Exam 2 April. 10, 2014 Phsc/Hist 107

Please answer the questions in your blue books. Answer each question as completely as you can. Partial credit will be given for partially correct answers. Each question is worth 25 points, and you must answer at least four of them. If you answer more than the minimum number, then only your best answers will be counted.

1) Based on the experiences of Galileo and Newton, describe the role of universities in the conduct of scientific research from the late 1500's to the early 1700's.

Based on the experiences of Galileo and Newton, the role of universities in conducting scientific research was minimal. In each case the curriculum was largely limited to that taught in medieval times, which for science meant Aristotle. Galileo was a professor at universities in Italy for much of his career, so while the university did not support his research directly, it did provide him with a job so that he could conduct research on his own in his spare time. Galileo's first job that specifically enabled him to work on scientific research was as "philosopher and mathematician" at the Medici court in Florence. Similarly, Newton spent most of his productive scientific career at Cambridge University, where natural science was not part of the official curriculum. He was employed as a professor of mathematics (which normally meant geometry at this time), but often lectured on the topics he was experimenting with, even those not mathematical in nature, like optics. So Newton derived income from his university job, but not much in the way of direct support for his research.

2) Describe how Maxwell's work on electromagnetism fits into the scientific method.

Maxwell's work was an attempt to explain a series of experimental results discovered by others, like Faraday for example. He eventually developed a set of four (relatively) simple equations that could successfully explain everything that was known about electricity and magnetism at that time. However, explaining what is currently known does not satisfy the scientific method. Once a theory has been proposed that does successfully explain things must then be used to make predictions. These predictions must be tested to see if they come true. In the case of Maxwell's theory, some predictions include the existence of electromagnetic waves (light) and radiation pressure. These predictions were eventually shown to be correct, thereby giving strong support for the theory.

3) Describe how astronomy helped foster a major change in our understanding of physics. Focus on the work by Galileo and Newton.

Astronomical discoveries provided motivation for a re-examination of physics,

especially in the physics of motion. Galileo was heavily invested in the Copernican theory and wanted to provide proof that it was correct. One of the biggest arguments against the idea that the Earth moved was that we don't feel the spin motion that would be necessary for the Sun to rise and set the way it does if the Earth was not the center of the solar system. Galileo used his research in physics, in part, to try to explain away this argument. In particular he studied the ideas of relative motion and inertia, and also attacked Aristotle's notions about how gravity works.

In the case of Newton, the development of the theory of gravity was greatly inspired by Newton's thinking about the orbit of the Moon, and ultimately deciding that the same force that causes things to fall down near the Earth could also cause the Moon's motion around the Earth. Another important influence of astronomy on Newton's physics work was the fact that it was a visit by Halley to Newton to ask about the shapes of planetary orbits that inspired Newton to begin thinking about gravity and the physics of motion once more. This ended up with him writing his masterpiece, Principia Mathematica*.*

4) Many scientists, including the ones we've discussed this semester, are very religious. Using any or all of Galileo, Newton or Faraday, describe how these scientists reconciled their religious faith with their scientific work.

Galileo believed that faith and reason (i.e. science) cannot be in contradiction because both come from God. If there is an apparent conflict, then the problem is probably in the interpretation of Scripture, which could possibly be misunderstood by fallible humans, whereas science merely describes reality, which cannot be in error, it simply is. In a more practical and political sense, Galileo tried to reconcile his work on heliocentrism with Church views by saying he didn't believe it was true, but was just comparing it to other theories.

Newton thought of his scientific work as a form of theology. It allowed him to come to a greater understanding of God by first understanding better God's creation. He also believed in an active God, and that the various physical phenomena that scientists studied were caused by the active presence and will of God. This is distinct from the "Divine Clockmaker" idea of God that would be held later on by Deists inspired by Newton's work.

Faraday was also a very devout person. He took the approach of compartmentalizing his religious and scientific lives. While he did not think at all that anything in science was contrary to religious beliefs, he did strive to maintain a sense of impartiality when he did his research, to keep his mind open to all possibilities. Like Newton, Faraday viewed his scientific work as part of an exploration of God's creation which would bring him closer to God.

5) How did Newton's optics experiments prove that white light is composed of all the colors of the rainbow, rather than colors being imparted to light when it interacted with objects.

Newton used a first prism to produce the rainbow of colors from sunlight. According to the traditional theory, the prism somehow put the colors into what had been simply white light. Newton then separated a single color from the spectrum and allowed that color alone to pass through a second prism. If the traditional theory was correct, the second prism should then produce all the colors of the rainbow once again. Instead, only the original color emerged from the second prism, proving that the color of light was a property inherent to the light itself, and that white light was a mixture of all the colors.

6) Which of the other famous scientists we've discussed so far is most like James Clerk Maxwell in terms of background, and their approach to science. Justify your answer.

There are any number of possible answers which can receive credit as long as there is sufficient evidence used to support your arguments. One possibility would be to compare to Newton, as both of them developed a mathematical based theories to explain observed phenomena caused by forces.

7) Describe the relationship between experiment and theory in the electromagnetic work of Michael Faraday.

Michael Faraday was an experimental genius who could devise a new apparatus to demonstrate a well known physical phenomenon, or invent something new to learn something new about physics. Faraday was not mathematically inclined, and tended to distrust theories, especially ones that made wild and or grand claims that could not be proven. Faraday would always criticize theory when it diverged from real experimental results. On the other hand, he did recognize the role of theory in providing explanations for experimental results, and tried his hand at making a theory to explain electromagnetic induction in 1831, introducing his concept of "lines of force" that surround magnets.

8) What are the differences between Faraday's "lines of force" explanation for how forces work and the older "action at a distance" idea?

Faraday introduced the "lines of force" concept as an attempt to explain electromagnetic induction. The greater the concentration of the lines, the stronger magnetic force was felt. He argued that these lines of force were the mechanism by which force was transmitted, and might extend beyond just magnetic force and apply to electricity and gravity as well. Because these lines would pass physically between, for example, the poles of a magnet, the space in

between the poles would be affected by them. Faraday also determined that the forces propagated by the lines of force did not occur instantaneously but rather took time to occur. The "action at a distance" idea held that forces propagated between interacting object instantaneously and did not influence the intervening medium. Many proponents of the "action at a distance" idea did not like Faraday's lines of force because they seemed to imply that it was necessary for there to be physical contact for forces to operate, which was an old, discarded idea that originated back in Aristotle's day.

EXTRA CREDIT (10 points):

9) Both electrical and gravitational forces follow an inverse square law that describes how the strength of the force declines as you increase distance from the source of the force. However, despite this important similarity, there is one extremely major difference and very basic difference in how these forces operate. What is it?

   The difference is that electricity and magnetism have two sources – positive and electric charges for electricity, north and south poles for magnetism. In contrast, gravity has only one source – mass. There is not positive or negative mass that give gravitational attractions or repulsions.