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How does the thickness of the layer of air between two panes of glass in a double pane window affect the ability of the window to insulate?

Abstract:

Heat in houses is lost through windows by conduction or convection currents formed between the two panes of glass; more air between the panes provides more air to insulate, but too much space has room for a convection current which would cause heat loss. Three boxes with double-paned windows were made, increasing the space between the panes glass. The boxes were heated and then put outside in the cold while the temperature loss was measured. As the space between the panes of glass increased, the average temperature loss decreased. This is because the greater amount of air provided more insulation, but because the window was so small compared to a real window there was not enough space for a convection current to form.

Introduction:

Heat is the passage of energy from one object to another. When an object has more heat, the molecules in that object are moving faster in a disorderly way (Cezairliyan 1). Temperature is a measure of how easily an object gives up or receives heat. Heat will always flow from an object with higher temperature to an object with lower temperature until the objects are the same temperature (Kieran 1). If the difference in temperature between two objects is greater, then the heat will flow faster from one to another (Cezairliyan 1). This means that heat will escape through a window, even if it is closed, until the temperature outside a house and inside that house are the same.

Heat passes from one thing to another by conduction, convection, and radiation. Conduction is the movement of heat through a material without carrying any of that material with it. The atoms vibrate faster and bump into other atoms, which causes them to vibrate. Convection is the movement of heat by the movement of the heated material. Hot objects expand and rise, and cooler objects go into the space that was occupied by the hot object. Those cooler

objects are then heated the same way that the original hot objects were heated. The cycle starts again. This is called a convection current. Radiation is the transmission of heat by infrared rays (Cezairliyan 1).

To prevent heat transfer, insulation is used. Insulation is defined as the restriction of heat, sound, or electricity within a specific area. It reduces the natural flow of heat from hot objects to cool objects (McElroy 1). Glass is not a very good insulator compared to other materials (Windows for Commercial Buildings). To improve the ability of windows to insulate, modern windows usually have two or more panes of glass (Wing 95). There is a layer of air, argon, krypton, or vacuum between the panes of glass. This air, vacuum, or gas slows the transmission of heat through the window (Krutz 2). A wider space provides more insulation, up to a point. If there is too much space between the panes of glass, a convection current could form, which would decrease the efficiency of the window. There should be between 1/4 of an inch to 1 inch of space between the panes of glass (Krutz 2). Those measurements translate to between 0.635 centimeters and 2.54 centimeters. If the thickness of the layer of air between two panes of glass is increased to a maximum of 2.54 cm., then the room will lose less heat when exposed to cold, because the greater amount of air will provide more of the insulating substance.

Materials:

1. Three corrugated cardboard mailing boxes with interior space that is 256 mm by 103 mm by 103 mm; one of the sides that is 256 mm by 103 mm should be open and have a top that can open and close
2. Box cutter
3. Self-healing mat on which to cut off the tops of the boxes and cut the Styrofoam insulation
4. Nine pieces of Styrofoam insulation that are 13 cm by 5 cm by 28 cm

5. Six sheets of glass that are 256 mm by 103 mm and are 3.175 mm thick

6. Weatherstrip /caulking cord

7. Circular saw to cut wood

8. Six pieces of wood that are 10 cm by 1.9 cm by 5.6 cm to hold up the glass on the inside of the boxes

9. Two pieces of wood that are 10 cm by 1.9 cm by 1 cm

10. Two pieces of wood that are 10 cm by 1.9 cm by 2.5 cm

11. Two pieces of wood that are 10 cm by 1.9 cm by 4 cm

12. Carpenter's glue

13. Ruler that has metric measurements

14. Four thermometers that have the Celcius scale

15. A house that is room temperature inside

16. A cold outdoor climate

17. Writing implements with which to record data and mark materials

18. Three chairs

19. A timer

Procedure:

1. The mailing boxes were put together and the tops were cut off using the box knife and self-healing mat.

2. The boxes were labeled "A," "B," and "C" with a pencil.

3. The wood was measured in order to cut it into pieces of the sizes indicated in the "Materials" section. It was marked and labeled with a pencil.

4. The wood was cut along the pencil lines with a circular saw.

5. Glue was put on one of the pieces of wood that is 10 cm by 1.9 cm by 5.6 cm.

6. It was put in the side of the box so that the glue was touching the side and bottom of the box.

7. Step 5 was repeated and the piece of wood was placed in the other side of the same box.

8. Steps 5, 6, and 7 were repeated two times so that there were two pieces of wood in the sides of each box.

9. One thermometer was placed in each box.

10. One piece of glass was placed on top of the pieces of wood in a box.

11. Some of the caulking cord was pressed all around the glass in that box so it sealed the space between the glass and cardboard.

12. Steps 10 and 11 were repeated twice for the other boxes.

13. Glue was put on the two pieces of wood that were 10 cm by 1.9 cm by 1 cm.

14. The pieces of wood were glued on top of the layer of glass in the box marked “A.”

15. Glue was put on the two pieces of wood that are 10 cm by 1.9 cm by 2.5 cm.

16. The pieces of wood were glued on top of the layer of glass in the box marked “B.”

17. Glue was put on the two pieces of wood that are 10 cm by 1.9 cm by 4 cm.

18. The pieces of wood were glued on top of the bottom layer of glass in the box marked “C.”

19. A pane of glass was put on top of the pieces of wood in each box.

20. The caulking cord was pressed all around the glass in all three boxes, so the space between the glass and cardboard was sealed.

21. Using the box cutter and self-healing mat, the Styrofoam insulation was cut into pieces that were of the size indicated in the “Materials” section.

22. A piece of insulation was glued to the bottom and both long sides of a box.

23. Step twenty-two was repeated for the other two boxes.

24. The boxes were put inside the house located at 24 Saunders Road, Saunderstown in the same spot. The experimenter waited until they all came to similar temperatures.

25. Three chairs were set up outside in a spot that gets no direct sunlight. The remaining thermometer was placed on one of the chairs.

26. The temperature outside was measured and recorded using the thermometer.

27. The temperature inside the boxes was measured and recorded before they were taken outside.

28. All the boxes were taken outside into the cold at the same time. They were placed on the chairs. All boxes were exposed to the same conditions.

29. The timer was set so it would go off every five minutes.

30. Every time the timer went off, the temperatures of the boxes were measured and recorded.

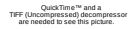
31. Twelve measurements of the temperatures of the boxes were taken until they had been outside for 1 hour.

32. The boxes were brought inside. The experimenter waited until they all came to room temperature again.

33. Steps 25-32 were repeated nine times so that there had been ten trials in all.

Safety Precautions: Be careful not to cut off fingers while using circular saw. Be careful not to break any glass, because pieces of broken glass are very dangerous. Be careful while using glue, and make sure not to get glue on skin, furniture, or anything else that was not meant to be glued.

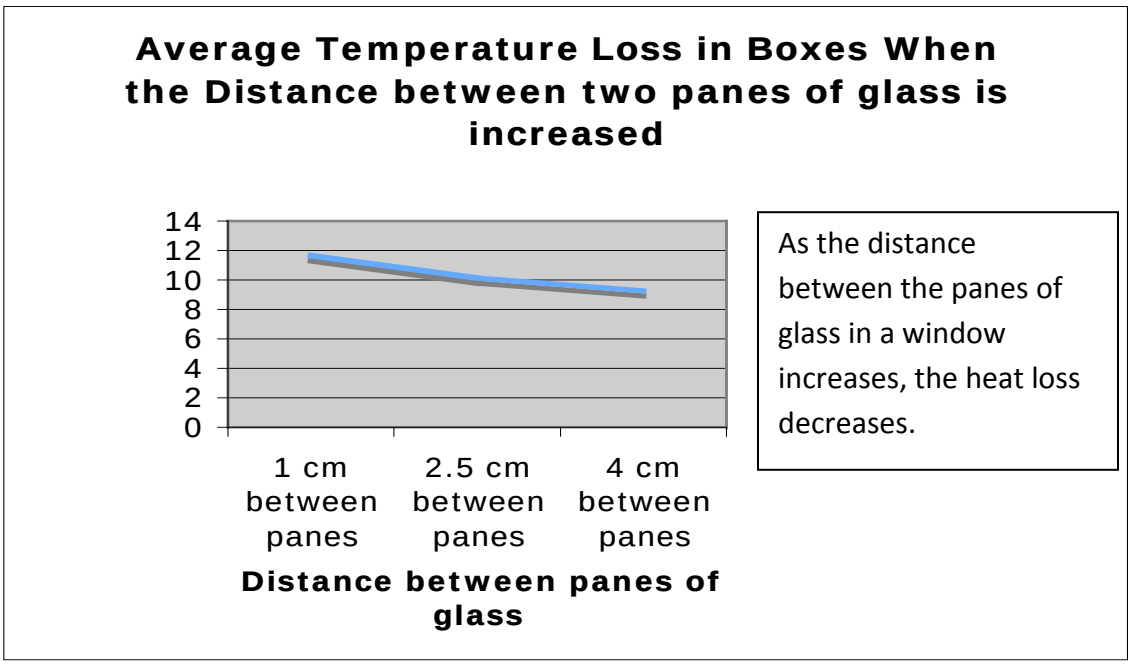
Diagram of Set up:



Results:

- When it was very cold outside, condensation formed on the windows after they were taken outside.
- When the boxes were exposed to a heat source inside right before being taken outside, the temperature of the box would continue to rise after being taken outside. This might be because the thermometer is slow.
- When taken inside after being outside for an hour, the boxes took a while to warm up. The box with the greatest space between the panes of glass in the window, box C, took the longest amount of time to warm up.

	Temperature loss in Box A – 1 cm between panes (degrees Celsius)	Temperature loss in Box B – 2.5 cm between panes (degrees Celsius)	Temperature loss in Box C – 4 cm between panes (degrees Celsius)
Trial 1	10	9	8.5
Trial 2	11.5	7.5	8
Trial 3	16	14	13
Trial 4	14	13	11.5
Trial 5	10	10	9
Trial 6	10	8.5	8
Trial 7	16	14	12
Trial 8	14.5	14	12.5
Trial 9	5	3.5	3.5
Trial 10	9.5	8	6.5
Average Temperature loss (degrees Celsius)	11.65	10.15	9.25



Discussion:

If the thickness of the layer of air between two panes of glass was increased to a maximum of 2.54 cm., then the room should have lost less heat when exposed to cold, because the greater amount of air would provide more of the insulating substance. This hypothesis was proven to be partially correct. As the graph shows, the box with 1 cm of air between the two panes of glass lost the most heat, the box with 2.5 cm between the two panes of glass lost the second greatest amount of heat, and the box with 4 cm between the two panes of glass lost the least heat. This shows that the more air between the two panes of glass, the better the insulation.

Even though the box with 4 cm between the two panes of glass went over the recommended 2.54 cm, it still lost the least heat. This might be because the box window was so small that it wasn't really an accurate representation of a real room. The window in the box might not have been large enough for a convection current to form, which was the factor that could have decreased the efficiency of a window with more than 2.54 cm between the panes of glass. The greater amount of air provided more of the insulating substance, which prevented air from being conducted out of the window. However, it was not enough to start a convection current.

One error in the experimentation was that sometimes the temperatures of the boxes were not all the same at the beginning. The experimenter did make sure to record the temperature loss correctly by subtracting the final temperature from the initial temperature. However, the greater the difference in temperature between two objects, the faster heat flows from one object to another (Cezairliyan). That means that if one of the boxes had a greater temperature, heat would flow out of that box faster than the other two boxes. This would increase the total temperature loss of that box. Two trials were discarded because the difference in temperature between the

boxes was too great. Another possible error is that although the boxes were placed directly next to each other, they might not have all been exposed to the exact same temperature. Yet another factor that could have affected the results is if the caulking cord was creating a complete seal. It appeared as if it was, but a small part might have been unsealed.

Energy conservation is a very important issue today, both because of the high price of fuel and to protect the environment. A lot of heat from houses is lost through the windows; inefficient windows can account for up to 40% of heat loss in winter (Krutz 1). Therefore, it is very important today to make sure that windows are efficient as possible. This experiment showed that the larger the space between two panes of glass in a window, the less heat is lost. However, this experiment might not be valid because it was done on such a small scale. The boxes that were built by the experimenter are probably not accurate representations of a modern house. In conclusion, the space between the panes of glass in a real window should be more than 1 cm apart to provide enough of the insulating substance (air) but less than 2.5 cm to prevent a convection current from forming.

Works Cited

Cezairliyan, Ared. "Heat." World Book Online Reference Center. 2008. Willett Free Library online database. 8 Nov. 2008 <http://www.worldbookonline.com/wb/Article?id=ar250080>.

Krutz, Jamie. Comfort Blues? Keep the heat outdoors this summer with ENERGY STAR windows. 2008. Smart Energy Living Alliance. 21 October 2008 <http://www.smartenergyliving.org>

Lipinski, Edward R. "HOME CLINIC; Replacing Insulated Glass Windows." *New York Times* (20 Feb. 2000): <http://query.nytimes.com/gst/fullpage.html?res=9D0CE6DC1630F933A15751C0A9669C8B63>

McElroy, David L. "Insulation." World Book Online Reference Center. 2008. Willett Free Library online database. 6 Dec. 2008 <http://www.worldbookonline.com/wb/Article?id=ar277780>.

Mullen, Kieran. "Temperature." World Book Online Reference Center. 2008. Willett Free Library online database. 8 Nov. 2008 <http://www.worldbookonline.com/wb/Article?id=ar550260>.

Windows for High Performance Commercial Buildings. 2007. University of Minnesota in association with Lawrence Berkeley National Laboratory. 21 October 2008. <http://www.commercialwindows.umn.edu/materials_glazing1.php>

Wing, Charlie. House Warming. Boston: Little, Brown, and Company: 1983.