Experiment #1

Objectives:

a) Demonstration of using a Pyranometer

b) Measurement of Beam and Diffuse Solar Radiation

Theory:

The sun generates radiation over the range of wavelengths from 0.15 to 4.0 μm which is known as the solar spectrum. The amount of this radiation is called as global solar radiation or sometimes known as short-wave radiation. The global solar radiation can occur when both the solar radiations like direct & diffuse receives from the hemisphere on the plane of the Pyranometer. It is hard to find out an environmental development on the earth which is driven directly otherwise indirectly through the energy of the sun. The measurements of global solar radiation are used in various applications for various purposes. Solar energy determines the efficiency of the panel because these panels will change the energy from the sun's energy to electrical.

A Pyranometer measures the solar radiation received by a plane surface from a 180 ° field of view angle. This quantity, expressed in W/m^2, is called "hemispherical" solar radiation. The solar radiation spectrum extends roughly from 285 to 3000 x 10^{-9} m. By definition a Pyranometer should cover that spectral range with a spectral selectivity that is as "flat" as possible. A Pyranometer produces a voltage from the thermopile detectors that is a function of the incident radiation. It is necessary to use a potentiometer to detect and record this output. Radiation data usually must be integrated over some period of time, such as an hour or a day. It has been estimated that with careful use and reasonably frequent Pyranometer calibration, radiation measurements should be good within ±5%; integration errors would increase this number.

The working principle of the Pyranometer mainly depends on the difference in temperature measurement between two surfaces like dark and clear. The solar radiation can be absorbed by the black surface on the thermopile whereas the clear surface reproduces it, so less heat can be absorbed. The thermopile plays a key role in measuring the difference in temperature. The potential difference formed within the thermopile is due to the gradient of temperature between the two surfaces. These are used to measure the sum of solar radiation. But, the voltage which is generated from the thermopile is calculated with the help of a potentiometer. The information of radiation needs to be included through an electronic integrator.

In an irradiance measurement by definition the response to "beam" radiation varies with the cosine of the angle of incidence; i.e. it should have full response when the solar radiation hits the sensor perpendicularly (normal to the surface, sun at zenith, 0 ° angle of incidence), zero response when the sun is at the horizon (90 ° angle of incidence, 90 ° zenith angle), and 50 % of full response at 60° angle of incidence. A Pyranometer should have a so-called "directional response" (older documents mention "cosine response") that is as close as possible to the ideal cosine characteristic.

In order to attain the proper directional and spectral characteristics, a Pyranometer's main components are:

- A thermal sensor with black coating. It has a flat spectrum covering the 200 to 50000 x 10^{-9} m range, and has a near-perfect directional response. The coating absorbs all solar radiation and, at the moment of absorption, converts it to heat. The heat flows through the sensor to the sensor body. The thermopile sensor generates a voltage output signal that is proportional to the solar irradiance.
- A glass dome. This dome limits the spectral range from 285 to 3000 x 10^{-9} m (cutting off the part above 3000 x 10^{-9} m), while preserving the 180 ° field of view angle. Another function of the dome is that it shields the thermopile sensor from the environment.

Pyranometer can be manufactured to different specifications and with different levels of verification and characterization during production. The ISO 9060 - 1990 standard, "Solar energy - specification and classification of instruments for measuring hemispherical solar and direct solar radiation", distinguishes between 3 classes; secondary standard (highest accuracy), first class (second highest accuracy) and second class (third highest accuracy). From second class to first class and from first class to secondary standard, the achievable accuracy improves by a factor 2.

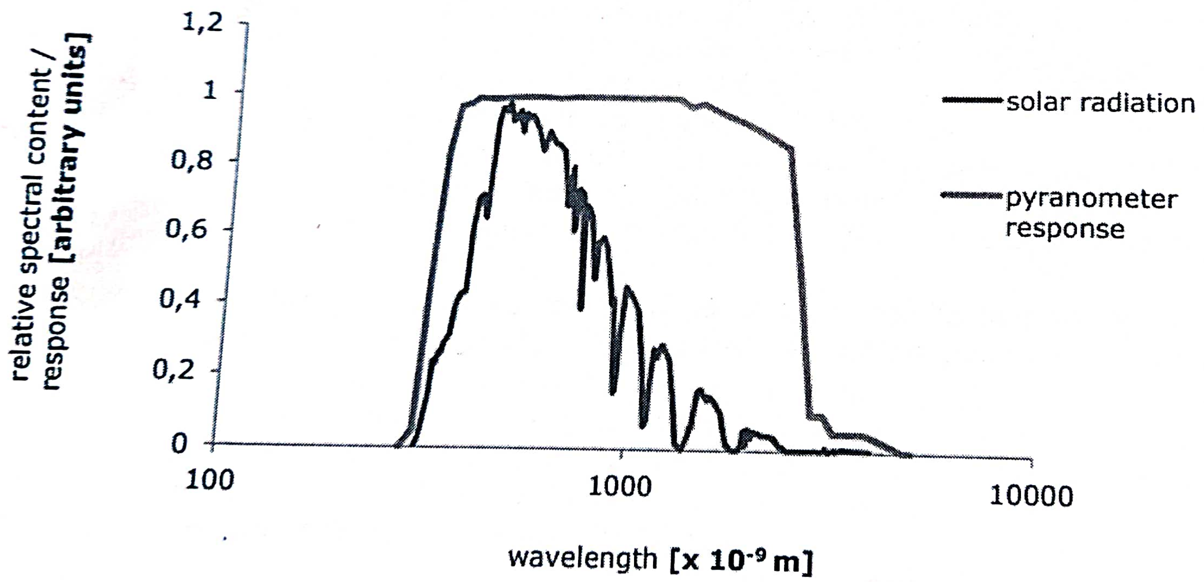

Fig. 1: Spectral response of the Pyranometer compared to the solar spectrum. The Pyranometer only cuts off a negligible part of the total solar spectrum.

Description of apparatus & instrument:

SR05 in its standard configuration is equipped with a visible bubble level and two mounting holes. For easy mounting and levelling on a (non-)horizontal surface, SR05's optional ball levelling is recommended.

When installing SR05, ball levelling allows SR05 to rotate 360 ° and to tilt up to 10 °. This allows compensation for up to a ten degree angle when installing on a non-horizontal surface. A 4 mm hex key unlocks the ball levelling mechanism. When using a tube or rod for installing SR05, the optional tube mount is recommended. Combined with ball levelling it allows mounting to a 25 to 40 mm diameter tube with the same ease of levelling and instrument exchange.

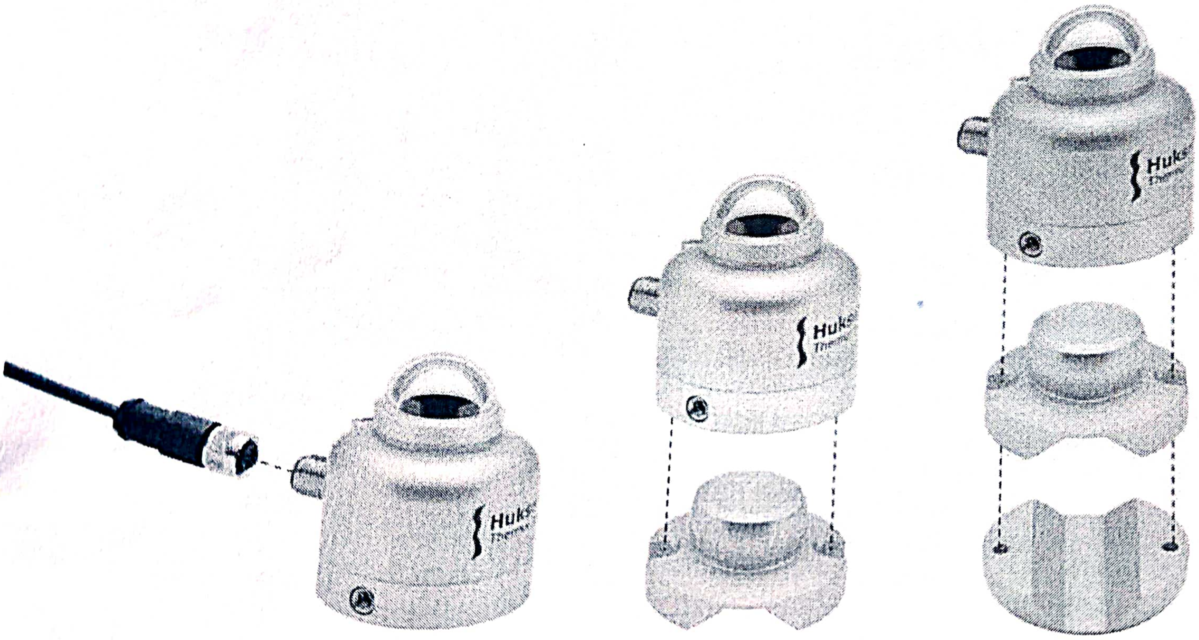

Fig. 2: From left to right: SR05 in its standard configuration with 3 meter cable; with optional ball levelling for easy mounting and levelling on a (non-)horizontal surface; with optional ball levelling and tube mount for easy installation on a 25 to 40 mm diameter tube. Mounting screws are included with the ball levelling and / or tube mount.

Two M5x20 bolts and two M5 nuts are included with SR05's ball levelling option. These are to be used to mount SR05 with its ball levelling to a (non-)horizontal surface.

Two M5x30 bolts and two M5x40 screws are included with SR05's tube mount with ball levelling. These screws are to be used to clamp both ball levelling and tube mount to a 25 to 40 mm diameter tube. For tube diameters larger than or equal to 33 mm, use the M5x40 bolts instead of the M5x30 bolts for a secure fit.

The unique ball head mechanism of SR05's ball levelling mount is used to level SR05. When ordering ball levelling with SR05, it is delivered attached to SR05. In that case follow steps 1 to 7 below to mount and level SR05. Make sure the glass dome is protected at all times. In case SR05 is not attached to its ball levelling mount yet, the user has to ensure a shim is placed properly in the center of the bottom plate of SR05 before mounting and levelling. The shim allows smooth levelling and is shown top left in Figure 3.

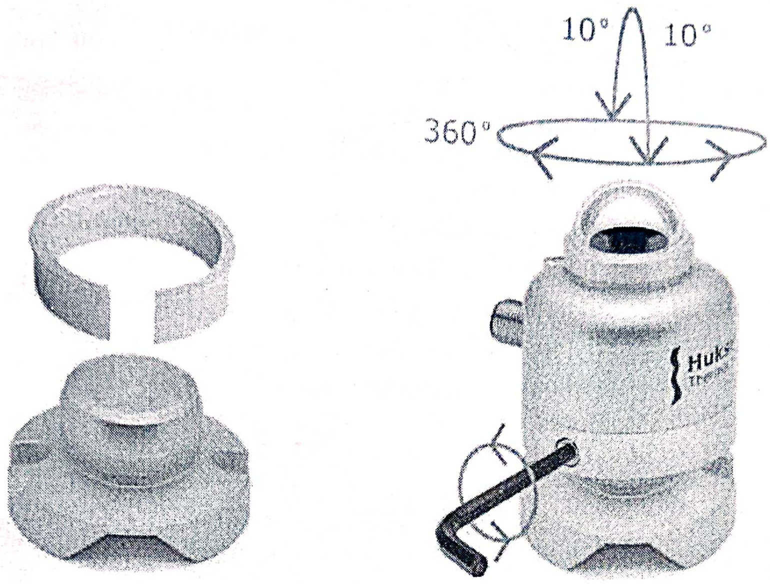

Fig. 3: On the left SR05's ball levelling including shim (mounting bolts not displayed) and on the right SR05 placed on the ball levelling mount. Loosen the countersunk set screw on SR05's side to unlock, allowing placement of the ball head and SR05 levelling, and tighten it to lock the ball head mechanism. A 4 mm hex key is the only tool needed to place and remove the ball levelling and to allow and disallow levelling adjustment. The shim, included when ordering ball levelling, allows for smooth levelling and should be positioned properly in the centre of the bottom plate of SR05.

1) Loosen SR05's countersunk set screw with a 4 mm hex key by turning the hex key counter clockwise until the screw is slightly protruding (sticking out).
2) Hold SR05 in one hand, the ball levelling mount in the other.
3) Separate SR05 from the ball levelling mount by gently pulling out the ball levelling mount.
4) Mount the ball levelling to a surface or platform with its M5 bolts and nuts. See chapter on tooling required.
5) Place SR05 on the ball levelling mount by gently pushing the sensor onto the ball head until it clicks.
6) SR05 can now be rotated 360 ° on its ball head by hand. This rotation allows easy cable orientation adjustment. It can be tilted up to 10 °. This allows angle compensation on non-horizontal surfaces up to 10 °.
7) When SR05 is mounted and levelled, judging by its bubble level, lock the ball head mechanism by turning the set screw clockwise with the 4 mm hex key until it is tightened. SR05 is now locked in its position.

Electrical Connection of Pyranometer:

In order to operate, a Pyranometer should be connected to a measurement system, typically a so-called data logger. SR05-A1 is a passive sensor that does not need any power. Cables generally act as a source of distortion, by picking up capacitive noise. We recommend keeping the distance between a data logger or amplifier and the sensor as short as possible.

Table 1: Wiring diagram of Pyranometer

PIN	WIRE	SR05-A1 analogue millivolt output
1	Brown	not connected
4	Black	not connected
3	Blue	not connected
2	White	signal [+]
5	Grey	signal [−]
	Yellow	shield

Note: at the connector-end of the cable, the shield is connected to the connector housing

Specifications:

ISO classification (ISO 9060: 1990)	second class pyranometer
WMO performance level (WMO-No. 8, seventh edition 2008)	moderate quality pyranometer
Response time (95 %)	18 s
Zero offset a (response to 200 W/m² net thermal radiation)	< 15 W/m² unventilated
Zero offset b (response to 5 K/h change in ambient temperature)	< ± 4 W/m²
Non-stability	< ± 1 % change per year
Non-linearity	< ± 1 % (100 to 1000 W/m²)
Directional response	< ± 25 W/m²
Spectral selectivity	< ± 5 % (0.35 to 1.5 x 10^{-6} m)
Temperature response	< ± 3 % (-10 to +40 °C)
Tilt response	< ± 2 % (0 to 90 ° at 1000 W/m²)