EXPOSURE

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"PHOTOGRAPHY IS THE EASIEST ART, WHICH PERHAPS MAKES IT THE HARDEST" – LISETTE MODEL

Having correct exposure is fundamental to understanding photography.

This statement does oversimplify the problem, because in reality the scene and therefore your photograph has a range of different brightness levels – brightest at the highlights and darkest in the deep shadows. A good photographer will understand this, and use their knowledge to create an image that shows the subject at its best. Lighting is adjusted to suit the subject, either by careful selection of the time of day and the angle of the sun, or by the use of artificial lighting. Lighting can be flat – that is even over the subject (cloudy day), or contrasty – with dark shadows and bright highlights (strong sunlight, no clouds). When there is a lot of contrast it is impossible to capture all the tones in a single exposure. Having large areas of black in your image may be what you want, but you need to understand how to control tones in your image.

The photographer needs to consider how the subject will be rendered in the final image. A black horse's image should be black, with enough detail to show the texture of the mane and eye. An image of a snow scene should show the snow as white, but with enough detail to show the texture of the snow. The real difficulty comes when there is a need to show both a dark and a light subject – the bride in the white dress and the groom in a dark suit.

Modern digital cameras have a through-the-lens exposure meter. They are usually set so the exposure is averaged over the whole frame area, sometimes with the intelligence to recognise a subject and expose that more correctly.

UNITS OF EXPOSURE

It is fortuitous that exposure really does not need to be measured accurately. Doubling or halving the illumination has since photography began has been the fundamental unit of exposure. Doubling or halving the amount of light is a change of 1 stop or of one exposure value (1 EV). More about Exposure Values later.

Originally lenses and shutters for film and plate cameras were fitted with click stops to easily enable the aperture and exposure time to be adjusted by feel. This is how the term Stop was used to indicate a change by one exposure value. The thumb adjuster on modern cameras is similar, except that adjustments are 1/3 or ½ stop.

> *For now, remember each unit of exposure is doubling or halving the light and is one stop.*

EXPOSURE TIME (SHUTTER SPEED)

The amount of light reaching the sensor can be controlled by setting the Exposure Time. Increasing the time will lighten the image, and reducing it will darken the image.

> *Doubling or halving the exposure time will change the exposure by 1 stop*.

The camera controls the exposure time with a shutter. This opens to expose the sensor to light through the lens and then closes when the exposure time is complete. Exposure time is very often also called shutter speed. This name is a misnomer, because the shutter moves just as quickly irrespective of the length of time it is open. Sometimes shutter speed is used to denote the bottom of the fraction, so 1/800 second exposure time is called a "shutter speed" of 800.

Most cameras, particularly prosumer and professional models, have a mechanical shutter just in front of the sensor (a focal plane shutter), however many newer cameras are using an electronic shutter. The shutter used for video photography is electronic.

Exposure times are expressed in whole number seconds or in fractions of a second: the decimal system has never taken over. Typical values, each separated by 1 stop (double or half the amount of light) are:

1/15 1/30 1/60 1/125 1/250 1/500 1/1000

MOVEMENT BLUR

The choice of exposure time is dependent on movement of the subject and steadiness of the photographer if the camera is hand-held.

CAMERA SHAKE

Having the camera on a sturdy tripod will avoid camera shake in most situations. Lightweight tripods are not much use, except for lightweight cameras. Those of carbon fibre are the best combination of stiffness and weight, and are worth the extra you pay over aluminium legged versions.

It is recognised that for hand-held images, the divisor of the exposure time should be equal to or greater than the lens focal length in millimetres to avoid camera shake.

> *50mm focal length - exposure time less than 1/50 second if hand held*
>
> *500mm focal length- exposure time less than 1/500 second if hand held*
>
> *For longer exposure times, use a tripod or other camera support*

This rule of thumb is approximate. It only applies for a photographer using best technique. Stand with two feet firmly planted slightly apart on solid ground, elbows tucked in, and camera held firmly against the eye. Breath in and hold your breath as you take the shot. If the photographer has a particularly steady hand, or is sitting or lying down, or is leaning against a solid object, they may increase exposure time by one or two stops.

It does not apply to a camera held at arms-length viewing the LCD screen. As we get older and more unsteady, particularly with a heavy camera and lens, reducing exposure time by one or two stops is necessary for handheld shots.

If the lens or camera has an image stabiliser, the exposure time for hand-held exposures may be lengthened by 2 to 5 stops – see your camera or lens manual. The image stabiliser should not be used for tripod shots.

SUBJECT MOVEMENT

The exposure time needs to be short to stop action of the subject; such as when capturing sports like football, surfing, gymnastics, or motor sport; or moving wildlife such as a bee flying into a flower. Exposure time of shorter than 1/500 second are typically used. The image stabiliser has no effect on subject movement.

Conversely long exposure times are used to express motion as a blur, as for moving water or clouds. In this case, shutter times of quarter a second to as much as several minutes may be required to give the blur effect. These long times require the use of a dark neutral density filter (6 to 10 stops) and a tripod. This technique is also useful when photo-bombers walk through your shot. They just don't show on the image because of the long exposure.

LENS APERTURE

The other factor affecting how much light reaches the sensor is how much light passes through the lens. This is directly related to the area of the lens aperture. Camera lenses have a variable aperture or iris to control the light level. This is designed to be as close to circular as possible.

> *If the aperture area is doubled, the light reaching the sensor is doubled, or increased by one stop or 1 EV.*

The light level reaching the sensor is also dependent also on how far the aperture is from the sensor. The lens aperture is close to the focal point. So, the focal length of the lens also affects the level of light reaching the sensor – a longer focal length lens has the aperture further away from the sensor, and if the aperture area is not changed there is less light reaching the sensor. The earliest camera and lens design engineers worked out a way of expressing aperture that takes into account both aperture area and lens focal length, we call the f/stop number. How convenient is that – we don't have to include focal length in our exposure determination!

The lens aperture diameter is the focal length, f in millimetres, divided by the f/stop number.

A 50mm focal length lens at f/2 has an aperture of 50/2 = 25mm diameter. A 100mm focal length lens at f/2 has an aperture of 50mm diameter.

An aperture of f/2 gives the same level of light on the sensor whatever the focal length of the lens.

The f/number is the divisor of a fraction, so f/2 is larger and lets more light than f/4.

If we increase the aperture **diameter** by a factor of 2 we increase the **area** by a factor of 4, and the exposure by 2 stops. f/2 lets 4 times as much light (2 stops) as f/4.

To increase the exposure by 1 stop or 1 EV, we increase the diameter of the aperture by the square root of 2, or 1.4. So, f/2.8 is one stop smaller than f/2. This is how we end up with the standard f/number series, with each step being one stop or 1 EV from the next.

f/1 f/1.4 f/2 f/2.8 f/4 f/5.6 f/8 f/11 f/16 f/22

There is the tendency for the divisor symbol '/' to be omitted, which shows a lack of literacy. The symbol f/ means focal length divide by the number. It indicates the f/ number is the bottom or divisor of a fraction. It

shows f/11 is smaller and lets less light than f/8. We still have the divisor sign for exposure times, so why not for apertures? 1/500 second is a shorter time than 1/250 second.

THE IMPORTANT THING TO REMEMBER IS THAT INCREASING THE APERTURE BY ONE STOP AND REDUCING THE EXPOSURE TIME BY ONE STOP BOTH GIVE THE SAME EXPOSURE.

BOKEH AND DEPTH OF FOCUS

The other thing that aperture affects is depth of focus. This is the distance between the nearest acceptably sharp object and the furthest when the camera is focused at a particular distance. Depth of focus can be significantly increased by reducing the aperture size. Often a large aperture, with a narrow depth of focus is chosen to ensure the background is strongly out-of-focus. This produces some lovely artistic effects (bokeh) and emphasises the subject.

Depth of focus is also dependent on lens focal length and distance to the subject. A wide-angle lens with 14mm focal length, will have a depth of focus from 300mm to subjects at infinite distance at f/11 when focused at 600mm. A 100mm macro lens will have a depth of focus of less about 2mm when focused at a distance of 200mm at f/11.

Depth of focus can be determined with a smartphone app, and there are several free ones available. However, I recommend PhotoPills, which does a lot more useful things. See the article on lenses for more information on depth of focus and hyperfocal distance.

SENSITIVITY - ISO

The third factor in determining exposure is the sensitivity of the sensor or film, which is determined by its design.

In the days of film, we could choose more sensitive (faster) film to make it easy to photograph in low light conditions, or where we wanted to use a short exposure time for action shots. The catch was that fast film was grainier and the image inferior.

Sensitivity is expressed as an ISO number. Historically each country had their own standard for specifying film speed, but the International Standards Organisation (ISO), a body set to unify standards worldwide in a wide variety of disciplines, convinced everyone to use one standard. The whole world now uses the ISO system for specifying film and sensor light sensitivity.

Gone are the days where Kodachrome slide film had a sensitivity of ISO 25. Now the lowest digital camera sensitivity is ISO 50, and some cameras can use sensitivity of ISO 250,000.

The thing to remember is:

> *To increase the sensitivity by 1 EV or 1 stop the ISO number is doubled*.

If the sensitivity is increased by one stop from ISO 100 to ISO 200, the exposure time or aperture may be reduced by 1 stop to give the same exposure.

ISO AND IMAGE NOISE

Digital cameras have the ability to change sensitivity electronically, but there is a loss of quality, the higher the sensitivity is set. Turning up the sensitivity is like turning up the radio volume level; eventually the sound is

distorted. It shows as increasing noise on the image. The Canon 5D Mk IV has an ISO range of 50 to 102,400. The realistic limit is 12,800.

THE EXPOSURE TRIANGLE

The three factors that define exposure, exposure time, aperture and ISO, can be considered as at the corners of the exposure triangle. The correct exposure is one with a correct selection of these three factors.

The important thing to remember are that if one of them is changed, then one or more of the other two have to be changed by the same number of stops or EV to compensate and maintain the same exposure.

If we have a scene in bright sunlight (with an EV_{100} of 15 – see below) we can determine a range of exposures. All the following settings will give exactly the same exposure.

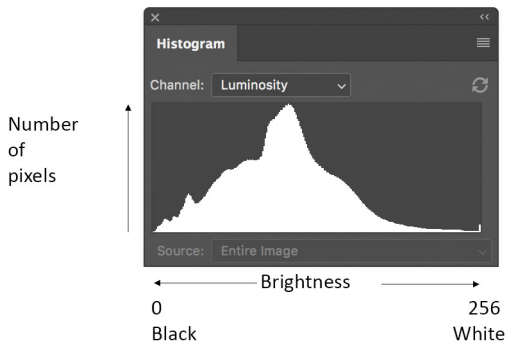
Exposure time	f/number	ISO
1/125	8	100
1/250	5.6	100
1/250	8	200
1/1000	8	800

CHECKING YOUR EXPOSURE - THE HISTOGRAM

At the start of this article I stated that exposure is dependent on ensuring the subject is exposed so that it is rendered as required on the image. We need to know how to assess the image for correct exposure.

The great thing about digital photography is that you can look at the image on the LCD monitor on the back of the camera after you have taken it. This will show roughly if it is correctly exposed, but the camera will also show a histogram which gives a much better idea. Understanding the histogram is fundamental to understanding exposure and image development in photography. Find out how to view your camera's histogram from the manual. You have the option of showing a Brightness (luminance) or Colour histogram.

All image development software uses histograms. The histogram below is from Photoshop, but the brightness histogram on your camera will be similar.



Brightness is displayed on the horizontal graph axis, from black, through dark grey, light grey to white on the right axis. The vertical axis represents number of pixels of each tone. Really the histogram is a representation

of the brightness range of the scene you have photographed. A flat contrast image will have a peak in the centre with no black or white pixels.

A peak at the left-hand side of the histogram indicates there are a large number of pixels with a light intensity of zero, which will show as black. For a JPEG camera image or developed image, a high level at the left-hand side of the histogram will represent a large area of blackness in the image with no shadow detail. If you are shooting RAW, there will to be some shadow detail that can be recovered, because camera histograms are based on shooting in JPEG mode.

A peak at the right-hand side shows there are a large number of pixels with an intensity of 256, which will be rendered pure white with no highlight detail. Again, for a camera histogram of a RAW image, there will be some detail that can be recovered in development.

One with a high dynamic range (deep shadows and very bright highlights) will have both black and white pixels. See the section on photographing *High Contrast Scenes* below for how to deal with these.

For camera histograms, in most cases blown highlights are regarded as not good, so exposure is aimed at getting detail in highlights, and letting the shadows take care of themselves. However, this is not always the case. If your image is high key, large areas of white with no detail help concentrate the attention on the subject. Similarly, for night scenes or low key images, large areas which are black negative space may be what you want. There is no ideal histogram.

Some cameras have the ability to show blown highlights as an alert when you view the image on the LCD screen, which is known as The Blinkies. With Highlight Alert turned on, overexposed highlights will flash. This is a quick way of showing overexposed highlights, and is especially good for JPEG capture.

You probably have the option of turning on a colour histogram instead of the monochrome one. The principle is the same, but the display will show the primary pixel colours, Red, Green and Blue. The most common situation is where you are photographing a red subject, and you end up with a red peak at the right-hand side. If you are shooting a JPEG, this shows that the reds are over exposed, and will show as a bright red patch with no detail. The term for this is that the reds are out of gamut. With a JPEG image, reducing exposure is about all you can do to avoid this. It can be corrected if you shoot RAW and reduce the saturation in image development. It is possible to have greens or blues out of gamut too.

EXPOSURE COMPENSATION

The camera through-the-lens (TTL) exposure meter in matrix mode will average the illumination over the whole frame, sometimes applying a correction if a subject is detected that requires compensation. This works well most of the time, but can be fooled if the subject is small and is much lighter or darker than the background. It is also fooled if the subject is predominantly light or dark toned, where it will be rendered as an average grey tone.

Imagine a spider orchid lit in a shaft of sunlight, with shadow in the background. The correct exposure will give the colour and detail in the orchid, however most of the frame is shadow background. This will cause the orchid to be overexposed with matrix metering, because the meter is reading the dark background.

Spot metering may give a better result, but often the shape of the orchid means it cannot be covered by the meter spot, and overexposure is still likely.

The other situation requiring exposure compensation is where the subject is dark or light, such as an animal with black fur, or white snow. Caucasian skin is really mid toned, and will meter accurately, but where the

subject has dark skin, one or 2 stops less exposure is required. Even if spot metering is used, the exposure will need compensation.

One solution is to temporarily put a grey card in the same light, and set the exposure for that. That should give just the right exposure, whatever the tone of the subject and its size.

For most exposure modes, exposure is increased or reduced by using the Exposure Compensation dial, which reads in number of stops or EV. Alternatively use manual mode, and set exposure time, aperture and ISO manually. The exposure meter display will have marks either side of the main balance point in 1 stop graduations.

EXPOSURE LATITUDE

The exposure latitude is the ability of the film or camera sensor to record a wide range of tones, when the subject has high contrast, such as on a bright cloudless day with deep shadows. Colour slide film only has an exposure latitude of 0.5 stop. Colours in the correctly exposed image are saturated, but often bright areas are washed out – that is have insipid colours or are white. Under-exposed areas have muddy colours or are black with no detail.

Colour print film has more latitude – 2 to 3 stops, depending on film speed. High speed film has less latitude.

The early digital camera sensors suffered low latitude, but improvements in their design have led to a remarkable high latitude with most digital cameras. The best cameras have more than 6 stops latitude. For the best sensors, think of those on professional level cameras, such as the Canon 1DX, which use fewer larger pixels, or the medium format cameras such as the Phase One.

Having greater latitude does mean the exposure captures a wider range of tones. It does make exposure less sensitive, but it is foolish to rely on this. Accurate exposure determination is necessary to make the best images.

The high latitude only applies at low ISO. As ISO is increased so latitude is decreased.

PHOTOGRAPHING HIGH CONTRAST SCENES

A high contrast scene is one with very dark shadows and very bright highlights. It is shown on the histogram as peaks on both the left-hand side (shadows), and the right-hand side (highlights).

It can be photographed by combining several different exposures, using HDR (High Dynamic Range), or a multiple layer technique in Photoshop. Some cameras will create a HDR image automatically. They take 3 images and then make a combined HDR image for you.

Where you want to capture a high contrast scene with multiple exposures, the difference in exposure between the images should be one stop. When making these exposures, keep the aperture, white balance and ISO constant, and vary the exposure time. Most cameras have a bracketing setting where multiple exposures can be made in one go. Set up the number of exposures, usually 3, 5 or 7. Then set the shutter to motor wind. Now when you fire the shutter the bracketed exposures are exposed in rapid succession. The motor wind will stop when this is complete. Often only two images are required, one for the sky and another for the foreground. Exposure bracketing can have problems where objects in the frame move, and a breeze may be enough to rustle leaves enough to spoil the composite.

The alternative instead of multiple exposures for landscapes with a bright sky, is to use a graduated neutral density filter (ND-grad). The top of the filter is dark and the bottom clear. The transition between light and dark is graduated. With this filter the sky is darkened, but the main subject is not.

One popular approach for high contrast is to expose for the highlights and let the dark areas underexpose to blackness. This gives a dramatic low key image with no distractions in shadow areas. Exposure needs to be determined carefully.

EXPOSURE VALUES

An exposure value is a combination of exposure time and aperture. It was used by some cameras in the days when the camera was totally mechanical to simplify exposure. The concept is still used today. While 1 EV and one stop are both equivalent to doubling or halving exposure time, there is one subtle difference. Exposure values are on an absolute scale, whereas stops are relative.

> *0 EV is defined as 1 second exposure at an aperture of f/1.*

The exposure value of typical scenes at ISO 100 (EV_{100}) are tabulated below, so that it is possible to estimate exposure without an exposure meter. This can be used for cameras without exposure meters, or for planning a photoshoot.

Today's digital camera exposure meters have a light range outside which they do not work, which is often stated in the operating manual. This typically is from 0 EV to 20 EV at ISO 100 (Canon EOS 5D Mk III and Mk IV).

The same units are used to express the focus brightness range, outside which autofocus won't work. For the Canon EOS 5D Mk IV, the focus brightness range is -3 to 18 EV at ISO 100. On the EOS R, the focus brightness range is -6 to 18 EV at ISO 100. Often the camera manufacturer will forget to state that the ISO that the EV is at, in which case it is safe to assume it is ISO 100.

Below are some estimates of exposure value, including for scenes where the camera exposure meter or autofocus will struggle. It's worth remembering that bright sunlight is typically 15 EV_{100}, because that can be used to compare other scenes.

Lighting Condition	**EV_{100}**
Light sand or snow in full sun	16
Typical scene in full sun or slight haze	15
Typical scene in hazy sunlight (soft shadows)	14
Full moon at an altitude over 40˚	15
Gibbous moon at an altitude over 40˚	14
Scene moonlit by a full moon at an altitude over 40˚	-3 to -2
Moonlit scene by gibbous moon at an altitude over 40˚	-4
Aurora Borealis and Australis, bright	-4 to -3
Galactic centre of Milky Way	-11 to -9
Night sports under floodlight	9
Fires – bonfires, campfires, burning buildings, bushfires	9
Home interiors	5 to 7
Christmas tree lights	4 to 5

This information can be used to estimate where to start with exposure calculations.

The exposure of a typical scene in bright sunlight (EV_{100} of 15) will be 1/500 second at f/8 with ISO 100.

THE ZONE SYSTEM

Ansel Adams and Fred Archer used the same concept as stops or exposure values for their zone system for pre-visualising photographic prints. There are 11 zones of exposure, each 1 stop from the next. They used Roman numerals to distinguish from other systems. Zone 0 is rendered as black, Zone V is mid grey, and Zone X as pure white.

FILTER FACTORS

Photographers use filters in front of the lens (usually) to modify the image. Whether they are coloured, neutral density, graduated or polarised, they all cut down the light level at the sensor or film. Fortunately, because today's cameras use through-the-lens metering the photographer does not need to think about the effect on exposure – the camera automatically corrects it. However, the photographer does need to consider filter strength when purchasing filters, so as to understand their effect. There are two different methods of denoting filter strength, which some find confusing.

One method that is common is to use a filter factor. The exposure is multiplied by this number to correct it for the effect of the filter. If the filter has a factor of 8, the exposure time has to be increased 8 times to account for the filter. If the original exposure time was 1/800 second, using this filter will change it to 8 x 1/800 = 1/100 second.

The other method is to denote the filter strength in number of stops. One stop is doubling exposure. Two stops increase is 4-times exposure and 3 stops increase is 8-times exposure. In this case, when the filter is used, just count the number of clicks. The adjustment can be made to the aperture or exposure time. A 10 stop ND filter requires increasing the exposure 1000-times.

If this all sounds a bit complicated, help is at hand. Download a smartphone app from NiSi. This is free, even though you don't have any NiSi filters. With this you can choose an exposure time – they call it "shutter speed", then a filter, which is given as both a filter factor and number of stops (ND8 – 3 stops). It then displays "shutter speed with filter"

KNOW YOUR CAMERA

I have a series of exercises that can be used to practice the above principles. Check the website for Exposure Practical Exercises.

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