Some Notes Concerning

FILM SENSITOMETRY AND EXPOSURE

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Issue 6.4 22/11/24 simplifies the use of cardioid incident light meters in various common scenarios without the use of a spot meter.

INTRODUCTION

It is important to remember the following:

Hurter & Driffield, 31 May 1890 :

"The production of a perfect picture by means of photography is an art ; the production of a technically perfect negative is a science."

Exposure errors cannot be corrected

Incorrect film gamma (gradient) can be partially corrected using multigrade papers.

Towards the end of the heyday of film photography, there was a consistent recommendation in the literature that to obtain the best performance from negative material it is necessary to expose accurately to ensure that the compression of tones in the toe of the characteristic curve is correctly utilised. The counter intuitive result of over exposure is less shadow detail and wasted film speed. This means having little or no margin for exposure error.

To do this, a good understanding of negative materials is necessary, combined with some testing.

Print dynamic range is controlled by a combination of film and paper characteristics with a strong emphasis on paper characteristics, which may dominate the overall process.

We appear to have only two 'absolute' parameters at our disposal. One is the supposition that a final overall gamma of 1 should give the most natural looking print, which may not be the case .

The second proposal may be expressed as a requirement to adjust the film gamma so that we can simultaneously print a test image of a grey and white card correctly on to grade 2 paper. This again is also, in practice, likely to be compromised.

Dunn & Wakefield in their excellent book "Exposure Manual" often refer to a technique which they call "exposing for the mid tones" as opposed to the more traditional approach of exposing for the high lights or shadow area of a scene.

This method involves the use of Dunn's "duplex" technique which is explored in detail in later chapters.

It is also assumed that all exposure and processing times are calculated for grade 2 paper. Different results are obtained from condenser and diffuser enlargers which will be automatically taken care of if an **enlarger densitometer** is used to measure film densities .

Also, bear in mind that any under development of the negative will introduce progressively lower and unacceptable gammas into our final print.

Since a typical printing paper has 60:1 dynamic range, one conclusion we have to accept, is that photographing difficult scenes, previously described as 'high contrast' or 'high dynamic range', may require a combination of the use of graduated filters, dodging or burning in during printing, or other compromised techniques.

However, the duplex method of exposure of difficult scenes does give excellent prints on to grade 2 papers with very little extra effort, giving prints that cannot be achieved any other way.

A modified version of the original duplex technique is suggested which eliminates other exposure difficulties and any requirement for the photographer to have to use too much of his or her own judgement.

The gamma of a film can be easily measured using an enlarger densitometer and sacrificing just one frame in a roll of film for a photograph of a specially designed and calibrated test card and densitometer as supplied by b-wtechnik.

Enter these density measurements into the spreadsheet, available for download, and the appropriate gammas are calculated.

Here is another quotation this time from **Dunn & Wakefield (page 28) :**

"Consistency, in fact, is one of the main key notes in photographic work, and until this is attained, results will rarely be satisfying."

PHOTOGRAPHIC LIGHT METERS

Much has been written on this topic so I will only discuss particular points of immediate interest.

Typical 30 degree angle reflection light meters, as opposed to other meters, have limited use for accurate exposure as they are only calibrated for an average scene. They will not be discussed further.

Incident light meters or spot meters will be assumed to be used in the remainder of the article.

Several types of meters will be discussed:

- Flat cosine responding sensors which are 1 stop down at 60 degrees and no response at 90 degrees. These do not appear to be available commercially for photographic use but are common in light level measurement.
- Meters with fully integrating spheres with a cardioid response. These are one stop down at 90 degrees. A good example is the Weston Master V with a modern Invercone fitted, or Gossen products.
- Spot meters with typically 1% angle of coverage for example the early Pentax spot meter.

Figure 2 shows the three types of response including a hemisphere.

The cosine meter was primarily intended to be used with the Duplex Method, readings are taken from the subject to the camera and then from the camera, towards the subject. The exposure used is the geometric average reading between the two measurements.

When correctly used, all the incident light meters will give similar results in most situations but for critical work there are differences.

Consider Figure 1. which is an extreme

Figure 1 **Incident Light Meter Anomalies**

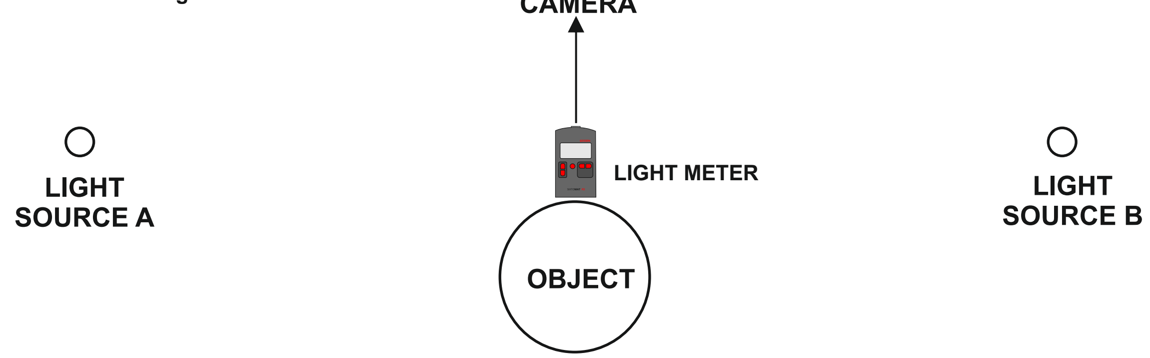
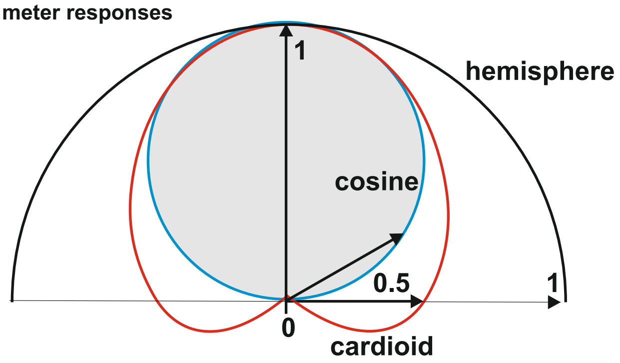


Figure 2 **Various incident meter responses**



example.

The relative output from each incident meter would be as follows

a. Cosine pointing at camera: 0
b. Cosine pointing at either source: 1
c. Cardioid pointing at camera: 1
d. Hemisphere pointing at camera: 2
e. Cosine/cardioid in duplex mode : 1
(Average, pointing to both light sources)

Turn off one of the lights and repeat.

f. Cosine pointing at camera: 0
g. Cosine pointing at source: 1
h. Cardioid pointing at camera: 0.5
i. Cardioid pointing at source: 1
j. Hemisphere pointing at camera: 1
k. Cosine in duplex mode, not applicable
(Only 1 light source)

The old style hemisphere records twice as much light in case (d) which is clearly wrong so it should be eliminated from the contest .

The cardioid pointed at the camera in case (h) is also going to lead to under exposure.

The cardioid when pointed at the light source (i) will give the correct exposure.
Note the cardioid response is often unsuitable for duplex measurements.
As you can see there is scope for errors with integrators. Duplexing with the cosine will most likely give the optimum exposure as was discovered by Dunn but it is unfortunate that light meters with flat integrators are a rarity. I have modified my Gossen meter by adding a flat diffuser in place of the cardioid one and then re-calibrating. However there is a modified duplex technique which will be explained below.

The cardioid meter duplex technique is where a geometric average of a measurement facing the camera and another measurement facing the subject is used. However an adjustment should still be made, typically 1 stop, if the subject is biased towards low key or high key.

It is a tried and tested compromise and is worth considering as a simple technique. Note the average has to be on a logarithmic scale i.e. in stops.
For example, the geometric average between f/5.6 and f/16 = $\sqrt{5.6 \times 16}$ = 9.5

See page 8 for further examples of actual measurements and more considerations.

Spot Meters are advocated by users of the zone system primarily for determination of the dynamic range between a selected highlight and shadow areas . This meter type is still available.
On their own, spot meters cannot be used to determine the absolute exposure required but all we need, though, is a standard grey card or preferably, a white card . If the card is not fully diffusing and has specular reflections, care has to be taken with the angle that may exist between the card, source and spot meter.

However, tests have shown that using good quality matt photo ink jet paper gives an accurate cosine response, which is the theoretical requirement, and is suitable for up to 80 degrees off axis making spot meter measurements easy and reliable.

As Kodak Grey cards are expensive, using a white card is a suitable low cost alternative. All we have to do is subtract 2.5 stops from the measurement, assuming we want to emulate an 18% grey card, and that will give us our normal exposure value.

In fact, genuine Kodak grey cards are not fully matt and have significant specular reflections so they would have to used with some care.

Alternatively, highlight or shadow areas in the scene can be selected and measured. With a white card, subtract 2.5 stops to give the actual exposure. Deciding on which shadow region to use is a problem both for this method and the "Zone" system.

Measure the high keytone, and with the correct film gamma, will print close to full white.

To put matters into perspective, the range usually falls between 6 and 7 stops. Alternatively a black card with a reflection density of 2% can be used.

This is 3.2 stops below an 18% grey card and 5.5 stops below a white card.

I strongly recommend the book by J.F. Dunn and G.L Wakefield for a full explanation of the more advanced exposure techniques but in the meantime here is a resume of the adjustments required to give the best exposure in more difficult circumstances.

Dunn & Wakefield describe the following scenarios as leading to incorrect exposure

"Long Range Subjects" which means a print dynamic range greater than 50:1 (log density range 1.7). Using lower grade papers will give a flat print lacking in brilliance. It is better to develop the film normally and burn in or hold back affected tones accordingly.

Likewise, if the highlights are important then expose for the highlights and ignore the shadow areas.

If the shadow areas are important, expose for the shadow areas and ignore the highlights.

There is no point exposing for the shadows if they are going to be ignored.

Controlled lighting subjects i.e. in the studio are adequately measured using a cardioid (or cosine) meter which should automatically place the toe exposure in the optimum position.

Expose for the MIDDLE tones if possible

This is one of Dunn's favorite topics. There is his original paper called **"Exposure for the Middle Tones"** on the **b-wtechnik** download page. He says;

"There is some doubt as to the general use of "expose for the highlights" or "expose for the shadows." Neither include the wider scope of directional side and contre-jour lighting. "

Use either the Duplex cosine method, or, cardioid integrators as explained later.

Using this method spreads the effect of over or under-exposure between the toe and shoulder of the film dynamic range.

Scenes with an extreme tone unbalance. For example; back lit sea, snow, glassware.

The solution here, suggested by Dunn is:

Take a reflected reading of the foreground and a normal incident reading pointing at the camera. Use the center reading as in the Duplex method.

We can now move on the use of spot meters. "The method with spot meters is 100% keytone pegging" which normally means pegging the shadow detail and highlights. Pegging the highlight is usually easy or we can use a white card. The shadow pegging is usually 5 to 6 stops lower so you can then shift around the keytones depending on which part of the scene is important. The rest is similar to the other meters with the following considerations.

Note scenes with low dynamic range i.e. snow with 1:20 range (log density range 1.3) and no black objects, the scene would all be placed in the toe. Add 2 or more stops to move the range to the center of the film characteristic.

"Blended Scene Luminance" occurs in landscapes where, for example, a tree trunk gets progressively darker when measured with a spot meter. So if you want to use a tree trunk as a shadow keytone, use one at a reasonable distance.

Distant scenes

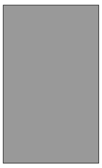
Use the spot meter shadow method but if the tone range is small, increase the exposure by 1 - 2 stops due to distance effects.

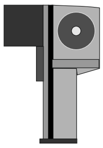
Some Fundamental Calculations

Before we go any further, it is probably better to point out some calculations and constants that we will often be using and how they were derived.

Spot Meter Calibration

18% Grey Card





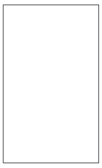
(1) The meter reading gives the incident light exposure value.

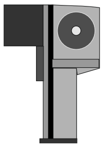
$Log_2(18/100) = -2.5$ reflection density in stops using log base 2

$Log(18/100) = -0.74$ log to base 10 density

Note that the negative signs are normally omitted.

100% Reflectivity White Card





(2) The meter reading now gives a value 2.5 stops greater than the grey card.
To arrive at the correct exposure value we have to subtract 2.47 stops from the reading which is easy if EV values are being used.

With the correct exposure, indicated by the meter, and the correct film processing giving the appropriate film gamma, the white card should print a clear white tone with minimum detail and the grey card reflection density, with a value close to the calculated density above of 0.74 .

If parts of the scene have highlights exceeding the white card value, a compromise has to be found if detail in some of the full range of highlights is required. The compromise often used is the Duplex technique.

If we do not have a calculator that has a Log_2 function we can use the normal Log function to base 10 but multiply the result by 3.322.

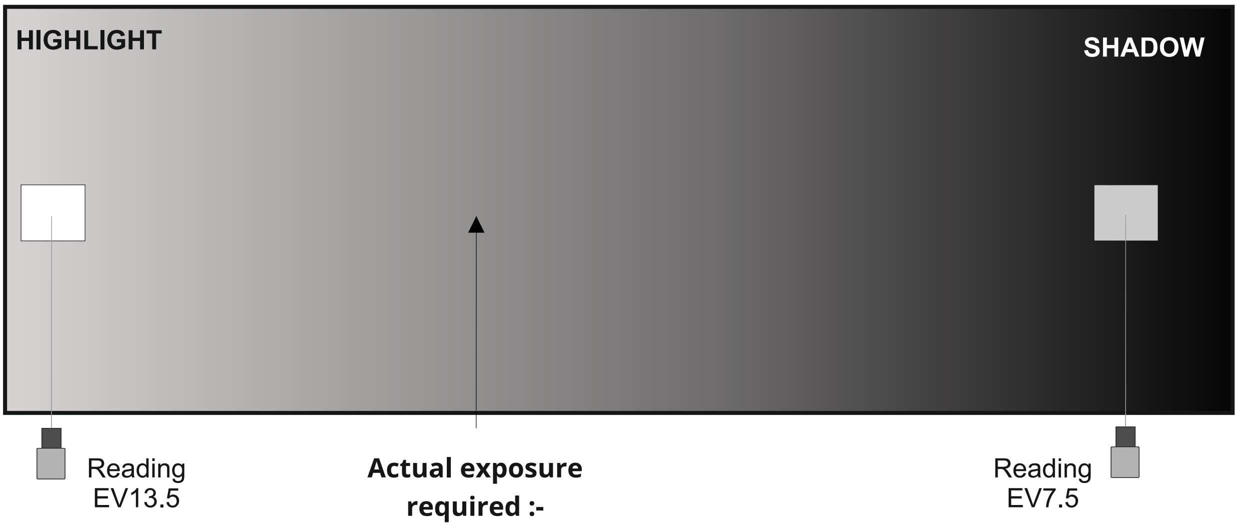
$\log(18/100) = 0.74, \quad 0.74 \times 3.322 = 2.458$

$2.458 / 0.74 = \mathbf{3.322}$

finally, $\log_2(10) = 3.3219$

The use of a white card in place of an 18% grey card can be confusing so I have added two examples below which should make the procedure clear.

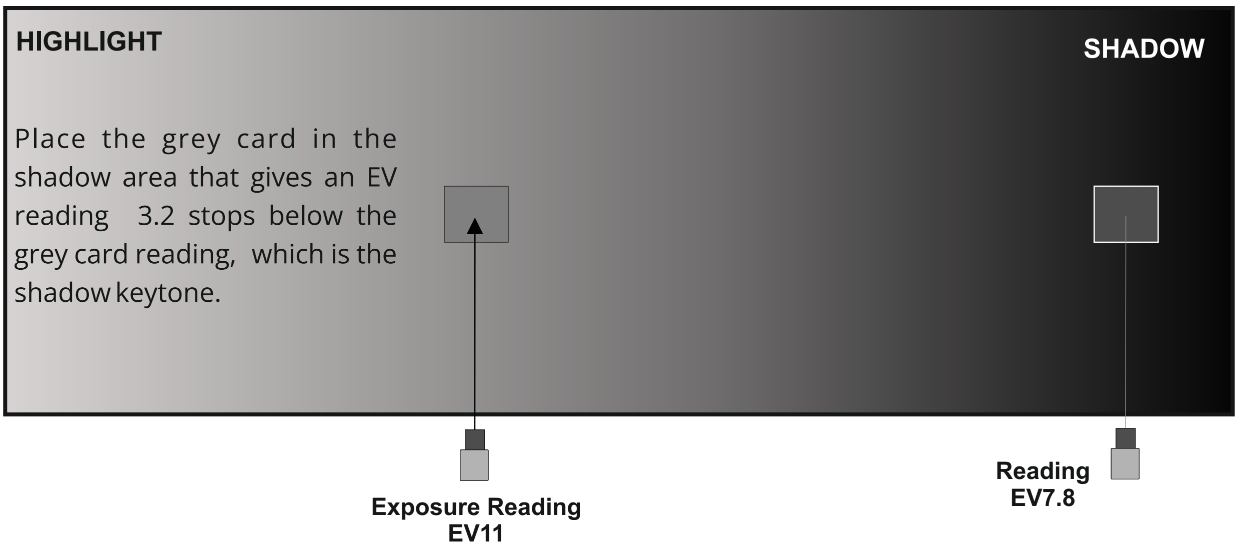
SPOT METERING USING A WHITE CARD



Actual exposure required :-
Highlight Reading - 2.5
= EV11
equivalent to 18% grey

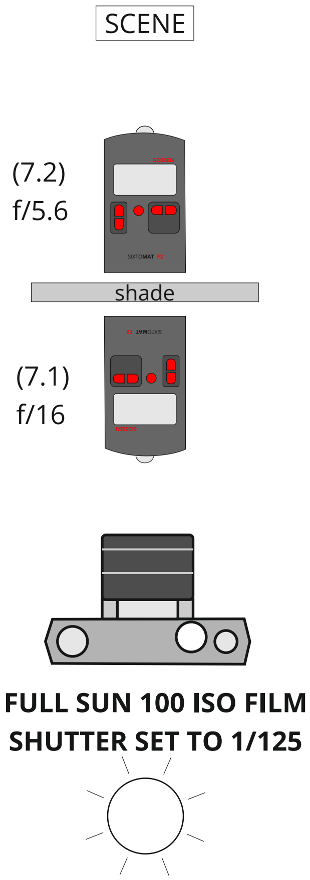
Place the white card in the shadow area that gives an EV reading 5 to 6 stops below the highlight reading which is the shadow keytone.

SPOT METERING USING AN 18% GREY CARD



Example of Simple Duplex Measurements with CARDIOID Meters

To calculate the mid point aperture use : sqrt (f/No. Full Sun x f/No. Away from Sun)
In the case below we get $\sqrt{16 \times 5.6}$ = f/9.5



To expose for the sky highlights, use f/16
(not recommended)
To expose for the mid range, use f/9.5

Note the typical 3 stop difference in readings and the requirement to shade the meter sensor from direct sun in measurement (7.2)

Some digital meters give readings with 1/10 stop accuracy using 3 digits as follows:

$f/5.6_3$ which represents **f/5.6 + $\frac{3}{10}$ stop**

In this case, the actual f number, can be calculated as follows

f/number = $5.6 \times 1.414^{0.3}$ = f/6.89

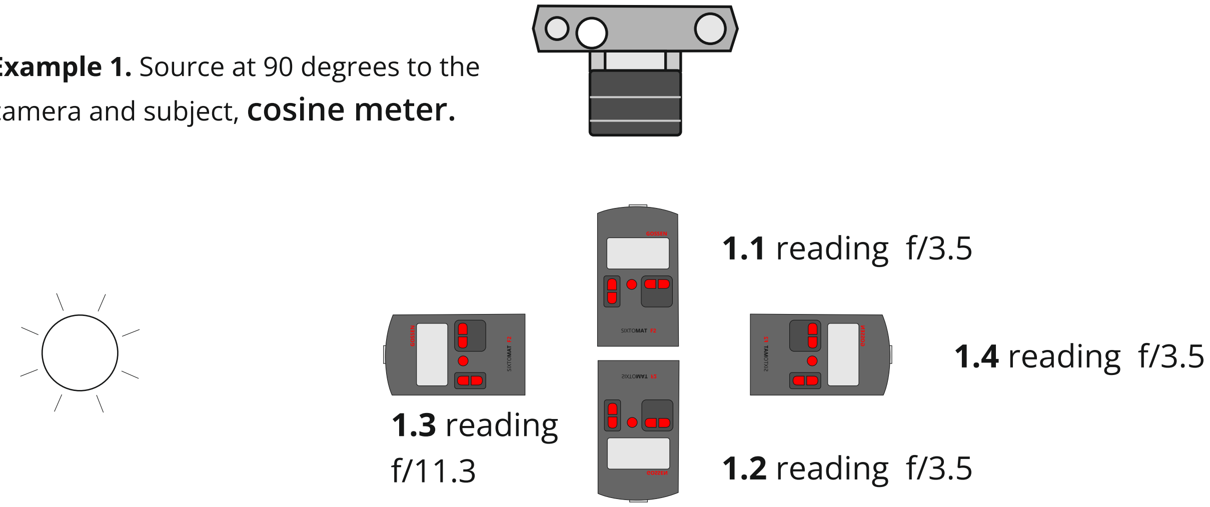
Tables to help all calculations are provided on pages 15 and 16.

Examples of Duplex Measurements with COSINE and CARDIOID Meters

These measurements were made in full sun, a cloudless sky and a fixed exposure of 1/125 s, with 100 ISO film speed setting. This represents a high dynamic range scene outside the range of printing. The cosine meter is a modified Gossen SIXTOMAT F2 and the cardioid meter is a Weston Master V with the final version “Invercone” diffuser.

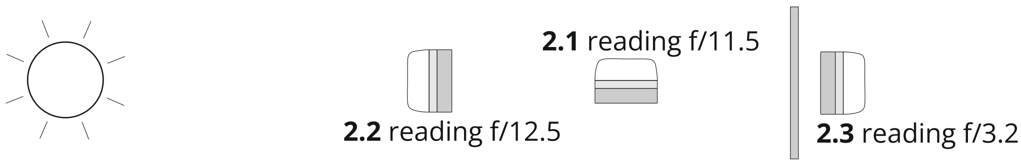
The geometric mean of two aperture values can be found to an accuracy of 1/3 stop using the table on page 15.

Example 1. Source at 90 degrees to the camera and subject, **cosine meter.**



The normal duplex (1.1 and 1.2) method is not applicable and so the alternative method is to measure the light source and use the geometric average between reading 1.3 and 1.4 giving **f/6.3** .

Example 2. Sun at 90 degrees to the camera as above but using the cardioid Weston Master V meter.



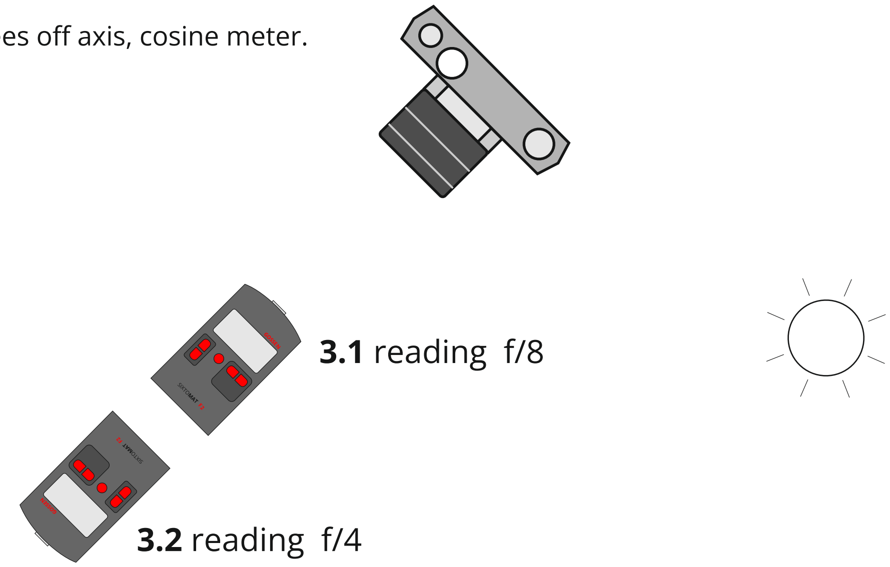
If example 1 above is assumed to be the best compromise, then using a typical cardioid reading as in 2.2, is going to underexpose the film. Note the 1 stop difference between 2.1 and 2.2 as expected from a cardioid response. A better approach would be to use the 2.3 reading method and using your body, to shade the “Invercone” from the direct rays of the sun.
The measurement of 2.2 and 2.3 give a final average of **f/6.3**, as with the cosine meter.

The above examples are quite severe in their dynamic range. It may be possible to assume the reflected light measured by 2.3 is typically 4 stops less than the main source, as was the difference in the above case. In full sun this is usually the difference between the maximum incident light from the dominant source and that measured in full shadow areas.

As the Gossen meter using its original cardioid diffuser, and the Weston Master V are closely matched, it is clear that duplexing using the above technique as in Example 2, does not require cosine diffusers. Any errors will be minimal especially when compared with errors mentioned above. The next example is with the source at 45 degrees.

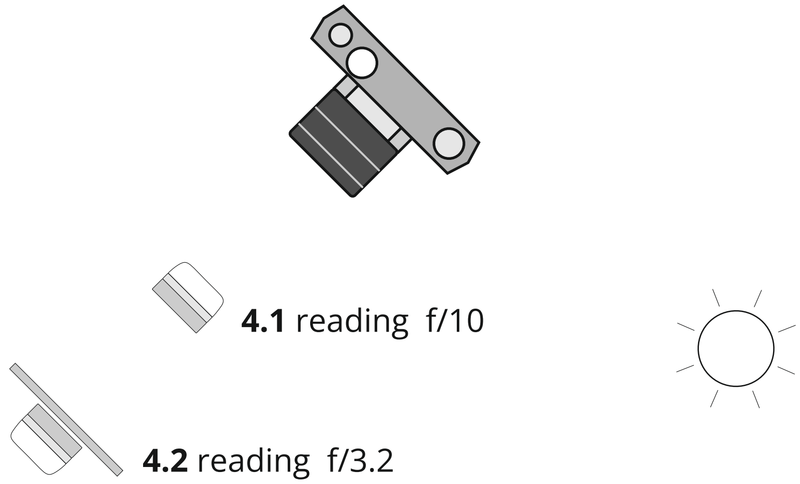
Examples of Duplex Measurements

Example 3. Sun at 45 degrees off axis, cosine meter.



This is a normal duplex situation with a **cosine** response and the duplexed average is **f/5.7**

Example 4. Sun at 45 degrees off axis, Weston Master V cardioid meter with some shading.



The duplexed average is **f/5.7**

Using a non duplexed measurement, there is again a significant difference of 3.5 stops between 4.1 and the duplexed value.

If reading 4.1 is used, background shadow detail will most certainly be compromised.

The correction imposed by the duplex method is still correct but if parts of the background receive full sun, and may have greater reflectivity in some parts of the scene, then a decision has to be made as to whether or not the full, or any correction has to be applied.

This is the only "grey area" in the current method.

Dunn & Wakefield stated in their book that it is sometimes difficult to present a rational argument for some of the duplex methods that they suggested. However, I think their methods are still valid but that a minor variation leads to a simplified method that is clearly easy to understand, rational, and will apply both to cosine and cardioid integrating meters.

The next section is an attempt to summarise the simple changes required.

Examples of Duplex Measurements

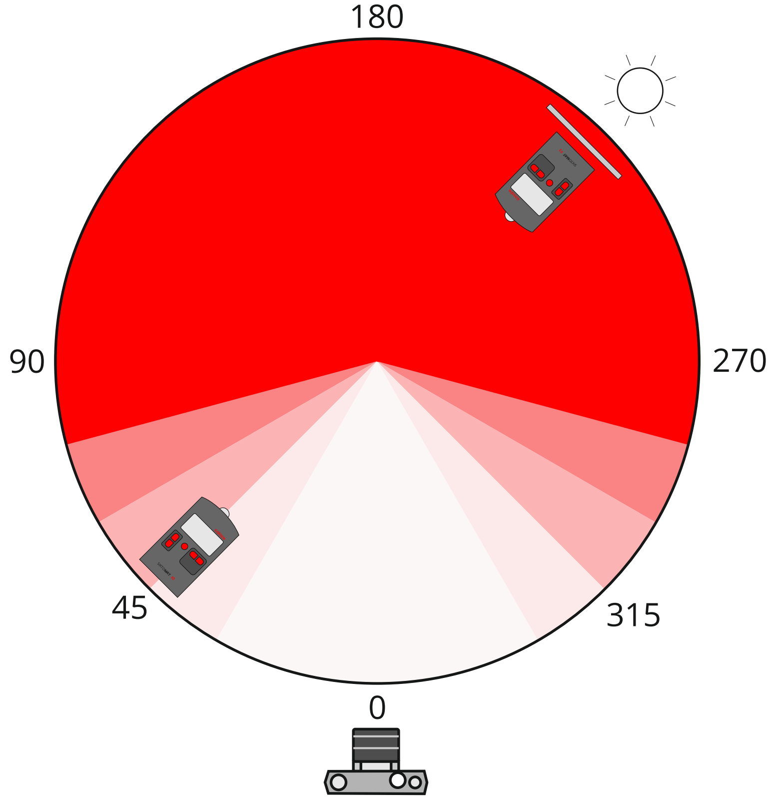


Figure 2. above shows all options of meter and light source positions. As the sun changes its position from 0 to 360 degrees, the darker red areas indicate the increasing risk of failing to decide on the correct exposure compromise and incorporates all the previous discussions. As most photographers will know, the maximum difficulty occurs at 180 degrees when the camera points at the light source.

The suggested changes to the duplex method are:

1. In the difficult dark red areas, Dunn's original duplex method has to be changed to measure the dominant light source and the reflection from the background in the opposite direction.

2. When using a meter with the common cardioid response and taking a reading away from the light source, shade the meter from any direct light from the light source as shown above and in the previous examples.

These changes remove the meter anomalies for both cosine and cardioid meters mentioned in page 3.

Examples of More Complex Exposure Problems

Here we will move on to identify scenes which only a spot meter can resolve.

Imagine the above scene where we have a dull overcast sky in all directions with the odd patch of brighter cloud, as shown, and a foreground.
The objective is to produce a negative that gives the same look as the original dull overcast sky including the correct tone for the lighter grey area. The bright areas are not large enough to act as a dominant light source and so duplexing is not appropriate as we will get similar reading wherever we point an incident or reflection light meter.

The actual readings for such a scenario with 100 ISO film, are as follows:

1. Incident light meter readings	f/3.5 at 1/60 s	**(EV 9.5)**	(1)
2. Spot meter reading on the light sky area	f/14 at 1/60 s	(EV 13.5)	(2)
3. Spot meter reading on the main sky	f/7 at 1/60s	(EV 11.5)	(3)

4.The **spot meter reading (2)** gives us an exposure value of :
exp.(2) EV 13.5 - 2.5 stops = f/5.6 at 1/60s **(EV 11)** (4)

If we choose exp.(1) i.e. f/3.5, our normal print time will render the main sky area and the small bright area pure white which is not the same as it appeared in the actual scene.

If we choose exp.(4) from the spot meter reading, detail in the shadow will be lost although this choice is correct. Perhaps duplexing between the 2 options is required which gives f/4.4 equivalent to **EV10⅓** (to the nearest ⅓ stop)

Here is another example :-

Rain clouds are in front of the camera with some small areas of clear sky or white clouds.
The sun is behind a cloud and behind the camera. Incident meter reading in all directions are the same which is f/8.$_6$ (digital) which is **1/60 @ f/9.8** or **EV 12.4**

A spot meter reading of the brighter clouds give **EV16.5** $\xrightarrow{-2.5}$ **EV 14, 1/60 @ f/16**
a difference of 1.6 stops. What is the correct choice , the spot meter reading ? This is a case where the spot meter reading i.e. shorter exposure time, should be used in order to render the important cloud areas accurately.

Examples of More Complex Exposure Problems

Final Example:

A scene with a grey sky and a constant light reading in all directions, ISO 100 film.

A spot meter reading of the sky is EV14.2 less 2.5 giving EV11⅔ or 1/60 at f/8

A Gossen cardioid meter reading gives EV11 or 1/60 at f/5.6

The spot meter reading will print the grey sky white and the Gossen meter reading will give over exposure by approximately 1 stop. If the requirement is to print the sky a shade of grey close to the scene then the spot meter reading has to be adjusted accordingly. The simple option is to use the meter reading suggested by the spot meter, and double the print time or, take advantage of the reduced exposure time and use a normal print time.

The above discrepancy between the two meter readings appears to be as a result of the calibration methods chosen for each meter. Set up a typical test using a single lamp as light, source approximately 1 meter away from the light meter. Take a reading using the cardioid meter pointed directly at the lamp. Then place a white card at the same location from the light source and take a reading using the spot meter. The two meters should agree.
If a photograph is taken of the white card and then processed according to the manufacturers requirements, the density of the white card image on the negative should be close to 1.2 . With a typical enlarger having a condenser light system, there should be a normal print time on grade 2 paper. Of course, without an enlarger densitometer, it is difficult to determine how close a negative is to the ideal.
The conclusion is that cardioid meter are not calibrated for diffuse light, a correction is needed.

Limitations of Incident Light Meter methods

The examples given in the previous pages show that in situations where incident light levels are essentially the same in all directions, significant over exposure is likely to take place.

If there are small highlights in the scene then it is necessary to use a spot meter in order to peg the highlights at their level.

A common example of this error occurring is on a normal summers day when the sun is temporarily behind a cloud. Distant clouds in the scene may appear brighter than the rest but have little effect on the average incident light level.

Another way of looking at the problem is that the highlight reading is expanding the dynamic range outside the expected range. This shift can be calculated from the difference between the average incident light reading and the highlight reading as explained on the previous page.

With this data, and if it seems to be required, one option is to use the duplex system and force the extra exposure range to both ends of the exposure scale. Simply reduce the exposure by half the shift to include the highlight reading.

However, if the highlights are the most important part of the scene then use the full correction required. Dunn goes a step further (see page 31of the Exposure Manual) by dismissing shadow techniques (zone system) except for positives, in favour of simpler highlight techniques.

The main point is that with all the above exposure data, the photographer can accurately choose how the final negative can be adjusted to suit a particular purpose.

As this phenomenon can occur in any scene it leads to the conclusion that the only theoretically correct exposure system that can give you all the required information is spot metering.
This can give you highlight levels, and, with a white or grey card, average incident light metering if the duplex method is required, but from a more practical point of view:-

The overall problem can now be summarized as follows :

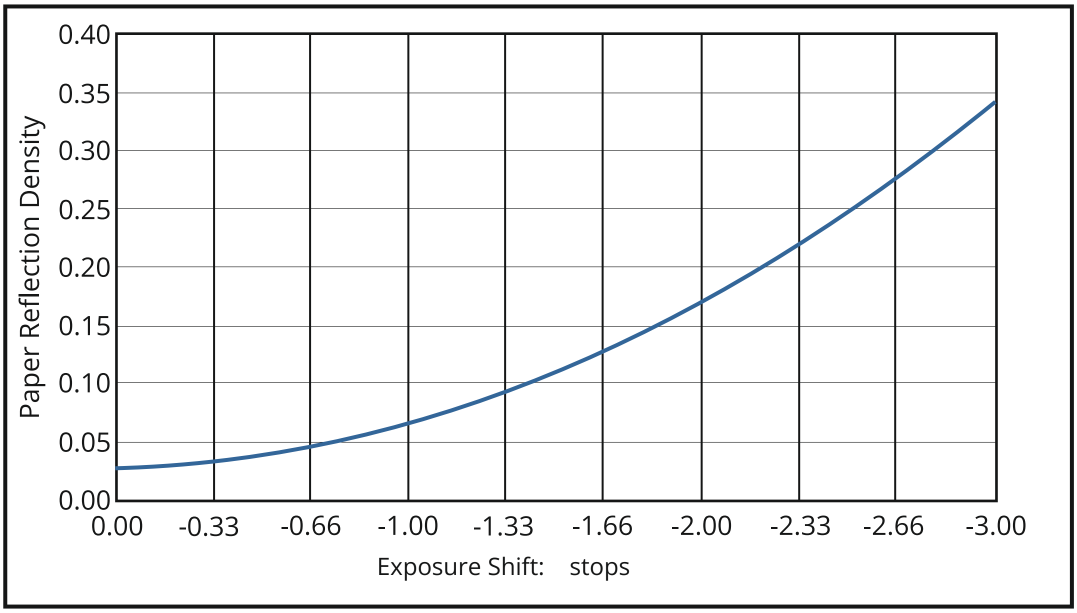
1. If we have a directional light source i.e. the sun, then:
A cardioid meter will give a correct reading when pointed at the light source, but the dynamic range in the scene will probably be excessive therefore:
USE THE CARDIOID DUPLEX TECHNIQUE

2. If we have diffuse lighting dominating the scene then:
USE A CARDIOID METER BUT UNDER EXPOSE BY 1 TO 2 STOPS
This will bring you closer to a highlight reading with a spot meter.
(This option should ideally be tested to by each user before use)

3. If you have a SPOT METER, ***USE IT FOR EVERYTHING !***

Fortunately, most exposure problems can be solved without a spot meter.

The graph below shows the typical effect of underexposing
a negative on the reflection density of the highlight on a print.



Exposure Geometric Mean Tables

This table is provided for the quick calculation of the geometric mean between two numbers when using the Duplex technique.

F/number									
2.0	**2.2**	**2.5**	**2.8**	**3.1**	**3.5**	**4.0**	**4.5**	**5.0**	**5.6**
2.2	2.2	2.4	2.5	2.7	2.8	3.0	3.2	3.4	3.5
2.5	2.4	2.5	2.7	2.8	3.0	3.2	3.4	3.6	3.8
2.8	2.5	2.7	2.8	3.0	3.1	3.3	3.5	3.8	4.0
3.1	2.7	2.8	3.0	3.1	3.3	3.5	3.8	4.0	4.2
3.5	2.8	3.0	3.1	3.3	3.5	3.8	4.0	4.2	4.4
4.0	3.0	3.2	3.3	3.5	3.8	4.0	4.2	4.5	4.7
4.5	3.2	3.4	3.5	3.8	4.0	4.2	4.5	4.8	5.0
5.0	3.4	3.6	3.8	4.0	4.2	4.5	4.8	5.0	5.3
5.6	3.5	3.8	4.0	4.2	4.4	4.7	5.0	5.3	5.6
6.3	3.8	4.0	4.2	4.4	4.7	5.0	5.3	5.6	5.9
7.1	4.0	4.2	4.4	4.7	5.0	5.3	5.6	6.0	6.3
8.0	4.2	4.5	4.7	5.0	5.3	5.7	6.0	6.3	6.7
9.0	4.5	4.8	5.0	5.3	5.6	6.0	6.3	6.7	7.1
10.1	4.8	5.0	5.3	5.6	6.0	6.3	6.7	7.1	7.5
11.0	5.0	5.3	5.5	5.9	6.2	6.6	7.0	7.4	7.8
12.3	5.3	5.6	5.9	6.2	6.6	7.0	7.4	7.9	8.3
13.9	5.6	5.9	6.2	6.6	7.0	7.4	7.9	8.4	8.8
16.0	6.0	6.3	6.7	7.1	7.5	8.0	8.5	9.0	9.5
18.0	6.3	6.7	7.1	7.5	8.0	8.5	9.0	9.5	10.0
20.2	6.7	7.1	7.5	8.0	8.4	9.0	9.5	10.1	10.6
22.0	7.0	7.4	7.8	8.3	8.8	9.4	9.9	10.5	11.1
24.7	7.4	7.9	8.3	8.8	9.3	9.9	10.5	11.2	11.8
27.7	7.9	8.4	8.8	9.3	9.9	10.5	11.2	11.8	12.5
32.0	8.5	9.0	9.5	10.0	10.6	11.3	12.0	12.7	13.4
35.9	9.0	9.5	10.0	10.6	11.3	12.0	12.7	13.5	14.2
40.3	9.5	10.1	10.6	11.3	11.9	12.7	13.5	14.3	15.0
45.0	10.0	10.6	11.2	11.9	12.6	13.4	14.2	15.1	15.9
F/number									
5.6	**6.3**	**7.1**	**8**	**9.0**	**10.1**	**11**	**12.3**	**13.9**	**16**
6.3	6.3	6.7	7.1	7.5	8.0	8.3	8.8	9.3	10.0
7.1	6.7	7.1	7.5	8.0	8.4	8.8	9.3	9.9	10.6
8.0	7.1	7.5	8.0	8.5	9.0	9.4	9.9	10.5	11.3
9.0	7.5	8.0	8.5	9.0	9.5	9.9	10.5	11.2	12.0
10.1	8.0	8.4	9.0	9.5	10.1	10.5	11.2	11.8	12.7
11.0	8.3	8.8	9.4	9.9	10.5	11.0	11.7	12.3	13.3
12.7	8.9	9.5	10.1	10.7	11.3	11.8	12.5	13.3	14.3
14.3	9.5	10.0	10.7	11.3	12.0	12.5	13.3	14.1	15.1
16.0	10.0	10.6	11.3	12.0	12.7	13.3	14.1	14.9	16.0
18.0	10.6	11.3	12.0	12.7	13.5	14.1	14.9	15.8	16.9
20.2	11.3	11.9	12.7	13.5	14.3	14.9	15.8	16.7	18.0
22.63	11.9	12.6	13.5	14.3	15.1	15.8	16.7	17.7	19.0

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0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1.03527	1.072	1.110	1.149	1.189	1.231	1.275	1.320	1.366

1/10 Stop decimal multipliers for use with digital exposure meters that give readings as stops + a decimal fraction from 0.1 to 0.9.

Example : From the table, **$f/2.8_6$** gives **2.8 x 1.231 = f/3.45**

To calculate any value $f/(N)_d$ aperture = N x 1.414^d. In the above case, N = 2.8 and d = 0.6

EV100 1/3 STOP TABLES

EV_{100} TABLE

	Aperture														
Time	1.00	1.12	1.26	1.40	1.57	1.76	2.00	2.24	2.52	2.80	3.14	3.53	4.00	4.49	5.04
1	0	0.3	0.7	1	1.3	1.7	2	2.3	2.7	3	3.3	3.7	4	4.3	4.7
1/2	1	1.3	1.7	2	2.3	2.7	3	3.3	3.7	4	4.3	4.7	5	5.3	5.7
1/4	2	2.3	2.7	3	3.3	3.7	4	4.3	4.7	5	5.3	5.7	6	6.3	6.7
1/8	3	3.3	3.7	4	4.3	4.7	5	5.3	5.7	6	6.3	6.7	7	7.3	7.7
1/15	4	4.3	4.7	5	5.3	5.7	6	6.3	6.7	7	7.3	7.7	8	8.3	8.7
1/30	5	5.3	5.7	6	6.3	6.7	7	7.3	7.7	8	8.3	8.7	9	9.3	9.7
1/60	6	6.3	6.7	7	7.3	7.7	8	8.3	8.7	9	9.3	9.7	10	10.3	10.7
1/125	7	7.3	7.7	8	8.3	8.7	9	9.3	9.7	10	10.3	10.7	11	11.3	11.7
1/250	8	8.3	8.7	9	9.3	9.7	10	10.3	10.7	11	11.3	11.7	12	12.3	12.7
1/500	9	9.3	9.7	10	10.3	10.7	11	11.3	11.7	12	12.3	12.7	13	13.3	13.7
1/1000	10	10.3	10.7	11	11.3	11.7	12	12.3	12.7	13	13.3	13.7	14	14.3	14.7

Time	8.0	9.0	10.1	11.0	12.3	13.9	16.0	18.0	20.2	22.0	24.7	27.7	32.0	35.9	40.3
1	6	6.3	6.7	7	7.3	7.7	8	8.3	8.7	9	9.3	9.7	10	10.3	10.7
1/2	7	7.3	7.7	8	8.3	8.7	9	9.3	9.7	10	10.3	10.7	11	11.3	11.7
1/4	8	8.3	8.7	9	9.3	9.7	10	10.3	10.7	11	11.3	11.7	12	12.3	12.7
1/8	9	9.3	9.7	10	10.3	10.7	11	11.3	11.7	12	12.3	12.7	13	13.3	13.7
1/15	10	10.3	10.7	11	11.3	11.7	12	12.3	12.7	13	13.3	13.7	14	14.3	14.7
1/30	11	11.3	11.7	12	12.3	12.7	13	13.3	13.7	14	14.3	14.7	15	15.3	15.7
1/60	12	12.3	12.7	13	13.3	13.7	14	14.3	14.7	15	15.3	15.7	16	16.3	16.7
1/125	13	13.3	13.7	14	14.3	14.7	15	15.3	15.7	16	16.3	16.7	17	17.3	17.7
1/250	14	14.3	14.7	15	15.3	15.7	16	16.3	16.7	17	17.3	17.7	18	18.3	18.7
1/500	15	15.3	15.7	16	16.3	16.7	17	17.3	17.7	18	18.3	18.7	19	19.3	19.7
1/1000	16	16.3	16.7	17	17.3	17.7	18	18.3	18.7	19	19.3	19.7	20	20.3	20.7

Some Useful Equations

CONVERT	TO	USE	RESULT
% Reflectance Let R = 15	Log_{10} Density	Log_{10}(R/100)	1.176
Log Reflection Density Log RD = -1.5	% Reflectance	$100 \times 10^{(-RD)}$	3.162 %
% Reflectance	Stops value let S = 1/3	$R = \frac{100}{2^S}$	79.4 %
Log Exposure H Let H = 1.9	Stops	$H \times \log_2(10)$ or $H \times 3.322$	6.312 stops
Stops S Let S = 5.1	Log_{10} Density	$\frac{S}{\log_2(10)}$ or $\frac{S}{3.322}$	1.505
Stops S Let S = 7.3	linear value n	2^S	157.6
linear number Let n = 108	Stops	$\log_2(n)$ or $(\log_{10}(n)) \times 3.322$	6.754 stops
Calculate Geometric mean of two apertures A1 and A2 Let A1 = 16, A2 = 5.6		$\sqrt{A1 \times A2}$	f/9.47
Calculate EV number N=aperture = f/9.5 t = exposure time = 1/60	***Assumes meter is set to required film speed***	$EV = \log_2(N^2/t)$ or $EV = \log(N^2/t) \times 3.322$	12.4
Calculate aperture N from EV = 12.4 and t = exposure time = 1/60	***Assumes meter is set to required film speed***	$N= \sqrt{2^{EV} \times time}$	f/9.5

Convert lux level to EV Let ISO Speed = 100 lux level = 1280	EV	$\log_2\left(\frac{lux \times ISO\ speed}{250}\right)$	9 EV
Convert EV level to lux Let ISO Speed = 100 EV value = 9	lux	$lux = 2^{\{EV - \log_2(ISO) - \log_2(1/250)\}}$ or $lux = 2.5 \times 2^{EV}$	1280

When selecting a low cost calculator, note that some do not have all the functions used in the above table, in particular the $\log_n$ requirement. Suitable calculators are the Casio fx-85GT and Genie 92 SC. However for most calculations the tables provided will suffice, or, a low cost JOINUS JS-82MS-A for about £5.

In practice, the use of the EV numbers can be awkward. As an example, to convert an EV number such as EV11⅔, to an aperture and time, requires the calculation of 2^{11} which cannot be done on small low cost calculators. The most common requirement is to calculate the geometric mean of two aperture values, as when duplexing, and this only requires the ability of the calculator to calculate square roots. This is always available on the lowest cost calculators.

Book References:

J.F. Dunn & G.L.Wakefield **"Exposure Manual"** Fountain Press 1981 ISBN 0 85242 762 X
Fourth Edition

G.L. Wakefield **"Practical Sensitometry"** Fountain Press 1970 ISBN 0 852 42310 I