COURSE OUTLINE FOR 132. 277 AND 16. 271

HISTORY OF SCIENCE II

132. 177 (3)
016.271 (3) ***Concepts of Physical Science from 1900***

Winter term 2003
Location: Room: 300 Education.
Time: 5:30 -8:30, Mondays
Instructor:

Dr. Art Stinner, Professor of Science Education, Faculty of Education,
Room 237, (474-9068). Stinner@cc.umanitoba.ca

Office Hours: 9:00-10:00 every morning, except Friday

Websites : www.ihpst.uwinnipeg.ca www.hsse.uwinnipeg.ca

Office Hours: Tue, Thur: 1:00 - 2:00.

Website for the two courses:
www.umanitoba.ca/faculties/science/astronomy/courses/history/

Course Description:

This course is a continuation of 132.170 (or 16.270), where the major ideas and discoveries in science, from the Greeks to the beginning of the 19th century, are discussed. Although it is desirable that students take these courses first, it is not a prerequisite to the study of the history of physical science in the 20th century.

The approach taken is based on a thematic development involving the evolution of the periodic table of elements, from roughly 1870 to about 1935. An attempt will be made to trace the evolution of the periodic table of elements and how this evolution is connected to discoveries made and the conceptual struggle experienced by physicists and chemists. The class will begin by tracing a time line, indicating connections and then using this as a guide for the topics to be discussed. The thematic approach will satisfy the twin objectives of providing a 'story line' as well as show students the interrelationship between the disciplines of physics and chemistry.

Based on class discussions of the evolution of the periodic table and the emerging "new physics", students will design *case studies* to present to class. These case studies 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 nature of conceptual change in science are fundamentally the same in the *discovery* and in the *learning* processes.

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 the discovery of the electron, for example, the richness of the historical setting will be emphasized. This will be accomplished partly by comparing actual achievements with typical textbook versions. Moreover, by imposing the framework of *contexts of inquiry* on investigations of the science of an era the "process" and the "products" of science are studied *together,* rather than separately. In conclusion, this approach will acquaint both the science students and the future science educators with historical context, the nature of science and the educational possibilities in presenting all this to the young science student.

Please note: this is **not** a formal course in the history of science. The emphases and the objectives of the course should be read carefully by the student prior to reading the course outline.

Resource Materials:

1. Simple laboratory equipment found in conventional science labs and is available to students.

2. More sophisticated laboratory equipment, such as the cyclotron in the physics department, to be demonstrated.

3. Articles available in such journals as *Scientific American, Science Education, Chemistry Teacher, American Scientist, Physics Today, Physics in Canada, Science & Education, Physics Teacher,* and *New Scientist.* Most of these journals are available in the Education Library and the Science Library.

4. *Third Genre* science books: see bibliography.

5. Books in the history of science: See Bibliography.

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 presenting a case study.

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 science 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* approach that implicitly contains such conventional process notions as *observation, inference, hypothesis, theory, and experiments.*

More Details about the course:

The time allotted for the course is 40 contact hours. Each session will be 3 hours long. About 13 of these sessions will be spent in a demonstration and experiment-based lecture and discussion. About 3 sessions will be devoted to student presentations of case studies. Two case studies are planned for every class-time allotment of about one hour. A two hour period will be used for a final examination.

For each lecture and discussion session a cluster of topics will be chosen under a unifying idea or theme. As much as possible hands-on activities will be planned (demonstrations, experiments) that involve the students. One of the main objectives will be to set the stage for students to pick a case study for later presentation and the final development of case studies.

ASSIGNMENTS:

<u>Assignment Format:</u>

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.

ASSIGNMENT I.

(2 Students)

Individual preparation for each week's work. Each group of two student will be responsible for one historical context.

Students will be asked to prepare *historical contexts* for discussion in class. Most of these are discussed in the hand-out: “Historical Contexts for Class Discussion”.

These contexts will serve to initiate and encourage class discussion.

ASSIGNMENT II: 10%

1 Student
Occasional class assignments handed out in class, marked and then discussed. See calendar. Context presenters will be acquainted with the assignment handed out and will assist in answering the questions, solving the problems, and helping with the demo activities. There will be 5 assignments given. See due date in calendar.

ASSIGNMENT III

Book Presentation: "Third Genre" science literature presentation.

(2 students)

This is to be a class presentation by two students, based on the reading of one book taken from the list called "third genre" science literature. Point out the strength, referring to readability, the quality and appropriateness of the illustrations, the correctness of the scientific content, the timing of the publication, author's position and reputation, relevance to the core of the curriculum, and the suitability of the topic for science teaching in general. Don't make outrageous claims: remember your audience will consist of science teachers and science specialists.`

Hand in a 500-1000 word report. To be distributed to class.

ASSIGNMENT IV:

(3 students)

A CASE STUDY .

Your Task: For a case study presentation students will be asked to form groups of three (with at least one education student and in the group) and make a commitment for planning a case study. This commitment will be made no later than the middle of the lecture-discussion phase. Each group will be asked to present the case study in three parts, one part prepared by each student:
(The time allotment will be one hour).

Historical context: Student No.1 presents the scientific ideas of the historical period and how they are connected to the topic.

The experiment(s) and the main ideas: Main ideas and/or empirical support for what is central to the case study is presented by student No.2, assisted by his/her colleagues. If possible, these demonstrations should also involve the students in the audience.

Implications for scientific literacy and the teaching of science: Student No.3 responds to the following questions: where do the concepts fit in the science curriculum? How can we operationally connect the logical plane of activity with the evidential plane? What are the diverse connections of the concepts under discussion?

The presentation should be planned and given so that there is a continuous conversation going on between the three presenters, as well as the members of the class.

This is a type-written report, one for each of the sub-presentations (3-4 pages each).

Care should be taken to ensure that the "story line" is not disturbed by the three different sections.

A note for Assignment III: Thomas Kuhn begins his influential book *The Structure of Scientific Revolutions*, with this sentence:

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 (Kuhn, 1962).

Until Kuhn's seminal work historians and philosophers of science generally looked upon the history of science in terms of a "logical and rational reconstruction". History of science then was written from the vantage point of the present. In other words, the main question was: "How should scientists then have acted if they had been as smart as we are today?" So the history of science was represented as a progression from "error" to "truth" as shown in modern scientific theories and concepts.

Early in his carrier, studying the history of science as a trained physicist, Kuhn asked the question:

"How is it that Aristotle, who was so brilliant in other philosophical and scientific endeavors, could be so 'wrong' in his physics?" Kuhn said (in a recent interview) that after a lecture he gave to arts students on Aristotle's physics the answer to that question came to him, while looking out his dormitory window:

"Aristotle's views of such basic concepts as motion and matter were totally unlike Newton's. Aristotle used the word "motion", for example, to refer not just to change in position but to change in general-the reddening of the sun as well as its descent toward the horizon. Understood on its own terms, *Aristotle's physics "wasn't just bad Newton, it was just different* ".

All of us have had the experience of looking with disbelief at Aristotle' physics, the phlogiston theory of early chemistry, the theory of spontaneous generation or the caloric fluid theory of the early 19th century. We ask ourselves: "How could a scientist have believed these theories?" Behind this question, however, is an attitude of condescension that is generally referred to as the *Whig* interpretation of the history of science. Of course, science textbooks generally reinforce this attitude.

Kuhn thought that in order to understand science in historical context we must look at history with new eyes. Indeed, he thinks we must become Aristotelians, phlogiston theorists or caloric fluid theorist if we hope to understand how scientists in these historical settings thought about the world.

Case Studies in Science.

Examples of case studies:

1. William Thomson (Lord Kelvin) and *the dissipation of energy:*
A curious interaction between physics, mathematics, geology, biology, **and theology.**

2. Max Planck and *the discovery of the quantum:*
Was there really an *ultraviolet catastrophe*?

3. J.J. Thomson and *the discovery of the electron:*
Is the electron an elementary particle?

4. Rutherford and *the Structure of Matter.* "I consider them my friends", referring to electrons and protons.

5. Wilhelm Roentgen and *the discovery of X-rays*:
How to exploit an accident.

6. Madame Curie and *experiments in radioactivity.*
The result of the *power of patient thought.*

7. Michelson and Morley and *the impossibility of detecting the motion of the earth:*
There is no evidence for the existence of an *ether.*

8. Crick & Watson and the *double helix:* Science is a complex human endeavor.

9. Bohr and his *'hybrid' model of the atom*: How do electrons "jump" from one energy level to the next?

10. Millikan and his *oil drop experiment*: Is charge quantized?

11. Chadwick and *the discovery of the neutron*: The nucleus of the atom is now complete.

12. Anderson and *the discovery of the positron:* Antiparticles really exist.

ASSESSMENTS:

ASSIGNMENT	**I (Historical Context)**	**15%**
ASSIGNMENT	**II (Occasional class assignments)**	**15%**
ASSIGNMENT	**III (Book Presentation)**	**10%**
ASSIGNMENT	**IV (Case Study)**	**25%**
MIDTERM TEST		**10%**
FINAL EXAM		**25%**
		100%

TOPICAL OUTLINE AND DAILY PRESENTATIONS:

The following is only a suggested content for presenting the course using *themes* or *big ideas* that will help the organization of each three hour session.

From about 1800 to about 1860:

- Dalton's atomic theory
- Young's interference experiment of light
- The law of definite proportions
- Avogadro's Hypothesis
- Davy's hypothesis of 'combining volumes of gases'.
- Proust's conjecture about atomic structure
- Faraday's electrolysis experiments
- Faraday's electromagnetic induction
- The determination of Lohschmidt's number
- The kinetic molecular theory of gases
- The age-of-the-earth debate

●Phase I: Mendeleev's periodic table (~1870), based on:

The law of definite proportions
Knowledge of atomic (equivalent weights) of elements
Knowledge of physical properties of elements

From about 1860 - to about 1910:

●Kirchhoff's spectroscopy
●The Michelson and Morley experiment
●Hertz's experiments with electromagnetic radiation (radio waves).
●The cathode ray tube
●The discovery of x-rays
●The discovery of radioactivity
●The photoelectric effect
●The discovery of helium
●The discovery of the electron
●Blackbody radiation
●Planck and the idea of the quantum
●Einstein's three papers of 1905:
Brownian motion,
The Photoelectric Effect, and
The Special Theory of Relativity
●The determination of Avogadro's number
●Rutherford's gold foil experiment
●Bohr's atomic model
●Rutherford's 'mouse trap' to detect alpha particles
●The Franck-Herz experiment
●Moseley's experiments
●Bragg's diffraction of x-rays
●Sommerfeld's model of the atom
●Einstein predicts the LASER
●The discovery of isotopes

●Phase II: The new periodic table of the elements (~1922), based on:

The Bohr model of the atom
Rutherford's model of the nucleus, and
Moseley's law
Brownian motion and the existence of molecules

●De Broglie's matter-wave theory
●The Compton effect
●The Stern-Gerlach experiment
●Heisenberg's quantum mechanics
●Schroedinger's quantum mechanics
●Pauli's exclusion principle
●Heisenberg's uncertainty principle
●Thomson and Davisson: Electron diffraction in crystals
●Fermi and his theory of beta decay: neutrinos
●Dirac's argument for antiparticles
●The discovery of the neutron
●The discovery of the antiproton
●The electron theory of crystals
●The invention of the transistor

Phase III: The new periodic table of the elements (~1935), based on:

The new quantum mechanics,
The discovery of the neutron,
The discovery of isotopes
Pauli's Exclusion Principle

Experiments, demonstrations, and discussions, taken from the following:

- Newton's experiment with a prism
- Young's interference of light experiment
- Brownian motion
- Faraday's electrolysis experiments
- Simple demonstration of the photoelectric effect
- Spectroscopic study of gases
- Sir William Crookes and the theory of the radiometer,
- Discharge tubes (Crooke) and the nature of cathode rays
- Black Body radiation, illustrated by an incandescent show-case lamp.
- Roentgen and the discovery of X-rays
- J.J. Thomson's e/m ratio experiment
- Thomson's "plump pudding" model of the atom
- Simple demonstration of the nature of radioactivity
- A model for the Rutherford 'gold foil experiment'.
- The Franck-Herz experiment
- Electron diffraction experiment
- Diodes and transistors

BIBLIOGRAPHY:

I. Suggested history of science and science education books:
Note: Some of these books will be on (3 day) reserve: most of them are in the Education Library, some in the Science Library. Note: It is expected that you will become well acquainted with a number of these books (3-4).

Archer, Richard, L. (1921). *Secondary Education in the nineteenth Century.* Educ. 373.42 A672

Bronowski, Jacob, and Mazlish, Bruce (1975). *The Western Intellectual Tradition: From Leonardo to Hegel.* Dafoe Lib. B 791.B75

Clarke, M.L. (1971). *Higher Education in the Ancient World.* Educ. LA 71 .C55

Cordasco, Francesco (1920). *A Brief History of Education: A handbook of information on Greek, Roman, medieval, Renaissance, and modern educational practice.* Educ. LA 14.C72

Curtis, S.J. and Boultwood, M.E.A. (1965). *A Short History of Educational Ideas.* Educ. LA 21.C8

Dampier, Sir William Cecil (1961). *History of Science*. Sci Q125 C68 1961.

Fraser, C. (1948). *Half hours with great scientists.*

Grant, Edward (1971). *Physical Science in the Middle Ages.* Sci Q 153.G76

Hall, Alfred, Rupert (1954). *The Scientific Revolution*. Sci Q 125 H28

Hall, Alfred, Rupert (1964) *A Brief History of Science.* Sci Q 125 H27

Hall, Alfred, Rupert (1983). *The Revolution in Science* Sci Q 125.R53

Harre, Rom (1981). *Great Scientific Experiments.* Sci Q 182.3.H37

Kuhn, Thomas (1962). *The Structure of Scientific Revolutions.* Educ. Q 182.3.H37

Mason, Stephen F. (1962). *A History of the Sciences.* New York: Collier Books. Sci Q 125.M36
Middleton, William (1963). *The Scientific Revolution.*
Sci Q125 M 422
Midwinter, Eric (1970). *Nineteenth century Education.* Educ. LA 631.7.M47
Neuburg, Victor (?). *Popular Education in Eighteenth Century England.* Educ. LA 631.5.N49
Neugebauer, O. (1969). *The Exact Sciences in Antiquity.* St. Pauls College Library QA 22.N36
Radcliffe, Douglas (1973). *The University World: A synaptic View of Higher Education in the Middle Ages and the Renaissance.* Educ. LA 177.U5
Reichen, C.A. (1968). A History of Physics. Edito-Service S.A. Geneva.
--------------------. A History of Chemistry.---------------------

Ronan, Colin A. (1981). *Science Its History and Development Among the World's Cultures*. New York: Facts and Files Publications.
Ronan, Colin A. (1966). *The Ages of Science.* Sci Q125.R74
Sedgwick, W.T. and Taylor, H.W. (1929) *A Short History of Science*. Sci Q125 S5
Shamos, Morris (1960). *Great Experiments in Physics.* Sci 530.9 S528
William A. (1969). *Ancient Education.* Educ. LA 31 S63
Smith, Alan, G. (1972). *Science and Society in the sixteenth and seventeenth centuries.*
Sci. Q 125 .S68
Sutherland, Gillian (1971). *Elementary Education in the Nineteenth Century.* Educ. LA 633.S9
Taton, Rene (1963) *The Scientific Revolution.* Sci 509.T188 Hi ZP77
Toon, E., & Ellis, G. ((1978). *Foundations of Chemistry*. Holt, Reinhart and Winston, Toronto.

The Project Physics Course, Reader 3 (1971)

The Project Physics Course, Handbook 2 and 3 (1971).

Great Experiments in Physics. (1959). Morris Shamos, (Ed.).

The Romance of Physics (1966). Keith Gordon Irwin.

History of Physics (Selected Reprints. AAPT.

Physics History (Volume I and II). AAPT.

II. Suggested books related to the history of science and science education:

Cohen, R.C. *Reason and Nature.* New York: Dover Publications, Inc., 1959. (Selected pages only)
Dyson, Freeman, *Infinite in all directions.* Harper & Row, New York, 1985. (available in most book stores in paperback.)
Conant, James B. *Harvard Case Histories in Experimental Science,* Vol I and II. (On reserve in the Ed. library).
Giere, Ronald N. *Understanding Scientific Reasoning.* Holt, Rinehart and Winston, 1979.
Hanson, N.R. *Patterns of Discovery.* Cambridge: University Press, 1969.
Holton, Gerald *Thematic Origins of Scientific Inquiry.*
Holton, G. ed. *The Scientific Imagination.* New York: Cambridge University Press, 1962.
Kuhn, Thomas *The Structure of Scientific Revolutions.*
Structure of Scientific Revolutions. Chicago: University Press, 1962. (ideas of Kuhn summarized in *outline.*)
Kuhn, Thomas. "The Historical Structure of Scientific Discovery".
Science 136 (June 1962): 760-764.

Emberly, E. and Loly, P. (1995). Fermi Surfaces Coloured with the Group Speed to Reveal Critical Points for Singularities of the Density of States, *Mathematica in Education and Research*, Vol. 4, No.1, 8-13.

Buchheit, M. and Loly, P. (1972). A Simple Procedure for Computing Density of States Spectra in Solid State Physics. American Journal of Physics, 40:289-93.

Medawar, P. *The Art of the Soluble.* London: Methuen and Co., 1967.

Pearson, Karl *The Grammar of Science*. London: J.M. Dent and Sons Ltd., 1951. (Selected pages only).

Exploration of the Universe (1969). George Abell.

Relevant Articles from Science and Science Education Journals:

Munby, Hugh (1982) "What is Scientific Thinking?", a discussion paper, Science Council of Canada**,** 1982. (Available in Ed. Library).

Stinner, A. 1989. "The Teaching of Physics and the Contexts of Inquiry: From Aristotle to Einstein". *Science Education*, 73 (5) . (In Ed. library).

Stinner, A. and Williams, H. (1993) "Conceptual Change, Historical context and Science Stories", *Interchange*, 24, 87-104.

Stinner, A. 1994. The Story of Force: From Aristotle to Einstein. *Physics Education*, Vol. 29. p 77-86.

Stinner, A. (1998). The Hungarian Phenomenon. *The Physics Teacher*, Vol. 35, Dec., pp. 520-524.

Stinner, A. & Williams, H. (1997). "History and Philosophy of Science in the Science Curriculum", a chapter in the forthcoming *The International Handbook of Science Education,* Kluwer Academic Publishers, pp. 1027-1045.

Stinner, A. (1996). *Contextual Settings, History of Science of Science, and Physics Education*. A monograph, published by the University of Szombathely as part of my induction into "The Szombathelyi Learned Society" (*Societas Scientiarium Savariensis*).

Stinner, A. (1998). Linking 'The Book of Nature' and 'The Book of Science': using Circular Motion as an Exemplar beyond the Textbook. *Physics in Canada*, January/February. Pp. 38-50.

Stinner A., McMillan, B., Metz, D., Jilek, J., Klassen, S. (2003). Renewal of Historical Case Studies: from Early years to College. *Science & Education.*

Stinner, A. (2003). Scientific Method, Imagination, and the Teaching of Physics. *Physics in Canada*.

Stinner, A. & Metz, D. (2003). Pursuing the Ubiquitous Pendulum. *The Physics Teacher.* Vol. 41. 38-43.

Stinner, A.& Teichmann,J. (2003). Lord Kelvin and the The-Age-of-the-Earth debate: A dramatization. *Science & Education.***12**: 213-228.

The Big Ideas of Science

The *big ideas* of science are those that organize thought in order to understand better the bewildering array of phenomena in the world. Some of these *big ideas* were anticipated by the Greek philosophers over 2000 years ago. The conviction that nature could be understood by a *rational* approach, i.e. the belief that **regularities in nature can be described by the power of mathematics**, and the assumption that matter is corpuscular, are examples of ideas that guided and organized scientific thinking.

The Greeks began to search for eternal patterns in a world of change. Thus Heraclitus maintained that everything around us is in continuing state of change. Parmenides, on the other hand, was convinced that nothing really changes. Plato pointed out that the difficulty in pointing out change lies in the difference in what we perceive and what is *really out there*. For Plato then change belonged to the world of senses and permanence to the world of ideas. One of the *big questions* that Plato left for future natural philosophers (scientists) was this:

By what assumptions of what uniform and ordered motions can the apparent motions of the planets be accounted for?

This famous question became a challenge for natural philosophers and astronomers for 2000 years. It was not fully answered until Kepler solved it in the 16th. century.

It is arguable that *Plato's Problem* (as it is often called) set the stage for modern scientific inquiry:

"Facts" of observation impress themselves on our senses; we find a puzzling mixture of complexity and order; we resolve the puzzle by a model. The model is usually based on one or more of the "big ideas" and on the scientific imagination. The final test of the "goodness" of our model is its ability to explain and to predict observables, in the case of Plato's problem such observables as *the retrograde motion of Mars, the position of a new planet*

We will discuss the notion of *big ideas* in science by way of retracing the *contexts of inquiry* for each major scientific era (see Stinner: *Contexts of Inquiry...).* The class activities will involve the discussion of these *big ideas* for *science in general* as well as for the various disciplines. This will be followed by looking at he implications for science teaching, including:

i. Class discussion and group discussion of the *big ideas* in various science disciplines. Are there *big ideas* which belong only to one discipline? Cross some disciplines? Cross all disciplines?

ii. Group discussion: The *big ideas* of science and the science textbook. How do science textbooks deal with *big ideas* (in physics, in chemistry, in biology)?

iii. Class discussion: How do new disciplines (especially those parasitic on all the sciences, like *ecology*) deal with *big ideas*?

iv. Write down what you think are the *big ideas* of science in chronological order. Start with Dalton, then go on to the beginning of the 20th.

v. There are in science a small list of really big ideas (often called "themata") that supersede the scientific disciplines, that is, all sciences are connected with them. Some of these have their origin in antiquity. Name a few of them.

vi. Now indicate in a table where, when, and how these ideas influenced developments in the disciplines of physics, chemistry and biology.

The "Third Genre" of Science Writing

Science in the movies, on television, and in literature will be discussed. The emphasis, however, will be on literature, i.e. current publications on science of a *new* science literature, we shall call the *third genre* of science literature. These are the writings of famous scientists for the general public and often involve recognized experts in a field of study.

The following are good examples of *third genre* (the origin of this label will be discussed in class) science writing are:

Cold Fusion, The Making of a Scientific Controversy, by F. David Peat

A Brief History of Time, Stephen Hawking

The Mismeasure of Man, Stephen J. Gould

Beyond Einstein, The Cosmic Quest for the Theory of the Universe.
Michio Kaker & Jennifer Trainer

Time's Arrow, Time's Cycle, Stephen J. Gould

What is the World made of? Gerald Feinberg

The Omega Point, The search for the missing mass and the ultimate fate of the universe.
John Gribbin

Quantum Reality Beyond the New Physics. Nick Herbert

Faster than Light, Superluminal Loophole in Physics. Nick Herbert

The Double Helix, James D. Watson.

Origins The Sceptic's Guide to the Creation of Life on Earth. Robert Shapiro.

The Cosmic Code, Quantum Physics as the Language of Nature, Heinz Pagels.

Infinite in all Directions, Freeman Dyson.

Ideas and Information, information processing theory, Arno Penzias

Microcosmos, Four Billion Years of Microbial Evolution, Lynn Margulis
& Dorian Sagan.

Chaos, Making a New Science, James Gluick.

Cosmic Coincidences, Dark Matter, Mankind, Anthropic Cosmology,
John Gribbin.

The Breakthrough The Race for the Superconductor, Robert M. Hazen.

The Race for the Double Helix, John Gribbin.

In Search of Schroedinger's Cat, Paul Davies.

In Search of the Big Bang , Paul Davies.

Superforce, Paul Davies.

Night Thoughts of a Classical Physicist, Russell McCormack.

The Birth of a New Physics, Bernard Cohen.

What Mad Pursuit, Francis Crick.

The following is a more complete list of *third genre* science writings:

Asimov, Isaac. *Where do we go from here*? Greenwich, Conn.: Fawcett Publications Inc., 1971.

Barrett, William. *Death of the Soul: From Descartes to the Computer*. Garden City, New York: Anchor Press/Double Day, 1987.

Cohen, I. Bernard. *The Birth of a New Physics: revised and updated.* New York: W. W. Norton and Company, 1985.

Commoner, Barry. *Science and Survival*. New York: The Viking Press, 1963.

Davies, Paul. *God and the New Physics*. New York: Viking Penguin, 1983.

Davies, Paul. *Superforce.* New York: Simon and Schuster Inc., 1985.

Dawkins, Richard. *The Selfish Gene*. Toronto: Granada Publishing, 1978.

Fritzsch, Harald. *Quarks: The Stuff of Matter*. New York: Basic Books, Inc., Publishers, 1983.

Gamow, George. *The Birth and Death of the Sun: Stellar Evolution and Subatomic Energy.* New York: The New American Library, 1952.

Gamow, George. *One Two Three . . . Infinity: Facts and Speculations of Science*. New York: Bantam Books, 1971.

Gibbins, Peter. *Particles and Paradoxes: The Limits of Quantum Logic*. New York: Cambridge University Press, 1987.

Gleick, James. *Chaos: Making a New Science*. New York: Penguin Books, 1987.

Gould, Stephen J. *Times Arrow Time's Cycle: Myth and Metaphor in the Discovery of Geological Time.* Cambridge, Massachusetts: Harvard University Press, 1987.

Gribbin, John. *In Search of the Big Bang: Quantum Physics and Cosmology.* Toronto: Bantam Books, 1986.

Gribbin, John. *In Search of the Double Helix: Quantum Physics and Life.* Toronto: Bantam Books, 1987.

Gribbin, John. *In Search of Schrödinger's Cat: Quantum Physics and Reality*. Toronto: Bantam Books, 1984.

Gribbin, John. *The Omega Point: The Search for the Missing Mass and the Ultimate Fate of the Universe.* Toronto: Bantam Books, 1988.

Gribbin, John and Martin Rees. *Cosmic Coincidences: Dark Matter, Mankind, and Anthropic Cosmology.* Toronto: Bantam Books, 1989.

Gould, Stephen Jay. *The Mismeasure of Man*. Markham, Ontario: Penguin Books, 1981.

Harrison, Edward. *Darkness at Night: A Riddle of the Universe*. Cambridge, Massachusetts: Harvard University Press, 1987.

Hawking, S. *A brief History of Time*, Cambridge University Press, 1987..

Hazen, Robert M. *The Breakthrough: The Race for the Superconductor*. New York: Ballantine Books, 1988.

Herbert, Nick. *Faster than Light: Superluminal Loopholes in Physics*. Markham, Ontario: Penguin Books, 1988.

Herbert, Nick. *Quantum Reality: Beyond the New Physics*. Garden City, New York: Anchor Press/Double Day, 1987.

Hey, Tony and Patrick Walters. *The Quantum Universe*. New York: Cambridge University Press, 1987.

Jastrow, Robert. *God and the Astronomer*. New York: Warner Books, 1978.

Medawar, P.B. *Advice to a Young Scientist.* New York: Harper & Row Publishers, 1979.

Pagels, Heinz R. *The Cosmic Code: Quantum physics as the language of nature*. Toronto: Bantam Books, 1982.

Pagels, Heinz R. *Perfect Symmetry: The Search for the Beginning of Time.* Toronto: Bantam Books, 1985.

Polkinghorne, J. C.. *The Quantum World*. New York: Penguin Books, 1986.

Rucker, Rudy. *Infinity and the Mind: The Science and Philosphy of the Infinite*. Boston: Birkhäuser, 1982.

Sagan, Carl. *Brocca's Brain: Reflections on the Romance of Science*. New York: Ballatine Books, 1974.

Sagan, Carl. *Cosmos*. New York: Ballantine Books, 1980.

Shapiro, Robert. *Origins: A Skeptic's Guide to the Creation of Life on Earth*. Toronto: Bantam Books, 1986.

Silk, Joseph. *The Big Bang.* New York: W.H. Freeman and Company, 1989.

Talbot, Michael. *Beyond the Quantum*. Toronto: Bantam Books, 1986.

Trefil, James. *The Darkside of the Universe: A Scientist Explores the Mysteries of the Cosmos*. New York: Anchor Books Double Day, 1989.

Trefil, James. *From Atoms to Quarks: an Introduction to the Strange World of Particle Physics.* New York: Charles Scribner's Sons, 1980.

Watson, James. *The Double Helix: A personal account of the discovery of the structure of DNA*. Scarborough, Ontario: Mentor Books, 1968.

Weinberg, Steven. *The First Three Minutes: A Modern View of the Origin of the Universe.* Toronto: Bantam Books, 1977.

Note: We will add to this list during the course.