SYLLABUS for SPRING 2008 V55.0209 Natural Science I: Quarks to Cosmos

Lecture	Laboratory SECTION 4	Laboratory SECTION 5
T,Th 2:00 – 3:15	**Mon. 1:00 -2:40**	**Mon. 3:00 – 4:40**
Room 121 Meyer Hall	**Room 103 Meyer Hall**	**Room 103 Meyer Hall**
Prof. Allen Mincer	**George Lewis**	**Lisa Goodenough**
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Office hours by appointment	**Office hours TBA**	**Office hours TBA**

COURSE DESCRIPTION:

Modern science has provided us with some understanding of age-old fundamental questions, while at the same time opening up many new areas of investigation. How old is the Universe? How did galaxies, stars, and planets form? What are the fundamental constituents of matter and how do they combine to form the contents of the Universe? The course will cover measurements and chains of scientific reasoning that have allowed us to reconstruct the Big Bang by measuring little wisps of light reaching the Earth, to learn about sub-atomic particles by use of many-mile long machines, and to combine the two to understand the Universe as a whole from the sub-atomic particles of which it is composed.

PREREQUISITE:

Prior completion of or exemption from the MAP Quantitative Reasoning course.

COURSE COMPONENTS:

Read the material on which each lecture is based (as listed in the schedule below) before the lecture.

You must also be registered for a section of the laboratory course. At the beginning of each lab there will be a short quiz to determine whether you have read the laboratory manual section for the experiment before coming to class.

Homework assignments are listed after the schedule. Homework should be handed in at the beginning of the laboratory session at which it is due, as listed in the schedule below.

A few of the HW assignments described below (not the ones out of the book) involve some small activities and a little bit of equipment. Make sure that you look at the problems far enough in advance to have time to do the assignment.

A homework clinic will be held Tuesdays and Wednesdays 3:30 to 4:30 in Meyer Hall Room 425B.

TEXTBOOKS:

- Seeds M.A., Horizons 10th edition, Thomson Brooks Cole, 2008
- Steven Weinberg, The Discovery of Subatomic Particles, Cambridge, 2003
- Lab Manual

COURSE GRADING:

- 2 Midterms 20% each
- Final 20%
- HW 10%
- Labs 30% (Quiz 10%, reports plus participation 20%)

SCHEDULE

******************************* WEEK1 ********************************

Jan. 21 Martin Luther King's Birthday, no classes, no laboratory this week
No HW due.

Jan. 22 Introduction, distance scales
Seeds pp. 2 – 8
Weinberg pp. 1 - 8

Jan. 24 Geometrical methods, parallax
Seeds pp. 144 - 146

******************************* WEEK2 ********************************

Jan. 28 Laboratory: Math Review
HW 1 due.

Jan. 29 Newton's Laws
Weinberg pp. 22 – 26, Appendix A (pp. 160 – 161)

Jan. 31 Kepler, Newton, gravitation
Seeds pp. 44 - 69

******************************* WEEK3 ********************************

Feb. 4 Laboratory: Parallax
HW 2 due

Feb. 5 Energy
Weinberg pp. 51 – 57, Appendix D (pp.166 – 168)

Feb. 7 Electric and Magnetic Forces
Weinberg pp. 29 – 35, 38 - 45

******************************* WEEK4 ********************************

Feb. 11 Laboratory: Kinematics
HW 3 due.

Feb. 12 The Electron: Thomson Experiment, Avogadro, Electrolysis
Weinberg pp. 9 – 22, 27 – 29, 36 – 38, 45 – 51, 61-66, 70-75, 80-84, Appendix B (pp.161 – 163)

Feb. 14 Millikan Experiment, Mass and Charge of electrons and atoms
Weinberg pp. 67-70, 76 – 80, 85 – 93, Appendix G (pp. 174-176)

******************************* WEEK 5 *******************************

Feb. 18 President's Day, no classes, no laboratory this week

Feb. 19 Waves, Measuring the Wavelength of Light
Seeds pp. 74 – 76

Feb 21 Radioactivity, Rutherford Experiment, The Nucleus, Photoelectric Effect
Weinberg pp. 94 – 123

******************************* WEEK 6 *******************************

Feb. 25 Laboratory: Review for Exam I.
HW 4 due.

Feb. 26 Exam I. Covers material up to and including lecture of Feb. 14.

Feb. 28 Atomic Spectra, Blackbody Radiation, Emission and Absorption Lines
Seeds pp. 98 – 111, 113-114

******************************** WEEK 7 ********************************

Mar. 3 Laboratory: Newton's Second Law
HW 5 and HW 6 due.

Mar. 4 Luminosity, Intensity, Apparent and Absolute Magnitude, Mass of Stars
Seeds pp.14 – 15, 146 – 160

Mar.6 Doppler Effect, H-Z Diagrams
Seeds pp. 111- 114, 161 - 166

******************************** WEEK 8 ********************************

Mar. 10 Laboratory: Electrolysis
HW 7 due

Mar. 11 Example Binary System

Mar. 13 Special Relativity I

****************************** RECESS WEEK ******************************

Mar. 17 – Mar. 21 SPRING RECESS

******************************** WEEK 9 ********************************

Mar. 24 Laboratory: Measuring the Size of a Molecule
HW 8 due

Mar. 25 Special Relativity II

Mar. 27 Nuclear Stability, Neutrons, Neutrinos
Weinberg pp. 123 – 148

******************************** WEEK 10 ********************************

Mar. 31 Laboratory: Measuring the Wavelength of Light
HW 9 due

Apr. 1 Formation and Structure of Stars
Seeds pp. 168 – 193

Apr. 3 The Death of Stars
Seeds pp. 196 - 221

******************************** WEEK 11 ********************************

Apr. 7 Laboratory: Review for Exam II

Apr. 8 Exam II Up to and including lecture of Mar. 27

Apr. 10 General Relativity

******************************** WEEK 12 ********************************

Apr. 14 Laboratory: The Photoelectric Effect
HW 10 and 11 due.

Apr. 15 Neutron stars and Black Holes
Seeds pp. 224 - 245
HW due

Apr. 17 Galaxies
Seeds pp. 248 – 259, 276 – 291, 300 - 317

******************************** WEEK 13 ********************************

Apr. 21 Laboratory: Measuring the Cosmological Redshift
HW 12 due.

Apr. 22 Anti-particles, mesons, strange particles, the eightfold way, quarks
Weinberg pp. 148 – 156

Apr. 24 QED, QCD, W,Z and SUSY
Weinberg pp. 156 - 159

******************************** WEEK14 ********************************

Apr. 28 Laboratory: Laboratory: Spectroscopic Analysis of Light
HW 13 due.

Apr. 29 Cosmology I
Seeds pp. 320 - 343

May 1 Cosmology II

******************************** WEEK15 ********************************

May 5 Laboratory; review for Final
HW 14 due

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HOMEWORK SETS

********************************* HW1 *********************************

Seeds p. 9 Problems 1, 4, 5, 7, 8
p. 167 Review question 1

Additional problems:

1. For this you will need a container of milk, a can of soda, or any other container that states on the label the contents by volume.
   (a) Using a ruler, measure the dimensions of the container (length, width and height; or diameter and height, depending on the container shape).
   (b) Calculate the volume of the container.
   (c) Is it bigger, smaller, or the same as the value on the label? Why?
   Remember to convert units as needed!
2. If you are making a parallax measurement that gives an accuracy of 1 minute of a degree between summer and winter measurements, what is the approximate maximum distance that you can measure? How does this compare with distances of astronomical objects?

********************************* HW2 *********************************

Seeds p. 71 Questions 15, 18 Problems 4, 5, 6

Additional problems:

1. A 5 kg block is resting on a table. What is the magnitude and direction of the force of the table on the block? What is the force of the block on the table? What measurements could you make to prove that the block exerts a force on the table? You can use a different block if you wish (hint: does a table bend when a 5kg mass is put on it?)
2. How much force does the ground have to exert on the tires of a one ton car in order for it to accelerate from rest to 60 miles an hour in 30 seconds?

********************************* HW3 *********************************

Problems:

1. An electron in a Hydrogen atom is 5.3×10^{-11} meters from a proton.
   (a) Look up the charge and mass of an electron and proton.
   (b) What force does the proton exert on the electron?
   (c) Is the force attractive or repulsive?
   (d) What force does the electron exert on the proton?
   (e) What is the electrical potential energy of the electron?
   (f) How much kinetic energy (in Joules) does the electron need in order for the system not to be a bound one?
   (g) If the electron is moving with a velocity of 2.2×10^{6} meters per second, how much energy do you have to add to it to free the electron from the proton's grip?
   (h) Convert the answers to (f) and (g) to electronvolts.
2. Wires 1 and 2 are parallel to each other and separated by 10 centimeters. They are carrying current going in the same direction. 3600 Coulombs per hour enter Wire 1, and 7200 Coulombs per hour enter Wire 2.
   (a) How much current is in wire 1?
   (b) How much current is in wire 2? CONTINUED ON NEXT PAGE

(c) What force does wire 1 exert on wire 2?
(d) What force does wire 2 exert on wire 1?
(e) If you build a frame to keep the wires stable, how much force will the frame exert on each of the wires?
(f) An electron located half way between the wires is moving parallel to them at a speed of 1000 m/s. What is the magnetic force on the electron?
(g) Which way will the electron accelerate?

******************************** HW4 ********************************

Problems:

1. A typical television picture tube today may accelerate electrons horizontally with a potential difference of about 25,000 Volts. The moving electrons are then vertically deflected by electric or magnetic fields in a region we will assume to be 10 cm long. When the electrons leave the accelerating region they are 40 cm from the glass surface that they strike.
   (a) What is the velocity of the electrons after they are horizontally accelerated?
   (b) If the vertical electric field is of strength 1000 Newtons per Coulomb, what is the maximum deflection?
   (c) What magnetic field is needed to get the same deflection?
2. For this problem you will need to look at a full bottle of water. The density of water is about 1gram per cubic centimeter, and the chemical formula for water is H_2O. A mole is about 6.02×10^{23}.
   (a) Find the volume of the bottle of water in cubic centimeters (you may convert from the number on the label).
   (b) What is the mass of this amount of water?
   (c) How much does the water weigh?
   (d) How many water molecules does the bottle contain?
   (e) Iron has a density of approximately $7 g/cm^3$. How much mass is in a piece of iron with the same number of iron molecules as there are water molecules in the glass?
   (f) Use these results to estimate the volume of an iron atom.
   (g) Estimate the length of an iron atom.

******************************** HW5 ********************************

Problems:

1. A beam of red light (wavelength 620nm) has an intensity of 1000 Watts per square meter and fully illuminates a square screen of size10 cm by 10cm placed perpendicular to the beam direction.
   (a) What is the frequency of the light?
   (b) If the screen has two slits in it separated by .01 mm, at what angle from the incident direction is the first dark band?
   (c) What is the energy of each photon in the beam?
   (d) How many photons per square meter per second are incident on the screen?
   (e) How many photons will hit the screen in 10 seconds?
2. If the Rutherford experiment had seen only small angle scattering of the alpha particles, what might one have concluded about the atom?

******************************** HW6 ********************************

Seeds p. 117 Problems 1, 2, 4, 6, 7

******************************** HW7 ********************************

Seeds p. 21 Problems 1, 4

p. 117 Problems 9, 10

p. 167 Problems 2, 3, 7, 11, 14

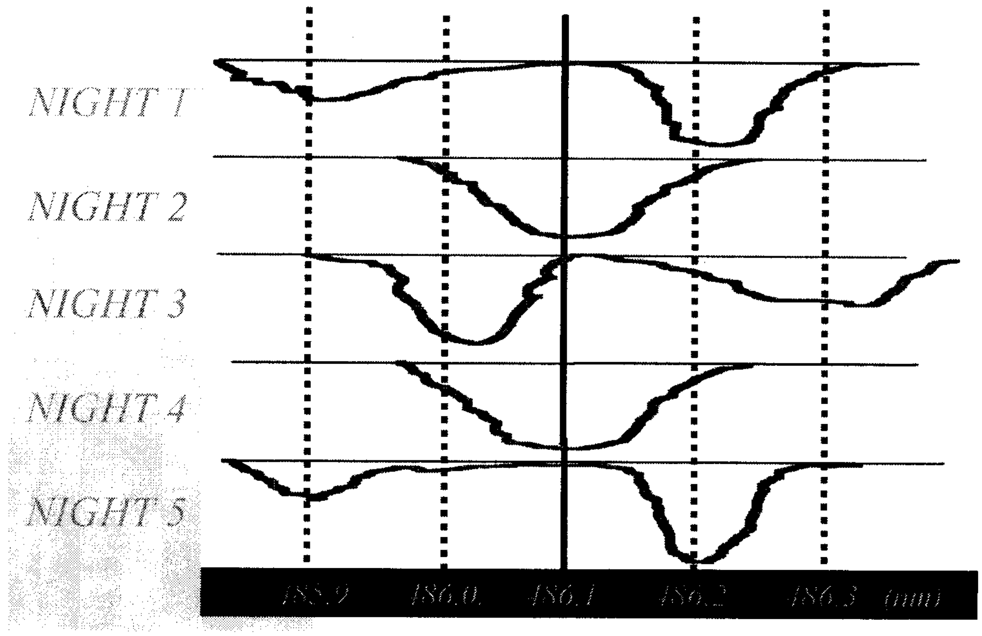
Problem:

1. For this problem you will need a lamp with a light bulb of as small wattage as possible, a page size sheet of cardboard (preferably black, but it doesn't have to be) and a room in which you can turn off all the lights.
   (a.) From the wattage of the bulb and the fact that you can see the light, make a rough estimate of the maximum number of visible photons leaving the bulb. Assume that 5% of the bulb's energy goes into visible light.
   (b.) Assuming the photons are emitted uniformly over the surface of the bulb, find the number of photons per square meter emitted at the bulb's surface.
   (c.) Using a pin, punch a tiny hole in the cardboard and put it about a meter from the bulb. Turn off the light in the room. Can you see light coming from the bulb when you look through the hole? Try making smaller and bigger holes and moving the cardboard closer and further from the bulb. Can you get to the point where you can just barely see the bulb? Estimate the number of photons that you are seeing.

******************************** HW8 ********************************

Problems:

1. You observe the following spectral changes in the 486.1 nm region for an astronomical source, which you interpret to be a binary system.



(a)What is the period of revolution of the system? CONTINUED ON NEXT PAGE

(b)What are the velocities of the two objects in the binary system?
(c)What are the orbit radii of the two objects?
(d)What is the sum of the object masses?
(e)What are the masses of the two objects?

2. Would simultaneity depend on reference frame if the speed of light were infinite? Why or why not?
3. Does simultaneity of two events happening at the same place depend on the observer's reference frame?

********************************* HW9 *********************************

Problems:

1. Two photons collide and create two particles each with mass the same as that of an electron (we will see later in the semester that this is possible when on one of the created particles is an electron, and the second is a particle called a positron).
   (a) Find the energy of the two colliding photons if they were identical to each other and the two particles are created with zero velocity.
   (b) What is the frequency and wavelength of each of the photons?
   (c) Do (a) and (b) for the particles created with velocity 1/10 the speed of light.
   (d) Do (a) for the particles having the mass of a proton.
2. The mass of a ^{12}C atom is defined as 12.0000 amu, the mass of ^{4}He is 4.0026 amu, the mass of ^{56}Fe (iron) is 55.934, the mass of ^{235}U is 235.0439, and the mass of ^{238}U is 238.0508 .
   (a) List these in order from most to least stable.
   (b) Are any of these isotopes unbound systems?

********************************* HW10 *********************************

Seeds. p.195 Problems 2, 4, 6, 9,
p. 223 Problems 2, 7, 8, 9,

********************************* HW11 *********************************

Problems:

1. For this problem you will need a globe, a map of the world on which you can write, a string, scissors, a ruler, paper, scotch tape, and a protractor. The bigger the globe, the more accurate your measurements will be.
   (a.) Find Los Angeles, California; Warsaw, Poland; and Rio de Janeiro on the globe.
   (b.) Tape one end of a piece of string to Los Angeles, and find the path on the globe for which you need the least string to get to Warsaw. Tape the string in place. Now do the same for Warsaw to Rio and Rio to Los Angeles.
   (c.) Trace out the paths on the map. On the same map, draw straight lines connecting the cities.
   (d.) Using the protractor, measure the angles on the globe of the three vertices formed by the strings. How many degrees in this triangle?
   (e.) Repeat these steps for Los Angeles, New York City, and Victoria British Columbia. CONTINUED ON NEXT PAGE

(f.) Repeat these steps for Los Angeles, Phoenix, and Salt Lake City.
(g.) What do you conclude about geometry on the surface of a sphere?

********************************* HW12 *********************************

Seeds p. 247 Problems 2, 5, 6
p. 299 Problems 1, 2, 6, 9
p. 319 Problems 6, 7, 8

********************************* HW13 *********************************

Problem:

1. Make a list of 10 of the particles about which you have learned.
   (a) Which of them interacts with the strong nuclear force?
   (b) Which interacts with the weak nuclear force?
   (c) Which interacts with the electromagnetic force?
   (d) Which of them interacts only with gravity?
   (e) Out of which of these particles are humans built?
   (f) Which of these particles mediate forces? List the force for each.
   (g) Stretch out your hand. Which particles in your list are likely to pass through your hand?
   (h) Write down the particles in order of increasing mass.
   (i) Write down the particles in order of decreasing lifetime.

********************************* HW14 *********************************

Seeds: p. 345 Problems 1, 5, 6, 8

Problem:

1. In the order of the distance to which they are useful, list the techniques used to measure the distances of astrophysical objects and the minimum and maximum distance to which they are useful. Is there an overlap of each method to the next longer-distance method?

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