Module 1, Lesson 1 – Sensors and the Environment

Teacher

45 minutes

Purpose of this lesson

- Introduce students to sensors and sensor networks
- Introduce students to the SENSE IT project

Overview

The **Sensor development** module will require students to design and construct sensors to test water quality parameters. Students will use various mechanisms of data gathering (e.g. voltmeters) to measure sensor output and will devise experiments to estimate the accuracy, repeatability and sensitivity of their devices. This module will require the use of mathematics skills (e.g. systems of equations, data plotting and curve fitting, rearranging formulae), science skills (understanding physical quantities, measurement and error estimation, electrical components and circuits), pre-engineering skills (engineering design, tool use, testing and debugging) and general skills (teamwork, communication).

Background Material

A sensor is a device which detects or measures a physical quantity and converts the measurement into a signal which can be read by an observer or by another device.

For example, a mercury thermometer converts the measured temperature into expansion and contraction of a liquid which can be observed or read on a calibrated glass tube.

Important characteristics of a sensor include:

- **Accuracy**
- **Repeatability/Precision**
- **Sensitivity**
- **Range**

Often choice of sensor is a tradeoff between several of above. For example, moderate accuracy over a large range may be preferable to great accuracy over a very small range.

Accuracy is the degree of conformity of a measured or calculated quantity to its actual (true) value. Often accuracy is quantified in terms of error – the difference between the measured value and the true value.

Repeatability (sometimes called precision or reproducibility) is closely related to accuracy but has a distinct meaning. A measuring device is repeatable if many measurements of the same thing all give the same result.

An analogy: Imagine an archer who shoots arrows at a target. If all of the archer's arrows always hit the target close together in a tight cluster, then we can say that the archer is repeatable. If, additionally, the arrows all land near the bulls eye, then we can say the archer is accurate as well. However, if the arrows fall in a tight cluster that is far from the bulls eye, then the archer is repeatable but not accurate. A repeatable system can be made into an accurate system through the process of calibration.

In this project, a *thermistor* will be used to measure temperature. The thermistor is a resistor that changes its resistance as the temperature changes. If the thermistor reliably returns to the same resistance, whenever it is placed at a particular temperature, then it is repeatable. We can use a repeatable thermistor to make an accurate temperature measurement system by calibrating – i.e. figuring out which temperatures correspond to which thermistor resistance levels.

Calibration is the process of establishing the relationship between a measuring device and the units of measure. This is done by comparing a devise or the output of an instrument to a standard having known measurement characteristics. For example, the length of a stick can be calibrated by comparing it to a standard that has a known length. Once the relationship of the stick to the standard is known the stick can be used to measure the length of other things.

Sensitivity is the minimum size change in the "thing to be measured" that will be noticed by the measuring device. For example, if you use a mercury thermometer, and the smallest detectable

change in mercury height corresponds to temperature change of 1 °C, then your temperature measurement system is “sensitive to the nearest degree” or has a “sensitivity of 1 °C”.

Understanding sensitivity requirements is very important in determining the appropriate equipment to obtain or in this case design and construct. If you only care about measuring water temperature to the nearest +/- 1 degree, there is no point buying an expensive device that is sensitive to +/- 0.01 degree.

Range. It is important to choose a sensor that covers the range you are interested in. If you need to know the temperature of the water in your sampling location to the nearest degree, and the river water can have temperatures ranging from 0°C up to 20°C, then it is useless to buy a sensor that is accurate to 0.001°C but only works for temperatures between 0°C and 5°C.

A *transducer* is a device that converts one type of energy or physical attribute to another for various purposes including measurement.

Examples:
- A microphone converts sound energy into electrical energy.
- Mercury in a thermometer converts temperature changes into volume changes (which can then be observed as change in height of the mercury.
- The thermistors used in this project convert changes in temperature into changes in electrical resistance.

Transducers are the vital component of all sensors. When designing our sensor, we will need to choose an appropriate transducer.

The transducer must convert the quantity we are interested in (e.g. temperature) into a quantity we can easily measure (e.g. electrical resistance or voltage which we can measure with an Ohm meter or volt meter).

The transducer must operate over a suitable range (e.g. what range of temperatures do we need to be able to measure).

The transducer must be sensitive to the smallest temperature changes that we wish to observe.

The transducer must be repeatable enough (so that once we calibrate it, we have an overall measurement system that is accurate enough*)

* “Enough” depends entirely on what task we are trying to accomplish – measuring the temperature of a nuclear reactor and measuring the temperature of the Hudson River are different tasks. They require different ranges and accuracies and sensitivities and thus will need different sensors, built using different transducers.

Assessment

Complete a Concept Map based on temperature as an important parameter of water quality.

Add-on Lesson:

Water quality and temperature

Transition Lesson:

Soldering practice