THEORY OF
INFRARED THERMOMETERY

INNOTIQ
Measure test solution

An infrared thermometer measures radiant energy. This radiation is simply "light" that is slightly outside the human eye's sensitive range. All objects radiate infrared energy. The intensity of infrared radiation is relative to the temperature of the object. Should an object become sufficiently heated, infrared energy will become visible as the object becomes red hot. As the temperature increases, it emits wavelengths further across the visible range. Ultimately, the object glows white hot.

Infrared radiation (IR) is electromagnetic radiation with a wavelength interval between approximately 0.75 microns and an indefinite upper boundary. This boundary is sometimes arbitrarily set at 1,000 microns (1 mm). Infrared radiation is divided into three spectrum bands: near infrared (0.75 microns to 1.5 microns), intermediate infrared (1.5 microns to 7 microns) and far infrared (7 microns to 1,000 microns), as shown in Figure 1. Infrared radiation obeys all the laws of light, such as shadowing, reflection, refraction and other optical behaviour.
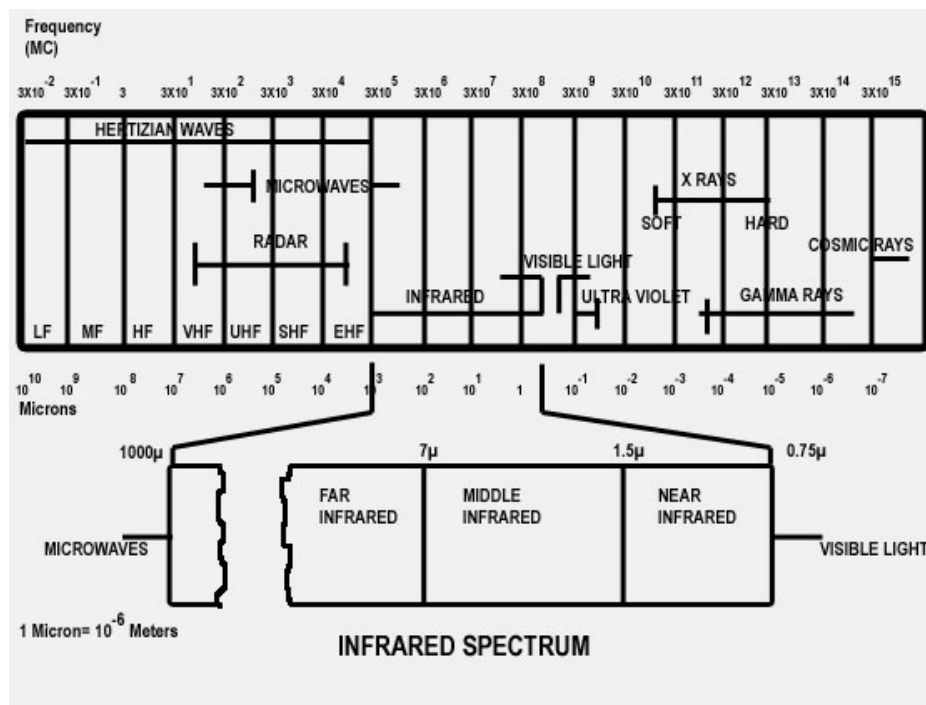

Figure 1

For two objects of different temperature, net infrared radiation will flow from the hotter to the cooler object. For example, if a hot iron is placed in cool water, there will be a net transfer of radiation from the iron to the water. The amount of radiation transfer follows Stefan-Boltzmann's Law. The Stefan-Boltazmann law hypothesises a black body that absorbs all radiation that falls on it. For a hypothetical black body, the total emitted radiation is:

$$W_{TOT} = rT^4$$

W   is the total radiation expressed in watts/cm^2
T   is the absolute temperature of the body
r   is the Stefan-Boltzmann Constant

The emitted radiation of a black body is therefore proportional to fourth power of the body's temperature. The Stefan-Boltzmannn constant is equal to 5.672 x 10^{-12} when watts are expressed in square centimetres. The emitted radiation of a black body is therefore equal to:

$$5.672 \times 10^{-12}/\text{watts cm}^{-2}\text{ degrees}^{-4}$$

T = Absolute temperature in degrees Kelvin

In other words, the net radiation flow between two objects is proportional to the difference between their absolute temperatures to power of four, and to the area of the cooler object that is exposed to the hotter object.

Instrumentation theory and practice teach that all instruments, in order to measure a quantity, must either consume or divert a small portion of that quantity in the process of measurement. This act disturbs the original quantity, altering its magnitude, and since it is the altered magnitude that is actually measured, an erroneous reading results (Figures 2 and 3).
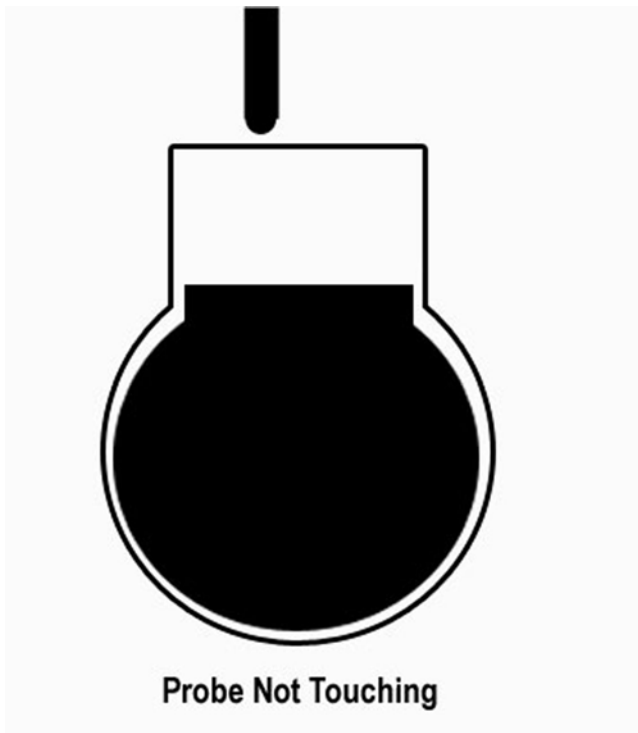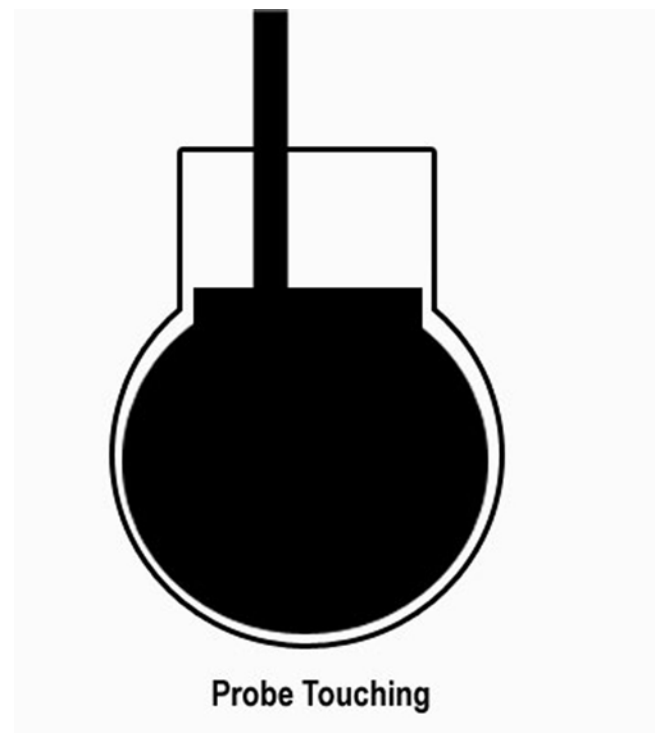

Probe Not Touching

Figure 2

Probe Touching

Figure 3

This error-producing process applies to all know temperature measuring instruments except infrared thermometers. All conventional thermometers require a probe to touch the object being measured, which is usually at a different temperature. Consequently, heat will be transferred from the thermometer probe to the object, or vice versa.. After equilibrium between the probe and the object occurs, the temperature measurement is said to have "come up," but the object is now either colder or warmer than it was before the probe "intruded upon it". The difference in initial temperature between the probe and the object is a part of the error of measurement.

Infrared thermometers produce no "intrusion error." A hot object "target" is radiating its infrared radiation in all directions whether or not the infrared thermometer is there taking its temperature. The object's radiation characteristics, and hence its temperature, are not disturbed by the presence of the infrared thermometer.

Assume that an infrared thermometer is the cooler of the two objects and that its front end optical "telescope" is the area that is exposed to a hotter object being measured.

The infrared thermometer optics collect a sample of infrared radiation from the hot object being measured and focus it on the tiny infrared detector. The detector, in turn, converts it to a proportional electrical signal, which is the exact electrical analog of the incoming infrared radiation, and hence the hot object's temperature.

This minute electrical signal is then amplified in the preamplifier as shown in Figure 4, converted to a digital signal, and digitally linearized (to change the T4 radiation characteristics to a perfectly linear voltage-temperature relationship). After linearization and further conditioning, the resultant temperature number is shown on the display of the instrument.
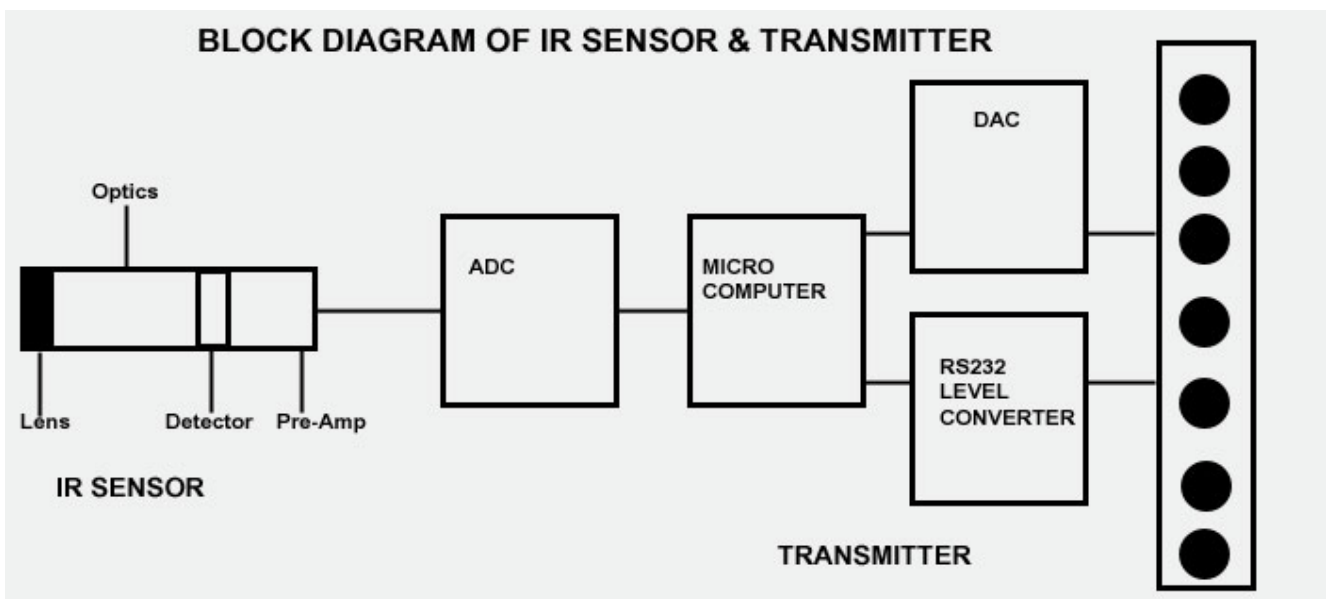

Figure 4

Transmission, Absorption and Reflection

When radiant energy that has been emitted by one object strikes another object, that energy is transmitted, reflected or absorbed by the second object to various degrees. If the total energy received by the second object is one unit, then total energy can be expressed as:
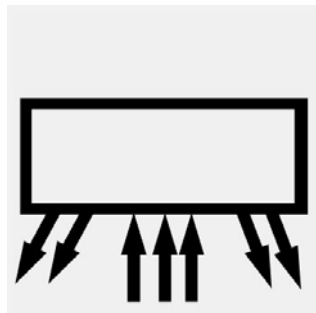
$$t + r + a = 1$$

t = fractional transmittance
r = fractional reflectance
a = fractional absorption

If an object is transparent, the bulk of the radiant energy is transmitted through it as follows:
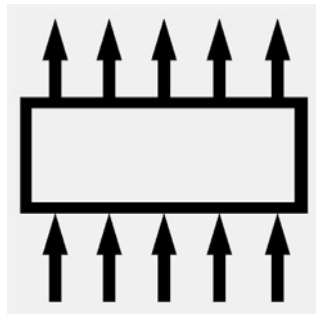
If an object is mirror-like, most energy will be reflected as shown below:

Objects that transmit and reflect energy poorly absorb more radiant energy: