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Investigating the effect of multiple layers of insulation with a bubble wrap experiment

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Abstract

We provide a fun, inexpensive laboratory experiment for students to investigate the effects of multiple layers of insulation and observe diminishing values for additional layers using bubble wrap. This experiment provides an opportunity for students to learn about heat transfer through conduction using readily available materials. A water-ice pack is placed on top of five layers of bubble wrap. The temperature is taken between each layer periodically for 15 minutes. Students determine asymptotic temperatures for varying layers. This experiment also suggests a real world application.

Introduction

For over a quarter century, writers and teachers have recognized that "physics is inextricably part of our modern way of thinking and living" and they have realized the importance of "applying the basic physics that you learn in the classroom to real life situations." [1] The application in this paper provides an opportunity to addresses the very important applied area of energy conservation, specifically, reducing heat loss from buildings, and associated reductions in carbon emissions. The laboratory experiment allows students to learn about heat transfer through conduction using readily available materials. Students explore the effects of multiple layers of insulation and observe diminishing values for additional layers using bubble wrap.

The laboratory experiment

The supplies consist of a 5 mm (3/16 inch) thick roll of clear bubble wrap, five digital thermometers with long probes, a resealable food bag, a beaker, ice, chilled water, and a timer. All of these supplies are easy to obtain.

Cut five sheets of bubble wrap to a size of 30 cm x 30 cm (1 square foot). Stack the five sheets on a desk. If using bubble wrap with only one smooth side, place the rough side down. Insert a thermometer probe between each layer with the tip directly under the area to be covered by the bag of water and ice. Pour 400 ml of chilled water into a container and add ice filling to a total volume of 1000 ml. In earlier experiments, we found that using less ice or unchilled water resulted in the ice melting before the experiment was completed. Pour the ice-water mixture into the resealable bag. Press the bag to remove as much air as possible and seal the bag. Place the bag of ice and water on the top of the stack of bubble wrap, covering the area over the thermometer probes as illustrated in the photo in figure 1. The ice should be evenly distributed in the bag.

Figure 1. Experiment for taking temperature readings under 1, 2, 3, 4, and 5 layers of bubble wrap when ice is placed on top.

Immediately begin recording data. We recommend beginning each recording at 15-second intervals although shorter intervals are informative during the first 3 minutes if the students are able to capture them. One student rapidly calls out the temperature readings at periodic time intervals, cycling through the thermometers and another quickly records the data.

There is an offset in time for each measurement; however, the relative times are very close if the temperatures are read by the same person at the same speaking rate. An alternative method that would alleviate the time offsets is to use the video recorder on a smartphone to record the temperature display on the thermometers with another smartphone used as a timer, also in the frame. Students could then review the recording, capturing data for each thermometer at the same times.

Our students have invariably expressed a strong desire to immediately pop the bubbles, that often being their only prior experience with bubble wrap. Caution them to refrain completely from doing so until after the experiment is complete.

A quick, additional exercise increases the direct experiential value of this activity. Place six bags of ice and water on a table and cover them with 0, 1, 2, 3, 4 and 5 layers of bubble wrap. Students can then place each hand on top of different stacks for 10 to 20 seconds in order to feel the difference in cooling effect for various layers. This invariably results in many of them exclaiming "Wow!"

Data and Student-Guided Questions

The temperature data are plotted in figure 2 as discrete points. The precision of the thermometers is about ±1 °C. In our experiment, the ambient initial temperature was a little over 22 °C. Note the effectiveness of the various layers. Were there no insulation, the temperature below the bag would rapidly approach 0°C. The asymptotic temperatures for 1 and 5 layers are about 3 °C and 11 °C, respectively.

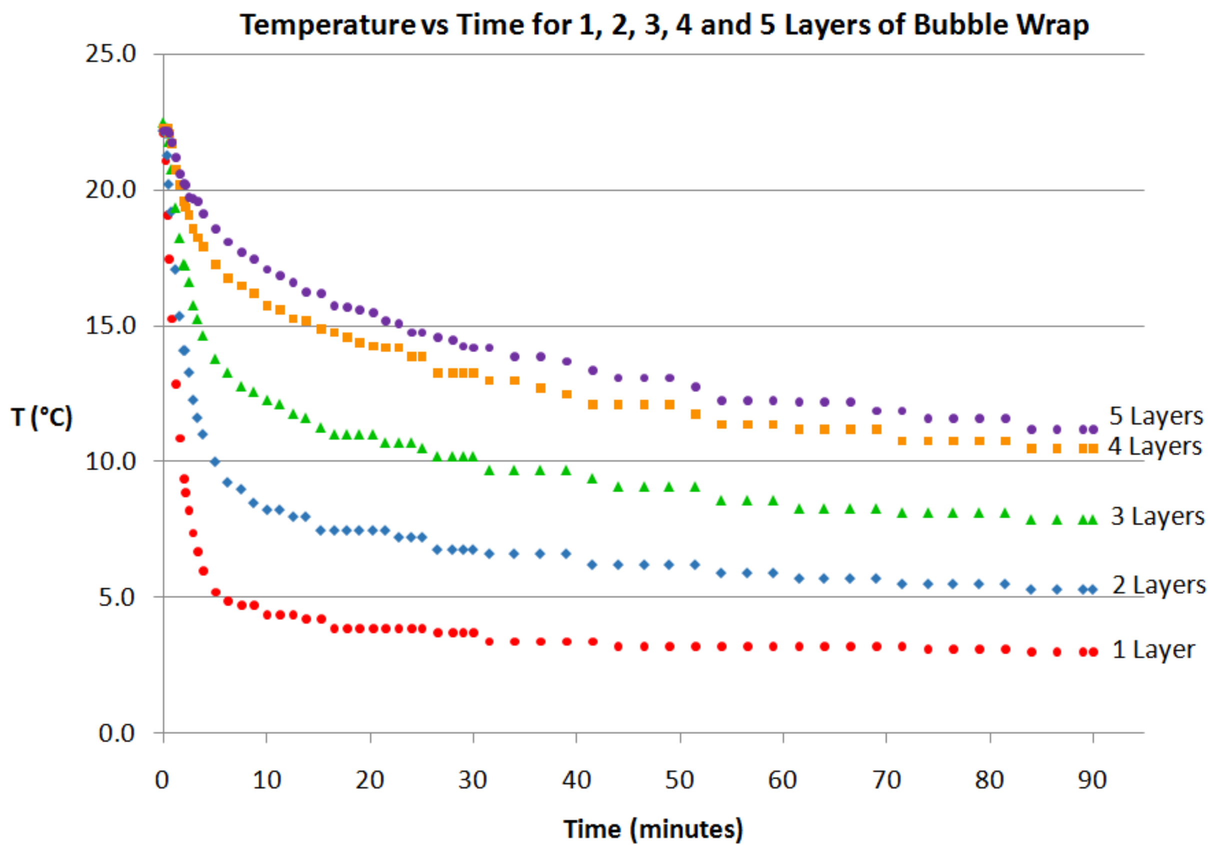

Figure 2. Temperature plots as a function of time for various layers of bubble wrap with an ice pack on the top layer.

Some student-guided questions follow. What was the asymptotic temperatures for each layer? How many degrees of insulation does each layer provide? Are there diminishing returns for additional layers of bubble wrap? Would you consider putting bubble wrap on some of the exterior windows of your home?

Applying the knowledge

Other than air gaps, which provide zero insulation, windows are generally the least insulated exterior surface in most buildings. They account for significant heat loss during cold months. An economical way to improve insulation of a home is to place bubble wrap on the inside of windows.

Bubble wrap can be easily attached to a window by spraying the glass with a dilute soapy water solution, e.g., 2-5%. Bubble wrap is then applied to the wet surface, bubble side toward the glass. It will adhere by itself at this point and remain against the glass after the solution dries. To illustrate the idea, see figure 3.

To be an effective insulator, the bubble wrap should cover the entire glass surface. Bubble wrap need not be applied to all windows to provide energy savings. It can be easily removed or replaced if desired. Coauthor Eggers has experienced substantial energy savings from bubble wrap applied to most of her windows for several years.

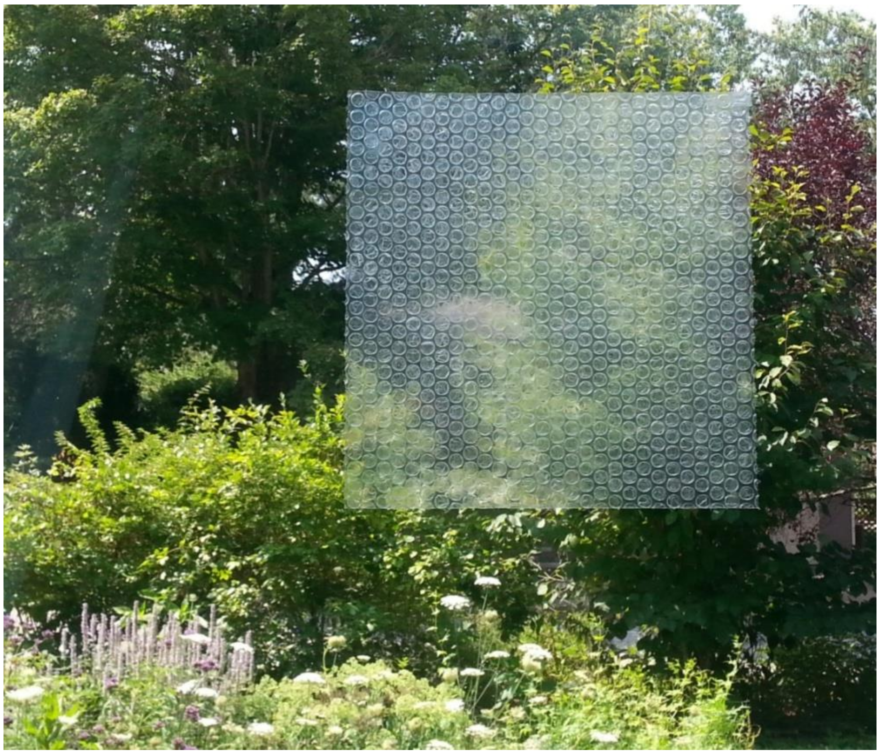

Figure 3. A 30 cm x 30 cm piece of bubble wrap placed on a window for illustration purposes.

Conclusion

This paper provides a fun way to explore the effects of multiple layers of insulation and the diminishing effects of additional layers of insulation. The experiment described suggests a solution for a real-world problem: providing highly effective, added insulation in a home in a very simple and economical way. The interdisciplinary connections among physics, and environmental science described in this paper reinforce for the student the importance of applying physics to our energy challenges of today.

Acknowledgment

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References

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Authors

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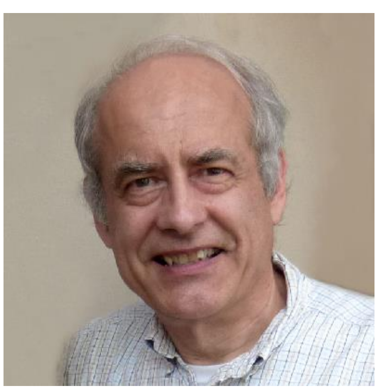

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