Digital Photography Quick Reference Guide

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Thank you Neale Eckstein for reviewing the manuscript and Jake Jacobson for reviewing the manuscript and contributing the fireworks photograph.

Contents

Introduction

Digital cameras have revolutionized photography from the consumer market to the highest end professional applications.

Digital cameras can now be made so small and inexpensively that most cell phones include a digital camera that for many casual photographers is of acceptable quality to be their primary camera. For more serious photographers there are relatively inexpensive point and shoot cameras and so called prosumer grade digital single lens reflex (DSLR) cameras.

For the high end professional, the latest professional quality DSLR used in conjunction with programs like Photoshop and Lightroom offers performance and flexibility beyond what film cameras can offer.

The primary purpose of this book is to provide a quick reference guide to the experienced digital photographer, however, we have also included a Basics section that is designed to allow less experienced photographers to get the background they need to make use of the rest of the guide.

Following the Basics section the Techniques section provides specific equipment recommendations and tips for common shooting situations. The Definitions section provides detailed information on the terms introduced in the Basics sections and is organized for quick reference. Finally all of the Abbreviations used in the Guide are presented in a single comprehensive list.

Throughout this guide any terms defined in the definitions section are capitalized.

Basics

1.1. The Digital Camera

The description of a digital camera given here is for a Digital Single Lens Reflex (DSLR) camera. The references to "see" with capitalized terms all in parenthesis refers to terms or techniques defined in the subsequent sections of this guide.

The major components of the camera are:

- Camera body
- Camera lens (depending on the camera, the lens may be interchangeable or built-in and varies in complexity)
- Battery
- Memory card
- External flash (optional). Most consumer and prosumer cameras have built in flashes, most professional cameras do not. External flashes are generally much more powerful and can light up subjects much farther away (see Guide Number)

Figure 1.1 illustrates the front of a Nikon D200 prosumer level digital camera with the major parts labeled.

Figure 1.1. Nikon D200 prosumer level digital camera - front view.

The key features in figure 1.1 include:

- The on/off switch to power the camera on and off.
- The shutter release button, pressing the button part way focuses the camera and pressing it all the way takes a photograph.

- There are a number of buttons and dials to set various camera features including a command dial and various unlabeled controls. The exact layout of the controls and control functions will vary camera to camera.
- The lens (on this particular camera the lens is interchangeable).
- A pop-up flash.

Figure 1.2 illustrates a rear view of the same Nikon D200 camera.

Figure 1.2. Nikon D200 prosumer level digital camera - rear view.

Key features in figure 1.2 include:

- A flash hot shoe for attaching external flash units.
- The view finder that allows the user to see through the camera lens to compose and focus the photograph. On this particular camera the view finder only shows 95% of the what the sensor actually sees. This is common on all but the highest end DSLRs.
- Command screen - displays a variety of camera settings.
- Monitor - can be used to view photographs after they are taken, or to view a variety of camera settings that can then be set with the multi-selector. Some cameras have a live view mode where the monitor can be used to compose a photograph.
- Multi selector - used to make selections from the menus displayed on the monitor.
- Various unlabeled buttons and dials used to control the camera settings.

Figures 1.3, 1.4 and 1.5 show the same camera with the memory card partially inserted, the battery partially inserted and the lens removed respectively.

Figure 1.3. DSLR showing memory card partially inserted.

Figure 1.4. DSLR showing the battery partially inserted.

Figure 1.5. DSLR with the lens removed.

There are a variety of memory cards for digital cameras, two of the more common are the compact flash card (figure 1.6 left side) and the SD card (figure 1.6 right side). Compact flash is more common in higher end cameras and SD cards are more common in point and shoot cameras.

Figure 1.6. Common digital camera memory cards.

Figure 1.7 illustrates the optical path inside a DSLR.

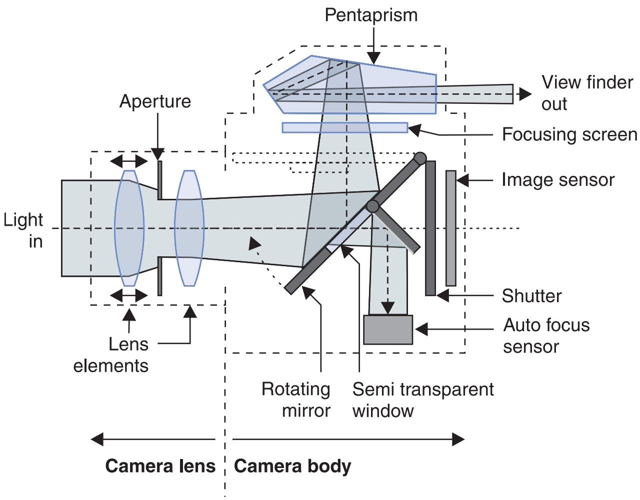

Figure 1.7. DSLR optical path.

The key elements in figure 1.7 are:

- Camera lens - light enters the camera through the camera lens. The lens is made up of multiple lens elements (10 to 15 elements are not unusual) and a variable Aperture (see Aperture). Some of the lens elements are movable to provide focusing.
- The camera body contains the rest of the optics.
- A rotating mirror splits the incoming light so that part of the light goes to the auto focus sensor that is used to determine when the lens is in focus, the other portion of the light goes

through the focusing screen, is turned in the pentaprism and exits the camera body through the view finder.

- When a photograph is taken the rotating mirror pivots up and the shutter opens allowing the light from the lens to reach the image sensor. Once the image is captured the shutter closes and the mirror pivots back down to prepare for the next photograph.
- The battery and memory card (not shown) would also be housed in the camera body (see figures 1.3 and 1.4).

The camera image sensor is made up of an array of pixels where each pixel outputs a voltage proportional to the intensity of the light reaching the pixel. Figure 1.8 illustrates an image sensor with an array of pixels.

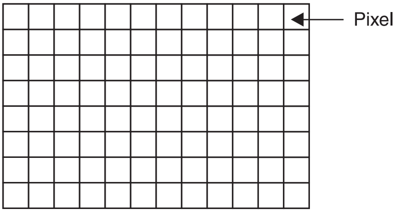

Figure 1.8. Image sensor.

35mm camera film was 36mm by 24mm in size and that is the standard for digital camera full frame sensors. The are also a variety of partial frame sensor cameras (see Sensor Size).

The number of pixels in the sensor determines how large the image can be enlarged with acceptable quality (see Pixel Counts).

In order to produce a color image an array of color filters are aligned over the image sensor, see figure 1.9.

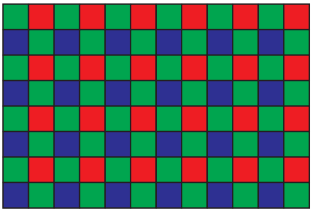

Figure 1.9. Color filters.

In figure 1.9 an array of red, green and blue color filters are aligned over the image sensor. You may notice that there are twice as many green filters as there are red or blue filters, this is because the human eye is more sensitive to green. The pattern illustrated in figure 1.9 is called the Bayer pattern developed by Bryce Bayer of Kodak in 1976. There are other methods but this is the most common.

Figure 1.10 illustrates the path the data takes from the image sensor to the memory card.

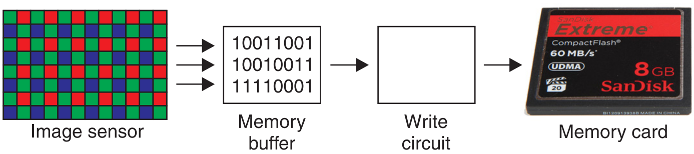

Figure 1.10. Digital camera image storage system.

The system illustrated in figure 1.10 operates as follows:

- The image sensor produces a series of voltages that correspond to the light intensity captured by each pixel. The voltages are then converted to digital numbers 8 bits or more in length.
- The digital values from the sensor are output to a memory buffer. Current generation full frame DSLR image sensors range in size up to 36 million pixels (megapixels, MP) (medium formats go as high as 80MP) (see Sensor Size). With each pixel outputting 8 or more bits of data the total data volume per image is very large. Some DSLRs can also produce up to 10 images per second and all of that data has to be moved off of the image sensor and stored in between each image capture. The camera buffer is very fast memory built into the camera that holds images until the data can be written to the memory card. Writing to memory cards is relatively slow and cannot keep up with the rate the camera can produce images if continuous shooting is being used. This means that once the camera buffer is full, the camera must take longer periods of time between image captures.
- The image can be stored on the memory card in a variety of formats. The data can be stored in RAW format (see RAW Format)

an uncompressed format, or the data may be compressed and stored as a JPEG or TIFF files.

The overall camera electronics and control system are very complex. Figure 1.11 illustrates a simplified block diagram of the overall system.

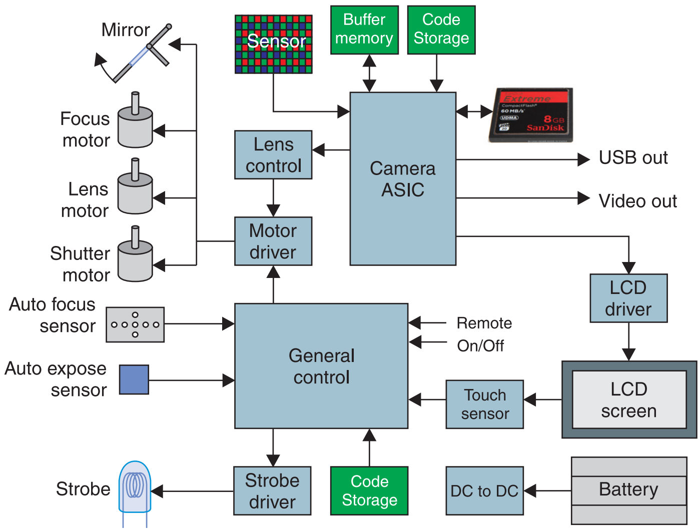

Figure 1.11. Digital camera electronics block diagram.

The specifics of the electronics inside a digital camera vary manufacturer to manufacturer and camera to camera but figure 1.11 gives an idea of the overall system.

1.2. Lens Characteristics

The primary characteristics of lenses are the Focal Length (see Focal Length) and Aperture (see Aperture and f Number).

The lens Focal Length is typically expressed in millimeters (mm) and determines the Magnification of the lens (see Magnification) and the Angle of View (see Angle of View). Longer Focal Lengths give higher Magnification with a narrower Angle of View and shorter Focal Lengths give lower Magnification and wider Angle of View.

Table 1.1 summarizes lens characteristics versus Focal Length.

Table 1.1. Lens characteristics versus Focal Length for a Full Frame Camera (see Sensor Size).

Focal Length (mm)	Type	Magnification	Angle of View	Typical Usage
<21	Extreme wide angle	<0.42	>81^o	Architecture
22-35	Wide angle	0.44 - 0.70	79^o- 54^o	Landscape
36-70	Normal	0.72 - 1.40	53^o- 29^o	General use. 50mm is 1.0 magnification.
71-135	Near telephoto	1.42 - 2.70	28^o- 15^o	Portraits
>135	Telephoto	>2.70	<15^o	Sports, wildlife

Lens focal length may be fixed to a single length (also called a prime lens) or may be variable in a lens referred to as a zoom lens. As a general rule zoom lens are more complex than fixed lens and therefore more expensive. Fixed lens are also typically sharper although there are high end zoom lenses that are competitive in performance with even the best fixed lenses.

The second characteristic of a lens is the Aperture (see Aperture). The Aperture in a lens is a a variable size opening that determines how much light passes through the lens. Aperture is expressed in f Number (see f Number). The lower the f Number the larger the Aperture and conversely the higher the f Number the smaller the Aperture. Large f Numbers let in very little light, but limits the lens to the center section dramatically improving Depth of Field (see Depth of Field). Lower f Numbers let in a lot of light but results in very shallow Depth of Field.

Lenses are specified with a range of f Numbers the lens supports. Less expensive lenses will have a minimum f Number of f/4.0 or f/ 5.6 or more (generally the longer the Focal Length the higher the minimum f Number) whereas more expensive lenses may maintain an f Number of f/2.8 even out to telephoto Focal Lengths (if the lens minimum f Number is specified as a range of numbers it means the minimum f Number changes with Focal Length). The advantage of the lens with the lower f Number is in very low light conditions you can shoot a shorter exposure (see the next section).

Table 1.2. Fixed lens minimum f Number versus Focal Length

Focal Length (mm)	Professional lens minimum f Number	Consumer lens typical minimum f Number
50	f/1.2	f/1.8
85	f/1.4	f/2.8
200	f/2.0	--
300	f/2.8	--
400	f/2.8	--
600	f/4.0	--
800	f/5.6	--

Table 1.3. Zoom lens minimum f Number versus Focal Length

<table>
<tr><th>Focal Length (mm)</th><th>Professional lens minimum f Number</th><th>Consumer lens typical minimum f Number</th></tr>
<tr><td>14-24</td><td>f/2.8</td><td>--</td></tr>
<tr><td>24-70</td><td>f/2.8</td><td>--</td></tr>
<tr><td>24-85</td><td>--</td><td>f/3.5-4.5</td></tr>
<tr><td>55-200</td><td>--</td><td>f/4.0-5.6</td></tr>
<tr><td>70-200</td><td>f/2.8</td><td></td></tr>
<tr><td>80-400</td><td colspan="2">f/4.5-5.6</td></tr>
<tr><td>200-400</td><td>f/4.0</td><td></td></tr>
</table>

Table 1.2 and 1.3 present just a sampling of available lenses. The differences between the professional and consumer f Numbers may not look that big, but in low light situations it can be the difference

between getting a shot and not getting the shot. That is why professional photographers shooting sporting events as an example will spend $5,000 to $10,000 on a single lens to get the best performance possible.

1.3. Exposure

In a digital camera, exposure is the result of three interacting variables, Shutter Speed (see Shutter Speed), Aperture (see Aperture) and ISO Speed (see ISO Speed). For each situation the three factors need to be balanced against each other to achieve the correct image exposure while optimizing the quality of the resulting image.

Shutter Speed is the amount of time the shutter is open allowing light to reach the image sensor. The longer the shutter is open the more light reaches the images sensor. Shutter speed is typically limited by either the movement of the object being photographed or the ability of the photographer to hold the camera still. As a general rule when holding a camera in your hands (as opposed to mounting it on a tripod) that longest acceptable exposure before camera shake becomes an issue is one over the Focal Length of the lens, so 1/50 second for a 50mm lens, 1/100 of a second for a 100mm lens and so on. If the subject being photographed is moving you may need to further reduce the exposure time, for example when shooting Sports Photography (see Sports Photography) unless you want the subject to be a blur for artistic effect.

The Aperture of the lens determines how much light is let in through the lens. Lower f Numbers are larger Apertures letting in more light but at the expense of shallower Depth of Field. Higher f Numbers are smaller Apertures letting in less light but with greater Depth of Field. In most situations a high f Number with the resulting deep Depth of Field is desirable so that everything in the photograph is in focus. There are however some situations where a shallow Depth of Field is desirable, for example in a portrait you may want the subject to be in focus and the background blurry so that the subject stands out (see Portrait Photography). This is the artistic aspect of how to set up a camera.

ISO Speed basically determined how much the output of the image sensor is amplified (see ISO Speed). The higher the ISO the less light is required to reach the sensor for a correctly exposed image but as ISO is increased, so does noise particularly in the dark parts of images.

The interaction of these three factors is referred to as the Exposure Triangle because all three are interacting and trading off versus each other (see Exposure Triangle). In bright sunlight the trades offs are relatively easy, shoot a low ISO for the lowest noise with a short exposure to minimize camera shake and object movement and a high f Number to provide a deep Depth of Field. In dim light however a high ISO may be required even though the images will be noisier, while shooting the lowest f Number supported by the lens and the longest exposure time possible without camera shake. It is exactly these situations that drive professionals to very low f Number lens (referred to as fast lens) and very expensive cameras that can shoot at high ISO Speeds with low noise. Conversely you may make different decisions for artistic reasons and use shallower Depth of Field or the subjects motion to create a specific effect.

The trades offs between the three factors are something that a photographer has to develop a feel for and will also vary camera to camera and lens to lens. Each year new digital cameras come out with lower noise at high ISO speed. Luckily for the beginner, today's digital cameras have automatic program modes that manage all of the trade offs and do it well in most shooting situations.

1.4. File storage formats

There are three main storage formats seen in digital cameras:

- RAW - mainly seen in high end cameras, RAW is a format proprietary to each manufacturer that captures 100% of the image sensor data (see RAW Format). RAW is the highest quality format but requires special software to process the image.
- JPEG (Joint Photographic Expert Group) - probably the most common format and the one used by most photographers. JPEG is a standard way of taking the data from the image sensor and compressing the data to take up less storage space. For example in one of my cameras a RAW file is nearly 17 Mb (Megabytes) in size and a JPEG of the same image is only about 4 Mb. JPEG is a lossy compression technique and data is lost but the com-

pression is carefully designed to minimize the loss in visible image quality.

- TIFF (Tagged Image Format File) - currently becoming less common. TIFF is a file format owned by Adobe systems and is a flexible file format that can hold both lossy or loss less data.

1.5. Conclusion

In this chapter the basics have been covered to set the stage for the rest of this guide. In the next chapter practical techniques and the equipment required to execute them is presented for common photographic applications. The Techniques chapter is followed by the Definitions chapter that discusses each of the terms introduced in this chapter in more details.

From this point on this book is organized to be easily accessed as a quick look-up reference guide.

Techniques

2.1. Buildings

Buildings can present specific challenges due to their size and location.

2.1.1. Basic principles

- Use the lowest ISO Speed your camera supports to maximize resolution.
- Use a tripod and a high f Number for maximum Depth of Field.
- Pay attention to lighting, consider shooting just after sun rise or just before sun set for the best light.
- Focus on details, don't just shoot the whole building.
- Use a longer Focal Length lens if possible to avoid wide angle lens distortion.
- Consider framing the building using other surrounding elements.

In some situations it may be necessary to use a wide angle lens to get a shot due to size and location constraints. Programs such as Lightroom allow the wide angle lens distortion to be corrected during post processing.

Figure 2.1. Building in Newport RI, taken from a boat during a harbour cruise. 28-300mm f/4.0 to f/5.6 lens, set to 92mm and f/9.0, ISO200, 1/320 of a second exposure.

2.2. Fill Flash

Fill Flash is the use of a flash to fill in shadows most commonly in bright sunlight but may be used anytime the background is brighter than the subject.

Fill Flash is accomplished by setting the exposure time based on the background lighting level and then using just enough flash to correctly light the foreground. Many cameras have fill flash modes that automatically control the flash output to accomplish this.

This technique will help lighten shadows in bright sunlight, it also works well in the shade and can even be used at night when lighting is uneven.

Figure 2.2. Fill Flash - on a sunny day I moved the subjects into the shade and used fill flash to provide even lighting.

2.3. Fireworks Photography

Although fireworks occur at night in a generally dark environment, the fireworks themselves are very bright. Fireworks also occur over time so the best photographs capture them for relatively long time periods.

2.3.1. Basic principles

The following are some basic principles for shooting fireworks:

- Mount your camera on a tripod and use a remote release to avoid camera shake during long exposures.
- Use a medium f Number in the range of f/8 to f/22. Lower f Numbers will overexpose the fireworks and they will not be sharp.
- Use a low ISO number of ISO100 or ISO200, once again to prevent overexposure.
- Use the bulb setting on your camera so you can hold the shutter open to capture enough of the fireworks for an interesting picture. If you don't have a bulb setting on your camera use a several second exposure time.
- Manually focus the lens to infinity.
- Optionally cover the lens between bursts during long exposures to prevent extraneous light from getting in.

Figure 2.3. Fireworks photograph, copyright 2013 Jake Jacobson, reprinted by permission, all other right reserved. 30mm lens, f/22, ISO200, 2 second exposure.

2.4. Head Shots

Head shots are commonly used in resumes, web sites, promotional material, school photographs and other applications.

2.4.1. Basic principles

- Run the camera in full manual mode.
- To minimize the effect of ambient light use the shortest exposure your camera can sync the flash to (see Flash Sync), typically around 1/250 of a second and the lowest ISO speed, typically ISO200 or ISO100.
- Set the aperture to f/4 to f/5.6 to insure the subject's whole face is in focus but the background it out of focus.
- The subject should be approximately 4 feet in front of the backdrop to insure the back drop is out of focus.
- A 24" softbox should be placed at a 45^o angle to the line between the camera and subject and at a 45^o angle above the same line. The soft box should be close to the subjects face (around 4'). The flash on the softbox should be run in manual and adjusted until correct exposure of the subject is achieved.
- A second flash is place on the other side of the subject firing onto a reflector card at a 45^o angle to the line between the camera and the subject. The second flash should be set to 1/2 to 1/4 the power of the first flash and is used to insure the subjects face is evenly lit on both sides.
- The camera lens should be selected to frame the face from a distance of approximately 13'.

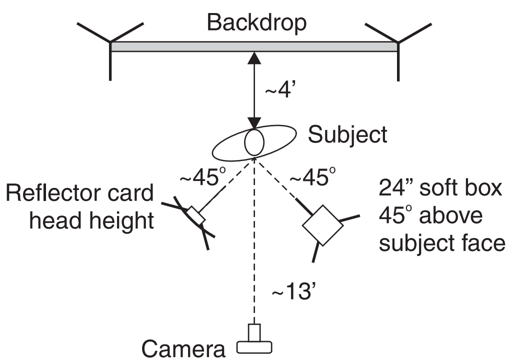

Figure 2.4. Set up for head shots.

Figure 2.5. Head shot - 1/250 sec, f5.6, ISO200, main flash 1/8 power, fill flash 1/16 power, 80-200mm f2.8 lens set to 100mm.

2.5. Landscapes

2.5.1. Basic principles

- Use the lowest ISO speed your camera supports to maximize resolution.
- Use a tripod and a high f Number for maximum Depth of Field.
- Focus one third of the way into the scene for maximum Depth of Field (see Depth of Field and Hyperfocal Distance).
- Use circular polarizing filters to reduce reflections and increase color intensity.
- Pick a focal point to give the photograph interest. You may want to set your focal point location based on the Rule of Thirds (see Rule of Thirds).
- Consider your foreground and place points of interest in the foreground to give your photograph a sense of depth.
- Consider the sky, most landscape photographs are dominated either by the foreground or the sky. If the foreground is most interesting keep the sky to one third of the image or less but if the sky is interesting consider making the sky two thirds of the image.
- Consider the horizon, make sure it is straight and place it on one of the Rule of Thirds lines (see Rule of Thirds)
- Take the light into account. Shoot in the hour before sunset or the hour after sunrise to get the most even light possible. Don't be afraid of cloudy days, clouds can give interest to the sky and also help diffuse the light.
- Try different points of view, don't just shoot the first photograph that you see but rather move around and look at the landscape from different angles.

Figure 2.6. Beavertail cliffs and lighthouse, Jamestown RI. 28-300mm f/4.0 to f/5.6 lens, set to 28mm and f/14, ISO200, 1/60 of a second exposure.

Figure 2.7. Block Island, RI. 28-300mm f4.0 to f/5.6 lens, set to 28mm and f/10, ISO200, 1/400 of a second exposure.

2.6. Low Light

In low light situations it is often a struggle to get a short enough exposure to produce sharp hand held photographs. High ISO speed with small f Numbers helps tremendously but there is still the need to minimize exposure times.

Experience has shown the most digital cameras tend to over expose photographs in low light. This has proven to be true in high end cameras from both Nikon and Canon.

One useful technique is to shoot in full manual mode. Set the highest acceptable ISO numbers your camera is capable of with the lowest f Number supported by the lens you are using. Then take a series of pictures increasing the shutter speed one step at a time above what the camera recommends and reviewing each image on the cameras monitor screen. Select the exposure with the lowest acceptable brightness to minimize exposure time and produce the sharpest image (shorter exposure times minimize camera shake). Also keep in mind that if you shoot in RAW you can easily increase the image brightness a step or more later in Lightroom. This technique will typically gain multiple steps of exposure speed and yield noticeably sharper images.

Image stabilization lenses also help with low light shooting increasing the allowable exposure time versus non stabilized lenses for the same sharpness. The degree that image stabilization helps depends on the specific shooting situation and is generally less than lens manufacturers might like you to believe.

Auto shutter speed: 1/80 sec, ISO6400, f/2.8, 80-200mm f/2.8 lens at 80mm. Note that some of the performers are over lit.

Manual shutter speed: 1/200 sec, ISO 6400, f/2.8, 80-200mm f/2.8 lens at 80mm. Lightened in Lightroom, the performers are now properly lit.

Auto shutter speed: 1/40 sec, ISO6400, f/2.8, 80-200mm f/2.8 lens at 80mm. Note that some of the performers are over lit and not sharp.

Manual shutter speed: 1/100 sec, ISO 6400, f/2.8, 80-200mm f/2.8 lens at 80mm. Lightened in Lightroom, the performers are now properly lit and sharper.

Auto shutter speed: 1/50 sec, ISO6400, f/2.8, 50mm f/1.4 lens. Note that some of the performers are over lit.

Maual shutter speed: 1/160 sec, ISO6400, f/2.8, 50mm f/1.4 lens. Note that the performers are now properly lit. No post processing.

Figure 2.8. Low light automatic versus manual exposure.

2.7. Lunar Photography

The moon is a small bright object in a dark sky. If you try to take a picture with a camera in automatic mode it will likely be overexposed.

2.7.1. Basic principles[1]:

- Use a tripod and remote camera release to minimize camera shake.
- Use the lowest ISO speed your camera supports, typically ISO100 or ISO200.
- Use an aperture of f/5.6 to f/8.0. Lens are sharper if they are not run "wide open" so stop down from the lowest f Number by a couple of steps.
- Use manual mode on the camera and adjust the exposure by reviewing test images. Typical shutter speeds will be 1/100 to 1/500 second.
- Use the longest telephoto lens you have available and manually focus the lens to infinity.
- It is a good idea to shoot a few days before or after a full moon so that shadows will outline the craters and make them show up better.
- Nights with clouds surrounding the moon can provide interesting effects.

1. "Shooting the Moon" by Jake Jacobson

Figure 2.9. Lunar photograph, ISO200, f/8.0, 1/100 second, 28-300mm f/4.6-f/5.8 lens set at 300mm. The photograph has been cropped to further enlarge the moon.

Figure 2.10. Lunar photograph with clouds, ISO1000, f/5.6, 1/60 second, 28-300mm f/4.6-f/5.8 lens set at 300mm. The photograph has been cropped to further enlarge the moon.

2.8. Macro Photography

Photography where the image size is equal to or larger than the object size is referred to as Macro Photography. Typically Macro Photography is utilized for extreme close-up photography of very small objects.

Reproduction ratio - image size divided by the object size:

$$RR = i/o \tag{2.1}$$

where: *RR* is the reproduction ratio, *i* is the image size and *o* is the object size. RR > 1.0 defines macro photography.

2.8.1. Macro lens

Specialized macro lenses, are lenses with long barrels for close focusing and are optimized for high RR. Typical macro lenses and usage are:

- 45 to 65mm - product photos
- 90 to 105mm - insects, flowers and small objects from comfortable distances.
- 150 to 200mm - insects and small animals where additional working distance is required.

2.8.2. Techniques to adapt standard lens

Techniques for adapting a regular lens to macro usage include:

- Extension tubes or bellows - extends the lens away from the camera increasing RR.
- Close up filter - screws onto the front of a lens and increases RR. Relatively low quality.
- Reversing ring - allows a lens to be put on the camera “backwards” increasing RR to as much as 4. Relatively good quality.

2.8.3. Basic principles

- Use the lowest ISO setting your camera supports, typically ISO100 or ISO 200.
- Use a tripod to minimize camera shake.
- Use a high f Number to maximize Depth of Field - Depth of Field tends to be very shallow for Macro Photography.
- Manual focusing is typically required due to shallow Depth of Field.

- Multiple light sources are often required for even lighting. Small soft boxes can also work well.

Figure 2.11. Nikon 60mm macro lens (left) versus 50mm standard lens (right). Note the much longer macro lens for a similar focal length.

Figure 2.12. Amethyst photographed with a 60mm f/2.8 macro lens. A 24” softbox was used to provide even lighting.

2.9. Portrait Photography

Carefully composed photographs of individuals or groups.

2.9.1. Lens

- The human brain recalls facial features as seen at 15’. Portraits taken from 15’ are the most “natural”.
- At 15’ to photograph a whole person; for a standing subject use a 50-70mm lens, for a sitting subject use a 70-105mm lens and for a head only shot use a 200-300mm lens. In the field professional photographers often use 300mm or 400mm lens.
- Short Focal Length lenses require the photographer to get close to the subject to fill the frame and can make the subject uncomfortable.
- Sort Focal Length lenses can also distort the subject’s features accentuating close features (see figures 2.13 and 2.14).

2.9.2. Lighting

- In bright sunlight have the subject face away from the sun so their whole face is in shadow and then overexpose or use fill flash.
- Indoors use a light colored surface to bounce the flash and get a more diffuse light source.
- The smaller the light source the harsher the light, larger more diffuse light sources produce softer light.

Figure 2.13. Photograph taken with a 28mm lens - note the distorted facial features and prominent nose.

Figure 2.14. Photograph taken with a 100mm lens, note the more natural facial features.

2.10. Rule of Thirds

The Rule of Thirds is a guideline for composing photographs.

Divide the image into nine equal areas by using two equally spaced horizontal and vertical lines. Important elements should be placed along the lines or at the line intersections.

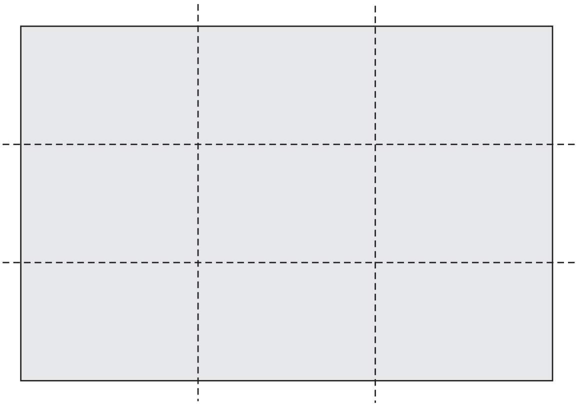

Figure 2.15. Diagram for the rule of thirds.

2.10.1. Applying the rule of thirds

- For an image of the horizon (an important horizontal element) place the horizon on one of the horizontal lines and not the center of the photograph.
- Important vertical elements such as people should be placed on the vertical lines.
- The key to this rule is to discourage putting key elements in the center dividing the picture in half.

The Rule of Thirds is a useful guideline but is not always the best way to compose a photograph. This is where your individual judgement comes in.

Figure 2.16. Lighthouse photograph - lighthouse centered and the horizon cuts the photograph in half horizontally.

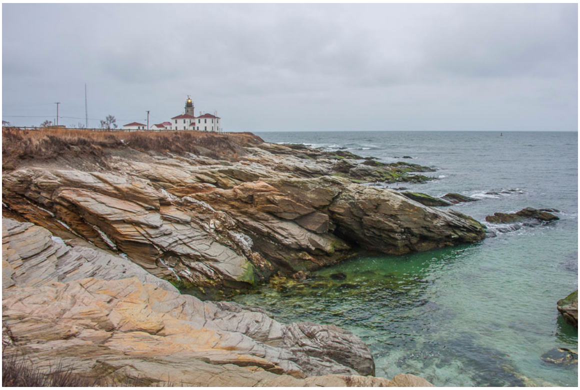

Figure 2.17. Lighthouse photograph - lighthouse on a rule of thirds vertical line and horizon on a rule of thirds horizontal line.

2.11. Sports Photography

Sports photography requires freezing motion at long distances.

2.11.1. Lenses by application

- Baseball - from the dugout, 200mm to the nearest base, 400mm+ for the farthest bases or outfield. Multiple lens are required such as a 70-200mm f/2.8, a 400mm f/2.8 and 600mm f/4.0.
- Basketball - from the baseline under the basket, 85mm to the near basket, 135mm for mid court and 200mm to 300mm for the far basket. 70-200mm f/2.8 lens is a good choice.
- Football (soccer is similar) - from the 30 yards line, 300mm covers from the goal line to mid field. A 300mm f/2.8 lens is a good choice or ideally a 70-200mm f/2.8 on one body and a 400mm f/2.8 on a second body. Recently 600mm f/4 lens have become popular for really tight shots.

In order to stop the action and avoid camera shake the one over the focal length rule for exposure times becomes:

$$t(max) = 1/(4F) \tag{2.2}$$

where: *t(max)* is the longest permissible exposure time and *F* is the lens Focal Length.

Table 2.1. Recommended maximum exposure time for sport photography.

Lens focal length (mm)	Exposure time (secs)
100	1/1000
200	1/1000
300	1/1250
400	1/1600
600	1/2500

Note that in table 2.1 a maximum exposure time of 1/1000 of a second is used to insure that action is frozen regardless of lens Focal Length.

Figure 2.18. Basketball photograph, 80-200mm f/2.8 lens at 100mm, f/2.8, ISO6400, 1/1000 of a second.

2.12. Studio Lighting

Studio lighting uses one or more light sources to obtain specific artistic effects from even lighting, to shadows, to outlines.

2.12.1. Types of light usage

- Key - the main light.
- Fill - fills in shadows.
- Rim - set up behind the subject to outline them with light.

2.12.2. Light direction

The direction that light comes from determines how the subject looks.

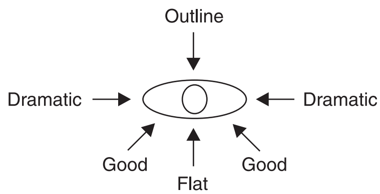

Figure 2.19. Effect of lighting direction on the subject.

2.12.3. Diffusers and bounce

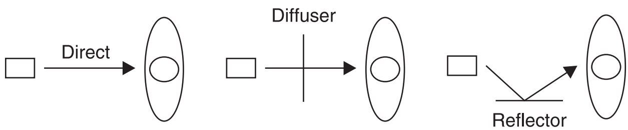

Figure 2.20. Diffusers and bounce create a softer light.

2.12.4. Single source lighting techniques

Light sources that are smaller than the subject are harsh. Light sources that are bigger than the subject are soft. Light boxes, umbrellas and bounce cards are common techniques to spread out the light from a flash and achieve a large-soft light source.

Common single source lighting techniques include: Rembrandt, Butterfly, Broad, Split, Loop and Close Wall.

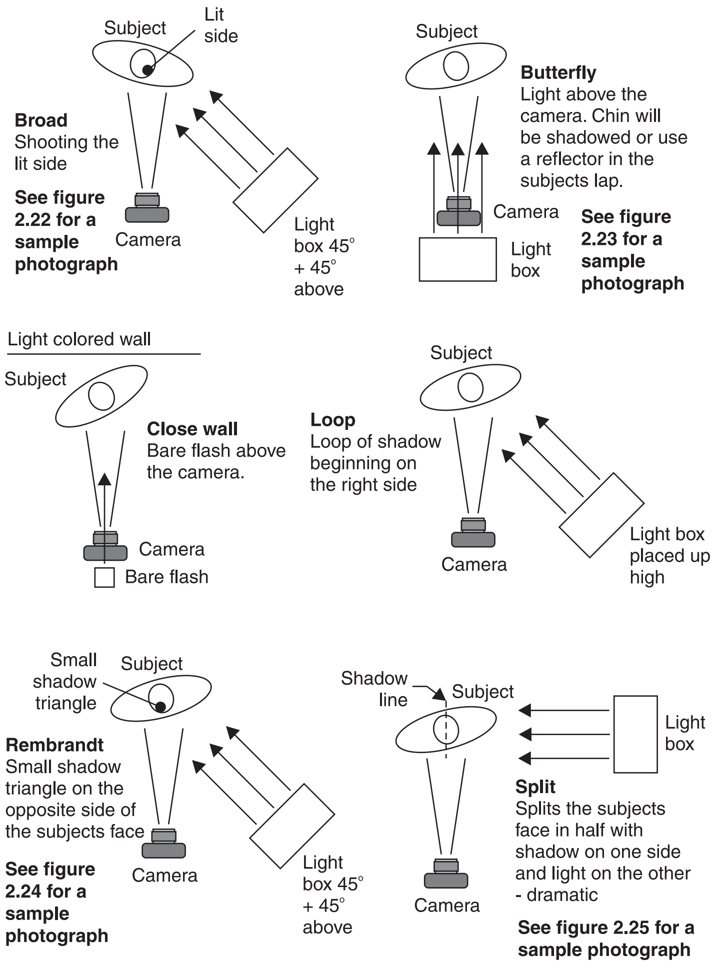

Figure 2.21. Common single source lighting configurations.

Figure 2.22. Broad lighting configuration. The face towards the camera is well lit.

Figure 2.23. Butterfly configuration. Note the shadow under the chin.

Figure 2.24. Rembrandt configuration.

Figure 2.25. Split configuration. Note the dramatic shadowing of one side of the models face.

2.13. Weddings

Weddings present a number of challenges spanning low light in a church where flash may not be allowed, to bright outdoor light during group photographs, back to low light at the reception. Weddings and receptions also move along at their own pace dictating the photographer's working speed.

2.13.1. Recommended equipment

- Two camera bodies so that you always have a backup and can also mount two different lenses at once. Two full frame cameras or a full frame and a cropped frame camera as long as they can use the same lenses.
- Two essential lenses are the 24-70mm f/2.8 lens for crowd and portrait shots and 70-200mm f/2.8 lens for ceremony pictures. Although many wedding photographers bring additional lenses, with these two lenses you can do a good job.
- Optional lenses include a 14-24mm f/2.8 lens for tight spaces and prime lenses such as a 28mm f/1.8, 50mm f/1.8 and 85mm f/1.8. The prime lenses also provide a backup in case a zoom lens fails.
- 2 to 3 speed lights. Studio photographers may prefer mono heads but they typically take too long to set up.
- Wireless flash controllers.
- Light stands, umbrellas and a soft box.
- Extra memory cards, batteries and gaffers tape.
- A tripod, monopod or both.

2.13.2. Managing the shoot

- Make up a list of key shots and who needs to be in them and check them off as each one is completed.
- Designate a member of the wedding party to organize people for photos.
- Move group photos along quickly to prevent boredom.
- Bring an assistant who can help capture candid shots.
- Often the best pictures are unscripted so be ready at all times.

2.13.3. Lighting tips

- Bounce flashes and use diffusers. Gary Fong half globes are popular with wedding photographers.

2.13.4. Aperture settings

- Bridal portraits, >f/2, f/2.8 to f/4 are best, the low f Number blurs everything but the bride.
- Groom portrait, ~f/4, <f/4 is a dreamy look generally not suited to men.
- Couple shots, >f/4 unless their faces are very close together.
- Family formal shots, >f5.6 to keep everyone in focus.
- Group shots, ~f/11.

2.13.5. Other tips

- Shoot in RAW format and post process the photographs in Lightroom.
- Post processing can take 2 to 4 days for a wedding.

Figure 2.26. Wedding photo, ISO400, 80-200mm f/2.8 lens at 200mm, f/5.6, 1/125 sec.

Definitions


1

3.1. Aberrations

Aberrations are failures on the part of the lens to create a true image of an object.

- Astigmatism - rays of light from a single point on an object that are off-axis to the lens fail to converge to a single point of focus in the image. Astigmatism causes points on the object to be imaged as a line radial to the lens optical axis and another line perpendicular to the radial line.
- Chromatic - different wavelengths (colors) of light come to a focus at different distances from the lens. Lens that bring all colors in the visible spectrum to the same plane of focus are called apochromatic (also called APO, EP, LD, SD or UDD).
- Coma - off-axis points of light appear as comet shaped blurs of light.
- Curvature of field - an object plane perpendicular to the optical axis focuses on a curved image surface rather than a plane.
- Distortion - even if there are no other aberrations in a lens, if the image does not match the object distortion has occurred.
- Spherical - rays of light parallel to the optical axis fail to converge at the same point.

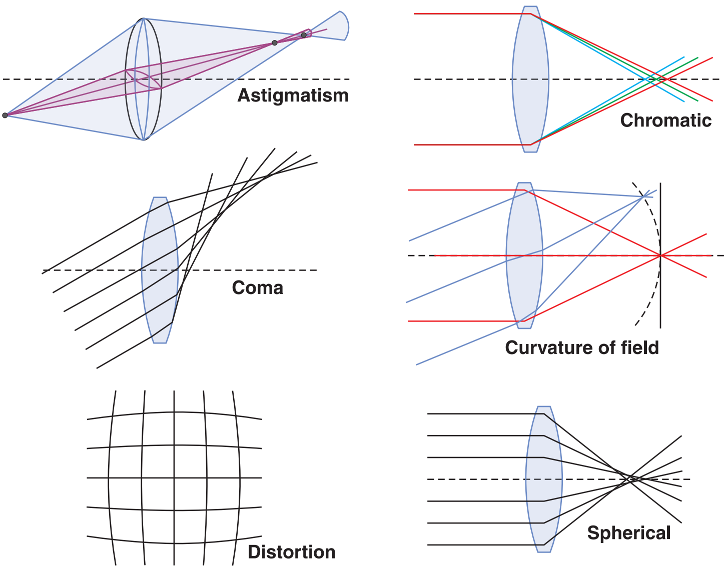

Figure 3.1. Aberrations.

3.2. Angle of View

The Angle of View of a lens is given by:

$$\alpha = 2\arctan(d/2F) \qquad (3.1)$$

where: α is the Angle of View in radians, d is the dimension of the image sensor (mm) and F is the effective Focal Length of the lens (mm). Note that the length, width and diagonal dimensions of the image sensor will each have different values and therefore Angles of View.

To convert from radians to degrees multiply by 57.29578.

This formula only holds for non-distorted images and is invalid for fish eye and macro lens.

Table 3.1. Angle of View in degrees versus sensor dimension (mm) and lens focal length (mm)

F (mm)	36mm full	24mm partial	16mm partial
12	113	90	67
24	74	53	37
50	40	27	18
100	20	14	9
200	10	7	5
400	5	3	2

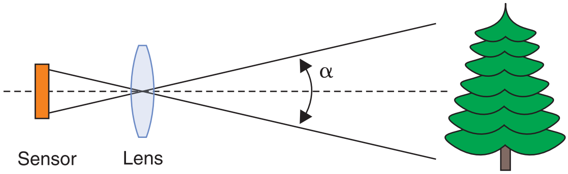

Figure 3.2. Angle of view.

3.3. Aperture

The lens diaphragm opening that determines how much light passes through a lens into a camera.

Figure 3.3. Aperture.

The Aperture can typically be varied in steps referred to as f stops (see also f Number and Stop). Reducing the Aperture (higher f Number) reduces the amount of light reaching the image sensor and increases the required exposure time.

A full f step reduction in Aperture doubles the required exposure time.

The principle advantage of smaller Aperture (high f Number) is increased Depth of Field (see also Depth of Field) but at the expense of longer exposure times.

Larger Apertures (smaller f Number) result in shallow Depth of Field that may be used to artistic effect to blur the background making a foreground object stand out.

A lens is typically sharpest when the Aperture is set at least two steps above the minimum value.

3.4. Bokeh

How a lens renders out of focus images - the quality of the blur.

Bokeh is important for portraits where low f Numbers are often used to render the background out of focus.

3.5. Camera Modes

Consumer cameras may have modes specific to different shooting situations. Professional cameras typically have most or all of the following modes:

- Av or A (Aperture priority) - the user manually sets the ISO and aperture and the cameras sets the exposure time (shutter speed) automatically.
- B (bulb) - the user manually sets the ISO and aperture and the shutter stays open as long as the shutter release button is held down.
- M (manual) - the user sets the ISO, aperture and shutter speed.
- P (program) - the user sets the ISO and the camera automatically sets the aperture and shutter speed.
- Tv or S (shutter priority) - the user sets the ISO and the shutter speed and the camera automatically sets the aperture.

3.6. Circle of Confusion

Circle of Confusion (CoC) is an optical spot caused by a cone of light rays from a lens not coming to a perfect focus when imaging a point source.

For most people 25cm is the closet comfortable viewing distance and a person with good vision can distinguish 5 lines/mm.

The Circle of Confusion is given by:

$$CoC = V/R/e/25 \qquad (3.2)$$

where: CoC is the Circle of Confusion (mm), V is the viewing distance, R is the desired resolution at 25cm (lines/mm) and e is the enlargement ratio.

Common estimates for 35mm film range from 0.025 to 0.033.

For digital cameras we assume 0.030 for a full frame 36mm x 24mm image sensor and 0.020 for partial frame 24mm x 16mm image sensor.

3.7. Color Temperature

Color Temperature is the spectrum of light emitted by a black body at that temperature. Color Temperature is a convenient way of characterizing the color spectrum of various light sources.

Color Temperature is specified in degrees kelvin with 2000K having a reddish cast, 5500K is roughly neutral and 9000K is bluish.

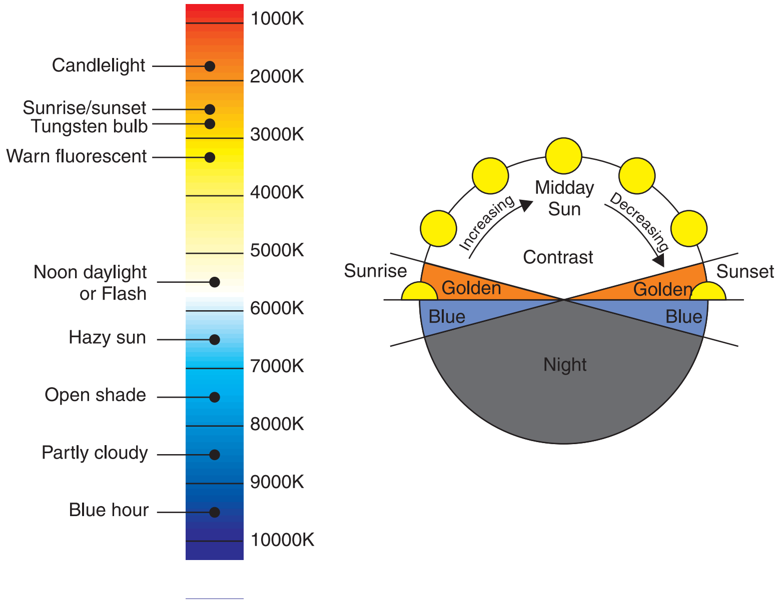

Figure 3.4. Color Temperature.

Color Temperature and contrast vary with the time of day and amount of cloud cover:

- Contrast increases from dawn until noon and then decreases.
- Increasing cloud cover reduces contrast.
- The hour after sunrise and before sunset is the golden hour.
- The hour before sunrise and after sunset is the blue hour.

For more information on dealing with Color Temperature with a digital camera see also White Balance.

3.8. Depth of Field

The distance between the closet and farthest away objects in acceptable focus. For s < H, DOF is given by:

$$DOF \approx \frac{2fcCoCF^2s^2}{F^4 - f^2CoC^2s^2} \tag{3.3}$$

where: *DOF* is depth of field (mm), *H* is the Hyperfocal Distance (mm), *s* is the focus distance, *CoC* is the Circle of Confusion, *f* is the f Number and *F* is the Focal Length (mm).

Depth of Field depends on:

- Increases as f Number increases (H decreases as f Number increases).
- Decreases as lens Focal Length increases.
- Decreases as focus distance decreases.
- Decreases when cropping and enlarging an image.

Figure 3.5. Shallow Depth of Field image, f/3.2.

Figure 3.6. Deep Depth of Field image, f/22.

3.9. Depth of Focus

Similar to Depth of Field but on the image sensor side of the lens.

3.10. Dynamic Range

The difference between the brightest and darkest part of an image.

If Dynamic Range exceeds the cameras limits you lose details in the highlights or shadows or both. This is referred to as blowing out the highlights of crushing the shadows.

Direct reflections of a light source are referred to as spectral highlight.

Digital camera sensors overload more sharply than film if the highlights are too bright. Conversely shadow details in digital cameras are generally better than film.

A useful technique for dealing with blow out is to deliberately underexpose and then lighten the image later in Lightroom or Photoshop. This technique avoids blow out and takes advantage of the superior digital image sensor detail.

3.11. Exposure

The amount of light reaching each unit area of the image sensor.

Photometric or luminous exposure is given by:

$$H_v = E_v t \tag{3.4}$$

where: H_v is the luminous exposure (lux seconds), E_v is the sensor illuminance (lux), and t is the exposure time (secs).

Radiometric quantity or radiant exposure is given by:

$$H_e = E_e t \tag{3.5}$$

where: H_e is the radiant exposure (joules per square meter), E_e is the radiance (watts per square meter), and t is the exposure time (secs).

3.12. Exposure Sensing

Camera exposure sensors sense exposure by assuming all objects are 18% grey. If an object is very light colored the camera meter will tend to underexpose the image resulting in a grey image. If an object is predominantly black the camera will tend to over expose the image also resulting in a grey image. This effect can be compensated for by using exposure compensation on a camera or by adjusting exposure time manually.

3.13. Exposure Triangle

There is a trade off between ISO, aperture and shutter speed that determines picture quality and exposure. The three factors and trade-offs are frequently portrayed by the exposure triangle.

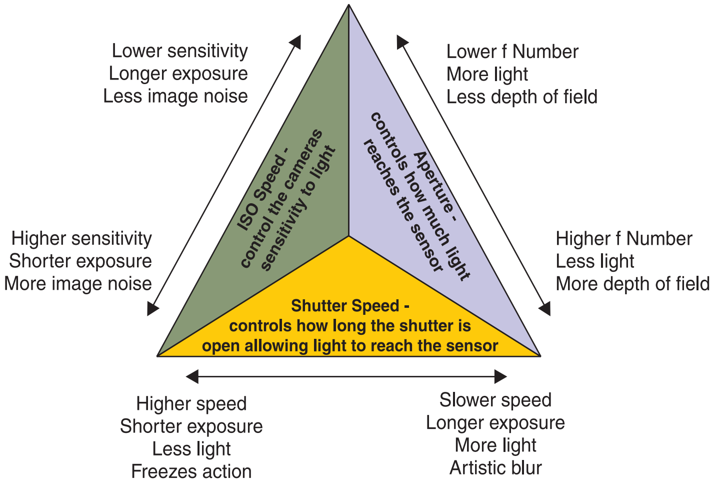

Figure 3.7. Exposure triangle.

3.14. Exposure Value

Exposure Value (EV) denotes all possible values of shutter speed and f number that result in the same exposure. EV is given by:

$$EV = Log_2 f^2 / t \qquad (3.6)$$

where: *EV* is Exposure Value, *f* is f Number and *t* is exposure time (secs).

EV reflects the fact that reducing f Number by one full step increases the lens Aperture area by 2 and reduces the required exposure time by 1/2.

Table 3.2. Exposure time in seconds or minutes (m denotes minutes) versus EV and f Number.

EV	f Number										
	1.0	1.4	2.0	2.8	4.0	5.6	8.0	11	16	22	32
-6	60	2m	4m	8m	16m	32m	64m	--	--	--	--
-5	30	60	2m	4m	8m	16m	32m	64m	--	--	--
-4	15	30	60	2m	4m	8m	16m	32m	64m	--	--
-3	8	15	30	60	2m	4m	8m	16m	32m	64m	--
-2	4	8	15	30	60	2m	4m	8m	16m	32m	64m
-1	2	4	8	15	30	60	2m	4m	8m	16m	32m
0	1	2	4	8	15	30	60	2m	4m	8m	16m
1	1/2	1	2	4	8	15	30	60	2m	4m	8m
2	1/4	1/2	1	2	4	8	15	30	60	2m	4m
3	1/8	1/4	1/2	1	2	4	8	15	30	60	2m
4	1/15	1/8	1/4	1/2	1	2	4	8	15	30	60
5	1/30	1/15	1/8	1/4	1/2	1	2	4	8	15	30
6	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	8	15
7	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4	8
8	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2	4
9	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	1/2	1	2
10	1/1000	1/500	1/250	1.125	1/60	1/30	1/15	1/8	1/4	1/2	1
11	1/2000	1/1000	1/500	1/250	1/125	1/60	1/30	1/15	1/8	1/4	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

3.15. f Number

A measure of the Aperture of a lens given by:

$$f = F/D \tag{3.7}$$

where: *f* is the f Number, *F* is the Focal Length of the lens (mm) and *D* is the diameter of the entrance pupil (effective aperture) (mm).

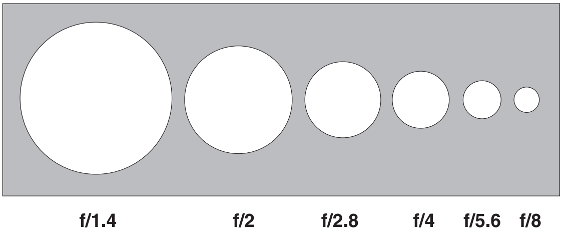

Figure 3.8. f Number versus aperture.

Each increase in f Number represents one half of the light being allowed through the lens versus the previous f Number.

The full step f Number sequence is give by:

$$(\sqrt{2})^{-1}, (\sqrt{2})^{0}, (\sqrt{2})^{1}, \ldots\ldots(\sqrt{2})^{n} \tag{3.8}$$

The one half step f Number sequence is given by:

$$(\sqrt{2})^{-1}, (\sqrt{2})^{-0.5}, (\sqrt{2})^{0}, \ldots(\sqrt{2})^{n} \tag{3.9}$$

The one third step f Number sequence is given by:

$$(\sqrt{2})^{-1}, (\sqrt{2})^{-0.66}, (\sqrt{2})^{-0.33}, \ldots(\sqrt{2})^{n} \tag{3.10}$$

Increasing f Number denotes decreasing lens Aperture reducing the amount of light reaching the sensor requiring longer exposure times. However, increasing f Number also improves Depth of Field.

Decreasing f Number denotes increasing Aperture increasing the amount of light reaching the sensor requiring shorter exposure times. However, decreasing f Number reduces Depth of Field.

Full step scale	Half step scale	Third step scale	Quarter step scale
0.7	0.7	0.7	1.0
1.0	0.8	0.8	1.1
1.4	1.0	0.9	1.2
2.0	1.2	1.0	1.3
2.8	1.4	1.1	1.4
4.0	1.7	1.2	1.5
5.6	2.0	1.4	1.7
8.0	2.4	1.6	1.8
11	2.8	1.8	2.0
16	3.3	2.0	2.2
22	4.0	2.2	2.4
32	4.8	2.5	2.6
45	5.6	2.8	2.8
64	6.7	3.2	3.2
90	8.0	3.5	3.4
128	9.5	4.0	3.7
180	11	4.5	4.0
256	13	5.0	4.4
	16	5.6	4.8
	19	6.3	5.2
	22	7.1	5.6
	27	8.0	6.2
	32	9.0	6.7

Figure 3.9. f Number scales.

3.16. Flare and Haze

Unwanted light entering the lens and creating unwanted image formation due to reflection off of lens surfaces or defects.

- Flare - unwanted artifacts in the image.
- Haze - a general reduction in image sharpness.

The most common circumstances for lens flare is when taking pictures in bright sun light and the sun is at a close angle to the lens direction.

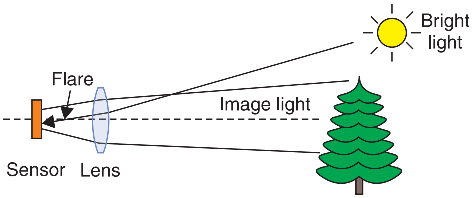

Figure 3.10. Lens flare.

1.3.17. Reducing Flare and Haze

- Lens hoods - extends off the end of the lens and helps reduce off angle light intensity.
- Anti reflective coatings - high quality lens have coatings to reduce reflections off the lens.
- Shoot away from bright light sources, not towards them.
- Bright light behind a camera can enter the optics through the view finder. Many cameras have shutters to close the view finder.
- Zoom lens are more prone to flare due to the large number of lens elements.

3.18. Flash Sync

Most high quality single lens reflex (SLR) cameras use focal-plane shutter (FPS). In an FPS there are two curtains:

- The front curtain covers the image sensor and opens to start the exposure.
- The rear curtain closes over the image sensor to stop the exposure.
- Following exposure the front curtain closes and the rear curtain opens to prepare for the next exposure.

For very short exposure times the front curtain starts opening and the rear curtain starts closing simultaneously resulting in a slit being scanned across the image sensor.

For flash photography the flash only lasts approximately 1/1000 of a second. In order for the flash to properly expose an image both curtains must be completely open. This limits most cameras to about 1/250 second exposure times with flash.

1.3.19. Types of sync

Flashes fire and produce output for periods of time shorter than the shutter is open.

- Front sync - the front curtain opens, the flash fires, the sensor then gathers additional ambient light before the rear curtain closes. The shorter the exposure time the more the flash lights the scene and the less ambient light is gathered.
- Rear sync - the front curtain opens and the sensor gathers ambient light, then just before the rear curtain closes the flash fires. Moving objects will show up as a streak in this mode.
- Slow sync - during flash shooting cameras will limit shutter speed to some minimum value that will result in a well lit subject but a dark background. Slow sync allows additional time for ambient light to reach the image sensor.

As the exposure time is shortened up to the maximum sync speed of the camera, less ambient light is captured and the lighting of the photos is more dependent on the flash. At longer exposure times more ambient light is captured and the lighting of the photo is less dependent on the flash.

3.20. Focal Length

A measure of how strongly a lens converges or diverges light rays. The Focal Length is the distance from the center of a lens that two parallel light rays converge.

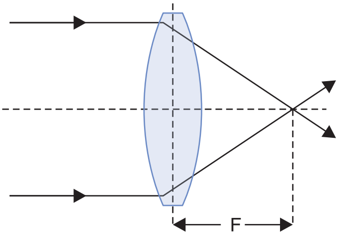

Figure 3.11. Focal length definition.

In photography most objects are much farther away from the lens than the focal distance and the Focal Length of the lens is a measure of the lens Magnification.

Lens Focal Length for single lens reflex cameras is typically stated for full frame sensors, that is a 36mm x 24mm sensor. For smaller sensors the effective Focal Length of the lens is increased by a Focal Length multipliers (see Sensor Size).

28mm

50mm

100mm

200mm

Figure 3.12. Photographs taken from the same distance with different lens Focal Lengths (Focal Lengths as marked).

3.21. Guide Number

A measure of the output of a flash unit. Guide Number is given by:

$$GN = Sf \tag{3.11}$$

where: GN is the Guide Number, S is the subject distance and f is the f Number.

Guide Number is typically calculated at ISO100, for ISO200 multiply GN by 1.4, for ISO400 multiply by 2.0.

Typical GN for on camera flash is 12 to 18 for compact cameras and around 40 for single lens reflex. External flashes typically have a GN of 100 or more.

Table 3.3. Flash distance in feet versus f Number and Guide Number, ISO100.

f number	GN 10	GN 25	GN 50	GN 100	GN 150
1.4	7.1	17.9	35.7	71.4	107
2.0	5.0	12.5	25.0	50.0	75.0
2.8	3.6	8.9	17.9	35.7	53.6
4.0	2.5	6.3	12.5	25.0	37.5
5.6	1.8	4.5	8.9	17.9	26.8
6.0	1.7	4.2	8.3	16.7	25.0
11	0.9	2.3	4.5	9.1	13.6
16	0.6	1.6	3.1	6.3	9.4

Table 3.4. Flash distance in feet versus f Number and Guide Number, ISO200.

f number	GN 10	GN 25	GN 50	GN 100	GN 150
1.4	10.0	25.0	50.0	100	150
2.0	7.0	17.5	35.0	70.0	105
2.8	5.0	12.5	25.0	50.0	75.0
4.0	3.5	8.8	17.5	35.0	52.5
5.6	2.5	6.3	12.5	25.0	37.5
6.0	2.3	5.8	11.7	23.3	35.0
11	1.3	3.2	6.4	12.7	19.1
16	0.9	2.2	4.4	8.8	13.1

Table 3.5. Flash distance in feet versus f Number and Guide Number, ISO400.

f number	GN 10	GN 25	GN 50	GN 100	GN 150
1.4	14.3	35.7	71.4	143	214
2.0	10.0	25.0	50.0	100	150
2.8	7.1	17.9	35.7	71.4	107
4.0	5.0	12.5	25.0	50.0	75.0
5.6	3.6	8.9	17.9	35.7	50.0
6.0	3.3	8.3	16.7	33.3	50.0
11	1.8	4.5	9.1	18.2	27.3
16	1.3	3.1	6.3	12.5	18.8

3.22. Hyperfocal Distance

The distance whereby if a camera is focused at that distance, objects are in focus from one half that distance to infinity.

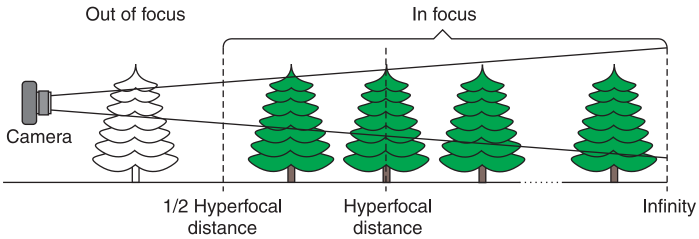

Figure 3.13. Hyperfocal distance.

The Hyperfocal Distance is give by:

$$H = F^2/(fCoC) + F \tag{3.12}$$

where: *H* is the Hyperfocal Distance (mm), *F* is the lens Focal Length (mm), *f* is the f Number and *CoC* is the Circle of Confusion (mm) (see Circle of Confusion).

Divide H by 304.8 to get feet and by 1,000 to get meters.

The hyperfocal concept is very useful when taking pictures of objects receding into the distance and keeping everything in focus. Hyperfocal Distance is reduced for shorter Focal Length lens and higher f Numbers and increased for longer Focal Length lens and lower f Numbers.

Hyperfocal Distance leads to a useful rule when shooting landscapes to focus one third of the way into the scene for maximum Depth of Field.

Table 3.6. Hyperfocal Distance in feet for full frame sensors. 36mm x 24mm, Nikon FX, Canon.

f Number	Lens Focal Length (mm)									
	12	16	20	25	30	40	50	70	100	150
1.4	11	20	31	49	70	125	195	383	781	--
2.0	8	14	22	34	49	88	137	268	547	--
2.8	6	10	16	24	35	63	98	192	391	879
4.0	4	7	11	17	25	44	69	134	274	616
5.6	3	5	8	12	18	31	49	96	196	440
8.0	2	4	6	9	12	22	34	67	137	308
11	1	3	4	6	9	16	25	49	100	224
16	1	2	3	4	6	11	17	34	69	154
22	1	1	2	3	5	8	13	25	50	112
32	1	1	1	2	3	6	9	17	35	77

Table 3.7. Hyperfocal Distance in feet for partial frame sensors. 24mm x 16mm, Nikon DX, Pentex, Sony.

f Number	Lens Focal Length (mm)									
	12	16	20	25	30	40	50	70	100	150
1.4	17	30	47	73	106	188	293	574	--	--
2.0	12	21	33	51	74	131	205	402	821	--
2.8	8	15	24	37	53	94	147	287	586	--
4.0	6	11	16	26	37	66	103	201	410	923
5.6	4	8	12	18	26	47	73	144	293	660
8.0	3	5	8	13	19	33	51	101	205	462
11	2	4	6	9	14	24	37	73	149	336
16	2	3	4	6	9	17	26	50	103	231
22	1	2	3	5	7	12	19	37	75	168
32	1	1	2	3	5	8	13	25	52	116

3.23. ISO Speed

ISO speed was originally developed to characterise the light sensitivity of film.

For digital cameras, ISO sensitivity is an exposure sensitivity and as a general rule denotes performance similar to a film of the same ISO speed.

For film, increasing ISO speed allows shorter exposure times but at the expense of grain. For digital cameras, higher ISO speeds are available than were ever achieved for film. The trade-off for digital cameras is that as ISO speed is increased there is more noise in the dark portions of the image. The maximum acceptable ISO speed on a camera varies from camera to camera with higher end cameras currently offering usable ISO 6400 to 12800 whereas color film was only available to ISO 3200 and that was very grainy.

Each full step in ISO rating reduces the required exposure by 1/2, for example ISO200 requires 1/2 the time of ISO100 and ISO400 requires 1/2 the time of ISO200, etc.

Full ISO steps are: 50, 100, 200, 400, 800, 1600, 3200, 6400, 12800, 25600, 51200, 102400, 204800, 409600.

Note the increasing noise with higher ISO values in figure 3.14.

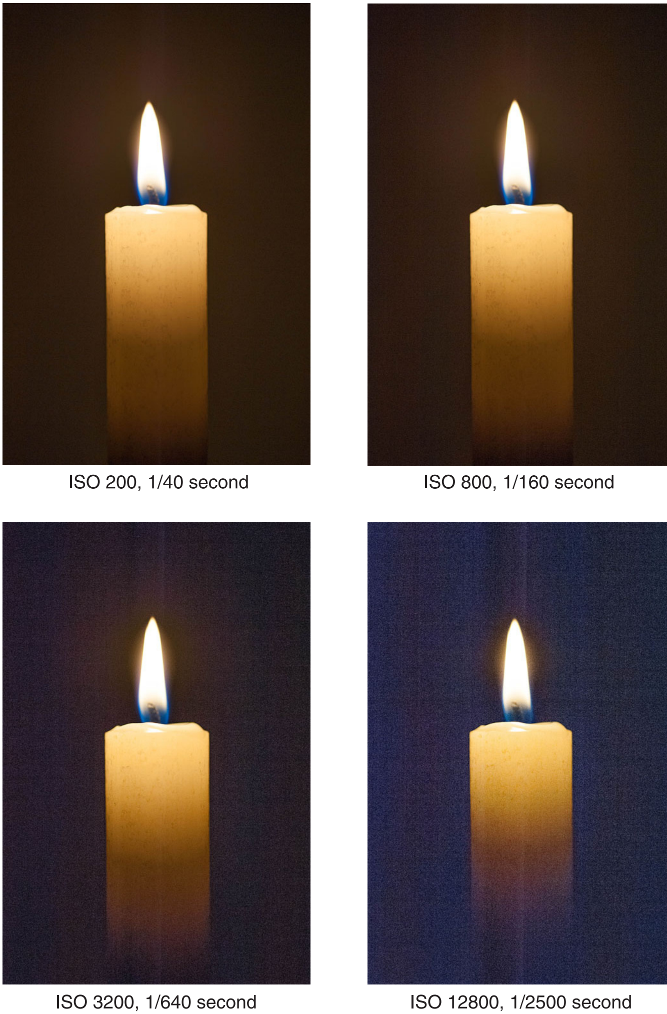

Figure 3.14. Candle photographed using four different ISO Speeds. All photographs taken at f/4.5.

3.24. Light Characteristics

There are five characteristics to light:

- Direction - the direction the light is coming from. If light is directly behind the camera or on the camera (as in a camera mounted flash) the subject will appear flat. Light from the sides is dramatic. Light from behind the subject outlines them. Light from a 45^{o} angle to either side is flattering.
- Intensity - how bright the light is.
- Color - is the light cool (green/blue) or warm (red/yellow) (see also Color Temperature).
- Contrast - how different is the intensity of the light between the shadows and highlights.
- Hardness - what do the edges of the shadows look like. Sharp edges are hard light, fuzzy edges are soft light.

3.25. Magnification

The Magnification of a lens on a full frame sensor camera is given by:

$$m = F/50 \tag{3.13}$$

where: m is the magnification ratio and F is the lens Focal Length (mm). For partial frame cameras the Focal Length of the lens is adjusted by:

$$F(FF) \times \frac{d(FF)}{d(PF)} \tag{3.14}$$

where: F is the Focal Length, and d is the full frame and partial frame sensor dimensions (see also Sensor Size).

Table 3.8. Magnification versus Focal Length and sensor size.

F (mm)	m (36mm x 24mm)	m (24mm x 16mm)
14	0.28	0.42
24	0.48	0.72
50	1.00	1.50
100	2.00	3.00
200	4.00	6.00
400	8.00	12.00
600	12.00	18.00
800	16.00	24.00
1000	20.00	30.00

3.26. Pixel Counts

A pixel is a fundamental unit of a digital sensor. Each pixel outputs a number corresponding to the color or light intensity reaching the pixel.

The number of pixels in the sensor determines the resolution of the sensor and how large a photograph that can be produced from the resulting image with acceptable quality. Pixels are typically reported in millions of pixels (megapixels).

Printer quality is typically expressed in dots per inch. For high quality printing 300dpi is typically used although 200dpi is generally acceptable for posters. Inkjet printers use matrices of dots to produce each color reducing the effective dpi.

Table 3.9. Maximum picture size for various dpi versus image sensor megapixels.

Megapixels	300dpi	200dpi	150dpi
2	5.8” x 3.8”	8.7” x 5.8”	11.5” x 7.7”
3	7.1” x 4.7”	10.6” 7.1”	14.1” x 9.4”
4	8.2” x 5.4”	12.2” x 8.2”	16.3” x 10.9”
5	9.1” x 6.1”	13.7” x 9.1”	18.3” x 12.2”
6	10.0” x 6.7”	15.0” x 10.0”	20.0” x 13.3”
8	11.5” x 7.7”	17.3” x 11.5”	23.1” x 15.4”
12	14.1” x 9.4”	21.2” x 14.1”	28.3” x 18.9”
16	16.3” x 10.9”	24.5” x 16.3”	32.7” x 21.8”
24	20.1” x 13.4”	30.1” x 20.1”	40.1” x 26.8”
36	24.5” x 16.4”	36.8” x 24.6”	49.1” x 32.7”

3.27. RAW Format

RAW Format is a method of storing the uncompressed output data from the image sensor.

1.3.28. RAW format characteristics

- Proprietary to the camera manufacturer.
- Not viewable as an image without special software.
- Read only.
- At least 8 bits per color and sometimes more.
- Higher in dynamic range, lower in contrast and less sharp.
- A large file size, on a 12 megapixel camera the resulting file will be >12Mb versus a JPEG file that would be around 4Mb.

1.3.29. JPEG characteristics

- A standard format.
- Viewable on most devices; computers, smart phones, tables, etc.
- Editable (but every edit results in data loss).
- Exactly 8 bits per color.
- Lower in dynamic range, high in contrast and sharper.
- A smaller file size at about 1/3 the size of a raw file.

1.3.30. Choosing between RAW and JPEG

- If you need the image to be immediately available, shoot JPEG or some cameras allow images to be stored simultaneously in both formats (although this takes a lot of storage space).
- If you have sufficient storage and want the best possible image quality shoot RAW. With RAW instead of the camera processing the image you process it later on a computer with much greater power and control over the final image.
- Programs like Lightroom and Photoshop can process RAW files from the major camera manufacturers. By working with RAW you can always get back to the original image and you have all of the original data to work with.
- A RAW file is like a digital negative that can always be reprocessed.

3.31. Reciprocity Failure

Reciprocity is the inverse relationship between intensity and duration of light that determines the reaction of light-sensitive materials given by:

$$E = It \qquad (3.15)$$

where: E is exposure, I is intensity and t is time.

At very low or very high intensity the relationship in equation 3.15 no longer holds and this is referred to as reciprocity failure. This is a problem seen in film but not digital cameras although for long - low intensity exposures in digital cameras noise can be a problem.

3.32. Red Eye

Red Eye is a phenomena where the subject's eye(s) appear red in flash photography. Flash exposure flashes are on the order of 1/1000 of a second, too short for the subjects pupils to have time to contract. The light from the flash enters the subject's eye(s) and bounces off the back of the eyeball to the camera lens.

Red eye is less likely at angles greater than 5^{o}.

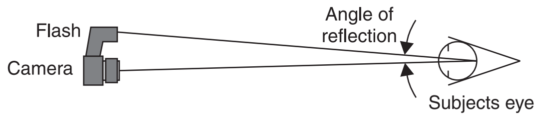

Figure 3.15. Red eye and angle of reflection.

1.3.33. Reducing red eye

- Move the flash further away from the camera lens with a bracket or by holding the flash in your hand (requires a special cord or wireless controllers).
- Some cameras have red eye reduction built in, the flash pre flashes to contract the pupils and then flashes again taking the photograph.
- Bounce the flash off a nearby light colored surface so it isn't aimed right at the subjects eyes.
- Increase the ambient light level to contract the subjects pupils.
- Move closer to the subject increasing the angle of reflection. Conversely moving further away increases red eye.

3.34. Sensor Size

The size of the image sensor in a digital camera is important in two respects:

- The larger the sensor size for a given number of pixels, the larger the pixel size. As a general rule larger pixels produce better signal to noise ratios and allow higher ISO with acceptable noise.
- 35mm film is 36mm x 24mm in size. Standard 35mm lenses are designed to work with standard 35mm film. Smaller (cropped) sensor sizes result in longer effective Focal Length for standard lens and shallower Depth of Field.

Table 3.10. Image sensor sizes

Format	Length (mm)	Width (mm)	Area (mm^2)	Focal Length multiplier[a]
Medium format	50.7	39.0	1,977.3	0.7
35mm full frame (Canon, Nikon FX)	36.0	24.0	864.0	1.0
APS-H (Canon)	28.7	19.0	545.3	1.3
APS-C (Nikon DX, Pentex, Sony)	23.6	15.7	370.5	1.5
APS-C (Canon)	22.2	14.0	310.8	1.6
Fovean (Sigma)	20.7	13.8	285.7	1.7
Four Thirds System	17.3	13.0	224.9	2.0
Nikon 1/CX	13.2	8.8	116.2	2.7
1/1.7”	7.6	5.7	43.3	4.6
1/1.8”	7.2	5.3	38.2	4.8
1/2.5”	5.8	4.3	24.7	6.0

a. Multiplier for a standard 35mm lens design for full frame use.

3.35. Shutter Speed

Shutter Speed is the amount of time the shutter is open allowing light to reach the image sensor.

The rule of thumb for hand held exposures of stationary objects without unacceptable blur is (see Sports Photography for the rule for moving subjects):

$$t(max) = 1/F \tag{3.16}$$

where: *t(max)* is the longest allowable exposure time and *F* is the lens Focal Length.

1.3.36. Shutter Speed usage for a 50mm lens

- 1/8000 - sharp photographs of high speed objects such as planes and birds.
- 1/1000 to 1/2000 - sharp photographs of moderately fast objects such as players during sporting events.
- 1/250 to 1/500 - sharp every day shots. 1/250 is the fastest exposure for panning.
- 1/125 - panning and high depth of field landscapes.
- 1/60 - panning, stationary objects. The longest time for sharp hand held photographs.
- 1/30 - panning, subjects less than 30mph (tripod).
- 1/15 to 1/8 - motion blur, panning shots, low light (tripod).
- 1/4 to 1 - motion blur (tripod)
- 1 minute to several hours - astronomy and special effects (tripod).

3.37. Stop

A Stop is a step up (doubling) or down (halving) by one EV (see also Exposure Value).

- Changing ISO200 to ISO400 is a Stop (see also ISO Speed) because image sensor light sensitivity is doubling.
- Changing exposure time from 1/60 to 1/30 is a Stop (see also Shutter Speed) because the exposure time is doubling.
- Changing f Number from f/2.0 to f/2.8 is a Stop (see also f Number) because the amount of light passing through the lens is cut in half.
- Changing flash power from 1 (full output) to 1/2 (half output) is a Stop because the flash output is cut in half.

	ISO	f Number	Shutter Speed (secs)	Flash power
Slower ↑	200	22	4	1/64
	400	16	2	1/32
	800	11	1	1/16
	1600	8	1/2	1/8
	3200	5.6	1/4	1/4
	6400	4	1/8	1/2
	12800	2.8	1/15	1
		2	1/30	
		1.4	1/60	
↓ Faster		1	1/125	

Figure 3.16. Stops.

3.38. Sunny 16 Rule

On a sunny day using an aperture of f/16, a correct exposure is 1/ISO speed. For example 1/200 of a second for ISO200. The Sunny 16 rule was of more use back when some cameras didn't have built in exposure metering but today digital cameras all include exposure metering.

3.39. t Number

f Number adjusted to take into account the actual light transmission of the lens. In a perfect lens with 100% transmission f Number and t Number would be the same but in practice t Number is typically slightly higher due to light transmission being less than 100%.

3.40. White Balance

Digital camera sensors are not good matches to the human eye in terms of how they render color. The goal of White Balance is to insure neutral colors in photographs are true to neutral colors as seen by the human eye.

White Balance removes color cast so that white objects appear white in photographs. Proper white balance takes into account color temperature and adjusts the green-magenta balance, particularly for fluorescent lighting.

Most digital cameras have a variety of color balance settings for different situations for example: indoors, daylight, cloudy, flash, shade and fluorescent.

White Balance can very easily be adjusted in Lightroom if you shoot RAW files. If you shoot a picture of a neutral reference card or if one of your subjects is wearing a neutral color you can sample that spot in light room and it will automatically set the correct color temperature.

When shooting during the golden hour or blue hour make sure automatic white balance is off on your camera or the camera will attempt to adjust the color temperature away from the golden or blue color you are trying to capture.

Figure 3.17. White balance set to daylight under fluorescent light.

Figure 3.18. White balance set to fluorescent under fluorescent light.

Abbreviations

Abbreviations

Abbreviations used in this guide:

α	angle of view
A	camera aperture priority mode
APO	apochromatic lens
Av	camera aperture priority mode
B	camera bulb mode
CoC	circle of confusion
d	image sensor dimension
D	diameter of the lens entrance pupil
DOF	depth of field
dpi	dots per inch
e	enlargement ratio
E	exposure
Ee	radiance
EP	apochromatic lens
Ev	sensor illuminance
EV	exposure value
f	f number
F	focal length of the lens
FF	full frame image sensor
GN	guide number
H	hyperfocal distance
He	radiant exposure
Hv	luminous exposure
i	image size
I	intensity
ISO	ISO speed
JPEG	compressed image format
K	degree kelvin
LD	apochromatic lens
m	magnification
M	manual camera mode
Mb	megabyte
Mp	megapixel
o	object size
P	camera program mode
PF	partial frame image sensor
R	desired resolution

Abbreviations continued

RAW	uncompressed image sensor data
RR	reproduction ratio
s	focus distance
S	subject distance
SD	apochromatic lens
t	time
t (max)	maximum allowable exposure time
T	t number
UDD	apochromatic lens
V	viewing distance