Exam 1 Answers                    Phsc/Hist 107

1) Assume you have a friend who is really into astrology. How would you try to explain to your friend why astronomy is considered a science, and gives reliable information about the way the Universe works, while astrology is not?

*Astronomy is considered a science while astrology is not because astronomy: 1) uses only natural causes to explain observed phenomena; 2) makes predictions which not only are testable, but those predictions agree with the test results far more often than not; 3) results are repeatable – anyone can make the same observation and get. the same result. The predictability part is probably the key difference, since astrology* ***does*** *make predictions, and they are often testable, but they very rarely come to pass. The explanations for observed phenomena from astronomy are based upon basic scientific laws from physics and chemistry, and don't require any special circumstances to apply – in other words, the same physical laws seem to apply all over the universe. Astrology is not based on any underlying scientific principles.*

2) What is the difference between knowledge of the natural world and science?

*It could be argued that knowledge of the natural world is the* ***beginning*** *of science. One definition of science is that of a set of experimental or observational procedures used to explore the natural world and to confirm or disprove theories about its behavior. Clearly in order to make a theory to explain some natural phenomenon, you must be aware of the phenomenon, which is part of knowledge of the natural world. But the main difference between these two is that science goes beyond knowledge of relevant facts about the natural world, and tries to explain why the natural world is the way it is. Knowledge would be that the Sun rises in the east and sets in the west. Science would be explaining that fact either by suggesting that the Sun orbits around the Earth, or that the Earth spins on its north/south axis.*

3) Summarize the basic level of astronomical knowledge of ancient societies before

ancient Greece. Why would we not consider this to be real science today?

*Ancient societies, even pre-literate societies, were clearly aware of basic observational facts about the sky, such as the period of the cycle of lunar phases, and the locations of the equinoxes and solstices on the sky. Ancient sites such as Stonehenge in England and Nabta in Egypt, just to name a few, illustrate that with the lines of sights of groupings of stones that point to the solstices and equinoxes. Early civilizations like those in Mesopotamia used such basic knowledge of astronomy to design solar and lunar calendar systems (365 days per solar year, 29 or 30 days per lunar month, 12 months per year). Later, Babylonians had developed the necessary tools to predict with reasonable accuracy future positions of planets, calculate the times of the solstices and equinoxes, predict eclipses, and predict rising and setting times for various objects. The Egyptians had much of the same knowledge, and also used sundials and observations of stars to design a timekeeping system to split night and day each into 12 hours. The Chinese made detailed maps and catalogs of stellar positions. The Mayans maintained an extremely complex calendar system, and were especially interested in observing Venus for religious reasons. They had also calculated the solar year to be 365.25 days and the lunar month to be 29.53 days, and could predict eclipses.*

4) Compare the influence of society on the way science was done in Hellenic Greece (e.g. Thales, Plato, Aristotle) to Renaissance Europe (e.g. Copernicus, Tycho, Kepler).

*In Hellenic (pre-Alexander) Greece, there was no official role for society (in the form of government) in science. Most scientists were philosophers who supported themselves by being independently wealthy, or tutoring the children of wealthy families, or by being doctors, architects, or engineers. Science was not taught as an official subject at schools, but rather scientists and their pupils had informal gatherings that eventually took on significant prestige, like Plato's Academy. Because the scientists were not paid to do science, they could think about any subjects they wanted, and many of these subjects were not of applied nature i.e. practical things that could be turned to immediate use. Instead many of them focused on "big picture" ideas such as the nature of reality, or of matter.*

*In Renaissance Europe, some scientists were employed as professors at universities, but these individuals did not contribute greatly to the major advances in scientific thought. The most historically relevant scientists were those who supported themselves by other work, much like the Ancient Greeks. Copernicus worked for the Church, Tycho and Kepler were courtiers to the Holy Roman Empire, and even Galileo quit his university position to work as Philosopher and Mathematician to the Medicis in Florence. In the Renaissance there was greater interaction between science and society, and the work of the scientists could often be of great value – such as Tycho's and Kepler's planetary tables being in great demand for use in astrology, or Galileo's improvements on the telescope making that device more practical for non-scientific uses. Maybe one of the biggest differences was in the degree to which society tried to impose itself on the* *activities of scientists during the Renaissance, especially in the form of the Church trying to suppress science that it did not like.*

5) Even though Plato had very influential ideas about science, and even proposed scientific theories, we do not consider him to be a scientist, while we do consider his student Aristotle to be a scientist. Why is that?

*Although Plato did propose a fairly comprehensive scientific framework to describe the natural world, his framework was developed from his preconceived notions on the nature of reality and the physical world. He did not use any evidence from the natural world, either experimental or observational to help develop or confirm his ideas. Aristotle, on the other hand, built upon some of Plato's ideas, but tried to tie them into commons sense notions of the material world. For example, he used the observation that heavy objects fall down to develop a theory in which heavy elements fall towards the center of the universe, and the heavier they are, the further towards the center they end up. This explains why water sits upon Earth (rivers, lakes, oceans) and air lies over top both.*

6) Describe in as much detail as you can the Ptolemaic model of the solar system. How did it explain retrograde motion? How did it preserve the idea of constant circular velocity for planetary orbits?

*The basic notion of the Ptolemaic model is that the Earth sits at the center of the Universe, and that in motion around the Earth in the heavens are various crystalline spheres to which the planets and the "fixed stars" are attached. The constant circular motion of these spheres drags their associated planets along, giving rise to the observed daily rising and setting of astronomical objects. Various layers of complexity were added as it became apparent that this simple model was not adequate. To explain retrograde motion epicycles were added. These were small circular motions that were attached to the spheres, so that a planet might complete two separate circular motions simultaneously. When it was observed that planetary motions were not at fixed, constant speeds but did vary in speed, Ptolemy added the idea that the Earth was not at the true center of these spheres, but the center was instead a point called the eccentric a short distance away from the Earth. When that proved insufficient, he added the concept of the equant, a second point off center from the Earth* ***and*** *the spheres, from which a person who observed the planets would in fact see constant, uniform circular motion.*

7) Why did Copernicus rebel against the geocentric theory of the Solar System that had prevailed for nearly 1,500 years? What was his scientific justification for placing the Sun at the center of the Solar System?

*Copernicus was unhappy with the Ptolemaic system because it was noticeably inaccurate in predicting planetary motions. The predicted location of a planet on the sky would be in the same general area as the actual location, but often they were not very close. Copernicus also thought that the introduction by Ptolemy of epicycles, eccentrics and equants meant that the motion of the planets under the system was not purely circular, and thus violated Aristotelean physics. Copernicus believed he could restore the simple, pure circles by putting the Sun at the center of the solar system, and making the Earth move around it as one of the planets. While this did remove the need for epicycles as an explanation for retrograde motion, it turned out that Copernicus did need to include epicycles anyway just to get the same degree of accuracy as Ptolemy for predictions of planetary motion.*

8) In 1577 Tycho Brahe made very careful observations of the motions in the sky of a comet. How did this series of observations influence his understanding of the Solar System? How did this bring Tycho into conflict with Aristotle's teachings on planetary motions?

*Tycho's observations of the comet showed that it was too distant to be a phenomenon of the Earth's atmosphere, and thus must be in "the heavens". But when he determined its motion, he noticed that it did not move on a circular orbit, as the planets apparently did. This was a problem for Aristotelean ideas of motion of heavenly objects, which taught that the planets and stars were fixed to solid, crystalline spheres that rotated around the Earth, making the planets and stars attached to them move. Each planet had a sphere of a different size, corresponding to their distance from the center of their orbit. If the orbit of the comet was non-circular, it could not fit within the nested set of crystalline spheres – it would crash into them as it moved around the Sun. Thus Aristotle's spheres could not really exist.*

EXTRA CREDIT (10 points):

9) What is the difference between a scientific theory and a scientific law? Use an example that illustrates this difference.

*A scientific theory is an explanation of some natural phenomenon that tries to tell us why that phenomenon occurs the way it does. A scientific law is a useful generalization about a known set of facts. The Law of Gravity, for example, tells us that if you release a ball, it will drop down towards the ground. The Law of Gravity does not tell us* ***why*** *it drops.*