8^{th} Grade Physics Lesson Plans

(Based upon an 18-day lesson)

November 2018

****Note:** All items marked with ** may be left out if the main lesson is only three weeks long.

<u>Recommended Reading</u>:

- *Physics is Fun!* Roberto Trostli. Many good ideas for experiments.
- *Phenomena Based Physics – Grade 8*, Manfred von Mackensen. Gives deep background for understanding phenomenological science in light of the 8^{th} grade physics curriculum.
- *Teaching Sensible Science*, Michael D'Aleo and Stephen Edelglass. Excellent source book for both conceptual understanding and many experiments.
- *Connections*, James Burke. Great background for a historical perspective for these topics. In particular, pertaining to the 8^{th} grade physics curriculum, read chapter 3, titled "Distant Voices". You may also find the same material in the form of his TV show which aired beginning in 1978.

Overview of the whole block.

<u>Three-week plan</u> (14 days)

Optics: 3½ days
Electromagnetism: 5 days
Pressure: 4½ days
Review: ½ day
Test: ½ day

<u>Four-week plan</u> (18 days)

Optics: 4½ days
Electromagnetism: 6 days
Pressure: 6 days
Review: 1 day
Test: ½ day

Optics Day #1

- Story of me on the beach on the North Shore of Cape Cod in June. I was watching the sunset, and was "freaked out" that the sun was <u>not</u> setting (directly) in the West. How is it that I could have studied so much science, and yet I wasn't fully aware of how the sunset moves over the course of the year? How is it that most people can't identify a planet in the sky, yet they "learned" at a young age the names of the planets?
- What is science? What is the purpose of studying science?
- What is the difference between Waldorf and mainstream science?
- Talk about the importance of coming to theory through careful observations, as opposed to starting with the theory.
- **Do Optics Experiments #1, #2, and #3** in rotating groups. Emphasize that the drawings for #1 and #2 need to be done so that they are as exactly like a photograph would be.
- Hand out and go over "Expectations" sheet.
- <u>Biography</u>: On Isaac Newton.
- <u>*Homework*</u>: Rough drafts of #1, #2, and #3.
- <u>*Questions to think about*</u>:
    1. How is color produced?
    2. What does it look like if you and your friend are standing waist-deep in water?
    3. What does it look like if you are looking from 3 feet under water at:
        a. A stick that enters the water at an angle?
        b. Your friend who is standing waist-deep in water?
        c. Your friend who is standing completely under water?

Optics Day #2

- Go over rough drafts of #1, #2, #3.
  - With #1: Lines appear to be broken or curved.
  - With #2: There is distortion of shape and a lifting effect.
  - With #3: Color is produced where there is a boundary between light and dark.
- Talk about the writing skills that are necessary for writing up observations, and doing other essays in the main lesson book.
- Go over "questions to think about" from yesterday.
  1) Mention that this will be answered later in the lesson. (See *Newton and Goethe,* below.)
  2) The floor under the water appears to be raised. Your friend's legs appear to be shortened.
  3) a) The part of the stick under the water appears as it really is. It appears to be bent where it contacts the surface of the water. The part above the water appears to be raised away from the surface.
     b) My friend's legs appear to be of normal length. His torso appears longer than normal.
     c) My friend appears to be normally proportioned.
     - **Note:** Looking up from under the water, there is a circular window directly overhead through which objects above the surface can be seen. At a line of sight less than about 45° to the surface results in total reflection.
- This should lead to the question: "How can we find a mathematical value that tells us how much the lifting effect is in water?"
- <u>*History*</u>*: Newton and Goethe.* Isaac Newton found that colors appeared in his telescope where they shouldn't have been. He wanted to find a way to get rid of these colors. He preformed an experiment with a prism, where white light was passed through a prism and a color spectrum was then projected on a wall. He said then that color comes from the separation of white light.

  Goethe heard of Newton's experiment and borrowed a prism from a friend to try and duplicate the experiment, but had no luck. Upon returning the prism he happened to glance through the prism and he saw colors. So he took back the prism and did several experiments based upon *looking through* the prism, and developed his own theory of color.
- **Do Optics Experiments #4, #5, and #6** in rotating groups. For #5, have all the measurements written on the board and saved for doing calculations tomorrow.
- <u>*Homework*</u>: Rough drafts for #4, #5 (calculations to be worked on tomorrow).
  In book: Experiments #1, #2, #3.
- <u>*Questions to think about*</u>:
  1) How can we use the measurements for #5 in order to make a calculation that will tell us, *for any depth of water*, how much deeper it is than it appears to be?
  2) You are standing above the water. There is a fish in front of you and well under the surface. How do you aim at the fish with an arrow so that you hit it? (Assume that the arrow isn't deflected as it enters the water.)
  3) What was the world's greatest mystery for thousands of years up until about 1600?

Optics Day #3

- Continuing threads from yesterday:
  - Shooting a fish: They should conclude that the fish *appears* to be higher up than it actually *is*. So we must aim lower than it appears. It is interesting that if we were to make a hollow tube that goes from our eye to the fish, that the tube would have to be bent downwards as it enters the surface in order to see the fish through it. This tube (which follows our normal line of sight) *is bent but appears straight*, and the path of the arrow *is straight but appears bent*.
    - Make a viewing tube as described above. How bent the tube is depends upon the angle of incidence that you look into the water, because the tube is simply following the normal line of sight – e.g. If the top part of the tube is at 60° (α) off vertical, then the bottom part of the tube needs to 40.7° off vertical (which means the tube is bent at the point that it enters the water by 19.3°, which is ϕ). These values are determined by the formula $I = \frac{\sin\alpha}{\sin\phi}$. The top part of the tube can then be attached to the back wall of an aquarium at the "magic" angle (about 60°) and so that the bend is at the surface, thereby allowing students to view a carefully placed coin at the bottom of the aquarium. Or course, it is good to point out that you cannot look through this tube at all if it is out of water. It is best to have another straight tube attached to the other side, which you can't see through.
  - Ask students what their ideas were for what to do with yesterday's measurements with experiment #5.
  - Do the calculation of the index of refraction using the measurements from exp #5. Find an average value for each group and a class average. The actual value is about 1.33. Ask the students what this means. (It means that when looking straight down into water, the actual depth is 1.33 times as deep as it appears, or that it is 33% deeper than it appears.)
- _History_: The World's Greatest Mystery – Part I. The movement of the planets against the background of the stars was an unsolved mystery for thousands of years. Give the history including the role of Copernicus's book stating the planets go around the sun; Galileo using a telescope to make his discoveries and his pushing the heliocentric theory; and finally Kepler discovering that the planets orbit the sun in elliptical paths.
- **Do Optics Experiments #7** in rotating groups.
- ****Do Optics Experiments #8, and #9** in rotating groups.
- Tell class what they need to bring in for making motors next week.
- Get volunteers to come in to help make motor kits.
- _Homework_: Experiments #4, #5, #6 in book. Rough drafts for #7, #8, #9.
- _Questions to think about_:
  1) **How is it that a lens enlarges something?
  2) **How do you make a telescope and how does it work?

Optics Day #4

- *Review*:
    - The difference between the line of sight into water, and the path of the arrow.
    - Go over exp #7, and the creation of the two color spectrums.
    - **Exp#8: Note especially the difference between viewing the two rulers.
    - **Exp #9: A convex lens has a special instant at which things appear completely blurred, an instant before the image becomes upside down. (It is interesting to ask if the image is right-side up or upside down at this instant.) This happens sooner the farther back the observer is standing. If the observer is standing far away, then the distance from the lens to the object being viewed is called the blurring distance (BD). This blurring distance is also the distance from the observer's eye to the lens when a distant object becomes blurry. Give the blurring distances for each of the two lenses.
- Go over how to create a color wheel.
- *Main Lesson Book Page*: **Refraction**

    Refraction occurs when looking through two different mediums (e.g. air and water). Objects appear distorted in size and shape. Straight lines may appear bent, curved, or broken.
    Lifting. The index of refraction for water is about 1.33. This means that if you look down into water, the actual depth is 33% greater than it appears.

    **Displacement: There is greater displacement in a triangular prism when looking through a corner with a greater angle. The displacement is always in the direction of the angle.
- *Main Lesson Book Page*: **The Creation of Color**

    When looking through a prism, colors appear where light meets dark. Generally, we see cyan and violet together and yellow and red together.

    A white strip surrounded by black merges yellow and cyan, producing green in the middle, which is Newton's spectrum. A black strip surrounded by white merges violet and red, producing magenta in the middle, which Goethe called the night spectrum. When viewing the spectrums side by side, complementary colors are seen next to one another.

    Putting all of our observations together gives us a color wheel.

    <Draw the color wheel here.>
- *History*: The World's Greatest Mystery – Part II. After Kepler, the question was left: "What keeps the planets from spinning out of orbit?" Kepler had said that they were "pushed by angels". In the meantime, Galileo was formulating the laws falling bodies. Newton then came along and united both of these thoughts into one comprehensive theory with the idea of gravity – the force that keeps both the planets in orbit and causes objects to fall to the earth.

    This, of course, leaves us with further questions, such as: "What is gravity". Likewise, science has not fully answered many difficult questions, like what is light, electricity, magnetism, life, etc. Yet impressive progress has been made in many areas of science.
- ****Do Optics Experiments #10, and #11** in rotating groups.
- *Homework*: Rough draft of World's Greatest Mystery. Exp #7 into book.
- ***Homework*: Experiments #8, #9 in book. Rough draft for #10. (#11 doesn't go into book.)

**Optics Day #5 (½ day only)

- **Explanation of how a lens works. The line of sight through the middle of the lens has no displacement. The further out toward the edge of the lens you go, the more displacement you get.
- **Review
  - Exp #10: The image of the flame was actual size when both the screen and the candle were twice the blurring distance from the lens. The distance from the lens to the place where the image was most focused on the screen is called the focal distance. As the flame was further from the lens, the focal distance got closer and closer to the blurring distance of the lens. Therefore we conclude that the lens can serve two purposes: (1) enlarging an object when looking through the lens, and (2) focusing an image onto a screen. And then we can say that: <u>focal distance = blurring distance</u>.
  - Exp #11: Emphasize that if the telescope were made from two lenses of the same size, then there would be no enlargement. The amount of enlargement is the ratio of the BDs of the two lenses. The Objective lens focuses the image (onto an imaginary screen??) and the ocular lens enlarges this image. See below page for "**How a Telescope Works".**
- ***<u>Main Lesson Book Page</u>*: **The Lens**

  The *blurring distance* is the distance that a convex lens is held from a viewed object such that it is infinitely enlarged. This is the instant between right-side up and upside down. Also from this point a screen can be placed which will give a focused, upside-down image of the scene on the other side of the lens.

  Blurring Distance = Focal Distance

- *<u>Homework</u>*: World's Greatest Mystery in book.
- ***<u>Homework</u>*: Experiment #10 in book.

Electromagnetism Day #1 (½ day only)

- Review 7th grade Electricity
    - Batteries need two different types of metals. (e.g. Copper & Zinc, or Nickel & Cadmium)
    - A battery has two poles: + and -.
    - The idea of a circuit.
    - When a thin wire is electrified, much heat is produced.
    - Voltage is the spark or the potential to create current. More cells means more volts.
    - Current (amperage) is what produces the heat as it corrodes the metal.
    - Do a comparison of these batteries: D; AA; 9-volt; 6-volt lantern; 12-volt car.
- Review 7th grade Magnetism
    - A magnet has two poles: N and S.
    - Opposites attract, likes repel.
    - A magnet is created when a piece of metal comes in contact with a strong magnet.
    - Magnetic field lines.
- Review 7th grade history
    - Especially Leyden jar (1745), Galvani (1791), Volta (late 1790's)
- <u>*History*</u>: *Oersted's Experiment.* In the late 1700's people noticed that there seemed to be a lot in common between electricity and magnetism. In the early 1800's an experiment was done where a live voltaic pile with 1480 cells was floated on a raft expecting it to align north-south, but it didn't. So in the early 1800's it was believed that there was no connection between electricity and magnetism.

    In April 1820 at the University of Copenhagen, Hans Oersted performed an experiment expecting to confirm that a live wire would not affect a compass, but it did!
- <u>*Demonstration*</u>: Oersted's experiment. Use a motorcycle battery, and place a compass first above, then below the wire.
- <u>*Projects*</u>: Make the field magnet for the motor. To begin, tie the end so it doesn't slip.
- <u>*Homework*</u>: Rough draft of Oersted's experiment: both history and demonstration.
- <u>*Questions to think about*</u>:
    - How can we use what Oersted's experiment shows to make a powerful magnet?

Electromagnetism Day #2

- *Review*: Oersted’s experiment.
- *The Left-Hand Rule*: See if the students can figure out how things would be if the wire were running vertically up through a horizontal board with several compasses sitting around the wire. State the left-hand rule.
- *An Electromagnet*: Explain how coiling a wire around a metal bar creates an electromagnet. This is what we made yesterday!
- *History*: *In the Wake of Oersted.* Oersted published his findings in July 1820, and soon the entire European scientific community was in a race to discover the laws and uses of electromagnetism. In September, André Ampère sees a demo of Oersted’s experiment and within two weeks he publishes his first of several papers on the laws of electromagnetism. In 1821 Michael Faraday discovers that this new force can be used to create motion – later this was used to develop the electric motor. In 1825 William Sturgeon invents the electromagnet. In 1831, Faraday discovers electrical induction – a moving magnet can create a current in a coiled wire, giving the ability to create a never-ending electrical current without a battery. In 1832, Sturgeon invents the electric motor (with a commutator). In 1844, Samuel Morse invents the telegraph. In 1858, transatlantic telegraph works for about one month. In 1879, Edison invents a light bulb that can be mass produced. Power plants for producing electricity, mostly for businesses, were developed over the next 20 years.
- *Projects*: Give lots of time to work on motors. At least make the armature.
- *Homework*: Rough draft on *In the Wake of Oersted*. In Book: *Oersted’s Experiment*.
- *Question to think about*: What difference does it make that Europe has 220V circuits, and the US has 120V circuits?

Electromagnetism Day #3

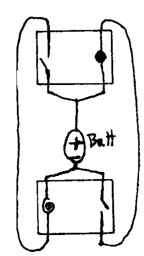
- *Biography*: On Michael Faraday.
- *Electricity*: Don’t hand out *Essence of Electricity* sheet yet, but go over these terms from it:
  - Voltage differences between here and Europe.
  - Resistance; Power; How Ground works (in a fair bit of detail);
- *Projects*: Give lots of time to work on motors. Perhaps a few students will finish.
- *Main Lesson Book Page*: **The Left-Hand Rule**
  The magnetic field surrounding a wire is such that if your left hand wraps around the wire pointing in the direction of the “+” terminal of the battery, your fingers show the direction that a compass needle will point. In the case of creating an electromagnet, the fingers indicate which end should be labeled as “N”. <Draw a picture of a wire running vertically up through a horizontal board with several compasses sitting around the wire.>
- *Main Lesson Book Page*: **The Electromagnet**
  A coiled wire greatly increases the strength of the magnetic field surrounding a wire. Placing a metal bar in the coil produces an electromagnet. <Draw a picture of an electromagnet.>
- *Homework*: Rough draft on *Michael Faraday*. In Book: *In the Wake of Oersted*.
- *Question to think about*: How does a light bulb and a toaster oven work?

Electromagnetism Day #4

- *Electricity*:
  - Review yesterday: Voltage, resistance, power. Good example: a light bulb in a 200V 0.3A circuit has 60 watts of power, as does a bulb with 100V 0.6A.
  - Hand out *Essence of Electricity* sheet, and go over everything except the topic labeled "energy".
  - How a light bulb works, compared to how a toaster oven works. Pass around a transparent light bulb.
  - How a dynamo (generator) works and can be used to power a bike light. Pass one around that has been sawed open.
- ***Biography*: On Thomas Edison, especially his efforts to make a good light bulb. He tried 6000 different materials for a filament. Today tungsten is used because it has a melting temperature of 6170°F, whereas iron is only 2100°F. The tungsten filament of a light bulb is above 5000°F.
- *Projects*:
  - Finish motors.
  - **Some students can start telegraph.
- *Homework*: Rough draft on ***Thomas Edison* and on *The Light Bulb and Toaster Oven*.
  In Book: *Michael Faraday*.
- *Question to think about*: How is it that our motor works?

Electromagnetism Day #5

- *Characteristics of Electricity*:
  - Light, sound, and heat all affect their surroundings and can be sensed.
  - Voltaic electricity (i.e. in a circuit) does not occur naturally. It can pass through its environment unnoticed. It is beyond the senses.
- *Electricity*:
  - Review *Essence of Electricity* sheet from yesterday.
  - Review comparison of light bulb and toaster oven.
- *How our Electric Motor Works*: Draw one on the board and show which side of the field magnet and armature is N and S; how these poles switch once the armature moves past horizontal, and which way (e.g. clockwise or counter-clockwise) the thing spins.
- *Projects*:
  - Finish motors.
  - **Some students continue telegraph. The challenge is to wire it with one battery and three wires only. Note that the two side wires could be saved by using ground.



- *Homework*: Rough draft on *How Our Electric Motor Works.*
  In Book: ***Thomas Edison* and *The Light Bulb and Toaster Oven*.
- *Question to think about*: (1) An electric bill says that you used 300 kwh last month. What does that mean? Ask a parent. (2) What does a 15 amp fuse do?

Electromagnetism Day #6

- *Review*:
  - How the Electric Motor works.
- *Electricity*:
  - Go over topic labeled "energy".
  - Mention that a house typically has several circuits (look inside your fuse box tonight). A 15A fuse is designed to break once the current gets to be greater than 15A. For example, since a 60W bulb runs on 0.5 amps, 31 of these bulbs would blow a 15A fuse. Also mention how cutting a live wire will blow a fuse, and why this is so.
- ***History*: *Samuel Morse and the Telegraph.*
- *Projects*: Finish motors and continue telegraph.
- *Homework*: Rough Draft: *Morse and the Telegraph.* In Book: *How Our Electric Motor Works.*

Electromagnetism Day #7 (½ day only)

- This half day is set aside to catch up with anything
- *Homework*: In Book: *Morse and the Telegraph.*

Pressure Day #1(½ day only)

- *Review 7th Grade Heat*:
  - When heated, air expands greatly.
  - When heated, water expands slightly.
- *Demo #1*: Push in on a syringe filled with air and closed. Compare this with pushing in on a syringe filled with water and closed.
- *Demo #2*: Fill a glass container with cold air and cork it with a pressure gauge attached to the end. Now put it into a bowl of ht water. Observe what happens as the temperature increases.
- Mention that our goal is to come to an understanding of how each of these works: a hydraulic jack, a barometer, and a straw.
- *Homework*: Rough Draft: *Demo #1 and #2.*
- *Question to think about*:
  - What would be the result of redoing demo#2 with a glass container filled with water instead of with air?

Pressure Day #2

- *Review*:
  - (From 7th grade) How does a thermometer work?
  - Demo #1: Air is easily compressible; water is not compressible. Pressure does not change the volume of water, but temperature does. At any particular temperature, water must occupy the amount of space that it wants to.
  - Regarding the "question to think about" from yesterday: If a closed container of water is heated but not allowed to expand, then it will break! This is why soda bottles must have an air bubble in them.

- *Main Lesson Book Page*: Make sure the students understand everything in this table.

The Exchange of Temperature, Pressure, & Volume

Substance	**Control**	**Result**	**Conclusion**
Air	Temp up; Pressure steady	Great volume increase	Air expands greatly when heated.
Water	Temp up; Pressure steady	Slight volume increase	Water expands slightly when heated.
Air	Pressure up; Temp steady	Great volume decrease	Air is very compressible.
Water	Pressure up; Temp steady	No change in volume	Water is not compressible.
Air	Temp up; Volume steady	Slight pressure increase	Air pres. increases slightly when heated.
Water	Temp up; Volume steady	Can't! Container breaks.	Water must expand when heated.

- *What is Pressure*?
  - While weight can affect pressure, pressure is not weight.
  - It is a pushing force. As with demo #2 the air inside the bottle is pushing against the walls of the jar.
  - Pressure is measured in PSI (pounds per square inch).
  - Do demonstration with one student being pushed by two others from opposite sides. If the pressure is equal from both sides then there is no movement. If the pressure is not balanced, then there is movement.
  - Discuss what happens when, with a closed syringe of air, you pull out on the plunger. (Answer: It feels like the plunger is being pulled in. The volume goes up and the pressure goes down.)
- *Demo#3*: *The Leaking Bottle*. The bottle has equal-sized holes lined up vertically. Observe what happens as the bottle drains.
- *Demo #4*: *Two Syringes*. Have two syringes of very different size (cross-sectional area) attached to each other. First, push back and forth and observe what the difference is. Secondly, see what happens if you push equally hard on both syringes.
- *Biography*: Blaise Pascal. (Not to be put into book.)
- *Homework*: Rough Draft: *Demo #3 and #4.* In Book: *Demo #1 and #2.*
- *Questions to think about*: (1) A hydraulic system essentially has two pistons (like syringes). How is it that a very heavy weight can be lifted with little effort? (2) Where inside the two-syringe system is the pressure the greatest if you are pushing on both syringes such that there is no movement?

Pressure Day #3

- *Discussions* regarding yesterday's demos and questions:
  - Demo #3: We see that the pressure in water increases with depth. Every 10 feet of depth adds about 4½ psi.
  - Demo #4:
    - The smaller syringe (i.e. piston) is easier to push in. Ask students why. It is because it can produce more pressure.
      - Example #1: Imagine lying down and having standing on your stomach. If there is a board on your stomach, then the weight is more spread out resulting in less pressure. If the person is standing on stilts then the result is much more pressure, even though the weight is the same.
      - Example #2: There are two closed containers filled with water. One has a piston with an 40-inch cross-sectional area and a 200-pound weight on top, and the other has a 2 inch cross-sectional area and a 200-pound weight on top. The two resulting pressures are 5 psi and 100 psi, respectively.
    - If there is no movement in the system, then the pressure everywhere is the same.
    - Show a hydraulic pump where you can see the pistons. Perhaps get one from a junk yard that you can take apart somewhat.
    - Where hydraulics are used: Heavy machinery & construction equipment; House jack; Car breaks; Airplane landing gear.
- *Main Lesson Book Page*: **Hydraulics**

  A Hydraulic system works by having a thin piston greatly increase the pressure of the fluid inside the system. This, in turn, drives a large piston with a heavy weight on it. The thin piston is pushed in a long way in order for the large piston to be driven up a short distance. A hydraulic system is always tightly sealed; the volume of the fluid always remains constant. <The student adds a drawing of a car being jacked up.>
- *History*: Archimedes. A bit of biography and the story of the king's crown. End with him shouting (naked) "eureka!", leave how he solved it hanging until tomorrow.
- *Demo#5*: *Pascal's Flask.*
- *Demo #6*: *Displaced Water*. Using a spring scale measure the weight of something (denser than water) first out of water, then measure the weight of it hanging in water, and the weight of the displaced water.
- *Homework*: Rough Draft: *Demo #5 and #6.* In Book: *Demo #3 and #4.*
- *Question to think about*: (1) How did Archimedes solve the crown puzzle?

Pressure Day #4

- *Review*:
  - Demo #5: Pascal's flask. The water pressure was equal in all directions.
- *History*:
  - Archimedes (continued). Tell how Archimedes solved the crown puzzle. Then state and explain what Archimedes' is. It is best if you can do a demonstration that shows (See main lesson book page, below.)
  - The Barometer. Story (from *Connections*) of Galileo, Torricelli, Pascal and the invention of the barometer. Aristotle: "Nature abhors a vacuum". Don't mention 32 feet. End with Torricelli's letter to Pascal saying: "We live in a sea of air."
- *Demo #7*: Magdeburg Hemispheres. The real experiment was done by the mayor of Magdeburg (Baron Otto von Guericke) in Germany in 1657, who had invented a vacuum pump. The hemispheres were 52cm in diameter and two teams of 12 horses each could not pull them apart.
- *Demo #8*: *The Cartesian Diver*. (Not to be written up in book.)
- *Homework*: Rough Draft: *Demo #7*, and *Archimedes and the Crown.* In Book: *Demo #5 and #6.*
- *Questions to think about*: (1) A particular suction pump is used for raising water up from a hole in the ground. What is the highest that the most powerful suction pump can raise the water?
  (2) Why couldn't the hemispheres be pulled apart? If all of the air could be pumped out of the hemispheres, creating a perfect vacuum, then how much force would it take to pull it apart?
  (3) *Pascal's Vases*. The below drawing shows the side view of four strangely shaped swimming pools. If they are all filled to the top, then which pool has the most and the least pressure at the bottom?

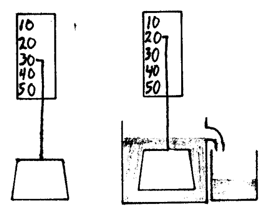
Pressure Day #5

- *Review*:
  - Demo #8: The Cartesian Diver. Changing the pressure changed the size of the air bubble. A larger air bubble pushes harder upward against the beaker.
- Yesterday's questions:
  - #3: Pascal's Vases. The pressure at the bottom is all the same! Pressure only depends on the depth, not the shape of the container.
  - Ask the students for what think the answers are for questions #1 and #2, but don't give the answers until tomorrow.
- *Main Lesson Book Page*: **Under Water**

  The pressure in the water only depends on the depth, not upon the shape of the container. The pressure in water increases by 4½ psi with every additional 10 feet of depth.

  Pascal's Principle: At any point in water the pressure is exerted equally in all directions.

  Archimedes' Principle: An object *less dense than water* floats and displaces an amount of water equal to its weight. An object *more dense than water* sinks and weighs less by the amount of water that it has displaced.

  Weight of displaced water is 10.

- *History*:
  - The Barometer. Review and then continue yesterday's story. Ask students what the implications of Torricelli's statement is: "We live in a sea of air." Then ask how you could test this theory. Tell about how, in 1647, Pascal did the water column experiment in Rouen, where there are no mountains, using a giant glass "test tube" tied to a ship's mast. A year later, Pascal's brother-in-law measured the column of mercury in a barometer at the bottom and at the top of the mountain Puy do Dome (4000 ft) to prove Torricelli's statement.
- *Air Pressure*:
  - Ask: Why did people think that there was no air pressure? They couldn't feel it. They assumed that air had no weight.
  - Air does have weight. It weighs 1.29 oz/ft^3.
  - Air pressure is about 14.7 psi at sea level, 12.1 psi in Boulder, and 4.6 psi at the top of Mount Everest.
  - Why don't we feel it?
- *Demo #9*: Egg in a bottle. Use a boiled, peeled egg, a large glass bottle with a narrow neck. Hold the bottle in hot water until the air inside gets quite hot. While taking the bottle out, put the egg on top to form a seal. Hold the bottle in cold water. At the very end hold the bottle upside down. Turn the bottle upside down and blow hard to get the egg out.
- *Homework*: Rough Draft: *Demo #9*, and *The Story of the Barometer*. In Book: *Demo #7*, and *Archimedes and the Crown*
- *Questions to think about*: (1) Why did the egg end up in the bottle?
  (2) How does a straw work?
  (3) Why does a helium balloon go up in the air?

Pressure Day #6

- *Demo #10*: Torricelli's water column experiment (actually done after his death by Pascal).
- *Answer the big questions*:
  - *Why does a helium balloon go up in the air?* Answer: it is lighter than air, so it floats in air.
  - *Why did the egg end up in the bottle?*
    - Answer: Someone will probably say that the egg was sucked into the bottle. Point out that if the egg were sucked in, then it would have broken. There was lower pressure inside than outside. It was pushed in!

      There's no such thing as suction!!
  - *How does a suction cup work?*
    - Answer: Once it's pushed into place, air gets pushed out. It then regains it shape, but with low pressure inside. There's lower pressure inside than outside. It is held in its place by the pushing of the outside pressure. A suction cup would not work well at the top of Everest.
  - *Why couldn't the hemispheres be pulled apart? If all of the air could be pumped out of the hemispheres, creating a perfect vacuum, then how much force would it take to pull it apart?*
    - Answer: It was held together by the air pressure from outside. It is pulled apart once the pulling force exceeds the pushing force of the air pressure on the hemispheres. For example, with the 52 cm hemispheres, if there was a perfect vacuum inside, there would be no pushing outward from within, but a pushing force of about 4,800 pounds from the air pressure pushing the hemispheres together.
  - *When you pull out on a closed syringe filled with air, why does it feel like the plunger is being pulled in?*
    - Answer: The pressure inside is less than outside. It is being *pushed* in from the outside.
  - *How does a straw work?*
    - Answer: The lungs, which form a closed container, expand thereby creating lower pressure. The water is pushed up the straw from the outside pressure.
  - *What is the highest that the most powerful suction pump can raise the water?*
    - Answer: It turns out to be about 32 feet at sea level, or about 28 feet in Boulder. It depends upon the air pressure on the given day, which is the idea behind a barometer.
  - *How did our water barometer work?* In a water barometer, the air pushes the water up the tube. Higher air pressure can support a higher column of water. The pressure at the bottom of the column of water caused by the water above it, is the same as the pressure on the surface of the water caused by all the air above it. Also, imagine a bug swimming up the hose filled with water. Show what the water pressure would be every 10 feet.
- Try to show a real mercury barometer.
- *Homework*: Rough Draft: *Demo #10,* and *How a Straw Works.* In Book: *Demo #9,* and *The Story of the Barometer.*
- *Questions to think about*: Check to see if there are any hanging questions.

Pressure Day #7 (½ day only)

- This half day is set aside to catch up with anything and to review.
- *Homework*: In Book: *Demo #10,* and *How a Straw Works*
- *Main Lesson Book Page*:

Aeromechanics

There is no such thing as suction! The egg was not sucked into the bottle, but instead the air pressure from outside pushed the egg into the bottle. There was no suction force inside the Magdeburg hemispheres pulling them together; they were being pushed together by the outside air pressure.

Air has weight! One cubic foot of air weighs 1.29 ounces

Torricelli was right! We live on the floor of an ocean of air. Higher altitudes have less air pressure.

Air can support water! In a mercury barometer, the air pushes the mercury up the tube. Higher air pressure can support a higher column of mercury. The pressure at the bottom of the column of mercury caused by the mercury above it, is the same as the pressure on the surface caused by all the air above it.

Atmospheric Pressure Table

Place	**Altitude**	**Pressure**	**Water Barometer***	**Mercury Barometer***
Sea Level	0	14.7 psi	33.8 ft	29.92 in.
Boulder	5,300 ft	12.1 psi	27.9 ft	24.6 in.
Longs Peak	14,200 ft	8.7 psi	19.9 ft	17.6 in.
Mt.Everest	29,028 ft	4.6 psi	10.6 ft	9.4 in.

***Barometers may go up or down by 5% depending upon the weather.**

Last Few Days of the Block

- Leave a whole day for a thorough review of the whole block.
- The test only needs to take 45 minutes, so the other half of the lesson can be used to cover anything that had been left out, or to do something else.

How a Telescope Works

Important Note: The formulas on this page are largely just for the teacher who may be curious about the details. Mostly, they would only be appropriate for high school or university-level studies. However, a teacher for 8th grade physics may find a way to bring the material, in an age-appropriate manner to the students.

Formulas:

- f is the focal distance (also blurring distance) of the lens
- d_0 is the distance of the object to the lens; d_i is the distance of the image to the lens
- h_0 is the size (height) of the object; h_i is the size (height) of the image
- Distance formula $\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$ or $d_i = \frac{f \cdot d_0}{d_0 - f}$
- Height formula $\frac{h_i}{h_0} = -\frac{d_i}{d_0}$ or $h_i = \frac{f \cdot h_0}{f - d_0}$ (where a negative value for h_i indicates inverted.)
- Example #1: A light bulb with a height of 6cm is placed 60cm from a lens with f = 20.

  Solution: $d_i = \frac{20 \cdot 60}{60-20} = 30$ the image is therefore 30cm from the lens

  $h_i = \frac{20 \cdot 6}{20-60} = -3$ the height of the image is therefore 3cm and inverted
- Example #2: A light bulb with a height of 6cm is placed 6000cm from a lens with f = 20.

  Solution: $d_i = \frac{20 \cdot 6000}{6000-20} \approx 20.07$ the image is therefore 20.07cm from the lens

  $h_i = \frac{20 \cdot 6}{20-6000} \approx -0.02$ the height of the image is therefore 0.02cm and inverted
- Example #3: A light bulb with a height of 6cm is placed 6000cm from a lens with f = 200.

  Solution: $d_i = \frac{200 \cdot 6000}{6000-200} \approx 206.9$ the image is therefore 206.9cm from the lens

  $h_i = \frac{200 \cdot 6}{200-6000} \approx -0.207$ the height of the image is therefore 0.02cm and inverted

Comparing Lenses

The last two examples show that when the object is relatively far from the lens, a lens that has 10 times the focal distance, has an image about 10 times as large. The students can also notice this relationship through observation, and without using the formulas. So, in general, we can say that an objective lens (which is less "fat" and has a greater focal distance) produces a larger image than an ocular ("fat") lens.

A Phenomenological Explanation/Demonstration of how a Telescope Works

Do the last of the Optics Experiments (see separate handout) which compare two telescopes – telescope A (without magnification) has two identical ocular lenses, and Telescope B (which is a normal, simple telescope) has an ocular lens and an objective lens. What is the difference between the two telescopes? In each case, the lens further from the eye projects an image, and then the ocular lens (which is closer to the eye) magnifies the image. With Telescope A, the image is focused down to a small size, and then is enlarged back up to its original size. We know (from above) that the objective lens (which has a greater focal distance) produces a larger image. With both telescopes, the eye-piece lens is enlarging the image by the same amount. But Telescope B has magnification because the (objective lens's) image is larger than with telescope A (which has no magnification).