(Teacher Page)

Activity One: Fundamentally Speaking

Goal: To stimulate discussion about particles and curiosity to learn more.

This initial activity introduces students to the evolving field of high-energy particle physics and challenges their knowledge and conceptions of the fundamentals of physics. The agree/disagree quiz featured in the activity is designed to spark students' interest in learning more about this field, by revealing recently discovered facts that they may find surprising.

You could introduce this activity by initiating a class discussion of "fundamental" things, asking students to suggest how the term "fundamental" might apply to physics. This can lead into a discussion of fundamental particles and forces.

Distribute the activity sheets and allow time for students to complete them individually or in small groups. Spend a short time in class discussion of their conclusions, but do not give the answers. Suggest that students will learn them as the program progresses. Then encourage them to take the activity sheets home to test the scientific awareness of family members. Return later to review this sheet as a wrap-up activity.

Answers:

1. There are subatomic particles that have no mass and no electric charge.
Agree. Neutrinos, photons and gluons are all particles with no mass (or masses so small they have not yet been detected) and no electric charge.

2. Some particles can travel through billions of miles of matter without being stopped (or interacting).
Agree. Low-energy neutrinos have only very weak interactions with matter. They could travel a light year through matter with only a small probability of an interaction.

3. Antimatter is science fiction and not science fact.
Disagree. For every fundamental particle there is a corresponding antiparticle with opposite values for all charges. For bosons with all zero charges, however, there is no distinction between particle and antiparticle.

4. Particle accelerators are used for cancer treatment.
Agree. The advantage of particle beams over the more common x-ray therapy is that most of the radiation can be deposited in the tumor with less damage to surrounding healthy tissue.

5. The smallest components of the nucleus of an atom are protons and electrons.
Disagree. Protons and neutrons, not electrons, are the components of the nucleus. Protons and neutrons are themselves composite, made up of quarks and gluons.

6. Particles and antiparticles can materialize out of energy.
Agree. As long as the available energy , a particle of mass m and its corresponding antiparticle (also of mass m) can be produced. Since they have equal but opposite values for all charges, all conservation laws can be satisfied in such a process.

7. Particle physicists need larger accelerators in order to investigate larger objects.
Disagree. A larger accelerator produces a higher-energy beam that has a shorter wavelength (E = hc/) and therefore can be used to probe structure on smaller scales than a lower-energy beam. It is, however, true that a higher-energy accelerator can be used to produce and study higher-mass fundamental particles.

8. Magnets are used in circular accelerators to make the particles move faster.
Disagree. The force on a moving charged particle due to a magnetic field is always perpendicular to the motion, and therefore does not change the speed but only the direction of the motion. Magnets are used to steer the particles.

9. Work done by particle physicists at accelerators is helping us understand the very early development of the universe.
Agree. At the beginning of its development, he universe was densely filled with energetic articles. Only by knowing about all types of fundamental particles and their interactions can we understand what could have occurred in that period.

10. Gravity is the strongest of the fundamental forces of nature.
Disagree.The strength of any force depends on the situation, but in most situations for fundamental particle processes, gravity is a tiny effect compared even to the weak interaction. In everyday life gravity is an obvious force because we live close to an extremely massive object, the Earth. Like people, most things around us carry little or no electric charge, so we experience only the residual effects of electromagnetism, such as forces due to the rigidity or elasticity of matter and friction forces. But even these are stronger than gravity in many situations; gravity does not make you fall through the floor, for example.
We are also dependent on strong forces to bind the nuclei of atoms, but we do not notice processes due to either strong or weak forces except in radioactive

decays (for more details, see the table in the center of the Standard Model chart, under the heading "Properties of the Interactions").

11. There are at least 100 different subatomic particles.
Agree. There are over 100 types of particles that have been reliably observed and verified; many are now understood to be composites formed from quarks. Many more are postulated but very difficult to observe because they are extremely unstable. (Subatomic is interpreted to mean "smaller in size than an atom"; most such particles do not exist inside ordinary atoms but can be produced in high-energy collisions.)

12. All known matter is made of leptons and quarks.
Agree. All observed matter is leptons or composites that contain quarks. The photon, the W and Z bosons and the gluons, although observed as particles, are the carriers of the force field and are not usually called "matter."

13. The protons in the Large Hadron Collider (LHC) at the CERN lab in Geneva, Switzerland cross the French-Swiss border 11,000 times each second (without a passport).
Agree. Traveling at near the speed of light, the protons circle the LHC accelerator 11,000 times a second. The LHC straddles the French-Swiss border, so the protons cross the border 11,000 times each way.

14. Friction is one of the fundamental forces of nature.
Disagree. Friction is a secondary effect that results from electrical interactions between the atomic structure of one surface with that of a nearby surface.

15. The world's largest magnet (which is at a particle physics lab) weighs half has much as the Eiffel Tower.
Disagree. It weighs more than the Eiffel Tower (which weighs 9441 metric tons or 10,407 American tons). The magnet is contained within a large particle detector.

16. Many of the physicists who will run the particle physics experiments are still students in high school.
Agree. These experiments (which take about ten years to build) run for about 15-20 years. To train a PhD scientist requires about 8 to 10 years after high school, so students now in high school will later be the researchers in these experiments. The Large Hadron Collider at the CERN lab in Geneva, Switzerland is the most powerful accelerator in the world. There are also exciting neutrino experiments, astrophysical experiments, and others that are under construction. We expect they will make important discoveries throughout their lifetime.

Follow-up Activities

1. Suggest that students ask a parent or grandparent to explain what they were

taught about the theory of atoms when they were in school. Have the students use this as the foundation for ongoing discussions with family members as each of the activities in this program is completed.

2. Encourage students to choose one statement from the quiz and do further research on that topic. Schedule a time when they can report back to the class with their findings.