Heat Flow Sensor

Product No. 3150

Range: ±2000 W/m^2
Resolution: 1 W/m^2

DATA HARVEST

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DS 036 ***No 3***

Smart Q TECHNOLOGY

Heat Flow Sensor

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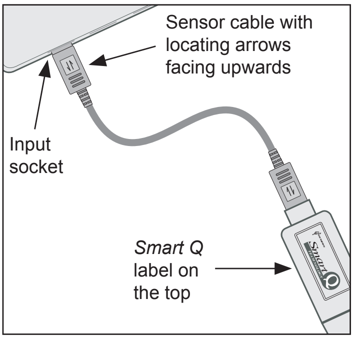
Introduction

The *Smart Q* Heat Flow Sensor is designed to measure the flow of heat energy between its upper and lower surfaces giving a bi-directional output in watts per square metre (W/m^2). Pupils can observe energy transfer directly rather than indirectly by measuring temperature changes. This makes it particularly useful in demonstrating the distinction between heat energy and temperature.

The *Smart Q* Heat Flow Sensor is equipped with a micro controller that greatly improves the accuracy, precision and consistency of readings. They are supplied calibrated and the stored calibration is automatically loaded when the Heat Flow Sensor is connected.

Connecting



- Hold the Heat Flow sensor housing with the *Smart Q* label showing on the **top**.
- Push one end of the sensor cable (supplied with the **EASY**SENSE unit) into the shaped socket on the sensor housing with the locating arrow on the cable facing upwards.
- Connect the other end of the sensor cable to the input socket on the **EASY**SENSE unit (with the locating arrow facing upwards).
- The **EASY**SENSE unit will detect that the Heat Flow Sensor is connected.
- Attach the Sensor to the test surface using adhesive tape or an elastic band. Do not try to hold the Sensor in position - the heat from your hand will produce false readings.
- Leave the sensor in position for at least 2 minutes to stabilise before recording data.

Principles of Operation

Heat Flow is a Sensor that has been designed to measure small amounts of thermal energy transfer. The sensing area of the device is a thermopile which consisting of 400 thermocouples potted in resin for protection.

Heat flow through the Sensor induces a temperature gradient between its faces. The temperature gradient and the heat flow are related as follows:

*Temperature Gradient (ºC/m) = λ *Heat Flow (Watts/m^2)*

The thermal Conductivity λ and the thickness of the Sensor are constants, so the temperature difference between the surfaces is proportional to the heat flow through the Sensor.

The Sensor uses the thermoelectric effect to convert the small temperature gradient into a voltage. The thermoelectric effect is very small so a large number of thermocouples are connected in series on each surface to increase the output. The output is bi-directional indicating the direction of heat flow.

Specifications

Operating Temperature Range: -25ºC to 85ºC
Thermal Properties: 200 (W/m^2) / ºC Conductance
0.005ºC / (W/m^2) Resistance
Resistant to mild solvents and humidity

Practical information

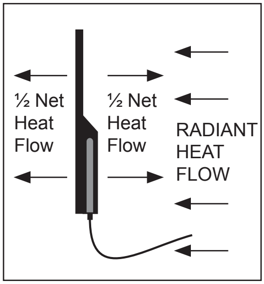
The Sensor can be covered with the same colouring as the test surface to create the same characteristics of absorption.

If used on metallic or glass surfaces, which have low emissivity, attach aluminium foil to the Sensor with double sided tape to improve accuracy.

In order to measure the heat flow accurately, the heat path in which the Sensor is placed should have a higher thermal resistance than the Sensor. The presence of the Sensor will then cause the minimum disturbance to the heat flow. If the material whose heat flow is being measured has a much higher conductivity than the Sensor e.g. copper, the heat will tend to flow around the Sensor producing a low reading.

Be aware of problems that can occur when a Sensor is attached to the outside of a window. Some of the ultraviolet energy falling on the glass will pass through into the room and some will be reflected back; little of it will absorb into the glass. If a bare Sensor is attached to the glass it will absorb solar radiation to a much greater degree than the surrounding glass. This heat will then flow into the glass by conduction giving a value that is not typical of the rest of the window. In winter, the temperature outside the window will be much lower than the temperature inside and heat will be flowing from inside to outside. By attaching a Sensor to the window, you have insulated an area and attached a ‘solar collector’ to it. For best results, cover with aluminium foil and shade the window from direct solar radiation.

Radiant energy falling on the Sensor will be absorbed by the face of the Sensor exposed to the radiation. Provided the Sensor is in still air, both faces of the Sensor will be cooled equally. Half the radiation will be re-radiated and conducted away from the side from which it was absorbed. The other half of the radiant energy will be conducted through the Sensor and be radiated and conducted away from the other side. The Sensor will therefore record half the net radiant energy passing through the space under investigation.



If readings should go off the scale, and measurements are being used purely as a comparison, dampen the sensitivity by covering the Sensor surface with a layer of insulation material.

Investigations

- Newton’s law of cooling
- Studying insulation properties
- Heat loss from the body
  E.g. through clothes; from different parts of the body; head with and without hair or a hat; exposed skin and then insulated with clothing; during exercise; estimate total heat loss from a body.
- Comparing heat flow or loss in buildings
  E.g. through single and double glazed window; from the different materials used for double-glazing; different areas of a door or frame; different building materials.
- Heat flow into cold objects
  E.g. ice cold fluids
- Heat flow from hot objects
  E.g. different types of fast food containers, a cup of hot water, heat loss from a container of cooling wax, testing different insulation materials.

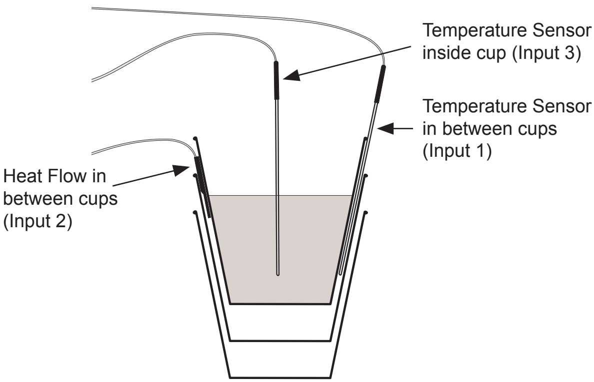
Energy transfer through a polystyrene cup

You may have noticed that a hot cup of coffee left on a table cools until the liquid is the same temperature as the room. This experiment involves monitoring the energy transfer from hot water stacked in three polystyrene cups. Two Temperature Sensors are used to measure the temperature gradient. The relationship between these three variables can then be explored.

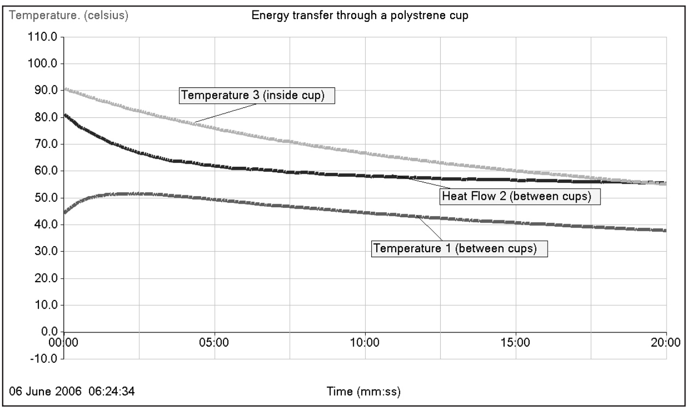
Acknowledgement:
We are grateful to Dr. Roy Barton from the School of Education at the University of East Anglia for details of this experiment.

Is the rate of cooling related to the temperature of the water?
Does the temperature of the room have any effect?

To explore these questions, a Heat Flow Sensor is used which will measure the rate of energy transfer (in watts per square metre) through a polystyrene cup containing hot water.



- Assemble the apparatus and open the **EASY**SENSE program and select Graph from the Home page.
- From the **New Recording Wizard** select Next, select a **20 minute** recording time and Finish.
- Pour the hot water into the cup.
- Click on the **Start** icon to begin.



Results:

Analysing the data: Describe and explain the shape of the three traces.

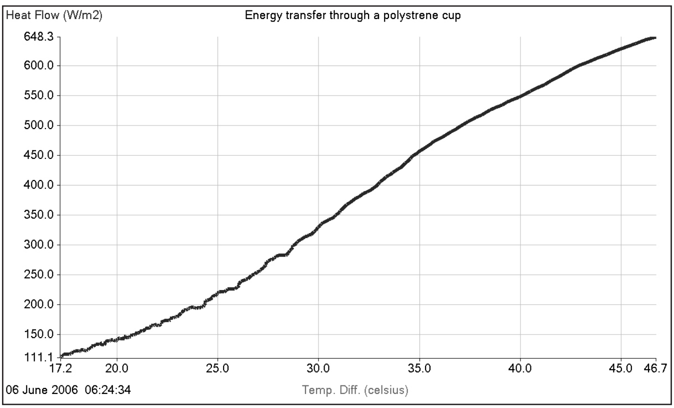
Testing a Hypothesis: One factor that may affect the rate of energy transfer is the difference between the temperature of the water and the temperature between the outside cups. We can test this by plotting the difference in temperature.

- Select **Post-log Function** from the **Tools** menu. Select **Preset function**. Select **Channel** from the first drop-down menu and **Subtract Channel from Channel** from the second, Next.
- Select **Temperature** in 3 (the Temperature Sensor inside the cup) as first channel and **Temperature** in 1 (the Temperature Sensor between the cups) as the second channel, Next.
- Type in the name as **Temp. Diff.** and OK.
- To hide the traces for the two temperature probes [1] & [3], **right** click in the graph area and select **Show or Hide Channels.** Untick the box for these sensors.

How does the temperature difference data compare with the one for the rate of energy transfer (heat flow)?

Use these results to explore more directly the link between the two traces by plotting the rate of energy transfer against the temperature difference.

- Select the **Option** icon, then the **X-axis** tab and select the X-axis as Channel, OK.
- If necessary alter the display (by clicking to the left of the axis) so that Heat Flow is on the Y-axis, and Temp.Diff. is on the X-axis.
- **Right** click in the graph area and select **Autoscale graph Min Max.**



Warranty

All Data Harvest Sensors are warranted to be free from defects in materials and workmanship for a period of 12 months from date of purchase provided they have been used in accordance with any instructions, under normal laboratory conditions. This warranty does not apply if the Sensor has been damaged by accident or misuse.

In the event of a fault developing within the 12-month period, the Sensor must be returned to Data Harvest for repair or replacement at no expense to the user other than postal charges.

> **Note:** *Data Harvest products are designed for **educational** use and are not intended for use in industrial, medical or commercial applications.*

WEEE (**W**aste **E**lectrical and **E**lectronic **E**quipment) Legislation

Data Harvest Group Ltd are fully compliant with WEEE legislation and are pleased to provide a disposal service for any of our products when their life expires. Simply return them to us clearly identified as 'life expired' and we will dispose of them for you.