasma.

Answer: The sun, stars, lightning, The Northern (and Southern) Lights, a flame (minor amount), a neon light, a fluorescent light

The plasma inside a fluorescent light is approximately 10,000 degrees Kelvin. Why is the glass of the bulb warm but not hot?

Answer: The pressure inside the bulb is much less than atmospheric pressure. The plasma does not have a sufficient heat capacity to increase the temperature of the glass to such a large amount.

U.S. ITER Office, Oak Ridge National Laboratory

Jamie Payne (paynejp@ornl.gov)

What is the ITER project?

Answer: ITER is an international collaboration between partners China, European Union, India, Japan, Korea, Russia and the United States to build a burning plasma experiment.

What kind of reaction, which occurs naturally on the Sun, does the ITER project hope to achieve on Earth?

Answer: A self-burning (or self-sustaining) fusion reaction.

What are the advantages of fusion energy?

Answer: It is a safe, abundant, carbon-free form of energy.

The Wonders of Physics (University of Wisconsin)

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How does a plasma globe operate?

Answer: There's a LOT of physics going on in a plasma globe! A plasma globe is a clear glass or plastic globe filled with a mixture of various gases at low pressure. The most commonly used gases are helium and neon; xenon and krypton may also be included. High voltage electricity is introduced through an electrode (the small ball at the center). The electricity alternates (changes direction) thousands of times every second.

When voltage is applied to the electrode, an electric field is created between the electrode and the outer globe. Under these conditions, electrons jump from the electrode and accelerate toward the globe. The electrons collide with the gas atoms in *the globe, knocking some of the electrons off the gas atoms. The atoms that are missing electrons are called IONS. A gas containing charged particles such as electrons and ions is called a PLASMA. Electrons have a negative CHARGE, and ions have a positive charge.*

Moving electrons create their own magnetic field. By rapidly alternating the electric field, we cause the electrons to "jiggle" back and forth, creating an alternating magnetic field. This alternating ELECTROMAGNETIC field helps to contain the plasma when it forms.

As more gas is ionized, an ion trail created, making it easier for more electrons to follow along in the same path. Pressure from the surrounding "unionized" gas, combined with the containing effect of the alternating electromagnetic field, keep the plasma moving along this path, forming a "streamer".

The streamers move around because the plasma is very hot. As it warms, the plasma expands and becomes less dense than the surrounding gas. This causes the plasma streamers to drift upwards in the globe, like rising hot air.

The streamers are also glowing. Atoms and ions have electrons "orbiting" around them at particular energy levels. Collisions between all these "jiggling" electrons, ions and atoms tend to knock electrons from their normal (ground state) levels to higher (excited) levels. Excited electrons quickly jump back to their ground levels. The difference in energy between the excited level and the ground level is dumped off as burst of light energy called a PHOTON.

The color of the light depends on the amount of energy dumped into each photon. The allowed "jumps" between energy levels are different for different gasses, so the color(s) you see will depend on what gas(es) are in the globe. (For example, neon gas gives off different colors than krypton).

The streamers connect between the electrode and the globe because of the voltage difference between the two. The globe, being made of glass or plastic, is an electrical INSULATOR. If the electrons only moved one way, they would quickly move from the electrode to the globe and cancel out any voltage difference.

Rapidly alternating the voltage keeps the electrons moving back and forth, allowing the glass to charge and discharge. This maintains a voltage difference between the electrode and globe –and keeps the streamers going.

Normally there are many small streamers distributed fairly evenly through the globe. But when you touch the globe, many of the streamers combine into one big streamer between the electrode and where you're touching.

The reason why has to do with CAPACITIVE COUPLING. As charge builds up on the inside of the globe, an equal but opposite charge builds up on the outside. When you *touch the globe, mobile charges in your body (mostly made of saltwater) flow to cancel the charges that build up on the outside of the globe.*

With the opposing charge cancelled, more charge inside the globe moves to the spot nearest your hand. And, as the charges move toward your hand, a large streamer is formed.

What is a Tesla coil?

Answer: Stripped down to it's most essential parts, a Tesla coil is a wire sticking out of the ground. To get sparks to fly out of the top the rest of the machine "sloshes" electrons up and down the wire.

The picture you should have in your head is a long bathtub, open to the ocean on one end. The machinery of the Tesla coil is like some dude in the bathtub sliding back and forth, splashing water (electrons) out of the closed end, while the tub is refilled from the ocean (ground).

[image caption] One possible circuit configuration for a Tesla coil.

The electricity in the primary coil is what's doing the pushing, and the electricity in the secondary coil is what's being pushed. To understand how the driving mechanism works requires a new metaphor and some answer gravy.

Answer gravy: To get sparks to really fly you need very high voltage (up to several million volts) at a fairly exact frequency. The current that flows up and down the secondary coil, and sloshes out the top, has a high resonant frequency (~MHz, unless the coil is ridiculously huge) that you really can't do much about. But the current coming out of the wall has a frequency of only 60 Hz (50 Hz for our Old World readers).

So how do you change frequencies? The answer is you "pluck" the primary coil. For example: If you pick a guitar string once a second you have a frequency of 1 Hz, but the string vibrates on its own at whatever frequency it's made for (~10 kHz).

The AC mains have a low frequency (60 Hz) while the secondary coil needs to be driven at a high frequency (~1,000,000 Hz). That means that the secondary will slosh back and forth thousands of times every time the current from the wall turns over just once. Since the fast part of the circuit is so much faster than the slow part, you can just pretend that the current from the transformer is DC (direct current = 0 Hz).

The secret to plucking is to change the circuit's "shape" using a spark gap. Spark gaps have some pretty slick properties. They have an essentially infinite resistance until a high enough voltage is applied across them, at which point they spark (hence the *name). The spark you see is the air being pulled apart and ionized. Now ionized gas is a really good conductor, so a spark is like instantly closing a switch.*

Also, spark gaps are the cheapest circuit element ever. Can you cut a wire? Now you got a gap! Adding spark gaps to a device is one of the quickest ways to bridge the divide between regular and mad science.

[image caption] The transformer on the left forces charge to build up in the capacitor on the top. But the voltage across a capacitor is proportional to the amount of charge it's holding, so eventually the voltage is high enough to trip the spark gap.

The only job that the slow part of the circuit has is to charge the capacitor (pull back the string). When the spark gap sparks (pluck!) the fast part of the circuit takes over, and the slow part is essentially ignored until all the energy is exhausted by exciting the secondary coil (string vibrates and slows).

[image caption] With the spark gap active the charge can flow out of the capacitor and swing back and forth many times, very fast (thousands to millions of times per second). The current through the primary coil then drives current up and down the secondary, causing electrons to "overflow" from the top of the Tesla coil. The "overflow" is a delight to children of all ages.

As current flows through the primary it creates a voltage across the secondary that's so high that electricity actually flies out of the top of the coil, despite having nowhere in particular to go. It generally takes at least several hundred thousand volts to make that happen.

The loop in the picture above forms and RLC circuit with a high resonant frequency (that matches the frequency dictated by the secondary). As the energy in this system runs out the voltage needed to maintain the spark gap (which is much less than the voltage needed to start it) is lost, and the whole thing returns to the slow, charging phase.

Since the power supply oscillates at 60 Hz, the whole system briefly turns off 120 times every second (the voltage is +, 0, -, 0, +, 0, ...). For this reason Tesla coils have a very loud 120 Hz hum that sounds "staticy" and ominous, as opposed to Jacob's ladders that are continuous, and tend to sound more like "tearing". Connoisseurs, I'm sure, will agree.
From "Q: How does a Tesla coil work?" October 9, 2010, by The Physicist
http://www.askamathematician.com

How does the Ring Launcher work?

Answer: A magnetic ring launcher is a coil, wound around an iron core that extends beyond the coil. A non-magnetic metal ring (e.g. aluminum) is placed around the core. When the coil is energized with an alternating current (AC), the ring leaps into the air! The alternating current in the coil creates a changing magnetic field. The changing magnetic field moves electrons in the metal ring, creating a current. The current in the ring generates its own magnetic field, opposite that of the coil. What happens when you put two North poles of a magnet together? They PUSH APART –and ….