Document 08

Section C. Photographic Techniques

Fundamentals of photography: Controlling exposure in ambient light

This discussion is directed toward what you need to know about using a camera in order to adjust film exposure. When the word *film* is used, it can be taken to mean the recording medium in general. That could be silver-halide film, a CCD chip, or magnetic tape, depending on the camera.

The *reciprocity law* for film states that the *exposure* of the film is the product of the *intensity* of the light on the film and the *time* during which the film is exposed to the light. Thus, greater intensity or greater time will give a greater exposure. You can think of *intensity* as the concentration of light on the film.[1]

Let's first look at how to control the exposure for *ambient* lighting. Ambient is taken here to mean natural or existing lighting, such as sunlight when outdoors and room light when indoors. In this case,

- intensity is controlled with the camera *aperture*. This is an approximately circular opening of adjustable diameter in the lens through which light passes to the film.
- duration of the exposure is controlled with the *shutter*. In a conventional camera, the shutter is a curtain that opens to expose the film for a selected amount of time. The reciprocal of this time is termed the *shutter speed*.

The f-stop series

Apertures are calibrated in steps called *f-stops*, denoted as f/#, where # represents a number. A typical f-stop sequence is the following: f/2 f/2.8 f/4 f/5.6 f/8 f/11 f/16. The two things you need to know about this sequence are that:

1. The diameter of the aperture decreases with increasing f-stop. All else being the same, a larger f-stop will mean less exposure.
2. The exposures for adjacent f-stops are a factor of 2 different from one another. For example, f/4 provides twice the exposure as f/5.6. The progression is geometric. This means, for example, that the exposure for f/8 compared to f/16 is the product of factors of 2: 2 x 2 = 4.

With a lens for which the aperture is adjusted mechanically, the f/# is typically selected by turning a ring, which has click stops at each f-stop. With a digital camera where the aperture is set electronically, the f/#'s needn't be limited to those in the previous sequence but instead can have a continuous range of values. These are usually given to the nearest tenth.

Shutter speed

As mentioned previously, the shutter speed is the inverse of the amount of time that the film is exposed. Therefore, a shutter speed of 125 indicates an exposure time of 1/125 s. Since adjacent f-stops provide exposures that differ by a factor of 2, the same holds true for adjacent shutter speeds.

[1] Strictly speaking, intensity is the *rate* at which light energy reaches the film per unit area of the film. Thus, when intensity is multiplied by time, the result is the *total* light energy on the film per unit area. The units of intensity are watt/meter^2 in the International System of Units.

This way, the photographer has the flexibility to change exposure by factors of 2 by adjusting either the aperture or the shutter speed. A typical shutter speed sequence is the following:[2]

2”	1	2	4	8	15	30	60	125	250	500	1000

Note that 2 indicates a duration of ½ second, while 2” indicates a duration of 2 seconds.

The characteristics of this sequence are that:

1. The amount of time the film is exposed decreases by a factor of 2 for each increase of shutter speed of a factor of 2.
2. The progression is geometric. This means, for example, that the exposure for 2 compared to 8 is the product of factors of 2: 2 x 2 = 4.

Film speed or sensitivity

Any particular film will require a characteristic exposure in order to produce the widest possible range of densities (shades of gray) in the recorded image. This is true whether one is recording on silver-halide film, magnetic tape, or digital film. The photographer selects a combination of aperture and shutter speed to provide the correct exposure or sets the camera in order to allow automatic selection.

Films are rated in terms of their sensitivity to light according a scale set by the International Standards Organization (ISO). The so-called *film speed* is proportional to the ISO rating. For example, a film with a speed of ISO 400 has 4 times the speed or sensitivity of a film with a speed of ISO 100. This means that the ISO 400 film requires one-quarter the exposure that the ISO 100 film requires.

The advantage of using a faster film is that one can use faster shutter speeds or larger f-stops. The disadvantage is that faster films typically have coarser *grain* than slower films. The grain consists of clumps of silver for a conventional black-and-white film and blobs of dye for a color film. For slower films, these clumps are smaller and closer together and generally give an image with finer detail. Images produced with digital cameras show a similar effect, although the explanation for it has an electronic rather than a chemical basis. On many digital cameras, the photographer has the option to select film speed even though the film doesn’t physically change. The quality of the image, however, will change. As for conventional film, slower film speeds generally produce better images. However, this is less of a concern for modern digital cameras as for film cameras.

Adjusting aperture and shutter speed in order to maintain constant exposure

For a given ambient lighting situation and film speed, the photographer selects the aperture and shutter speed in order to obtain the optimum exposure.[3] For some situations, such as capturing rapid motion, the photographer may wish to increase the shutter speed. He or she would then change the aperture

[2] Note that the numbers from 8 to 30 in the sequence aren’t exactly a factor of 2 apart. This is simply a result of conventional usage. Also, for digital cameras and other cameras where the shutter speed is set electronically, intermediate values of shutter speed are also available.

[3] Some cameras can make these selections automatically in auto-programmed modes. The latter, however, can be fooled by some lighting situations. A good photographer knows how to override the automatic modes and set aperture and shutter speed manually.

appropriately in order to maintain constant exposure. A general rule to use for making such changes is the following:

For each f-stop that the aperture is increased (decreased), decrease (increase) the shutter speed by a factor of 2.

We will see in the next session that when using flash lighting, exposure is determined differently than when using ambient lighting.

Fundamentals of photography: Controlling exposure when using electronic flash

In the previous section, we discussed how to control exposure under ambient lighting conditions. There's an important difference when using electronic flash. The flash of light is typically much briefer than the amount of time the shutter is open. For high-speed flash photography, the shutter may be open for a second, while the flash of light may last only one thirty thousandth of that time. Thus, the shutter speed has no influence in determining the exposure. Instead, the intensity and duration of the light source itself are important. In addition, the aperture continues to play the same role as it does for ambient lighting.

When you're using a flash unit in automatic exposure mode, it's simple to set it for correct exposure. There will be a calculator scale or dial somewhere on the flash unit. You set the film speed, and the calculator scale tells you what f-stop to set for the camera. This works because in automatic exposure mode, the flash unit is calibrated to quench the flash discharge at just the right time to provide enough light on the subject. As you've learned previously, quenching occurs when the light sensor has received sufficient reflected light. The time at which this occurs depends on how far away and how reflective the subject and its surroundings are. Of course, any automatic process is subject to being fooled. For example, a very small subject against a dark background may fool the flash into exposing for the background rather than the subject of interest. This would result in a greatly overexposed photo. In such cases, the knowledgeable photographer compensates by changing the camera aperture accordingly. Another case, which you aren't likely to encounter in your high-speed photography, is when the flash is so far from the subject that there isn't enough light to expose it correctly even if the flash discharges completely.

If you're using a variable resistor in place of the light sensor for flash duration control, then determining the correct aperture isn't as straightforward as using the calculator dial. However, a good starting point is to use an aperture of f/5.6 if the film speed is ISO 400 and the flash-to-subject distance is about a meter. Adjust the aperture accordingly for different film speeds and distances.

Another difference between using ambient lighting and flash lighting is the way in which intensity depends on distance. In a room that is lit by several ceiling lights, the intensity is approximately uniform throughout the room. If you were taking photos of various subjects in the room, you would use about the same aperture anywhere in the room. If using a single flash unit for lighting, however, the intensity depends strongly on how far the flash unit is from the subject. That's because the flash unit acts approximately as a point source of light, and the intensity from a point source varies inversely with the square of the distance from the source. As an example, assume that you had determined that an aperture of f/5.6 provided the best exposure when photographing a subject with flash at a distance of 1 meter. If you then moved the flash twice as far away to 2 meters, the intensity of the light on the subject would be $(\frac{1}{2})^2 = \frac{1}{4}$ as much. In order to get the same exposure, you would then need to open the aperture by two stops to f/2.8. Note that such manual adjustments in the aperture are only needed when you're using a resistor to control the flash duration. When using the flash in automatic exposure mode, distance changes are automatically accounted for.

As an example of how dramatic the difference between ambient and flash lighting can be, consider the two photos in Figures 1 and 2. Both are of the same forest subject photographed within a few minutes of each other. The lighting for the left-hand photo was the ambient lighting of the forest. The lighting for the right-hand photo was direct flash. For that photo, the background appears black even though the photo was taken during the day. The reason is that the trees in the background were far away compared to the main subject. As a result, the light reflected from the background had to travel much further than that reflected from the subject. The falloff of intensity with distance therefore provided much more intensity on the leaves than on the background trees. When the camera aperture was adjusted for correct exposure of the leaves, the background appeared black.

Figure 1. Leaves photographed in ambient light

Figure 2. Leaves photographed with direct flash

High-speed Photography with Digital Still Cameras

<u>Features</u>

Several years ago, consumer-grade digital still cameras didn't provide the manual control of aperture, shutter speed, and focusing needed for high-speed photography. That situation has changed, and there are now digital cameras under $500 with those features. When looking for a digital still camera for high-speed photography, check for the following features.

Manual focus control: Room lights are usually turned out before taking a high-speed flash photograph. In a dark room, a camera in auto focus mode will hunt continuously for something on which to focus. With manual control, the camera can be focused before the lights are turned out.

Manual aperture control: For high-speed flash photography, the flash unit is used off camera. This requires that the camera aperture be set manually for the expected flash exposure on the subject.

Manual shutter control: The shutter is held open in a dark room in readiness for the flash discharge. This usually requires a bulb setting, or ...

shutter durations of at least 1 second: For most high-speed photographic situations, it's possible to initiate the high-speed event in a time period of about a second. For example, for a balloon burst, the shutter button can be depressed and the balloon popped before the shutter closes a second later. This works because human reaction time is typically under a second. Shorter shutter durations can be used successfully, but 1 second provides a margin for error.

Ability to disable the built-in flash: Many digital cameras have built-in flash units. It must be possible to disable this flash. The high-speed event is captured with an external flash.

Flash override control: Some digital cameras won't allow you to take a picture if the subject is too dark and you're not using the built-in flash. The camera should provide a way to override this annoying feature. If not, there is a way to get around it. A pen light can be shined into the camera's photocell as the shutter is opened.

AC power adapter or rechargeable batteries: Digital cameras go through batteries quickly. An AC power adapter is a convenient accessory. While having a power cord connected to your camera is inconvenient for candid photography, it's no problem when the camera is mounted on a tripod for high-speed photography. Rechargeable batteries are good if they don't have to be recharged often.

Advantages and Disadvantages

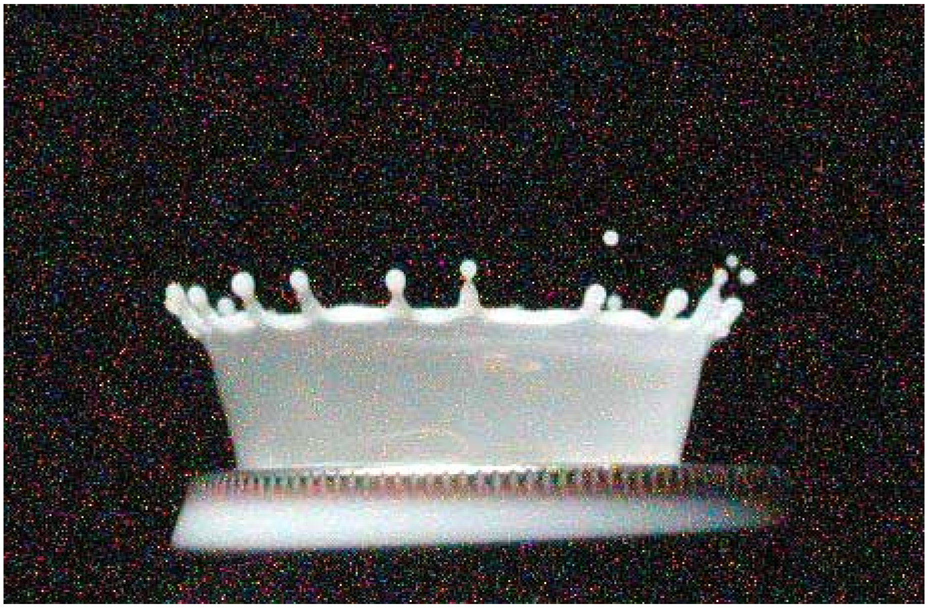
The advantage of immediate playback of recorded images is one that makes the digital camera attractive for capturing momentary events. With immediate playback, one doesn't have to develop and print film before deciding on how to improve a photographic setup. With these cameras, it's also possible to output images to a video display so that the whole class can view what other students are doing.

A disadvantage of digital cameras is that the image resolution doesn't match that of conventional film, although the former is improving. Some of the newer digital cameras with multi-megapixel CCDs have high enough resolution for good 11x14 enlargements. In order to get this quality, one must set the camera for the greatest image size and resolution.

An annoying aspect of many digital cameras is a long lag time between the pressing of the shutter release button and the opening of the shutter. A long lag time can cause one to miss a high-speed shot. When one presses the shutter in the dark to photograph a high-speed event, one has to wait for the lag time to pass before initiating the event. Of course, the amount of time to wait is a guess. The longer the lag time, the more likely one is to guess wrong and initiate the event before the shutter opens.

A potentially more serious problem is that the CCD chips in digital cameras generate random electrical signals that degrade image quality at long exposure times. This problem becomes particularly noticeable for exposures above a second. If the thermal noise in an image isn't too great, it can be removed in the image-editing process without significant degradation of the important information in the image.

Thermal noise always exists within a CCD, and the problem increases the longer the sensor is active. Some digital camera manufacturers caution the photographer about using shutter durations greater than a second. Noise manifests itself in the image as white specks. The greater the exposure time, the greater the number of specks will be. An example of an image with much noise is provided below. The image hasn't been resized, but it has been cropped to show the area surrounding the subject of interest, the splash of the milk drop. The shutter was held open for several seconds.



The best strategy to minimize noise is simply to keep the shutter duration as brief as possible. A photo taken with the shutter duration under a second is shown next. noise can also be removed with image-editing applications, but there will be some decrease in edge detail.