

A Brief History of the Theory of Gravity (5-E Model)

Purpose

The purpose of this lesson plan is to use the 5-E model to give students a framework of understanding of how the theory of gravity has evolved over the course of history, in addition to introducing students to the modern understanding of gravity, and the problems associated with the modern theory. This lesson works as an introduction to a unit on gravity and Newton's Law of Universal Gravitation. By the end of this lesson, students will be able to describe theories of gravity under Aristotle, and Newton. Students will also be able to describe the major problem with the understanding of gravity in the modern context.

Safety Issues

Safety has been considered, but this lesson provides no notable hazards.

Relevant Virginia SOL's

PH.12 The student will investigate and understand how to use the field concept to describe the effects of gravitational, electric and magnetic forces. Key concepts include a) inverse square laws (Newton's law of universal gravitation)

PH.14 The students will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts include e) relativity; g) nuclear physics

Relevant NSTA standards

2a-b) Understand the historical and cultural development of science and the evolution of knowledge in their discipline; Understand the philosophical tenets, assumptions, goals, and values that distinguish science from technology and other ways of knowing the world.

3a) Understand the process, tenets, and assumptions of multiple methods of inquiry leading to scientific knowledge.

4a) Understand socially important issues related to science and technology in their field of licensure, as well as process used to analyze and make decisions on such issues

7a) Identify ways to relate science to the community involve stakeholders, and use community resources to promote the learning of science

Material and Resources

- Internet access with video display
- Copies of handout

Engage (15 minutes)

As the students walk in they will see the following written on the board/slide

THINK ABOUT NOW:

	Current Theory	Relative strength	Range
	QCD	1	Diameter of a medium sized nucleus
	QED	1/137	Infinite
	EWT	0.000001	A hundredth of the diameter of a proton
	GR	0.00000000000000000000 000000000000000000001	Infinite

THE HIERARCHY PROBLEM: WHAT BELONGS IN THE LEFT COLUMN? WHAT DOES RELATIVE STRENGTH MEAN?

Give the students an opportunity to guess at the meaning of the table and its numbers. After a short amount of time fill the table with the four fundamental forces, STRONG, ELECTROMAGNETIC, WEAK, GRAVITY. Briefly explain what it means to be a fundamental force that all interactions in the universe take place as part of these four fundamental forces and understood by the theories that describe them. Now ask the students what relative strength means. Explain the column, and the hierarchy problem associated with the relative strengths. To give students an idea of the relative strengths, pick up a paper clip with a simple bar magnet and hold it above. Explain to the students that the electromagnetic interaction allowing the miniscule bar magnet to hold the paper clip up, is beating out the gravity of the entire earth trying to pull the paper clip down. More so explain that the electromagnetic interactions of the atoms in holding the paper clip together are also winning over the gravity of the earth

Explain that this table represents an aspect of the standard model, the best, most widely accepted model of nature today, and that though gravity is one of the easiest practical forces to understand, ie “things fall down,” on the most basic level it does not nicely fit into the standard model and demonstrates an incompleteness in our understanding. Explain that this is not the first time in history a theory of gravity has seemed incomplete to us.

Explore (30 min)

Allow student to split into pairs and spread across the room. Students will read quotes throughout history that appeared under the Aristotelian and Newtonian views of gravity. Using these excerpts the students will attempt to summarize the two views of gravity as an in class essay.

Explain (30 min)

End the explore phase and explain to students that they may continue to take notes and add to their summaries as the research is “discussed” as a class in addition to a PowerPoint summarizing and extending the history of the two theories their context in a larger scientific and technological

progression and the idea of *paradigm* shifts in science. Emphasize Newton's Universal Law of Gravitation, its importance, its usefulness, and ultimately its incompleteness as a theory of gravity.

Elaborate (10 min)

http://www.youtube.com/watch?v=UV_X2B5OK1I&t=11m0s

Plan to stop this clip around 19:30. It serves as a very brief introduction to the theory of GR and its relation to Newton's theory of gravity. Briefly explain the evidence for GR by showing pictures of gravitation lensing.

<http://www.youtube.com/watch?v=Uy7rrrCQh2w>

If time permits or as a future extension into specifically special relativity.

Explain that the problem with GR is its incompatibility with parts of Quantum Mechanics. Explain that one of the great attempts of modern physics is finding a way to unify gravity with the three other fundamental interactions. The modern physical problem will be explained in detail later in the year when working with QM.

Evaluate

The attached rubric will be used to evaluate the student summaries. If time is still left in class, allowing students to evaluate their own work or that of a peer serves as an option.

Name: _____

Block: _____

From Aristotle to Newton: A Paradigm Shift

Explore and Explain: Read the quotes and excerpts provided. You will see two paradigms that describe gravity. The long standing Aristotelian view, and the Newtonian view of gravity that replaced it. Below try to piece together a summary of each theory.

For each summary include any mathematical relationships you can interpret and any evidence or everyday experience that supports the theory. Consider the differences in the nature of the theories, how do they describe the problem of gravity differently? Consider the technology necessary to test each theory. Site any confusing words or parts in the excerpts. Feel free to draw a picture to aid your explanation if necessary. As we go over the history as a class, feel free to modify what you have written. I encourage you to take notes on this handout, but write your summary on a separate sheet of paper that you will turn in for a grade. A rubric is provided.

“Some existing things are natural, while others are due to other causes. Those that are natural are ... the simple bodies such as earth, fire, air and water; for we say that these things and things of this sort are natural. All these things evidently differ from those that are not naturally constituted, since each of them has within itself a principle of motion and stability in place ... A nature is a type of principle and cause of motion and stability within these things to which it primarily belongs ... A nature, then, is what we have said; and the things that have a nature are those that have this sort of principle. All things are substances, for a substance is a sort of subject, and a nature is invariably in a subject. The things that are in accordance with nature include both these and whatever belongs to them in their own right, as travelling upward belongs to fire...” – Aristotle (~330 BCE)

“Every sensible body is by its nature somewhere.” – Aristotle (~330 BCE)

“A given weight moves a given distance in a given time. A weight which is greater moves the same distance in less time, the times being inversely proportional to the weights.” – Aristotle (~330 BCE)

“Bodies fall towards the earth as it is in nature of the earth to attract bodies, just as it is in the nature of water to flow.” – Brahmagupta – Indian mathematician (~600 CE)

“If the quicksilver (mercury) is poured into a vessel, and a stone weighing one hundred pounds is laid upon it, the stone swims on the surface, and cannot depress the liquid, nor break through, nor separate it. If we remove the hundred pound weight, and put on a scruple of gold, it will not swim, but will sink to the bottom of its own accord. Hence, it is undeniable that the gravity of a substance depends not on the amount of its weight, but on its nature.” – Vitruvius – Roman Engineer (~15 BCE)

“I greatly doubt that Aristotle ever tested by experiment whether it be true that two stones, one weighing ten times as much as the other, if allowed to fall, at the same instant, from a height of, say, 100 cubits, would so differ in speed that when the heavier had reached the ground, the other would not have fallen more than 10 cubits... But I... who have made the test, can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as much as a span

ahead of a musket ball weighing only half a pound, provided both are dropped from a height of 200 cubits” – Galileo (1638 CE)

“I deduced that the forces which keep the planets in their orbs must be reciprocally as the squares of their distances from the centers about which they revolve, and thereby compared the force requisite to keep the moon in her orb with the force of gravity at the surface of the earth and found them to answer pretty nearly.” – Isaac Newton (1666 CE)

“Every particle in the Universe attracts every other particle with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them. The direction of the force is along the line joining the particles.” – Isaac Newton (1666 CE)

“It is inconceivable that inanimate brute matter should, without the mediation of something else, which is not material, operate upon, and effect other matter without mutual contact, as it must be if gravitation in the sense of Epicurus be essential and inherent in it. And this is one reason why I desired you would not ascribe innate gravity to me. That gravity should be innate, inherent and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me a great absurdity, and I believe that no man who has in philosophical matters a competent faculty of thinking, can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial I have left to the consideration of my reader.” – Isaac Newton (1666 CE)

“Aristotelian "physics" is different from what we mean today by this word, not only to the extent that it belongs to antiquity whereas the modern physical sciences belong to modernity, rather above all it is different by virtue of the fact that Aristotle's "physics" is philosophy, whereas modern physics is a positive science that presupposes a philosophy.... This book determines the warp and woof of the whole of Western thinking, even at that place where it, as modern thinking, appears to think at odds with ancient thinking. But opposition is invariably comprised of a decisive, and often even perilous, dependence. Without Aristotle's Physics there would have been no Galileo.” – Martin Heidegger (1919 CE)

Rubric

Aristotelian Gravity Summary

	3	2	1
Organization and Development	Writer demonstrates logical sequencing of fully developed ideas	Attempted Logical organization, but ideas are not fully developed	No evidence of paragraph structure or logical organization
Use of Facts and Mathematic Relations	Writer apply uses quotes from the hand out or lecture and is able to describe both models with a mathematical relationship	Incomplete or incorrect mathematical description, or frequent misapplication of evidence	No attempt to describe the theory mathematically, Very little or no citation of evidence from the text or lecture
Mechanics and Language Usage	Less than 4 spelling, punctuation, or capitalization errors present.	Between 4-10 spelling, punctuation, or capitalization errors present.	Greater than 10 spelling, punctuation, or capitalization errors present.
Nature of Science	Writer makes a strong attempt to discuss the nature of science in his or her summary	Writer makes some attempt to discuss the nature of science in his or her summary	Writer makes no attempt to discuss the nature of science in his or her summary

Total: ____ / 12

Newtonian Gravity Summary

	3	2	1
Organization and Development	Writer demonstrates logical sequencing of fully developed ideas	Attempted Logical organization, but ideas are not fully developed	No evidence of paragraph structure or logical organization
Use of Facts and Mathematic Relations	Writer apply uses quotes from the hand out or lecture and is able to describe both models with a mathematical relationship	Incomplete or incorrect mathematical description, or frequent misapplication of evidence	No attempt to describe the theory mathematically, Very little or no citation of evidence from the text or lecture
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Total: ____ / 12