

TECHNOLOGY SEMINAR - 04

Sheldon L. Epstein

Bachelor of Science – Electrical Engineering, Massachusetts Institute of Technology

All science begins with a question in a format of: How? What? When? Why? Where? A scientist's or engineer's proposed answer to such a question is called a *hypothesis* (<http://en.wikipedia.org/wiki/Hypothesis>).

Scientists and engineers may formulate hypotheses from observations of physical phenomena (called the *empirical method*). Alternatively, they may use *deductive reasoning* to extend the scope of an existing hypothesis – including a hypothesis that has been discredited.

One interesting characteristic of all hypotheses is that they cannot be proven to be *True* because that would require *infinite* knowledge. Hypotheses can only be proven to be *False*, which generally means that they are of only limited or no value to scientific inquiry or practical use. Nevertheless, a false hypothesis may have practical value in limited circumstances or as a foundation for an enhanced hypothesis – as will be discussed below.

The language of science is *mathematics* (<http://en.wikipedia.org/wiki/Mathematics>). Mathematics is often used to describe or *model* relationships between attributes or variables defined in a hypothesis. For example, *Ohm's Law* (<http://en.wikipedia.org/wiki/Mathematics>) is a hypothesis that describes relationships between current, voltage and impedance or resistance in an electrical circuit. Similarly, *Darcy's Law* (http://en.wikipedia.org/wiki/Darcy%27s_law) is a hypothesis that describes relationships between the discharge rates of a fluid (e.g. water) through a porous material, fluid viscosity and pressure drop over a given distance.

Mathematics is also used to *test* a hypothesis to determine whether it is *False*. A mathematical tool most often used to test hypotheses is *Statistics* (<http://en.wikipedia.org/wiki/Statistics>), which itself is a science that allows scientists and engineers to focus on collection, analysis, and interpretation of data collected during tests of hypotheses. For example, *averaging* may reduce data errors caused by imprecise measurement instruments. *Probability theory* can help us judge whether a result from a test that supports or discredits a hypothesis is a result of random chance.

Hypotheses can have important cultural and social impact. One example that occupied mankind's thoughts for centuries in Europe is *The Earth is the center of the Universe* or, alternatively, *Rome is the center of the Universe*. Middle-Eastern variants include, *Jerusalem is the center of the Universe* and *Mecca is the center of the Universe*. History is replete with wars fought over the *Truth* of these hypotheses – despite the fact that scientists and engineers know that it is impossible to prove the *Truth* of any hypothesis. Today, it is generally agreed that our *Third Rock From The Sun* is not the center of the Universe; but, that was not the case 400-years ago.

In 1610, Galileo Galilei (http://en.wikipedia.org/wiki/Galileo_Galilei), a pioneer in use of telescopes in astronomy, published his theory – or hypothesis – that the Sun was the center of the Universe and that the Earth and other planets orbited around the Sun. He was subsequently convicted of heresy by the Catholic Church and sentenced to house arrest. It was not until 1992 that Pope John Paul II officially conceded that the Earth was not stationary.

Scientific inquiry did not end with Galileo's publications. One question that subsequently arose was *What mechanism caused Earth and other planets to orbit the Sun?* In 1687, Sir Isaac Newton (http://en.wikipedia.org/wiki/Isaac_newton) published his hypothesis of *Universal Gravitation*, which is now expressed in modern mathematical format as:

$$F = G \frac{m_1 m_2}{r^2}, \text{ where:}$$

- F is the magnitude of the gravitational force between the two point masses,
- G is the [gravitational constant](#),
- m_1 is the mass of the first point mass,
- m_2 is the mass of the second point mass,
- r is the distance between the two point masses.

(http://en.wikipedia.org/wiki/Universal_gravitation)

Simultaneously, Newton also published his *Three Universal Laws of Motion* (http://en.wikipedia.org/wiki/Isaac_Newton#Newton.27s_laws_of_motion):

1. An object at rest tends to stay at rest and that an object in uniform motion tends to stay in uniform motion unless acted upon by a net external force;
2. An applied force, \vec{F} , on an object equals the rate of change of its momentum, \vec{p} , with time ($\vec{F} = m \vec{a}$); and
3. For every action there is an equal and opposite reaction.

These *laws* went unchallenged for approximately 200-years before being proven *False* or at best incomplete. Nevertheless, almost all of us use them today for technical calculations where objects move at slow speeds.

Because man-made objects moved slowly and there was no instrumentation to prove otherwise, most scientists in Newton's time and for approximately 200-years more assumed that that light moved through *aether* and that it had no impact on the validity of *Newton's Laws*. That began to change in the 19th century as evidence began to accumulate that the *aether* did not exist.

James Clerk Maxwell's (http://en.wikipedia.org/wiki/James_Clerk_Maxwell) equations (http://en.wikipedia.org/wiki/Maxwell%27s_equations) were based on his 1864 publication stating that *light* is an *electromagnetic wave* that has a constant and finite *velocity of propagation* that now is identified by a constant, c . For some recent insight, see, <http://www.k9ape.com/publicservice/Faster%20Than%20The%20Speed%20of%20Light.html>.

Other experiments led up to the famous 1887 *Michelson-Morley experiment* (http://en.wikipedia.org/wiki/Michelson-Morley_experiment) that led to a hypothesis that *aether* did not exist. Albert Michelson subsequently joined the University of Chicago faculty and, in 1907, became the first American to win a Nobel Prize (<http://www.nobelprize.org/>) in Science.

In 1905 while working as an examiner in the Swiss Patent Office because he could not obtain a university appointment, Albert Einstein (<http://en.wikipedia.org/wiki/Einstein>) published four ground-breaking physics papers on a) the particle nature of light, b) Brownian or random motion of very small particles, c) special relativity and d) mass-energy equivalence or $E=mc^2$. At the time these papers were not considered important; however, today, they are recognized as tremendous achievements.

Of the four, Einstein's 1905 papers on:

- ◆ *Special Relativity* (http://en.wikipedia.org/wiki/Special_relativity), and
- ◆ *Mass-Energy Equivalence* (http://en.wikipedia.org/wiki/Mass%E2%80%93energy_equivalence)

led to the most controversy.

Basically, Einstein hypothesized that no mass could move faster than the speed of light. Given this predicate, it then followed that Newton's *Three Universal Laws of Motion* did not hold for *kinematics* where there was a mass moving at a *velocity* approaching the speed of light. He also predicted that gravitational effects on light would cause a shift in wavelength of light that would prove his hypothesis of a *space-time continuum*.

Einstein's theories caused a split in both the scientific community and European society, as well. Basically, Europeans considered Isaac Newton as the epitome of a Christian scientist and Albert Einstein was Jewish. Acceptance of Einstein's ideas was just as politically unacceptable in early 20th century Europe as Galileo's ideas had been 400-years earlier.

World War I interrupted the discord generated by the Newton-Einstein debate. However in 1919, a British astronomical team working in the Southern Hemisphere claimed to have confirmed Einstein's prediction of gravitational deflection of starlight by the Sun while photographing a solar eclipse. For many scientists, this evidence invalidated Newton's Laws.

Einstein was awarded a Nobel Prize in 1921 – but; not for his theory of *Special Relativity*. Einstein's Nobel Prize was awarded for theory of the *Photoelectric Effect*. It appears that a reason was that some of the prize committee members were biased against Jews, pacifists or theoretical physicists. Einstein was all three. Nevertheless, Albert Einstein is now recognized as the preeminent genius of the 20th century.

[N.B. Most of this paper is abstracted from www.wikipedia.org entries.]

This Technology Seminar note is at <http://www.k9ape.com/publicservice/PSM/TS04.pdf>. The INTERNET version contains active URL links for your convenience.