Photographic Concepts

Aperture (F-Stops)

- Aperture refers to the size of the opening inside the lens that the light must go through to reach the film
- Aperture is measured in f/stops as indicated in the series below:

  f1, f1.4, f2, f2.8, f4, f5.6, f8, f11, f16, f22, f32, f45
- These values are actually fractions. They should read as follows:

  1/1, 1/1.4, 1/2, 1/2.8, 1/4, 1/5.6, 1/8, 1/11, 1/16, 1/22, 1/32, 1/45
- The numbers represent the ratio of the focal length of the lens to the diameter of the lens diaphragm opening. That's why it's called an f(ocal) number. The designation f/2 means that the diameter of the aperture is 1/2 the focal length of the lens. The designation f/32 means that the diameter of the aperture is 1/32 the focal length of the lens. f/2 on a 100mm lens means that the diameter of the diaphragm opening is 100/2, or 50mm

  The f/numbers have been chosen such that decreasing/increasing by one f-stop (an internationally agreed range), doubles/halves the light let in. This is a result of considering that the amount of light reaching the film is actually dependent on the area of the opening. For example, f/2 on a 100mm lens represents an aperture diameter of 50mm, which gives an area of πr^2 or $\pi \frac{D^2}{4}$ and is approximately 1963.50mm^2. If the next f/stop (f/2.8) is considered, the aperture diameter is now 100/2.8=35.71mm, giving the surface area as 1001.78mm^2 – that is half the area, and half the amount of light

  Ratios are used instead of the actual surface area of the diaphragm opening because the actual surface area would be quite different between lenses of different focal lengths. Assume f/2 on both a 100mm and 50mm lens. The surface areas are 1965.50mm^2 and 490.87mm^2 respectively. So, the same amount of light is let in with very different areas for these two lenses – clearly ratios allow us to know that, for example, f/2 on a 100mm lens will let in exactly the same amount of light as f/2 on a 50mm lens
- To memorise the f/number series, only remember two numbers; 1 and 1.4. Double each one alternately and you will have two series:

  1, 2, 4, 8, 16, 32 and 1.4, 2.8, 5.6, 11, 22

  So, combining the two sequences in numerical order gives the full sequence:

  1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32

  Some cameras may include numbers between these numbers - representing half or third stops
- Shooting in aperture priority or shutter priority modes is an easy way to take advantage of this knowledge without having to remember formulas

  If you want motion blur or frozen action, go with shutter priority mode and use a long or short shutter speed respectively

  If you want to control the depth of field, use aperture priority mode and set the aperture to the smaller f-stops for shallower dof (portraits) and larger f-stops for deeper dof (landscapes)

Shutter Speeds (sec)

- 1/8000;1/4000;1/2000;1/1000; 1/500; 1/250; 1/125; 1/60; 1/30; 1/15; 1/8; 1/4; 1/2; 1;2; 4; up to 2 ½ hours
- Shutter speed, aperture, and ISO are usually expressed in numbers that indicate a halving or doubling of exposure, for example:
  - 1/30s lets in twice the amount of light as 1/60s but half as much as 1/15s
  - f/4 lets in twice as much light as f/5.6 but half as much as f/2.8
  - ISO 800 is twice as sensitive as ISO 400 but half as sensitive as ISO 1600

  This is useful to remember since, if you slow down the shutter speed by half, you can either decrease the aperture size to keep the same exposure (1/60s @ f/5.6 is the same as 1/30s @ f/8) or decrease the ISO while keeping the aperture constant (1/60s @ ISO 400 is the same as 1/30s @ ISO 200 with constant aperture)

  Understanding this will enable good control over the exposure needed for the shot that is desired
- There is an important rule regarding shutter speeds. If:

  $$ShutterSpeed < \frac{1}{Lens\,Focal\,Length}$$

  A tripod is recommended to avoid significant camera shake

For example, when using a 200 mm lens, the shutter speed must exceed 1/200 second (i.e. 1/250 or faster). If the subject is moving, double this shutter speed. If you are moving (such as in a boat or plane) triple the speed

For zoom lenses the minimum shutter speed will obviously change depending on the amount of zoom being used

Light Value

- LV levels have been used to denote EV (Exposure Value) at ISO 100. However, this term does not derive from a standards body, and has had several conflicting definitions. It is, therefore not used greatly
- LV (Light Value) is a term used to allow easy discussion of light without the confusion of the many equivalent combinations shutter speeds and apertures
- LV refers to how bright the subject appears, in absolute terms. It does not take film speeds or exposure into account
- LV levels measure light coming from a subject, or its "reflectance". They are not a measure of how much light is falling on a subject
- The scale is logarithmic in which each integer value is one stop from the next
- In photography values of about 0 to 18 are commonly used. Negative values are perfectly valid, just very dark and only occur in night photography. LV 15 is full daylight, for example

Exposure Value

- EV (Exposure Value) is a term used to allow easy discussion of light without the confusion of the many equivalent combinations shutter speeds and apertures
- LV measures how much light there is, and EV measures how much of the light is allowed into the camera (in turn, controlling the exposure setting)
- Each Exposure Value, or EV, represents any of many different but equivalent combinations of f/stop and shutter speed

  For instance, 1/250 at f/8 is EV14, and so is 1/125 at f/11 - 1/125 at f/8 (one stop more exposure) is EV13, whilst 1/250 at f/11, one stop less exposure, is EV15
- A change of 1 EV is equivalent to a change of one f-stop or one halving or doubling of shutter speed. If you are at 1/500 and wish to add 1 EV of exposure, the new shutter speed would be 1/250
- This system is the correct way to discuss light and exposure because it avoids the confusion of f/stops and shutter speeds. It is the way that digital camera operate
- The EV can be calculated from the aperture and shutter speed thus:

$$EV = \log_2\left(\frac{N^2}{t}\right)$$

  Where:

  N = Relative aperture (f-stop)
  t = Exposure time (shutter speed)

  Since,

$$\log_2 x = \frac{\log x}{\log 2}$$

  We have:

$$EV = \frac{\log_{10}\left(\frac{N^2}{t}\right)}{\log_{10} 2} = 3.3219\ \log_{10}\left(\frac{N^2}{t}\right)$$

  For example, an exposure of 1/250s at f8 is equivalent to:

$$EV = 3.3219\ \log_{10}\left(\frac{8^2}{1/250}\right) \cong 14$$

- EV 0 corresponds to an exposure time of 1 s and a relative aperture of f/1.0. If the EV is known, it can be used to select combinations of exposure time and f-number, as shown here:

EV	**f-number**												
	1.0	**1.4**	**2.0**	**2.8**	**4.0**	**5.6**	**8.0**	**11**	**16**	**22**	**32**	**45**	**64**
−6	60	2 m	4 m	8 m	16 m	32 m	64 m	128 m	256 m	512 m	1024 m	2048 m	4096 m
−5	30	60	2 m	4 m	8 m	16 m	32 m	64 m	128 m	256 m	512 m	1024 m	2048 m
−4	15	30	60	2 m	4 m	8 m	16 m	32 m	64 m	128 m	256 m	512 m	1024 m
−3	8	15	30	60	2 m	4 m	8 m	16 m	32 m	64 m	128 m	256 m	512 m
−2	4	8	15	30	60	2 m	4 m	8 m	16 m	32 m	64 m	128 m	256 m
−1	2	4	8	15	30	60	2 m	4 m	8 m	16 m	32 m	64 m	128 m
0	1	2	4	8	15	30	60	2 m	4 m	8 m	16 m	32 m	64 m
1	1/2	1	2	4	8	15	30	60	2 m	4 m	8 m	16 m	32 m
2	1/4	1/2	1	2	4	8	15	30	60	2 m	4 m	8 m	16 m
3	1/8	1/4	1/2	1	2	4	8	15	30	60	2 m	4 m	8 m
4	1/15	1/8	1/4	1/2	1	2	4	8	15	30	60	2 m	4 m
5	1/30	1/15	1/8	1/4	1/2	1	2	4	8	15	30	60	2 m
6	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	8	15	30	60
7	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	8	15	30
8	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	8	15
9	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	8
10	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4
11	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2
12	1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1
13	1/8000	1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2
14		1/8000	1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4
15			1/8000	1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8
16				1/8000	1/4000	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15

- The exposure values in the previous table are at ISO 100. For a different ISO speed, increase the values by the number of exposure steps by which the speed is greater than ISO 100, formally:

$$
\begin{aligned}
EV_S &= EV_{100} + \log_2\left(\frac{S}{100}\right) \\
&= EV_{100} + \left(\frac{\log_{10}\left(\frac{S}{100}\right)}{\log_{10} 2}\right) \\
&= EV_{100} + 3.3219 \log_{10}\left(\frac{S}{100}\right)
\end{aligned}
$$

- Exposure values (ISO 100 speed) for various lighting conditions

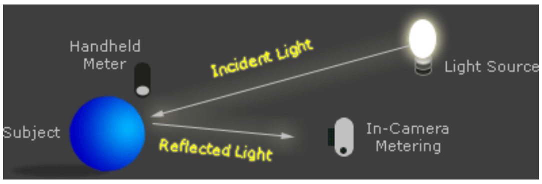
Lighting Condition	**EV_{100}**
Daylight	
Light sand or snow in full or slightly hazy sunlight (distinct shadows)	16
Typical scene in full or slightly hazy sunlight (distinct shadows)	15
Typical scene in hazy sunlight (soft shadows)	14
Typical scene, cloudy bright (no shadows)	13
Typical scene, heavy overcast	12
Areas in open shade, clear sunlight	12
Outdoor, Natural light	
Rainbows	
Clear sky background	15
Cloudy sky background	14
Sunsets and skylines	
Just before sunset	12–14
At sunset	12
Just after sunset	9–11
Moon, altitude > 40°	
Full	15
Gibbous	14
Quarter	13
Crescent	12
Moonlight, Moon altitude > 40°	
Full	−3 to −2

Gibbous	−4
Quarter	−6
Aurora borealis and australis	
Bright	−4 to −3
Medium	−6 to −5
Outdoor, Artificial Light	
Neon and other bright signs	9–10
Night sports	9
Fires and burning buildings	9
Bright street scenes	8
Night street scenes and window displays	7–8
Night vehicle traffic	5
Fairs and amusement parks	7
Christmas tree lights	4–5
Floodlit buildings, monuments, and fountains	3–5
Distant views of lighted buildings	2
Indoor, Artificial Light	
Galleries	8–11
Sports events, stage shows, and the like	8–9
Circuses, floodlit	8
Ice shows, floodlit	9
Offices and work areas	7–8
Home interiors	5–7
Christmas tree lights	4–5

Exposure

- The combination of aperture (f/number) and shutter speed is termed the "exposure"
- Exposure is crucial, since it controls the amount of light that falls onto the sensor (or film) - to get this wrong is the most popular cause of problems in photography
- The real world generally contains a wider range of tones than you can represent with the best digital sensors. You have to make an artistic decision about where you place those tones. Some detail will inevitably be lost as tones that are distinguishable in the real world are mapped to a digital sensor or film. Common experience is that a 4 f-stop difference between bright and dark is the maximum that can be handles. Understanding exposure will give control to predict which details are lost
- The exposure problem can be seen when taking a picture of a scene with a predominance of snow, water or sky, using automatic camera settings. The result will be a badly underexposed photograph - snow will look grey, whilst landscapes with big expanses of sky or water will be too dark
- Obtaining good exposures requires a recognition of such issues as:
  - Incidental (light falling on subject) vs. Reflected light (light reflecting from subject)
  - Assumptions made when calibrating the light meters within camera

Incidental vs. Reflected Light



- Different photographic subjects reflect light in different amounts depending on whether the surface is rough or smooth, more white than black (and vice versa), or transparent such that light is refracted within the subject
- The fact that different subjects, under the same light source, will reflect different amounts of light provides for the biggest complication in estimating the correct exposure
- Two measuring options:
  1. Incident light metering
     - In principle, the most accurate way of finding the correct exposure
     - Only light meters can do this effectively, but they need to be held close to the actual subject to be of real value
     - A diffuser is attached to the light meter so that the meter measures the light ***falling*** on the subject from all directions
     - This method discounts the reflectivity of the subject, and means that light and dark parts of the subject are represented accurately

2. Reflected light metering
    - Most common and convenient method
    - The method of DSLRs, and also light meters
    - The meter points at the subject and measures the brightness of the light reflected from it
    - The reflected light meter, therefore, provides an exposure that tends to compensate for the reflectivity of the subject

- Both reflected and incident light meters are calibrated to measure the light in a scene and produce a medium tone. Note this is a "tone", not a "colour". Each of the main colours has a "medium" light tone. The light meter thus places the light tones detected in the frame within the midrange of the sensor to minimise loss of detail due to excess of darkness or light
- If a camera is aimed directly at any object lighter or darker in tone than this middle tone, the camera's light meter will under or over expose correspondingly

18% Grey Tone	18% Red Tone	18% Green Tone	18% Blue Tone

- Considering only a black and white spectrum, we literally find the middle grey tone. It is this tone that is used to calibrate the light meter – via what is called the 18% grey[1] card
- An in-camera light meter can work surprisingly well if object reflectance is sufficiently diverse throughout the frame. In other words, if there is an even spread varying from dark to light objects, then the average reflectance will remain roughly middle grey. Unfortunately, some scenes may have a significant imbalance in subject reflectivity, such as a photo of a white dove in the snow, or of a black dog sitting on a pile of charcoal. For such cases the camera may try to create an image with a histogram whose primary peak is in the mid-tones, even though it should have instead produced this peak in the highlights or shadows
- Take a picture of a person standing in the shade with a bright background or with the sun behind them, backlighting their head. This can be very flattering portrait lighting if you know how to use your light meter correctly, but if you don't adjust your exposure to compensate for the bright background, you'll end up with near silhouettes.
- A comparison of the exposure settings for a camera focused, in turn, on a white and then a black dog will show that much less light is reflected from the black fur, compared to the white fur – even though the dogs may be under exactly the same lighting conditions

  For the white the EV level would be 15 (say). This would indicate to the camera that we have light conditions equivalent to a bright cloudless, sunny day. For the black dog, the camera sensor would experience an EV=12 (say), indicating a heavy overcast sky. The camera looks up in a table or calculates (as described earlier) two separate exposure settings for the same incident light level – but neither will give a correct exposure

  The above examples assume the use of an in-camera reflected light meter. If an incident light meter was used (measuring the light actually falling on the dogs), it would not only have provided the same exposure for both dogs (the same amount of light is falling on them), but the exposure would have been "correct", showing a truly white and a truly black dog
- There is a 3rd measuring option: Reflected grey card

  A grey card is held in front of the subject and its reflected light is used for the exposure settings. It is also possible to take the meter reading using your hand when the skin tones of the subject are important.

18% Grey: What Is It?

- What constitutes middle grey? In the printing industry it is standardised as the ink density which reflects 18% of incident light, however cameras seldom adhere to this. Each camera has a default somewhere in the middle grey tones (~10-18% reflectance)
- Is this 18% gray assumption reasonable? If you take portraits of Caucasian people and meter off their facial skin you'll probably find that your slides come out a bit too dark. Typical Caucasian skin is about 1/2 f-stop lighter than 18% gray. So the reflected meter thinks that the subject is lit somewhat brighter than in reality

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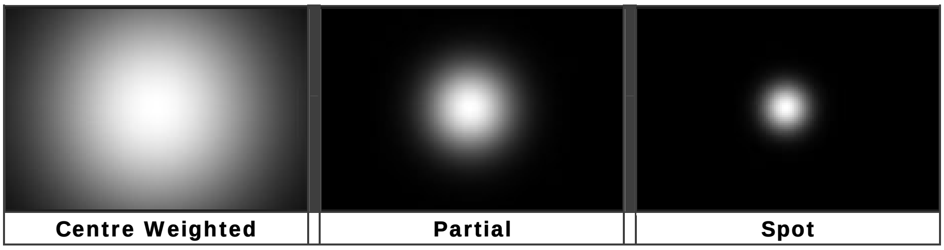
[1] *In a nutshell, a grey card represents the standard reference value which all photo light meters are calibrated against. A grey card reflects 18% of the light which falls upon it*

Metering Options

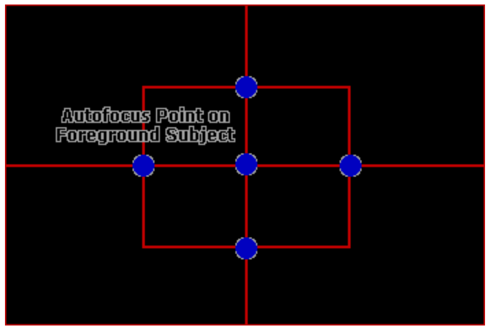
- Most cameras feature several metering options. Each option works by assigning a weighting to different light regions. Those with a higher weighting are considered more reliable, and thus contribute more to the final exposure calculation
- The whitest regions (below) are those which contribute most towards the exposure calculation, whereas black areas are ignored. Each of the metering diagrams shown below may also be located off-centre, depending on the metering options and autofocus point used:



- More sophisticated algorithms may go beyond just a regional map and include evaluative, zone and matrix metering

  These are usually the default when your camera is set to auto exposure. Each generally works by dividing the image up into numerous sub-sections, where each section is then considered in terms of its relative location, light intensity or colour

  The location of the autofocus point and orientation of the camera (portrait vs. landscape) may also contribute to the calculation



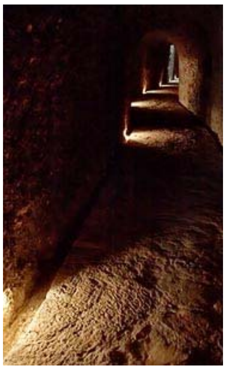
When To Use Partial & Spot Metering

- Partial and spot metering give the photographer far more control over the exposure than any of the other settings, but this also means that these is more difficult to use-- at least initially. They are useful when there is a relatively small object within your scene which you either need to be perfectly exposed, or know that it will provide the closest match to middle grey
- Spot metering is probably the most useful. This system allows you to isolate a single part of the scene to take light reading from only that part. The actual spot is usually in the centre of the viewfinder and varies in size depending on your camera. If you point your spot to anything in the scene, it will tell you how much light is being reflected from it

  It is a simple mistake to believe the reading given by the spot is the one which will deliver the correct exposure for that object - the meter will only indicate what exposure is needed to make that object appear as a mid-tone. For a black object, the exposure would be wrong. The trick is to find the object in the scene in front of you that you want to reproduce as mid-tone in your final image (i.e. a shadow on a flower) and spot meter for that

  To do this, the camera needs a button that locks the exposure setting for a short while, so that focus on the required subject can be done and the shot taken. Locking the exposure is necessary since otherwise the exposure will be taken at the focusing point

  One of the most common applications of partial metering is a portrait of someone who is backlit. Metering off their face can help avoid making the subject look like an under-exposed silhouette against the bright background. On the other hand, care should be taken as the shade of a person's skin may lead to inaccurate exposure if it is far from neutral grey reflectance-- but probably not as inaccurate as what would have been caused by the backlighting
- Spot and partial metering are also quite useful for performing creative exposures, and when the ambient lighting is unusual. In the examples below one could meter from the diffusely lit foreground tiles, or the directly lit stone below the opening to the sky

Exposure Compensation

- Any of the above metering modes can use a feature called exposure compensation (EC). The metering calculation still works as normal, except the final settings are then compensated by the EC value. This allows for manual corrections if you observe a metering mode to be consistently under or over-exposing. Most cameras allow up to 2 stops of exposure compensation; each stop of exposure compensation provides either a doubling or halving of light compared to what the metering mode would have done otherwise. A setting of zero means no compensation will be applied (default).
- Exposure compensation is ideal for correcting in-camera metering errors caused by the subject's reflectivity. No matter what metering mode is used, an in-camera light meter will always mistakenly under-expose a subject such as a white dove in a snowstorm (see incident vs. reflected light). Photographs in the snow will always require around +1 exposure compensation, whereas a low-key image may require negative compensation.
- When shooting in RAW mode under tricky lighting, sometimes it is useful to set slightly negative exposure compensation (0.3-0.5). This decreases the chance of clipped highlights, yet still allows one to increase the exposure afterwards. Alternatively, positive exposure compensation can be used to improve the signal to noise ratio in situations where the highlights are far from clipping.

Depth of Field

- Depth of field is related to the absolute size of the aperture (lens length divided by aperture diameter) not the f-number
  Consider a 600mm lens at f4, which implies an aperture (diameter) of 150mm. That is, the depth of field at f4 on a 600mm lens will be shallower than at f1 on a 50mm lens
- The easiest way to achieve overall image sharpness is to choose a composition where everything is roughly the same distance from the lens
- Other approaches include (some more convenient than others):
  - Change distance from subject:
    - Get up close ➔ less depth of field
    - Move away ➔ more depth of field
  - Change aperture:
    - Increase f-stop ➔ more depth of field
    - Decrease f-stop ➔ less depth of field
  - Change focal length:
    - Wide-angle lenses ➔ very large depth of field, even at small distances
    - Long lenses ➔ very small depth of field, even at long distances
  - Change sensor/film size:
    - Full frame ➔ smaller depth of field cf. Half frame
- With a (D)SLR, what you see through the viewfinder is what the film will see after the mirror flips up. The fact that the depth of field changes with focal length, means that zooming to a different focal length or stopping down by increasing the f-number should cause the changed depth of field to be noticeable in the viewfinder
  It does not, since the lenses still use an automatic diaphragm introduced in the 1960s, and the lens will be stopped down by the camera an instant before exposure, just as the mirror is flipping up
  For viewing and composing pictures, the lens is kept wide open for maximum brightness. To visualise the depth of field, the depth of field preview button should be pressed
- Circle of confusion:
  - Defines what it means to be in focus. Only points in the scene that are actually at the plane of focus are perfectly in focus; all other points are fuzzy circles that get fuzzier the farther away they are from the

plane of focus. The circle of confusion is the size below which the fuzzy circles will still look to the viewer as if they are sharp points, and, therefore, in focus

Proportions of depth of field:

- The 1/3 "rule" is really only true when the lens is focused at one third of the hyperfocal distance
- Close to the camera, the depth of field is split with half in front and half behind the point of focus
- As the point of focus is moved further from the camera, the proportion of depth of field that is behind the point of focus increases
- At or beyond the hyperfocal distance, everything past the point of focus to infinity will be within the depth of field