

OWNER'S MANUAL

QUANTUM METER

Model JMQ-100, JMQ-200, and JMQ-300 Series



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DECLARATION OF CONFORMITY

CE and ROHS Certificate of Compliance

Declare under our sole responsibility that the products:

Models: JMQ -100, JMQ -200, JMQ -301, JMQ -303, JMQ -306

Type: Quantum Meter

are in conformity with the following standards and relevant EC directives:

Emissions: EN 61326-1:2013

Immunity: EN 61326-1:2013

Safety: EN 61010-1:2010

EU directive 2004/108/EC, EMC

EU directive 2002/95/EC, RoHS (Restriction of Hazardous Substances)

EU directive 2011/65/EU, RoHS2

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials, including Cadmium, Hexavalent Chromium, Lead, Mercury, Polybrominated Biphenyls (PBB), Polybrominated Diphenyls (PBDE).

INTRODUCTION

Radiation that drives photosynthesis is called photosynthetically active radiation (PAR) and is typically defined as total radiation across a range of 400 to 700 nm. PAR is often expressed as photosynthetic photon flux (PPF): photon flux in units of micromoles per square meter per second ($\mu\text{mol m}^{-2} \text{s}^{-1}$, equal to microEinsteins per square meter per second) summed from 400 to 700 nm (total number of photons from 400 to 700 nm). While Einsteins and micromoles are equal (one Einstein = one mole of photons), the Einstein is not an SI unit, so expressing PPF as $\mu\text{mol m}^{-2} \text{s}^{-1}$ is preferred.

Sensors that measure PPF are often called quantum sensors due to the quantized nature of radiation. A quantum refers to the minimum quantity of radiation, one photon, involved in physical interactions (e.g., absorption by photosynthetic pigments). In other words, one photon is a single quantum of radiation.

Typical applications of quantum sensors include incoming PPF measurement over plant canopies in outdoor environments or in greenhouses and growth chambers, and reflected or under-canopy (transmitted) PPF measurement in the same environments.

JMQ series quantum meters consist of a handheld meter and a dedicated quantum sensor that is integrated into the top of the meter housing (JMQ-100) or connected by cable to an anodized aluminum housing (JMQ-200 and JMQ-300 series). Integrated and separate sensors consist of a cast acrylic diffuser (filter), photodiode, and are potted solid with no internal air space. JMQ series quantum meters provide a real-time PPF reading on the LCD display and offer measurements for both sunlight and electric light calibrations (menu selectable) that determine the radiation incident on a planar surface (does not have to be horizontal), where the radiation emanates from all angles of a hemisphere. JMQ series quantum meters include manual and automatic data logging features for making spot-check measurements or calculating daily light integral (DLI).

SENSOR MODELS

JMQ series quantummeter covered in this manual are self-contained and come complete with handheld meter and sensor.

Line quantum meters, JMQ-300 series, provide spatially averaged PPF measurements. All sensors along the length of the line are connected in parallel, and as a result, quantum meters display PPF values that are averaged from the location of the individual sensors.



Sensor model number and serial number are located on a label on the backside of the handheld meter.



JMQ-100 Series: meter w/ integral sensor

JMQ-200 Series: meter w/ separate quantum sensor

JMQ-300 Series: meter w/ separate line quantum sensor

SPECIFICATIONS

Calibration Uncertainty: $\pm 5 \%$ (see Calibration Traceability below)

Measurement Repeatability: $< 1 \%$

Non-stability (Long-term Drift): $< 2 \%$ per year

Non-linearity: $< 1 \%$ (up to $3000 \mu\text{mol m}^{-2} \text{s}^{-1}$)

Response Time: $< 1 \text{ ms}$

Field of View: 180°

Spectral Range: 410 nm to 655 nm (wavelengths where response is greater than 50 % of maximum; see Spectral Response below)

Directional (Cosine) Response: $\pm 5 \%$ at 75° zenith angle (see Cosine Response below)

Temperature Response: $0.06 \pm 0.06 \%$ per C (see Temperature Response below)

Operating Environment: 0 to 50 C

$< 90 \%$ non-condensing relative humidity up to 30 C

$< 70 \%$ non-condensing relative humidity from 30 to 50 C

Separate sensors can be submerged in water up to depths of 30 m

Meter Dimensions: 12.6 cm length, 7.0 cm width, 2.4 cm height

Sensor DimensionsJMQ -200: 2.4 cm diameter and 2.8 cm height

JMQ-301: 70 cm length, 1.5 cm width, 1.5 cm height

JMQ-303, -306: 50 cm length, 1.5 cm width, 1.5 cm height

MassJMQ-100: 150 g

JMQ-200: 180 g

JMQ-301: 380 g

JMQ-303, -306: 300 g

Cable: 2 m of shielded, twisted-pair wire.

Additional cable available

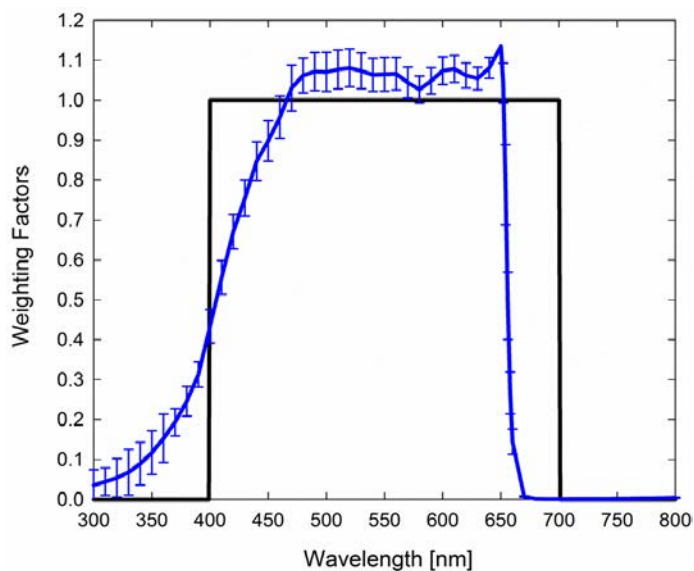
Santoprene rubber jacket (high water resistance, high UV stability, flexibility in cold conditions)

Calibration Traceability:

JMQ series quantum meters are calibrated through side-by-side comparison to the mean of four model JSQ -110 or JSQ-120 transfer standard quantum sensors under high output T5 cool white fluorescent lamps. The transfer standard quantum sensors are calibrated through side-by-side comparison to the mean of at least three LI-COR model LI-190 reference quantum sensors under high output T5 cool white fluorescent lamps. The reference quantum sensors are recalibrated on a biannual

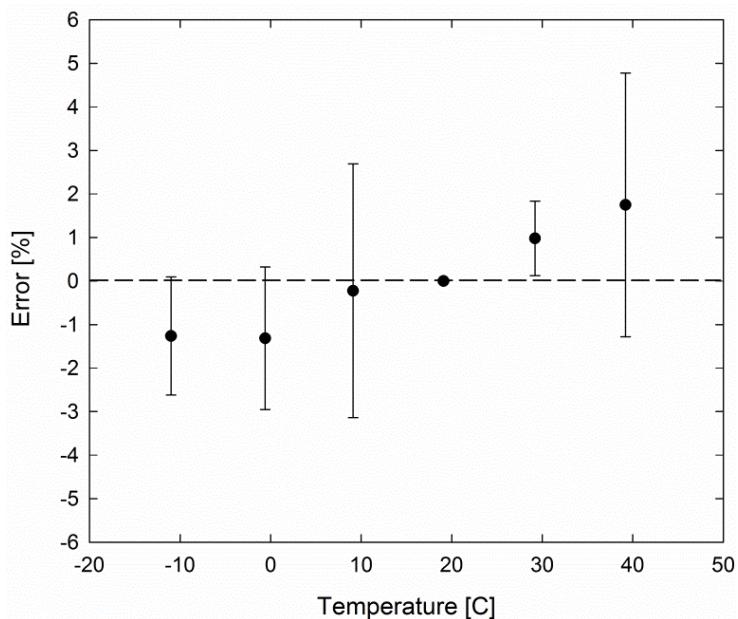
schedule with a LI-COR model 1800-02 Optical Radiation Calibrator using a 200 W quartz halogen lamp. The 1800-02 and quartz halogen lamp are traceable to the National Institute of Standards and Technology (NIST).

Spectral Response:



Mean spectral response of six SQ series quantum sensors (*error bars represent two standard deviations above and below mean*) compared to PPF weighting function. Spectral response measurements were made at 10 nm increments across a wavelength range of 300 to 800 nm in a monochromator with an attached electric light source. Measured spectral data from each quantum sensor were normalized by the measured spectral response of the monochromator/electric light combination, which was measured with a spectroradiometer.

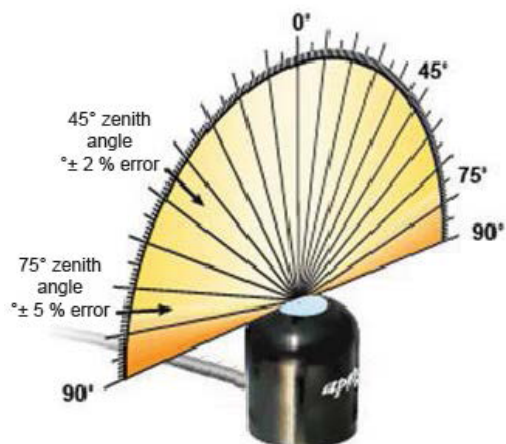
Temperature response:



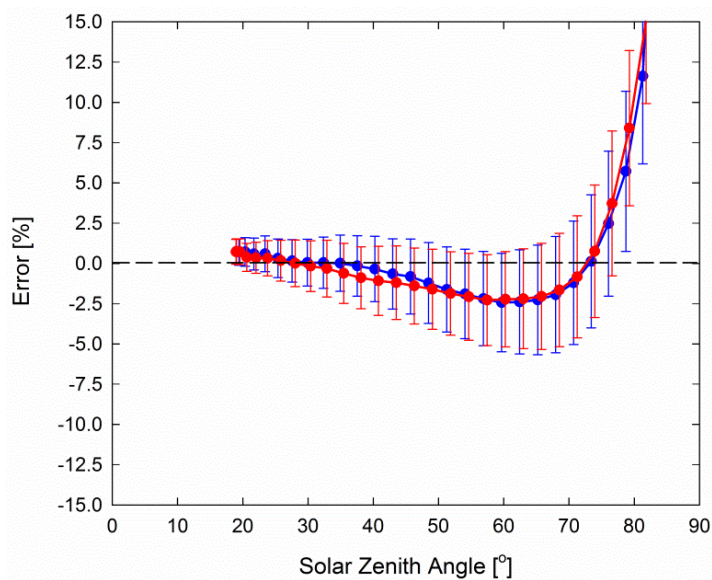
Mean temperature response of eight SQ series quantum sensors (*errors bars represent two standard deviations above and below mean*). Temperature response measurements were made at 10 C intervals across a temperature range of approximately -10 to 40 C in a temperature controlled chamber under a fixed, broad spectrum, electric lamp. At each temperature set point, a spectroradiometer was used to measure light intensity from the lamp and all quantum sensors were compared to the spectroradiometer. The spectroradiometer was mounted external to the temperature control chamber and remained at room temperature during the experiment.

Cosine Response:

Cosine Response of Apogee JSQ Series Quantum Sensors



Directional, or cosine, response is defined as the measurement error at a specific angle of radiation incidence. Error for JMQ series quantum meters is approximately $\pm 2\%$ and $\pm 5\%$ at solar zenith angles of 45° and 75° , respectively.



Mean cosine response of twenty-three JSQ series quantum sensors (*error bars represent two standard deviations above and below mean*). Cosine response measurements were made by direct side-by-side comparison to the mean of four reference thermopile pyranometers, with solar zenith angle-dependent factors applied to convert total shortwave radiation to PPF. Blue points represent the AM response and red points represent the PM response.

DEPLOYMENT AND INSTALLATION

JMQ series quantum meters are designed for spot-check measurements, and calculation of daily light integral (DLI; total number of photons incident on a planar surface over the course of a day) through the built-in logging feature. To accurately measure PFF incident on a horizontal surface, the sensor must be level. For this purpose, each JMQ model comes with a different option for mounting the sensor to a horizontal plane.



The AL-210 leveling plate is recommended for use with the JMQ-100.



The AL-100 leveling plate is recommended for use with the JMQ-200. To facilitate mounting to a cross arm, the AM-110 mounting bracket is recommended for use with the AL-100.

JMQ-300 series line quantum sensors are leveled using the built-in bubble level located in the handle of the sensor. In addition to leveling, all sensors should also be mounted such that obstructions (e.g., weather station tripod/tower or other instrumentation) do not shade the sensor.

OPERATION AND MEASUREMENT

JMQ series quantum meters are designed with a user-friendly interface allowing quick and easy measurements.



To power the meter, slide the included battery (CR2320) into the battery holder, after removing the battery door from the meter's back panel. The positive side (designated by a "+" sign) should be facing out from the meter circuit board.



Press the power button to activate the LCD display. After two minutes of non-activity the meter will revert to sleep mode and the display will shut off to conserve battery life.



Press the mode button to access the main menu, where the appropriate calibration (sunlight or electric light) and manual or automatic logging are selected, and where the meter can be reset.



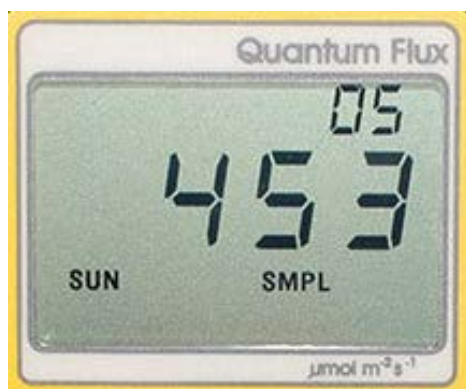
Press the sample button to log a reading while taking manual measurements.



Press the up button to make selections in the main menu. This button is also used to view and scroll through the logged measurements on the LCD display.



Press the down button to make selections in the main menu. This button is also used to view and scroll through the logged measurements on the LCD display.



The LCD display consists of the total number of logged measurements in the upper right hand corner, the real-time PPF value in the center, and the selected menu options along the bottom.

Calibration: To choose between sunlight and electric light calibration, push the mode button once and use the up/down buttons to make the appropriate selection (SUN or ELEC). Once the desired mode is blinking, press the mode button three more times to exit the menu.

Logging: To choose between manual or automatic logging, push the mode button twice and use the up/down buttons to make the appropriate selection (SMPL or LOG). Once the desired mode is blinking,

press the mode button two more times to exit the menu. When in SMPL mode press the sample button to record up to 99 manual measurements (a counter in the upper right hand corner of the LCD display indicates the total number of saved measurements). When in LOG mode the meter will power on/off to make a measurement every 30 seconds. Every 30 minutes the meter will average the sixty 30 second measurements and record the averaged value to memory. The meter can store up to 99 averages and will start to overwrite the oldest measurement once there are 99 measurements. Every 48 averaged measurements (making a 24 hour period), the meter will also store an integrated daily total in moles per meter squared per day ($\text{mol m}^{-2} \text{d}^{-1}$).

Reset: To reset the meter, in either SMPL or LOG mode, push the mode button three times (RUN should be blinking), then while pressing the down button, press the mode button once. This will erase all of the saved measurements in memory, but only for the selected mode. That is, performing a reset when in SMPL mode will only erase the manual measurements and performing a reset when in LOG mode will only erase the automatic measurements.

Review/Download Data: Each of the logged measurements in either SMPL or LOG mode can be reviewed on the LCD display by pressing the up/down buttons. To exit and return to the real-time readings, press the sample button. Note that the integrated daily total values are not accessible through the LCD and can only be viewed by downloading to a computer.

Downloading the stored measurements will require the AC -100 communication cable and software (sold separately). The meter outputs data using the UART protocol and requires the AC -100 to convert from UART to USB , so standard USB cables will not work.

(SMPL) 99 Sample Measurements	(LOG) 99 Log Measurements	(LOG) 99 Daily Total Measurements
Viewable on meter LCD & downloadable		Downloadable Only

Spectral Errors and Yield Photon Flux Measurements:

Quantum meters are calibrated to measure PPF for either sunlight or electric light (menu selectable). The difference between the calibrations is 14 %. A sensor calibrated for electric lights (calibration source is T5 cool white fluorescent lamps) will read approximately 14 % low in sunlight.

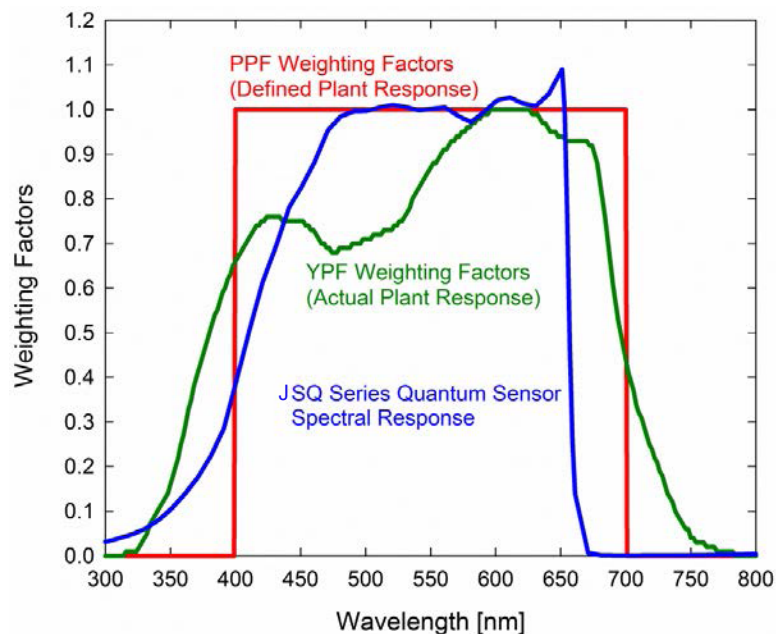
In addition to PPF measurements, JMQ series quantum meters can also be used to measure yield photon flux (YPF): photon flux weighted according to the plant photosynthetic action spectrum (McCree, 1972) and summed. YPF is also expressed in units of $\mu\text{mol m}^{-2} \text{s}^{-1}$, and is similar to PPF, but is typically more closely correlated to photosynthesis than PPF. PPF is usually measured and reported because the PPF spectral weighting function (equal weight given to all photons between 400 and 700 nm; no weight given to photons outside this range) is easier to define and measure, and as a result, PPF is widely accepted. The conversion factor to calculate YPF from the PPF measurements displayed on the LCD is 0.90 and 0.89 for sunlight and electric light measurements, respectively.

The weighting functions for PPF and YPF are shown in the graph below, along with the spectral response of quantum sensors. The closer the spectral response matches the defined PPF or YPF spectral weighting functions, the smaller spectral errors will be. The table below provides spectral error estimates for PPF and YPF measurements from light sources different than the calibration source. The method of Federer and Tanner (1966) was used to determine spectral errors based on the PPF and YPF spectral weighting functions, measured sensor spectral response, and radiation source spectral outputs.

(measured with a spectroradiometer). This method calculates spectral error and does not consider calibration, cosine, and temperature errors.

Federer, C. A., and C. B. Tanner, 1966. Sensors for measuring light available for photosynthesis. *Ecology* 47:654-657.

McCree, K. J., 1972. The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. *Agricultural Meteorology* 9:191-216.



Radiation weighting factors for PPF (defined plant response to radiation), YPF (measured plant response to radiation), and quantum sensors (sensor sensitivity to different wavelengths of radiation).

Spectral Errors for PPF and YPF Measurements with JMQ Series Quantum Meters

Radiation Source (Error Calculated Relative to Sun, Clear Sky)	PPF Error [%]	YPF Error [%]
Sun (Clear Sky)	0.0	0.0
Sun (Cloudy Sky)	1.4	1.6
Reflected from Grass Canopy	5.7	-6.3
Reflected from Deciduous Canopy	4.9	-7.0
Reflected from Conifer Canopy	5.5	-6.8
Transmitted below Grass Canopy	6.4	-4.5
Transmitted below Deciduous Canopy	6.8	-5.4
Transmitted below Conifer Canopy	5.3	2.6
Radiation Source (Error Calculated Relative to Cool White Fluorescent, T5)		
Cool White Fluorescent (T5)	0.0	0.0
Cool White Fluorescent (T8)	-0.3	-1.2
Cool White Fluorescent (T12)	-1.4	-2.0
Compact Fluorescent	-0.5	-5.3
Metal Halide	-3.7	-3.7
Ceramic Metal Halide	-6.0	-6.4
High Pressure Sodium	0.8	-7.2
Blue LED (448 nm peak, 20 nm full-width half-maximum)	-12.7	8.0
Green LED (524 nm peak, 30 nm full-width half-maximum)	8.0	26.2
Red LED (635 nm peak, 20 nm full-width half-maximum)	4.8	-6.2
Red, Blue LED Mixture (85 % Red, 15 % Blue)	2.4	-4.4
Red, Green, Blue LED Mixture (72 % Red, 16 % Green, 12 % Blue)	3.4	0.2
Cool White Fluorescent LED	-4.6	-0.6
Neutral White Fluorescent LED	-6.7	-5.2
Warm White Fluorescent LED	-10.9	-13.0

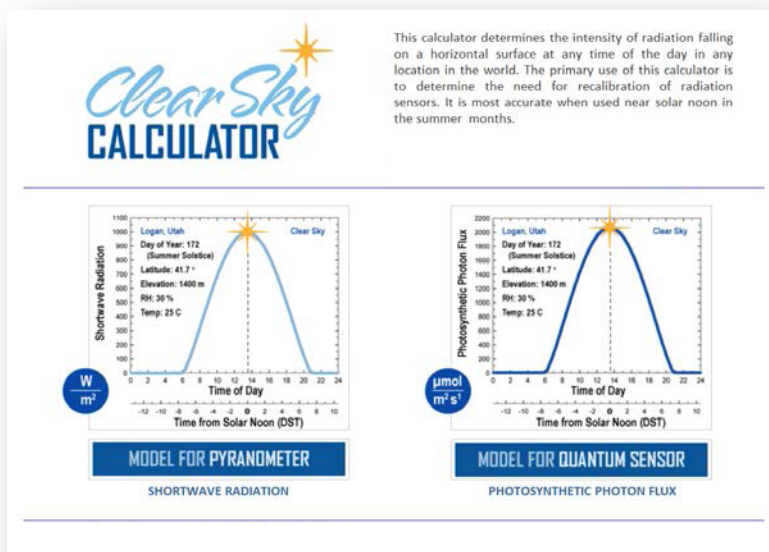
Quantum sensors can be a very practical means of measuring PPF and YPF from multiple radiation sources, but spectral errors must be considered. The spectral errors in the table above can be used as correction factors for individual radiation sources.

MAINTENANCE AND RECALIBRATION

Moisture or debris on the diffuser is a common cause of low readings. The sensor has a domed diffuser and housing for improved self-cleaning from rainfall, but materials can accumulate on the diffuser (e.g., dust during periods of low rainfall, salt deposits from evaporation of sea spray or sprinkler irrigation water) and partially block the optical path. Dust or organic deposits are best removed using water, or window cleaner and a soft cloth or cotton swab. Salt deposits should be dissolved with vinegar and removed with a soft cloth or cotton swab. **Never use an abrasive material or cleaner on the diffuser.**

The Clear Sky Calculator (www.clearskycalculator.com) can be used to determine the need for quantum meter recalibration. It determines PPF incident on a horizontal surface at any time of day at any location in the world. It is most accurate when used near solar noon in spring and summer months, where accuracy over multiple clear and unpolluted days is estimated to be $\pm 4\%$ in all climates and locations around the world. For best accuracy, the sky must be completely clear, as reflected radiation from clouds causes incoming radiation to increase above the value predicted by the clear sky calculator. Measured values of PPF can exceed values predicted by the Clear Sky Calculator due to reflection from the sides and edges of clouds. This reflection increases the incoming radiation. The influence of high clouds typically shows up as spikes above clear sky values, not a constant offset greater than clear sky values.

To determine recalibration need, input site conditions into the calculator and compare PPF measurements to calculated PPF values for a clear sky. If sensor PPF measurements over multiple days near solar noon are consistently different than calculated values (by more than 6 %), the sensor should be cleaned and re-leveled.



Homepage of the Clear Sky Calculator. Two calculators are available: one for quantum sensors (PPF) and one for pyranometers (total shortwave radiation).

Clear Sky CALCULATOR FOR QUANTUM SENSORS

1 For best accuracy, comparison should be made on clear, non-polluted, summer days within one hour of solar noon.

2 Enter input parameters in the blue cells at right. Definitions are shown below.

3 Sensor must be level and perfectly clean. Enter your measured solar radiation in the blue "Measured PPF" cell at far right.

4 Difference between the model and your sensor is shown in the yellow "DIFFERENCE FROM MODEL" cell at right.

5 Run the model on replicate days. Contact Apogee for recalibration if the measured value is more than 5 % different than the estimated value. You will be contacted within two business days.

For a discussion on model accuracy and sensitivity of input parameters, [CLICK HERE](#).

Input Parameters for Estimating Photosynthetic Photon Flux (PPF):

Latitude = 41.7°
Longitude = 111.8°
Longitude_U = 105°
Elevation = 1400 m
Day of Year = 172
Time of Day = 12.9 (6 min = 0.1 h)
Daylight Savings = + 1 hr
Air Temperature = 25 °C
Relative Humidity = 30 %

Output from Model:

Model Estimated PPF = 2037 $\mu\text{mol m}^{-2} \text{s}^{-1}$
Measured PPF = 1990 $\mu\text{mol m}^{-2} \text{s}^{-1}$
DIFFERENCE FROM MODEL = -2.3 %

CONTACT APOGEE FOR RECALIBRATION

Name: _____
E-mail: _____
Phone: _____
Serial #: _____
Comments: _____

Please include all requested information.
[SEND INFO TO APOGEE](#)

INPUT AND OUTPUT DEFINITIONS

Latitude = Latitude of the measurement site [degrees]; for southern hemisphere, insert as a negative number; info may be obtained from <http://touchmap.com/latlong.html>

Longitude = Longitude of the measurement site [degrees]; expressed as positive degrees west of the standard meridian in Greenwich, England (e.g. 74° for New York, 263° for Bangkok, Thailand, and 358° for Paris, France).

Clear Sky Calculator for quantum sensors. Site data are input in blue cells in middle of page and an estimate of PPF is returned on right-hand side of page.

TROUBLESHOOTING AND CUSTOMER SUPPORT

Verify Functionality:

Pressing the power button should activate the LCD and provide a real-time PPF reading. Direct the sensor head toward a light source and verify the PPF reading responds. Increase and decrease the distance from the sensor to the light source to verify that the reading changes proportionally (decreasing PPF with increasing distance and increasing PPF with decreasing distance). Blocking all radiation from the sensor should force the PPF reading to zero.

Battery Life:

When the meter is maintained properly the coin cell battery (CR2320) should last for many months, even after continuous use. The low battery indicator will appear in the upper left hand corner of the LCD display when the battery voltage drops below 2.8 V DC. The meter will still function correctly for some time, but once the battery is drained the pushbuttons will no longer respond and any logged measurements will be lost.

Pressing the power button to turn off the meter will actually put it in sleep mode, where there is still a slight amount of current draw. This is necessary to maintain the logged measurements in memory. Therefore, it is recommended to remove the battery when storing the meter for many months at a time, in order to preserve battery life.

Master Reset:

If a meter ever becomes non-responsive or experiences anomalies, such as a low battery indicator even after replacing the old battery, a master reset can be performed that may correct the problem. Note that a master reset will erase all logged measurements from memory.

First press the power button so that the LCD display is activated. While still powered, slide the battery out of the holder, which will cause the LCD display to fade out. After a few seconds, slide the battery back into the holder. The LCD display will flash all segments and then show a revision number (e.g. "R1.0"). This indicates the master reset was performed and the display should return to normal.

Error Codes and Fixes:

Error codes will appear in place of the real-time reading on the LCD display and will continue to flash until the problem is corrected. Contact if the following fixes do not rectify the problem.

Err 1: battery voltage out of range. **Fix:** replace CR2320 battery and perform master reset.

Err 2: sensor voltage out of range. **Fix:** perform master reset.

Err 3: not calibrated. **Fix:** perform master reset.

Err 4: CPU voltage below minimum. **Fix:** replace CR2320 battery and perform master reset.

Modifying Cable Length:

Although it is possible to splice additional cable to the separate sensor of the appropriate JMQ model, note that the cable wires are soldered directly into the circuit board of the meter. Care should be taken to remove the back panel of the meter in order to access the board and splice on the additional cable, otherwise two splices would need to be made between the meter and sensor head.

Unit Conversion Charts:

JMQ series quantum meters are calibrated to measure PPF in units of $\mu\text{mol m}^{-2} \text{s}^{-1}$. It is possible to convert the PPF value to units of light quantity (e.g., footcandles or lux), but it requires conversion factors that are specific to the radiation source of interest.

WARRANTY POLICY

What is Covered

All products manufactured are warranted to be free from defects in materials and craftsmanship for a period of four (4) years from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated either at our factory or by an authorized distributor.

What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation or abuse.
2. Operation of the instrument outside of its specified operating range.
3. Natural occurrences such as lightning, fire, etc.
4. Unauthorized modification.
5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered

This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

What We Will Do

At no charge we will:

1. Either repair or replace (at our discretion) the item under warranty.
2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer's expense.