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July 25, 2011

Abstract

The present is a guide to conduct an Experiment with the purpose of verifying the hypothesis of the greenhouse effect due to radiation trapped by the atmosphere. This guide is addressed to high school students. I have described the experiment step by step, including photographs so the students can easily carry out the experiment.

Introduction

Before we start preparing the materials that we will use to conduct the experiment, it is meaningful to say why we need to carry out this kind of experiment.
Take your book of physics or biology and go to Index. Seek out the concept “Greenhouse Effect”. Read the description of the greenhouse effect. Perhaps you will find an explanation on the greenhouse effect as follows:

“It is called greenhouse effect because the atmosphere works like the glass panels of a greenhouse…a greenhouse warms up because it absorbs sunlight and traps the reradiated infrared radiation.”

Almost all authors of academic books state the process described above as granted knowledge and, more or less, with the same words.

On that description of the greenhouse effect we find two main arguments:

1. The atmosphere behaves like the glass windows of a greenhouse.
2. The atmosphere permits the passage of sunlight and blocks the longwave infrared radiation reflected or emitted by the Earth’s surface towards the space.

However, the labor of a scientist is to test every argument, presented as scientific knowledge, to falsify or verify such argument, especially if different opinions around a natural phenomenon arise from academic sources. This is the case of the greenhouse effect in the atmosphere.

In 1909, Professor Robert W. Wood conducted an experiment consisting of testing the effect of the longwave infrared radiation trapped inside a greenhouse with respect to the elevated temperature inside a greenhouse during insolation.

His experiment was described in an article that he published in the journal Philosophical Magazine, in 1909.

After Prof. Wood’s experiment, many other investigators carried out experiments, like Saussure’s experiment, who did not falsified the experiment of Prof. Wood, but only demonstrated that the solar radiation was the same radiation emitted by a fire and invented a primitive solar oven able to conserve enough heat as to fry an egg or to cook some chops.

Recently, Prof. Vaughan Pratt conducted an experiment trying to repeat the experiment of Prof. Wood. Prof. Pratt’s experiment is described succinctly; however, he assures to have failed on reproducing the experiment of Prof. Wood and attributes the failure to possible errors made by Prof. Wood in 1909.

As the conclusions of Dr. Pratt contradict the conclusions of Prof. Wood, another science investigation by a third arbiter is absolutely necessary.

This is the reason that I am asking you, the high school student who is reading this guide, to repeat once and once again -with me together- the 1909 experiment of Prof. Wood, using the materials used by Prof. Pratt in his experiment and most additionally materials that you could have in mind, to test the greenhouse hypothesis and to obtain trustworthy results.

The materials, tools, and equipment necessary to conduct this experiment are cheap and can be obtained without problems from known suppliers like Lowe’s®, Home Depot®, Office Depot®, Wal-Mart®, HEB®, etc. Some devices can be easily found at Amazon.com; for example, Hanna® thermometers (to record
temperature), ExTech® Hygro-thermometers (to record ambient temperature and relative humidity), and anemometers (to record the trajectory and speed of wind).

Let us start this fascinating and enjoying scientific experiment.

**WARNING:** Solar radiation can cause skin cancer or skin burns if exposed to direct sunlight during prolonged periods of time. As the students will be exposed to long periods under the action of the sunlight, dust and wind, it is highly commendable to use sun protection creams or lotions (sunscreens) applied on exposed skin, anti-UV eyeglasses, and hats. Take a good cool box filled with ice cubes and beverages, in particular, water.

**EQUIPMENT**

4 Hanna Instruments® Digital Thermometers, Model HI98501. Range of Temperatures: -50 to 150 °C. Accuracy of ±0.3 °C (inside) and ±0.5 °C (outside). EMC deviation ±0.3 °C.

1 Hygro-Thermometer. Any good hygro-thermometer will work. You can find a broad variety of this device at Wal-Mart, Sam’s, Hobby Lobby, etc.

1 Anemometer. You can find this instrument at amazon.com.

**MATERIALS**

4 Lowe’s® corrugated cardboard boxes, measuring 30 x 30 x 20.32 cm. If you do not find cardboard boxes with such dimensions, you can buy the smaller box and cut them down to size.

1 impact modified acrylic plate Plaskolite®-Duraplex®, 3 mm thick.

1 silica glass panel, 3 mm thick. Optically translucent; **no multilayered**.

Crystal Clear Polyethylene Film, 0.3 mm thick (0.0118 inches).

1 tube of white acrylic latex sealant for joints by DAP® (AlexPlus®, for example). You can find other brands at Home Depot®, Lowe’s®, Hobby-Lobby®, and Office Depot®.

1 tube of Qualtex® Silicone by GE®, translucent multipurpose silicone. TUGT-08347. Premium Waterproof, 3HR rain-ready, Sun/Freeze proof. You can find other brands at Home Depot and Lowe’s

Reynolds’ Wrap® Heavy Duty Aluminum Foil. 45.72 centimeters wide.

White Glass Wool. Find it at Hobby Lobby. It is used generally to fill dolls and pillows. Do not buy packaging glass wool because it contains impurities that degrade its reflectivity.

Quartet® Cork tiles. Buy it at Lowe’s or Home Depot.

Masking tape with similar absorbivity coefficient than that of corrugated cardboard. For example, Masking Tape by Scotch 3M, W2020. High Adhesion (adhesion is a very important quality because most masking tapes lose adhesion at high temperatures).
Scotch® Crystal Clear Tape CC1920-B, 19 mm width.

Sticky Aluminum tape. Any aluminized tape would be fine, although Shurtape® AF912 would be an excellent choice.

Aluminum plastic sheeting, 2 m x 0.85 m.

Matte Black Paint. Look for paint with a reflectivity index of 0.05 to 0.1.

**TOOLS**

1 Plastic & Laminate Cutter. Any brand.

**WARNING:** Use lab coat, leather gloves, and protective eyeglasses every time you are working on constructing your boxes. Lab coat and protective eyeglasses must be used all along the construction of the boxes.

**PROCEDURE FOR THE FIRST STAGE OF THE EXPERIMENT**

Construct four identical boxes of corrugated cardboard. Dimensions: 30 cm wide x 30 cm long x 20.32 cm depth. Leave an open side. This side will be covered by a panel or a sheeting of film.

Seal all the joints of the walls with white acrylic latex sealant (Figure 01)

![Figure 01: Corrugated cardboard boxes before and after sealing](image)

Once the sealant has dried, paint the inner walls of the boxes with matte black paint (Figure 02).
Figure 02: Paint the five inner surfaces.

IMPORTANT: Give the paint enough time to dry; otherwise, you will have serious problems of moisture inside the boxes after you have covered them with plates or film.

Once the paint has dried completely, wrap the external surfaces of three boxes with aluminum foil (Figure 03). Leave one box unwrapped for now with aluminum foil because this box will be wrapped with white glass wool before covering it with aluminum foil.

It is essential to paste the borders of the aluminum foil on the boxes using silicon glue. Silicon glue will impede the cardboard becoming wet.

WARNING: The edges of the aluminum foil and the cutting edge are sharp. Use gloves every time you are handling it.
Wrap the fourth box with white glass wool. Glue the white glass wool with silicon glue. Do not leave areas without covering. (Figure 04).
Cover with aluminum foil the box wrapped with white glass wool (Figure 05). The sheeting that is covering the box of the photograph is a 0.051 mm Low Density Polyethylene film. The aluminum foil prevents the white glass wool from excessively absorbing solar radiation.

Place a 2.5 x 2.5 cm square of cork exactly on the center of the bottom lid of the four boxes (Figure 06). The cork will prevent the thermometer loses its perpendicularity through the rear covers of the boxes.
Figure 06: Adhere a piece of cork 2.5 x 2.5 cm exactly on the center of the bottom surface of the rear wall on each one of the four boxes.

Do not punch a hole in the cork yet. We will do that when we are ready to insert the rods of the thermometers through the rear cover of the boxes.

Once the glue has dried, cover the cork with aluminum foil or sticky aluminum tape (Figure 07).
Figure 07: Piece of cork covered with aluminum foil.

Now it is time to close the open sides of those boxes.

Take an acrylic plate as received. Do not peel off the protective adhesive film until you have finished cutting off the plate.

**WARNING:** Plastic & Laminate Cutters and putty knives are extremely sharp. Use protective gloves along the following steps.

Cut off two 30.5 x 30.5 cm squares. The area of the squares of acrylic must be a little larger than the open side of the boxes on which you will place the squares to block the passage of air.

Trim a small portion from one the corners of one of the plates of acrylic. The trimming must measure 7 x 7 cm (Figure 08).

Now you have a holed acrylic plate and an uncut acrylic pane.

Take one box with the open side facing up. Run a bead of silicone on the four free edges of the box. Be careful to run a homogeneous bead of silicon. Do not leave a single segment on the edges without applying silicone.

Carefully, place the uncut acrylic panel on the open side of the box to cover it completely. Press a little on the acrylic pane for the silicone is drips to both sides of the edges of the box.

Smooth the bead of silicone with a putty knife. Let the silicone dries.

Take another box and repeat the procedure, but cover it with the holed acrylic pane.
Place the third box on the project center table. Run a bead of silicone on the free edges of the box.

**WARNING:** The edges of the silica glass pane and the 0.3 mm LDPE film are razor-sharp and can hurt you. Use protective gloves along the following steps and handle the silica glass pane with extreme caution. If the glass panel slips off your hands, let it to fall and crash on the floor. Do not try to avoid that it drops. I have seen many grave injuries on forearms, thighs, thorax, etc., of people who have tried to prevent the falling of panels of glass.

Take the silica glass pane and place it over the open side of the box to cover it completely.

Repeat the same procedure with the fourth box, which you will cover with two sheets of 0.3 mm low density polyethylene (LDPE) film (Figure 09). Run a bead of silicone around the edges of the first panel and place the second sheet of LDPE film upon the first sheet. The panel of LDPE film will be 0.6 mm thick. **You could use a single sheeting of 0.3 mm LDPE film.**
Once the silicone has solidified, seal the four edges of each box around the panels with the crystal clear 2.2 cm width scotch adhesive tape. Procure to cover at least 0.5 cm on the edges of the top surface of the panels. This will optimize the isolation of the inner atmosphere of the boxes.

Up to this point, we have constructed four boxes that are ready for being tested before the experiment starts.

Put the four boxes directly under sunlight. Observe for any signs of water vapor condensation on the bottom surface of the panels. If you find water vapor condensation on the bottom surface of the box (Figure 10), it means that the cardboard is wet and you have to correct the problem.

Condensed water vapor deposited on the bottom surface of the panels fatally affects the transmission of radiation inwards and outwards the boxes; therefore, the records of temperature would be flawed and the results would be unpredictable.

The inner atmosphere of the boxes must contain the same amount of water vapor than the surroundings.
Figure 10: Condensation of water vapor on the bottom surface of the 0.051 mm LDPE film (I sprayed water inside the box before I sealed it with LDPE film. The temperature of the box in the photograph increased until evaporation occurred, and decreased by 8 °C after condensation appeared. Try to explain this phenomenon; your explanations would constitute scientific hypotheses that must be congruent with the known theories on this issue. Your hypotheses must be subject to be falsified).

As soon as you find water vapor condensation in any of your boxes, unstuck the panel at a corner of the box and put an object (a wood strip, for example) between the pane and the edge of the box to maintain it open at least up to one hour after the condensed water vapor disappears from the panel. Carefully, run again a bead of silicone and adhere the panel on its original position. Check any possible segment without silicone and cover it before the silicone applied on the edge of the box solidifies.

After you have sealed the boxes, take each box and wrap the joints, all around, between the box edges and the panes with Scotch Crystal Clear Tape CC1920-B, 19 mm width. Be careful and do not touch the edges of the panels with bare hands. PLEASE, USE GLOVES!

Once you have sealed the joints with Scotch crystal clear adhesive tape, wrap the joints again with Masking Tape (Scotch 3M, W2020). This will constitute a third blockage to air leaking through the joints.

The final part of construction consists on placing a piece of adhesive aluminum tape, 5 x 7 cm, exactly on the center of the top surface of the panels (Figure 11). This will provide a shadow to avoid the sunlight strikes on the thermometers rods and therefore you will not obtain false records of temperature.
Figure 11: Aluminum tape placed on the center of the top surface of the silica glass panel.

Now we are almost ready to conduct your experiment to test the greenhouse effect due to longwave radiation.
EXPERIMENTAL PHASE

Before starting your experiment, copy and print the following table (Figure 13):

<table>
<thead>
<tr>
<th>Time Lapse</th>
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Figure 13: Table to record your observations.

To conduct your experiment, chose a day with clear skies and with calm winds. Clouds block sunlight and the recorded temperatures will be highly variable and confusing, although consistent with the physics principle (Figure 12).

Figure 12: Clouds could cause your results to be confusing. Notice the different densities of clouds.
You will write down the recorded temperatures under the correspondent mark.

Record the ambient temperature and relative humidity.

In a shadowed place, arrange in a line the four boxes on a white table.

Insert the thermometers’ rods through the center of the squares of cork on each box. The rod must be completely inserted inside the box and only the body of the thermometer with the LCD must be outside the box (Figure 14).

![Figure 14: Correct position of thermometers through the rear pane of the boxes.](image)

Place some wood strips behind the boxes as supports to maintain the boxes in a stable position. Silica glass is heavier than acrylic and polyethylene film, so it will be necessary to place another piece below the inferior side of the wall for it does not fall forward. Repeat this technique with the boxes covered with acrylic pane if necessary.

Cover the four boxes with the aluminum plastic. Be careful to cover all boxes completely.

Place the table under the sunlight and take the aluminum plastic sheeting off. The sunlight must reach the bottom pane of the boxes without projected shadows, except the shadow of the aluminum tape that you placed on the panels to screen the thermometer rods.

**WARNING:** Use eyeglasses and hat during the following steps of the experiment. Be careful your shadow does not obstruct the sunlight hitting the boxes!

Observe the temperature of each box every five minutes and record it on your table.
Be aware that the Earth rotates and the angle of sunlight declines with time. Pay special attention to the rods of the thermometers for these are never hit by sunlight.

**WARNING:** Plastic & Laminate Cutters and putty knives are extremely sharp. Use protective gloves along the following step.

After 60 minutes of observation, carefully remove one half of the LDPE film with your cutter taking extremely care of not removing the side where the aluminum tape that screens the thermometer rod is adhered. Wait for 30 minutes and record the temperature of all boxes, including the box partially covered with LDPE film.

**ANALYSIS OF THE RESULTS**

Before graphing your results, you must analyze your results and write your conclusions down. Answer the following questions:

1. Was the temperature the same in all boxes?
2. What box reached the highest temperature?
3. What box reached the lowest temperature?
4. What the average difference of temperature is between the box covered with the silica glass pane and the box covered with the uncut acrylic pane?
5. What the average difference of temperature is between the box covered with silica glass and the box covered with the holed acrylic plate?
6. What the average difference of temperature is between the box covered with silica glass and the box covered with the 0.3 mm LDPE film?
7. What the possible explanations to the difference of temperature between the box covered with silica glass and the box covered with 0.3 mm LDPE film could be?
8. What happened after you removed one half of the LDPE film panel?
9. What is the more plausible explanation to the dramatic decrease of temperature of the box covered with LDPE film?

Now answer the three most important questions:

1. If the LDPE film permits the inward and outward passage of longwave and shortwave solar radiation and the longwave radiation reflected and emitted by the inner surfaces of the box covered with it, what is the reason for the dramatic decrease of the temperature of the box covered with LDPE film after you removed one half of this sheeting?
2. According to the Greenhouse Effect Hypothesis, the greenhouse effect is due to longwave IR radiation trapped by the atmosphere. Have you corroborated or falsified this hypothesis through your experiment?
3. What is the reason for the temperature of the box covered with the holed acrylic pane was lower than the temperature of the other boxes before you removed one half of the LDPE film of the fourth box?

Clue: Read about heat transfer by convection, conduction, and radiation and chose the most plausible cause.

Graph your results.

WRITE DOWN YOUR CONCLUSIONS AND ADD TABLES AND GRAPHS ON A REPORT.

REFERENCES:


FURTHER READING:


http://principia-scientific.org/pso/publications/The_Model_Atmosphere.pdf

http://www.biocab.org/Heat_Transfer.html

http://www.biocab.org/Heat.html