

# Radiation Measurement Instruments



***The Standard for More Than 30 Years***

***LI-COR***<sup>®</sup>

Biosciences

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# LI-190SA Quantum Sensor

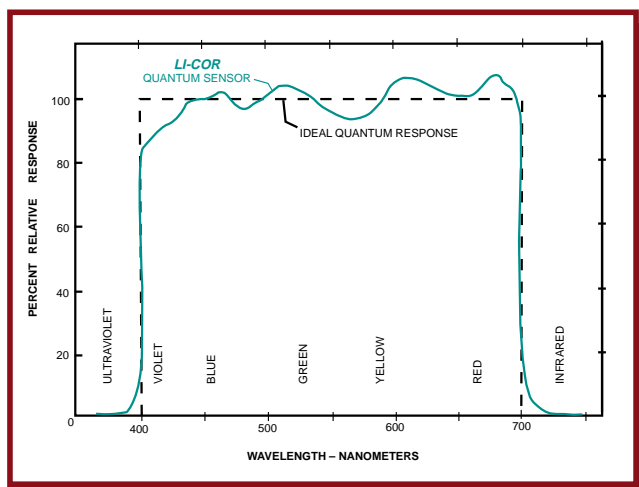
## Measure Photosynthetically Active Radiation

During photosynthesis, plants use energy in the region of the electromagnetic spectrum from 400-700 nm (3,9). The radiation in this range, referred to as Photosynthetically Active Radiation (PAR), can be measured in energy units (watts m<sup>-2</sup>) or as Photosynthetic Photon Flux Density (PPFD), which has units of quanta (photons) per unit time per unit surface area. The units most commonly used are micromoles of quanta per second per square meter (mmol s<sup>-1</sup> m<sup>-2</sup>). Plant scientists, horticulturists, ecologists, and other environmental scientists use the LI-190SA Quantum Sensor to accurately measure this variable.

Accurate measurements are obtained under all *natural and artificial lighting conditions* because of the computer-tailored spectral response of the LI-190SA. Colored glass filters are used to tailor the silicon photodiode response to the desired quantum response. An interference filter provides a sharp cutoff at 700 nm, which is critical for measurements under vegetation where the ratio of infrared to visible light may be high. A small response in the infrared region can cause an appreciable measurement error. This sensor, developed from earlier work (1), was pioneered by LI-COR and has become the standard for PPFD measurement in most photosynthesis-related studies.

The LI-190SA is also used in oceanography, limnology, and marine science as a reference sensor for comparison to underwater PAR measured by the LI-192SA Underwater Quantum Sensor.

\* Units currently used are moles, einsteins, photons and quanta (2, 4, 5).  $1 \mu\text{mol s}^{-1} \text{m}^{-2} \equiv 1 \mu\text{E s}^{-1} \text{m}^{-2} \equiv 6.02 \times 10^{17} \text{photons s}^{-1} \text{m}^{-2} = 6.02 \times 10^{17} \text{quanta s}^{-1} \text{m}^{-2}$ .



Typical spectral response of LI-COR Quantum Sensors vs. Wavelength and the Ideal Quantum Response (equal response to all photons in the 400-700 nm waveband).

## LI-190SA Specifications

**Absolute Calibration:**  $\pm 5\%$  traceable to the National Institute of Standards and Technology (NIST).



**Sensitivity:** Typical 5  $\mu\text{A}$  per 1000  $\mu\text{mol s}^{-1} \text{m}^{-2}$ .

**Linearity:** Maximum deviation of 1% up to 10,000  $\mu\text{mol s}^{-1} \text{m}^{-2}$ .

**Stability:** Typically  $< \pm 2\%$  change over a 1 year period.

**Response Time:** 10  $\mu\text{s}$ .

**Temperature Dependence:** 0.15% per  $^{\circ}\text{C}$  maximum.

**Cosine Correction:** Cosine corrected up to  $80^{\circ}$  angle of incidence.

**Azimuth:**  $< \pm 1\%$  error over  $360^{\circ}$  at  $45^{\circ}$  elevation.

**Tilt:** No error induced from orientation.

**Operating Temperature:**  $-40$  to  $65^{\circ}\text{C}$ .

**Relative Humidity:** 0 to 100%.

**Detector:** High stability silicon photovoltaic detector (blue enhanced).

**Sensor Housing:** Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.

**Size:** 2.38 cm Dia.  $\times$  2.54 cm H (0.94"  $\times$  1.0").

**Weight:** 28 g (1 oz).

**Cable Length:** 3.0 m (10 ft).

## Ordering Information

The LI-190SA Quantum Sensor cable terminates with a BNC connector that connects directly to the LI-250A Light Meter or LI-1400 DataLogger. The 2290 Millivolt Adapter should be ordered if the LI-190SA will be used with a strip chart recorder or datalogger that measures millivolts. The 2290 uses a 604 Ohm precision resistor to convert the LI-190SA output from microamps to millivolts. The Quantum Sensor can also be ordered with bare leads (without the connector) and is designated LI-190SZ. Both are available with 50 foot cables, LI-190SA-50 or LI-190SZ-50. The 2003S Mounting and Leveling Fixture is recommended for each sensor unless other provisions for mounting are made. Other accessories are described on the Accessory Page.

**LI-190SA Quantum Sensor**

**LI-190SZ Quantum Sensor**

**LI-190SA-50 Quantum Sensor**

**LI-190SZ-50 Quantum Sensor**

**2290 Millivolt Adapter**

**2003S Mounting and Leveling Fixture**

**2222SB-50 Extension Cable**

**2222SB-100 Extension Cable**

# LI-191SA LINE QUANTUM SENSOR

U.S. Patent 4,264,211



The LI-191SA Line Quantum Sensor spatially averages PPFD over its one meter length.

## Measure Photosynthetically Active Radiation in Plant Canopies

During photosynthesis, plants use energy in the region of the electromagnetic spectrum from 400-700 nm (1, 2). The radiation in this range, referred to as Photosynthetically Active Radiation (PAR), can be measured in energy units (watts  $m^{-2}$ ) or as Photosynthetic Photon Flux Density (PPFD) which has units of quanta (photons) per unit time per unit surface area. The scaled units most commonly used are micromoles of quanta per second per square meter ( $\mu mol s^{-1} m^{-2}$ ).

Measuring PAR within a plant canopy can be very difficult because of the non-uniformity of the light field. When PAR is measured with a small diameter quantum sensor such as the LI-190SA Quantum Sensor, intensity can vary 10-fold between sunflecks and shadows, requiring a large number of readings to get an accurate average. The LI-191SA Line quantum Sensor reduces the number of individual readings required because it effectively averages PPFD over its one-meter length. One person can quickly make plant canopy PPFD measurements in many plots in a short period of time.

Rather than using multiple detectors linearly arranged over its one-meter length, the LI-191SA uses a one-meter-long quartz rod under a diffuser to conduct light to a single, high-quality quantum sensor whose response is shown in the graph on Page 3.

There are two advantages of this design. First, the sensor has a very good quantum response unlike sensors using inexpensive gallium arsenide detectors with only an approximation of the ideal quantum response. Second, the single quantum sensor is much easier to keep in calibration than multiple (up to 80) individual gallium arsenide detectors.

## LI-191SA Specifications

**Absolute Calibration:**  $\pm 10\%$  traceable to NIST. The LI-191SA is calibrated via transfer calibration from a LI-COR reference Quantum Sensor.

**Sensitivity:** Typically 7  $\mu A$  per 1000  $\mu mol s^{-1} m^{-2}$ .

**Linearity:** Maximum deviation of 1% up to 10,000  $\mu mol s^{-1} m^{-2}$ .

**Stability:**  $< \pm 2\%$  change over a 1 year period.

**Response Time:** 10  $\mu s$ .

**Temperature Dependence:**  $\pm 0.15\%$  per  $^{\circ}C$  maximum.

**Cosine Correction:** Acrylic diffuser.

**Azimuth:**  $< \pm 2\%$  error over  $360^{\circ}$  at  $45^{\circ}$  elevation.

**Sensitivity Variation over Length:**  $\pm 7\%$  maximum using a 1" wide beam from an incandescent light source.

**Sensing Area:** 1 meter L  $\times$  12.7 mm W (39.4"  $\times$  0.50").

**Detector:** High stability silicon photovoltaic detector (blue enhanced).

**Sensor Housing:** Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.

**Size:** 116 L  $\times$  2.54 W  $\times$  2.54 cm D (45.5"  $\times$  1.0"  $\times$  1.0").

**Weight:** 1.8 kg (4.0 lbs.).

**Cable Length:** 3.1 m (10.0 ft.).

## Ordering Information

The LI-191SA Line Quantum Sensor comes with a bubble level, detachable 10 ft. cable and hardsided carrying case. The cable is terminated with a BNC connector and can be directly connected to a readout device such as the LI-250A Light Meter, LI-1400 DataLogger or to the 2290 Millivolt Adapter for connecting to readout devices requiring a millivolt signal. Other accessories are described on the Accessory Page.

**LI-191SA Quantum Sensor**

**2290 Millivolt Adapter**

**2222SB-50 Extension Cable**

**2222SB-100 Extension Cable**

# UNDERWATER PAR MEASUREMENT

## LI-192SA Underwater Quantum Sensor

### Underwater or Atmospheric PPFD Measurement

Underwater or atmospheric *Photosynthetic Photon Flux Density* (PPFD) can be accurately measured using the LI-192SA Underwater Quantum Sensor. The LI-192SA is cosine corrected and features corrosion resistant, rugged construction for use in freshwater or saltwater and pressures up to 800 psi (5500 kPa, 560 meters depth).

## LI-192SA Specifications

- Absolute Calibration:**  $\pm 5\%$  in air traceable to NIST.
- Sensitivity:** Typically  $4 \mu\text{A}$  per  $1000 \mu\text{mol s}^{-1} \text{m}^{-2}$  in water.
- Linearity:** Maximum deviation of  $1\%$  up to  $10,000 \mu\text{mol s}^{-1} \text{m}^{-2}$ .
- Stability:**  $< \pm 2\%$  change over a 1 year period.
- Response Time:**  $10 \mu\text{s}$ .
- Temperature Dependence:**  $\pm 0.15\%$  per  $^{\circ}\text{C}$  maximum.
- Cosine Correction:** Optimized for underwater and atmospheric use.
- Azimuth:**  $< \pm 1\%$  error over  $360^{\circ}$  at  $45^{\circ}$  elevation.
- Detector:** High stability silicon photovoltaic detector (blue enhanced).
- Sensor Housing:** Corrosion resistant metal with acrylic diffuser for both saltwater and freshwater applications. Waterproof to withstand 800 psi (5500 kPa, 560 meters).
- Size:** 3.18 cm Dia.  $\times$  4.62 cm H (1.25"  $\times$  1.81").
- Weight:** 227 g (8 oz.).
- Mounting:** Three 6-32 holes are tapped into the base for use with the 2009S Lowering Frame or other mounting devices.
- Cable:** Requires 2222UWB Underwater Cable.



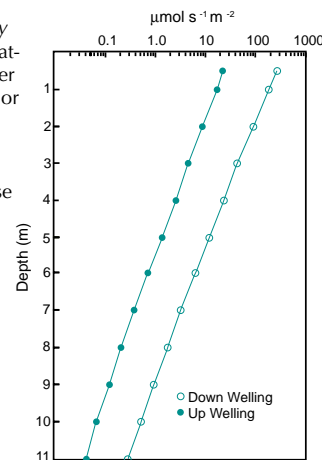
Clockwise from top left: LI-190SA Quantum Sensor, LI-192SA Underwater Quantum Sensor, LI-193SA Spherical Quantum Sensor

## UNDERWATER PAR MEASUREMENT

Accurate measurement of *Photosynthetically Active Radiation* (PAR, 400-700 nm) in aquatic environments is accomplished using either the LI-192SA Underwater Quantum Sensor or the LI-193SA Spherical Quantum Sensor. Limnologists, oceanographers and biologists conducting aquatic productivity studies and vertical profiling have used these sensors extensively.

For extremely turbid conditions, radiation levels with resolution to  $0.01 \mu\text{mol s}^{-1} \text{m}^{-2}$  can be measured with the LI-192SA or LI-193SA quantum sensors and the LI-1400 DataLogger.

Both the LI-192SA and the LI-193SA use computer-tailored filter glass to achieve the desired quantum response. Calibration is traceable to NIST.



## LI-193SA Spherical Quantum Sensor

### Underwater PAR From All Directions

The LI-193SA Underwater Spherical Quantum Sensor gives an added dimension to underwater PAR measurements as it measures photon flux from all directions. This measurement is referred to as *Photosynthetic Photon Flux Fluence Rate* (PPFFR) or *Quantum Scalar Irradiance*. This is important, for example, when studying phytoplankton which utilize radiation from all directions for photosynthesis.

The LI-193SA features a high sensitivity optical design and compact, rugged construction (3400 kPa, 350 meters depth).

## LI-193SA Specifications

- Absolute Calibration:**  $\pm 5\%$  in air traceable to NIST.
- Sensitivity:** Typically  $7 \mu\text{A}$  per  $1000 \mu\text{mol s}^{-1} \text{m}^{-2}$  in water.
- Linearity:** Maximum deviation of  $1\%$  up to  $10,000 \mu\text{mol s}^{-1} \text{m}^{-2}$ .
- Stability:**  $< \pm 2\%$  change over a 1 year period.
- Response Time:**  $10 \mu\text{s}$ .
- Temperature Dependence:**  $\pm 0.15\%$  per  $^{\circ}\text{C}$  maximum.
- Angular Response:**  $< \pm 4\%$  error up to  $\pm 90^{\circ}$  from normal axis (see Angular Response chart on Page 6).
- Azimuth:**  $< \pm 3\%$  error over  $360^{\circ}$  at  $90^{\circ}$  from normal axis.
- Detector:** High stability silicon photovoltaic detector (blue enhanced).

# UNDERWATER PAR MEASUREMENT (CONTINUED)

**Sensor Housing:** Corrosion resistant metal for both saltwater and freshwater applications with an injection molded, impact resistant, acrylic diffuser. Units have been tested to 500 psi (3400 kPa, 350 meters) with no failures.

**Size**

**Globe:** 6.1 cm Dia. (2.4").

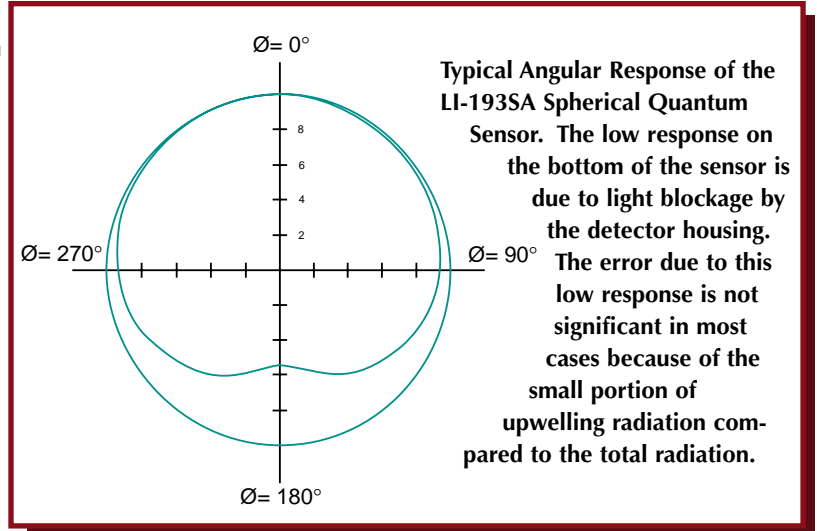
**Housing:** 3.18 cm Dia. (1.25").

**Overall Height:** 10.7 cm (4.2").

**Weight:** 142 g (0.31 lbs.).

**Mounting:** Three 6-32 mounting holes are tapped into the base for use with the 2009S Lowering Frame or other mounting devices.

**Cable:** Requires 2222UWB Underwater Cable.



## 2009S Lowering Frame

The 2009S Lowering Frame provides for the placement of two underwater cosine sensors, one each for downwelling or upwelling radiation (shown below), or a single LI-193SA Spherical Quantum Sensor. The 2009S provides stability for proper orientation of the sensor(s), minimizes shading effects, and features a lower mounting ring for stabilizing weight attachment if necessary.

**Construction:** Anodized aluminum.

**Size:** 51.4 L (20.3") × 35.6 cm W (14.0").

**Weight:** 327 g (0.72 lbs.).



2009S Lowering Frame

## 2222UWB Underwater Cable

This 2-wire shielded cable is used with underwater sensors and has a waterproof connector on the sensor end. The other end of the cable is fitted with a BNC connector for attaching the cable directly to the readout instrument for type "SA" sensors (also attaches to the calconnector of "SB" type sensors). Standard cable lengths are 3, 10, 30, 50 and 100 meters. Custom lengths, including over 100 meters, can also be ordered.

**Underwater Sensors** require 2222UWB Underwater Cable.

## Ordering Information

Underwater Sensors can be purchased with several accessories. Please see Accessory Page for more details.

LI-192SA Underwater Quantum Sensor

LI-193SA Spherical Quantum Sensor

2009S Lowering Frame

2291 Millivolt Adapter (1210 ohm)

2222UWB-3 Underwater Cable, 3 meters

2222UWB-10 Underwater Cable, 10 meters

2222UWB-30 Underwater Cable, 30 meters

2222UWB-50 Underwater Cable, 50 meters

2222UWB-100 Underwater Cable, 100 meters

100L Lubricant

# LI-200SA PYRANOMETER SENSOR

## Total Solar Radiation

The LI-200SA Pyranometer is designed for field measurement of global solar radiation in agricultural, meteorological, and solar energy studies. In clear, unobstructed daylight conditions, the LI-COR pyranometer compares favorably with first class thermopile-type pyranometers (5, 11), but is priced at a fraction of the cost.

Patterned after the work of Kerr, Thurtell and Tanner (7), the LI-200SA features a silicon photovoltaic detector mounted in a fully cosine-corrected miniature head. Current output, which is directly proportional to solar radiation, is calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions in units of watts per square meter ( $W m^{-2}$ ). Under most conditions of natural daylight, the error is  $< 5\%$  (7).

The spectral response of the LI-200SA does not include the entire solar spectrum, so it must be used in the same lighting conditions as those under which it was calibrated.

**Therefore, the LI-200SA should only be used to measure unobstructed daylight. It should not be used under vegetation, artificial lights, in a greenhouse, or for reflected solar radiation.**

## LI-200SA Specifications

**Calibration:** Calibrated against an Eppley Precision Spectral Pyranometer (PSP) under natural daylight conditions. Typical error under these conditions is  $\pm 5\%$ .

**Sensitivity:** Typically  $90 \mu A$  per  $1000 W m^{-2}$ .

**Linearity:** Maximum deviation of  $1\%$  up to  $3000 W m^{-2}$ .

**Stability:**  $< \pm 2\%$  change over a 1 year period.

**Response Time:**  $10 \mu s$ .

**Temperature Dependence:**  $0.15\%$  per  $^{\circ}C$  maximum.

**Cosine Correction:** Cosine corrected up to  $80^{\circ}$  angle of incidence.

**Azimuth:**  $< \pm 1\%$  error over  $360^{\circ}$  at  $45^{\circ}$  elevation.

**Tilt:** No error induced from orientation.

**Operating Temperature:**  $-40$  to  $65^{\circ}C$ .

**Relative Humidity:**  $0$  to  $100\%$ .

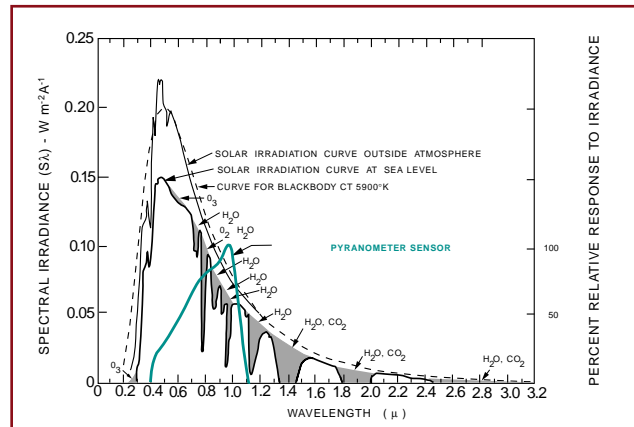
**Detector:** High stability silicon photovoltaic detector (blue enhanced).

**Sensor Housing:** Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.

**Size:**  $2.38$  Dia.  $\times$   $2.54$  cm H ( $0.94'' \times 1.0''$ ).

**Weight:**  $28$  g ( $1$  oz).

**Cable Length:**  $3.0$  m ( $10$  ft).



The LI-200SA Pyranometer spectral response is illustrated along with the energy distribution in the solar spectrum (8).

## Ordering Information

The LI-200SA Pyranometer Sensor cable terminates with a BNC connector that connects directly to the LI-250A Light Meter or LI-1400 DataLogger. The 2220 Millivolt Adapter should be ordered if the LI-200SA will be used with a strip chart recorder or datalogger that measures millivolts. The 2220 uses a  $147$  ohm precision resistor to convert the LI-200SA output from microamps to millivolts. The sensor can also be ordered with bare leads (without the connector) designated LI-200SZ. Both are available with  $50$  foot cables, LI-200SA-50 or LI-200SZ-50. The 2003S Mounting and Leveling Fixture is recommended for each sensor unless other provisions for mounting are made. Other accessories are described on the Accessory Page.

**LI-200SA Pyranometer**

**LI-200SZ Pyranometer**

**LI-200SA-50 Pyranometer**

**LI-200SZ-50 Pyranometer**

**2220 Millivolt Adapter**

**2003S Mounting and Leveling Fixture**

**2222SB-50 Extension Cable**

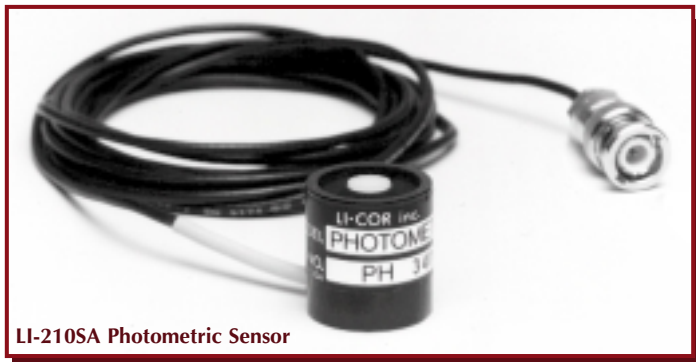
**2222SB-100 Extension Cable**



LI-200SA Pyranometer Sensor

# LI-210SA PHOTOMETRIC SENSOR

## Measures Illuminance as Related to the CIE Standard Observer Curve



LI-210SA Photometric Sensor

The LI-210SA Photometric Sensor utilizes a filtered silicon photodiode to provide a spectral response that matches the CIE curve within  $\pm 5\%$  with most light sources. This photodiode and filter combination is placed within a fully cosine-corrected sensor head to provide the proper response to radiation at various angles of incidence.

Some of the applications for the LI-210SA Photometric Sensor include interior and industrial lighting, outdoor illuminance, passive solar energy, architecture and lighting models, illumination engineering, and biological sciences that require illuminance measurements. The LI-210SA is a research grade photometric sensor that is very reasonably priced.

## LI-210SA Specification

- Absolute Calibration:**  $\pm 5\%$  traceable to NIST.
- Sensitivity:** Typically 30  $\mu\text{A}$  per 100 klux.
- Linearity:** Maximum deviation of 1% up to 100 klux.
- Stability:**  $< \pm 2\%$  change over a 1 year period.
- Response Time:** 10  $\mu\text{s}$ .
- Temperature Dependence:**  $\pm 0.15\%$  per  $^{\circ}\text{C}$  maximum.
- Cosine Correction:** Cosine corrected up to  $80^{\circ}$  angle of incidence.
- Azimuth:**  $< \pm 1\%$  error over  $360^{\circ}$  at  $45^{\circ}$  elevation.
- Tilt:** No error induced from orientation.
- Operating Temperature:**  $-20$  to  $65^{\circ}\text{C}$ .
- Relative Humidity:** 0 to 100%.
- Detector:** High stability silicon photovoltaic detector (blue enhanced).

**Sensor Housing:** Weatherproof anodized aluminum case with acrylic diffuser and stainless steel hardware.

**Size:** 2.38 Dia.  $\times$  2.54 cm H (0.94"  $\times$  1.0").

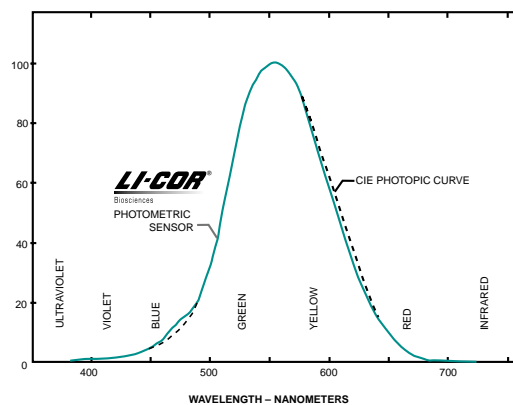
**Weight:** 28 g (1 oz.).

**Cable Length:** 10 ft. standard.

## Photometric Sensors

Photometry refers to the measurement of visible radiation (light) with a sensor having a spectral responsivity curve equal to the average human eye. This curve is known as the CIE Standard Observer Curve (photopic curve).

Photometric sensors are used to measure lighting conditions where the eye is the primary receiver, such as illumination of work areas, interior lighting, television screens, etc. Although photometric measurements have been used in the past in plant science, PPFD and irradiance are the preferred measurements.



## Ordering Information

The LI-210SA Photometric Sensor cable terminates with a BNC connector that connects directly to the LI-250A Light Meter or LI-1400 DataLogger. The 2290 Millivolt Adapter should be ordered if the LI-210SA will be used with a strip chart recorder or datalogger that measures millivolts. The 2290 uses a 604 Ohm precision resistor to convert the LI-210SA output from microamps to millivolts. The Photometric Sensor can also be ordered with bare leads (without the connector) and is designated LI-210SZ. The 2003S Mounting and Leveling Fixture is recommended for each sensor unless other provisions for mounting are made. Other accessories are described on the Accessory Page.

- LI-210SA Photometric Sensor (with BNC connector)**
- LI-210SZ Quantum Sensor (with bare leads)**
- 2003S Mounting and Leveling Fixture**
- 2222SB-50 Extension Cable (50 ft.)**
- 2222SB-100 Extension Cable (100 ft.)**
- 2290 Millivolt Adapter**



# SENSOR ACCESSORIES

## Accessories for Terrestrial Sensors

### 2003S Mounting and Leveling Fixture

The 2003S is for use with all LI-COR terrestrial type sensors (2.38 cm Dia.). The base is anodized aluminum with stainless steel leveling screws and a weatherproof spirit level.

**Size:** 7.6 cm Dia. (3.0”).

**Weight:** 95 g (0.21 lbs).



### 2222SB Extension Cable

This cable is for use with LI-COR terrestrial type sensors. Standard length is 15.2 m (50 ft) or 30.4 m (100 ft). Custom lengths up to 304 m (1000 ft) may be ordered. Cable lengths up to 1000 feet can be used with LI-COR readout instruments. For mV applications, consult LI-COR.

### Millivolt Adapters

Millivolt adapters are used only for connecting sensors to a user's datalogger or stripchart recorder, not the LI-1400 or other LI-COR readout devices.



### 2290 Millivolt Adapter

For LI-190SA Quantum Sensor, LI-191SA Line Quantum Sensor, or LI-210SA Photometric Sensor (604 Ohm resistance).

### 2220 Millivolt Adapter

For LI-200SA Pyranometer Sensor (147 Ohm resistance).

### 2291 Millivolt Adapter

For LI-192SA Underwater Quantum Sensor or LI-193SA Spherical Quantum Sensor (1210 Ohm resistance).

### Type SZ Sensors

Type SZ sensors have the same specifications as the type SA sensors except that they are terminated with bare wires for connection to the terminal blocks for the LI-1400 Data-Logger or other current measuring devices. These sensors can be converted to millivolt output by connecting a resistor across the leads and measuring the voltage across the resistor.

## Accessories for Underwater Sensors

### 2222UWB Underwater Cable

This 2-wire shielded cable is used with underwater sensors and has a waterproof connector on the sensor end. The other end of the cable is fitted with a BNC connector for attaching the cable directly to the readout instrument for type "SA" sensors (also attaches to the calconnector of "SB" type sensors). Standard cable lengths are 3, 10, 30, 50, 75 and 100 meters. Custom lengths over 100 meters can also be ordered.

### 2009S Lowering Frame

The 2009S Lowering Frame provides for the placement of two underwater cosine sensors, one each for downwelling or upwelling radiation (shown below), or a single LI-193SA Spherical Quantum Sensor. The 2009S provides stability for proper orientation of the sensor(s), minimizes shading effects, and features a lower mounting ring for stabilizing weight attachment if necessary.

**Construction:** Anodized aluminum.

**Size:** 51.4 L (20.3") x 35.6 cm W (14.0").

**Weight:** 327 g (0.72 lbs.).



### Underwater Sensors

Require 2222UWB Underwater Cable. The 2009S Lowering Frame is an accessory.

### 100L Lubricant

Provides lubrication between the sensor and the underwater cable.

# LI-250A LIGHT METER

**Direct Digital Readout:** Instantaneous sensor output or 15-second averages can be shown on the LI-250A's display. Measurement units for any LI-COR sensor ( $\mu\text{mol}$ , lux, klux, or  $\text{W m}^{-2}$ ) are also displayed.

**High Quality Circuitry:** The high quality amplifier in the LI-250A provides excellent long-term stability and automatic zeroing. This high gain amplifier gives very low input impedance to sensors, resulting in excellent linearity. Typical accuracy is 0.4% of reading at 25 °C.

**Automatic Range Selection:** The LI-250A simplifies operation by automatically selecting the range with the best accuracy and resolution for a given sensor input signal. The wide dynamic range allows measurements in a wide variety of light environments.

**Sensor Calibration:** Calibration multipliers for LI-COR sensors can be entered by simply pressing the CAL key, setting the display units (UNITS key), and then changing the sensor calibration multiplier with the up and down arrow keys. Two sensor multipliers can be held in memory to aid in switching between sensors.

**Hold Key:** Pressing the HOLD key lets you retain the current reading on the display. Pressing the HOLD key again returns the LI-250A to measurement mode where the display is continuously updated.

**Average Key:** 15-second averages can be collected and then held on the display by pressing the AVG key.

**Hand-held, Battery Operated:** The LI-250A's low power consumption gives you more than 150 hours of operation from a single 9-volt transistor battery. To conserve battery life, the meter automatically shuts off after 20 minutes of inactivity.

**Weathertight:** The LI-250A case is O-ring sealed to make it weathertight.



## Applications

Like all LI-COR instruments, the LI-250A is designed for applications demanding performance, reliability and ruggedness. The LI-250A provides direct digital readout of LI-COR radiation sensors.

### Photosynthetically Active Radiation (PAR)

The LI-190SA Quantum Sensor is used by plant scientists, horticulturists, and other environmental scientists to measure Photosynthetic Photon Flux Density (PPFD - the preferred measurement of PAR) in natural sunlight, under plant canopies, and in growth chambers and greenhouses.

The LI-190SA is also used in oceanography, limnology and marine sciences as a reference sensor for comparison to underwater PPFD measured by the LI-192SA Underwater Quantum Sensor. The LI-250A can hold calibration multipliers in memory for both a surface and underwater sensor.

### Illuminance

For lighting studies or architectural modeling, the LI-250A and LI-210SA Photometric Sensor provide a direct readout of illuminance in lux. The LI-210SA measures visible radiation and has a spectral response curve equal to that for the average human eye. This curve is known as the CIE Standard Observer Curve and is matched by the LI-210SA to within 5% under most light sources.

### Solar Irradiance

Solar irradiance measurements for meteorological, hydrological and environmental research can be made using the LI-200SA Pyranometer Sensor. The LI-200SA measures global solar radiation (sun plus sky) and provides a typical accuracy of  $\pm 5\%$  under unobstructed daylight conditions.

## Sensor Compatibility

Type "SA" sensors (e.g. LI-190SA) are recommended for use with the LI-250A. Older type "SB" sensors (e.g. LI-190SB) can also be used by removing the calibration connector. Other types of older LI-COR sensors can be made compatible by adding a BNC connector to the cable.



**LI-250A Light Meter with LI-210SA Photometric Sensor and 2003S Mounting and Leveling Fixture.**

## Accessories

**250-01 Carrying Case:** The 250-01 has a tough nylon exterior and is padded to protect the LI-250A during transport. Internal compartments provide storage for the LI-250A and several sensors. For field use, the 250-01 also lets you hang the meter on your belt.

**Size:** 20 L × 9.5 W × 9 cm D.



250-01 Carrying Case.

## LI-250A Specifications

### Accuracy:

**25 °C:** Typically ± 0.4% of reading ± 3 counts on the least significant digit displayed (all ranges).

**0 - 55 °C:** Typically ± 0.6% of reading ± 3 counts on the least significant digit displayed (all ranges).

**Range Selection:** Autoranging (3 ranges).

**Linearity:** ± 0.05%.

**Sensors:** Any LI-COR type "SA" or type "SB" sensor with BNC connector; Quantum, Pyranometer, or Photometric. Older LI-COR radiation sensors, or those without any connector must have a BNC connector installed. Contact LI-COR.

**Sensor Calibration:** Each sensor is supplied with a calibration multiplier. Calibration multipliers for two sensors can be stored in memory. Calibration multipliers are entered from the keypad.

**Signal Averaging:** Sensor output can be collected and displayed as a 15-second average (approximately 60 readings). Averages are retained on the display in HOLD mode.

**Display:** 4 1/2 digit LCD display. Updated every 0.5 seconds in Instantaneous mode.

**Keypad:** Sealed, 5-key tactile response keypad.

**Battery Life:** 150 hours typical with continuous operation.

**Power Requirement:** One 9V Eveready Alkaline #522 or equivalent (LI-COR part number 216).

**Low Battery Detection:** Low battery indicator displayed with approximately 20 hours battery life remaining.

**Operating Conditions:** 0 to 55 °C, 0 to 95% RH (non-condensing).

**Storage Conditions:** -55 to 60 °C, 0 to 95% RH (non-condensing).

**Size:** 14 cm L × 7.7 cm W × 3.8 cm D (5.5" × 3" × 1.5").

**Weight:** 0.26 kg (0.57 lbs).

**Warranty:** 1 year parts and labor.

## LI-250A Range and Resolution

Sensor	Range	Resolution
Quantum	199 $\mu\text{mol s}^{-1} \text{m}^{-2}$	0.01 $\mu\text{mol s}^{-1} \text{m}^{-2}$
	1999	0.1
	19999	1
Radiometric	19 $\text{W m}^{-2}$	0.001 $\text{W m}^{-2}$
	199	0.01
	1999	0.1
Photometric	1999 lux	0.1 lux
	19999 lux	1
	199 klux	0.01 klux

## Ordering Information

### LI-250A Light Meter

Battery included. Order sensors separately.

### Options

**250-01 Carrying Case**

**216 Replacement Battery. 9 volt transistor type.**

Requires 1 for replacement.

### Sensors

**LI-190SA Quantum Sensor**

**LI-200SA Pyranometer Sensor**

**LI-210SA Photometric Sensor**

**LI-191SA Line Quantum Sensor**

**2003S Mounting and Leveling Fixture**

**2222SB Extension Cable (50 ft.)**

**2222SB-100 Extension Cable (100 ft.)**

### Underwater Sensors

**LI-192SA Underwater Quantum Sensor**

**LI-193SA Spherical Quantum Sensor**

**2222UWB Underwater Cable.** Standard lengths

range from 3 to 100 meters. Custom lengths available.

**2009S Lowering Frame**

# LI-1400 DATA LOGGER

High accuracy with LI-COR light sensors. Three external light sensor connectors for fast setup.

Two additional current channels, four voltage channels, one pulse counting channel and several regulated and unregulated voltage supplies.

96K Bytes RAM for data storage.

Ergonomic, light weight for hand-held operation as a meter with instantaneous or averaged read-out.

RS-232 data output to PC-compatible or Macintosh computers in "spreadsheet-ready" format.



Nine math channels for direct readout of saturation vapor pressure, dew point temperature, vertical light attenuation coefficients (underwater), and more.

Two-line LCD display shows sensor instantaneous or logged sensor outputs, stored data, battery voltage and more.

Autoranging electronics with low power consumption.

Easy-to-use internal software with setup macro libraries to simplify sensor configuration.

Alphanumeric keypad speeds entry of remarks for data identification.

## Simplified Data Logging

Operating the LI-1400 is easy. All functions are selectable from short lists using cursor keys. Commonly used functions like printing and memory management are assigned to a function list on a dedicated key for quick access. Other important functions like instrument setup and data display are also assigned to dedicated keys.

## Fast Setup

Channel setup is simplified by the use of log routines that eliminate entering repetitive information. The LI-1400's log routines allow you to enter the logging period, start/stop times and other information in one place, and then apply that log routine to as many channels as required.

Each channel can be individually configured to collect data for logging periods as short as 1 second or as long as 24 hours. Sampling intervals within each logging period are selectable from 1 second to one hour.

For each logging period, data can be integrated or averaged. Alternatively, an instantaneous point reading can be taken at the end of each period. The maximum and minimum readings within the logging period and the time of their occurrence can also be stored.

## Math Functions

Channel setup includes choosing from a list of math functions that can be applied to sensor inputs. In addition to sensor input scaling or linearization, several powerful calculations can be performed using math functions:

**Math Operators (+, -, ×, ÷):** Used to combine one input with another through channel addition, subtraction, etc. For example, math operators can determine the ratio of two similar sensors in different environmental conditions, like an LI-190SA Quantum Sensor at the water's surface and an LI-192SA Quantum Sensor underwater.

**Steinhart-Hart Function:** Calculates temperature from thermistor type temperature sensors such as LI-COR air and soil temperature sensors.

**Saturation Vapor Pressure:** Calculated when temperature is input from an air temperature sensor.

**Dew Point Temperature:** Calculates the dew point temperature using signals from the 1400-104 Relative Humidity and Air Temperature Sensor (or equivalent).

**Natural Log:** Multiplies a constant by the natural log of a channel input. When used in conjunction with math operators, this function can be used to calculate the vertical light attenuation coefficient between two underwater quantum sensors submerged at different depths.

**Polynomial:** A fifth order polynomial is provided for sensor linearization.

**Math Libraries:** Five math libraries are available to store values for any of the above math functions. For example, if the same linearization polynomial is to be used for several sensor inputs, storing the polynomial in one of the math libraries eliminates re-entering the polynomial for every sensor.



## Math Channels

The logging and calculation capabilities of the LI-1400 are extended by nine math channels. Math channels let you perform additional logging or math routines using any other current, voltage or math channel. For example, if you are logging total daily solar radiation from an LI-200SA Pyranometer sensor connected to current channel #1, you can also log hourly integrations or averages from the same sensor by adding the channel #1 input to a math channel and then setting the log routine on the math channel for hourly integrations. Any of the math operators or math functions described above can be used in the math channels as well.

## Circuitry

The LI-1400 uses an autoranging, trans-impedance, chopper stabilized amplifier for high resolution (8 picoamp), high accuracy measurements of LI-COR radiation sensors and other sensors with a current output. The high gain amplifier and unique circuit topology gives an extremely low input impedance (< 0.03 ohm) to current sensors, resulting in excellent linearity. Measurement accuracy is enhanced by performing an auto zero and span before every reading (or once per minute with 1-second sampling rate) using a high precision, low drift reference. A precision sigma-delta analog-to-digital converter allows high speed, low noise measurements to be made.

Highly accurate, single-ended voltage measurements are achieved using a precision instrumentation amplifier. Voltage output transducers with low or high output impedance are accurately measured because of very high amplifier input impedance.

## Current Channels

The LI-1400 has unrivaled resolution for LI-COR radiation sensors. Current resolution down to 8 picoamps is available through three sealed BNC connectors and two additional channels on the 1400-301 Terminal Block.

The three BNC current channels are designed for type "SA" radiation sensors like LI-COR's LI-190SA Quantum Sensor, LI-200SA Pyranometer Sensor or LI-210SA Photometric Sensor. LI-COR Type "SZ" radiation sensors, with bare wire leads, are recommended for use with the terminal block.

For other sensors, the LI-1400 can measure current up to  $\pm 250$  microamps with very high resolution.

## Voltage Channels

Four single-ended voltage channels ( $\pm 2.5$  VDC) provide high input impedance for measuring a wide range of sensors, including LI-COR temperature sensors and humidity sensors. Voltage measurements require the 1400-301 Terminal Block.

## Pulse Counting

The LI-1400 has one pulse counting channel for logging total rainfall from a Tipping Bucket Rain Gauge. The counter channel can be accessed through the 1400-301 Terminal Block.

## Environmental Operation

The LI-1400's rugged, splash-resistant case protects it from exposure to the environment. Operating temperatures are from -25 to 55°C. For operation at remote sites, the 1400-201 Vented Instrument Enclosure is recommended to protect sensor connections from rain water and to shade the LI-1400 from direct sunlight.

The LI-1400 is powered by four "AA" batteries which provide over 60 hours of hand-held, instantaneous operation as a meter. For remote logging applications, the 1400-402 external "D" cell battery pack provides over a

year of data logging operation from six batteries. To ensure continuous operation, a low battery warning is displayed when the batteries are depleted; a lithium back-up battery protects the memory while changing batteries.

While logging data, the LI-1400 conserves battery life by operating fully powered only when it must sample a given channel. After sampling channels and storing data (if necessary), the LI-1400 automatically returns to a state of low power consumption.

## Data Storage

The LI-1400 has 96K bytes RAM for data storage. The storage capacity is dependent on the software configuration.



**Table 1.** Storage Capacity Examples.

Setup Description		Time Until Memory Full	Bytes/Day
2 channels, 1 hr periods	no max/min	208 days	432
	with max/min (each channel)	110 days	816
Daily integration and hourly means from a radiation sensor; hourly means of humidity and temperature, daily rainfall.	no max/min	141 days	638
	with max/min (all channels except integral)	64 days	1406
9 channels, 1 hr periods and 9 math channels, 1 hr periods	no max/min	45 days	1968
	with max/min (all channels)	16 days	5424

## Data Output

Windows® communication software is included for:

- Rapid binary data transfer
- ASCII data transfer
- Datalogger configuration changes from the computer.

Stored data can also be transferred to PC-compatible or Macintosh® computers using any terminal program. The LI-1400 data is formatted for easy import into widely used spreadsheet and database software.

Data can be automatically output via the RS-232 port after every logging period. When using short logging periods, this feature allows data capture by a computer with large storage capacity.

## Hand-Held Operation

As an autoranging meter, the LI-1400 provides direct read-out for up to three LI-COR radiation sensors without requiring a terminal input block.



LI-190SA Quantum Sensor

The output of a given sensor can be viewed on the LCD display or stored in memory by simply pressing the ENTER key on the keypad (data for all operative channels are stored, along with the time at which the data were logged).

Radiation measurements in water or under changing cloud cover often require an averaged reading of sensor output to obtain the best results. The LI-1400 can display a continuous running average for each sensor. The length of the average is user selectable for each channel. Instantaneous or averaged values for any sensor can also be displayed while the LI-1400 is logging data.

## Ordering Information



1400-301

**LI-1400 DataLogger:** Includes 4 "AA" batteries and Windows® communication software. Sensors not included.

**1400-301 Standard Terminal Block:** Allows connection to two additional current channels, 4 voltage channels, 1 pulse counting channel, two unregulated voltage supplies, and two regulated

+5 volt DC supplies for LI-COR temperature sensor and other sensors requiring a constant voltage input.

**1400-401 AC Adapter:** Requires 120 VAC, 60 Hz. Used for applications where continuous operation is required.

**1400-402 External Alkaline Battery Pack:** Holds 6 "D" cell batteries for remote logging applications. The 1400-402 has provisions for mounting in the 1400-201 Vented Instrument Enclosure.

**1400-320 Storage Case:** Foam-lined plastic case for LI-1400, sensors, and accessories.

**1400-310 Mounting Bracket:** For mounting the LI-1400 in third-party instrument enclosures, or any other vertical or inclined surface.

## Sensors

**Quantum Sensors:** LI-190SA Quantum Sensor, LI-190SZ Quantum Sensor, LI-191SA Line Quantum Sensor, LI-192SA Underwater Quantum Sensor, LI-193SA Spherical Quantum Sensor.

**Pyranometer Sensors:** LI-200SA, LI-200SZ.

**Photometric Sensors:** LI-210SA, LI-210SZ.

**1400-103 Soil Temperature Sensor:** 20 foot cable. Accuracy:  $\pm 0.5$  °C.

**1400-101 Air Temperature Sensor:** 20 foot cable. Accuracy:  $\pm 0.5$  °C.

**1400-102 Air Temperature Sensor:** Same as 1400-101 except cable length is 2 ft. for mounting in 1400-201 Vented Instrument Enclosure.

**1400-104 Relative Humidity and Air Temperature Sensor (Vaisala):** 9 ft. cable. Can be mounted in 1400-201 Vented Instrument Enclosure.



1400-104 Relative Humidity/Temperature Sensor, 1400-101 Air Temperature Sensor, and 1400-103 Soil Temperature Sensor (left to right).

## Data Output Accessories

**9975-016 RS-232 Cable:** For connection to PC-compatible computers with a 9-pin RS-232C communication port (DTE-to-DTE).

# Specifications

**Current Inputs:** Five channels; three through external sealed BNC connectors, and two through the 1400-301 Standard Terminal Block.

**Voltage Inputs:** Four high impedance (>500M ohm) single-ended channels accessed through the 1400-301 Terminal Block.

**Pulse Counting Input:** One pulse counting channel. Switch closure for tipping bucket rain gauge (1 Hz maximum).

**Math Channels:** 9 math channels. Math channels combine results of two channels with addition, subtraction, multiplication and division operators. Other math channel functions include fifth order polynomial, Steinhart-Hart function for thermistors, natural log, saturation vapor pressure, and dew point. Five math libraries are available to store commonly used functions.

**ANALOG-TO-DIGITAL CONVERTER:**

**Resolution:** 16 bit (1 part in 65,536).

**Scanning Speed:** 10 channels per second.

**Voltage Accuracy:** < 0.15% of full scale reading (25 °C). ± 0.2% (0 to 55 °C).

**Current Accuracy:** ± 0.3% of full scale reading (25 °C). ± 0.5% (0 to 55 °C).

**Temperature Coefficient:** ± 0.01% of reading per °C.

**Linearity:** 0.07%.

**Frequency Rejection:** >90 dB at 50 or 60 Hz (software selectable).

**Input Noise** (25 °C)

	<u>Typical</u>	<u>Maximum</u>
<b>Voltage</b>	± 76 µV	± 152 µV
<b>Current</b>	± 7.6 picoamps	± 30.4 picoamps

**VOLTAGE RANGE (CHANNELS V1-V4):**

<u>Voltage Range</u>	<u>Resolution</u>
± 2.5 volts	76 microvolts

**Current Range Selection:** Autoranging.

<u>Current Ranges</u>	<u>Resolution</u>
1 ± 250 nanoamps	7.6 picoamps
2 ± 2.5 microamps	76 picoamps
3 ± 25 microamps	760 picoamps
4 ± 250 microamps	7.6 nanoamps

**Typical Resolution with LI-COR radiation sensors (Range 1)**

LI-190SA	.0015 µmole sec <sup>-1</sup> m <sup>-2</sup>
LI-200SA	.0001 watts m <sup>-2</sup>
LI-210SA	.025 lux

**Current Channel Input Impedance:** Typically < 0.03 ohm for ranges 1, 2, or 3; < 0.3 ohm for range 4.

**Voltage Channel Input Impedance:** >500M ohm on voltage channels V1 through V4. 100K ohm for current channels I4 and I5, when configured for voltage input.

**D.C. Voltage Excitation:** Two regulated: + 5.0 V ± 0.2% at 3 mA; Two unregulated: 9.5V ±10% or higher at 6mA. With external 14V input, unregulated output is ≈13.4V.

**Logging Periods:** Seconds: 1, 5, 15, 30. Minutes: 1, 5, 15, 30. Hours: 1, 3, 6, 12, 24.

**Sampling Interval:** Seconds: 1, 5, 15, 30. Minutes: 1, 5, 15, 30, 60.

**Short Term Averaging:** Selectable at 1, 5, 15, or 30 seconds. While averaging, the oldest point is dropped when the newest point is added. Averaged readings reduce instrument noise by approximately the square root of the number of samples.

**Keyboard:** Sealed, 24-key tactile response keypad.

**Display:** Two line, 16 character alphanumeric LCD. Updated once per second. Temperature compensated readability from -15 to 55 °C.

**Real Time Clock:** Year, month, day, hour, minute, seconds. Accuracy: ± 3 minutes per month (25 °C).

**Internal Memory:** 96K bytes available for data storage.

**Program Memory:** Stored in Flash memory for easy upgrades via the RS-232 port.

**Communications:** RS-232, hardwired Data Terminal Equipment (DTE) through 9-pin port. Baud rates are software selectable at 300, 1200, 2400, 4800 and 9600. Communication is bi-directional.

**Battery Requirements:** Four Alkaline "AA" batteries in sealed battery compartment.

**Back-up Battery:** Internal lithium battery maintains memory up to seven years.

**Battery Voltage:** Automatic low battery instrument shut-off. Remaining power after shut-off maintains data stored in memory. Low battery warning displayed before automatic shut-off. Power management software also shuts off the instrument after 15 minutes of inactivity.

**Battery Capacity with "AA" Batteries:** 60 hours continuous operation.

**External DC Power:** 7-16 VDC.

**Case:** ABS plastic case for splash resistant operation and protection from wind blown dust. Equivalent to an IP54 level.

**Operating Conditions:** -25 to 55 °C; 0 to 95% RH, non-condensing.

**Storage Conditions:** -30 to 60 °C; 0 to 95% RH, non-condensing.

**Size:** 22L × 13W × 4.3 cm D (8.6 × 5.1 × 1.7"). 9.3 cm (3.7") width of the lower case allows easy hand-held operation.

**Weight:** 0.7 kg (1.5 lb).

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**Other LI-COR Environmental products** include the LI-8100 Automated Soil CO<sub>2</sub> Flux System, the LI-6400 Portable Gas Exchange and Fluorescence System, CO<sub>2</sub>/H<sub>2</sub>O Gas Analyzers, and Area Meters.



LI-8100 Automated Soil CO<sub>2</sub> Flux System



LI-6400 Portable Gas Exchange and Fluorescence System



LI-7000 CO<sub>2</sub>/H<sub>2</sub>O Analyzer



LI-840 CO<sub>2</sub>/H<sub>2</sub>O Gas Analyzer

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“Trust in the LORD with all your heart; and do not lean on your own understanding. In all your ways acknowledge Him, and He will make your path straight.” *Proverbs 3:5,6*

The LI-COR® Board of Directors would like to take this opportunity to return thanks to God for His merciful providence in allowing LI-COR to develop and commercialize products, through the collective effort of dedicated employees, that enable the examination of the wonders of His works.

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