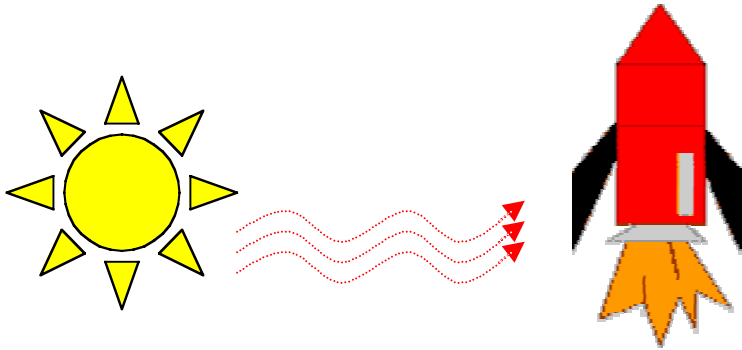


**Heat: An Agent of Change**

**Protecting the Genesis Space Craft from Heat**

**STUDENT ACTIVITY**



Name \_\_\_\_\_

The engineers designing the Genesis spacecraft encounter many problems caused by the intense heat of the Sun. One such problem is that the parts facing the Sun heat up to around 200 °C. Engineers need to prevent this heat from transferring to sensitive electronics inside. The electronics must not become too hot or they may malfunction, causing them to work incorrectly, or not at all.

Heat is transferred in three ways: conduction, convection, and radiation. **Conduction** is the transfer of heat through molecular collision. This can happen when a hot piece of metal is in contact with a cooler piece. **Convection** is the transfer of heat through fluid currents. Finally, **radiation** is the transfer of heat through electromagnetic waves. Radiation is the primary means of heat transfer through the vacuum of outer space. It is how the Sun’s heat reaches the spacecraft. Engineers are most concerned with conduction and radiation influences on the Genesis spacecraft because convection requires molecules in the liquid or gas state, which are uncommon in outer space.

Engineers must insulate the electronics module from the collector dish to minimize the amount of heat build-up in the electronics module. Selection of poorly conducting or insulating materials is critical to the success of the mission.

Engineers use models to test their ideas about materials to use. **Structural models** are made to look exactly like the spacecraft, and may be made of the same materials, but may not work as eventually intended. On the other hand, **functional models** simulate the way the spacecraft will work, but are not necessarily made of the materials that will be used in the final production. Models are often not the same size as the spacecraft that will eventually be built. These **scale models** may be either larger or smaller than the spacecraft that will orbit L1.

**PROBLEM**

How can we build a model of the Genesis spacecraft to illustrate a way to insulate components from heat conduction?

**PROCEDURE**

**Part A—Building the Models**

To evaluate the effectiveness of insulating materials in the spacecraft, a non-insulated control model must be built that matches an insulated experimental model. Comparing data from the control model to data from the experimental model will show whether the temperature difference between the collector dish and interior of the module is less when insulators are used.

### Part A.1 - Building the Control Model

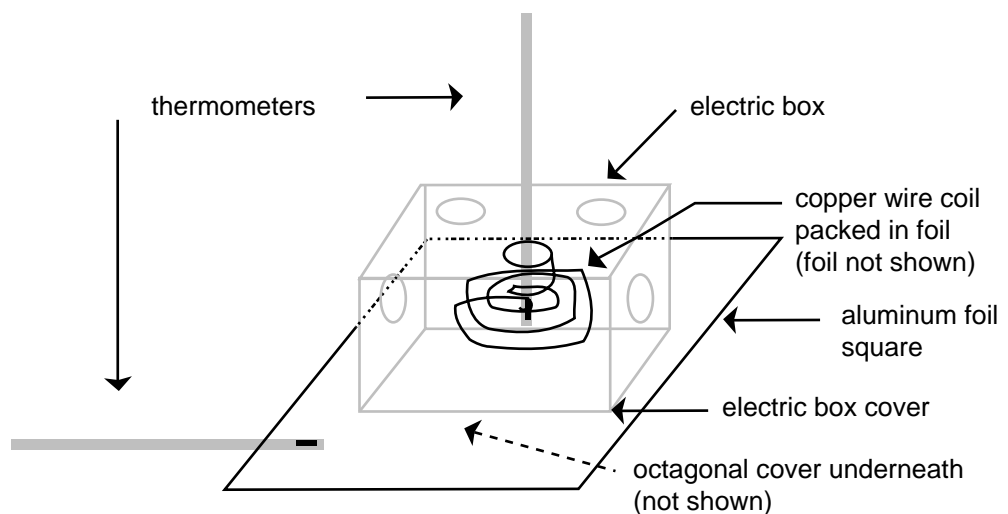
1. Obtain the following materials for your lab group.

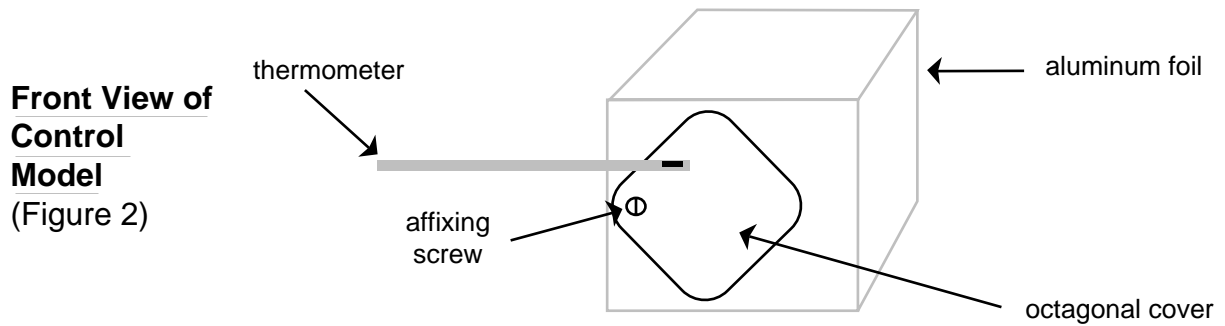
Metal electric switch box and cover  
 Scissors  
 5 m of wound copper wire  
 Masking tape  
 Flat head screw driver (this can be shared among lab groups)  
 Metal octagonal box cover  
 1/2 m length of aluminum foil

The octagonal cover represents the collector dish, while the electronic box represents the spacecraft. The copper wire models the delicate electric instruments that need to be protected from overheating.

2. Tightly coil the copper wire around the bulb of one of the thermometers.
3. Punch out only the center-back conduit hole in the switch box. You should be able to push out the metal piece with the screwdriver, but sometimes it requires a tap of a hammer. Put the thermometer through the back hole of the switch box with the copper wire ends located inside the box.
4. Tear off a square piece of aluminum foil and fold it over twice into a smaller square.
5. Fill the space around the copper wire with crumpled aluminum foil until the box is filled.
6. Close the box and screw in the screws half way.
7. Place the folded aluminum foil square on top of the box cover. Push the screws through the square of foil. Screw in only one of the screws completely.
8. Place the octagonal cover over the aluminum foil square. Use the remaining screw to tightly affix the octagonal cover to the electric box and aluminum foil. Use tape to affix the other thermometer to the octagonal cover.
9. Use masking tape to fasten the remaining thermometer to the front of the model, on top of the octagonal cover.

**Control  
 Model**  
 (Figure 1)





### Part A.2 - Building the Experimental Model

To evaluate the effectiveness of insulating materials in the spacecraft, a non-insulated control model must be built that matches an insulated experimental model, using conductors in place of insulators. The control data will show whether the temperature difference between the collector dish and interior of the module is less when insulators are used.

1. Obtain the following materials for your lab group.

Metal electric switch box and cover  
 Scissors  
 5 m of wound copper wire  
 Masking tape  
 2 Celsius thermometers  
 Flat head screw driver (this can be shared among lab groups)  
 Metal octagonal box cover  
 Styrofoam plate  
 Glue suitable for bonding metals  
 1 m length of polyester batting (blanket fill)

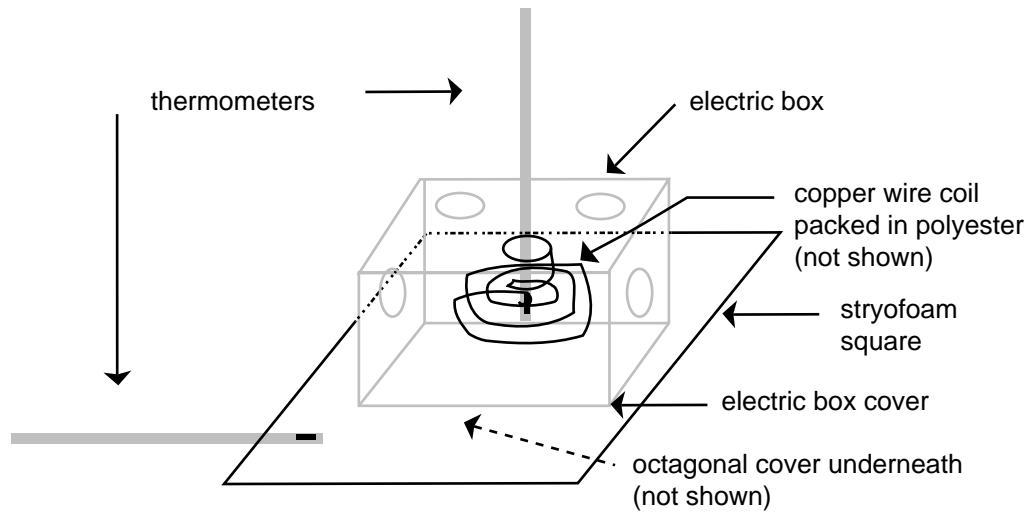
The octagonal cover represents the collector dish, while the electronic box represents the spacecraft. The copper wire models the delicate electronic instruments that need to be protected from overheating.

2. Tightly coil the copper wire around the bulb of one of the thermometers.
3. Punch out all of the conduit holes in the switch box. You should be able to push out the metal piece with the screwdriver, but sometimes it requires a tap of a hammer. Put the thermometer through the back hole of the switch box with the copper wire ends located inside the box.
4. Cut a piece of flat styrofoam to cover the top of the box.
5. Wrap polyester batting around the copper wire. Do not let the copper wire touch the sides of the electric box. Fill the remaining space in the box with shreds of batting.
6. Close the box.
7. Place the styrofoam square on top of the box cover. Use glue instead of screws to affix the collector dish and the styrofoam.
8. Place the octagonal cover over the styrofoam square. Use glue to tightly affix the octagonal cover to the electric box and aluminum foil. Use tape to affix the other thermometer to the octagonal cover.

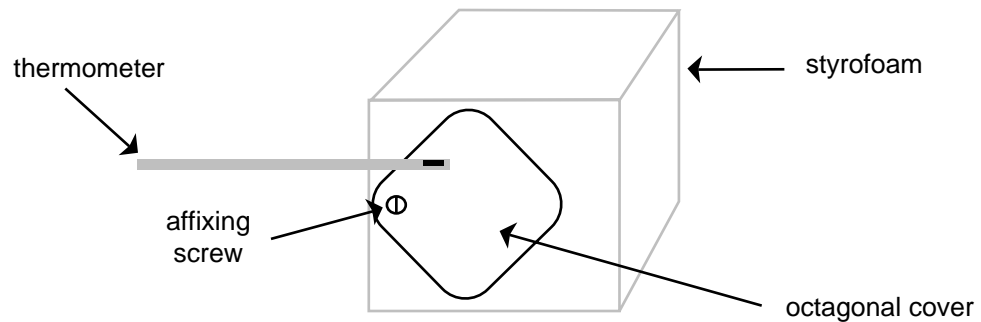
(\*Figure of experimental model shown on next page.)

An interesting modification of the experimental model would be to compare varied insulators such as rubber, wood, and glass.

**Experimental Model**  
(Figure 3)



**Front View of Experimental Model**  
(Figure 4)



**Part B—Collecting Data**

Use the same procedure to collect data on both the control and experimental models. It doesn't matter which one you collect data from first.

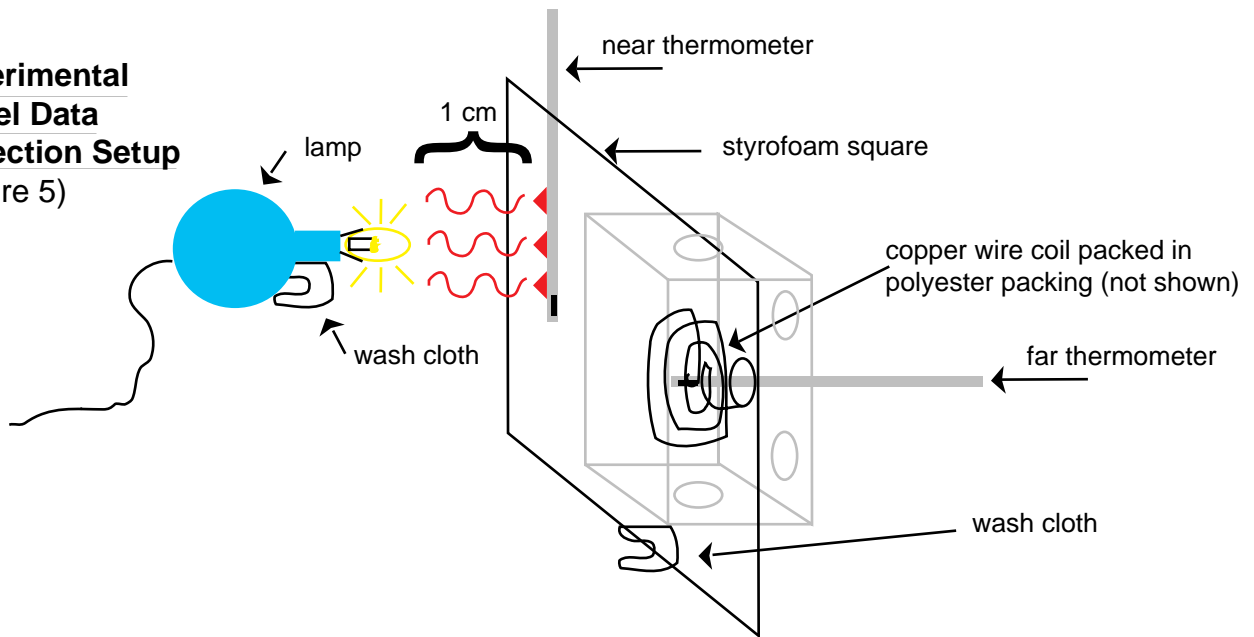
1. Obtain the following materials for your lab group.
  - Lamp that can operate on its side, or other safe heat source
  - Materials for propping, for example, a wash cloth
2. Set up the lamp as a heat source as shown in Figure 3. Wash cloths make good props for the equipment. If you are doing this at home, an ironing board makes a good lab bench. For safety purposes, have an adult set up the test equipment and monitor for continued safety during operation.

3. It is important to collect accurate data, so be sure you have an uninterrupted 40 minutes to run the equipment. Set up two data tables, one for the control model, and the other for the experimental model.
4. Turn on the lamp and start collecting data. Record your first reading just as the lamp is turned on. Continue for 40 minutes.

Data on \_\_\_\_\_ Model

Time in 10 min. increments	Near Thermometer Temperature °C	Far Thermometer Temperature °C	Temperature Difference (Δ T) (near-far)

**Experimental Model Data Collection Setup (Figure 5)**

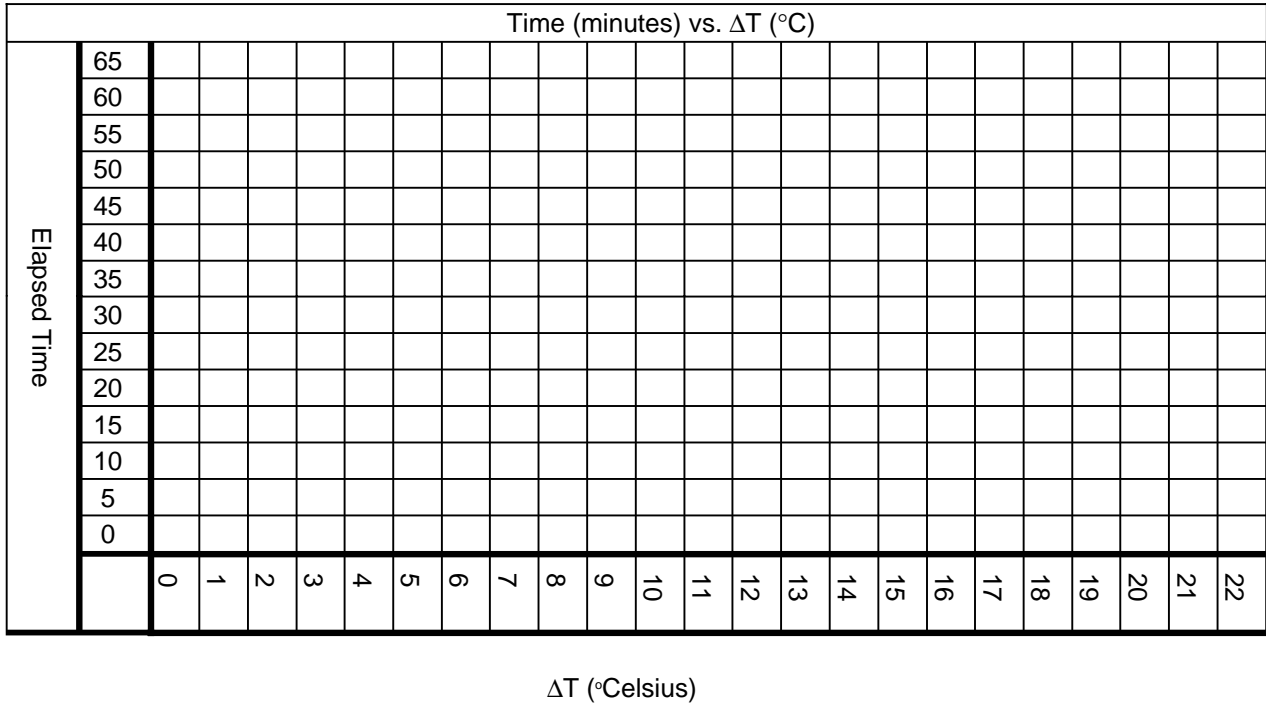


**Part C—Analyzing the Data**

- Construct a graph of time vs.  $\Delta T$  for both the control and the insulated model.

The graph should have two smooth curved lines. Label all parts of the graph.

**Key:**  
 \_\_\_\_\_ control data  
 \_\_\_\_\_ experimental data



**Conclusion**

Write a conclusion in paragraph format that addresses the following points:

Did the experimental design address the problem as stated?

What effect did replacing parts on the control model with insulation have on the results? Support your answer by citing your data, especially the graph.

Compare your group's data to the class average data. Does it match well? Why or why not?

If you were an engineer in charge of choosing materials for the Genesis spacecraft, how would the results of this experiment affect your decision?

Write a paragraph discussing the use of a model in this experiment.

Was this a structural model or a functional model? Explain your choice.

What did the polyester batting represent in the experimental model?

Why was glue used rather than screws in the experimental model?