Light meter

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A **light meter** is a device used to measure the amount of light. In photography, a light meter is often used to determine the proper exposure for a photograph. Typically a light meter will include a computer, either digital or analog, which allows the photographer to determine which shutter speed and f-number should be selected for an optimum exposure, given a certain lighting situation and film speed.

Use of a light meter for portrait cinematography in a music video set

Light meters are also used in the fields of cinematography and scenic design, in order to determine the optimum light level for a scene. They are used in the general field of lighting, where they can help to reduce the amount of waste light used in the home, light pollution outdoors, and plant growing to ensure proper light levels.

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Use in photography

A handheld digital light meter showing an exposure of 1/200th at an aperture of f/11, at ISO 100. The light sensor is on top, under the white integrating sphere.

The earliest type of light meters were called *extinction meters* and contained a numbered or lettered row of neutral density filters of increasing density. The photographer would position the meter in front of his subject and note the filter with the greatest density that still allowed incident light to pass through. The letter or number corresponding to the filter was used as an index into a chart of appropriate aperture and shutter speed combinations for a given film speed.

Extinction meters suffered from the problem that they depended on the light sensitivity of the human eye (which can vary from person to person) and subjective interpretation.

Later meters removed the human element and relied on technologies incorporating selenium, CdS, and silicon photodetectors.

Amateur analog light meter (1968, USSR)

Selenium and silicon light meters use sensors that are photovoltaic: they *generate* a voltage proportional to light exposure. Selenium sensors generate enough voltage for direct connection to a meter; they need no battery to operate and this made them very convenient in completely mechanical cameras. Selenium sensors however cannot measure low light accurately (ordinary lightbulbs can take them close to their limits) and are altogether unable to measure very low light, such as candlelight, moonlight, starlight etc. Silicon sensors need an amplification circuit and require a power source such as batteries to operate. CdS light meters use a sensor based on photoresistance, i.e. their electrical resistance changes proportionately to light exposure. These also require a battery to operate. Most modern light meters use silicon or CdS sensors. They indicate the exposure either with a needle galvanometer or on an LCD screen.

Many modern consumer still and video cameras include a built-in meter that measures a scene-wide light level and are able to make an approximate measure of appropriate exposure based on that. Photographers working with controlled lighting and cinematographers use handheld light meters to precisely measure the light falling on various parts of their subjects and use suitable lighting to produce the desired exposure levels.

There are two general types of light meters: reflected-light and incident-light. **Reflected-light meters** measure the light *reflected by the scene* to be photographed. All in-camera meters are reflected-light meters. Reflected-light meters are calibrated to show the appropriate exposure for “average” scenes. An unusual scene with a preponderance of light colors or specular highlights would have a higher reflectance; a reflected-light meter taking a reading would incorrectly compensate for the difference in reflectance and lead to underexposure. Badly underexposed sunset photos are common exactly because of this effect: the brightness of the setting sun fools the camera's light meter and, unless the in-camera logic or the photographer take care to compensate, the picture will be grossly underexposed and dull.

This pitfall (but not in the setting-sun case) is avoided by **incident-light meters** which measure the amount of light *falling on the subject* using an integrating sphere (usually, a translucent hemispherical plastic dome is used to approximate this) placed on top of the light sensor. Because the incident-light reading is independent of the subject's reflectance, it is less likely to lead to incorrect exposures for subjects with unusual average reflectance. Taking an incident-light reading requires placing the meter at the subject's position and pointing it in the general direction of the camera,


An automatic light meter/exposure unit from an 8 mm movie camera, based on a galvanometer mechanism (center) and a CdS photoresistor, in opening at left.

something not always achievable in practice, e.g., in landscape photography where the subject distance approaches infinity.

Another way to avoid under- or over-exposure for subjects with unusual reflectance is to use a **spot meter**: a reflected-light meter that measures light in a very tight cone, typically with a one degree circular angle of view. An experienced photographer can take multiple readings over the shadows, midrange and highlights of the scene to determine optimal exposure, using systems like the Zone System. Many modern cameras include sophisticated multi-segment metering systems that measure the luminance of different parts of the scene to determine the optimal exposure. When using a film whose spectral sensitivity is not a good match to that of the light meter, for example orthochromatic black-and-white or infrared film, the meter may require special filters and re-calibration to match the sensitivity of the film.

There are other types of specialized photographic light meters. Flash meters are used in flash photography to verify correct exposure. Color meters are used where high fidelity in color reproduction is required. Densitometers are used in photographic reproduction.

Exposure meter calibration

In most cases, an incident-light meter will cause a medium tone to be recorded as a medium tone, and a reflected-light meter will cause *whatever is metered* to be recorded as a medium tone. What constitutes a “medium tone” depends on meter calibration and several other factors, including film processing or digital image conversion.

Meter calibration establishes the relationship between subject lighting and recommended camera settings. The calibration of photographic light meters is covered by ISO 2720:1974.

Exposure equations

For reflected-light meters, camera settings are related to ISO speed and subject luminance by the reflected-light exposure equation:

$$\frac{N^2}{t} = \frac{LS}{K}$$

where

- N is the relative aperture (f-number)
- t is the exposure time ("shutter speed") in seconds
- L is the average scene luminance
- S is the ISO arithmetic speed
- K is the reflected-light meter calibration constant

For incident-light meters, camera settings are related to ISO speed and subject illuminance by the incident-light exposure equation:

$$\frac{N^2}{t} = \frac{ES}{C}$$

where

- E is the illuminance
- C is the incident-light meter calibration constant

Calibration constants

Determination of calibration constants has been largely subjective; ISO 2720:1974 states that

> The constants K and C shall be chosen by statistical analysis of the results of a large number of tests carried out to determine the acceptability to a large number of observers, of a number of photographs, for which the exposure was known, obtained under various conditions of subject manner and over a range of luminances.

In practice, the variation of the calibration constants among manufacturers is considerably less than this statement might imply, and values have changed little since the early 1970s.

ISO 2720:1974 recommends a range for K of 10.6 to 13.4 with luminance in cd/m². Two values for K are in common use: 12.5 (Canon, Nikon, and Sekonic[1]) and 14 (Minolta,[2] Kenko,[2] and Pentax); the difference between the two values is approximately 1/6 EV.

The earliest calibration standards were developed for use with wide-angle averaging reflected-light meters (Jones and Condit 1941). Although wide-angle average metering has largely given way to other metering sensitivity patterns (e.g., spot, center-weighted, and multi-segment), the values for K determined for wide-angle averaging meters have remained.

The incident-light calibration constant depends on the type of light receptor. Two receptor types are common: flat (cosine-responding) and hemispherical (cardioid-responding). With a flat receptor, ISO 2720:1974 recommends a range for C of 240 to 400 with illuminance in lux; a value of 250 is commonly used. A flat receptor typically is used for measurement of lighting ratios, for measurement of illuminance, and occasionally, for determining exposure for a flat subject.

For determining practical photographic exposure, a hemispherical receptor has proven more effective. Don Norwood, inventor of incident-light exposure meter with a hemispherical receptor, thought that a sphere was a reasonable representation of a photographic subject. According to his patent (Norwood

1938), the objective was

> to provide an exposure meter which is substantially uniformly responsive to light incident upon the photographic subject from practically all directions which would result in the reflection of light to the camera or other photographic register.

and the meter provided for "measurement of the effective illumination obtaining at the position of the subject."

With a hemispherical receptor, ISO 2720:1974 recommends a range for C of 320 to 540 with illuminance in lux; in practice, values typically are between 320 (Minolta) and 340 (Sekonic). The relative responses of flat and hemispherical receptors depend upon the number and type of light sources; when each receptor is pointed at a small light source, a hemispherical receptor with C = 330 will indicate an exposure approximately 0.40 step greater than that indicated by a flat receptor with C = 250. With a slightly revised definition of illuminance, measurements with a hemispherical receptor indicate "effective scene illuminance."

Calibrated reflectance

It is commonly stated that reflected-light meters are calibrated to an 18% reflectance,[3] but the calibration has nothing to do with reflectance, as should be evident from the exposure formulas. However, some notion of reflectance is implied by a comparison of incident- and reflected-light meter calibration.

Combining the reflected-light and incident-light exposure equations and rearranging gives

$$\frac{L}{E} = \frac{K}{C}$$

Reflectance R is defined as

$$R = \frac{\text{flux emitted from surface}}{\text{flux incident upon surface}}$$

A uniform perfect diffuser (i.e., one following Lambert's cosine law) of luminance L emits a flux density of πL; reflectance then is

$$R = \frac{\pi L}{E} = \frac{\pi K}{C}$$

Illuminance is measured with a flat receptor. It is straightforward to compare an incident-light measurement using a flat receptor with a reflected-light measurement of a uniformly illuminated flat surface of constant reflectance. Using values of 12.5 for K and 250 for C gives

$$R = \frac{\pi \times 12.5}{250} \approx 15.7\%$$

With a K of 14, the reflectance would be 17.6%, close to that of a standard 18% neutral test card. In theory, an incident-light measurement should agree with a reflected-light measurement of a test card of suitable reflectance that is perpendicular to the direction to the meter. However, a test card seldom is a uniform diffuser, so incident- and reflected-light measurements might differ slightly.

In a typical scene, many elements are not flat and are at various orientations to the camera, so that for practical photography, a hemispherical receptor usually has proven more effective for determining exposure. Using values of 12.5 for K and 330 for C gives

$$R = \frac{\pi \times 12.5}{330} \approx 11.9\%$$

With a slightly revised definition of reflectance, this result can be taken as indicating that the average scene reflectance is approximately 12%. A typical scene includes shaded areas as well as areas that receive direct illumination, and a wide-angle averaging reflected-light meter responds to these differences in illumination as well as differing reflectances of various scene elements. Average scene reflectance then would be

$$\text{average scene reflectance} = \frac{\text{average scene luminance}}{\text{effective scene illuminance}}$$

where "effective scene illuminance" is that measured by a meter with a hemispherical receptor.

ISO 2720:1974 calls for reflected-light calibration to be measured by aiming the receptor at a transilluminated diffuse surface, and for incident-light calibration to be measured by aiming the receptor at a point source in a darkened room. For a perfectly diffusing test card and perfectly diffusing flat receptor, the comparison between a reflected-light measurement and an incident-light measurement is valid for any position of the light source. However, the response of a hemispherical receptor to an off-axis light source is approximately that of a cardioid rather than a cosine, so the 12% "reflectance" determined for an incident-light meter with a hemispherical receptor is valid only when the light source is on the receptor axis.

Cameras with internal meters

Calibration of cameras with internal meters is covered by ISO 2721:1982; nonetheless, many manufacturers specify (though seldom state) exposure calibration in terms of K, and many calibration instruments (e.g., Kyoritsu-Arrowin multi-function camera testers[4]) use the specified K to set the test parameters.

Exposure determination with a neutral test card

If a scene differs considerably from a statistically average scene, a wide-angle averaging reflected-light measurement may not indicate the correct exposure. To simulate an average scene, a substitute measurement sometimes is made of a neutral test card, or *gray card*.

At best, a flat card is an approximation to a three-dimensional scene, and measurement of a test card may lead to underexposure unless adjustment is made. The instructions for a Kodak neutral test card recommend that the indicated exposure be increased by ½ step for a frontlighted scene in sunlight. The instructions also recommend that the test card be held vertically and faced in a direction midway between the Sun and the camera; similar directions are also given in the *Kodak Professional Photoguide*. The combination of exposure increase and the card orientation gives recommended exposures that are reasonably close to those given by an incident-light meter with a hemispherical receptor when metering with an off-axis light source.

In practice, additional complications may arise. Many neutral test cards are far from perfectly diffuse reflectors, and specular reflections can cause increased reflected-light meter readings that, if followed, would result in underexposure. It is possible that the neutral test card instructions include a correction for specular reflections.

Use in illumination

Light meters or light detectors are also used in illumination. Their purpose is to measure the illumination level in the interior and to switch off or reduce the output level of luminaires. This can greatly reduce the energy burden of the building by significantly increasing the efficiency of its lighting system. It is therefore recommended to use light meters in lighting systems, especially in rooms where one cannot expect users to pay attention to manually switching off the lights. Examples include hallways, stairs, and big halls.

There are, however, significant obstacles to overcome in order to achieve a successful implementation of light meters in lighting systems, of which user acceptance is by far the most formidable. Unexpected or too frequent switching and too bright or too dark rooms are very annoying and disturbing for users of the rooms. Therefore, different switching algorithms have been developed:

- difference algorithm, where light switch on lower light level than they switch off, thus taking care that the difference between the light level of the 'on' state and 'off' state is not too big
- time delay algorithms:
  - certain amount of time must pass since the last switch
  - certain amount of time of sufficient illumination.

See also

Wikimedia Commons has media related to ***Light meters***.

- Selenium meter
- Photometer | Photodetector
- Colorimetry | Photometry | Radiometry
- Light value
- Photomultiplier tubes for detecting light at very low levels.
- PIN diode solid state electronic devices for detecting incident light.

Notes

1. **^** Specifications for Sekonic light meters are available on the Sekonic (http://www.sekonic.com/) web site under “Products.”
2. ^ ***a b*** Konica Minolta Photo Imaging, Inc. left the camera business on March 31, 2006. Rights and tooling for Minolta exposure meters were acquired by Kenko Co, Ltd. in 2007. Specifications for the Kenko meters are essentially the same as for the equivalent Minolta meters.
3. **^** Some authors (Ctein 1997, 29) have argued that the calibrated reflectance is closer to 12% than to 18%.
4. **^** Specifications for Kyoritsu testers are available on the C.R.I.S. Camera Services (http://www.criscam.com/) web site under “kyoritsu test equipment.”

References

- Ctein. 1997. *Post Exposure: Advanced Techniques for the Photographic Printer*. Boston: Focal Press (http://www.focalpress.com). ISBN 0-240-80299-3.
- Eastman Kodak Company. Instructions for Kodak Neutral Test Card, 453-1-78-ABX. Rochester: Eastman Kodak Company.
- Eastman Kodak Company. 1992. *Kodak Professional Photoguide*. Kodak publication no. R-28. Rochester: Eastman Kodak Company.
- ISO 2720:1974 (http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=7690). *General Purpose Photographic Exposure Meters (Photoelectric Type) — Guide to Product Specification*. International Organization for Standardization.
- ISO 2721:1982 (http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=7692). *Photography — Cameras — Automatic controls of exposure*. International Organization for Standardization.
- Jones, Loyd A., and H. R. Condit. 1941. The Brightness Scale of Exterior Scenes and the Correct Computation of Photographic Exposure. *Journal of the Optical Society of America*. 31:651–678.
- Norwood, Donald W. 1938. Exposure Meter. US Patent 2,214,283, filed 14 November 1938, and issued 10 September 1940.

External links

- The Problem with Lux Meters (http://www.otc.co.uk/Problem_With_Lux_Meters.php) An article suggesting that Lux meter may read incorrectly when measuring light not from a tungsten source (i.e. fluorescent, metal halide, sodium, LED and other types).
- Meters Don't See 18% Gray (http://www.bythom.com/graycards.htm) An article suggesting that photographic light meters are calibrated for 12% average reflectance.

- Exposure Metering: Relating Subject Lighting to Film Exposure (http://www.largeformatphotography.info/articles/conrad-meter-cal.pdf) (PDF) A discussion of meter calibration and its practical effects.
- A Kodak guide to Estimating Luminance and Illuminance (http://www.kodak.com/cluster/global/en/consumer/products/techInfo/am105/am105kic.shtml) using a camera's exposure meter. Also available in PDF (http://www.kodak.com/cluster/global/en/consumer/products/techInfo/am105/am105kic.pdf).
- DIY Example of Photography Light Meter (https://skydrive.live.com/?cid=d785cf2f7b775fdb#cid=D785CF2F7B775FDB&id=D785CF2F7B775FDB%21155)

Categories: Photography equipment | Electromagnetic radiation meters | Lighting