

A110G Exam #1

Science

Science is a discipline which seeks to describe the physical world and understand and explain its processes. (The physical world is that accessible to the human senses and their instrumental extensions.) Science presumes that the universe is causal, rational, and ultimately understandable. The basic tools of science are observation, experiment, and the precepts of logical reasoning. The application of science to understanding the physical universe is formalized in the Scientific Method. Indeed, the fundamental assumptions of Science, that the universe is causal, rational, and understandable, constitute testable hypotheses.

The Scientific Method

The Scientific Method is defined by the formalism inherent in its application. It consists of three fundamental components:

- **OBSERVATION:** The observations might consist of naturally occurring phenomena as things or processes or of the results of experiments. The results of observations and experiments should be repeatable. Ideally, the observations will be expressed in quantitative form and their uncertainties known or estimated.
- **HYPOTHESIS:** A scientific hypothesis is a tentative explanation of the phenomenon or the set of observations. It may be as simple as a description of a particular set of observations and the assertion that the behavior of the system will characterize the behavior of other systems. It may be an explanation of the observations in terms of existing understandings of the behavior of natural systems. In any case a scientific hypothesis will explain the observations in a way that it, at least, not inconsistent with other observations and well-established physical laws. It is a requirement of any scientific hypothesis that it be falsifiable. That is, it must have predictive power.
- **VERIFICATION:** A scientific hypothesis must have predictive power; it must offer explanations for phenomena or aspects of nature beyond the observations upon which the hypothesis was formulated. (Of course, even those observations must be subject to reconfirmation). It is the presence of testable predictions of this kind that really distinguishes a scientific theory from a mere hypothesis. A theory which fails to satisfy its predictions is said to be falsified; the theory must then be rejected as being "untrue"

The above process is generally iterative; an hypothesis might be modified in response to new information or if falsified. The modified hypothesis is subject to the same requirements as was the original.

Speculation: A tentative explanation of some phenomenon.

Hypothesis: An explanation meeting the above requirements with predictive power.

Theory: An hypothesis which provides verifiable predictions or tests and has failed none.

Law: Generally a hypothesis (or empirical rule) which has significant predictive power and has survived many tests of these predictions might be elevated to the status of a "law".

PTOLEMY, COPERNICUS, AND TYCHO

The **Ptolemaic System** was geocentric and geostatic. Motions of objects were described in terms of uniform and circular motions. In the most basic form of Ptolemy's system each object moved in a circular epicycle which moved, in turn, upon a circular deferent which was, at least approximately, centered on immobile Earth. The first epicycles were required to explain the phenomenon of retrograde motions; additional epicycles were later added to "fine tune" the Ptolemaic system. There were six kinds of objects, distinguished by the way in which they moved - or didn't: The Earth, the Moon, the Sun, the inferior planets, the superior planets, and the rotating celestial sphere which held the fixed stars.

In contrast, the **Copernican System** was heliocentric and geodynamic. The planets,

including the Earth, moved about the Sun in essentially circular orbits. (Epicyles were added only to fine tune the system; they were not needed to explain retrograde motions.) Only the Moon really orbits the Earth in the Copernican System. The celestial sphere is now static and Sun-centered, without the diurnal motion about the Earth as was the case in the Ptolemaic Picture. Note that in the Copernican System all of the planets move in basically the same way. Copernicus' system was basically simpler.

The **Tychonic System** was a a short-lived hybrid of its predecessors. It was geocentric and geostatic with the Moon, Sun, and the celestial Sphere rotating about an unmoving Earth - as in the Ptolemaic System. The other planets, however, rotated about the Sun as in the Copernican System. The Tychonic System also assumed uniform circular motions and employed a system of epicyles. However, as in the Copernican System, these were only needed for fine-tuning; epicyles were not necessary to explain retrograde motions.

Both the Ptolemaic and Tychonic system explained why no stellar parallax had (so far) been observed : it didn't exist because the Earth didn't move. Eventual demonstration that the Earth did move, and that stellar parallaxes did exist falsified both the Ptolemaic and Tychonic systems - but that didn't happen until much later than 1600. At the time, the apparent absence of this parallax was the strongest (valid) scientific argument against the Copernican view. However, the Ptolemaic model seemed to predict an incorrect sequence of planetary brightness variation whereas the Copernican and Tychonic models made successful predictions. Later observations (by Galileo) confirmed that the planets shone by reflected sunlight thus falsifying the Ptolemaic System. But Galileo's observations were consistent with either the Copernican or Tychonic pictures. Indeed, one could make the argument that, in 1600, the preponderance of evidence (planetary brightness variations and the absence of a detectable stellar parallax) actually favored the Tychonic view.