EDUB 2500 A44

Science Stories: The History of Science through Stories

Winter Term 2012

January 2012

Location: Rooms: 309 and 300, Education.

Time: 1:00 to 3:00 PM, Wednesdays and Fridays

Instructor:

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(Note: Ian Cameron of the Physics and Astronomy Department may be helping out in some of the classes).

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Office Hours: To be announced

"Lectorem delectando pariterque monendo"

"... Delighting the reader at the same time as instructing him"

Quintus Horatius Flaccus, (1. Century BCE

"History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed".

Thomas Kuhn, *The Structure of Scientific Revolutions*, (1964)

Course Description:

This course looks at the historical development of science in terms of the big ideas of the times, the contemporary mode of scientific reasoning and what was considered evidence to support these big ideas. This will be done by way of a narrative approach, a series of well-crafted stories. These stories will constitute a scientific argument...Referring to the above quote, we could interpret the idea of Flaccus the following way:

“Instruction and learning is more fruitful if it is also entertaining”.

And Thomas Kuhn, the famous historian of science, is saying:

“When we use the history of science to teach scientific concept we must go beyond anecdotes and the memorization of dates.”

Science stories in general may be entertaining but are often not significantly instructive. Such well-known stories as Archimedes’ discovery of the law of flotation, Galileo’s inclined plane experiment, and Newton’s response to the falling apple are good examples to illustrate this. What is required, therefore, is a good knowledge of the historical context in which the story is imbedded and be acquainted with the main ideas and scientific concepts of the time. The objective of this course is to give future science teachers a good sense of chronology and a self-confident knowledge of the history of science that allows them to write narratives that entertain and instruct at the same time.

Three historical periods are studied:

1. **Greek Science** (sixth century BC to the second century AD);
2. **The scientific revolution** (from about 1500 to about 1700); and
3. **Modern science** (from about 1700 to the 20th Century).

Based on the presentation of science stories and class discussions of these historical periods students will design “science stories” to present to class. These stories can be seen as contributing to a deeper understanding of science as well as providing contexts that allow the development of hands-on teaching that can be used in the science classroom. The pedagogical assumption for creating these contexts is based on recent findings in science education. Research strongly suggests that the narrative mode of science presentation leads to a firmer understanding of science concepts.

What counts as achievement in science in a given historical context will have to be defined, as well as the science methodology used clarified. In highlighting an achievement, such as Archimedes' law of flotation, for example, the richness of the historical setting will be emphasized. This will done by the narrative mode, by telling stories. In conclusion, this approach will acquaint the future science educator with historical context, the nature of science and the educational possibilities in presenting all this to the young science student.

Resource Materials:

The following books , available in inexpensive photocopied form, should be bought:

a. *Short History of Science to the Nineteenth Century*, by Charles Singer. Available at the University Bookstore.

b. *A History of the Sciences*, by S. Mason. Available in the University bookstore

Other books recommended:

a. *Harvard Project Physics*. Available from instructor, given for overnight reference only

b. *Making Modern Science: A Historical Survey*, by Bowler P. and Rhys Morus, Ivan. Available from instructor, given for overnight reference only.

3. Simple laboratory equipment available in conventional science labs.

4. Articles available in such journals as *Science Education, Science & Education, Science Teacher, Science and the Child, Chemistry Teacher, Biology Teacher, Scientific American, Physics Teacher, Physics Education, International Journal of Science Education, American Scientist,* and *New Scientist.*

5. The Internet: Reflective and judicious use of the Internet is expected.

Course Objectives:

1. To give the student a fine sense of science history, according to the injunction of Thomas Kuhn (the introductory sentence of his famous *The Structure of Scientific Revolutions*):

History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science by which we are now possessed.

2. To acquaint the student with the richness of the scientific imagination that the conventional science study in formal courses based on textbooks cannot give.

3. To provide the student with an opportunity to engage in several small exercises of original historical research in science by way of a science story.

4. To have the student develop an appreciation for the difficult task scientists had to face in *every* historical period in trying to understand the world.

5. To assist the students in developing a number practical, hands-on contexts, in which young students can learn to engage the world according to their own predilections and understanding.

6. To give prospective science teachers a background for applying the findings of the history (and some philosophy) of science to their every day teaching.

7. To give students a good understanding of the nature of science, especially the deep connection between *science content* and *science processes* .

8. To help students develop the habit of looking at scientific activity by way of the *Contexts of Inquiry* found in the contextually based science story approach that **implicitly** contains such conventional process notions as *observation, inference, hypothesis, theory, and experiments.*

A thematic approach will be used, based on the presentation of the "big ideas" of science, and when possible, key- experiments and concepts that support these ideas.

ASSIGNMENTS I and II Value: 40% (20% each)

Students (in groups of two) will be asked to prepare two *historical contexts*, taken from the three historical periods , written and presented in a science story form, taken from two different historical periods.

The format as well as the content of these are discussed in the section called *Historical Contextsand Science Storie* on pages 6-13. Presentations should be done in PPt accompanied by demonstrations. Time allots for each presentation will be about 30 min.

These contexts will serve to initiate and encourage class discussion.

Students should summarize their presentations on **1 page only** (both sides) and hand these out to each member of the class, before the beginning the presentation.

The instructor (with Ian Cameron) will present the first story, a story about the scientific thinking of Aristotle.

Your Task: In preparing and presenting a historical context by way of a well-crafted story, pay attention to

THE DESCRIPTION OF THE HISTORICAL CONTEXT :

the scientific ideas of the historical period and how they are connected to the topic

THE MAIN IDEAS AND EXPERIMENTS INVOLVED: Main ideas and/or empirical support for what is central to the historical context. If possible, these demonstrations should also involve the students in the audience.

QUESTIONS AND PROBLEMS BASED ON THE HISTORICAL CONTEXT

Each story presentation should conclude with 3-4 questions and inserted into your one-page summary to students. These questions and problems must be discussed with the instructor prior to printing out your one-page summary.

A DRAFT OF A STORY THAT YOU PRESENT TO THE STUDENTS.

The questions posed will be discussed in the next class, presented by the students who developed the story

ASSIGNMENT III : (20%).

Write a publishable science story (as an article in science education journal)) based on Assignment I or Assignment II, about 2000-3000 words.

Assignment Format:

Suggested exercises in **Class Assignments must** be typed and neatly presented. The cover sheet must identify the assignment as well as bear the name of the instructor. Assignments must be handed in on or before the agreed schedule of dead lines.

ASSESSMENT:

ASSIGNMENT I, **II** (Historical Contexts):	40%, (20% each).
ASSIGNMENT III (A publishable science story)	20 %
MIDTERM TEST	15%
FINAL EXAM	25%
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	100%

Final letter grades will be determined as follows:

A+	**95-100**	**Exceptional**
A	**90-94**	**Outstanding**
B+	**85-89**	**Excellent**
B	**80-84**	**Very good**
C+	**75-79**	**Good**
C	**70-74**	**Satisfactory**
D+	**65-69**	**Pass**
D	**60-64**	**Borderline**
F	**<60**	**Fail**

Description of historical contexts that provide the background of the science story you are developing. (Assignments I and II)

In preparing for the story presentation, pay attention to the following:

1. All presentation should be made on PPt.
2. The PPt presentations should include demonstrations, using drawings, sketches, and simple apparatus that are part of your story.
3. One page of typewritten paper (with both sides used) should be given to all students, either prior or at the end of the presentation (see the example handed out on Day 1).
4. The paper handed out should follow the format given below:

THE DESCRIPTION OF THE HISTORICAL CONTEXT IN WHICH YOUR STORY IS IMBEDDED

THE MAIN IDEAS AND PERSONALITIES INVOLVED

QUESTIONS AND PROBLEMS FOR THE STUDENT

(About 3-4 questions, at least one being a problem that requires a quantitative solution. These questions will be taken up at the beginning of the next class, led by the presenters).

A DRAFT OF YOUR STORY

You can present your story in the following "forms"

1. As a <u>conventional story</u> that is presented by both students.
2. As a dialogue between the scientist (natural philosopher) chosen and his/her student.
3. As dialogue between two scientists of opposite viewpoints (different "theories"..
4. A dramatization of an important event

Historical contexts available you can use as the background for your story.

Prepare one of the following contexts and frame a story that uses that context. Begin by briefly outlining the *historical context*, present the *main ideas and personalities* and then outline your story.. Problems and questions should naturally arise from the context of your story.

Note: The presenters of the historical contexts/stories are expected to meet with the instructor prior to the class presentation. The hand-out prepared as well as the demonstrations planned must be discussed and approved. The PPt used must also be reviewed and approved by the instructor.
The following are some details that you can use in your story presentation:

1. **Aristotle's physics of motion (Instructor and Ian Cameron)**

Aristotle's ideas of motion using simple demonstrations, told in the context of a dialogue between Aristotle and one of his students, the young Alexander the Great. Alexander was a student of Aristotle for three years. We are describing his last meeting with the Master, at the age of 16, at the age when he was asked by his father, Phillip of Macedonia, to represent him at home while he went to war. In this last meeting Alexander thanks Aristotle for his wisdom and mentorship in philosophy in general, but is finally interested in the physics of motion and forces, in preparation for his military role in the future.
By dropping small spheres into large graduate cylinders Aristotle's conclusions about free fall are tested. A number of well-sequenced activities that allows the student to study (and sometimes challenge) Aristotle's physics of motion. Aristotle discusses the following:

a. Free fall of light and heavy objects. (For light objects like leaves and paper Aristotle's physics seems to work).
b. Objects falling through a medium like water or oil. (Aristotle's physics here was quite good.).
c. Aristotle's anticipation of the law of inertia. (Some historians of science suggest that he "almost got it right").
d. His notion that forces are either natural or violent. Discuss examples of such forces around us.

e. His insistence that terrestrial physics and celestial physics must be separated.

2. **The Ptolemaic model of the solar system. (Ian Cameron)**

Ian Cameron will demonstrate models by way of applets, illustrating Ptolemy's solution to Plato's problem and how the sizes of the earth, moon and the sun, and the distances between them were determined. The problem of scaling will be illustrated.

3. The beginnings of geometry.

1. Briefly outline the historical context Thales, an Ionian scientist, circa 600 BC).
2. Set up a number of well-sequenced activities that involve the student in "discovering":

   a. How to determine the distance across a river,

   b. How a captain of a ship might have found the position of his ship relative to the shore,

   c. How such exercises hinted at developing the beginnings of a generalized geometry involving deductive reasoning.

   Make up a plausible story that captures the interest of the student.

4. Pythagoras and he mathematizationof the world.

Discuss Pythagoras' ideas about how mathematics relates to the world. Demonstration of this relationship using musical instruments. The modern (19th century) solutions to the three outstanding mathematical problems discussed. Zeno's paradoxes will be illustrated with drawings and models.

1. Briefly outline the historical context (Pythagoras, circa 530 BC). Make up a plausible story that captures the imagination of the student.
2. Set up a number of well-sequenced activities that involve the student in "discovering":

   a. The structure of triangular and square numbers, the relationship between their shape and their corresponding number.

   b. "Perfect" and "amicable" numbers. Let the student imagine himself/herself as a member of the secret Pythagorean society, making up simple games involving *magic squares* and *golden rectangles* .

c. The mathematical relationship (simple ratios) between the notes of the musical scale and the lengths of vibrating strings and columns.

d. Pythagoras' theorem by making measurements on large right angled triangles.

e. The sum of an arithmetic sequence, the solution to the "number of grains on a chessboard' problem.

f. Other activities.

5. The three laws of physics that the Greeks discovered.

Set up a number of well-sequenced activities that involve the student in "discovering", as well as in working out problems, using these laws. Your story should show:

a. How the law of reflection *might* have been discovered.

b. How the law of the lever *might* have been discovered.

c. How the law of flotation *migh*t have discovered by Archimedes.

These three laws should be tested using simple equipment and models. Stories about how Archimedes used these three laws in designing "war machines" should be examined.

6. The three unsolved problems in Greek mathematics.

Set up a number of well-sequenced activities that show the student why these three problems were considered "unsolvable". It is *suggested* that you discuss especially:

a. The problem of "trisecting a triangle", probably first proposed by Plato.

b. The problem of "doubling the volume", (or the so-called *Delian* problem), i.e. the problem of what dimensions would double the volume of a cube.

c. The problem of "squaring the circle", i.e. the problem of how to construct a square that has the same area as a given circle. This problem was first worked on by Anaxagoras and later partially solved by Hippocrates of Chios.

7. "Measuring" the size of the earth.

This is the story of how Eratosthenes "measured" the size of the earth. It was first successful "measurement" of the dimensions of the earth.

Set up a number of well-sequenced activities that involves the student in making scale drawings to determine these distances. The mathematics used should not involve more advanced concepts than notion the of ratios.

8. How the Greeks measured the distances to the moon and the sun.

Set up a number of well-sequenced activities that involves the student in making scale drawings to determine these distances. The mathematics used should not involve more advanced concepts than notion the of ratios.

a. Briefly review the story of how Eratosthenes "measured" the size of the earth.

b. How the Greeks calculated the distance to the moon and to the sun. Use large-scale drawings in your exercises.

c. Why the Greeks were unable to find the distances to the planets. Suggest reasons for their inability to do so.

9. Aristotle's biology and Hippocrates' medicine

Aristotle is regarded as a great biologist. Present his contributions to biology. Hippocrates is considered the "father of modern medicine". See especially Singer's book. Here you will find a very comprehensive discussion of the biology and the classification scheme of Aristotle. The Internet is a good source for studying the ideas and the works of Hippocrates.

10. Copernicus' model of the solar system

Recount the objections of the contemporaries of Copernicus to his theory. Set up demonstrations and arguments for students to defend his theory. These demonstrations and arguments should be simple, assuming no previous knowledge of physics. See especially *Harvard Physics Project.* Copernicus' heliocentric model should be compared to the geocentric model of Ptolemy.

11. Aristotelian objections to Copernicus' theory of the heavens.

Recount the objections of the contemporaries of Copernicus to his theory. Set up demonstrations and arguments for students to defend his theory. These demonstrations and arguments should be simple, assuming no previous knowledge of physics. Note: <u>You can use my dialogue between a Copernican and an Aristotelian</u>

12. William Gilbert and the magnetic field of the earth.

Gilbert worked along Baconian principles of scientific investigation: making sense of observations without being guided by hypotheses and mathematical analysis. This approach is not unlike what older, serious-minded children use in exploring the world. Read the excerpts of his *De Magnete* and set up a number of well-sequenced activities that involve the student in "discovering" the magnetic field of the earth. Have the student suggest a model for this field that can be tested.

13. Kepler's laws of planetary motion (Instructor)

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1. Tycho Brahe's exemplary naked eye measurements will be discussed with reference to accuracy.
2. A simplified reconstruction of Kepler's twenty year quest to establish his laws will be presented.
3. The fascinating history of the quest for a routine method to establish latitude on board of a ship will be given.

14. Galileo and his telescope: "The Starry Messenger".

Galileo was one of the developers of the telescope. He used it to show that the surface of the moon is not smooth, that Venus has phases, and that Jupiter has moons that revolve around it in a predictable way.

You could have a student pretend to be Galileo, and others to be representatives of the church. Work out a dialogue between Galileo and the representatives of the church in which the confrontation between the Aristotelian teachings of the church and the new world system becomes apparent.

Galileo showed that there are mountains on the moon and there is another "solar system": A vindication of Copernicus. See also my play about Galileo and Kepler on my website.

15. Harvey's discovery of the circulation of the blood.

Reconstruct this famous discovery by reading Harvey's own account of it. Sequence your activities chronologically.Recommended for students of biology.

16. Galileo's inclined plane experiment

Look up Galileo's description of this famous experiment and adapt it to a class room. Do not use mathematics beyond ratios. Recommended for students of physics only.

17. Torricelli's experiment: "The weight of the atmosphere".

Torricelli determined the pressure of the atmosphere, using his famous method of the mercury tube.This is one of the earliest 'controlled' experiments in science. Torricelli's experiment will be discussed in detail and the Torricelli tube demonstrated.

18. Boyles' law: "Testing the Springiness of Air".

Look up how Robert Boyle (with the assistance of Robert Hooke) discovered his law. Set up activities to test this law. (Instructor will assist in demonstrating the law, using a U-tube and mercury). Recommended for chemistry and/or physics students.

19. One day in the life of Robert Hooke, the secretary of the *Royal Society*.

Robert Hooke was probably the most prolific applied scientist of the 17th century. Read about his contributions in the assigned *Scientific American* ***article*** and pretend that you and his assistant are presenting a newly discovered device or principle to the *Royal Society.*

20. Newton's laws of motion.

Discuss Newton's laws of motion and the law of universal gravity:

1. The motion of free fall,
2. The oscillation of a pendulum,
3. How planetary movement and tidal forces are connected: show how his physics seemed to be applicable to describing the motion of the planets as well as the motion of "particles" in a gas.

   Recommended for students of physics. See my article "The History of Force..." Can be downloaded from my website.

   (Instructor will assist with this important context).

21. Roemer's determination of the speed of light.

It was the Danish astronomer, Olaus Roemer, who, in 1676, first successfully measured the speed of light. His method was based on observations of the eclipses of the moons of Jupiter (by Jupiter).

...Roemer's estimate for the speed of light was 140,000 miles/second, which is remarkably good considering the method employed.

The above statement is a typical one found in textbooks. Did he actually calculate the speed of light? What did he really set out to show?

22. The development of modern chemistry, from the phlogiston theory to Lavoisier.

Demonstrations will be done to illustrate the confrontation between the phlogiston theory and Lavoisier' new chemical theory. The foundations of the "New Chemistry" will be presented. Usually done by the instructor.

23. Count Rumford and the caloric theory of heat. (Instructor).

Rumford's famous experiments that founded the heat theory of the eighteenth century will be discussed. About 30 years later, the French scientist Sadi Carnot's argued that limit there is alimit to the energy output of any energy transformation device, such as a steam engine and an internal combustion engine, thus anticipating the first and the second law of thermodynamics.

24. Dalton's atomic theory.

Discussion of the "scientific method" used by Dalton to establish his atomic theory. He seems to have based his arguments on a number of assumptions, each of which were either logically fallacious, or physically wrong. Separation of water into hydrogen and oxygen will be demonstrated. Discussion of why Avogadro's hypothesis and Gay-Lussac's experiments strengthened atomic theory. The story of Mendeleev's attempt to build an organizing model based on the physical and chemical properties of the elements.

25. Stephen Hales and *the circulation of sap in plants.*

The English scientist and clergyman Stephen Hales (1677-1761) pioneered the study of plant physiology, contributed the first major account of blood pressure, and invented a machine for ventilating buildings.

Use the above quote to discuss the ideas and the experiments performed by this ingenious early plant physiologist.

26. Biology in the eighteenth century

Discuss Linnaeus' system of classification in biology that was then further developed by Lamarcke, and is essentially still used today. Elaborate on Erasmus Darwin's theory of evolution and Cuvier's belief in the fixity of species.

27. The Cell Theory and the question of the spontaneous generation of life.

Read about the development of the cell theory from the development of the microscope to Pasteur's experiments to show that life cannot be produced from non-living matter. The elegant early experiments of Redi (17th century) and Spallanzano (18th century) that suggested that life only came from life are especially suitable for early science instruction.

One or two of Pasteur's experiments to show that life can only come from life (that cells can only arise from pre-existing cells) may also be suitable to early inclusion in science education.

28. Darwin's "Voyage of the Beagle"

Give an account of Darwin's intellectual odyssey that led to the statement of the theory of evolution. Your story should include Darwin's debt to Malthus, Lamarck and to his grandfather, Erasmus Darwin.

Mention why he had a profound disagreement with Cuvier, especially with Cuvier's belief in the fixity of species. Discuss the fruitfulness of his lifelong friendship with the great geologist Charles Lyell and the noted biologist T.E. Huxley should be discussed. Finally, you could touch on the profound difficulties such physicists as Lord Kelvin had in trying to reconcile the bible, geological dating and the methods of thermodynamics.

29 Lord Kelvin and the Age-of-the-Earth controversy.

The fascinating story of Lord Kelvins debate with the geologists about the age of the earth. The debate is interesting because 1. it involved 'non-scientific ideas' and 2. the argument was 'premature' since nuclear energy had not yet been discovered. Much of this presentation will be based on the instructor's play o9f the same title. See the instructor's website for an article as well as a play about Lord Kelvin and the Age of the Earth. The play is called "The "Age-of-the- Earth" debate.

30. The study of electricity, from the Voltaic Cell to Faraday's laws of electrodynamics

(Presented by instructor) this 3-hour workshop will given in Room 300.

Franklin's model of electricity is tested by students using electroscopes. Coulomb's experiment discussed. Volta's experiments partially replicated using simple equipment and HCL solution. Simplified demonstrations of Faraday's famous electromagnetic experiments. Using a Teltron deflection tube a simplified version of the Thomson's experiments is given.

Franklin's model of static electricity

Volta's experiments with electric batteries.

Oersteds demonstration of magnetic field around a current carrying wire.

Faraday's electromagnetic experiments.

Franklin's model of electricity is tested by students using electroscopes. Coulomb's experiment discussed. Volta's experiments partially replicated using simple equipment and HCL solution. Simplified demonstrations of Faraday's famous electromagnetic experiments. Using a Teltron deflection tube, a simplified version of the “electron gun” constructed by J.J. Thomson in 1897, will be used to replicate this famous experiment.

31. Mendel’s laws of inheritance.

32. The story of penicillin

READING ASSIGNMENTS:

Only assignment 1 and 4 are to be handed in.

Assignments 2 and 3 should be prepared for class discussion only.

Reading Assignment 1. (To be handed in).

The following questions, problems and situations are based on *The Scientific Revolution* , by Herbert Butterfield. In addition, it is assumed that you have access to such books as *A History of the Sciences,* by Stephen F. Mason. Prepare your answers by making notes and have these ready for class discussion.

1. Butterfield closes his introductory remarks with this statement: "It would be interesting to know why Western man, though he started late, soon proved himself to be so much more dynamic than the peoples farther east". Comment briefly.

2. Butterfield implies that the preoccupation with the recovery of the lost learning of ancient Greece and Rome was a *necessary*, but not *sufficient* precondition for scientific progress. One is immediately reminded of the struggle of such outstanding figures as Copernicus, Galileo and Harvey. Copernicus spent a great deal of time mastering Ptolemy's *Almagest*, Galileo had to come to terms with Aristotelian physics before he could go on with his studies in kinematics, and Harvey studied the works of Galen thoroughly before going on with his work on the circulation of the blood. Expand on these statements and suggest other important figures in this period who had to come to terms with the ideas and accomplishments of the ancients before going on.

3. It is arguable that modern science emerged partly from the laboratories of such artist-craftsmen as Albrecht Dürer and Leonardo daVinci: they embarked on interrogating nature directly. Butterfield reminds us, however, that they could not get far "because the modern scientific method had not

yet emerged". What do you think Butterfield could have understood by "scientific method"?

4. Butterfield reminds us that the compass, gunpowder, and the printing press were technological inventions that "had not been handed down from classical antiquity". First find out how these were developed or discovered and then briefly discuss in what ways these set the stage for the scientific age.

5. Compare the "sciences" of Frances Bacon (exemplified by the experiments on magnetism by Gilbert) and Galileo. Both men claimed that their work was based on the *inductive method* of discovery. Inspite of this claim they had fundamentally different approaches to the investigation of nature. In what essential features were their approaches different?

6. Many scholars argued that a mere shift of the frame of reference does not necessarily result in a superior description of phenomena. Comment.

7.Compare the astronomies of Ptolemy and Copernicus with respect to the following:

a. The presuppositions they make about the world.

b. The degree of conflict with the teachings of the church.

c. Observational precision of the motion of stars and planets.

d. Scientific validity, as understood in the 16th century.

Reading Assignment 2: (<u>To be prepared for class discussion only</u>)

The following questions, problems and situation are based on <u>GALILEO</u>, an article written by the famous historian of science Bernard Cohen. Prepare your answers and have these notes ready for class discussion.

1. Why does Cohen think that "The example of Galileo provides one of the best possible arguments for the need of a continuing and increasing scholarship in the history of science"? Briefly discuss.

2. The Canadian Galileo-scholar Stillman Drake took up Cohen's challenge

and wrote several (five?) articles on Galileo in Scientific American, between 1973 and 1985. Using a Scientific American Index, trace these articles. In addition, point out others that have been published during that time on the science history, especially those that are relevant to this course.

3. Galileo predicted that "the new star", sighted in 1604 would "vanish into obscurity". On what grounds did he decide that what was seen in the sky was "a new star"? Why was this considered "a bold assertion"?

4. Discuss how the development of the telescope helped to "vindicate the Copernican idea".

5. List the observation Galileo made with his telescope. How did these observation place Aristotle's ideas into question?

6. How did these observations confirm Copernicus' ideas?

7. Explain how Galileo's discovery of the phases of Venus challenged the accepted Ptolemaic system.

8. Try to reconstruct the "method" Galileo used in establishing his law of free fall.

9. Give an example of a "thought experiment" relating to free fall. Why are "thought experiments" considered so compelling?

10. Read the paragraph on page 46, beginning with..."Galileo's writings abound...". Compare the views of Cohen with those of conventional textbooks as far as Galileo's method of investigating natural phenomena is concerned.

Reading Assignment 3. (To be prepared for class discussion only).

The following questions, problems and situation are based on Isaac Newton, an article written by the famous historian of science Bernard Cohen. Prepare your answers and have these notes ready for class discussion.

1. Newton graduated from Cambridge University at about the age of 21 and then returned to his home at Woolsthorpe for 18 months. Cohen does not mention that Newton returned to his home to escape the plague, which was

ravaging London. At any rate, Cohen claims that these 18 months can be described "as the most fruitful 18 months in all the history of the creative imagination".Cohen attempts to back up this astonishing claim. List Newton's accomplishments during this fruitful period of his life. If you are acquainted with any or all of these elaborate a little.

2. Describe the telescope Galileo invented and compare it to Newton's reflecting telescope.

3. In addition to what Cohen says about Newton's theory and experiments on light try to reconstruct his discoveries and his theory-building of the nature of light. Refer to texts, history books. Look at the appropriate section in Harvard Project Physics.

4. Newton shunned people in his middle age and was by all accounts a cantankerous man. How does Cohen account for this? Look up in another book or article about Newton's personality. Find an account of his feud with Robert Hooke (described in another article by Cohen, suggested in the reading list).

5. Compare Newton's absent-mindedness, as described by Cohen, with stories you have heard about Einstein.

6. There was a great controversy during the 18th century as to who discovered the calculus, Newton or Leibnitz. Look up this debate and discuss it briefly.

7. The story of how the writing of the *Principia*, commonly acknowledged to be the greatest and most influential scientific book ever written, is an interesting one. Retell it.

8. The physics of the Principia (three volumes) literally laid the foundations of our physical science. List these foundations and mention the seemingly disparate phenomena they explained.

9. This questions is for the physicists among us: How did Newton prove that a sphere acts gravitationally as if all its mass concentrated at its center? Why was this an important proof?

10. Newton worked out the results of his problems by first using the calculus that he invented (actually he called it *fluxions*). He then proceeded to use Euclidean geometry in his published proofs.

a. Why did he do that?

b. Historians of science are agreed that this way of communicating with his readers (other natural philosophers) "set back mathematics and physics in England a hundred years". Comment.

11. After laying the foundations for physics for the next 200 years Newton abandoned the academic life. But he continued speculating about many fundamental issues. Imagine that you could go back in time to about 1712, when Newton was 70 years old, and still, by all accounts very lucid. You are granted an audience with him. How would you respond to his speculations, as a 21. century physicist/scientifically literate person?

12. Compare the poetic homage to Newton by Pope with that of William Wordsworth. What kind of picture of the universe and of science, do you think, did Pope and Wordsworth have?

Reading Assignment 4: (To be handed in).

The following questions, problems and situations are based *Lavoisier and the Theory of Combustion,* by Homer W. Schwamp and on *The Invention of the Balloon and the Birth of Modern Chemistry* by Arthur F. Scott. Prepare your answers by making notes and have these ready for class discussion,

1. Schwamp claims that "the demonstration in which a jar and a burning candle (p. 61)... is not evidence that oxygen exists or that combustion uses it up. Develop an alternate explanation and comment.

2. Make a list of phenomena that a complete theory of combustion would have to be able to explain. (Remember: you are in the 18. century and have been indoctrinated by the phlogiston theory).

3. Using the phlogiston theory distinguish between *calcination and combustion*. Why was the phlogiston theory here problematic? What leads you to believe that the notions of buoyancy and weight (mass) were not clearly understood?

4. Schwamp reminds us (bottom of p. 63-64) that in magnetic and electric phenomena we deal with the concept of negative, so why is it so strange to consider the possibility of negative masses for gravitational phenomena?

5. Why did it seem natural for chemists to identify "inflammable air" (hydrogen) with phlogiston?

6. Consider the following reactions and explain them in terms of the phlogiston theory:

Magnesium burned in air -----→A white powder

Carbon and rust -----→ iron

7. Describe Priestley's experiment with the "red precipitate of mercury", and give an account of the series of experiments Lavoisier performed that led him to speculate that Priestley's new gas was "that part of the atmosphere that was responsible for combustion". How did Priestly explain these results in terms of the phlogiston theory?

8. Briefly discuss Lavosier's ideas about what role heat and light played in combustion.

9. Describe how "inflammable air" (hydrogen) was produced by the balloneers and speculate on the problems that they must have encountered in producing "inflammable air".

10. What was the approximate buoyant force acting on the balloon that J. Charles devised 1782 (page 126), and later on the one designed in 1783? Work this out using (grade 11) physics.

11. Give a brief account of the history of the phlogiston theory and explain why it had such a stranglehold on chemical practices.

12. Trace the development of the chemistry of gases from Black's discovery of "fixed air" to the discovery of "inflammable air" by Cavendish. How did Cavendish compare the masses (weights) of air and "fixed air"?

13. How did Lavoisier eliminate "earth" as an Aristotelian elementary substance ?

14. How did Priestly improve on the 18. century technique of collecting gases? Give a brief account of his discovery of "dephlogisticated air" (oxygen).

15. The phlogiston theory was not easy to replace. Trusted theories in science are difficult to overthrow (Newton's theory of gravitation, the caloric theory of heat). Scientists invent "protective hypotheses" to defend them (for example, Priestly claimed that phlogiston had a negative mass). What evidence did Lavoisier have to amass in order to finally bring down the phlogiston theory?

16. Compare Cavendish's account of what happens when an electric spark is passed through a mixture of common air and "inflammable air" with Lavoisier's explanation.

17. The connection between the discovery of hydrogen, the chemical revolution, and the development of the balloon is complex. Give your own brief account of it.

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I. Suggested history of science and science education books:

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