A *Brief* Introduction to Photography

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Goal: Get a well exposed photograph.

What does this mean? It means that the total light striking the film is (in some sense) correct. If there is too little light, then the image is dark and muddy, or underexposed. Fine details are lost in the shadows of the image. If there is too much light, then image is too bright, and fine details are lost in the highlights of the image.

To accomplish this we need to:

1. Define what we mean by the *exposure*, the total light striking the film
2. Specify what determines the correct exposure for a given film
3. Identify how *aperture* affects the exposure
4. Identify how *shutter speed* affects the exposure
5. Consider the trade-offs between aperture and shutter speed
6. Establish how to handle flash photographs

1 – What do we mean by *Exposure?*

We define the *exposure (E)* as the time integral of the *incidence (I)* of light onto the film. The *incidence* is just the instantaneous light intensity per unit area of the film. Its units are *lumen/m²*.[1] If we are using the ambient light (i.e., no strobe), the exposure is given by

$$E = \int_0^{\Delta t} I dt, \qquad \text{Eq. 1}$$

where Δt is the time over which the shutter is open and light strikes the film.

2 – What sets the required exposure*?*

The exposure required for a good image is set by the *film sensitivity* or *film speed*. The units are *ASA* or *ISO* (the two are equivalent for our purposes). The *sensitivity is linear with ASA*, i.e., if the film speed doubles (from, say, ASA 400 to ASA 800), the sensitivity to light doubles and the exposure required is cut in half.

Typical values for ASA include 80, 100, 200, 400, 800, and 1600. In this subject we will generally use an ASA 400 black-and-white film (Ilford HP5+).

3 – How does the *Aperture* change the exposure?

The *aperture* is the iris inside the lens. It can be opened or closed to increase or decrease the intensity of the light on the film. Notice that the size and shape of the image formed by the lens

[1] You might have expected the units to be W/m^2, which is what a physicist would use. However, we are only interested in the perceived intensity, so we need to normalize the light power (W) by the human eye response curve. For example, 1 W of green light is perceived as being approximately 10 times brighter than 1 W of red or blue light, so 1 W of green gives 10 times as many lumens as 1 W of red or blue.

is unchanged when the aperture is opened or closed. However, as the aperture is opened, the image gets brighter, and as the aperture is closed, the image gets darker.

The light intensity (which is proportional to the exposure) will vary with the *area* of the open aperture. That is, the exposure changes with the square of the diameter of the aperture. If the diameter of the aperture were to be doubled, the exposure would go up by a factor of four.

Aperture (*A*) is measured by the *f/#* and is defined as the focal length of the lens divided by the effective diameter of the lens (set by the diameter of the iris), or

$$A = \frac{focal\_length}{effective\_diameter} = \frac{f}{d_{EFFECTIVE}}. \qquad \text{Eq. 2}$$

Photographers prefer to work with doubling (or halving) the exposure, which requires changing the diameter of the iris by the square root of 2 (≈ 1.4) so the standard aperture settings change by factors of 1.4 (Table 1). In many lenses the aperture ring clicks into place on these standard settings, and they are known as the *f-stops*. In general, any change that increases or decreases the exposure by a factor of two is called a 1-stop change.

Table 1. Standard Aperture values

A (*f/#*)	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22
Exposure	Greater (More Light) ◄——► Less (Less Light)									
Aperture is	Open ◄——► Closed									
Depth of field is	Shallow ◄——► Deep									

Notice: *As the numerical value of A* <u>*increases*</u>*, the aperture* <u>*closes*</u> *and the exposure* <u>*decreases*</u>*.* Most people find this non-intuitive, and reverse the relationship at times.

Finally, as the aperture opens, the *depth of field* decreases. The depth of field is the range of distances from the lens that are in focus. If the depth of field is shallow, then objects just a little in front or behind the subject are blurry and out of focus. If the depth of field is deep, the subjects some distance in front of or behind the subject are crisp and still in focus.

4 – How does the *shutter speed* affect the exposure*?*

By *shutter speed* (or *exposure time*) we simply mean the total length of time over which the film collects light, For photos taken under the ambient lighting, the exposure time is the length of time during which the camera's shutter is open.

Clearly, if we double the exposure time we double the time over which we perform the integral of Eq. 1-1. If the lighting is constant when the shutter is open (generally true for photos not using a strobe), then doubling the exposure time doubles the exposure,

For cameras, the standard exposure times are a fraction of a second, as shown in Table 2. The values are selected so that the change between consecutive settings changes the exposure time, by a factor of two, that is, a change in exposure of *one f-stop*. The setting *B* stands for "bulb". When the camera is set on *B* the shutter is open for as long as the shutter release is depressed.

Table 2. Standard Shutter Speeds

Exposure Time (s)	Label on Dial	Exposure Time (s)	Label on Dial
1	1	1/60	60
½	2	1/125	125
¼	4	1/250	250
1/8	8	1/500	500
1/15	15	1/1000	1000
1/30	30	1/2000	2000

How shutters work
One type of shutter is the curtain shutter. There are two fabric curtains in the back of the camera. When you advance the film, they both are pulled to one side of the film, and a spring is cocked. When you press the shutter release, the first curtain opens, allowing light to strike the film. After the desired exposure time, the second curtain follows the first, covering the film and stopping the exposure.

For short exposures, the second curtain will start moving while the first is still in motion, This means that only a narrow strip of film is being exposed at any instant, but each piece of film will be exposed for the same length of time. One most cameras, the fastest shutter speed (i.e., shortest exposure time) that can work with a strobe is noted, often by being printed in a different color, or by having an *X* next to it.

5 – Trade-offs between aperture and shutter speed.
Notice that one can get the same expose with more than one pair of aperture and shutter speed. For example, assume that for a particular photo, the exposure is correct with an aperture of f/8 and a shutter speed of 1/60 second. Closing the aperture by one stop (from f/8 to f/11) will halve the exposure, and changing the shutter speed from 1/60 to 1/30 will double the exposure, so doing both will leave the exposure unchanged. Other such combinations are shown in Table 3.

Table 3. Different camera setting can give the same exposure.

	1/250	1/125	1/60	1/30	1/15
f/4	Well Exposed	+1 stop	+2 stops	+3 stops	+4 stops
f/5.6	-1 stop	Well Exposed	+1 stop	+2 stops	+3 stops
f/8	-2 stops	-1 stop	Well Exposed	+1 stop	+2 stops
f/11	-3 stops	-2 stops	-1 stop	Well Exposed	+1 stop
f/16	-4 stops	-3 stops	-2 stops	-1 stop	Well Exposed

A long shutter speed has the problem that any objects in your scene that are moving may appear blurred in your photo. A more open aperture (smaller f-number) has the problem that the *depth of field* of your photo is reduced. Again, by "depth of field" we mean the distance in front and back of your subject that is in focus. If you need a short exposure with great depth of filed (i.e., a rather closed aperture) you need to have a lot of light.

6 – Exposure for strobe photos

Most of our photos will be taken using a strobe in a darkened room. Our general procedure is:

1. Set up the experiment,
2. Turn off the room lights,
3. Open the shutter,
4. Start the experiment
5. Flash the strobe at the appropriate time
6. Close the shutter
7. Turn on the lights.

In this case, the film only collects light when the strobe is lit, so the exposure time is set by the *flash duration* of the strobe, i.e., the length of time when the strobe is lit. Flash durations can be as long as several milliseconds, or as short as a fraction of a microsecond, depending on the flash used and its settings.

At any instant in time, a strobe is emitting some light intensity into its *hot spot* (the brightest portion of the beam). That intensity, which we denote *BCP*, is measured in Beam CandlePower:

CandlePower is a measure of the instantaneous light intensity in a given direction
Beam is a reminder that the light has been formed into a beam by a reflector, and we will make the measurement in the hot spot.

Strobes are characterized by their *BCPS* rating, the light intensity in the center of the beam of the strobe, integrated over the duration of the flash. The units are *Beam-CandlePower-Seconds (BCPS)*.

The BCPS is fixed for the strobe—it tells how much light the strobe is sending in a given direction (solid angle). Therefore, the incidence of light onto the film, I (Lumens/m^2), falls off as the inverse square of the distance, D, from the strobe to the subject. In other words, for a strobe photo, the exposure E is given by

$$E \propto \int_0^{\Delta t} BCP(t)dt \Big/ D^2 . \qquad \text{Eq. 3}$$

To get a well-exposed photo while using a strobe, you must arrange the *BCPS*; the distance, D, between the strobe and the subject (measured in feet); the aperture, A; and the film speed, s, so that they satisfy the *BCPS equation,*

$$D \times A = \left(\frac{1}{1+m}\right)\sqrt{\frac{BCPS \times s}{c}} , \qquad \text{Eq. 4}$$

where m is the magnification factor defined in the lens handout and c is a constant equal to 20 (for D in feet, A in f/#, s in ASA, and *BCPS* in BCPS).