To Kolb 2/24/05

UWUCC Appr 2/8/05

Senate Info 3/1/05

04-44

Undergraduate Distance Education Review Form

(Required for all courses taught by distance education for more than one-third of teaching contact hours)

Existing and Special Topics Course

Course: ______________ SCI 105 – Physical Science I ______________

Instructor of Record: V. Wijekumar, R. Freda, and M. Numan_ phone: 7.4588- e-mail: vjwije@iup.edu

Step One: Department or its Curriculum Committee

The committee has reviewed the proposal to offer the above course using distance education technology, and responds to the CBA criteria as follows:

1. Will an instructor who is qualified in the distance education delivery method as well as the discipline teach the course? ✓ Yes ___ No

2. Will the technology serve as a suitable substitute for the traditional classroom? ✓ Yes ___ No

3. Are there suitable opportunities for interaction between the instructor and student? ✓ Yes ___ No

4. a. Will there be suitable methods used to evaluate student achievement? ✓ Yes ___ No

   b. Have reasonable efforts been made to insure the integrity of evaluation methods (academic honesty) ✓ Yes ___ No

5. Recommendation:

   ✓ Positive (The objectives of the course can be met via distance education.)

   ____ Negative

Kenneth E. Hershman 1-25-05

signature of department designee date

If positive recommendation, immediately forward copies of this form and attached materials to the Provost and the Liberal Studies Office for consideration by the University-Wide Undergraduate Curriculum Committee. Dual-level courses also require review by Graduate Committee for graduate-level offering. Send information copies to 1) the college curriculum committee, 2) dean of the college, and 3) Dean of the School of Continuing Education.

Step Two: UNIVERSITY-WIDE UNDERGRADUATE CURRICULUM COMMITTEE

X Positive recommendation

___ Negative recommendation

Gail S Sechrist 2/8/05

signature of committee chair date

Forward this form to the Provost within 24 calendar days after review by committee.

Step Three: Provost

✓ Approved as distance education course

___ Rejected as distance education course

[signature] 2/22/05

signature of Provost date

Step Four:

Forward materials to Dean of the School of Continuing Education.

IUP I-Mail: Message from InBox Folder

Reply | Reply All | Forward | Delete | Close Unread | Flag | Add Address | Folders | Compose | Rules | Settings | Log Out

Next Unread | Back To Folder | Copy To | Move To | Print

Header | Deco

From: "Jean Serio" <JSERIO@iup.edu>
Subject: Summer Distance Education
Date: Thu, 14 Oct 2004 11:55:43 -0400
To: <ronfreda@iup.edu>, <mznuman@iup.edu>, "VJ Wijekumar" <vjwije@iup.edu>
Cc: "John Eck" <jseck@iup.edu>, "Aleksandra Kaniasty" <akaniast@iup.edu>, "Karen Thiel" <ksthiel@iup.edu>, "Kenneth Hershman" <hershman@iup.edu>

Message from Nicholas Kolb:

Congratulations! Dean Eck has selected your course, SCI 105 Physical Science I, to be offered via distance education technologies during Summer School 2005. The course must be completely online and must be capable of enrolling at least 25 students.

The course must be approved by the University-wide Curriculum Committee no later than February 2005. The first step is to develop a syllabus and some representative modules. Then, fill in the attached review form and submit the materials to the department curriculum committee. Upon approval, the committee chair should follow the directions on the attached procedures form.

If you need assistance with the development of the course, contact the IUP Instructional Design Center (www.iup.edu/idc). You can attend the workshops offered by the IDC or ask to meet with Brian Carothers, or any of the instructional designers.

A development stipend will be paid to you soon after the course begins in the summer. If other faculty members shared in the development of the course, the stipend will be shared as directed. In addition to the teaching salary, you will receive $40 per distance education student.

Thank you for participating in our effort to increase Summer School enrollment. Should you have any questions, feel free to contact me (nekolb@iup.edu).

Nicholas Kolb
Associate Provost

P.S. If you are unable to receive approval prior to February, you may list the course on Banner with the designation section 801 to indicate distance education. However, if the course does not earn approval, it will be cancelled and the students notified.

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SCI 105 – Physical Science – Distance Education Approval process for an existing course.

The following criteria listed under Article 42 Section E. appear on the form:

a) a qualified instructor;

The course instructors for the proposed SCI 105 course in distance education format have extensive experience in teaching the distance education courses at IUP. Dr. V. Wijekumar developed and taught a number of courses in the online format for six years. These online courses include PHYS 111, 112, 222/541, 331/531, and SAFE 462/562 at IUP. Dr. Numan developed and taught an online course PHYS 342/542 for three years at IUP. Mr. Freda taught distance education courses, PHYS 231, 242, 342, 331/531 and PHYS 222/541 for three years at IUP.

b) use of suitable technology as a substitute for the traditional classroom;

The course SCI 105 consists of a lecture section and a laboratory section. The lecture sections use the Physics Department Distance Education server and the server at IDC of IUP. A home page of the course resides at both sites. This home page contains hyperlinks to all the information necessary for the course. This includes hyperlinks to syllabus, study guide, references, WebCT links, lessons, homework assignments, quizzes, and contact information. Each lesson consists of objectives, outline, physical concepts and theory, examples, applications, and practice exercises. Hyperlinks are included in the lessons to take the reader to other sites which help them to understand the material better. The students should use the WebCT site to complete their assignments and quizzes except as noted in the syllabus for in-person test at the IUP site.

c) suitable opportunity for interaction between instructor and student;

Students will be given ample opportunity to interact with the instructors. Students should use the WebCT bulletin board and Chat-room to communicate with peers and instructors. Students should also use the email, phone, and in person when necessary to contact the instructors. Typically the instructors will respond to the students requests by email or bulletin-board within a few hours during weekdays or almost instantaneously when they use the WebCT Chat-room system. Students are also encouraged to contact the instructors by telephone when necessary. Students are also welcomed to visit their instructors when possible. According to our experience, typical online students contact their online instructors much more frequently than their counter part in-class instructors.

d) suitable evaluation of student achievement by the instructor; and integrity of the evaluation methods used.

Each student has to complete a set of online homework assignments and tests. Students are also required to take a test and a final examination at the IUP site to verify their identity. In limited cases, students will be permitted to take these tests at remote sites in the presence of proctors (typically faculty from other colleges) who are approved by the instructors.

Note: The syllabus of this course and the official syllabus of this have the same set of objectives even though the method of delivery is different. Each lesson developed for this online course has short video clips to emphasize the key concepts. In addition simulations are also provided for each lesson to add problem solving skills. We hope that the students will be able to achieve the same goals as in a traditional classroom.

Physical Science I – SCI 105
Syllabus
Department of Physics
Indiana University of Pennsylvania

Home Page	Study Guide	References	WebCT	Instructor

I. Catalog Description

SCI 105 Physical Science I, 3c-2l-4cr

A descriptive and conceptual course in physics for the non- Science major. High school physics is not a prerequisite. Course content is designed to develop an understanding and appreciation of the physical world around us, to produce changes in attitude and background essential for our modern society, and to clarify the following topics: motion, heat, sound, light, electricity, magnetism, and the structure of matter.

II. Course Objectives

After completing the course, the student will be able to
1. Develop an understanding of the role of physics in describing the phenomena of nature.

2. Provide the necessary experiences in the laboratory so that the processes of observation, classification and generalization may be used.

3. Explain in terms of the physical processes involved some of the more common natural phenomena.

4. Use mathematics both algebraic and graphical techniques to arrive at numerical answers for scientific problems.

5. Inculcate an attitude of appreciation for the importance of science in modern society.

6. Furnish a factual background as a foundation for making intelligent judgments concerning the worth of the applications of science.

7. Provide an understanding of some of the "great moments" in the history of physics and the individuals, including women and minorities, responsible for them.

Additional Laboratory objectives:

After completing the laboratory exercises for the course, the student will be able to
1. Reinforce his/her understanding of the concepts learned in lecture through a series of hands-on laboratory exercises.

2. Become familiar with the systems of measurement and the instruments associated with those systems.

3. Become familiar with various analytical techniques, to include graphing and graphical analysis of the data.

4. Overcome the reluctance to manipulate simple apparatus in exploring phenomena.

5. Develop the ability to quantify data through the performance of a laboratory exercise and to analyze the data to produce meaningful physics relationships.

III. Course Outline

PART 1 – ONLINE LECTURE CONTENT

Section 1 - MECHANICS (Equivalent of 13.5 lecture hours)

1. Introduction to Physics
2. Concepts of Motion
3. Free Fall & Projectile Motion
4. Newton's Laws
5. Energy
6. Impulse & Momentum
7. Circular Motion
8. Rotational Motion and Gravitation
9. Fluids

Section 2 – SOUND AND HEAT (Equivalent of 7.5 lecture hours)

10. Simple Harmonic Motion
11. Sound Waves & Music
12. Heat & Temperature
13. Heat Flow
14. Heat Engines & Thermodynamics

Section 3 – ELECTRICITY AND MAGNETISM (Equivalent of 6 lecture hours)

15. Electrostatics
16. Electric Circuits
17. Electronics
18. Magnetism

Section 4 – LIGHT (Equivalent of 4.5 lecture hours)

19. Electromagnetic Waves
20. Light & geometrical optics
21. Light & physical optics

Section 5 – ATOMIC AND NUCLEAR PHYSICS (Equivalent of 7.5 lecture hours)

22. Relativity
23. Quantum Mechanics

24. Atoms & Atomic Radiation
25. Nucleus & Nuclear Radiation
26. Nuclear Energy and Cosmology

PART 2 – ONLINE LABORATORY CONTENT

Section 6 - Laboratory Exercises (Equivalent of 26 laboratory hours of exercises)

1. Measurement - The Use of Numbers and Units
2. Measuring Instruments and Systems
3. Graphing and Graphical Analysis
4. Some Other Types of Motion
5. Systems in Equilibrium
6. Conservation of Energy - Work and Machines
7. Conservation of Energy - Heat, Temperature, and Thermal Energy
8. Vibrations, Resonance, and Waves
9. Reflection, Refraction, and Mirrors
10. Refraction and Lenses
11. Some Other Properties of Light
12. Conservation of Energy and Electric Circuits
13. Electronics Lab

PRODEDURE:

1. The use of online lectures, demonstrations, multi-media presentations to illustrate physical principles and develop a knowledge of them.

2. A sequence of laboratory exercises to provide "hands on" experiences with experimental techniques and instruments.

3. The use of homework assignments and outside readings to broaden the student's background.

4. Three one-hour tests, a two-hour final, weekly laboratory exercises, and assigned homework to help evaluate the student's progress and his/her assimilation of the topics covered.

5. For details on the online lectures and laboratory exercises, please refer to the course homepage site listed below:

http://www.py.iup.edu/dist-learn/sci105/sci105sch.html

IV. Evaluation Methods

The final grade for the course will be determined from three one-hour tests, a two-hour final examination, assigned homework, and weekly laboratory exercises.

30% Three one-hour tests consisting of solving problems and/or discussion type questions.

25% Homework

15% Final comprehensive examination

30% Laboratory exercises

You need to take one of the tests at our site (Physics Department at IUP). Please make arrangements for it with me. If you are unable to visit our site to take one of the tests on the dates posted, I will provide an alternative date and test for you. Please see the study guide for details.

V. Required Textbook

Conceptual Physics, Ninth Edition; Author: Paul G. Hewitt

Publisher; Addison Wesley – 2002 (ISBN # 0-321-05160-2)

Suggested Readings:

The physics of everyday phenomena, fourth edition; Author: W. Thomas Griffith

Publisher; McGraw Hill – 2004

Required Readings:

The American Institute of Physics has compiled the following applications of physics. Please click on the hyperlinks below to get an understanding of the extent of the applications of physics.

- Physics Saves Money - Energy Efficiency
- Physics Improves Health - Medical Physics
- Physics Creates Jobs - Computers
- Physics Drives Progress - Transportation
- Physics Protects People - National Defense
- Physics Fills Your Home - Consumer Goods
- Physics Connects the World - Telecommunications
- Physics Stimulates Industry - Lasers
- Physics Saves Lives - Medical Imaging
- Physics Designs the Future - New Materials
- Physics Clears the Air - The Environment
- Physics Launches New Business - Global Positioning System
- Physics On Display
- Physics is A Sound Investment
- Physics Weaves The Web

The student will:
(1) select two topics from the list above for additional reading.
(2) declare the choices to be read by the third laboratory period (second week during summer sessions) and inform your instructor about your reading choices.
(3) Work on an assignment consisting of eight multiple-choice questions per topic for a total of 16 questions, or 30 T-F items, selected randomly from our question bank on those topics. This assignment will be completed during the fourth week of summer session or the eleventh week of the semester.
(4) The graded assignment will be recorded and will count as two homework assignments in the normal

grade structure of the course.

VI. Online References:

Online Textbook:

http://occawlonline.pearsoned.com/bookbind/pubbooks/physicsplace/chapter1/deluxe.html

Other Online References:

1. http://www.mhhe.com/physsci/physical/jones/index.mhtml
2. http://physics.csustan.edu/general/general.htm
3. http://buphy.bu.edu/py105/Notes.html
4. http://www.ch.cutler-hammer.com/training/slfstudy/navigate/webmanualmenu.html
5. http://physics.csustan.edu/general/general.htm
6. http://buphy.bu.edu/py106/Notes.html

Please send your comments about the course to Dr. V. Wijekumar.

Last Modified: 1/16/05

COURSE SYLLABUS (Department Record of syllabus)

SC 1 05 PHYSICAL SCIENCE I

4 credits
3 lecture hours 2 lab hours

I. CATALOG DESCRIPTION

A descriptive and conceptual course in physics for the non-science major. High school physics is not a prerequisite. Course content is designed to develop an understanding and appreciation of the physical world around us, to produce changes in attitude and background essential for our modern society, and to clarify the following topics: motion, heat, sound, light, electricity, magnetism, and the structure of matter.

II. COURSE OBJECTIVES

1. To develop and understanding of the role of physics in describing the phenomena of nature.

2. To provide the necessary experiences in the laboratory so that the processes of observation, classification and generalization may be used.

3. To be able to explain in terms of the physical processes involved some of the more common natural phenomena.

4. To be able to use mathematics both algebraic and graphical techniques to arrive at numerical answers for scientific problems.

5. To inculcate an attitude of appreciation for the importance of science in modern society.

6. To furnish a factual background as a foundation for making intelligent judgments concerning the worth of the applications of science.

7. Provide an understanding of some of the "great moments" in the history of physics and the individuals, including women and minorities, responsible for them.

PRODEDURE:

1. The use of lectures, demonstrations, films and other audio-visual aids to illustrate physical principles and develop a knowledge of them.

2. A sequence of laboratory exercises to provide "hands on" experiences with experimental techniques and instruments.

3. The use of homework assignments and outside readings to broaden the student's background.

4. 3 one-hour tests, a 2 hour final; weekly laboratory exercises, scheduled quizzes, and assigned homework to help evaluate the student's progress and his assimilation of the topics covered.

III. COURSE OUTLINE

39 lectures total

A. Measurement (1 lecture) 1. Numbers and units

2. Systems of measurement

a. English b. Metric

3. Vectors and Scalars

3.' Motion (9 lectures)
1. Fundamental Concepts
a. Acceleration, velocity and displacement

. Describing motion
a. Graphical techniques

b. Use of formulas

:. Kinematics - the how of motion
ı. Uniformly accelerated
). Motion
:. Air resistance and motion

I. Dynamics - the why of motion
ı. Newton and his laws
1) Inertia
2) Impulse and momentum
3) Action and Reaction

5. Motion about an axis
a. Curvilinear versus line

3. Gravitation and Motion
a. The universal force
b. Kepler's Laws of planetary motion

C. Energy (8 lectures)
1. Types
a. Kinetic
b. Potential

2. Conservation of
a. Collisions and other things

3. Energy Transfer
a. Work
b. Heat

·. Applications

). Waves (8 lectures)
1. Sound
a. Echoes, the voice and the ear
b. Resonance
c. Doppler Effect

2. Light
a. Mirrors
b. Lenses

c. Color
   1) Rainbows and other phenomena

E. Electricity and Magnetism (5 lectures)
   1. Static Electricity
      a. Charged objects
         1) Forces of attraction and repulsion
      b. Friction and induction
      c. Electric Fields

2. Current Electricity
   a. Circuits
   b. Amps, volts and ohms
   c. Fuses and circuit breakers

3. Magnetism and Electricity
   a. The interconnection
   b. Magnetic fields and forces

4. Applications
   a. Motors
   b. Generators
   c. Appliances

5. Electricity and the Body
   a. Health hazards

F. Modern Physics (2 lectures)
   1. Relativity - Einstein

2. Quantum Theory - Planck
   a. Photon

3. Dual Nature of Reality - DeBroglie
   a. Wave and/or particle

4. You can't be too sure - Heisenberg
   a. How much can we know

G. The Atom (5 lectures)
   1. Its structure

2. The nucleus
   a. Fission
   b. Fusion

3. Atomic Energy - Good or Bad

H. The Kingdom of the Sun (1 lecture - but much of this is integrated into the study of motion)

1 . The Solar System
   a. Planets and the sun

2. The earth sun and moon

a. Days, months and years

3. The earth and its motions in space
   a. Rotation
      1) Days and nights
   b. Revolution
      1) The seasons

IV. EVALUATION METHODS

The final grade for the course will be determined from 3 one-hour examinations, a two hour final, scheduled quizzes, assigned homework, and weekly laboratory exercises.

V. REQUIRED TEXTBOOKS, SUPPLEMENTAL BOOKS AND READINGS

1. Readings - The student will:
(1) receive a listing of enough books, science fiction stories and articles that he or she can cater to any interest and still not have to purchase the outside readings.
(2) select one book, one science fiction book and two article readings from the list.
(3) declare the choices to be read in laboratory by the third laboratory period on a printed card.
(4) confirm the selection of readings on his or her card during the tenth laboratory period (reminds them to finish).
(5) be presented with an individualized, computer-printed exam consisting of five multiple-choice questions per book and three multiple choice questions per article, for a total of 16 questions, or 30 T-F items, selected randomly from our question bank, and different each time. This exam will be completed in the first 20 minutes of the eleventh laboratory of the semester.
(6) The graded test will be recorded with, but separate from, the laboratory grade and will count as one-half test in the normal grade structure of the course.

2. General Version
   a. Text - Introduction to Physical Science. Riban, McGraw-Hill, 1982

   b. Supplemental Text - Departmental Lab Manual available at Copies Now

3. Elementary Ed/Special Ed Version (1989-90)
   a. Text - Conceptual Physics. 6th Edition, Paul Hewitt, Little, Brown, 1989

SYLLABUS ADDENDUM

PHYSICAL SCIENCE I - GENERAL VERSION - LABORATORY ONLY

I. LAB OBJECTIVES,

1. To allow the student to reinforce his/her understanding of the concepts learned in lecture through a series of hands-on laboratory exercises.

2. To become familiar with the systems of measurement and the instruments associated with those systems.

3. To become familiar with various analytical techniques, to include graphing and graphical analysis of the data.

4. To overcome the reluctance to manipulate simple apparatus in exploring phenomena.

5. To develop the ability to quantify data through the performance of a laboratory exercise and to analyze the data to produce meaningful physics relationships.

II. LAB EXERCISES

1. Measurement - The Use of Numbers and Units
2. Measuring Instruments and Systems
3. Graphing and Graphical Analysis
4. Some Other Types of Motion
5. Systems in Equilibrium
6. Conservation of Energy - Work and Machines
7. Conservation of Energy - Heat, Temperature, and Thermal Energy
8. Vibrations, Resonance, and Waves
9. Reflection, Refraction, and Mirrors
10. Refraction and Lenses
11. Some Other Properties of Light
12. Conservation of Energy and Electric Circuits
13. Astronomy Lab

a. The Orbit of Mars
b. Parallax
c. The Earth and Its Motions in Space (Retrograde Loop of Mars) d. Triangulation.

NEWTON'S LAWS - LESSON 4
SCIENCE 105
Department of Physics
Indiana University of Pennsylvania

Home Page	Lesson 3	Lesson 5	(WebCT)
Syllabus	Homework 4	References	Instructor

Contents:

1. Force
    a. Gravitational Force
    b. Electromagnetic Force
    c. Nuclear Force (Strong Force)
    d. Weak Interaction (Force)
2. Motion
    a. Newton's Second Law of Motion
    b. Newton's First Law of Motion
    c. Newton's Third Law

Lesson Objectives:

Following the study of the materials of this chapter the student will be able to:

- Define force
- Identify the four fundamental forces of nature
- State and explain Newton's three laws of motion
- Distinguish between forces acting on an object and by the object on something else
- Know that the external forces acting on a system are only considered for applying Newton's first two laws
- Define weight
- Understand the difference between mass and weight

Lesson Outline:

1. Force

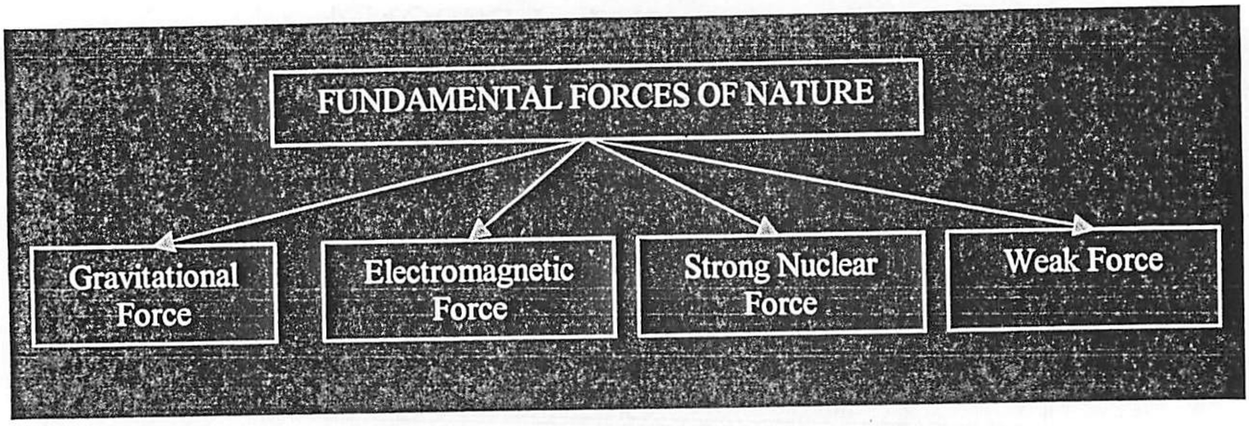


Figure 1: Fundamental forces of nature.

The motion of an object is affected by the forces acting on it regardless of its size. Everybody has an idea about the term force. We are familiar with the forces which push or pull an object. These forces are generally known as *contact forces* due to the obvious reason that two objects have to be in physical contact with each other to exert a force. In contrast, the gravitational force due to the Earth on an object, which is simply known as the weight of an object, does not require any physical contact between the objects. The observation of apples falling to the ground from a tree enabled Sir Issac Newton to come up with his theory of gravitation.

Gravitational Force

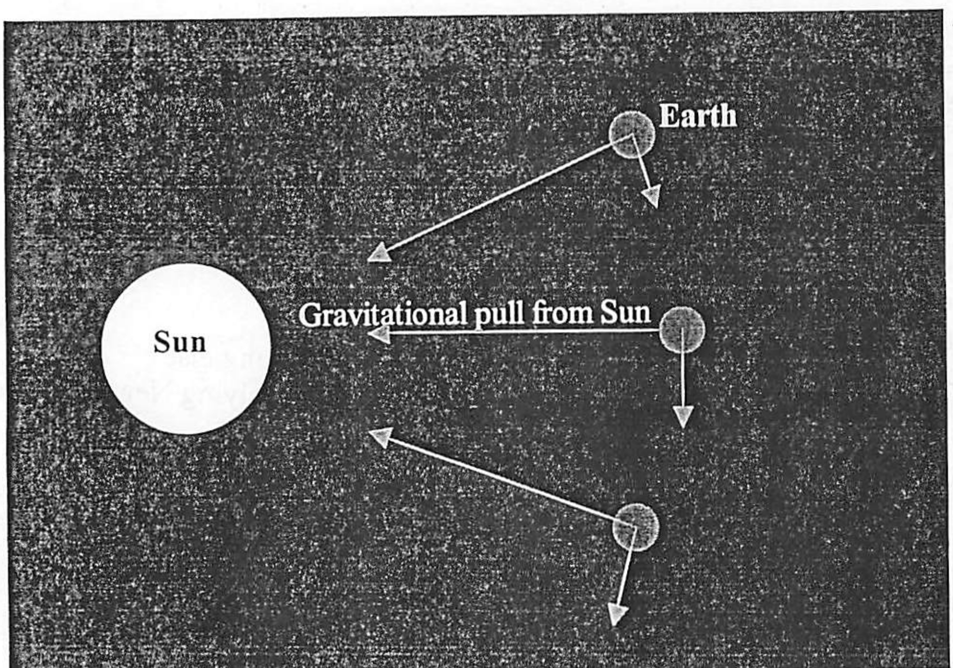


Figure 2: The gravitational pull of the sun on the earth keeps the earth in a nearly circular orbit. The gravitational force between galactic objects is responsible for the motion of planets, stars, galaxies, and other galactic objects.

One mass is universally attracted to another mass whether they are in physical contact, or at a distance, according to Newton's law of universal gravitation. This gravitational force, F_G, between two masses m_1 and m_2 is always an attractive force and gets smaller when the distance r between them is increased. The magnitude of this attractive force is given by the following equation:

$$F_G = [Gm_1m_2] / [r^2].$$

The term G is known as the universal gravitation constant and is equal to 6.67 x 10^{-11} $N.m^2/kg^2$. When both masses are small, like a few kilograms, the force is very small. However if one of them is very large, such as the Earth, then the force is significant even on an object such as a stone or an apple. The gravitational force on an object due to the Earth is known as the weight of the object. The *weight* W of an object of mass m at the Earth's surface is given by

$$W = F_G = [GmM_E] / [R^2].$$

where R is the radius of the Earth and M_E is the mass of the Earth. The weight W can also be rewritten as

$$W = m[GM_E] / [R^2]. = mg$$

The term g is known as the acceleration due to Earth's gravity at its surface and is almost constant. There is some variation in g due to earth's rotation and structure, but we will ignore that. Thus the term g depends only on the mass of Earth and its radius.

$$g = [GM_E] / [R^2].$$

The value of g at the surface of Earth is about 9.8 m/s^2.

Similarly the acceleration of gravity on the moon due to the mass of the moon is given by

$$g = [GM_m] / [R_m{}^2].$$

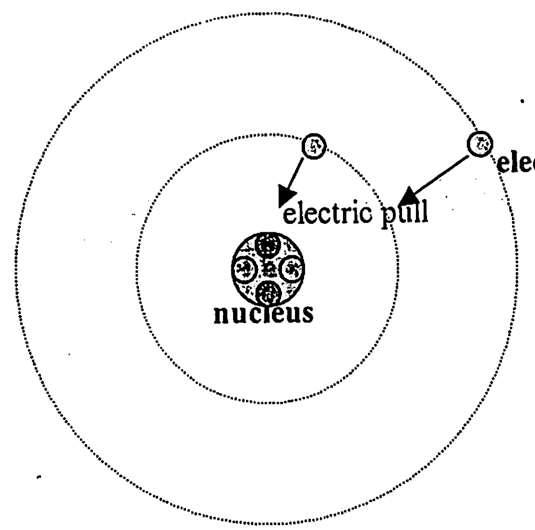
Where M_m is the mass of moon and R_m is the radius of the moon. The value for g at the surface of the moon is about 1.6 m/s^2 since the mass and radius of the moon are not the same as the Earth's.

Definition of a Newton (watch this video clip to learn more about weight)

Exercise:
Gravity on the surface of the moon is only 1/6 as strong as gravity on the Earth. What is the weight of a 50-kg person on the moon and on the Earth?

When both masses are large, the force is certainly significant. The reason for our Moon orbiting around the Earth, or for the Earth orbiting around the Sun, is the gravitational force between them. In fact, all galactic motion (planets, stars, galaxies etc.) is governed by the gravitational force. This is one of the fundamental forces of nature. There are three other fundamental forces of nature, which determine the fate of our Universe at the atomic and molecular levels. These are the electromagnetic force, strong nuclear force, and the weak force (also known as the weak interaction).

Electromagnetic Force



Positively charged protons(red circles) pull (electric force) the orbiting electrons (green circles) towards the nucleus of an atom.

Figure 3: The orbiting electrons experience a pull force towards the nucleus due to the electric force exerted by the protons inside the nucleus of an atom. The electric force between an electron and a proton is responsible for the existence of all the chemical elements from hydrogen to uranium and beyond.

Another force that does not require any physical contact between the objects is the force between two magnets. The origin for this magnetic force is classified as an electromagnetic force that exists between electric charges. When two electric charges are stationary, the force between them is called an electrostatic force or electric force and is given by the Coulomb's law. However when there is a flow rate of electric charges (simply known as an electric current), it produces a magnetic field, and another moving electric charge in the vicinity will experience a magnetic force. Both these forces combined are known as electromagnetic forces. The force, F, between two stationary electric charges q_1 and q_2 at a distance r is given by the Coulomb's law.

$$F = [kq_1q_2] / [r^2].$$

The term k is known as the Coulomb's constant and depends on the medium. In free space, the value of this constant k is 9.0×10^9 $N.m^2/C^2$. An electric charge can be positive or negative. The charge of an electron is negative but the charge of a proton inside the nucleus of an atom is positive. When both charges have the same sign, the force between them is repulsive, but if they have the opposite signs there is an attractive force between them. This force is also the origin for all the contact forces such as push force or pull force! When the space between atoms is squeezed, the distances between like charges are reduced, and the repulsive force between charges results in a push force. Similarly when the distance between the unlike charges of atoms is increased, when pulling, the attractive force between the unlike charges pulls them back, and results in a pull force. You will learn more about this electromagnetic force in a later lesson about electricity. This electromagnetic force is the one that governs the motion of atoms and molecules, as well as their structures, and is responsible for all the chemical reactions. The effects of the electromagnetic force can be felt on a large scale too. An example is lightning and thunder which is the result of the electrical discharge due to the tremendous electric force between charged clouds and ground.

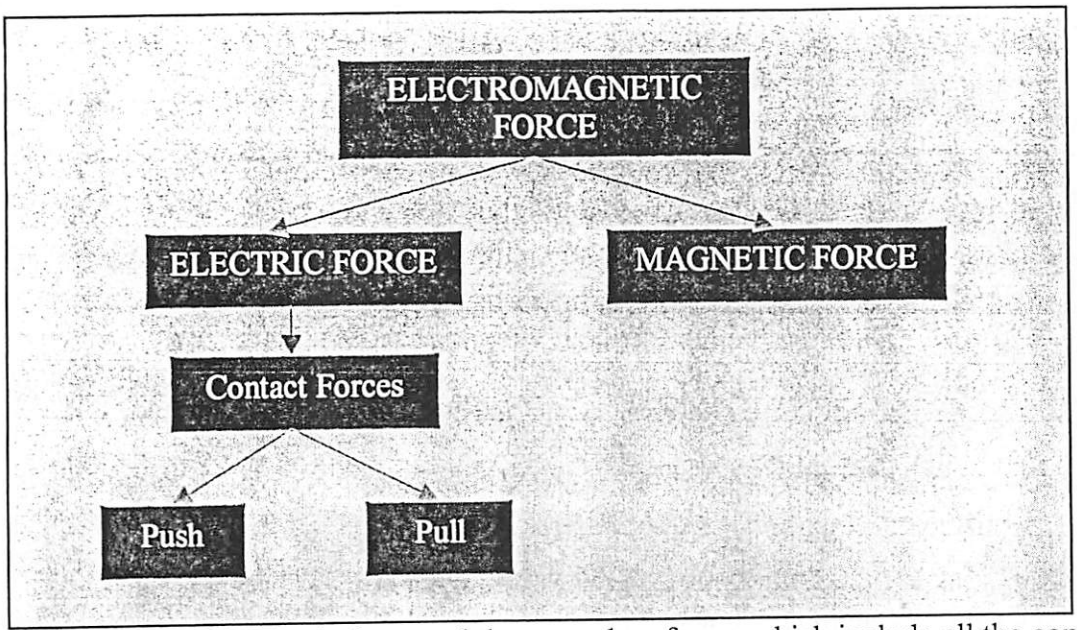


Figure 4: Electromagnetic force and the secondary forces which include all the contact forces.

Nuclear Force (Strong Force)

There is a very strong attractive force that exists between a pair of nucleons which exist inside a nucleus of an atom. A nucleon can be a proton or a neutron inside the nucleus. This strong attractive force exists between any two nucleons (proton-proton, neutron-neutron, or proton-neutron) provided their distance of separation is of the order of a nuclear radius or less. There is no nuclear force between two nucleons if the distance between them is increased to more than the size of the radius of a nucleus. This nuclear force is strong enough to overcome the repulsive Coulomb force (electrostatic force) between the protons, keeping the nucleons bound inside the nucleus of an atom. There are only a little more than one hundred chemical elements identified, but there are over two thousand different nuclei already identified. This is due to the reason that a chemical element can have more one type of nucleus. An example is chemical element carbon. The most abundant element in natural carbon (carbon-12) has only 6 protons and 6 neutrons in its nucleus, but the radioactive carbon (carbon-14) used in radioactive dating has 6 protons and 8 neutrons in its nucleus. Both are known as isotopes of carbon. An isotope of an element contains the same (iso) number of protons but can have different number of neutrons. The existence of various nuclei and the nuclear reactions that constantly go on in the stars are controlled by the strong nuclear force.

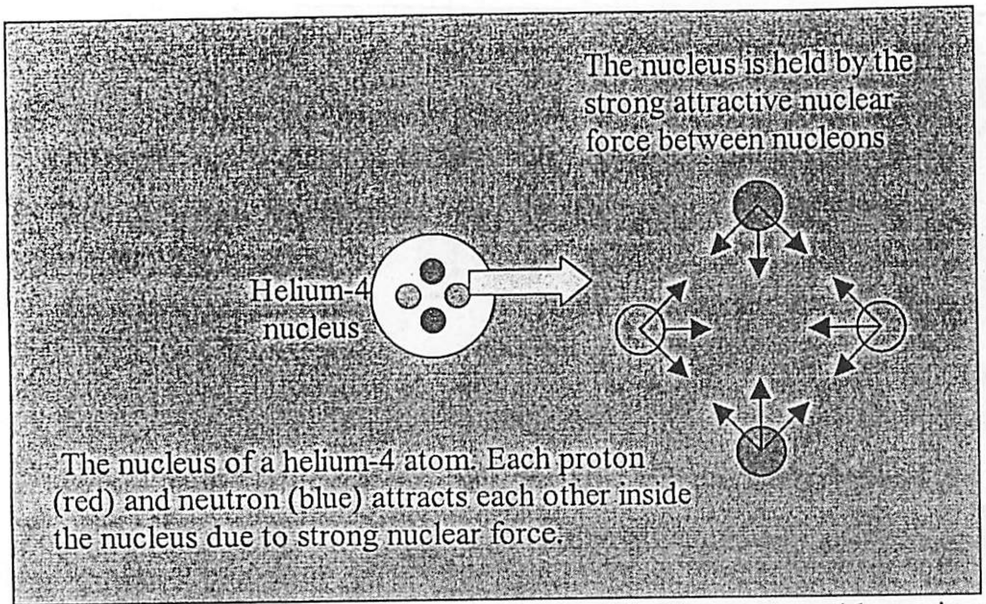
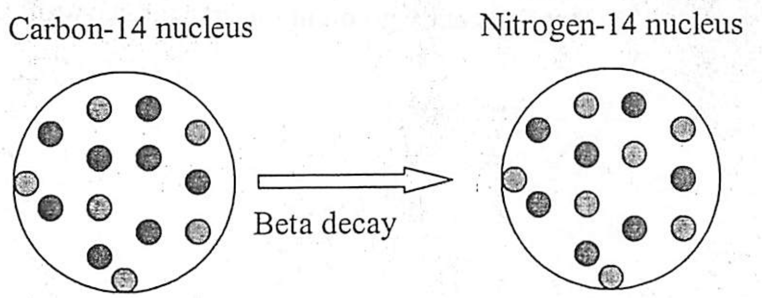


Figure 5: The nucleus of a helium-4 atom contains two protons (shown in red color) and two neutrons (shown in blue color). The strong nuclear attractive force overcomes the repulsive electric force the between protons to form a stable nucleus. The nuclear force is responsible for the formation of more than two thousand nuclei in nature.

Weak Force (Interaction)

This is the force that is responsible for one form of radioactivity of a nucleus in which a proton can become a neutron, or a neutron can become a proton, and is known as the beta decay of a nucleus. The magnitude of this force is much smaller than the nuclear force and is known as the weak interaction (force). This is a very complex force but you may imagine this force as the force of attraction between a proton and an electron that forms a neutron through another intermediate particle. A good example for this interaction (force) is the radioactive carbon-14 becoming a nitrogen-14 element during a beta decay. This weak interaction is responsible for keeping a certain balance in the number of nuclei in the universe by changing either protons into neutrons or neutrons into protons.



A carbon-14 nucleus emits a beta particle and becomes a nitrogen-14 nucleus. A neutron in a carbon-14 nucleus is converted into a proton and the nucleus becomes a nitrogen-14 nucleus during this beta decay.

Figure 6: During a beta (minus) decay, a neutron is converted into a proton and the nucleus changes from carbon-14 to nitrogen-14. The force that is responsible for this decay is known as a weak interaction and keeps a balance between the neutrons and the protons in the universe.

2. Motion

Force Causes Acceleration (watch this video clip to learn about what changes the velocity of an object)

Now let us return to the forces that are known as contact forces and consider how they affect the motion of objects that we encounter on a daily basis. A good example for us to consider is the motion of an automobile. Consider a car at a stop sign. The brakes and the road exert enough friction to overcome the force exerted by the idle engine to prevent the car from moving.

What causes an object to accelerate?

When the light changes to green, you release the brake pedal and step on the accelerator and the car starts accelerating and the speedometer moves up in speed. By pushing the accelerator pedal down, the engine exerts a net force (actually it is the reaction from the road pushing forward on the car) on the car in the forward direction and the car experiences an acceleration which is defined as the rate of change in velocity. An acceleration is a result of an unbalanced or "non-zero" net force acting on an object. In fact, the acceleration produced on an object is directly proportional to the net force acting on it. This is usually written as,

$$a \propto F$$

where a is the acceleration and F is the net force acting on the object. If the net force is doubled then the acceleration will be twice as before. It is important to pay attention to the term net force acting on the car. Net force acting on the car is the forward thrust force from the engine minus the frictional forces exerted on the car from the road and air.

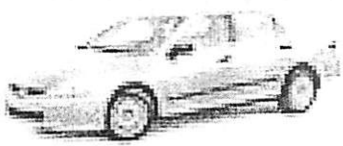


Figure 7: Honda Accord DX with a 160 hp engine with about 3000 lb weight.

Figure 8: Honda Accord EX V6 is a 240 hp with about 3000 lb weight. This car has a larger acceleration or quicker pickup than the DX model or the Odyssey.

Does the acceleration of an object depend on its mass?

You might have also experienced that a heavier car or truck with a similar size engine will experience a smaller acceleration compared to a light car. This is due to the fact that the acceleration of an object is inversely (reciprocally) proportional to the mass of the object. This is usually written as,

$a \propto 1/m$

where m is the mass of the object.

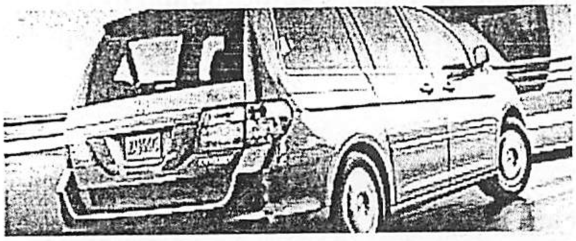


Figure 9. Honda Odyssey EX is a 250 hp with about 4500 lb weight. Even though this van has a similar engine as the Accord EX V6, its acceleration is smaller due to its heavier mass.

It is clear that the acceleration produced in a car depends on the net force acting on it and the mass of the car. This is usually written as,

$a \propto F/m$

In fact, this is true for any object and the relationship between force, mass and acceleration is given by *Newton's Second Law* of motion.

Newton's Second Law of Motion

Newton's 2nd Law (watch this video to learn more about Newton's Second Law)

The net external force acting on an object is the product of the mass of the object and the acceleration produced by the effect of the net force. This is expressed as,

Force = mass x **acceleration**

Or simply written as

$\mathbf{F} = m\mathbf{a}$

The net external force and acceleration are vector quantities and marked in bold letters. Both have magnitude and direction. Since mass is always positive, the acceleration will have the same direction as the net force on the object.

Note: **F** is the net external force acting on an object. If there is more than one external force acting on an object, then you need to find the resultant (net) or vector sum of all the external forces acting on the object.

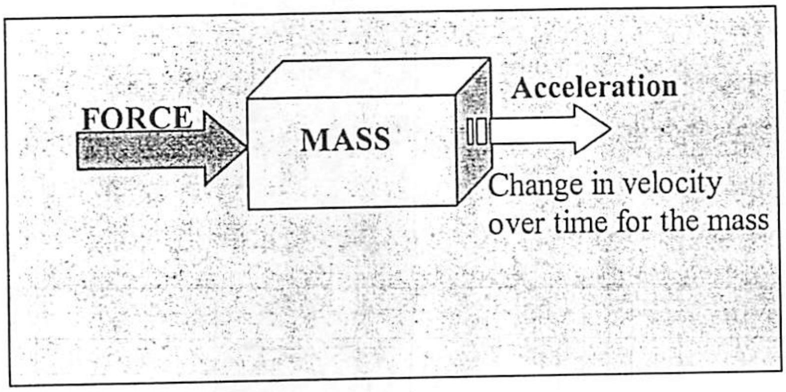


Figure 10: The application of a net force on an object produces an acceleration or rate of change of velocity for the object.

Example:
If a mass of 1 kg is accelerated 1 m/s^2 by a force of 1 Newton (N), what would be the acceleration of 4 kg acted on by a force of 8 N?

The force F is given as 8 N and the mass m is given as 4 kg. Thus using the equation F = ma, we get
8 N = (4 kg)a,
Therefore the acceleration, a = (8 N) / (4 kg) = 2 m/s^2.

Exercise:
What is the net force on a BMW traveling along a straight road at a constant speed of 100 mile per hour?

Newton's First Law of Motion

It is also important to note that if the net force acting on an object is zero then there is no acceleration. Thus in the absence of any external forces acting on an object, the object will remain in the *same state of motion*. That is, if the object is stationary, it will continue to stay stationary or if the object is in motion with a velocity it will continue to have the same velocity (constant) unless acted upon by an external force. This statement is known as the *Newton's First Law* of motion (this statement was first introduced by Galileo and then later adopted by Newton). Newton also came up with another important law known as *Newton's Third Law* that is also important to understand forces acting on objects.

Newton's Third Law

A simple way to express this law is to state that forces are always produced in pairs, between objects.

Change your weight by taking a trip in an elevator:

Suppose you stand on a weighing scale. Your weight is pushing the weighing scale down and the weighing scale is pushing you up with an equal and opposite amount of force according to Newton's Third law.

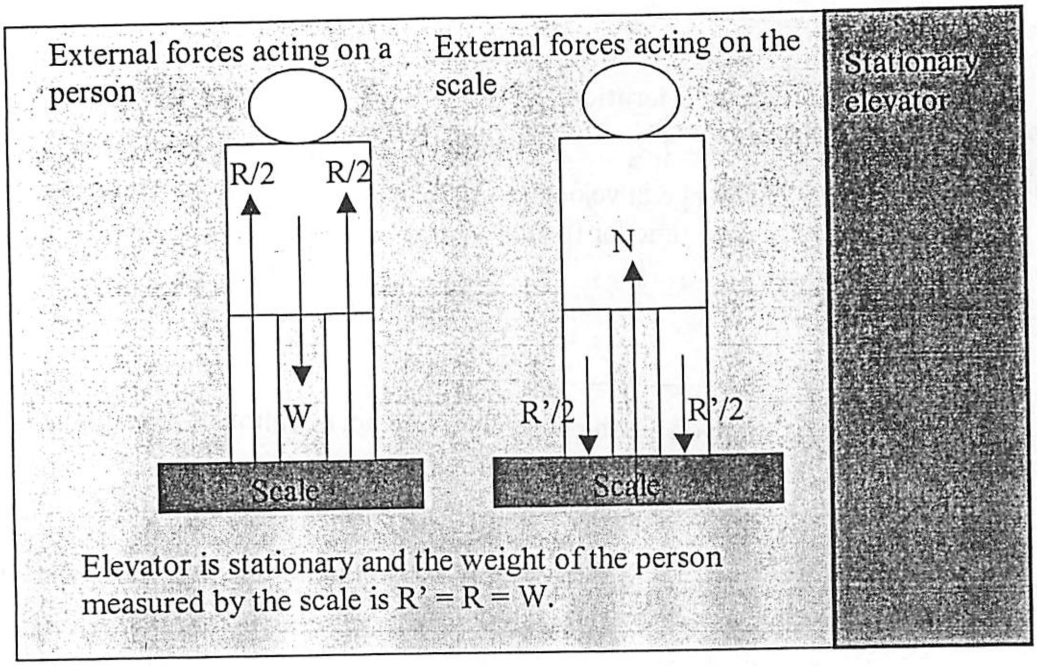


Figure 11: When a person is standing on a scale, his/her weight W is acting vertically downwards and the scale is pushing him/her vertically up with a force R.

The net force acting on the person is the vector sum of R and W and is equal to R – W if we choose the upward vertical direction as positive. When Newton's second law is applied to this person in the vertically upward direction, we get
$R - W = ma$ where 'a' is the acceleration of the person and 'm' is the mass of the person.
If there is no acceleration, $a = 0$, and we get
$R - W = 0$.
That is, R = W = weight of the person. But according to Newton's third law, the person will be pushing the scale down with a force R' which is equal in magnitude to the force R but opposite in direction. The person's weight is measured by this compressive force R' on the scale spring. The magnitude of R or R' is also the magnitude of the person's weight measured by the scale.

Now if the person is standing inside an elevator on this scale and decides to move up, there will be some initial acceleration for the elevator and the person inside. Now if we use Newton's second law to the moving person in the elevator with an upward acceleration, we get (the net force is still R – W),
$R - W = ma$.
Or, $R = W + ma$
But in this case, the weight of the person measured by the scale is more than the weight W by a positive quantity "ma" since m and a are both positive.

Example:
Suppose a 50-kg (about 110 lb) person is in an elevator which is moving up with an acceleration of 1.0 m/s^2, find R or the weight shown on a weighing scale for this person under this circumstance.

Given m = 50-kg and a = 1.0 m/s^2, we get

$$R = W + ma = mg + ma = (50\ kg)(9.8\ m/s^2) + (50\ kg)(1.0\ m/s^2) = 490\ N + 50\ N = 540\ N$$

That is the weighing scale would have read 490 N (110 lb weight) when the elevator was stationary but now it would read 540 N (121 lb weight).

If the elevator moves at a constant velocity then the acceleration a = 0 and the person's weight will be the same as the stationary case which is W.

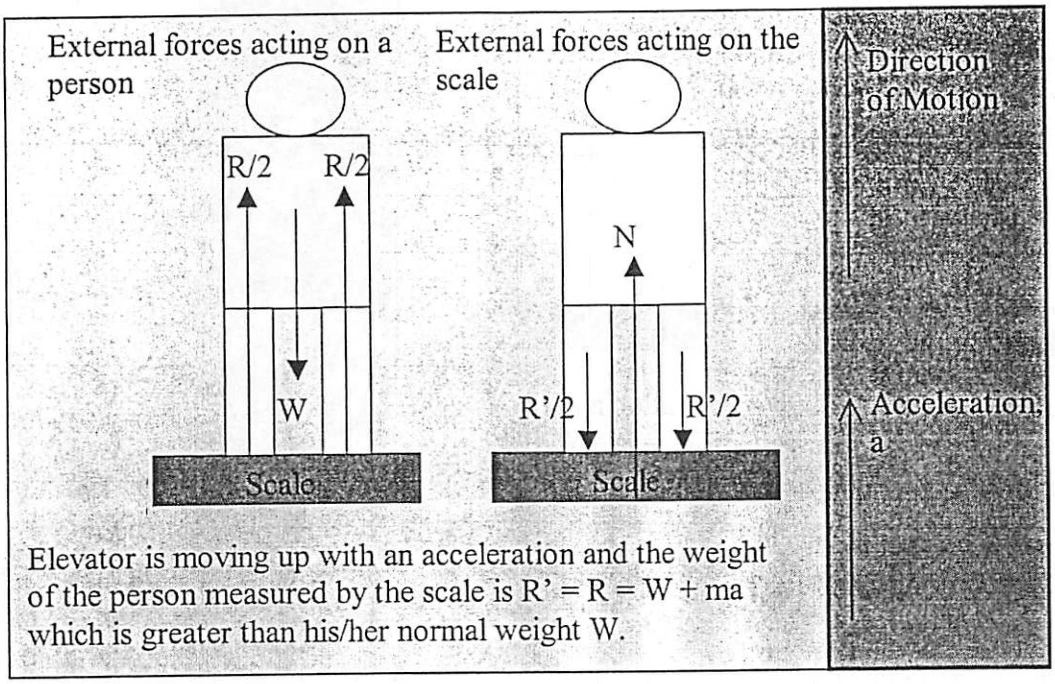


Figure 12: The person's weight measured by the scale in this situation is more than his/her weight, W.

But when the elevator starts slowing down, or decelerates to a stop, the acceleration is in the opposite direction to motion. It is a negative quantity if you choose the upward vertical direction as positive. Now if we apply the Newton's second law to the decelerating person standing on the weighing scale, we get

$R - W = ma$,

Or $R = W + ma = W - m|a|$, since a is negative.

Therefore the weight of the person is decreased by an amount $m|a|$. Now weight is $W - m|a| = mg - m|a| = m (g - |a|)$ where g is the acceleration due to gravity and is equal to 9.8 m/s^2. The magnitude of a is about 1.0 m/s^2 for elevators in typical sky-rise buildings. Thus a person can experience a 10% loss in weight during deceleration of an elevator moving upwards.

Example:

Suppose a 50-kg (about 110 lb) person is in an elevator which is moving up but with a deceleration of 1.0 m/s^2 in order to stop, find R or the weight shown on a weighing scale for this person under this circumstance.

Given m = 50-kg and a = 1.0 m/s^2, we get

$$R = W - ma = mg - ma = (50\ kg)(9.8\ m/s^2) - (50\ kg)(1.0\ m/s^2) = 490\ N + 50\ N = 440\ N$$

That is the weighing scale would have read 490 N (110 lb weight) when the elevator was stationary but now it would read only 440 N (99 lb weight)!

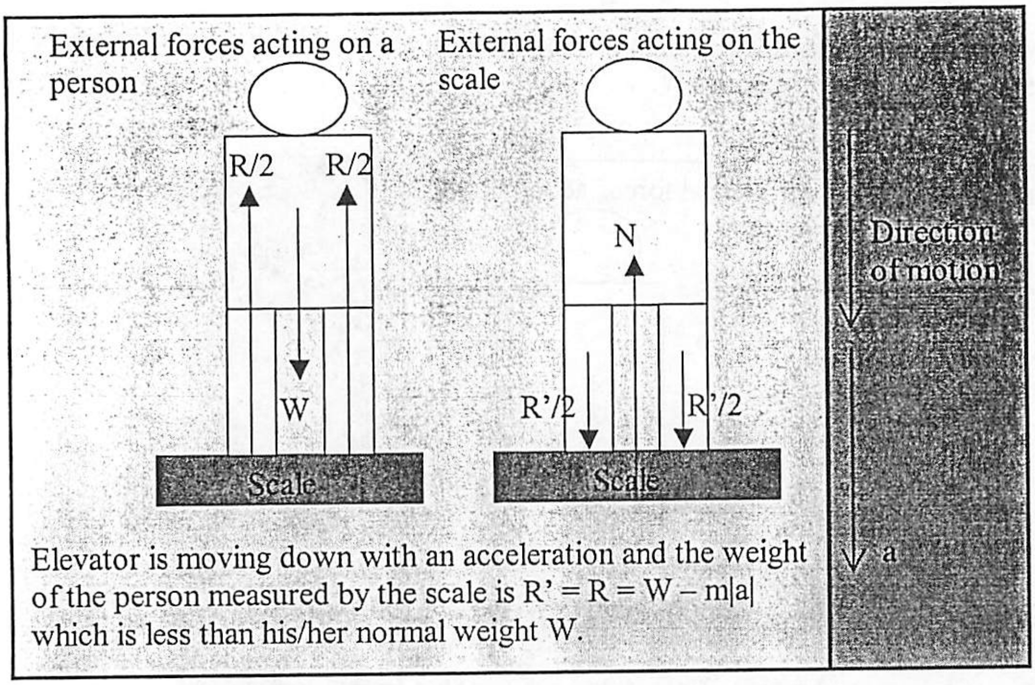


Figure 13: The person's weight measured by the scale in this situation is less than his/her weight, W.

Now consider the case, when an elevator is moving downwards, accelerating during the initial descent. For the person standing on the scale, if we apply Newton's second law in a vertically downwards direction, we get,

$W - R = ma$, note the change in direction. Now vertically downwards direction is considered positive.

Thus, the pushing force of the scale on the person is given by,

$R = W - ma$ where a is positive till the elevator reaches a constant velocity. This indicates that the weight of the person measured by the scale is decreased by ma from his stationary (or constant velocity) weight W.

Thus, $R = W - ma = mg - ma = m(g - a)$.

Typically the acceleration a is much less than g and the change in weight is a small percent. But during a free fall, or imagine that you make a small jump from a table to ground while the scale is tied or glued to your feet, your acceleration a is equal to g and your weight on the scale is zero since $R = m(g - a) = m(g - g) = 0$. [This is generally known as your weight is zero or weightlessness during a free fall or in an orbit around the Earth which is a form of free fall.] In other words, your body is not going to exert any force (R') on the weighing scale.

Now when the elevator is moving down with a constant velocity, the reaction force R is given by, $W - R = ma = 0$ since $a = 0$.

Thus, $R = W$ and no change in weight.

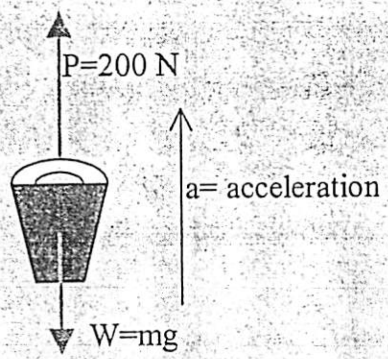
However, the elevator will decelerate to stop at a floor (ground floor) when it is moving downwards and during this situation, you will get,

$W - R = ma = - m|a|$ since a is negative now. We get,

$R = W + m|a|$ is more than W and the weight measured by the scale is higher than W.

Example:

What is the acceleration of a 10–kg pail of cement that is pulled upward (not sideways!) with a force of 200 N?



The forces acting on the pail and the direction of the acceleration.

Figure 14: The external forces acting on the 10-kg pail of cement.

There are two forces acting on the pail of cement. The weight W due to gravity on the pail of cement is given by W = mg where m is the mass 10-kg and g is the acceleration due to gravity, 9.8 m/s^2.

$W = mg = (10\text{-kg})(9.8\ m/s^2) = 98\ N.$

Since the pulling force 200 N is vertically upwards, the net force F acting vertically upwards is given by,

$F = 200\ N - 98\ N = 102\ N.$

Now we will apply Newton's second law to the cement pail to find the acceleration. That is

$F = ma$

$102\ N = (10\ kg)a$

$a = (102\ N)/(10\ kg) = 10.2\ m/s^2.$

Thus the cement pail will experience an upward acceleration of 10.2 m/s^2.

Assignment:

Please follow the link below to obtain the assignments for the week.

1. Homework 4

You should submit your answers to your homework problems at the WebCT site for assignments and quizzes by the due date posted at the course Home Page site. When you have questions about homework assignments, you can send them as attachments to my email address or post them at the Bulletin Board of the WebCT site to share your questions with your peers.

References:

1. http://occawlonline.pearsoned.com/bookbind/pubbooks/physicsplace/chapter2/deluxe.html
2. http://occawlonline.pearsoned.com/bookbind/pubbooks/physicsplace/chapter3/deluxe.html
3. http://occawlonline.pearsoned.com/bookbind/pubbooks/physicsplace/chapter4/deluxe.html
4. http://occawlonline.pearsoned.com/bookbind/pubbooks/physicsplace/chapter5/deluxe.html
5.

Please send your comments about the course to Dr. V. Wijekumar.
Last Modified: 1/14/05

ASSIGNMENT 4
Lesson 4 – Physical Science I
Newton's Laws

Home Page	Lesson 4	WebCT	Instructor

Assignment 4 (due date is posted at the homepage site)

Activity

Please post your activity results on the WebCT Bulletin Board.

Additional Review Questions, Exercises, and Problems from Chapter 4 of your textbook:

1. Question 11

2. Question 14

3. Question 16

4. Exercise 9

5. Exercise 23

6. Problem 2

7. Problem 3

8. Problem 4

9. Problem 9

Please enter your answers to these problems at the **WebCT** assignment section for Assignment 4.

Please send your comments about the course to Dr. V. Wijekumar.

Last Modified: 11/21/04

STUDY GUIDE
PHYSICAL SCIENCE I LECTURE (SCI 105)

Home Page	Syllabus	WebCT	Instructor

Course Material Access:

You can access the Physical Science I lecture Home page through two methods:

Method I

Home Page URL at the Physics Department:

http://www.py.iup.edu/dist-learn/sci105/sci105sch.html

Method II (requires username (IUP email username) and (initial) password (again IUP email username and NOT IUP email password))

Access through WebCT:

Home Page and the Course Content URL at the WebCT site:

http://idcs0400.lib.iup.edu:8900/SCRIPT/SCI105VW/scripts/serve_home

Course Syllabus:

You can access the course syllabus directly through this link or use the hyperlink in the course schedule web pages above. The textbook for the course is:
Conceptual Physics, Ninth Edition, by Paul G. Hewitt (ISBN # 0-321-05160-2).
Publisher: Addison Wesley
You can by the book at IUP Book Store.

Course Assignment:

Once you access the course schedule page, you will notice hyperlinks to daily lessons, assignments, and supplementary materials. Please open the daily lessons and try to go over the materials included. The assignments are included in each lesson. In order to do the assignments, please also refer to supplementary materials for each lesson. The supplementary materials contain most of the following:

- Useful Concepts
- Important Terms
- Chapter Web Links
- Simulations and Video clips
- Practice Problems

- Additional Instructional Materials

Please use the Bulletin-board feature of the WebCT to discuss your questions with your peers and me. The homework and test assignments are online. When you click on the assignments, you have to enter your username and password for WebCT. When you are done with the assignments, you will know your score too! There are three tests and one final examination. The dates are as follows:

Test 1 - June 12, 2005.

Test 2 - June 22, 2005.

Test 3 - June 30, 2005.

Final Examination - July 8, 2005.

You need to take one of the tests at IUP in our Department. Please make arrangements for it with me. If you are unable to visit our Department to take one of the tests on the dates posted, I will provide an alternative date and test for you. Other arrangements (remote proctoring) will be made for students who live far away from IUP. Please contact your instructor for details.

You can access the tests directly at the following URL:

http://idcs0400.lib.iup.edu:8900/SCRIPT/SCI105VW/scripts/serve_home

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Course Instructor:

Dr. V. Wijekumar (VJ)
Department of Physics
Indiana University of Pennsylvania
Indiana, PA 15705
Telephone: 724-357-4588

You can also email me directly.

Last modified: 1/12/05

SCIENCE 105
Summer 2005
Department of Physics
Indiana University of Pennsylvania

Syllabus	Study Guide	References	Bulletin Board(WebCT)	Instructor

COURSE SCHEDULE*

Please follow the schedule posted in the Table, Section 1 to 5 for online lecture assignments and Section 6 for online lab assignments.

Section 1 - MECHANICS			
Start Date	**Topics of Lesson**	**Assignments (due dates)**	**Supplementary Materials**
June 06	Introduction to Physics	Homework 1 (6/7)	SM1
June 07	Concepts of Motion	Homework 2 (6/8)	SM2
June 08	Free Fall & Projectile Motion	Homework 3 (6/9)	SM3
June 09	Newton's Laws	Homework 4 (6/10)	SM4
June 10	Energy	Homework 5 (6/11)	SM5
June 11 Test 1	Impulse & Momentum	Homework 6 (6/12) Test 1(6/12)	SM6
June 13	Circular Motion	Homework 7 (6/14)	SM7
June 14	Rotational Motion and Gravitation	Homework 8 (6/15)	SM8
June 15	Fluids	Homework 9 (6/16)	SM9

Section 2 – SOUND AND HEAT			
Start Date	**Topics of Lesson**	**Assignments (due dates)**	**Supplementary Materials**

June 16	Simple Harmonic Motion	Homework 10 (6/17)	SM10
June 17	Sound Waves & Music	Homework 11 (6/18)	SM11
June 18	Heat & Temperature	Homework 12 (6/19)	SM12
June 20	Heat Flow	Homework 13 (6/21)	SM13
June 21 Test 2	Heat Engines & Thermodynamics	Homework 14 (6/22) Test 2 (6/22)	SM14

Section 3 – ELECTRICITY AND MAGNETISM

Start Date	Topics of Lesson	Assignments (due dates)	Supplementary Materials
June 22	Electrostatics	Homework 15 (6/23)	SM 15
June 23	Electric Circuits	Homework 16 (6/24)	SM 16
June 24	Electronics	Homework 17 (6/25)	SM17
June 25	Magnetism	Homework 18 (6/26)	SM 18

Section 4 – LIGHT

Start Date	Topics of Lesson	Assignments (due dates)	Supplementary Materials
June 27	Electromagnetic Waves	Homework 19 (6/28)	SM 19
June 28	Light & geometrical optics	Homework 20 (6/29)	SM 20
June 29 Test 3	Light & physical optics	Homework 21 (6/30) Test 3 (6/30)	SM 21

Section 5 – ATOMIC AND NUCLEAR PHYSICS

Start Date	Topics of Lesson	Assignments (due dates)	Supplementary Materials
June 30	Relativity	Homework 22 (7/1)	SM 22

July 01	Quantum Mechanics	Homework 23 (7/2)	SM 23
July 02	Atoms & Atomic Radiation	Homework 24 (7/3)	SM 24
July 05	Nucleus & Nuclear Radiation	Homework 25 (7/6)	SM 25
July 06	Nuclear Energy and Cosmology	Homework 26 (7/7)	SM 26
July 08	**Final Exam**	**Final Exam** (7/8)	

Section 6 – LABORATORY EXERCISES

Start Date	Topics of Laboratory	Assignments (due dates)	Laboratory Materials
June 6	Measurement - The Use of Numbers and Units	Lab Exercise 1 (6/8)	Lab Materials
June 8	Measuring Instruments and Systems	Lab Exercise 2 (6/10)	Lab Materials
June 10	Graphing and Graphical Analysis	Lab Exercise 3 (6/13)	Lab Materials
June 13	Some Other Types of Motion	Lab Exercise 4 (6/15)	Lab Materials
June 15	Systems in Equilibrium	Lab Exercise 5 (6/17)	Lab Materials
June 17	Conservation of Energy - Work and Machines	Lab Exercise 6 (6/20)	Lab Materials
June 20	Conservation of Energy - Heat, Temperature, and Thermal Energy	Lab Exercise 7 (6/22)	Lab Materials
June 22	Vibrations, Resonance, and Waves	Lab Exercise 8 (6/24)	Lab Materials
June 24	Reflection, Refraction, and Mirrors	Lab Exercise 9 (6/27)	Lab Materials
June 27	Refraction and Lenses	Lab Exercise 10 (6/29)	Lab Materials
June 29	Some Other Properties of	Lab Exercise 11	Lab Materials

	Light	(7/1)	11
July 01	Conservation of Energy and Electric Circuits	Lab Exercise 12 (7/5)	Lab Materials 12
July 05	Electronics Lab	Lab Exercise 13 (7/7)	Lab Materials 13

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* Please follow this page for the due dates of all the assignments and quizzes.

TEXTBOOK FOR THE PHYSICS COURSES (SCI 105 - 801 and SCI 105 – 801Lab):

1. Conceptual Physics, Ninth Edition, by Paul G. Hewitt; Publisher; Addison Wesley – 2002 (ISBN # 0-321-05160-2)

Available at the student Co-Op: (Telephone 724-357-2590)

Please send your comments about the course to Dr. V. Wijekumar.

Last Modified: 12/23/04

SCIENCE 105 – LABORATORY ACTIVITY 10
THE THIN LENS

Home Page	Lab 10 Materials	WebCT	Instructor

CONTENTS

1. Purpose
2. Equipment
3. Introduction and Theory
   - Example
   - Simulation
4. Procedure
   - Part I
   - Part II
5. Pre- Laboratory Questions
6. Post - Laboratory Questions

PURPOSE

The purpose of this experiment is to find the focal length of a converging lens and to investigate the type, size and distance of the image produced by the lens when the object is placed at various distances from the lens.

EQUIPMENT

1. Bi-convex (Symmetric) glass lens. (Dia.: 50mm, Thickness: 12.9 mm, 60 mm focal length) - $4.95
   http://www.mpja.com/productview.asp?product=11496+LN
   Note: A hand magnifier can be used instead of the above lens.

2. A ruler or measuring stick

3. A light source such as a flashlight.

4. A piece of putty for holding the lens in place and another piece of putty to hold a thin card board (4" x 5"). This replaces a lens holder or a stand and a screen.

INTRODUCTION AND THEORY

Lenses have the ability to converge or diverge light waves. When a wave such as light encounters a new medium and enters it, the velocity of the wave is changed. If it strikes the new medium obliquely (other than 0^0 incidence as measured from a normal or line drawn perpendicular to the surface), it is refracted and travels in a new direction in the new medium. Whether it is bent towards or away from the normal depends upon the density of the media, i.e., whether the wave decreases or increases its velocity when it enters the new medium.

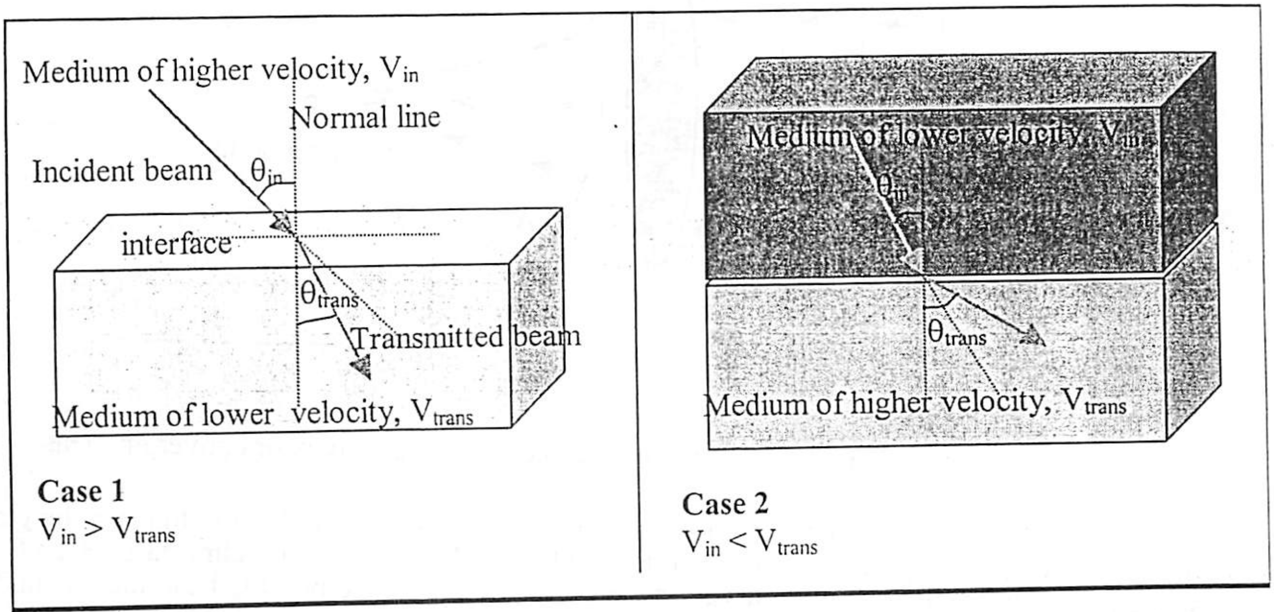


Figure 1: The refraction of light or the transmitted beam bends differently at the interface or surface of two medium depending on the density of incident medium to transmitted medium.

There exists a relation between the angle made by the original (incident) wave and the angle made by the refracted (bent) wave and the velocity of the wave in the medium through which it is traveling. This relation can be expressed also in terms of the index of refraction of the media involved.

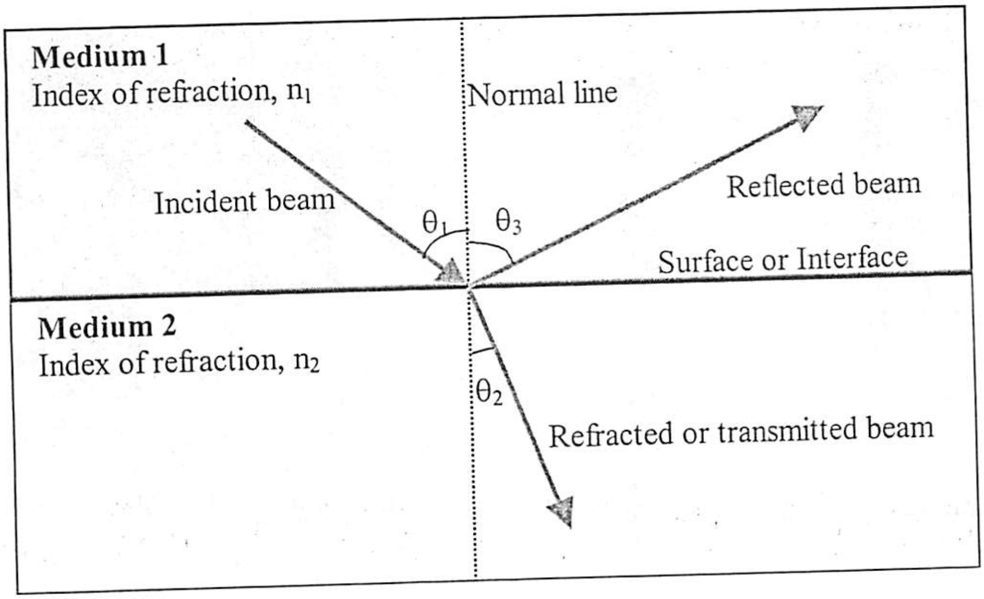


Figure 2: At the interface or surface between medium 1 and medium 2, the incident beam, the reflected beam, and the transmitted beam satisfy the rules for reflection and transmission. For reflection, the angles $\theta_1 = \theta_3$ and for transmission, $n_1 \sin \theta_1 = n_2 \sin \theta_2$.

What happens if a wavefront encounters a new medium which instead of having a flat surface has a curved surface such as a curved piece of glass (lens) whose index of refraction is greater than 1?

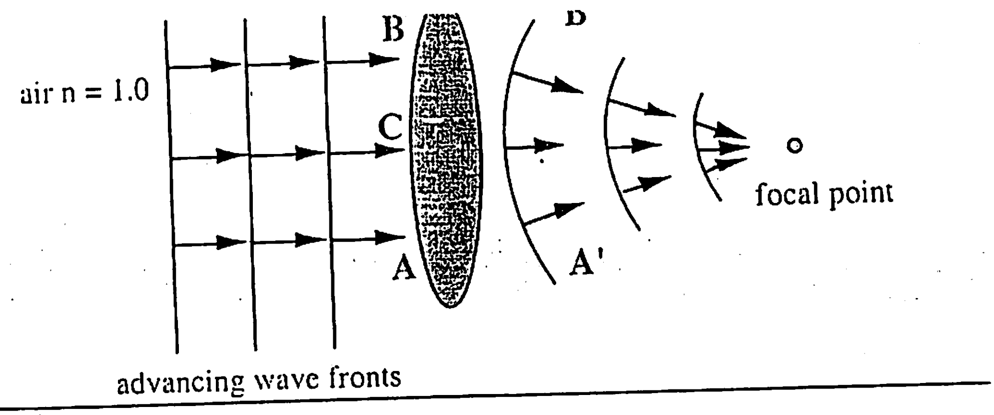


Figure 3

Figure 3: Parallel beam (or plane wavefronts) of light incident on a convex or converging lens.

When the wavefront reaches this position, the center of the wave front C touches the glass and starts to slow down, while points *A* and *B* on the front are still in air and traveling faster than C. When the wave emerges from the lens it is curved inward (converging) since point C has fallen behind *A* and *B*. As time passes the wave converges to a point called the focal point of the lens. The distance from the lens to this point is called the focal length *f* of the lens.

Not all lenses converge the light waves, a differently shaped lens could cause the waves to diverge. Points *A* and *B* encounter the glass first and are slowed down

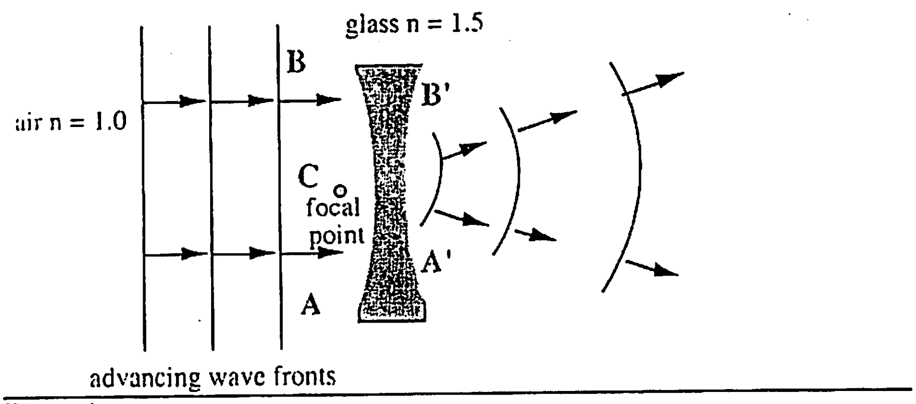


Figure 4

Figure 4: Parallel beam (or plane wavefronts) of light incident on a concave or diverging lens.

while C still travels in air at a higher velocity. Waves appear to come from the point *F*, the focal point of the diverging lens.

If we place a luminous object on one side of the lens, we can, if the conditions are right, project an image of the object on the screen on the other side of the lens. Since this image can be projected on a screen, it is a *real* image.

The image that is formed varies in size, position and orientation as the distance from the object from the lens varies. The image distance, object distance and focal length of a lens are related by the following equation, called the Thin Lens Equation:

$$1/f = 1/d_i + 1/d_o.$$

where:
f = the focal length of the thin lens
d_i = the distance of the from the image to the lens
d_o = the distance from the object to the lens

We can find the height of the image as compared to the object's height by using the equation for the magnification of the image:

$$M = - d_i / d_o = h_i / h_o.$$

where the image height h_i is negative if the image is inverted in comparison to the object.

The sign's of f, d_i and d_o have physical meaning as well

- The focal length for converging lenses is positive (+).
- The focal length for diverging lenses is negative (-).
- The magnification of an erect or upright image is positive.
- The object distance is positive when it is on the side of the lens from which the light is coming. That is the object distance is positive for real objects.
- The image distance is positive if it is on the side opposite from the direction the light is coming. That is the image distance is positive for real images and negative for virtual images.

EXAMPLE

Find the location and classify the image of an object that is 2 cm high, located 7 cm from a convex lens with a focal length of 5 cm.

Given that,
h_o = 2 cm, d_o = 7 *cm*, f = 5 cm.

Using the thin lens equation, we get

$$1/d_i = 1/f - 1/d_o = (1/ 5\text{cm}) - (1/ 7\text{cm}) = 0.200 \text{ /cm} - 0.143 \text{ /cm} = 0.057 \text{ /cm}$$

Therefore,
The image distance = d_i = (1/0.057 /cm) = 17.5 cm.

The magnification factor is:

$$M = - d_i / d_o = h_i / h_o.$$

That is

$$M = - (17.5 \text{ cm}) / (7 \text{ cm}) = h_i / (2 \text{ cm})$$

Therefore,

$h_i = (2\ cm)[-(17.5\ cm) / (7\ cm)] = -5.0\ cm.$

where the minus sign implies that the image is inverted in comparison to the object.

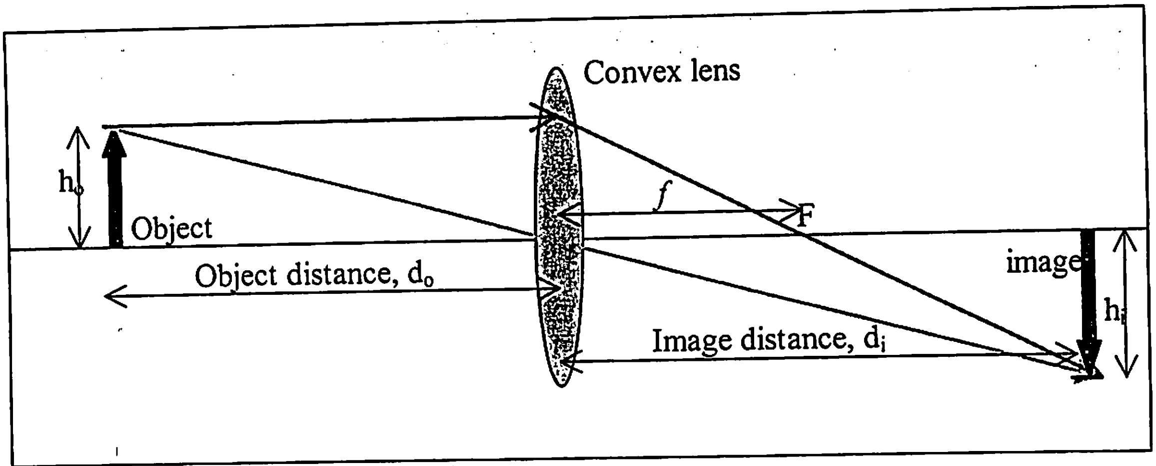


Fig 5: Image formed by a convex lens.

Two rays of light coming from the tip of the object travel as shown in Figure 5, forming an image after passing through the lens. Note that the ray that enters the lens parallel to the horizontal axis is bent by the lens in such as fashion that the ray passes through the focal point. The second ray passes through the center of the thin lens. In this case, the ray sees what is equivalent to a parallel plate of glass and is not bent by that portion of the lens. Where the rays cross is where the image of the point of the arrow is formed.

The ability of a lens to converge or diverge light waves depends not only on the shape of the lens, but also on the indices of refraction of the media. In other words, if a lens of a certain shape and material (n = 1.50) has a focal length of 15 cm when it is surrounded by air (n = 1.00) it will have a different focusing ability if it is surrounded materials such as water (n = 1.33), oil (n = 1.47) and so on. This can be understood from the Law of Refraction and studying carefully cases #1 and #2 in Figure 1. Lenses can also be put in various combinations to make a variety of optical devices such as microscopes, telescopes, etc. The final image has a size, type and location which is the result of the effect of an the lenses used in the device. The image produced is never a perfect reproduction of the object since the use of the lenses and/or mirrors will produce aberrations. For example, color aberrations of an image are produced due to the fact that different wavelengths of light are bent by different amounts for the same lens.

SIMULATION

Please click on the link below to learn more about thin lens equations. This is a simulation link about thin lens equation with interactive diagrams!

http://www.phy.ntnu.edu.tw/java/Lens/lens_e.html

Simulation on reflection and refraction is listed below:
http://www.phy.ntnu.edu.tw/ntnujava/viewtopic.php?t=66

Light propagation simulation at the interface between two media:

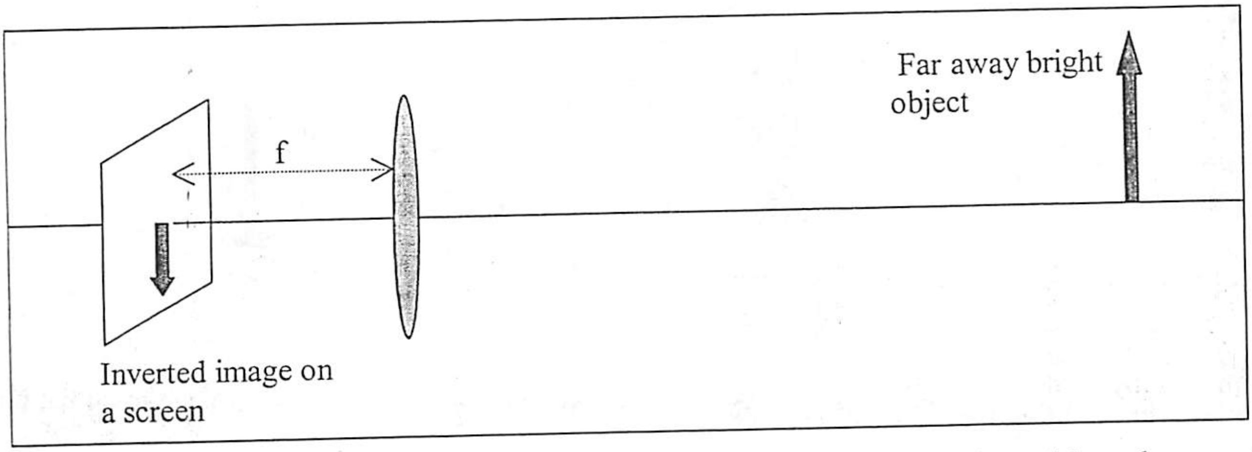
http://www.phy.ntnu.edu.tw/java/propagation/propagation.html

PROCEDURE

PART I

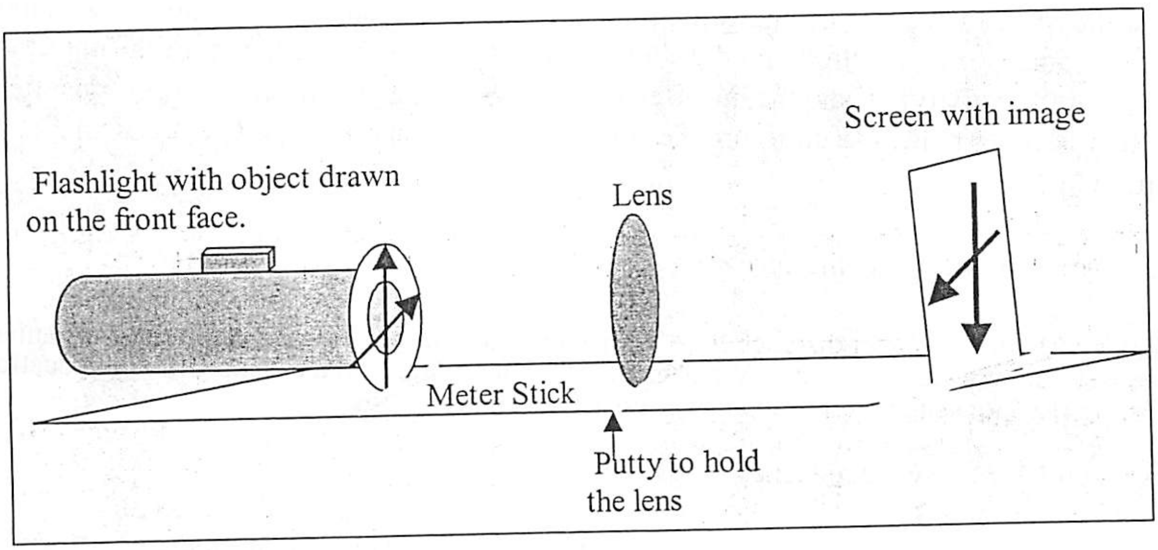
Find the focal length of a converging lens.

1. *Method A*



Using the putty, mount a thin white cardboard (screen) on the measuring stick such as a ruler or a meter stick. Point the lens towards a distant bright object such as the window frame or a tree and move the lens either towards the screen or away from the screen until a sharp image is formed on the screen. The distance *from the lens to the screen* where the image is formed is the focal length of the lens. Record this focal length *f* on the data sheet.

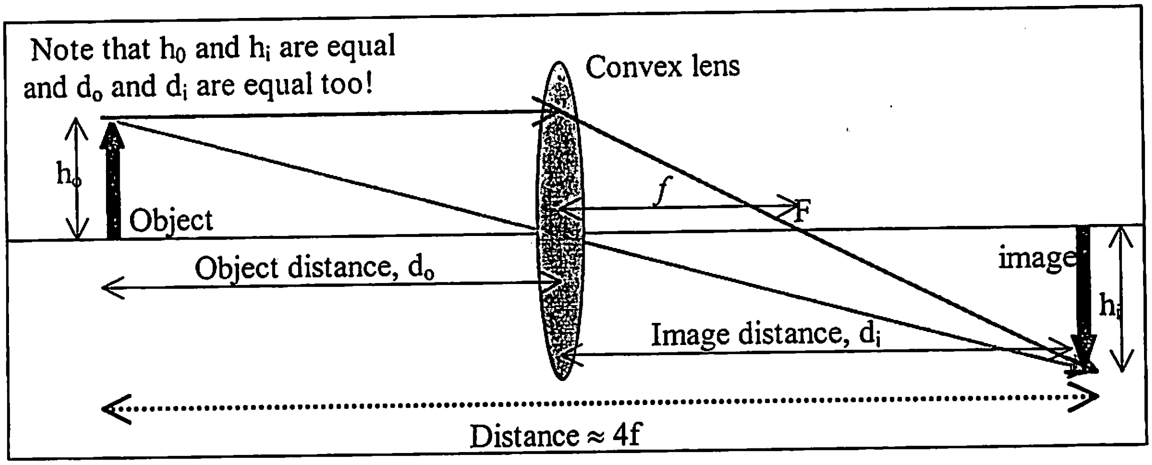
2. *Method B*



Use a marker (water soluble) to draw two thick arrows about 2 cm long and perpendicular to each other on the front face of a flashlight. These arrows are the object for the lens for this experiment. Mount the same lens on the measuring stick with a piece of putty and place it between the flashlight at one end and the screen at the other end. Adjust the lens and screen by moving them until the clearest possible image is obtained on the screen which is the same size as the object. This should occur when the distance d_o from the lens to the object and the lens to the image distance d_i are approximately equal, and d_o is approximately $2f$ (i.e. twice the distance of focal length). When the image formed is sharp *and the same size* as the object, the following relation holds true:

$(d_0 + d_i)/4 = f$.

From this relation, the focal length of the lens can be calculated. Record this focal length on the data sheet.



3. *Calculate the average focal length*
   Using the results from Method A and Method B, calculate an average value for the focal length.

PART II

Using your average focal length, place the object (flashlight) at the distance prescribed in each of the following steps. Measure and record d_o, d_i, h_o, and h_i and the type of image formed in each case.

1. Move the lens so that $d_o = 3 \text{ X} f$ (i.e., the object distance is three times the focal distance of the lens). Adjust the screen until a sharp image is formed. Consider the object to be the arrow painted on the flashlight, and h_o is its length. Record the measurements for d_i, h_o (the height of the object is constant throughout the activity), h_i and the image characteristics, i.e., is the image erect *E* or inverted *I*, real *R* or virtual *V*. Also, remember to record the correct sign for d_i and h_i (e.g., h_i = - 1.3 cm if the image is inverted) in each case.

2. Repeat step 1 for the object distance $do = 2.5 \text{ X} f$

3. Repeat step 1 for the object distance $d_o = 2 \text{ X} f$. For this step, record what happens to the image if half the lens is covered with a card. What changes? Image size, image shape, image location, image intensity? (Response is required to answer Post-Laboratory question #1.)

4. Repeat step 1 for the object distance $d_o = 1.5 \text{ X} f$

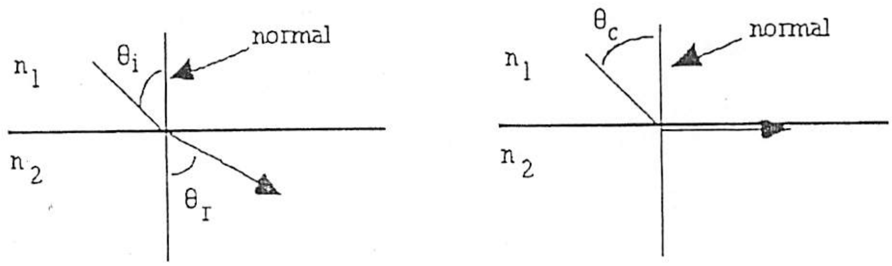
5. Repeat step 1 for the object distance $do = f$. Can you locate a good sharp image on screen? Calculate the image distance using the thin lens equation, and the image height from the equation for the image magnification.

6. Repeat step 1 for the object distance $do = 0.5 \text{ X} f$. Can you locate a good image on the screen?

Presuming you cannot, remove the screen and look into the lens towards the object. Describe the image you see. In order to calculate the position of the image, i.e., d_i use the thin lens formula to calculate the location of the image you see while looking into the lens. After calculating the image distance d_i calculate the image height from the magnification equation.

PRE- LABORATORY QUESTIONS

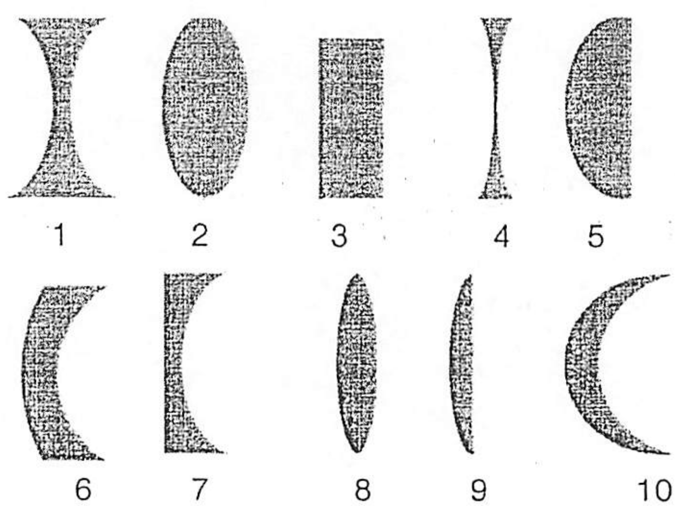
1. As light passes from an optically dense medium to a less optically dense medium, it is bent away from the normal as shown below. As the angle of incidence increases, the angle of refraction increases until θ_r reaches 90° at some critical angle of incidence θ_c. What happens if the angle of incidence is even greater than the critical angle of incidence?



2. For each of the lenses listed below, calculate the size of the image and the type of image produced. *All work must be shown.*

a) lens f = 25 cm, d_o = 50 cm, h_o = 6 cm
b) lens f = 15 cm, d_o = 45 cm h_o = 3 cm
c) lens f = 20 cm, d_o = 30 cm h_o = 4 cm
d) lens f = 10 cm, d_o = 10 cm, h_o = 5 cm
e) lens f = - 20 cm, d_o = 20 cm, h_o = 20 cm
f) lens f = 5 cm, d_o = 2.5 cm, h_o = 8 cm

3. Which of the following lenses are converging lenses? Which are diverging lenses? Assume that the lenses are made of glass and are surrounded by air.



4. Using the lenses above, state a general rule about the thickness of the lens at the center compared to the edges, and whether or not the lens is a converging or diverging lens.

5. List the converging lenses in question #3 in order of their converging power, starting with the lens with the most power.

6. List the diverging lenses in question #3 in order of their diverging power, starting with the lens with the most power.

7. The human eye has a lens which enables it to *focus* images on its retina. Since the length of the eyeball is fixed (d_i = constant), explain how the eye is able to produce sharp images on the retina for the various range of distances objects are located from the eye.

POST - LABORATORY QUESTIONS

1. When you covered half of the lens and observed the image, what was the difference in the image as compared to when the whole lens was uncovered?

2. An operator of a photo shop has a device which can enlarge or *reduce* the size of photographs. The enlarger consists of a convex lens of focal length equal to 20.0 cm. He has 5 possible positions do to place the photograph (object) he wants to copy:

a) $d_o > 40$ cm
b) $d_o = 40$ cm
c) 40 cm $> d_o >$20 cm
d) $d_o = 20$ cm
e) $d_o < 20$ cm

At which position (i.e., a, b, etc.) should he place the original photograph to obtain copies of the object which are
   i) the same size as the original
   ii) smaller than the original
   iii) larger than the original?

Use the conclusions from your experimental results to determine the correct answers.

3. A lens made of plastic (n = 1.60) has a focal length of 10 cm when surrounded by air. The same lens is placed in an oil (n = 1.47). What effect does this have on the focal length of the lens?

4. A lens shaped as shown below is made of a material which has an index of refraction (n = 1.5). The lens is placed in a liquid which has an index of refraction of 1.75. Parallel light coming from the left passes through the lens. What happens to the light after it passes through the lens? Does it converge, diverge, or stay parallel? Explain why you chose the answer you gave. You may use a diagram to help clarify your answer.

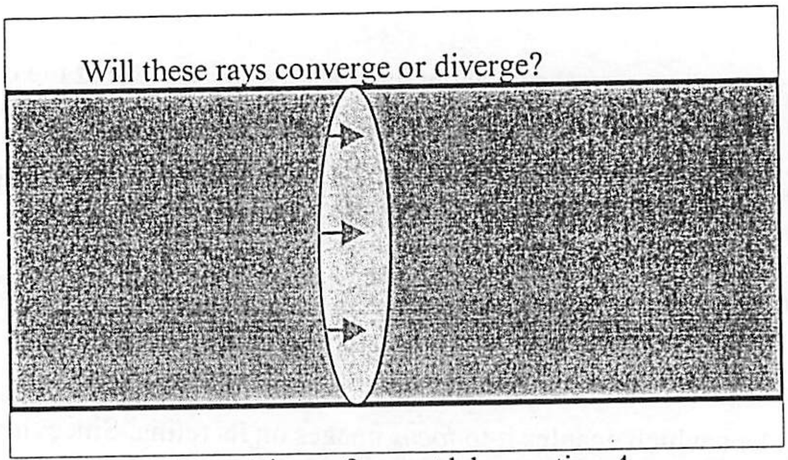


Figure: Figure for post lab question 4.

Please enter all your results at the WebCT site for SCI 105 lab.