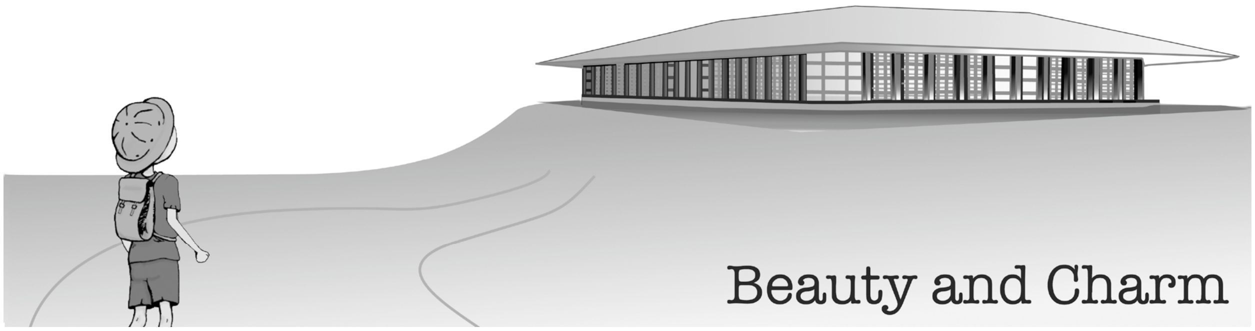


Physics Workshop and Field Trip for Grades 6-9

Sampler

Education Office / Fermi National Accelerator Laboratory
U. S. Department of Energy's Office of Science / Managed by Universities Research Association, Inc.
Kirk Road and Pine Street / M.S. 226 / P.O. Box 500 / Batavia, IL 60510 / 630.840.3092 / www-ed.fnal.gov

Introduction

"Beauty" and "Charm" are the fanciful names of two of six fundamental particles called quarks. Part of the experimental verification for the existence of quarks was carried out at Fermilab. However, this unit was titled *Beauty and Charm at Fermilab* with a second meaning in mind.

Fermilab, as any visitor will attest, is a place of beauty—a high-rise main building with architecture inspired by a French cathedral and set on a prairie-like plain reminiscent of early Illinois. In addition, Fermilab scientists, although a competitive breed in a rigorous and esoteric field, will charm you with their animated descriptions of particles and the universe, and with their cultural interests and human concerns.

This unit and its associated kit are a result of the cultural interests and human concerns of Fermilab Friends for Science Education (FFSE), an association devoted to the promotion of Fermilab as an education resource. With U.S. Department of Energy and FFSE funding and a good amount of volunteer effort, *Beauty and Charm at Fermilab* was developed to provide junior high and middle school students with a view and an active experience of the excitement of science in the world's premier accelerator laboratory.

The unit's activities were designed to present problems similar to what particle physicists face: How do you measure small things? How do you study something you can't see? What do you imagine the world inside the nucleus of an atom to be like? What can we see that tells us the tiny world of subatomic particles really exists? The activities help students develop a feeling for how physicists try to answer these questions. And, like physicists, students learn that the search for answers is never finished—and that is precisely why science is so challenging and fascinating.

The activities in this sampler were likewise chosen to give you some feeling for *Beauty and Charm at Fermilab*. We have attempted to select activities that display both the depth and the breadth of the unit.

If you feel intimidated at the prospect of teaching about particle physics, be assured that the activities were created and piloted by junior high and middle school teachers. Physicists have carefully reviewed the materials for accuracy in their relationship to scientific ideas and processes. The purpose of these materials, however, is not to instill directly the language and concepts of particle physics—some of this may happen—but to provide an experience of science to broaden and enrich attitudes and develop an appreciation for physics and the work conducted at U.S. Department of Energy laboratories.

Please see the yellow pages at the end of this sampler for more information on Fermilab teacher workshops and field trips.

Illinois State Learning Standards addressed by *Beauty and Charm*

Mathematics

6.A. Demonstrate knowledge and use of numbers and their representations in a broad range of theoretical and practical settings.
6.C. Compute and estimate using mental mathematics, paper-and-pencil methods, calculators, and computers.
7.A. Measure and compare quantities using appropriate units, instruments, and methods.
7.B. Estimate measurements and determine acceptable levels of accuracy.
7.C. Select and use appropriate technology, instruments, and formulas to solve problems, interpret results, and communicate findings.
9.A. Demonstrate and apply geometric concepts involving points, lines, planes, and space.
10.B. Formulate questions, design data collection methods, gather and analyze data, and communicate findings.

Science

11.A. Know and apply the concepts, principles, and processes of scientific inquiry.
11.B. Know and apply the concepts, principles, and processes of technological design.
12.C. Know and apply concepts that describe properties of matter and energy and the interactions between them.
12.D. Know and apply concepts that describe force and motion and the principles that explain them.
13.A. Know and apply the accepted practices of science.
13.B. Know and apply concepts that describe the interaction between science, technology, and society.

Social Science

18.B. Understand the roles and interactions of individuals and groups in society.

TABLE OF CONTENTS [items in **bold** appear in this sampler]

From Section 1: "Methods of Science"

Investigation 1: Measuring Small

Teacher Pages

Objective:
Students will use a microscope to measure an object 1/1000th of a centimeter in size. Teamwork and cooperative data gathering are emphasized. Speculation on the measurement of subatomic particles will be sought.

Purpose:
When scientists study the atom they have to measure very small objects. How would you teach another student what the word small means? What skills and techniques would you use to measure small things? As you begin to investigate atoms, you may find some surprising answers to these questions.

Materials:
Student Activity Sheet - Measuring Small

1. Describe the term macrocosm. Macrocosm is a large system such as the world or universe. *Macro* = large or enlarged; *cosmos* = a complete and orderly system.

2. Describe microcosm. Microcosm is a very small system such as a little world or miniature universe. *Micro* = little or small; *cosmos* = a complete and orderly system.

3. Tell students that in the unit *Beauty and Charm at Fermilab* they will learn how scientists study the infinitely small microcosm that is inside the atom. This world of particle physics is as interesting and little known as the universe beyond our solar system.

4. Review how to use and care for a microscope with your students. (Student ability may vary due to prior experience.)

5. Have the students focus the low-power objectives on the mm marks of a plastic metric ruler.

6. Then the students should measure the diameter of the field under low power.

Teacher Notes:
This investigation requires that your students can correctly measure the field of vision of a microscope. Rotate the low-power objective into position. Using a clear, thin, plastic centimeter ruler, place the ruler on the stage under the objective and focus in on the black millimeter marks.

Procedure:

1. Line up one of the black marks on the far left side of the field of view. Count how many spaces there are between the marks which are visible. (Remember that two whole marks equal one millimeter!) A 40X magnification produces a field approximately 4 mm wide. A 100X magnification produces a field approximately 1.8-2.0 mm wide.

2. Knowing the diameter of the field makes it much easier for a student to estimate the size of an object under the microscope. If an object covers one-half of the field, it is one-half of the diameter. Have the students then proceed to measure the length of a paramecia under low power, the width of a sand or salt crystal, the width of a strand of human hair. Finally, have them draw a sketch of a piece of lens paper under low power.

3. Next, display the set of magnified lens paper images, one at a time. Show the students exactly which section of the picture is being enlarged each time. Explain that each successive picture is approximately 20% larger than the previous one. The original picture was taken at 175X. The table below will help you discuss each new magnification with the students. Have your students tell you how the images change in each successive "blow-up."

Original photo	175X
Magnification number one	210X
Magnification number two	250X
Magnification number three	300X
Magnification number four	360X
Magnification number five	430X
Magnification number six	515X
Magnification number seven	620X
Magnification number eight	745X
Magnification number nine	895X
Magnification number ten	1075X
Magnification number eleven	1290X
Magnification number twelve	1550X

4. Be sure that the students realize that the lens paper is mostly empty space. One of the major concepts of particle physics is that ordinary matter is primarily space among interacting particles. Take time to emphasize this point. Have students discuss and evaluate their measurements.

5. Ask students to name and discuss the smallest particle that they have ever heard of. Have them speculate on how the size of this particle might be measured. Accept suggestions but do not try to evaluate them. (Probably electrons or protons will be suggested. Some students may mention quarks.)

Student Sheet Investigation 1: Measuring Small

Name______________________

Date_______________________

Purpose:

How would you teach another student what the word small means? What techniques or skills do you think would be important to use when you measure an object? If you were to shrink yourself to microscopic size, what do you think a grain of salt or a piece of tissue paper would look like?

In beginning a study of atoms these are questions that you will investigate, and you may find some surprising answers as you make observations and gather your data.

Procedure:

1. Obtain a clear metric ruler from your teacher.

2. Adjust and focus the low-power objective on the mm marks of a plastic metric ruler. Place the center of one mark on the edge of the field.

3. The field of the microscope is the lighted circle you see when you look into the microscope.

4. The diameter of the field can be measured by focusing your low-power objective on the millimeter marks of a plastic metric ruler.

5. What is the diameter of the field under low power?

6. Obtain a prepared slide of a paramecium from your teacher. Measure the length of the paramecium and record its length.

7. Take a sand or salt crystal and make a mount. Record the width of the crystal.

8. Take a strand of hair and mount it on a microscope slide. Record the width of the hair strand.

9. Prepare a slide of a piece of lens paper. Make a drawing below of the lens paper as you see it under low power.

10. From what can you see in your field of vision, what percent of the lens paper would you estimate to be empty space?

11. Record observations your lab team made while doing this investigation. Your teacher may also ask you to record class data.

From Section 2: "Accelerators"

Investigation 8: Step-Up Accelerators

Teacher Pages

Purpose:
An understanding of acceleration as a change in speed is sometimes best understood through graphing. Developing an understanding of this change in speed while practicing graphing skills is the focus of this activity. Students will gain a deeper understanding of incremental increases in speed through the use of a stepped accelerator.

Materials:
Stepped accelerator ramps
Stopwatches
Rulers
Marbles

Procedure:
1. Provide groups of students with ramps made of shelving that has been bent so that it looks like the picture below.

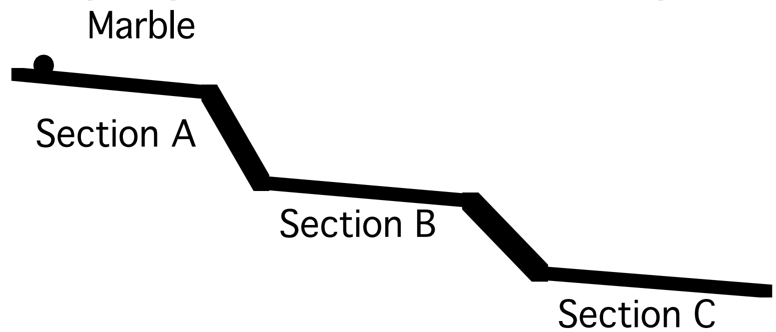
2. Instruct them to time the marble as it moves from level to level. They should try to time the marble on the flat parts of the ramp.

3. All of the timings do not have to be done on the same trial provided the ramp is set up in a fixed position.

4. Students should graph their results on a speed versus time graph.

5. Discuss the difference between speed and acceleration with your students based on their graph.

Step Up Accelerators Ramp



Student Sheet Investigation 8: Step-Up Accelerators

Name_______________________
Date________________________

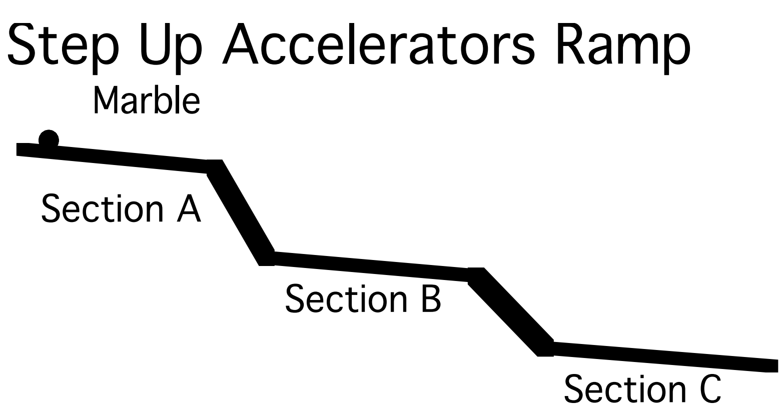
Purpose:
Scientists often need to carefully define things that they will use if they are to understand how the world works. Today you will help the class define exactly what is meant by acceleration.

Activity:
1. Your teacher will pass out some ramps, stopwatches, rulers and marbles.

2. Your job is to set up the ramp and let the ball roll down the "steps" toward the bottom.

3. After you have done this several times, describe in words what happens to the marble.

4. You can get a better understanding of acceleration by measuring what the ball does. Run the ball down the ramp several times. Drawn below is the track you will use with three sections labeled. Try to time the ball on each flat section of the ramp three times. You will need to watch carefully and then average your three trials.



5. Fill in the following data table describing the times you measured.

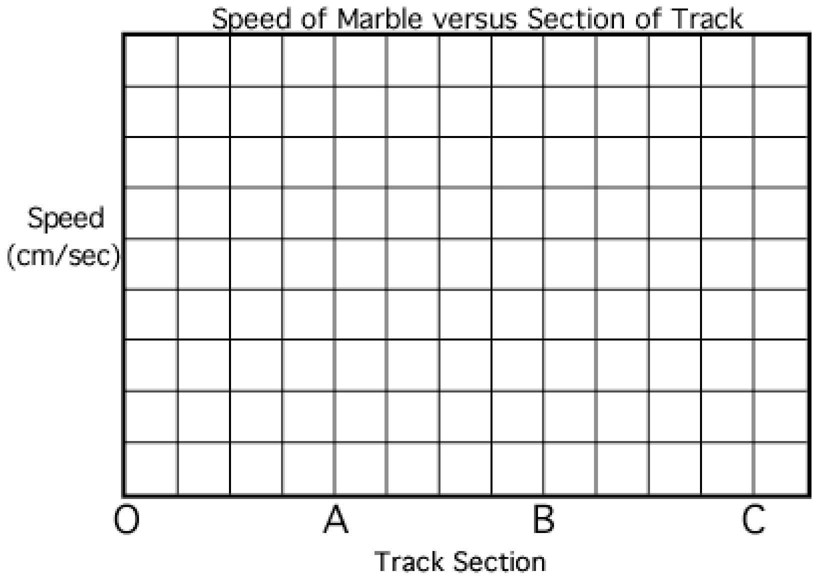
Section	Trial Times (seconds)	Average Time (sec)
A		
B		
C		

6. This should tell you where the ball was traveling the fastest. Which section had the ball moving the fastest?

7. You can tell just how fast the ball was moving by dividing the length of each section by the time. Measure each section with the ruler and divide this distance by the average time from above to find the speed. Enter this information in the data table below.

Section	Measured length	Length/Average Time
A		
B		
C		

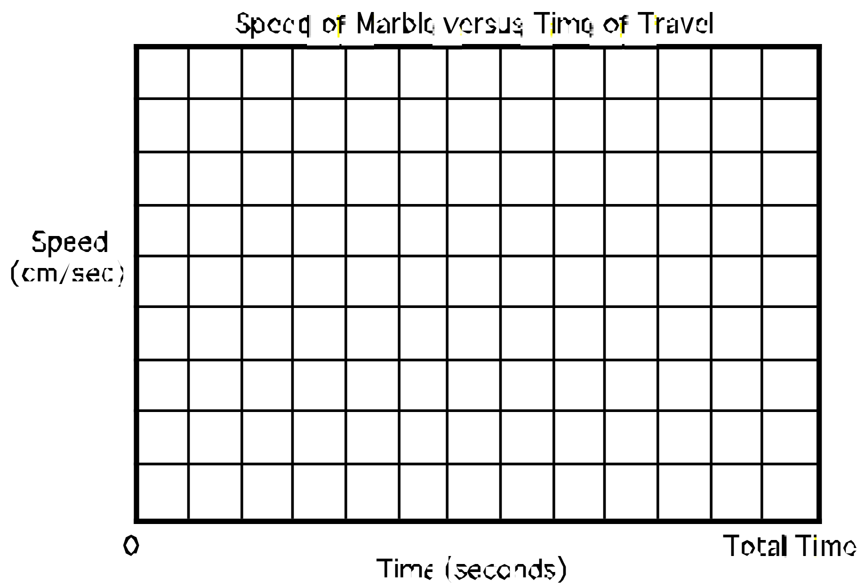
8. Now you can plot a graph of speed versus section of track. Try this on the following graph.



9. You can also plot the data a different way. You can look at speed as it changes with time. To do this you need to add up all the average times to find the approximate time it took the ball to get down the track. Do this in the following table.

Average Time A	Average Time B	Average Time C	Total Time

10. Now plot the speeds you got earlier versus time in the graph below.



11. Now compare your results with the rest of the class. Write the class definition of acceleration here.

From Section 3: "Seeing the Unseen"

Investigation 9: Studying Things You Can't See

Teacher Pages

Purpose:
Scientists often investigate objects so small that the objects cannot be seen. In this activity students will use indirect methods to visualize small hidden objects and to infer what the objects are.

Objective:
In this activity the student will use indirect methods to ascertain the "internal structure" of a mystery box.

Materials:
a scale or balance, preferably metric (school supply)
1 empty mystery box
8 mystery boxes in which you must place objects provided (See *Teacher Notes*.)
8 directional compasses
8 magnets, donut-shaped
8 rulers
Student Activity Sheet - "Studying Things You Can't See"

Teacher Note: In their quest to understand the internal structure of the atom and subatomic particles, scientists perform experiments of an indirect nature. These elementary particles of matter are so invisibly small that optical methods fail for direct observation. Data gathered from many different kinds of experiments enable scientists to collect enough "circumstantial evidence" to theorize about the structure matter.

Before the investigation begins place the following five objects in each of the students' boxes: a rubber stopper, a wooden block, a piece of steel wool, a steel ball and a cedar ball. (Other objects of the teacher's choice may also be used.) If you wish, seal the boxes with masking tape so that the students cannot gain access to the contents.

In a sense, the box is a simulation of an atom, a nucleus, a proton, or some other object with "internal structure." The quest to describe and identify the contents of the box simulates the physicists' quest to find out more about matter, to "see" what their eyes will never be able to see.

<u>Procedure</u>:

A. Divide your class into no more than eight groups.

B. Be sure to have an empty box available for student use, should they choose to do some observational comparisons with it.

C. Distribute one mystery box to each group.

D. Tell the students to follow the directions on their student sheet entitled "Studying Things You Can't See."

E. After about 15 minutes of work, collect the boxes without having students open them. Bring the class together. Then, as groups provide evidence or data about the contents, show them the described objects one by one. We recommend that you keep several objects "unseen" to simulate the scientists' inability to find all the answers. Explain that there are some things of which scientists are never sure. As better instruments are developed and new evidence is found, scientists improve their ideas about things unseen, but may never be completely certain they have the final answer.

Teacher Note: With less capable groups, you may wish to set up four mystery boxes with one item in each box. Have each group examine all four boxes. You can also list the following, and any other items on the chalkboard: battery, roll of tape, rubber stopper, washer, audio cassette, pencil, moth balls, wooden block, paper clip, safety pin, steel ball, steel wool, piece of chalk, magnet, penny and marble. The groups should list the evidence supporting their conclusion. After their investigations, as a group, students can choose which of the listed items are in their box. You can tell them what is in three of the four boxes, but the contents of the fourth box are not to be revealed. (See #5 above.)

Student Sheet Investigation 9: Studying Things You Can't See

Name________________________
Date_________________________

Purpose:
Scientists often investigate objects so small that the objects cannot be seen. In this activity you will use indirect methods, just like the scientists, to visualize small hidden objects and infer what the objects are.

Procedure:
1. Your teacher will divide your class into groups.

2. Your job is to identify the contents of a mystery box.

3. You may use any non-violent, non-intrusive way you can think of to infer what the mysterious objects are.

4. Here are some things you might try to help you discover what is in the box.
   - Probe the box with your senses.
   - Use a magnet.
   - Use a direction compass.
   - Find the mass of the box.

5. Can you think of any other ways to try to find what's in the box? List them.

Note: Check with your teacher before you try them.

5. List the equipment, how it was used in your investigation, and what you learned.

Box	What equipment did you use?	How did you use the equipment?	What did you find out?
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

7. Conclusion:
One item in the box is a/an:
We believe this because:

Another item in the box is a/an:
We believe this because:

A third item in the box is a/an:
We believe this because:

A fourth item in the box is a/an:
We believe this because:

A fifth item in the box is a/an:
We believe this because:

A sixth item in the box is a/an:
We believe this because:

A seventh item in the box is a/an:
We believe this because:

8. Discuss the following questions with your lab team and record your answers below.

A. Can your team think of other ways to investigate things without seeing them? Describe them.

B. What other instruments might have helped you guess what was in your mystery box?

C. What is indirect observation?

D. What are some instances where you use indirect evidence to learn about something you can't see? (Hint: Think of presents.)

E. How and/or where is indirect observation used by scientists? How do Fermilab scientists use indirect observations to learn more about particles?

From Section 4: "Ideas"

Investigation 17: The Symmetry Scavenger Hunt

Teacher Pages

Purpose:
Symmetry is a very common tool to particle physicists. They use this important idea to solve problems and discover new particles. The reason symmetry is such a powerful tool is that nature often has symmetric properties. Students will learn what symmetry is and how to use it to learn about problem solving where little evidence exists.

Objectives:
1. Students will become familiar with bilateral symmetry (also known as mirror symmetry).

2. Students will search for symmetry in the alphabet.

3. Students will look for symmetry in objects around them.

Materials:
Paper and pencils
Small mirrors for each student

Procedure:
1. Explain what symmetry is to the students by pointing out that people are generally symmetric left and right. That is, the left side of our bodies generally looks like the right side. Take the time to note interesting differences in people as well. Handedness is an excellent example of a break in symmetry.

2. Explain that our alphabet is made of many letters that are also symmetric. The letter W, for example, is symmetric left and right. This means that if you look at a W in a mirror that is placed next to the letter it still looks like a W!

3. Point out that W is not symmetric in a mirror placed above it (although the letter E is).

4. Ask the students to write the entire alphabet on a piece of paper with the mirror to the side of the letters and have them list the left-right symmetric letters.

5. Have them repeat the procedure with the mirror above the letters. Ask them to again list the up-down symmetric letters.

6. Now that students understand the concept of symmetry, ask them to go on a symmetry scavenger hunt in the room. Ask them to again make a list of those objects they find that exhibit this characteristic.

7. Based on the symmetry of the objects they found, ask them to decide how much of the classroom scientists could reconstruct if most of the items in the room were destroyed in an earthquake.

8. Discuss how important the idea of symmetry must be to an archeologist trying to determine what an entire dinosaur looked like based on only a small number of bones.

Student Sheet Investigation 17: The Symmetry Scavenger Hunt

Name________________________
Date_________________________

<u>Purpose</u>:
One of the most common ways physicists try to discover secrets of the natural world is to predict what an unseen particle might look like based on another particle that is well known. One process that helps the scientist is recognizing symmetry. You will model how scientists look for symmetry in the natural world by first discovering it in the alphabet and then looking for it in your classroom.

<u>Procedure</u>:

1. Set up a mirror next to a piece of paper and begin writing the capital letters of the alphabet while looking in the mirror. Some will appear backwards in the mirror, like E and ▯. Others will appear the same in both the mirror image and the paper image like A and A. Make a list of all letters that are the same both on paper and in the mirror in the space below. These are left-right symmetric letters.

2. Move the mirror to the top of the page and check the alphabet again. Notice this time that the letter A appears like ▯ in the mirror. It is symmetric left-right but not up-down! E, however, is up-down symmetric. Make a second list of up-down symmetric letters in the space below.

3. Compare your list to others in the room. Do you agree? Can you add any letters?

4. The symmetry you have discovered helps us to group letters in ways we had not before. In a similar way, scientists look for properties in nature which show some symmetry. Look around the classroom and make a list of objects in your classroom. Tell if these objects are symmetric or not.

5. Compare your list with someone else's. Do you agree on all symmetries?

6. Can you think of any ways that symmetry might help a scientist solve a mystery? Describe a situation where symmetry might be used to solve a scientific mystery. Write a short explanation below.

From Section 5: "Human Element"

Investigation 22: Name that Career!

Teacher Pages

Purpose:
Fermilab is like a small city, almost all the roles are represented—and without them, the Lab would not function as well. A common link between Fermilab workers is that they have great pride in what they do. Individuals truly know that without their help, the Lab would not operate well. They are proud to contribute to the mission of a world-class institution, and believe their work is important. They respect and value each other. In this activity, students will become more familiar with the variety of jobs people have at Fermilab.

Objectives:
1. Students will become familiar with the range of careers represented at Fermilab.

Materials:
Index cards, one per student
Student Activity Sheets—"Name That Role!"

Procedure:
1. On the index cards, before class begins, write the name of a Fermilab job from the list below.
2. Distribute one role card and one activity sheet to each student.
3. Allow the students a moment to think about what that job might look like, where it might take place, how someone in that job might go about doing their work, etc.
4. Break your class up into smaller groups of no more than 6 students per group.
5. Have one student from each group stand up. Allow the other students in his group to ask a total of four questions. The student will do his or her best to answer the questions. Then ask the other students write down the name of the job they believe was being portrayed on their Student Activity Sheets.
6. Continue this activity until all the students have represented their careers.
7. When the groups have finished their guessing, have them join the large group again. Ask each student to tell the class what job they had.

8. Discuss the range of jobs represented. You may use the Student Activity Sheet questions as a starting point for this discussion.

<u>Fermilab Jobs List</u>:

Theoretical Physicist	Chef	Custodian
Experimental Physicist	Astrophysicist	Electrical Engineer
Construction Worker	Librarian	Architect
Health Club Coordinator	Photographer	Videographer
Bank Teller	Fire Fighter	Biologist
Secretary	Inventor	Accountant
Educator	Director	Security Officer
Computer Engineer	Welder	Painter
Artist	Lawyer	Dormitory Manager
Public Relations	Auto Mechanic	Herdsman
Telecommunications	Purchaser	Human Resources Expert
Health and Safety Officer	Refrigeration Expert	Carpenter
Day Care Teacher	Activities Planner	Doctor
Nurse	Travel Planner	Machine Technician

Student Sheet Investigation 22: Name that Career!

Name________________________
Date_________________________

Purpose:
It takes a wide variety of people to make Fermilab work. In this activity, you will learn about the variety of jobs people have at Fermilab by playing the role of a Fermilab employee.

Activity:
1. Look at the job you have been given. Think about where it might take place, with whom, and how you might go about doing your work.

2. Find a person. Ask four questions about their job.

3. Write the name of the student's job on the line below.

4. Repeat the process for six students.

   Names of Roles:

   - ___________________________ • ___________________________
   - ___________________________ • ___________________________
   - ___________________________ • ___________________________

5. Pick any three roles from number 4 and write a sentence explaining how you think they contribute to making Fermilab work.

- ____

  ____
- ____

  ____
- ____

  ____

6. Explain how Fermilab is very much like a city.

____

____

As a group, discuss and answer the following questions.

7. Fermilab has approximately 2,000 workers, many from countries other than the United States. Can you think of any challenges to having so many diverse people at one place? Can you think of any solutions to these challenges? List them.

Challenges	Solutions
____________________	____
	____
____________________	____
	____
____________________	____
	____

8. The first Fermilab Director, Robert Wilson, wanted people of all kinds and all roles to talk to and learn from each other. That's why he is supposed to have made too few elevators that move very slowly at Wilson Hall. Why might this work? Can you think of any other ways to get people to "mix?"

    ____

    ____

    ____

    ____

    ____

9. Why might Fermilab need jobs such as a Recreation Coordinator, Activities Coordinator, Lifeguard, Arts Series Coordinator, etc?

____

____

From Section 6: "Human Element"

Investigation 24: *Beauty and Charm* Student Tour

Teacher Pages

Purpose:
Seeing first-hand where science is done can be a powerful and meaningful experience for students. It is important that you make every effort to prepare them for this important part of the program. Student preparation begins in the classroom and will be completed on site.

Objective:
Students will see the machines and meet the men and women who build, operate and understand these machines and the secrets the machines reveal.

Materials:
Students may wish to bring pencil and paper to take notes.
Cameras are welcome on tours.

Procedure;
1. Before leaving on the field trip to Fermilab, explain to students that Fermilab is a working laboratory. The machines students will see are being used in experiments even as they are there. The men and women at the Lab are involved in current research and the students' visit is a rare chance to glimpse what it is like to be a scientist in this decade.
2. Stress that the students must stay with the group and follow all directions given by the Fermilab docents (tour guides). Safety is of prime importance, so the students should not touch anything nor should they enter any areas unless they are directed to do so.
3. Upon arrival, the docents will give some reminders of safety procedures and general group directions. Please make sure the students listen.
4. Students will visit the Lederman Science Center with docents and have an opportunity to work with the exhibits in this Center. Docents will provide details of this portion of the visit.
5. Students will visit the first two stages of the acceleration process with docents. The first two accelerators are called the Cockcroft-Walton and the Linear Accelerator, or "Linac." If time permits, the students may also see the Main Control Room.
6. The students will go to the 15th-floor exhibits in Wilson Hall with docents. Here they will have an overview of the entire Fermilab property and the accelerator complex, which the docents will explain.
7. Students will meet with a scientist at the Lab. Here they will be able to ask questions they have prepared in advance, as well as any that have occurred to them during the day.
8. A very good follow-up activity is to have the students process what they saw and heard about when they get back to school. Some teachers may prefer a journaling activity, while

others will prefer a verbal discussion. In any event, it is good practice to let the students sort through the information they have acquired when they get back to school.