Exposure

Fundamentals

for

Film and Digital

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Introduction

I will treat both digital and film issues in this document especially since there is a lot of common material and a number of people are still using film.

Why do you need to learn about exposure meters, tonal values of surfaces, meter calibration, etc. when you have just purchased one of those fancy camera bodies either digital or film with sophisticated automatic exposure capability including Matrix/Evaluative metering? The answer is that the meter in your camera can be fooled and you need to know when to rely on it and when to ignore it. Metering techniques built into the camera are getting much better with the introduction of computer technology but they still have limitations. Just try that new exposure calculating machine on a snow scene or try to photograph a black locomotive and you will quickly see the need to override the camera calculated meter reading.

Reflected light metering

Reflected light metering as the name implies measure the light reflected from an object.

The main advantage of Reflected Light metering is that you can meter the light from where you are standing and you do not have to trek the 5 miles to the top of the mountain to measure the light. It speeds up the photographic process. This is the metering system that is included in your camera if it has a meter.

The main disadvantage is that the meter is correct only for middle tone colors and wants to see everything as middle tone. You have to adjust for light reflected from colors that are not middle toned. The problem is that different colors and different shades of the same color reflect light to a different degree. To observe this phenomenon just go out into bright sunlight and look at something whose color is brilliant white and then at something that is pitch black and let your eyes and brain tell you which reflects more light. You will note that looking at bright white that is reflecting sunlight "hurts your eyes", it is reflecting a lot of light into your eye and the Iris is having trouble stopping down. Black reflects very little light and it does not "hurt the eyes". Black is black because it is absorbing most of the light, not reflecting it.

Since film and a digital sensor are designed for correct exposure based on the light striking an object, a light meter, to be accurate, must determine the intensity of the light striking an object not the light reflected from it. The problem for the designer of a Reflected light meter would be very simple if all surfaces, colors and shades of colors reflected light to the same degree but they do not. The designer is forced to choose an average value of Reflectance of objects and colors. Years of data has indicated that the **average** outdoor nature scenic is composed of elements that reflect 18% of the light that strikes them. The meter designer uses the simplifying assumption that you only desire to photograph average outdoor scenics and designs the meter by measuring the reflected light and calculating the incident light by multiplying the reflected light by a constant to obtain the required incident light value. This is why we use a gray card that has an 18% reflectance value, it is matched to the characteristics of the meter.

This is also why the meter is accurate only for one set of conditions, a scene whose Reflectance value is 18%. This metering method is fairly accurate for most average outdoor scenic photographs but as we progress in that search for the above average photograph we pursue non-average subjects and non-average lighting conditions and that is when the Reflected meter can lead us astray. Consider what happens when we attempt to photograph the opposite poles of Reflectance, black and white. Since the meter assumes that the world is all middle toned, when you measure light reflected from a white surface the meter will tell you the correct settings to record this white object as middle gray. If you measure light reflected from a black object the light meter will again give you the settings to record this subject as middle gray. Neither of these light measurements is correct if you want to record the white as white or the black as black and therefore you have to compensate for the underlying assumption of the meter that the world is all middle toned.

The compensation process is simple to remember if you recall what the light meter is doing. When you measure the light reflected from white the light meter is telling you how to record it as middle gray so you have to open up to photograph the white as white. The adjustment can be in the range of 1 to 2 stops. If you meter light reflected from black the meter will again tell you how to record that as middle gray and if you want the reality of black you will have to close down by 2 to 3 stops. This process is applicable for all colors. For instance light toned green reflects much more light than a dark toned Evergreen tree and you have to compensate for the meter reading to get a correct exposure.

The best way to illustrate this basic principle to yourself is to take a gray card, a piece of white construction paper and a piece of black construction paper and put them in the **same** ambient light and take a reflected light meter reading of each one. Take the gray card reading first, this is the correct exposure, and then note what happens to the meter reading when you measure white and then black. If you do not compensate for these reflected light readings you will photograph all three objects as middle gray. That is why, if you do not compensate your incident light meter readings, your pictures of snow turn out a grayish blue and why metering black water causes that undesirable overexposure of the lighter objects surrounding it.

One way to overcome the fact that the Reflected Light meter reads accurately only middle toned colors is to measure the light reflected from a standard Gray Card. The Gray Card should be held in the same light as the subject and parallel to the plane of the subject for a correct reading. If you find yourself without a Gray Card you can always meter off the **palm** of your hand and open up 1/2 to 1 stop. (My palm says 1/2 stop and John Shaw says 1 stop. He uses better soap than I do.) The palm of the hand is approximately 1/2 to 1 stop lighter than middle toned. This also works for non-Caucasian individuals since palm color does not vary significantly.

Reflected Light Meter Metering Patterns

Reflected light meters that are built into the camera as Through the Lens metering systems have a variety of patterns to compensate for uneven lighting situations that occur in normal photographs. The two most popular are Center Weighted and Matrix.

Center Weighted uses the central area of the composed image in the viewfinder as the main image interest area and assigns it more "weight" when metering the amount of light. Each camera manufacturer and each model can use a different pattern for the central area. Some use top central weighted which means that the upper central portion is assigned more "weight" on the assumption that this is the normal above horizon sky area of the image. Think about turning this camera sideways for a vertical image and contemplate the non-applicability of the metering pattern. Camera manufacturers seem to perceive the world as horizontal.

Matrix metering is a refinement of center weighted metering and in general a number of small samples are taken of the light values in the viewfinder and then one "best compromise" exposure value is calculated. This metering scheme is generally employed only in models with built in compute capability.

Incident Light Metering

Incident light metering measure the light **falling on** an object and not the light reflected from it.

The main advantage of this type of metering scheme is that the meter does not see the world as middle toned colors.

The disadvantage of the Incident light meter is that you have to ensure that the meter is measuring the same incident light that you are going to photograph. When you use this type of meter you have to hold the meter in the same plane as the plane of the principal subject you are photographing and ensure that the same light is striking the meter cell as the subject. Don't read the meter in the shade and then photograph a sunlit object.

The best way to describe how to point the meter is very simple. Point the diffuser of the meter at the light you want to correctly expose. If you are taking a front lit subject simply point the cell at the camera lens ensuring that the full light strikes the diffuser and your body shadow is not blocking any light. If you want to correctly expose for the backlight on a subject point the diffuser at the backlight, facing 180 degrees away from the lens. If you want to expose correctly for the sidelight on a subject point the meter 90 degrees away from the lens towards the sidelight.

In situations of varying light intensities, bright open areas and shade areas, this metering system can be tricky. If the meter cell sees mostly bright light it will of course tell you to expose for that light value and if it sees mostly the light in the shadows it will tell you to expose for the shadows. If you want to expose for the highlights you will have to ensure that the meter sees only the bright light and conversely if you want to expose for the shadow areas you will have to make sure that the meter sees only the light in the shadow areas. This can be tricky when photographing areas of significant space and may require considerable walking, climbing and wading to get to that area you are photographing with your 600 MM lens.

Another disadvantage of an Incident light meter over a Through The Lens Reflected Light meter is that you have to compensate for filters and extension tubes that you use with the lens. An in-camera TTL metering system takes care of this compensation automatically since it reads the light coming through the lens to the viewfinder and any light loss due to filters or extension tubes is compensated for. You can easily determine the amount of compensation you need for any of these devices by taking in camera exposure readings of a uniformly lit scene one with and one without the device. The difference in the exposure readings is the amount of compensation required.

If you photograph with a macro (Nikon calls them Micro) lens there is one other factor that you have to take into account when you use an Incident light meter. Macro or Micro lenses exhibit light loss as you change the focusing distance since the lens works by adding extension between the rear lens element and the film plane. To determine the amount of light loss meter on an **evenly** illuminated surface with the through the lens camera meter while focusing between infinity and the closest focusing distance of the lens and note the amount of light loss. The amount of exposure compensation for a macro lens that you will have to apply to an incident meter reading is determined by the procedure stated above. If your lens had a variance of 1 1/2 stop at the furthest extension then you will have to apply that compensation to your Incident meter reading when you use the lens at that extension. This compensation gets tricky since it gets to be a guessing game to determine the amount of compensation required at any intermediate extension. I find that when I am working with a macro lens it is much easier to use the through the lens camera meter and a Gray Card.

If you take an incident meter reading all the tonal values from black to white will fall into place automatically with no exposure compensation required.

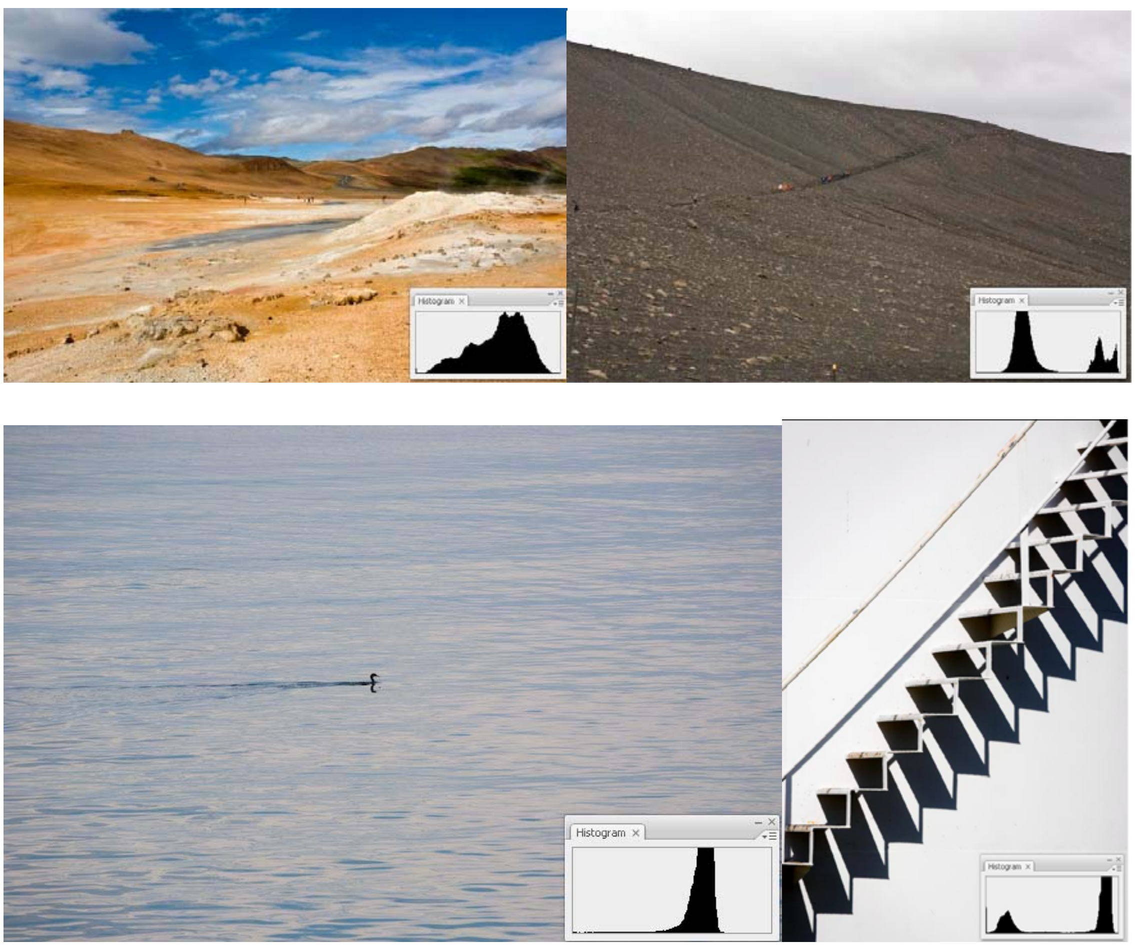
Summary - you pays your money and you takes your choice and there is no one perfect solution when it comes to the type of light meter. Each has their place in the search for the "best" exposure.

Digital Camera Metering

You still need to understand the principles of light metering described above but the digital camera, as long as it will display a histogram, makes metering a lot simpler. The histogram is a great way to evaluate exposure.

A histogram is very simple. It is a display in graph form of a count of pixels at all illumination levels from a luminance level of 0 to 255 with 0 being the lowest level and 255 being the brightest level. Even if your camera will record an image in 12 or 14 bit form the histogram is only displayed in 8 bit (256 possible values, 2^8). The darkest level is displayed to the left in the histogram and the brightest level is displayed to the right. There is no such thing as a good shape for the histogram. It is not supposed to look like a bell-shaped curve. The shape of the histogram depends on the tonality of the pixels in the image.

Good histograms



The first image has a large range of tonalities. The second one has two limited ranges of tonality. The third has a limited range of a single tonality not to be confused with hue. The fourth has two tones, very bright and very dark.

Bad histograms

A bad histogram is one that “clips” either the black end or the white end of the histogram.

Note that in the first histogram you cannot fix the histogram in the camera, it is clipped on both sides. The tonal range of the image is too large for the sensor and there is nothing you can do about it in the camera. As long as it is not too bad you can fix it later in Photoshop, Lightroom, etc.

It is generally a lot easier to fix clipping in the shadow areas but I have taken out a significant amount of highlight clipping when post editing the image.

In summary as long as the histogram is not clipped in the camera the exposure is acceptable and can easily be adjusted when post editing the image.

Clipping means that pixels that have different tonal values and thus yield discernible detail are converted to pixels of one tonal value losing the capability to differentiate between the pixels.

One of the main advantages of photographing in RAW format is that RAW contains more tones, generally 4096 tones versus 256 tones in JPG format and thus more tones to use in the recovery process.

I took the first bad image and processed it in Lightroom to recover the detail in the shadows. Note that I could not recover the detail in the white light in the windows at the front of the church. The highlights were still clipped.

Spot metering

The capability of a light meter to measure a very small area or spot of light. This metering capability is available only in reflected light meters.

The need for this metering capability occurs when there is uneven illumination on the scene to be photographed. This is especially important when using slide films or a digital camera since they have much less exposure latitude than print films. In an uneven lighting situation one has to decide whether to expose for the brightly lit areas or for the shadow areas. There is no one perfect solution to this situation as it is a compromise. The general rule is however that the eye/brain will tolerate underexposure more than it will tolerate overexposure but again this is only a general guideline and not a rule. If you want to photograph a face in a backlit situation you will have to meter for the light on the face and not the bright background light, if not you will get a very dark face with very little detail.

To use a Spot meter simply point the meter spot at the portion of the scene that you want correctly exposed and meter. Since the Spot meter is a reflected light meter you will have to compensate for the fact that it wants to accurately measure only middle toned colors. Thus if you spot meter something very light toned you will have to open up your aperture and correspondingly if you meter something darker than middle toned you will have to close down. (To my knowledge no one makes an Incident Spot meter, not to be confused with spot metering attachments that you can add to an Incident meter. These are used as reflected meters.)

Sunny 16 Rule

If all else fails use the Sunny 16 rule.

Take the ISO value of the film or ISO setting in a digital camera, then take the reciprocal (a fancy way of saying divide 1 by this number) and set the shutter speed to that value (e.g. for ISO 50 film set the shutter speed to 1/50 or the closest value, in this case 1/60. Then set the aperture to f16. Of course any corresponding combination of shutter speed and aperture will work as long as they are equivalent in exposure, e.g. 1/30 and f22, 1/125 and f11.

This rule works on bright sunny days for subjects in direct sunlight that are front lit. It also is applicable from approximately two hours after sunrise to two hours before sunset. (See that little yellow Kodak box. if you can still find one)

If you are in bright sunlight and in an area of high reflectance such as a beach or snow scene then you will have to modify the rule to be the Sunny 22 rule because the areas of high reflectance adds about a stop of light to the subject. This compensation should not be confused with the fact that you have to stop down from a Reflected Light meter reading when you are metering light toned colors. They are two very distinct issues. One deals with light being added to the scene due to high reflectivity surfaces and the other has to do with the fact that a Reflected Light meter measures accurately only middle toned colors.

If you think this is too elementary Dewitt Jones tells a funny story about one of his United Airlines shoots in Japan where he and two assistants took four of five different exposure reading with different meters both in camera and external and they were all different. After mopping the cold sweat off his brow (he had rented the stadium and the crowd) he relied on the Sunny 16 Rule, shot and got the published picture. If you have seen a United Airlines ad taken in a baseball stadium in Japan that is the shot. So don't be timid about using this highly sophisticated piece of metering equipment.

Meter Calibration

A lot of misleading information floats around on this subject. The best way to calibrate your in camera reflected light meter is to take it to a good camera technician and have him calibrate it. The next best is to calibrate it against someone else's meter that is known for exposure accuracy. Make sure you frame the same subject in the viewfinder. The next best way is to point you camera at a clear blue (no white should be included) northern sky at a 35 to 40 degree angle from the ground plane and the exposure should be the same as the Sunny 16 Rule. If you want to see the inaccuracy of this method just point your camera at a patch of blue sky that includes some thin white clouds and see what happens or move from the northern orientation or move from the 35 to 40 degree angle. **Also be wary of this rule since I have experienced it being off by some two stops even when following all the rules!!!! It was indicating f8 on a sunny 16 day and it was corroborated by another person with a different camera.**

If the camera light meter is not correctly calibrated it may be recalibrated in either one of two ways. If the camera has an Exposure Compensation setting then simply set the correct under or over exposure compensation into the camera to obtain the correct meter calibration. This can generally be accomplished in either 1/3 or 1/2 stop increments depending on the camera make. If you change batteries remember to reset the Exposure Compensation since it is lost on a battery change. If the camera does not have Exposure Compensation then you can change the ISO setting for each type of film you use. You can’t use this technique when using a digital camera. Each time you double the ISO or divide the ISO by 2 you change the meter setting by an f stop. If you double the ISO (say from 50 to 100) then you set 1 stop of underexposure and if you divide the ISO by 2 (say from 50 to 25) then you add 1 stop of overexposure to the camera meter. Setting the ISO setting is not as easy as setting Exposure Compensation since you have to calculate the amount of ISO adjustment for each type of film you use that has a different ISO rating. Using the Exposure Compensation method requires only one adjustment and it works for any ISO rated film speed.

An Incident Light meter can be checked in the same manner and recalibrated by modifying the ISO rating for the film that you are using in a manner similar to the method described for recalibrating a camera meter. Most Incident meters have an adjustment screw that will allow you to recalibrate the meter and if you are not squeamish about doing that adjustment it will keep you from having to fool the meter with a different ISO setting for each film that you use.

This calibration should not be confused with changing the rated ISO rating of the film that you shoot for additional saturation. That is an entirely different issue.

Film Calibration

After having calibrated your meter and compensated for non-middle tone colors you may still not get the desired results that please you by using the manufacturer's rated exposure index, ISO, for the film you shoot. You may want to increase the ISO to increase saturation or decrease the ISO if your photographs are constantly underexposed. There are two popular ways of doing this. One is to change the ISO for the film by changing the ISO setting on the light meter. The second method, if your camera contains that capability, is to add an exposure bias of plus or minus the number of stops compensation desired, e.g. -1/2 stop to underexpose or +1/2 stop to overexpose.

Do not believe that all films should be treated the same way. I personally used to expose Kodachrome 25 at -1/2 stop.

The newer films (Fuji Velvia and Ektachrome 100VS) with a high degree of saturation do not require the underexposure saturation technique we old timers have gotten used to with the Kodachrome films. If you use the underexposure technique on these saturated films you are likely to get very dense images that tend to go muddy. (It is funny to see the cyclical changes in this business. The original Kodachrome ASA 10 film was very highly saturated similar to Fuji Velvia and was changed for the European pastel color palette when it was modernized to its current ISO 25 version, first called Kodachrome II. As a Trivia question K64 was first marketed as Kodachrome X)

Film Projector Calibration

After going through all the trouble to get correctly exposed transparencies it seems less than desirable to project them with either underexposure or overexposure from your projector.

Projectors are designed to provide an optimum level of illumination at one distance between the projector and a particular type of screen and if you do not view at this distance you will either be experiencing some degree of over or underexposure. In addition each viewing screen has a different reflectance value which changes the brightness of the projected image.

The correct level of illumination, according to published Photographic Society of America data is a light value of EV 8.5 nominal with a low value of EV 8 and a high value of EV 9. At an ASA of 100 and a shutter speed of 1/15 second this yields the following f-stop values:

EV	f-stop
8	4.0
8.5	4.9
9	5.6 (This is the light level of the Club projector used in competitions)

In order to measure the light value of the projected image take a super slide mount without anything in it, a 1 ½ x 1 ½ opening, and cycle it into the projector. Set the screen to projector distance so that the lighted screen area is a square 70 inches on each side. Use only a reflected light meter since you want to measure the reflectivity of the screen in addition to the light output of the projector. Set the meter for ASA 100 and a 1/15 second shutter speed and measure the f-stop. The correct reading is between f4.0 and f5.6.

There are at least four methods to obtain the correct projected illumination.

1) Vary the distance between the projector and the screen. This is not always possible since the size of the projected image changes as you change the distance and the image may become too large for the screen or the room may become too small.
2) This method requires a modification to the projector and requires you to place a lamp dimmer in series with the projector's lamp. The purist will argue that this changes the color balance of the lamp and thus the color balance of the projected image but the brain seems to take care of the color shift unless it becomes very severe. I have not found the color shift to be a serious problem. This can easily be accomplished if purchase a Dissolve Unit connector since the lamp circuit is brought out to the Dissolve Unit on the rear of the projector. Simply connect the two larger diameter wires in the Dissolve Unit cord to the lamp dimmer.
3) The third method is to place a neutral density filter in front of the projector lens. My Kodak Carousel Model 4600 projector requires a 2 and a 1/2 stop neutral density filter to drop the light to the high value of f 5.6 or 3 stops to get to the mid f4.9 value. That is right, the normal projector output can be 2 and 1/2 stops brighter than your slides are getting judged with in competition!
4) The fourth method is to change the screen style. A matte screen has the lowest reflectance with a silver lenticular screen having a mid level of reflectance and a glass-beaded screen having the highest reflectance. A matte screen reflects one less f-stop of light than a lenticular screen. .

Some projectors used to be manufactured with an Iris ring in the lens for this compensation and they also adjusted the amount of transmitted light automatically.

When I first calibrated my projector the light value that I was using for my normal viewing distance was 2 and a 1/2 stops brighter than recommended, a huge difference. That explained why my slides looked different at home than when viewed at the Club. It also explained why some people preferred shooting Velvia at ASA 40 rather than 50.

Appendix 1

Camera Controls

The amount of light that reaches the film or sensor is controlled by two exposure controls on the camera; shutter speed and f stop.

Shutter Speed

Shutter speed determines the amount of time that light reaches each grain of film/sensor. The longer that light is allowed to reach the film/sensor the more exposure the film/sensor receives and thus the lighter the exposed image. Conversely the shorter the time that light reaches the film/sensor the less exposure and the darker the image. Shutter speeds are generally expressed in seconds either as a fraction of a second (1/60 of a second) or as a whole number (2 seconds). The camera display generally eliminates fractions and shows the fractions as a whole number such as 250 which signifies 1/250th of a second. Whole number of seconds are generally expressed as a number followed by a " such as 2" which signifies 2 seconds. Shutter speeds generally extend from 30 seconds (displayed as 30") to 1/8000th (displayed as 8000) of a second. 30 seconds will provide you with the maximum light and 1/8000th will provide you with the least light.

Main shutter speeds on the camera are one half of the previous and thus allows one half of the light to reach the film. This yields shutter speeds of 30, 15, 8, 4, 2, 1, 1/2, 1/4, 1/8, 1/15, 1/30, 1/60, 1/125, 1/250, 1/500, 1/1000, 1/2000, 1/4000, 1/8000. The newer models of electronic cameras allow shutter speeds to be set in half stop or third stop increments.

There is one special shutter Speed displayed as B and the B stands for Bulb (this expression stems from old cameras that had a bulb operated shutter). On B setting the shutter will remain open until you let go of the shutter release. In this setting you will have to time the shutter speed with an external clock. This setting is very useful for exposing star trails which require minutes to hours of exposure.

f Stops or Aperture

The second way of controlling exposure in the camera is by controlling the amount of light that passes through the lens. This is accomplished by an Iris Ring inside the camera lens which opens up to allow more light to pass through and closes down to limit the amount of light. This opening is referred to as the lens aperture. (This leads to the common expression of “stopping down” and “opening up” or shooting “wide open”.) The full f-stop range is 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 45 etc. Electronic cameras allow you to set f-stops in 1/2 or 1/3 increments. As you go up the scale to the next larger number you reduce the light by one half. That is going from f11 to f16 cuts the light in half and conversely going from f16 to f11 doubles the light striking the film/sensor.

If you are mathematically inclined f-stops are derived from the square root of each term of a Geometric Progression:

$$\sqrt{2^0},\ \sqrt{2^1},\ \sqrt{2^2},\ \sqrt{2^3},\ \sqrt{2^4},\ \sqrt{2^5},\ \sqrt{2^6},\ \sqrt{2^7},\ \sqrt{2^8},\ \sqrt{2^9},\ \sqrt{2^{10}},\ \sqrt{2^{11}} \ldots..$$

$$\sqrt{1},\ \sqrt{2},\ \sqrt{4},\ \sqrt{8},\ \sqrt{16},\ \sqrt{32},\ \sqrt{64},\ \sqrt{128},\ \sqrt{256},\ \sqrt{512},\ \sqrt{1024},\ \sqrt{2048} \ldots..$$

1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 45 ...

Film Speed

The other factor that affects exposure is film speed. Film is labeled in ISO ratings. ISO stands for the International Standards Organization. Film commonly comes in ISO ratings of 25, 50, 64, 100, 200, 400 and 1600. The lower the number the more light it takes for a given exposure. Films with low ISO numbers are referred to as slow films since for a given f stop you must shoot with a slower shutter speed to correctly expose the film. Each time the ISO speed is doubled it has an effect of one full f-stop. That is if the correct exposure for a scene taken with ISO 25 film is 1/60th at f11 then you could use ISO 50 film and use 1/60th at f16 or any other combination of shutter speed and aperture such as 1/125th and f11. In a digital camera you can set the ISO value which is equivalent to selecting a different ISO film. The advantage is that in a digital camera you can switch ISO values between images.