Natural Sciences 3: Physics:
Light and the Physical Bases of Explanation

Ours is a scientific age. This is so not only because of the technological and scientific advances we see around us. Our age is scientific because even the way we see the world has been affected by the scientific view.

But how do scientists see the world? How do they explain things? Can I apply this method of explanation to other topics and endeavors?

Natural Sciences 3 starts simply, with Galileo's explanation of falling bodies. He seems to have discovered an important law of nature without any observation at all, just by reasoning. Can we believe it? From this explanation of falling, the course goes to the explanation of motion in general—motion of people, cars, planets. With the explanation of motion established, we consider a motion that baffled and still baffles the best minds: the motion of light.

The fundamental questions of Natural Sciences 3 then become: "What is light?" and "Why does light act as it does?" Two competing explanations of the nature of light struggle for attention and approval. Which one to choose? And how to justify the choice?

The historical wave/particle controversy about light was settled in favor of waves, but only temporarily. A wave has to be a wave in some medium (like ocean waves need water); this medium for light waves was called the aether. What, then, is this aether?

The nature of this aether reveals itself through the study of electrical and magnetic forces. But the existence of the aether leads to other problems, both logically and observationally. Finally, the theory of relativity resolves these problems, and what is left of the aether is a new entity called the field. This is not merely a new name for aether; it is a new reality—as real as stones and trees. But the field is not fathomed by any of our senses, even when assisted by instruments, yet we know it through the intellectual tools of mathematics.

All this from a falling stone!

Table of Contents

The contents of this syllabus are as follows:

Texts

Required

The following works are required:

Einstein, *Relativity*
Fresnel, "Diffraction of Light"
Galileo, *Dialogues Concerning the Two New Sciences*

Hertz, "Electromagnetic Waves"
Huygens, *Treatise on Light*
Newton, *Opticks*
Newton, *Philosophy of Nature*
Oersted, "Electromagnetism"
Young, "Interference of Light"

Also required are selected works by the following authors, listed in approximate chronological order: DuFay, Franklin, Faraday, Hertz, and Maxwell.

The following works should also be included, space permitting:

Descartes, *Geometry*…
Descartes, *Optics*
Volta on electrochemistry

The following reading may also be used:

Einstein and Infeld, *Evolution of Physics*

Course Readings

A list of the books and articles used in this course follows in the order in which they are read. Additional assignments will be announced in class.

Galileo, *Dialogues Concerning the Two New Sciences*
Newton, *Philosophy of Nature*
Newton, *Opticks*
Einstein, *Relativity*
Shamos, *Great Experiments in Physics*
Shimer College Reprints:
- Descartes, *Optics*, *On Light,* and *On Refraction*
- Huygens, *Treatise on Light*
- DuFay, *The Two-Fluid Theory of Electricity*
- Franklin, *The One-Fluid Theory of Electricity*
- Maxwell, *On Action at a Distance (Faraday's Point of View)*
- Maxwell, *On Ether*
- Faraday, *On Static Electrical Induction*
- Faraday, *On the Induction of Electric Currents*
- Faraday, *On Some Points of Magnetic Philosophy . . .*
- Hertz, *Electromagnetic Waves*

Goals and Objectives

Philosophy of Learning

You have completed the level-1 and 2 courses in the core sequence, and so you've already begun to learn the skills of dialogue. Natural Sciences 3 now marks a shift away from a self-protective and conformist learning attitude that many students retain in the lower-level courses and toward a responsible and autonomous position in which dialogue and community become most important. In the level-3 and 4 courses you and the other students in the

class realize your corporate responsibility for class discussion; you move away from the "normal" student position of being both rewarded and punished by the faculty member in his/her role as sole judge. In adopting and practicing this policy, we all need to be conscious of the difficulty/fear we have in making and expressing judgments.

Student Competencies

The heart of the Shimer educational method is the encouragement and practice of those skills that will make possible lifelong learning. To this end certain commitments and competencies are expected in Natural Sciences 3. These include:

Commitment to one's own learning
Measured by your attending classes *on time*, letting others know what you *do* and *don't* understand, and identifying for yourself issues of safety in the class discussion

Reading the source materials for the class carefully and completely

Asking genuine questions within the discussion

A growing ability to recapitulate someone else's point of view
Measured by that other person agreeing that you have done justice to his/her position

The ability to understand and express your emotional reactions to the readings and to the process of learning

The ability to write effectively

Course Requirements

Each student will receive a semester grade based upon three things: class participation, one major paper, and a final exam.

The paper is an account of your experience and experiments with a prism supplied to you as part of the course materials. Carry your prism around with you; observe the world through it; take notes. Also, bring it to class on a regular basis. Your paper should be both a record of your observations and a theoretical explanation of them. Like the clearer authors in the class, structure the paper so that the readers:

- know what you did (your method, procedure, actions)
- know your observations (your data)
- understand the explanation of your observations and how your method yielded them
- could reproduce what you did and check the results for themselves.

The paper should be eight to twelve typed pages. You may hand in a draft version early, if you like, for comments and suggestions. Except under unusual circumstances, late papers will *not* be accepted. On-time papers may be rewritten, so if you feel that a paper is not "good enough," hand it in anyway and rewrite it. Please note that Natural Sciences 3 is a "writing class," and a student must hand in all work in order to pass the course.

Your class participation grade will be divided between your individual effort and the corporate effort of the class, as determined by the class as a whole.

Your course grade will be based upon the following components: class participation (quality, as well as quantity), 40 percent; papers, 40 percent; final, 20 percent.

If you have any difficulty with the class or the readings or if you have any suggestions, please talk with me. Don't wait.

Syllabus

September

9/4	Galileo	*Dialogues Concerning the Two New Sciences*, sections 106–126 (pp. 65–86)
9/5		*Dialogues Concerning the Two New Sciences*, sections 190–196 (pp. 147–153)
9/9		*Dialogues Concerning the Two New Sciences*, sections 197–213 (pp. 153–170)
9/11		*Dialogues Concerning the Two New Sciences*, sections 197–213, continued
9/12	Newton	*Philosophy of Nature*, pp. 1–8
9/16		*Philosophy of Nature*, pp. 9–24
9/18		*Philosophy of Nature*, pp. 25–29
9/19		*Philosophy of Nature*, pp. 29–40
9/23		*Philosophy of Nature*, pp. 105–116
9/25		*Philosophy of Nature*, pp. 116–134
9/26	Descartes	*Optics, On Light*
9/30		*Optics, On Refraction*

October

10/2	Huygens	*Treatise on Light,* ch. 1
10/3		*Treatise on Light,* ch. 2
10/7		*Treatise on Light,* ch. 3
10/9		*Treatise on Light,* ch. 4
10/10	Newton	*Opticks,* pp. 1–33
10/16		*Opticks,* pp. 33–63
10/17		*Opticks,* pp. 63–82, 168–178

10/21		*Opticks,* pp. 193–224, 270–282
10/23		*Opticks,* pp. 317–338
10/24		*Opticks,* pp. 339–374
10/28	Young	*The Interference of Light* (Shamos, pp. 93–107)
10/30	Fresnel	*The Diffraction of Light* (Shamos, pp. 108–120)
10/31	DuFay	*The Two-Fluid Theory of Electricity*
	Franklin	*The One-Fluid Theory of Electricity*

November

11/4	Faraday	*Static Electrical Induction*, pp. 848–850
11/6	Oersted	*Electromagnetism* (Shamos, pp. 121–127)
11/7	Faraday	*Induction of Electric Currents*, pp. 256–259
11/11	Faraday	*On Some Points of Magnetic Phil* . . ., pp. 830–834, 837–842
11/13	Maxwell	*On Action at a Distance (Faraday's Point of View)*
11/14	Maxwell	*The Electromagnetic Field* (Shamos, pp. 283–300)
11/18	Maxwell	*On Ether*
11/20	Hertz	*Electric Waves*
11/21	Hertz	*Electromagnetic Waves* (Shamos, pp. 184–197)
11/25	Einstein	*Relativity,* ch. 18–21

December

12/2		*Relativity,* ch. 22–25
12/4		*Relativity,* ch. 26–29
12/5		*Relativity,* ch. 30–33
12/9		Final presentations