LESSON

Thermal Boundary

BIG IDEA(S)

A thermal boundary includes an air boundary (through sealing) and insulation material.

OBJECTIVES

Students will:

- Describe how insulation works with regard to conduction, convection and radiation.
- Describe the factors involved in choosing insulation based on priority need, climate, house condition, etc.
- Distinguish the effectiveness of different kinds of insulation
- Describe install procedures along with necessary safety measures

BRIGHT SOLAR FUTURES

WEATHERIZATION

TOPIC OF STUDY

Building Sciences

3 HOURS
(TWO CLASSES)

TASK LIST SUBCATEGORY

802 Describe the interconnection of systems using the "House as a System" framework

806 Perform weatherization tasks including air sealing, moisture barriers, and insulation

810 Use energy efficiency industry vocabulary

OVERVIEW

A good thermal boundary for a house includes a good air boundary (through sealing) and insulation material. While air barriers prevent convective flow, insulation prevents conductive heat transfer as well as convective and radiant heat transfer. Insulation helps to slow heat loss and is good to install anywhere heat flow is to be controlled.

KEY TERMS

R-Value
thermal bridge
fiberglass
cellulose
facings
barriers
polystyrene

STANDARDS

PA/SDP

3.2.P.B3. Analyze the factors that influence convection, conduction, and radiation between objects or regions that are at different temperatures.

3.4.10.B1. Compare and contrast how the use of technology involves weighing the trade-offs between the positive and negative effects.

3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.

NGSS: SCIENCE AND ENGINEERING PRACTICES - DEVELOPING AND USING MODELS

- Use a model to predict the relationships between systems or between components of a system.
- Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.

INSTRUCTIONAL

TEXT/REFERENCES

Energy Conservation Handbook. pp. 205-214; Quiz 265-66

MATERIALS NEEDED

MATERIALS

- Samples of insulation:
  - Fiberglass: faced and unfaced batts; loose fill
  - Cellulose
  - Rigid insulation panels: choose a variety that represent diversity of application and material (*Energy Conservation Handbook*, p. 210-211)
- Materials for insulating experiment

Technology: Computer with access to YouTube

IMPLEMENTATION (LESSON PLAN)

1. *Stop Heat from Escaping Experiment*: https://www.youtube.com/watch?v=Yg8kXf_HKtU

   Materials needed
   - 4 empty plastic water bottles with lids
   - 4 kinds of insulating materials: Newpaper (cellulose), aluminum foil, plastic trash bag, wool sock (or any materials that you can wrap around the plastic bottles)
   - Digital scale, scissors
   - Masking tape
   - Thermometric with wire probe
   - Enough hot water to fill the 4 bottles (not so hot that it collapses the bottles)

   Procedure
   - To keep the results consistent, use the same amount of each insulator. Use mass area or thickness as your standards. For mass, use the scale and start with the sock since you can't cut it so easily to change the mass.
   - Wrap each bottle up to the cap area and secure with tape.
   - PREDICT which will insulate the best. On the board chart the 4 choices of each student's predictions in order from best insulator to poorest (1-4).
   - Fill each bottle with the hot water and take the temp of each bottle
   - Close the bottles and wait 15 minutes
   - Check the temperatures again. List in descending order of which help the most heat 1-4.
   - Have students check their predictions.
   - Discuss whether the loss of heat to the cooler outside is an example of conduction, convection, or radiation.
2. Ask *"How does insulation work? Explain what happened in our experiment."* Review R-Value and the idea that insulation works primarily through conductive resistance (*Energy Conservation Handbook*, pp. 205-206).

BRIGHT SOLAR FUTURES

WEATHERIZATION

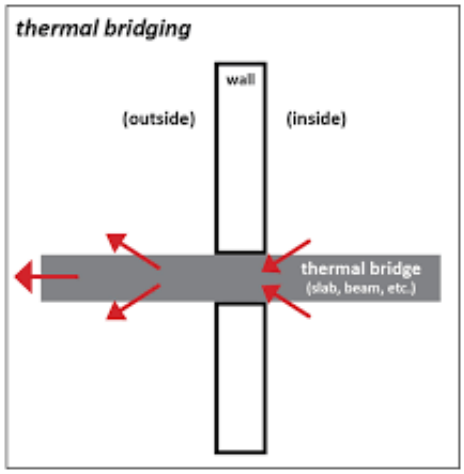
TOPIC OF STUDY

Building Sciences

3 HOURS
(TWO CLASSES)

IMPLEMENTATION (LESSON PLAN) - CONTINUED

3. Thermal bridges allow rapid conductive heat transfer and can be found within an area of higher thermal resistance, like a screw used to secure insulation batting, or as in the picture, something that traverses a wall.



4. Discuss how insulation is chosen based on climate areas, and in cases such as the far South, installed differently. (*Energy Conservation Handbook*: Map pg. 208; Chart for Vapor Barriers, p. 213).
5. Types of insulation: Show students samples of the insulation you have chosen, describing composition, properties, primary uses. Indicate which insulation is used mostly in retrofit and which is better in new construction (See appended DOE chart: Types of Insulation OR Use the Chart on p. 214)
6. Show how facings and barriers support insulation.
7. Insulation Quiz: *Energy Conservation Handbook*, pp. 265-266

RESOURCES/LINKS

Conduction, Convection, Radiation and Insulation

https://www.youtube.com/watch?v=aaUz_SqOXnI

This Old House Insulation (Vapor barrier, vapor retarder; new construction vs. retrofit; r-values, various materials)

https://www.youtube.com/watch?v=OJ9u3pDQeM4

Comparison of Fiberglass, Cellulose and Foam Insulation

https://www.youtube.com/watch?v=osWeSqCXpcE

Types of Insulation (DOE)

https://www.energy.gov/energysaver/weatherize/insulation/types-insulation
This is a very well organized presentation and presents costs as well. The following is taken from this source.

BRIGHT SOLAR FUTURES

WEATHERIZATION

TOPIC OF STUDY

Building Sciences

3 HOURS
(TWO CLASSES)

RESOURCES/LINKS (CONTINUED)

TYPES OF INSULATION

TYPE	MATERIAL	WHERE APPLICABLE	INSTALLATION METHODS	ADVANTAGES
Blanket: batts and rolls	Fiberglass Mineral (rock or slag) wool Plastic fibers Natural fibers	Unfinished walls, including foundation walls Floors and ceilings	Fitted between studs, joists, and beams.	Do-it-yourself. Suited for standard stud and joist spacing that is relatively free from obstructions. Relatively inexpensive.
Concrete block insulation and insulating concrete blocks	Foam board, to be placed on outside of wall (usually new construction) or inside of wall (existing homes): Some manufacturers incorporate foam beads or air into the concrete mix to increase R-values	Unfinished walls, including foundation walls New construction or major renovations Walls (insulating concrete blocks)	Require specialized skills Insulating concrete blocks are sometimes stacked without mortar (dry-stacked) and surface bonded.	Insulating cores increases wall R-value. Insulating outside of concrete block wall places mass inside conditioned space, which can moderate indoor temperatures. Autoclaved aerated concrete and autoclaved cellular concrete masonry units have 10 times the insulating value of conventional concrete.
Foam board or rigid foam	Polystyrene Polyisocyanurate Polyurethane	Unfinished walls, including foundation walls Floors and ceilings Unvented low-slope roofs	Interior applications: must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety. Exterior applications: must be covered with weatherproof facing.	High insulating value for relatively little thickness. Can block thermal short circuits when installed continuously over frames or joists.
Insulating concrete forms (ICFs)	Foam boards or foam blocks	Unfinished walls, including foundation walls for new construction	Installed as part of the building structure.	Insulation is literally built into the home's walls, creating high thermal resistance.
Loose-fill and blown-in	Cellulose Fiberglass Mineral (rock or slag) wool	Enclosed existing wall or open new wall cavities Unfinished attic floors Other hard-to-reach places	Blown into place using special equipment, sometimes poured in.	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
Reflective system	Foil-faced kraft paper, plastic film, polyethylene bubbles, or cardboard	Unfinished walls, ceilings, and floors	Foils, films, or papers fitted between wood-frame studs, joists, rafters, and beams.	Do-it-yourself. Suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present. Most effective at preventing downward heat flow, effectiveness depends on spacing.
Rigid fibrous or fiber insulation	Fiberglass Mineral (rock or slag) wool	Ducts in unconditioned spaces Other places requiring insulation that can withstand high temperatures	HVAC contractors fabricate the insulation into ducts either at their shops or at the job sites.	Can withstand high temperatures.
Sprayed foam and foamed-in-place	Cementitious Phenolic Polyisocyanurate Polyurethane	Enclosed existing wall Open new wall cavities Unfinished attic floors	Applied using small spray containers or in larger quantities as a pressure sprayed (foamed-in-place) product.	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
Structural insulated panels (SIPs)	Foam board or liquid foam insulation core Straw core insulation	Unfinished walls, ceilings, floors, and roofs for new construction	Construction workers fit SIPs together to form walls and roof of a house.	SIP-built houses provide superior and uniform insulation compared to more traditional construction methods; they also take less time to build.

BRIGHT SOLAR FUTURES

WEATHERIZATION

TOPIC OF STUDY

Building Sciences

3 HOURS
(TWO CLASSES)