

PHYSICS 121 LB
Laboratory Manual
East Campus Edition

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East Campus edition by S. Hoell (Fall 2008)

Physics 121 LB
Laboratory Manual

Name _____

Instructor _____

Experiment Due Dates

<u>#</u>	<u>Title</u>	<u>Format</u>	<u>Due Date</u>
Exp. 1	Measurement	short	_____
Exp. 2	Linear Motion	short	_____
Exp. 3	2 – D Motion	short	_____
Exp. 4	Force	short	_____
Exp. 5	Gravity	short	_____
Exp. 6	Friction	short	_____
Exp. 7	Centripetal Motion	short	_____
Exp. 8	Work & Energy	short	_____
Exp. 9	Linear Momentum	short	_____
Exp. 10	Ballistic Pendulum	long	_____

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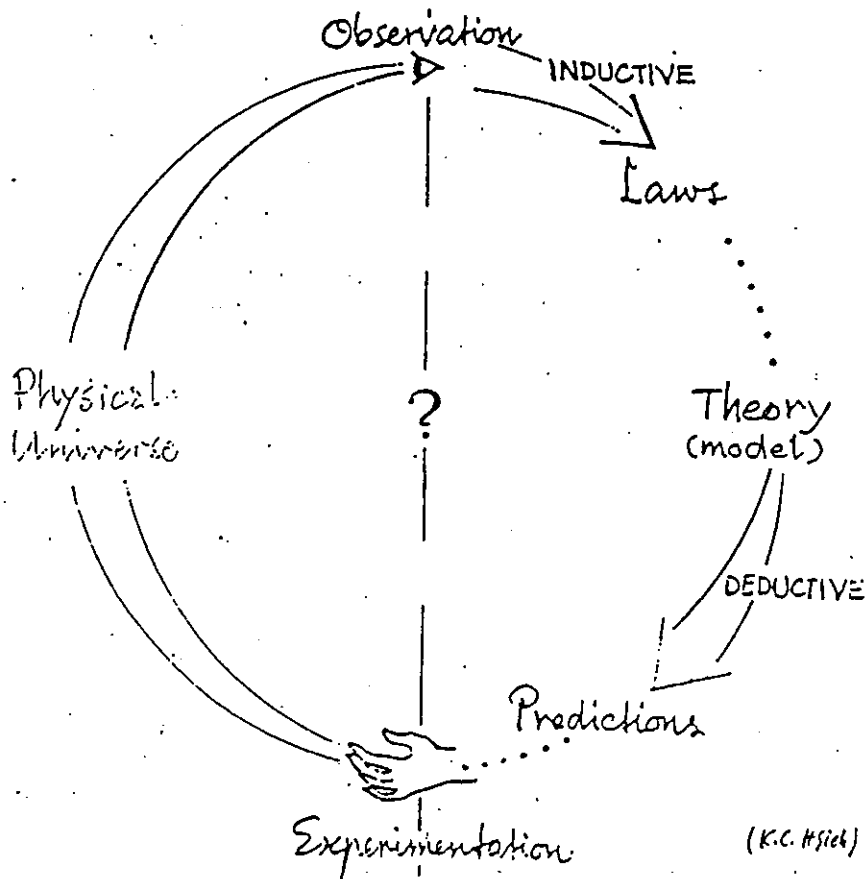
Where Physics is Learned

Steve Hoell

INTRODUCTION

Welcome to Physics 121 LB! Don't worry if this is your first Physics course. You will be surprised how much you already know. From infancy you have been exploring the physical universe about you, and now you will learn a (somewhat) disciplined way of discovering the laws of nature. This course is an Introduction to *experimental physics*, and it is by experimentation in a laboratory setting that you really learn how nature works. This is not to discount the lecture course Physics 121, for it is there that the concepts of physics are introduced and discussed. Actually it is possible to take Physics 121 LB without the lecture, but it is not recommended that you take the lecture without the lab!

Let's begin with a sketch of the scientific process:



The natural place to begin a scientific investigation of the physical universe is with an *observation*. How much can your eyes take in during a momentary glance? Perhaps more than you can ever make sense of. When we observe a phenomenon, we must pay attention to only a couple of features of the phenomenon and exclude everything else. Making an observation nearly always entails taking a *measurement* or a series of measurements. The data from these observations will provide a basis for

conclusions drawn from what is observed.

If we are judicious in what we choose to observe, we often find that the behavior of one quantity depends upon how another quantity behaves. By graphical or statistical methods, we can infer a *relation* between the quantities which is expressed mathematically as a *physical (or phenomenological) law*. The goal of many experiments in this course is the establishment of a physical law.

Our inquiry doesn't stop with a physical law because all we have is a relation between two variable quantities. It doesn't tell us anything about the underlying physics of what is going on in the situation. What we are ultimately seeking are the most fundamental laws of nature, and these laws are not borne out by superficial investigations. With some ingenuity, however, we can devise a *physical theory* that provides explanation for what we observe.

However interesting and intriguing a physical theory may be, it has almost no value until it is tested. The first step in testing a theory is to deduce the consequences of the theory - the phenomena which we hope to observe. Mathematically, if the physical theory is of the form of an equation then the consequences of the theory appear as solutions of the equation.

It is important to keep in mind that there may be several plausible theories behind a physical law and hence different consequences. To distinguish between theories, their respective consequences must be tested by means of an *experiment*, and designing an experiment which can differentiate one theory from another often requires considerable ingenuity as well.

Once experiments are designed and performed, new observations can be made, new laws are discovered and theories are refined. The cycle of scientific investigation never really ends; nothing is "proven." But the fund of knowledge continues to grow, and our conceptual grasp of the physical universe becomes ever more complete.

Just keep in mind that it took several centuries to attain our present picture of the physical universe, and you have just two semesters to understand it.

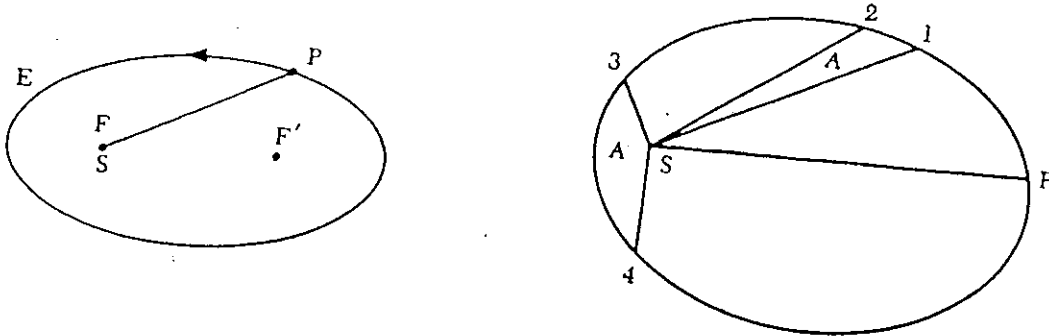
EXAMPLE: GRAVITY

What makes nature tick - as we currently understand nature from a physics point of view - are four fundamental *forces*. These forces are: the *gravitational force*, the *electromagnetic force*, and the *strong and weak nuclear forces*. One of the most profound discoveries of the latter half of the 20th Century is that the electromagnetic and the weak nuclear force are manifestations of a more fundamental force called the *electroweak force*. Physicists wonder if there is some force underlying all four fundamental forces. Several cycles of the above process have already been undertaken in this direction and there may be many more cycles to come. In this course, only the force of gravity will be studied with any depth.

Until the time of Copernicus (16th Century), it was widely believed that the earth was at the center of the known universe. Some astronomical observations suggested that

this was not so, and Copernicus proposed that the planets traveled in circular orbits around the sun, which was at the center of the solar system. Further observations suggested that the planets did not travel in circular orbits (Mars, in particular, exhibited a strange, wandering motion.) Very detailed observations of the orbits had to be made, and those were performed by the Danish astronomer Tycho Brahe in the early 17th Century.

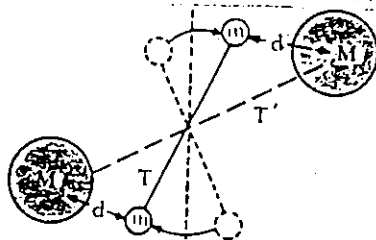
It was up to Brahe's assistant Johannes Kepler to "crunch the numbers" (it was around this time that the *natural logarithm* was invented for just such a purpose). From the massive set of Brahe's data, Kepler was able to extract three physical laws describing the motion of the planets.



The *Law of Ellipses* (1609) states that the orbit of each planet is an ellipse, the sun being located at one focus. The other focus is located in space and is not centered on any body. The *Law of Equal Areas* (1609) states that the line drawn from the sun to the planet sweeps out equal areas in equal times. The orbital velocities are nonuniform but vary in regular fashion: the farther a planet is from the sun, the more slowly it moves in its orbit. The *Harmonic Law* (1618) states that the square of the period of a planet relates directly to the cube of the planet's average distance from the sun.

But what governed the motion of the planets was still unknown. It took the genius of Issac Newton (17th Century) to propose an underlying cause: the force which we call *gravity*. The action of the force of gravity between two massive objects is captured by the mathematical expression called the *Universal Force of Gravitation*. From this expression Newton was able to derive Kepler's three laws of planetary motion. A byproduct of this investigation was the branch of mathematics called the *Calculus*.

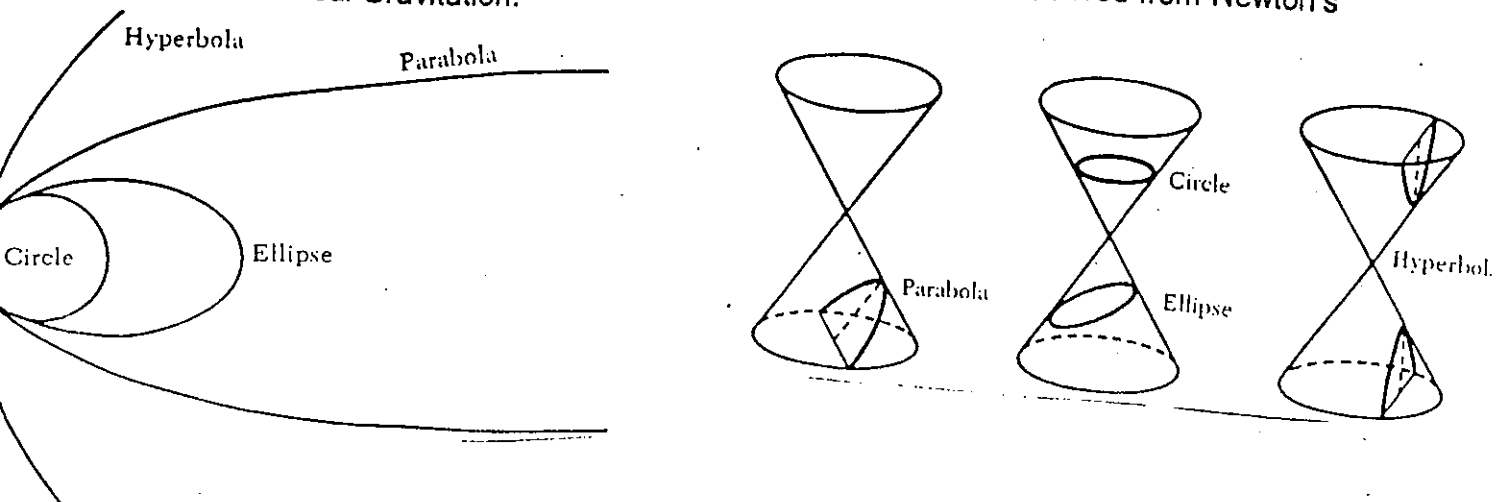
Still, the law of universal gravitation needed direct confirmation, and the scientist Henry Cavendish designed an experiment which not only detected a gravitational force but also yielded the numerical constant necessary for a quantitative estimate for the force between two massive objects. (See handout in lab for more details.)



Thus, one cycle of scientific investigation was completed.

The power of this law was such that it led to the prediction of the existence of an unknown planet. The planet Neptune was subsequently discovered in 1851. Then came some observational results that Newton's law of gravitation could not explain.

Other types of "conic section" orbits are possible - all can be derived from Newton's Law of Universal Gravitation.



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Then came some observational results that Newton's law of gravitation could not explain. First, the magnitude of the precession of the orbit of Mercury around the sun was beyond what Newton's law predicted. Then it was observed that light from distant stars was "bent" around the sun as it traveled from the star to the earth. This time it took the genius of Albert Einstein to discover a deep connection between gravity and the space it occupied. The theories of special and general relativity were postulated in the early 20th Century. These theories place the fundamental notions of space and time on an equal footing. The consequences of these theories did include the bending of starlight and the orbital precession magnitude. But further tests were needed. Finally a system was discovered which bore out several consequences of Einstein's general theory: a visible star rotating about a neutron star companion. The astronomical measurements of this system were precise enough to support the general theory, and the investigators Russell Hulse and Jack Taylor were awarded the Nobel prize in Physics in 1994.

Now it's your turn. The Physics Lab is a great place to start. I trust each of you will find this course a worthwhile episode of your personal intellectual journey. Best wishes!

References

- Feynman, Richard, *The Character of Physical Law*, (M.I.T Press, 1967).
- Hawking, Stephen (ed), *On The Shoulders of Giants*, (Running Press, 2002).
- Standage, Thomas, *The Neptune Files*, (Cambridge 2000).