# 1800-12
# Integrating Sphere
# Instruction Manual

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# Section I
# General Information

## 1-1 INSTRUMENT DESCRIPTION

The 1800-12 Integrating Sphere is an instrument for collecting radiation that has been reflected from or transmitted through a sample material. The sphere is designed for use with the LI-1800 Portable Spectroradiometer and 1800-10 Fiber Optic Probe. Alternatively, the LI-190S Quantum Sensor could be used as the measurement device.

Figure 1 illustrates the major parts of the 1800-12 Integrating Sphere. They are the handle (1), a sample holder (2) removable for large samples, a port for the reference disc (3), a port for the radiation sensor (4), and three ports (A,B,C) for the illuminator. Also shown is the illuminator (5), its battery 12B (6), the 1800-12B power supply (7), its battery charger (8) and the 1800-10 Fiber Optic Probe(9).

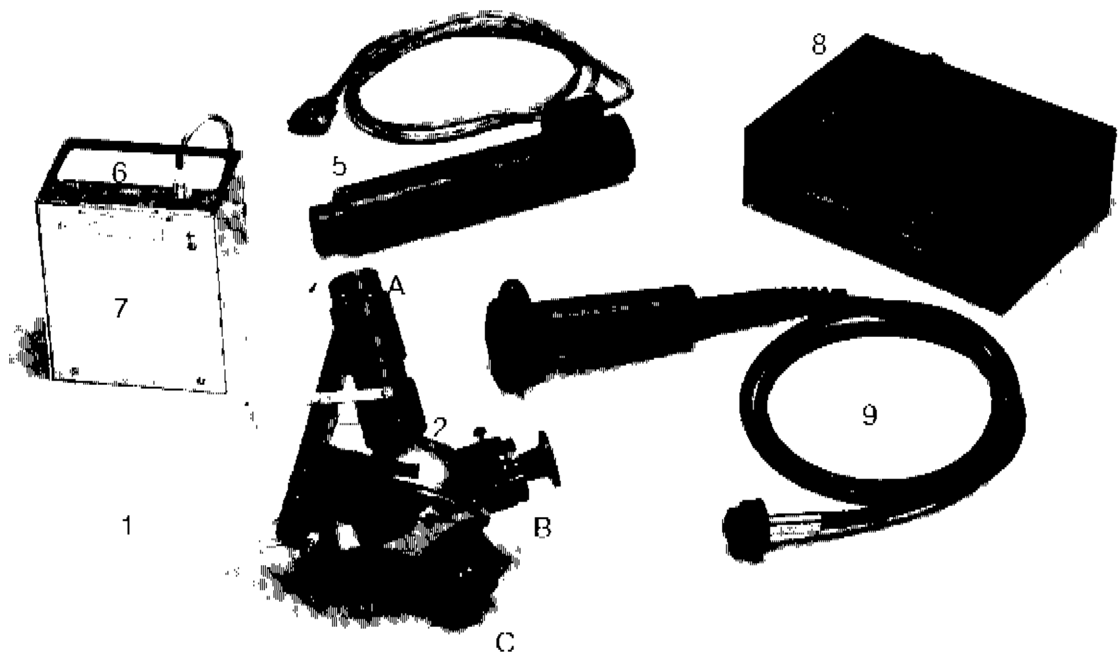


Figure 1.

## 1-2 THEORY OF OPERATION

The purpose of an integrating sphere is the collection of all the radiation that is reflected from or transmitted through a surface so that it can be measured. The 1800-12 is an external integrating sphere, which means that the sample is external to the sphere; when it is in place, a small part of the sample actually makes up part of the sphere wall. Internal integrating spheres, a style which is different from the 1800-12, have the sample entirely inside the sphere.

Figure 2 schematically presents the important features of an external integrating sphere. Note that the radiation receptor does not "see" any part of the sample; its field of view is instead entirely occupied by the sphere wall.

The most critical feature of any integrating sphere is that all points of the wall be illuminated uniformly by internal reflections. If there are bright or dark areas, then it becomes critical what part of the wall the receptor sees, and the measurement cannot be trusted. To accomplish uniform illumination of the walls, the sphere is internally coated with a reflective, diffusive material. In the case of the 1800-12, that material is barium sulfate. For further details on the performance of integrating spheres, consult "Integrating Sphere Performance" in the Appendix.

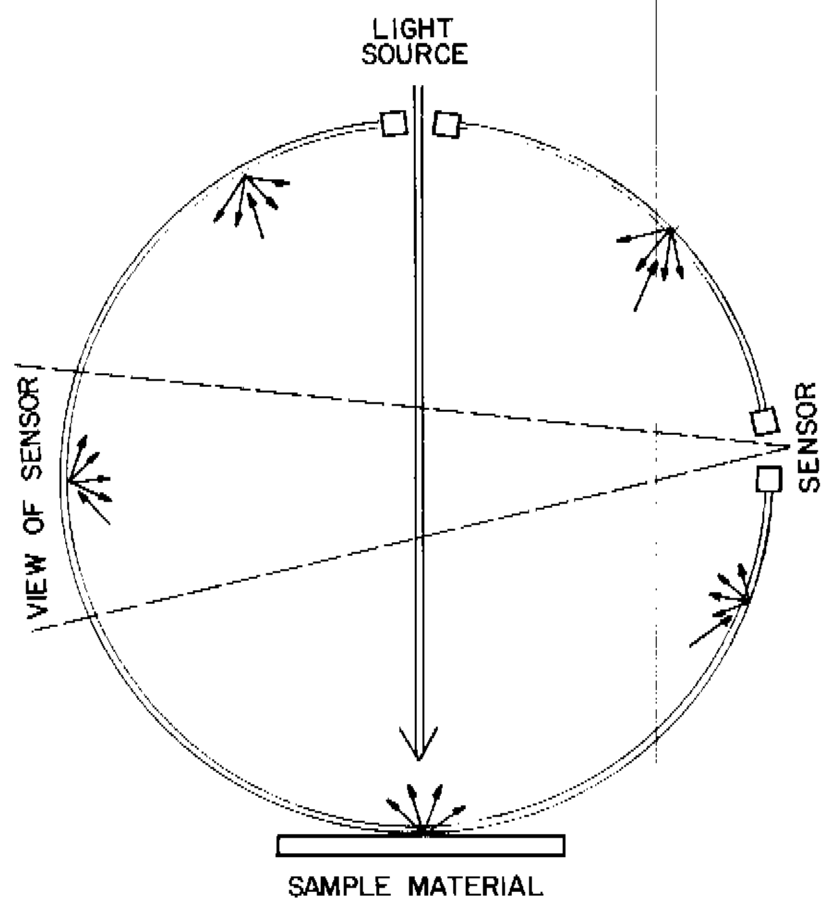


**Figure 2.**

## 1-3 REFLECTANCE

A measurement of reflectance (Figure 3) involves comparing the wall illumination caused by a focused beam of radiation reflected from the sample material (3a) to that reflected from the reference material (3b). The 1800-12 uses the same illuminator for both sample and reference measurements; it is moved from one port to the other between measurements.

In theory, the reflectance $R_s$ of the sample is

$$R_s \frac{I_s}{I_r} \tag{1.1}$$

where $I_s$ is the measured sphere output when the sample is illuminated and $I_r$ is that measured when the reference material is illuminated.

In practice, however, this may not necessarily be the case for two reasons:

1. The reference material is not 100% reflective.

2. The beam of radiation illuminating the sample or reference is not perfectly collimated. This means that some "stray" radiation is directly getting to the sphere walls without first striking the sample or reference.

If the reference material has a reflectance $R_r$, and $I_d$ is the illumination due to "stray" radiation, then

$$R_s = \frac{(I_s - I_d)\, R_r}{(I_r - I_d)} \tag{1.2}$$

$I_d$ can be measured by illuminating the sample port with no sample in place (with no radiation external to the sphere that can leak in through the uncovered sample port). Most of the radiation from the illuminator will pass out through the sample port. The only radiation illuminating the wall will be "stray".

## 1-4 TRANSMITTANCE

A measurement of transmittance (Figure 4) involves comparing the wall illumination caused by radiation that has been transmitted through the sample to that caused by radiation that did not pass through the sample. The 1800-12 uses the same illuminator for both measurements; it is moved from one port to the other.

The proper configuration for the transmittance reference (Figure 4a) is the same as that used for the reflectance reference. If, however, the sample material is not diffusive (e.g. a piece of glass), then the reflectance of the sphere wall opposite the sample port becomes important, since all the radiation coming through the sample is striking that one small spot before being diffused around the sphre. If this part of the sphere wall has a reflectance that differs from that of the reference material, then an error will be introduced in the transmittance measurement. Normally, this error is only a few percent. Non-diffuse reflective samples (e.g. mirrors) also have this potential problem. Measurements are of total reflectance (specular plus diffuse), since no light "trap" for the removal of the specular component is provided for in the sphere.

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**IMPORTANT**

The 1800-12 Integrating Sphere has not been designed for optimum performance measuring non-diffuse (specular) materials.

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When measuring non-diffusive samples, the configuration illustrated in Figure 4b could be used for the reference measurement with the sample removed from the holder. The same portion of the sphere wall will now receive the direct beam radiation for both the reference and sample measurements, and its reflectivity relative to the reference material does not matter. This method has a serious problem in that the reflectance from the sample back into the sphere effectively raises the sphere efficiency (energy out per energy in) giving transmittance values that are too large, since the sample is not in place for the reference measurement. For example, a sample whose reflectance (sphere side) is 50% can potentially raise the measured transmittance by 1.1 (10%). This points out the desirability and importance of having the sample in place for both the reference and transmittance measurements, as indicated in Figures 4a and 4b.

For diffusive samples, if the reference material has a reflectance $R_r$ less than 1 (100%), then the sample transmittance $T_s$ is

$$T_s = \frac{I_s R_r}{I_r} \qquad 1.3$$

where $I_s$ is the measured sphere output when the sample is illuminated and $I_r$ is the measured sphere output when the reference material is illuminated.

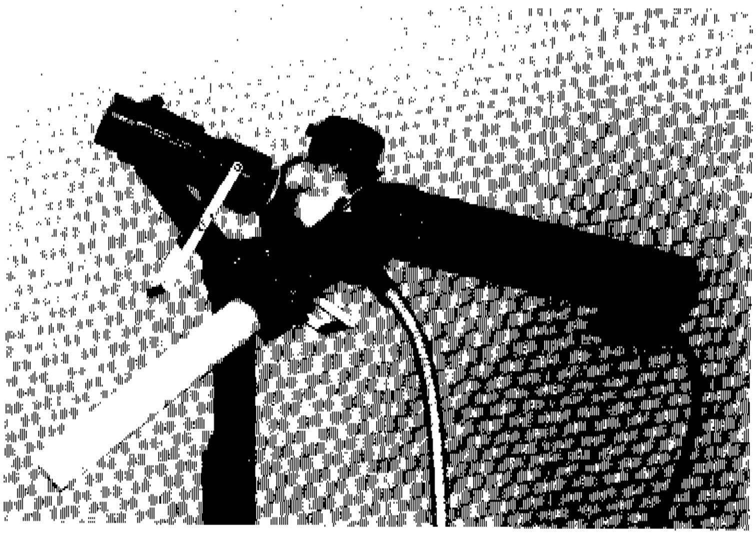


**Figure 3a.** (above) 1800-12 configured for sample reflectance measurements.

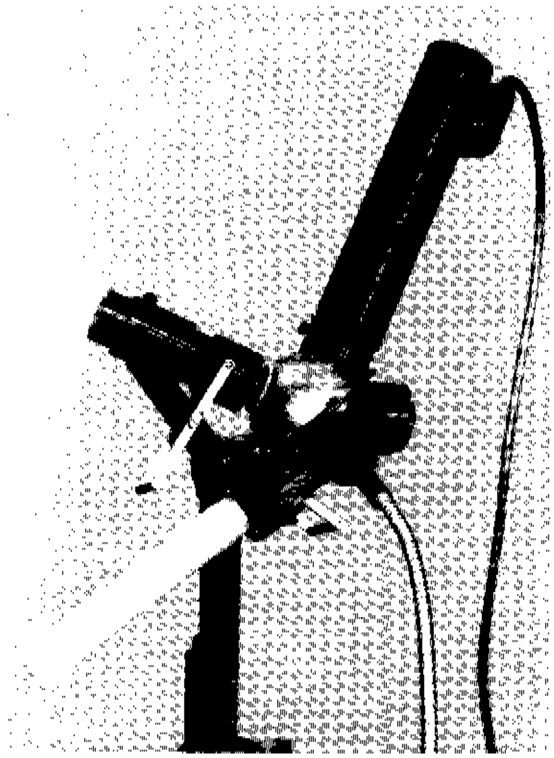
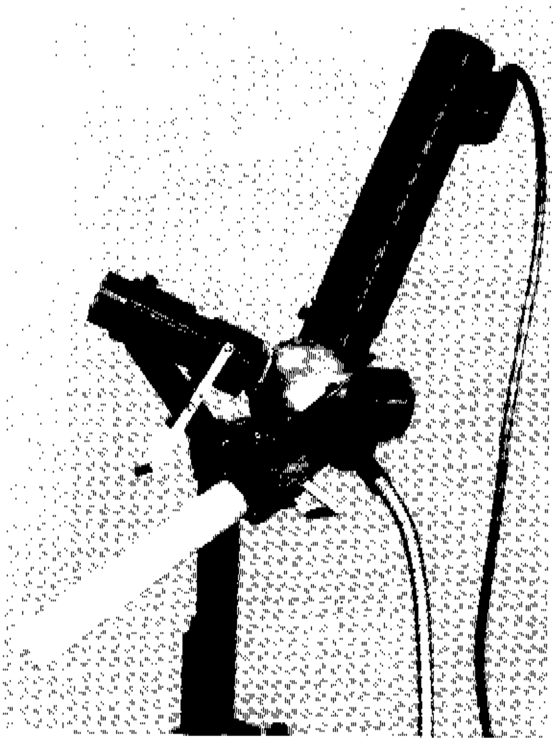


**Figure 3b.** (right) 1800-12 configured for reflectance reference measurements.



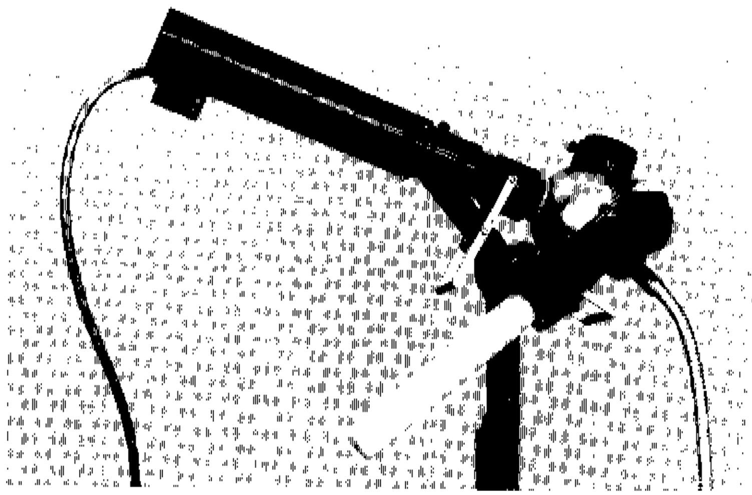


**Figure 4a.** (left) 1800-12 configured for transmittance reference measurements.

**Figure 4b.** (above) 1800-12 configured for sample transmittance measurements.

# Section II
# Preoperation

## 2-1 BATTERY

If the instrument remains unused for long periods, the battery pack should be occasionally charged, at least every two months. Batteries may be left connected to the charger for long periods.

CAUTION: Never short circuit the battery connections.

## 2-2 FILAMENT IMAGERY

A check of filament imagery should be done after shipment to verify correct alignment of the illuminator. Initial measurements of stray light and relative efficiency are done at the factory and data is supplied with the instrument. The user can verify these parameters following procedures in the maintenance section of this manual.

## 2-3 INSTALLING THE REFERENCE

NOTE: The 1800-12 is shipped with two references; one is in place already on the sphere, and the second is shipped covered by a white plastic cover held in place with a small screw.

The spare white reference standard is stored separately from the sphere to maintain cleanliness. To use, remove the cover and check (but DO NOT TOUCH) the surface. It should be smooth and flat. Withdraw the clamping screw and open fully the reference holder. Position the standard, being careful not to gouge the fragile surface. Allow the spring to close the holder and move the standard carefully until the retaining boss is inside the hole on the reference holder. Turn the retaining screw until light pressure is applied. The screw prevents the standard from being accidentally dislodged. Figure 5 illustrated the positioning of the standard in the holder.

Small indentations will occur where the edges of the reference hole touch the surface. These are not a problem.

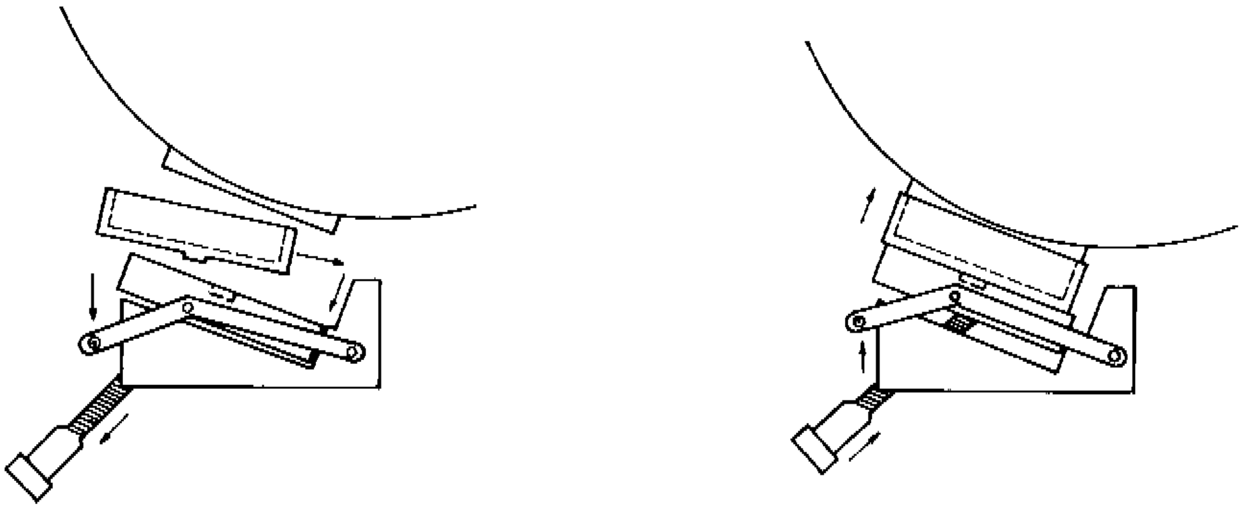


Figure 5. Positioning the standard in the holder.

# Section III
# Operation

## 3-1 MEASUREMENTS: REFERENCE, TRANSMITTANCE, REFLECTANCE

The 1800-12 Integrating Sphere has 5 ports, or openings. In addition, the sample port has behind it a port for the illuminator. Thus the key to correctly using the sphere is to know what goes where in the 6 possible locations.

The tables on this page and the next, along with Figures 3 and 4, illustrate the configurations. Each piece of the integrating sphere is color coded as a configuration aid for each mode of measurement. The color code is based on these two rules:

1. When mating any marked part, the 4 dots on the part must align with the 4 dots on the port.
2. For each mode, one of the color dots must match between the port and corresponding part; the color depends on the mode:

**WHITE** - Reference

**YELLOW** - Transmittance

**RED** - Reflectance

## 3-2 INTEGRATING SPHERE CONFIGURATIONS

<u>**Reflectance Measurements**</u>

| | **Reflectance Reference** | **Reflectance Dark Reading** | **Reflectance Sample** |
|---|---|---|---|
| **Sample Port** | Sample | Nothing | Sample |
| **Lamp Port A** | Hollow Black | Hollow Black | Hollow Black |
| **Lamp Port B** | Lamp | White Plug | White Plug |
| **Lamp Port C** | White Plug | Lamp | Lamp |
| **Dot Color** | White | Red | Red |
| **Quantity Measured** | $I_r$ | $I_d$ | $I_s$ |

For the equations below, assume $R_r = 1$ for a newly pressed barium sulfate reference.

Reflectance of a diffuse sample $$R_s = \frac{(I_s - I_d)\, R_r}{(I_r - I_d)} \qquad 1.2$$

## Transmittance Measurements

| | Transmittance Reference | Transmittance Sample |
|---|---|---|
| **Sample Port** | Sample | Sample |
| **Lamp Port A** | Hollow Black | Lamp |
| **Lamp Port B** | Lamp | Hollow Black |
| **Lamp Port C** | White Plug | White Plug |
| **Dot Color** | White | Yellow |
| **Quantity Measured** | $I_r$ | $I_t$ |

Transmittance of a diffuse sample $$T_d = \frac{I_t\, R_r}{I_r} \qquad 1.3$$

## 3-3 REMOVING THE SAMPLE HOLDER

For measuring the reflectance of objects that cannot fit in the sample holder, the holder can be removed by removing the 4 screws around the base of the plastic handle. The spare handle, included with the 1800-12, can then be inserted in the hole for the tripod mount.

## 3-4 USING THE LI-1800 PORTABLE SPECTRORADIOMETER

The 1800-12 Integrating Sphere is attached to the LI-1800 Portable Spectroradiometer by using the 1800-10 Fiber Optic Probe. The small end of the fiber cable attaches to a collar that in turn fits into the measurement port of the integrating sphere. Make certain the base is securely fastened to the LI-1800, as slight movements can cause large errors.

Once the sphere is configured for a particular measurement, that measurement is taken by instructing the LI-1800 to scan. Thus, for example, the reflectance data $I_r$, $I_s$, and $I_d$ (Eq. 1.2) would take the form of files in the memory of the spectroradiometer, and the resultant data $R_s$ would be a file as well.

Data below 390 nm is generally inaccurate since the illuminator's optics transmit little UV radiation (Fig. 6a). However, since the lamp does have a small output down to 350 nm, it is possible to qualitative data to 350 nm.

Three scans are generally used to characterize a sample; one each for reference, reflectance, and transmittance. Non-homogeneous samples (e.g. leaves) require two reference scans. When measuring leaves or other non-homogeneous materials, a separate reference scan for reflectance and transmittance is required if absorptance is to be computed (absorptance = 1 - reflectance - transmittance). The key is that the same side of the sample must be measured. The side that is facing the inside of the sphere for the reflectance measurement and reference must be facing away from the sphere's interior (but still over the port) for the transmittance measurement and its reference.

Both the reflectance and the transmittance files can be divided by the reference file using the DI function after the fact, or by setting the automatic divide (in PA function) to be the reference file before taking the reflectance or transmittance scans. NOTE: Be sure the calibration file is not being divided into three scans. It is changed using the PA function.

A typical sequence of operations to collect reflectance, transmittance, and absorptance data for the top and bottom surfaces of leaves or other non-homogeneous materials using the LI-1800 and 1800-12 is as follows:

1) Change the automatic divide in the parameters (PA) to N (not set).

2) Set the monochromator reset feature in the parameters to 1100 nm.

3) Use the H0 function to suppress the header information.

4) Take a reference standard scan with the top surface of the sample facing the sphere's interior. File name STDT.

5) Change the automatic divide in the parameters to Y and enter STDT as the file to divide by.

6) Take a reflectance scan of the top surface of the material. File name REFT.

7) Before changing the position of the material in the sample holder, take a transmittance scan through the bottom of the sample. File name TRB.

8) Change the automatic divide in the parameters to N.

9) Turn the material over and take a reference standard scan with the bottom of the material facing the inside of the sphere. File name STDB.

10) Change the automatic divide in the parameters to Y and designate STDB as the file to divide by.

11) Take a reflectance scan of the bottom surface of the material. File name REFB.

12) Take a transmittance scan through the top of the sample. File name TRT.

13) Find the absorptance of the top surface using the transform (XF) function. The equation used in this computation is F = aA + bB + c. In this example, F = absorptance, a = -1, A = REFT, b = -1, B = TRT, and c = 1.

14) To find absorptance of the bottom surface, use the transform function with a = -1, A = REFB, b = -1, B = TRB, and c = 1.

## 3-5 LOW BATTERY

The battery life of the 1800-12 is 1.5 hours of continuous operation. When the battery voltage drops to a certain level, an audible tone will sound. A few minutes of effective life remains at this point. Low batteries should be recharged as soon as possible. A full charge can be obtained by charging overnight (12-14 hours). If the LI-1800 is being used, it is good practice to repeat a scan that is in progress when the tone sounds, after installing a fresh battery.

## 3-6 FOR BEST RESULTS . . .

A certain amount of care and technique is required to get consistent, high accuracy with the 1800-12. Below are some items to keep in mind:

1. Keep the inside of the sphere clean and dry. Dust and debris should be removed carefully with dry air. **CAUTION:** The sphere coating is fragile and may be damaged by cleaning with a high pressure air source. Keep the ports covered and the cap on the illuminator when not in use. In dusty environments, store all components in a clean plastic bag. NEVER apply water to the sphere.

2. A reflectance or transmittance measurement is only as good as the reference. Periodic renewal is necessary. See Section IV MAINTENANCE.

3. Allow the illuminator lamp to warm up at least 30 seconds before taking any data. It can be shut off between measurements to preserve battery life. For highest accuracy at short wavelengths, a longer warm up may be needed.

4. If using the fiber optic cable, try to preserve its orientation from one measurement to the next. In other words, don't have it coiled for the reference measurement and uncoiled for the data measurement.

5. Illuminator output can vary 1% or more if its orientation with respect to gravity is changed. This is due to sag of the hot filament. This error can be eliminated by maintaining the sphere ports A, B, and C (Fig. 1) in a horizontal plane. Attaching the sphere to a standard camera tripod is a convenient way to do this. A test for the effect of gravity on the lamp is described in Section 4-10.

6. When measuring leaves or other non-homogeneous materials, a separate reference scan for reflectance and transmittance is required if absorptance is to be computed (absorptance = 1 - reflectance - transmittance). The key is that the same side of the sample must be measured. The side that is facing the inside of the sphere for the reflectance measurement and reference must be facing away from the sphere (but still over the port) for the transmittance measurement and its reference.

7. When measuring thick of non-flat samples, make sure that no ambient light enters the sphere around the sample. This can be accomplished by placing a black cloth cover over the sphere and the sample.

# Section IV
# Maintenance

## 4-1 RECHARGING THE BATTERIES

Make sure the AC line voltage matches that of the battery charger. Plug into AC and connect the battery pack. The FAST CHARGE lamp will illuminate progressively less as the battery charges.

Do not store batteries in a discharged state, as damage can occur.

Connecting the charger while using the instrument allows some charging to occur if the on time of the lamp is below 40%.

## 4-2 CHECKING ILLUMINATOR ALIGNMENT

The illuminator is designed such that a real image of the lamp filament is formed at approximately the exit plane of the illuminator. This assures optimum efficiency for all wavelengths by providing more light into the sphere and less dark reading "stray" light. Rough handling can alter this alignment.

To check illuminator alignment, place a translucent target (such as a piece of graph paper) at the exit hole, turn on the lamp, and observe the pattern. Avoid looking directly into the light, as it is very intense. The entrance ports of the sphere are elongated holes 1.14 by 2.08 centimeters. The filament image, which appears on the target as a blurry rectangle, must fall within this size and be as well centered as possible in the opening.

To adjust the alignment:

1. Remove the screws marked "A" in Figure 7a, and lift the cover off, being careful not to strain the wires connected to the lamp socket.

2. If the image is off center, lateral adjustment of the lamp socket is made by loosening screws "B" (Figure 7b) slightly until bracket "C" can be moved by slight pressure. Avoid overly loosening or removing these screws.

3. If the image of the filament is excessively blurry or indistinct, focusing can be done by moving the lamp closer to or further from the condensor lens. If the lamp is too close to the lens, an orange haze will surround the image. If the lamp is too far from the lens, a blue haze will surround the image. The optimal position is that which minimizes both colors of haze.

   To adjust the lamp-lens distance, loosen screws "D" (Figure 7b), and slide the bracket forward or backward. If this does not provide enough travel, it is necessary to loosen screws "E" and move the lamp socket. This may affect the lateral adjustment. If the lamp socket cannot be moved sufficiently, the bulb itself can be very carefully bent forward or backward.

   **CAUTION:** Do not overtighten screws "E" or the lamp socket will be broken.

Additional aids to these adjustments are as follows:

With the lamp off, loosen three set screws "F" (Figure 7a) and remove the end cover. Room light will pass back through the optics and appear as a circle of light on the lamp. Look closely at the lamp filament. It should be centered within this circle of light. If it is not centered, lateral adjustment is needed. If the position of the lamp centering in the circle of light appears to change when viewed from different angels, focusing is needed.

When all alignment and focusing adjustments are made, retighten all screws and reassemble. Recheck the illuminator using the translucent screen.

Errors which can result from incorrect alignment are:

1. Loss of sensitivity at all wavelengths or at certain spectral regions.

2. Increased stray light.

3. Inability to make accurate readings, particularly of transmittance.

## 4-3 CHECKING SPHERE EFFICIENCY AND STRAY LIGHT

Set the sphere to the reference mode with no sample present (white dots aligned). Scan the full wavelength range of the LI-1800 and plot the results, and compare with the efficiency data initially supplied with the 1800-12. As the sphere coating ages and becomes soiled, the magnitude of these values will decrease.

Illuminator misalignment will also cause the same thing, although it can cause more severe drop in certain spectral regions. When the values fall to about 1/3 of the original values, sphere recoating is advised unless the noisiness of the data is not considered a problem. The accuracy is not affected, only the signal to noise ratio. Fiber optic degradation can also cause these values to drop.

## 4-4 STRAY LIGHT

To check stray light, configure the sphere for reflectance (red dots aligned), but use no sample. Take one or more scans. Divide this file by the reference file (taken with no sample), and plot the results. The values should be under 1/2 % (0.005) and relatively constant across the spectrum. High values indicate misalignment or dirty optics.

The exit lens can be cleaned by blowing dry air towards the lens from the exit hole. Another cause of high stray light readings is port misalignment, such that the project spot from the illuminator strikes part of the edge of the sample port. This can be checked by holding a translucent target over the sample port hole and observing the spot, which should be completely contained in the perimeter of the hole. If it is not, sphere or illuminator damage has occurred.

## 4-5 BEAM BALANCE

Beam balance is a test of sphere efficiency for light entering the reference position and sample position illuminator ports.

1. Configure for reference measurements (white dots), with a white, diffuse reflector (such as the spare reference) in the sample port, and take one or more scans.

2. Configure the sphere for reflectance (red dots). In addition, exchange the reference and the sample, so that the illuminator is again shining on the reference. Take one or more scans.

3. Divide the reflectance file by the reference file. The average value of the result should be 1.00 +/-.01.

4. Carefully replace the reference.

If the results from number 3 above are out of tolerance, it may be an indication of sphere damage, or a reference with poor surface conditions rendering it insufficiently diffuse. It may also indicate significant illuminator misalignment.

## 4-6 TRANSMITTANCE MODE CHECK

Configure the sphere for a reference (white dots) with no sample in place, and take a scan. Reconfigure for transmittance (yellow dots) still with no sample in place, and take a scan. Divide the transmittance data by the reference data; this is a measure of a 100% transmitting specular sample, which depends on sphere wall reflectance. In a newly coated sphere, the average value should be greater than 0.97.

## 4-7 CLEANING THE SPHERE

The only practical method for cleaning the interior is clean, dry air.

CAUTION: High pressure air can damage the barium sulfate coating of the sphere, and is particularly harmful to the reference.

When cleaning the exterior, make sure no contamination of the interior occurs, either through the ports or through the hemisphere edges.

## 4-8 PACKING A REFERENCE BLOCK

The reference in the 1800-12 should be periodically checked for cleanliness. An easy test is to visually compare the used reference to the unused spare reference which is provided with the 1800-12. If the reference needs to be replaced, a suitable material is Eastman Kodak 6091 (catalog number 118 1841). This is a specially refined barium sulfate powder which is often used as an optical reference standard. The cavity of the reference block is packed with 9.6 grams of the material to a resulting density of 2 $gm/cm^3$. Contamination must be avoided. Pressing should be done with a very fine matte glass surface to provide a smooth, flat, yet non-glossy surface. Pay particular attention to the central 1.3 cm diameter. Outside of the central 1.3 cm, small surface irregularities are not critical.

If surface contamination or gouging occurs, scrape out about 3.0 mm or more of the material and repack with a proportional amount.

## 4-9 CHANGING THE ILLUMINATOR LAMP

The 1800-12L Lamp should provide approximately 100 hours of operating time. To replace the illuminator lamp, remove screws A (Figure 7a) and D (Figure 7b) completely, and carefully lift out the entire bracket and socket assembly. Loosen the 4 small screws G (Fig. 7c) retaining the lamp leads and replace the lamp.

**CAUTION:** Be certain no portion of the glass on the new lamp touches the socket.

**CAUTION:** Do NOT over-tighten the 4 small screws (G) holding the lamp leads or the socket may break. They should be snug, however. Be certain the lamp bulb is thoroughly clean before reassembly.

**CAUTION:** Scratches and fingerprints on the bulb can cause it to fail prematurely or even explode.

**CAUTION:** Never look directly at the lighted bulb.

Replace the socket and align as described above (4-2 CHECKING ILLUMINATOR ALIGNMENT). Coarse adjustments are possible by bending the lamp leads, being sure not to stress or crack the metal to glass seal area of the lamp. It is helpful to look at the old lamp being replaced to see what direction it was bent and by how much.

## 4-10 CHECKING LAMP GRAVITY EFFECT

Configure the sphere for reference mode (white dots aligned) with no sample present. Turn on the lamp and let it warm up for 30 seconds. Set the LI-1800 to point scan (PT command) at a wavelength such as 700 nm. Hold the sphere with the illuminator horizontal and slowly rotate it about the cylindrical axis of the illuminator. That is, rotate the sphere so as to roll the illuminator.

Observe the minimum and maximum values obtained while rotating the sphere. A difference of at least 1% is typical. If you find signigicantly larger differences it may indicate loose parts or poor alignment. If loose or misaligned parts are not found, the error is likely due to inconsistencies in the lamp envelope. The lamp gravity effect will not cause significant error if the sphere is always oriented so that the illuminator ports are in a horizontal plane.

## 4-11 CHECKING FIBER OPTIC STABILITY

Configure the sphere and LI-1800 as described for the LAMP GRAVITY CHECK (4-10). Slowly and very carefully flex the fiber optic cable, keeping the sphere and illuminator fixed, and observe the readings from the point scan. Be certain both ends of the probe are securely fastened.

Any changes in the readings due to moving the cable may indicate broken fibers in the probe, or loose parts. Normally this effect is negligible.

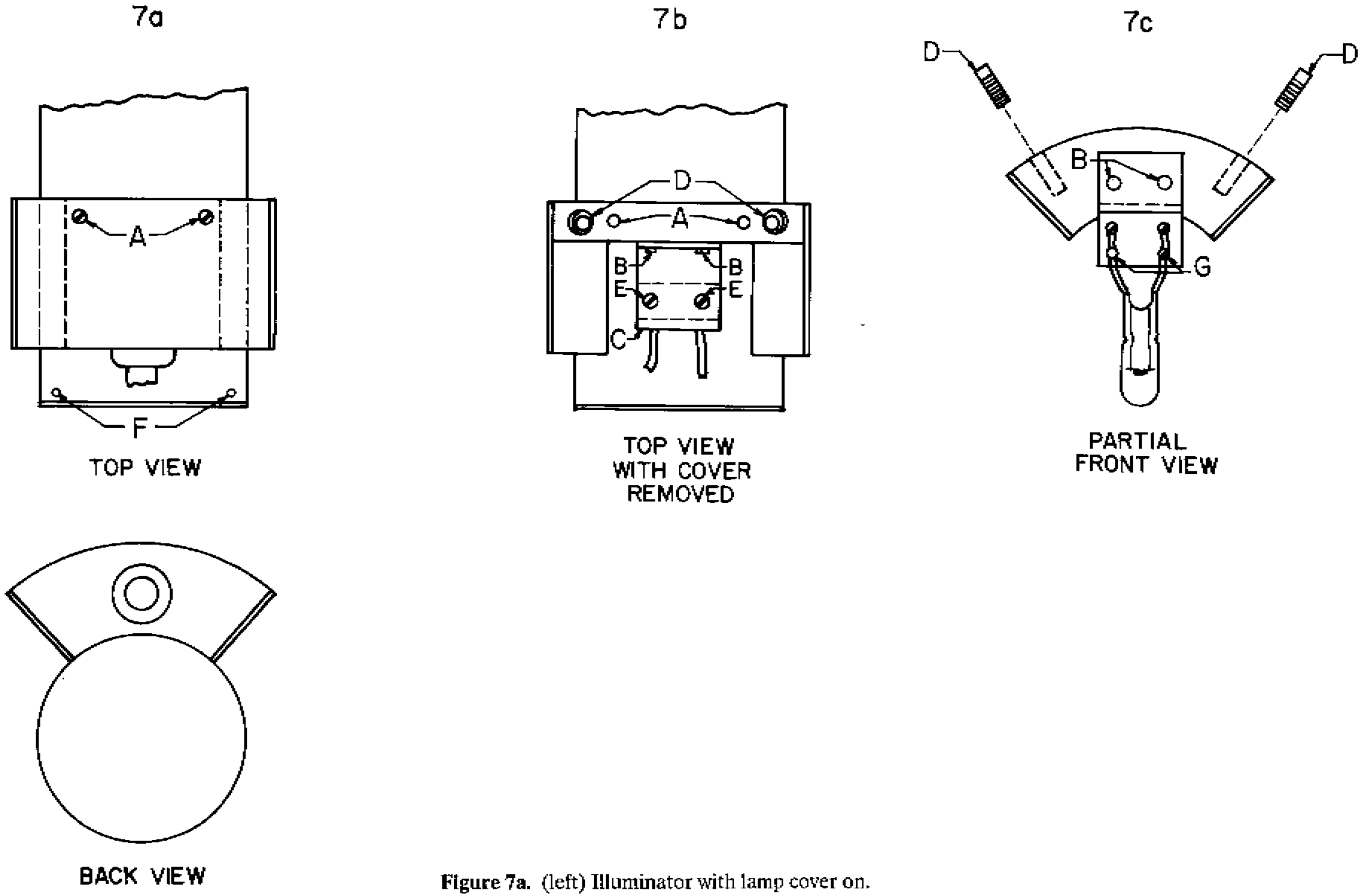



**Figure 7a.** (left) Illuminator with lamp cover on.
**Figure 7b.** (center) Illuminator with lamp cover off.
**Figure 7c.** (right) Lamp bracket, side view.

# Appendix A

## 1800-12 SPECIFICATIONS

**Wavelength Range:** 390-1100 nm.
**Sphere Coating:** Barium Sulfate.
**Sample Port:** 1.45 cm diameter.
**Sample Thickness:** 1.3 cm maximum with sample clamp in place. The clamp can be removed for reflectance measurements of solid samples.
**Entrance Ports (3):** One each for reference, reflectance, and transmittance.
**Output Port:** 0.64 cm diameter. Designed for use with 1800-10 Fiber Optic Probe (measurement angle: 20°) and LI-1800 Portable Spectroradiometer.
**Reference Sample Disk:** Uses pressed barium sulfate.
**Spot diameter:** 1.14 cm.
**Illuminator:**
- **Spot Diameter:** 1.14 cm.
- **Stray Light:** < 0.5%.
- **Lamp:** 6 V, 10 Watt glass-halogen.
- **Lamp Life:** 100 hours. The illuminator contains heat filters to reduce sample heating.
- **Size:** 5 cm Dia. x 20 cm L.

### 1800-12B Power Supply and Battery Charger

**Regulated Power Supply:** Uses a 12 V sealed lead acid rechargeable battery.
**Battery Capacity:** 1.5 hours of continuous operation (spare batteries are available).
**LI-6020 Battery Charger:** 92-138/184-276 VAC, 47-63 Hz, 25 watt maximum.
**Recharging Time:** 3 hours with 1 battery, 16 hours with 4 batteries.

# Warranty

Each LI-COR, inc. instrument is warranted by LI-COR, inc. to be free from defects in material and workmanship; however, LI-COR, inc.'s sole obligation under this warranty shall be to repair or replace any part of the instrument which LI-COR, inc.'s examination discloses to have been defective in material or workmanship without charge and only under the following conditions, which are:

1. The defects are called to the attention of LI-COR, inc. in Lincoln, Nebraska, in writing within one year after the shipping date of the instrument.
2. The instrument has not been maintained, repaired or altered by anyone who was not approved by LI-COR, inc.
3. The instrument was used in the normal, proper and ordinary manner and has not been abused, altered, misused, neglected, involved in an accident or damaged by act of God or other casualty.
4. The purchaser, whether it is a DISTRIBUTOR or direct customer of LI-COR or a DISTRIBUTOR'S customer, packs and ships or delivers the instrument to LI-COR, inc. at LI-COR inc.'s factory in Lincoln, Nebraska, U.S.A. within 30 days after LI-COR, inc. has received written notice of the defect. Unless other arrangements have been made in writing, transportation to LI-COR, inc. (by air unless otherwise authorized by LI-COR, inc.) is at customer expense.
5. No-charge repair parts may be sent at LI-COR, inc.'s sole discretion to the purchaser for installation by purchaser.
6. LI-COR, inc.'s liability is limited to repair or replace any part of the instrument without charge if LI-COR, inc.'s examination disclosed that part to have been defective in material or workmanship.

**There are no warranties, express or implied, including but not limited to any implied warranty of merchantability of fitness for a particular purpose on underwater cables or on expendables such as batteries and lamps.**

**Other than the obligation of LI-COR, inc. expressly set forth herein, LI-COR, inc. disclaims all warranties of merchantability or fitness for a particular purpose. The foregoing constitutes LI-COR, inc.'s sole obligation and liability with respect to damages resulting from the use or performance of the instrument and in no event shall LI-COR, inc. or its representatives be liable for damages beyond the price paid for the instrument, or for direct, incidental or consequential damages.**

The laws of some locations may not allow the exclusion or limitation on implied warranties or on incidental or consequential damages, so the limitations herein may not apply directly. This warranty gives you specific legal rights, and you may already have other rights which vary from state to state. All warranties that apply, whether included by this contract or by law, are limited to the time period of this warranty which is a twelve-month period commencing from the date the instrument is shipped to a user who is a customer or eighteen months from the date of shipment to LI-COR, inc.'s authorized distributor, whichever is earlier.

This warranty supersedes all warranties for products purchased prior to June 1, 1984, unless this warranty is later superseded.

DISTRIBUTOR or the DISTRIBUTOR's customers may ship the instruments directly to LI-COR if they are unable to repair the instrument themselves even though the DISTRIBUTOR has been approved for making such repairs and has agreed with the customer to make such repairs as covered by this limited warranty.

Further information concerning this warranty may be obtained by writing or telephoning Warranty manager at LI-COR, inc.

IMPORTANT: Please return the User Registration Card enclosed with your shipment so that we have an accurate record of your address. Thank you.

## Maintenance Instructions for Lead-acid Replacement Batteries

G811 battery for LI-1600 Steady State Porometer
6000B battery for LI-6000 Portable Photosynthesis System
12B/1 battery for 1800-12 External Integrating Sphere

Often extra batteries are purchased for portable electronic instruments. Sometimes these batteries are set on a shelf until the battery in operation runs down, expecting the stored battery to be in good condition. This scheme will not always work.

Although these lead-acid batteries are durable, long-life batteries, a certain amount of care in their use will ensure maximum life expectancy. Below are a few tips in addition to those in the instruction manual.

1) Storing the battery in a discharged state can ruin it. All batteries that have been used during the day should be charged at the end of that day. Waiting until all of the batteries are drained before charging could take several days and may be harmful to the batteries which were first discharged.

2) Do not charge fully charged and fully drained batteries at the same time. Overcharging of the fresh battery will result.

3) If a battery seems weak, cycle according to Section 8-2 in the LI-6000 instruction manual, allowing the battery to charge for 24 hours after the charge light goes out. Caution! This may only help slightly. What may need to be done is to force a charge into the battery. Contact LI-COR for advice.

4) Freshly discharged batteries usually recover somewhat after being idle for an hour or two, and might provide an additional 10 or 15 minutes of use. However, be cautious about taking advantage of this, since battery life (number of cycles) decreases with deeper discharges.

5) Store batteries in a cool place.

6) Batteries not in use need to be either recharged or rotated every 3 months. This ensures the stored ones are charged. Rotation should be exchanged with batteries in use.

7) To store your console longer than 1 month, unplug the battery from the console. The main battery is also charging the memory back-up battery. After 3 months the main battery will be drained. The memory back-up battery should keep the memory valid for over 6 months.

May, 1985