Global Air Conditioners

We have all heard that trees help to clean the air and cool the Earth, but how much difference does one tree make? In this activity, students will "weigh" a tree to estimate how much it cools our planet.

Global warming is an effect of the *carbon cycle*. Living and fossilized trees play an important role in this cycle because they remove carbon dioxide from the atmosphere and store the carbon in their leaves, branches, trunks, and roots. Much of the energy we use, the food we eat, and the products we buy are produced by destroying forests and burning fossil fuels. This releases the carbon stored in living and fossilized trees into the atmosphere as carbon dioxide.

Students weigh their trees by making measurements and performing some calculations. Since about half the weight of a tree is carbon, students can estimate the amount of carbon stored in their tree and the corresponding amount of carbon dioxide that it absorbed. Finally, students compare this amount of carbon dioxide to the average amount of carbon dioxide released by each person in the United States every year. They determine how many trees they would need to plant each year to offset the annual amount of carbon dioxide that they release in the course of daily living.

Topics Measurement, Geometry, Conversions, Problem Solving, Number Sense

Goals

- Students will learn about the causes of global warming.
- Students will learn about the carbon cycle.
- Students will learn some basic chemistry relating to trees.
- Students will practice using a ruler and a tape measure to determine lengths.
- Students will learn a fun and efficient method for determining the height of a tree.
- Students will use basic geometry and conversion formulas.

Activity Time 1 to 3 hours in all

Materials and Preparation

- 1 handout for each pair of students
- 1 pencil for each pair
- One 12 inch ruler for each pair
- 1 tape measure for each pair
- 1 calculator for each pair

Primary Sources

- The Environmental Protection Agency "Climate Change". http://www.epa.gov/
- Cooperative Research Centre for Greenhouse Accounting. http://www.greenhouse.crc.org.au/
- The Conservation Fund. http://www.conservationfund.org/

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Background

Depending on the age and mathematical background of your group, it may be helpful to break this activity up into sections. You may wish to cover each of the mathematical ideas used in this activity earlier in the year. This activity makes a good capstone learning experience.

Allow 5 minutes for a background discussion. Ask the students if they have ever heard of global warming, and ask them what it means. Here are some things they might know.

- Global warming refers to a world-wide trend of increasing average temperatures over the last century and especially during the last decade.
- Global warming is caused by "the greenhouse effect". Carbon dioxide and other gases in the atmosphere trap heat energy from the sun and prevent it from escaping into space. Without any greenhouse gases, Earth would be a very cold place. But right now, excess amounts of greenhouse gases are causing the greenhouse effect to be artificially enhanced.
- Carbon dioxide is one of the most prevalent gases causing the greenhouse effect.
- Ironically, global warming could lead to a sudden global freeze if ocean currents shut down and stop circulating warm water to the poles.

People are concerned about global warming because it may cause sudden shifts in climate. These climate shifts can cause:

- Flooding in low-lying areas as ice shelves melt into the sea
- More violent hurricanes and other storms as warmer, wetter air circulates
- Famine as crops fail
- Mass extinctions of animals around the world as animals lose habitat and have fewer places to move when the climate in their current location shifts
- Insect and parasite infestations as mild winters fail to kill as many as usual and as traditional predators die off
- Smog that makes breathing difficult

In the distant past, the Earth has been much warmer than it is now. There have been eons when there was no ice at either pole and the whole world was tropical. There have been lots of sudden climate changes and mass extinctions. However, for the past several million years, average global temperatures have been quite cool and many plants and animals, including humans, are adapted to that cooler weather. Human activities now dominate the global landscape, and many plants and animals around the world are already struggling to survive in the remaining margins of natural habitat. Accelerating climate change is likely to leave many species with nowhere to go.

The Role of Trees in the Carbon Cycle

You should spend some time discussing the carbon cycle. Depending on the age and temperment of your students, you may wish to have some of them act out the carbon cycle as you read instructions for what they should do. Allow about 10 minutes for this part of the activity.

Choose one student to be a "Tree". Appoint two of them to be "Carbon". Four of them are "Oxygen". Two students are "Heat Energy". One student is "Human". If you want to involve the rest of the students, have them form a circle around the other students to stand for the "Stratosphere".

Ask the students to role-play as you explain the carbon cycle. Ask the students playing the “Heat Energy” to go to the outside of the circle.

Each free “Carbon” links arms with an “Oxygen” on one side and another “Oxygen” on the other side to form “Carbon Dioxide Molecules”.

“Heat Energy” comes through the “Stratosphere”. They bounce off the Earth and start to head back into space. But the “Carbon Dioxide Molecules” grab onto “Heat Energy”. They become energized and dance around.

The “Human” feels very warm. He/she is having trouble finding free “Oxygen” to breathe.

But the “Tree” comes to the rescue. It breathes in one of the “Carbon Dioxide Molecules”. It pulls the “Heat Energy” off the chain and releases it so that it can escape into space again. It pulls the two “Oxygens” off the chain, links them together, and releases them into the circle. It uses the “Carbon” to grow more wood. Together, the two students form a bigger tree. The other “Carbon Dioxide Molecule” and its “Heat Energy” are still dancing around energetically.

Now the “Human” feels more comfortable – not too hot, not too cold. When “Heat Energy” comes in from the sun, it bounces off the Earth and escapes again into space. The “Human” is happy that he/she can find some free “Oxygen” to breathe.

Now the “Tree” continues to grow. They breathe in another “Carbon Dioxide Molecule”. They pull the “Heat Energy” off and release it into space. They pull the “Oxygens” off, link them together, and release them into the circle. They turn the “Carbon” into wood and form a bigger “Tree”.

The “Heat Energy” comes in from the sun, bounces off the Earth, and escapes again into space. There are no “Carbon Dioxide Molecules” to keep them in the atmosphere. The “Human” feels cold, but has lots of “Oxygen” to breathe.

Now we take a trip into the distant past. There are no “Humans” living, so the “Human” joins the circle or exits the stage. A large “Tree” is growing. The “Tree” dies and falls down to the ground. It gets buried in muck and turns into a fossil over millions of years. The “Tree” turns into a “Fossil fuel” such as coal, oil, or natural gas and stays in the ground.

The “Human” emerges into the world. He/she feels cold and decides to turn on the heat in her house. He/she harvests the “Fossil fuel” by digging it up. The “Human” burns some of the fuel and turns the “Fossil fuel” back into “Carbon.” He/she releases the “Carbon” into the atmosphere. The “Carbon” separates two “Oxygen” atoms and links arms with them to form a “Carbon Dioxide Molecule”. The “Human” burns more “Fossil fuel” and the same thing happens. He/she releases more “Fossil fuel”. If there are enough students, two new “Oxygen” atoms can join with the third “Carbon”. Three “Heat Energies” come in through the “Stratosphere” and get caught by “Carbon Dioxide”.

The “Human” is really, really warm now! He/she has a very hard time breathing. “Human” gets an idea. If he/she plants some trees, they can cool things down a little bit. (He/she does this by planting two students from the circle as new “Trees”.)

Again, the “Trees” come to the rescue by breathing in the “Carbon Dioxide Molecules”, releasing the “Heat Energy” and “Oxygen”, and *sequestering* the “Carbon” as part of their wood.

Moral of the Story

Burning fossil fuels that have been sequestering carbon for millions of years can really heat the Earth up! If we plant trees, they absorb some of the sudden increase in carbon dioxide and offset the heating effect. Any carbon stored in a tree or a fossil tree is carbon that would otherwise be part of a carbon dioxide molecule in the air. Trees live a very long time, and so they do a good job of keeping carbon dioxide out of the air for many years.

The Burning Question

How much carbon dioxide does one tree keep out of the air? How many trees would you need to plant to compensate for the carbon that you release from fossil fuels each year?

About half of the weight of a tree consists of carbon atoms, so if we knew the weight of a tree, we could figure out the amount of carbon in it. How can we weigh a tree?

Ask the students to think about how they might figure out the weight of the wood in a tree. Ask them if they could estimate the volume of wood in the tree. Ask them what sorts of shapes they might use to approximate the shape of a tree.

There are many ways that the students might propose to estimate the weight or volume. Their methods might well be more accurate than the one we use here. If students think of other promising methods, encourage them to implement their methods alongside the one outlined on the handout.

We will estimate the volume of wood in the tree as if the tree were a perfect cylinder. We will use the height of the tree as the height of the cylinder. We will measure the circumference of the tree at a comfortable standing height and use that to represent how big around the cylinder is. Using a cylinder makes sense because the main part of a tree trunk is cylindrical. Of course, a tree trunk is not a perfect cylinder – the trunk tapers off as it goes up. On the other hand, there is quite a bit of weight in all of the branches, twigs, and leaves of the tree which we are not counting. We are estimating that if the branches of the tree were gathered together into the trunk, that the overall volume could be approximated by a cylinder. Younger students may be more comfortable estimating the volume of the tree as a rectangular solid. If you choose to use this approach, you will need to change the handouts accordingly.

Once we know the volume of wood in the tree above the ground, we can estimate the amount of wood in the roots. We can then convert the total volume of wood in the tree into pounds by using information about the weight of a cubic foot of wood. Finally, we can estimate the fraction of this wood that is made up of carbon.

Talking about Taking Measurements

Allow 15 to 30 minutes to teach the students how to take the measurements.

Tree Identification

Encourage students to choose a mature tree that is near the edge of a clearing (so that students can get a clear view of it from a distance).

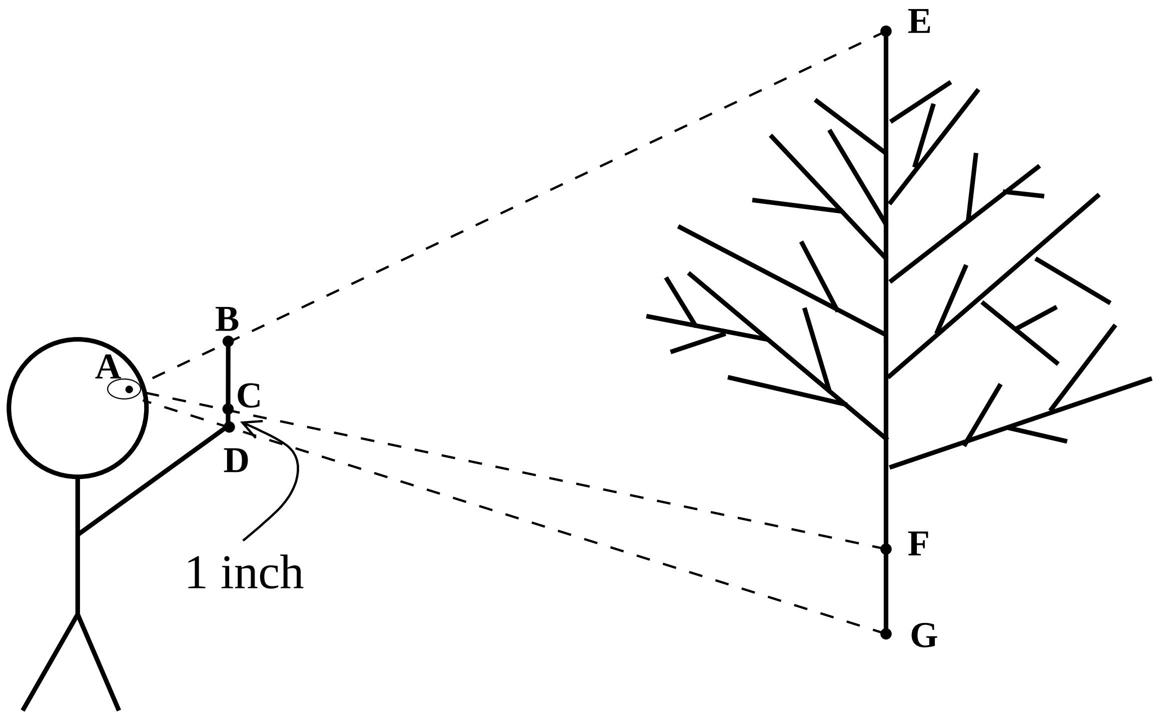
If you plan to ask the students to identify their trees, discuss that. If there are only a few types of trees in the area, you can teach them to distinguish those types.

Knowing the type of tree will give a more accurate estimate of its weight because different types of wood have different densities. However, you can choose to estimate the density of the wood as 50 pounds per cubic foot if you do not want to do tree identification. The worksheet includes a list of densities for some common trees in the United States.

Height

Ask the students if they can think of any ways to estimate the height of a tree. There are many ways they might choose to do this. If the students are familiar with similar triangles or trigonometry, they may be able to think of methods involving these ideas. If students come up with a promising approach, have them use their method alongside or instead of the method presented below. If the students come up with many methods, it may be worthwhile to test how feasible the methods are by using them to find the height of something with a directly measurable height.

Here is a neat method for estimating the height of a tree. This method is easy to implement and it does not require the ground between the student and the tree to be level. Each student will need a partner. One of the students should stand by the tree trunk. The other student should take a ruler in his or her hand and walk away from the tree. When that student is a good distance away, he/she should hold out the ruler at arm's length and look towards the tree. The ruler should be straight up and down with the 12 inch mark near the top. (You can tape a string with a washer on it to the ruler to use as a plumb bob if you wish.) The student should align the bottom of the ruler with the base of the tree trunk. If the top of the ruler looks like it is below the top of the tree, the student should go farther from the tree and try again. If the top of the ruler looks like it is above the top of the tree, the student should go closer to the tree. Eventually, the student should find the perfect distance where the bottom of the ruler looks like it is aligned with the base of the tree and the top of the ruler is aligned with the top of the tree.



Once the student has found the right place to stand, the partner should hold out his or her hand on the tree trunk. Keeping the ruler lined up properly, the student away from the tree should see whether the partner's hand looks like it is above the 1 inch mark or below the 1 inch mark. (The 12 inch mark should be at the top of the ruler, of course). The student should ask the partner to raise or lower the hand until it looks even with the 1 inch mark. The student should check again that the base of the tree looks like it is at the base of the ruler and that the top of the tree is still aligned with the top of the ruler.

The student by the tree should keep his or her hand where it was while the other student walks back. The student with the ruler should put his or her hand where the partner's hand was. The partner who was standing by the tree should use the tape measure and determine how many inches there are from the hand down to the ground. Ask the students how this information can be used to determine the height of the tree in feet.

When you explain this, you should draw a diagram like the one on the previous page and then ask students to explain the mathematical ideas behind why it works. They should be able to see that triangle ACD is similar to triangle AFG and that triangle ABD is similar to triangle AEG. You can then use algebra to show that the ratio of CD to BD is proportional to the ratio of EG to FG.

It turns out that the number of inches from the hand to the ground is the same as the number of feet in the total height of the tree. (The number of inches from the hand to the ground is 1/12 of the total height of the tree, so we could multiply it by 12 to find the height of the whole tree in inches. However, we would like to get the height of the tree in feet. There are 12 inches in each foot, so we should divide the number of inches by 12 to get the height in feet. But multiplying and then dividing by 12 will always bring us back to the number we started with, so we can skip those steps.)

The students should record the number of feet on the worksheet. You may wish to have the students switch roles and make a second measurement to check the accuracy.

Circumference and Diameter

Students should use the tape measure to find the *circumference* of the tree at a comfortable standing height. Remind the students that the circumference of a circle is the distance around the outside.

Students should use either their ruler or the tape measure to estimate the *diameter* of their tree at the same height. Remind them that the diameter of a circle is the distance from one side of the circle to the other if you go straight through the center. It is not possible to make the ruler go straight through the middle of the tree, but students can place the ruler across the tree trunk and visually estimate the distance from one edge to the other.

Taking Measurements

Allow 15 to 20 minutes for the students to identify the tree and measure its height, circumference, and diameter. Students should record their measurements on the worksheet.

Calculation Hints

Allow about 10 or 15 minutes for calculations. Students should round each step to one or two decimal places.

The formula for circumference is $C = \pi \times D$, where D is the diameter and $\pi \approx 3.14$. This means that if you cut a string as long as the diameter of the tree, you would need to join three strings of that length plus a little bit more (for the .14) to go all they way around the tree. Students should compare the Computed Diameters to the Measured Diameters when they get to that step. Ideally, these numbers should be the same. However, if the tree trunk was not circular in shape there may be a discrepancy.

Students will need to remember that the radius is the distance from the center of the circle to the outside edge and that the radius is equal to half of the diameter.

When it is time to compute the volume, students should fill in both of the blanks labeled r with the Tree Radius in feet. They should fill in the blank labeled h with the Tree Height in feet. Then they should use their calculators to multiply.

When the students come to the part where they are looking up the weight of a cubic foot of wood, remind them about how big the cube would be. (The cube is one foot by one foot by one foot). Ask them to imagine picking up a piece of solid wood that size.

Atomic weight is not something that most students will be familiar with. Atomic weight is basically a count of how many protons and neutrons that type of atom has in its nucleus. This determines how much the atom weighs. The facts about atomic weights are included to explain why we need to multiply by 44 and divide by 12 to convert between pounds of carbon and pounds of carbon dioxide.

Conclusion

Allow about 5 or 10 minutes for the Conclusion.

The number of trees that students find in their final calculation will vary depending on the size and type of tree that they weighed. Typical answers will range between 15 and 50 trees per year. Ask the students to share what they learned about their tree with the group. Remind them that if they planted that many trees every year (and the trees survived), they would cancel out many of the global warming effects that come from the energy they use, the food they eat, and the products they buy. Tree planting is a great follow-up activity for students who have made these computations.

Indiana Mathematics Standards

Indiana standards related to this activity include:

- Geometry 5.4.5: Identify and draw the radius and diameter of a circle and understand the relationship between the radius and diameter.
- Measurement 6.5.4: Understand the concept of the constant as the ratio of the circumference to the diameter of a circle. Develop and use the formulas for the circumference and area of a circle.
- Measurement 6.5.5: Know common estimates of π (3.14, 22/7) and use these values to estimate and calculate the circumference and the area of circles. Compare with actual measurements.
- Measurement 7.5.4, 8.5.4: Use formulas for finding the perimeter and area of basic two-dimensional shapes and the surface area and volume of basic three-dimensional shapes, including rectangles, parallelograms, trapezoids, triangles, circles, right prisms, and cylinders.
- Problem Solving 5.7.7, 6.7.9, 7.7.10, 8.7.10: Make precise calculations and check the validity of the results in the context of the problem.

References

The Conservation Fund. http://www.conservationfund.org/

Cooperative Research Centre for Greenhouse Accounting. http://www.greenhouse.crc.org.au/

The Environmental Protection Agency. "Climate Change". http://www.epa.gov/

Cassens, Daniel L. "Top Weight Estimates for Sawlog Size Hardwood Lumber" Purdue University Cooperative Extension Service; Forestry and Natural Resources: Marketing and Utilization. http://www.ces.purdue.edu/extmedia/FNR/FNR-109.html

Kuhns, Michael and Tom Schmidt. "Heating With Wood: Species Characteristics and Volumes." Utah State University Forestry Extension. http://extension.usu.edu/forestry/HomeTown/General_HeatingWithWood.htm

Sherman, Tracey. "Virginia Big Tree Program." Virgina Polytechnic Institute and State University College of Natural Resources. http://www.cnr.vt.edu/4h/bigtree/

"Trees of Western Montana." http://www.snowwowl.com/rlmontanatrees.html

Woodworkers Source. http://www.exotichardwoods-northamerica.com/

Measurements and Identification

Type of tree (if known): ____________________ Tree Circumference in inches: ___________

Tree Height in feet: ____________________ Measured Tree Diameter in inches: ___________

Circumference to Radius Computations

Formula for Circumference: $C = \pi \times D$, where D is the diameter, and $\pi \approx 3.14$.

Computed Tree Diameter in inches: ____________________

Tree Radius in inches: ____________________

Tree Radius in feet: ____________________

Tree Volume Computations

Formula for Volume of a Cylinder: $V = \pi r^2 h$, where r is the radius and h is the height

$V =$ 3.14 $\times$ ___________ $\times$ ___________ $\times$ ___________

Tree Volume in cubic feet: ____________________

Tree Weight Computations

Find the weight of each cubic foot of wood in your tree (use the table or enter 50 lbs if you do not know)

Tree Density in pounds per cubic foot: ____________________

Above Ground Tree Weight in pounds: ____________________

The weight of a tree's roots is about 1/5 of the above-ground tree weight.

Below Ground Tree Weight in pounds: ____________________

Total Tree Weight in pounds: ____________________

Carbon Sequestration

About half of a tree's weight is carbon.

Total Carbon trapped in the tree in pounds: ____________________

Carbon dioxide is built from one carbon atom and two oxygen atoms.

The atomic weight of carbon is 12.

The atomic weight of oxygen is 16.

The total atomic weight of carbon dioxide is 12 + 16 + 16 = ____________________

Every 12 pounds of carbon in the tree comes from 44 pounds of carbon dioxide that the tree absorbed out of the atmosphere.

Total Carbon Dioxide absorbed by the tree in pounds: ____________________

Bringing it Home

The United States releases 13,201,000,000,000 (over 13 trillion) pounds of carbon dioxide each year (as of 2004). The population of the United States is 281,421,906 (as of the 2000 census). This means that each person in the United States releases about 46,908 pounds of carbon dioxide.

How many trees like the one you weighed would it take to absorb 46,908 pounds carbon dioxide?

Number of trees needed to absorb the carbon dioxide I produce each year: ____________________

If you planted that many trees every year, then you would cancel out many of the global warming effects that come from the energy you use, the food you eat, and the products you buy.

Species	Pounds per cubic foot	Average Lifespan
Apple	61	100
Ash (Green)	52	120
Ash (White)	50	260
Aspen (Quaking)	43	120
Basswood/Linden	45	100
Beech (American)	57	300
Birch (Gray)	54	50
Birch (Paper)	54	100
Birch (Sweet)	54	150
Birch (Yellow)	54	150
Box Elder	45	75
Buckeye/Horse Chestnut	53	100
Catalpa	57	100
Cherry (Black)	46	100
Cedar (Eastern Red)	37	150
Cedar (Western Red)	41	1000
Cottonwood	58	120
Cypress (Bald)	51	600
Elm (American)	56	175
Fir (Douglas)	41	750
Fir (White)	45	250
Hackberry	50	150
Hickory (Pignut)	64	200
Hickory (Shagbark)	64	250
Honeylocust	58	120
Locust (Black)	58	60
Maple (Red)	49	130
Maple (Silver)	49	100
Maple (Sugar)	56	300
Mulberry	59	125
Oak (Black)	62	100
Oak (Bur)	62	100
Oak (Pin)	62	100
Oak (Northern or Southern Red)	62	200
Oak (White)	64	300
Osage Orange	64	75
Pine (Loblolly)	45	100
Pine (Lodgepole)	45	150
Pine (Ponderosa)	45	300
Pine (Red)	45	300
Pine (Shortleaf)	45	200
Pine (Eastern White)	45	200
Pine (Western White)	45	350
Spruce (Blue)	35	150
Sweetgum	57	200
Sycamore	64	300
Tupelo (Black)	58	250
Tulip (or Yellow Poplar)	47	250
Walnut (Black)	57	150
Willow (Black)	52	70