D. Gravitational, Electric, and Magnetic Fields

Gravitational, Electric, and Magnetic Fields
- Gravitational, electric, and magnetic forces act on matter from a distance.
- Gravitational, electric, and magnetic fields share many similar properties.
- The behavior of matter in gravitational, electric, and magnetic fields can be described mathematically.
- Technological systems that involve gravitational, electric, and magnetic fields can have an effect on society and the environment.

Specific Expectations
- Use appropriate terminology related to fields, including, but not limited to: forces, potential energies, potential, and exchange particles.
- Analyse, and solve problems relating to, Newton’s law of universal gravitation and circular motion (e.g., with respect to satellite orbits, black holes, dark matter).
- Analyse, and solve problems involving, electric force, field strength, potential energy, and potential as they apply to uniform and non-uniform electric fields (e.g., the fields produced by a parallel plate and by point charges).
- Analyse, and solve problems involving, the force on charges moving in a uniform magnetic field (e.g., the force on a current-carrying conductor or a free electron).
- Conduct a laboratory inquiry or computer simulation to examine the behavior of a particle in a field (e.g., test Coulomb’s law; replicate Millikan’s experiment or Rutherford’s scattering experiment; use a bubble or cloud chamber).
- Identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics).
- Compare and contrast the corresponding properties of gravitational, electric, and magnetic fields (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields).
- Use field diagrams to explain differences in the sources and directions of fields, including, but not limited to, differences between near-Earth and distant fields, parallel plates and point charges, straight line conductors and solenoids.

In 1916 Einstein expanded his Special Theory of relativity to include the effect of gravitation on the shape of space and the flow of time. This theory, referred to as the General Theory of Relativity, proposed that matter causes space to curve.

Four Fundamental Interactions

The four fundamental interactions are the strong force, the weak force, the electromagnetic force, and gravity. These forces are introduced when two particles encounter each other, they experience all four of the fundamental forces of nature simultaneously. The weak force governs beta decay and neutrino interactions with nuclei. The strong force, which we generally call the nuclear force, is actually the force that binds quarks together to form baryons (1 quark and an antinucleon). The nucleus of everyday matter, neutrons and protons, consist of the quark combinations uud and sdd, respectively. The symbol u represents a single up quark, while the symbol d represents a single down quark.

The force that holds nucleons together to form an atomic nucleus can be thought to be a residual interaction between quarks inside each individual nucleon. This is analogous to what happens in a molecule. The electrons in an atom are bound to its nucleus by electromagnetism: when two atoms are relatively near, there is a residual interaction between the electron clouds that can form a covalent bond. The nucleus can thus be thought of as a “strong force molecule.”

The force between two objects can be described as the exchange of a particle. The exchange particle transfers momentum and energy between the two objects, and is said to mediate the interaction. A simple analogy of this is a ball being thrown back and forth between two people. The momentum imparted to the ball by one person gets transferred to the other person when she catches the ball.
EYES ON THE MOON

In contrast to Earth, with its thick atmosphere and intense astronomical activity, the Moon is an ideal place for sensitive astronomical instruments. Earth’s satellite has no atmosphere to speak of—all of its air, at sea level pressure, could fit into a basketball arena. So, we can take advantage of this near-total absence of light and very low frequency radio waves to observe its surface unimpeded. And whereas Earth suffers some 10,000 powerful earthquakes annually, the Moon has only 500 gentle moonquakes a year.

As a potential site for a lunar observatory, many astronomers favor the Moon’s far side, which has a two-week night four times longer than Earth’s and is shielded from the planet’s radio noise by the body of the Moon itself. Lacking a direct line of sight for communications with Earth, the observatory could employ a relay satellite located near L2, one of five so-called libration points.

First described by the eighteenth-century French mathematician Joseph-Louis Lagrange, these invisible points of balanced forces, or libration, within any two-body system rotate as the system rotates about its common center of mass. The points may be visualized using the twentieth-century image of a gravity well in which bodies induce the fabric of space-time in proportion to their mass. Objects in the Earth-Moon system will roll into either Earth’s or the Moon’s well unless they lie precisely one of the libration points, where the extraneous forces of the rotating system balance the gravitational pull of the two bodies.