Light, your Camera, and your Photos
Viewfinders (film cameras)

There are two typical types of optical viewfinders:

– A single-lens reflex (SLR) camera allows you to see through the lens (almost) exactly what the film will see when you take the picture.

– A “point & shoot” camera typically provides an optical viewfinder that shows an approximation of what will be seen by the film.
Viewfinders (digital)

There are three common types of viewfinders on digital cameras:

– An LCD preview screen on the back of the camera showing you what the sensor sees.

– An electronic viewfinder (EVF) in the traditional viewfinder position showing you what the sensor sees.

  Note: With the above two you are possibly seeing this image on a relatively low-resolution screen, so it might not be as useful as an SLR.

– A Digital SLR that acts in the same way as a film SLR.

  • There are some dSLR cameras with live preview EVF (like the Olympus E-10 and E-330).
Beam Splitters

A technology that has been around for a number of years but which has the potential to become more mainstream is a beam splitter ‘mirror’ which sends most of the light to the sensor but some of the light to a viewfinder or to an auto-focus sensor.

The Sony A77 uses a pellicle mirror to send some light to an auto-focus sensor and the rest to the real sensor. (It also uses an EVF.)
What ISO numbers mean (I)

When purchasing film, you would buy a roll with a specific ISO rating based on the type of lighting conditions in which you expected to be shooting.

– A smaller number meant lower sensitivity to light, thus would generally require brighter conditions.
– Less sensitivity would also tend to mean less graininess (or visual noise) in the captured image.

With digital cameras, you set the ISO to specify how sensitive you want the image sensors to be to the light they receive. The same two bullets from above apply here as well.
What ISO numbers mean (II)

If you use a higher ISO, then you can use a smaller aperture or faster shutter speed, but you might have more visual noise in your picture.

– One nice thing about digital over film is that you can change the ISO between shots without having to change rolls of film.

Cameras with larger sensors historically tended to perform better in terms of noise on high ISO settings. More recently, smaller sensors of higher quality have been made.
ISO and Noise, Hot Pixels

At higher ISO settings, digital noise will typically appear more noticeable (slight defects become enhanced). It will tend to be more obvious on surfaces with uniform color.

Hot pixels also tend to become more obvious in pictures taken at higher ISO settings, though they also tend to become more obvious on longer exposures, so a lower ISO requiring a longer exposure could have the same type of problems.

We will also discuss later how using the JPG format over the camera’s RAW format can make a hot pixel’s effect more obvious.
Hot Pixel Example (JPG): Red

100% crop

Zoomed In:
Removing noise via a “flaw frame”

One “trick” that some cameras use (and that you can manually use as well) is to take a “flaw frame” to use to identify sensor-based noise.

A “flaw frame” is an image captured from the sensor right after the picture is taken, but with no light source actually getting to the sensor. Any non-black pixels captured represent photosite flaws.

This “flaw frame” can now be used as a mask over the actual picture to identify which pixels need to be corrected.

Some cameras do this automatically after you take a long exposure shot. We will see how we can do this manually later in the semester.
Shutter Speed (or Exposure Time)

The shutter speed indicates the amount of time (a) light is allowed to reach the film or (b) during which a sensor’s data is being collected for use in the construction of a single image.

There are several different designs for the shutter of a film camera.

- Focal plane shutters appear to be most common.
- Some shutters open and close like curtains splitting in the middle, others like curtains moving from one side to the other, and others like an iris.
Note: With a curtain shutter, if the subject or camera is in motion, the image might not be blurry but rather distorted…

Jacques Henri Lartigue’s
“Grand Prix of the Automobile Club of France” - 1912
Shutter Speed and Flash

If you are using a flash, you need to make sure that your shutter speed is slow enough that the entire sensor is exposed at the moment the flash fires.

– If it isn’t, you’ll get a dark band somewhere on the image (where depends on the type of shutter).

On a very long exposure, you will get different effects depending if you have the flash set to fire on “first” or “second” curtain.
Second-curtain Flash Experiment
Flash Power Math

As the distance between the flash and an object increases, the amount of light that will hit a given area of the surface.

If you have two objects where one is 2x as far away as the other, the illumination will actually be $1/4$ as much.
Aperture Size - The Diaphragm

• The aperture size describes the size of the hole in the diaphragm through which light is allowed to reach the film/sensor when the shutter is “open”.

• This opening is typically created using an iris diaphragm on modern cameras that allow for multiple apertures.
  – The iris diaphragm is composed of several blades moving to create larger or smaller (hopefully near-circular) apertures.
Aperture Size - The f-number (I)

The aperture on a camera is expressed as an f-number. This is the ratio between the current focal length (the distance from the lens to the film/sensor) and the diameter of the hole in the diaphragm.

- eg: f/8 means that the diameter of the aperture is \( \frac{1}{8} \) the focal length (the distance from the lens to the film/sensor).

The smaller the aperture, the less light reaching the film or sensor. Given identical lighting and ISO settings, a smaller aperture will require a slower shutter speed for the same overall exposure.

Lenses with iris diaphragms will typically have specific f-stops available to you, and will adjust the iris as appropriate based on the actual focal length.
Aperture Size - The f-number (II)

Originally the f-stops available would typically all be powers of $\sqrt{2}$ (around 1.4). This meant that changing by one stop would either double or halve the amount of light reaching the film/sensor.

– Recall: The area of a circle is $\pi r^2$.

Now cameras tend to have finer “presets” for f-stops that divide the range between two full stops into thirds.

divide the range between two full stops into thirds.

eg: $2.8$, $3.2$, $3.5$, $4.0$, $4.5$, $5.0$, $5.6$, $6.3$, $7.1$, $8.0$

One side-effect of larger apertures (smaller f-number) is that there is a shallower part of the space in front of the camera which appears in sharp focus.
Circle of Confusion and Bokeh

Windows application at http://www.cs.umd.edu/class/fall2011/honr208w/CircleOfConfusion.zip
Circle of Confusion

• For each point in a scene, light is being reflected off it at all angles.
  – The only beams that “matter” are the ones that go through the aperture.
  – Those beams will basically form a double cone (the aperture shape affects the sides of the cone).

• If the apex of the double cone for a given point intersects the sensor/film, that point is in focus. For other points, they will create a disk on the sensor. This is commonly referred to as the circle of confusion.

• The cones of light from any given point getting to the sensor is more narrow through a smaller aperture, so for the points that are out of focus, the circle of confusion is smaller when using a smaller aperture.
Bokeh

• One term used to describe a certain visual effect in photography is ‘bokeh’ - from the Japanese word ‘bokeru’ (pronounced boe-keh-roo) which literally means “to fade away” and is used to mean “blur”.

• The effect refers to the general “feel” of the out-of-focus foreground and background elements of an image.
  – For example, if a blurry background helps bring more attention to the subject, a complement might be “good bokeh”.

• The amount of blurriness in the out-of-focus regions, as well as the distance behind and ahead of our focusing target that is in focus, is a result of the focal length of the lens, the aperture, and the distance to our target.
Depth of Field - Concept

• The depth of field of a photograph is the region in which the circles of confusion will be below a certain limit. This is based on a number of things including the size of the sensor/film, the size to which you will enlarge, and the viewing distance.

• The diameter of the acceptable circle of confusion (ACC) is a central component needed for calculating the of the depth of field you can expect using a specific lens, aperture, and distance to the point on which you have focused.

• Since the ACC is subjective, and highly dependant on things like the sensor/film size and target enlargement size, the results of the calculations aren’t necessarily aesthetically precise.
Depth of Field - Calculation

• To calculate the depth of field, you determine the near and far focal distances - the distances at which the size of the circle of confusion for a point will exceed what you have defined as acceptable.

• Hyperfocal Distance $H=\frac{(\text{focal length})^2}{(f\text{-number} \cdot \text{ACC})}$

• Depth of Field:
  – $D=\text{distance to subject in focus}$
  – $\text{NF}=H \cdot D/(H+D)$
  – $\text{FF}=H \cdot D/(H-D)$
  – $\text{DoF}=\text{FF}-\text{NF}$

• Example:
  – You are using a 35mm lens (1.38 inches), you are at f/2.8, your ACC is 1/1000th of an inch, and the object in focus is 36 inches away.

…or just use an online calculator [http://www.dofmaster.com/dofjs.html](http://www.dofmaster.com/dofjs.html)
Slow Shutter, Small Aperture, ND Filter
Diffraction

While it might appear that having an incredibly small aperture (such as with a pinhole camera and many small devices such as camera phones) will cause the entire picture to be in focus, this is not the case due to diffraction.

When rays of light pass through a small opening, interference patterns create what is known as an Airy Disk (named for astronomer George Airy). At some point, the Airy disk will end up becoming larger than the acceptable circle of confusion, even though the actual circle of confusion will be smaller.
Contrast

- Contrast can refer to either tonal contrasts such as overall light/dark contrast or neighboring light/dark contrasts, or it can refer to color contrast.

- High contrast can help define the elements within your picture, can help draw attention to a particular element, or can be used to enrich the features of an individual element.

- A lack of contrast can make a picture appear softer. This might convey a desired mood, or it might just make the picture appear dull.
Example: High Contrast Tree/Sky
Example: Lower Contrast Tree/Sky
Example: Low Contrast Amsterdam
Example: Higher Contrast Amsterdam
White Balance

• Different types of light sources affect colors in different ways. A light source is said to have a “color temperature” to it.
  – Noon sunlight or flash-based lighting is typically close to white.
  – Sunrise and sunset lighting tends towards the red end of the spectrum, around yellowish or reddish orange.
  – A cloudy sky can tend towards more blue lighting.
  – Regular incandescent light bulbs tend towards medium yellow.

• In film photography, a filter can be used to help adjust for this. In digital photography, the camera can shift the values picked up by the sensor to adjust for the source lighting.
  – Automatic White Balance - the camera uses a specific point as “white” or estimates what color adjustment would create a natural range of colors.
  – Specific Lighting - many digital cameras allow you to identify the source lighting, and they will then adjusted based on the expected shift.
  – RAW - if you save the raw sensor data, then you can do white balance adjustments on the original data collected by the sensor.
Different White Balances: Golf Ball

- AWB
- Fine Weather
- Cloudy Weather
- Indoor Lighting
Different White Balances: Cloudy Sky

AWB

Fine Weather

Cloudy Weather

Indoor Lighting
Dynamic Range Problems

• The human eye has a dynamic range of at least around 10,000 in terms of contrast detection or relative differences in luminance. A digital camera’s sensor probably has an effective range closer to 100.

• When exposing a picture, if there are light and dark regions, the camera will need to make a decision. This will probably either lead to the light portions being blown out, or the dark portions being unseen, or both.

• We will see later, in digital image editing, how we can make changes to various settings (levels, curves, saturation) to adjust some images successfully.
Fireworks: Original

Notes © 2005-2011 : Evan Golub (egolub@acm.org)
Fireworks: Tone Mapping
Some resources:

Book: The Camera by Ansel Adams - 1995
http://library.thinkquest.org/25473/ph_03_02.shtml
http://www.dpreview.com/learn/?/key=viewfinder
http://www.photoxels.com/tutorial_iso.html
http://www.oswaldgallery.com/s.nl/sc.2/category.37/.f
http://www.nanomedicine.com/NMI/Figures/3.4.jpg
http://en.wikipedia.org/wiki/F-number
http://www.pbase.com/kleptolux/techtalk
http://www.cs.umd.edu/~egolub/honr279k/DOF/
http://www.clarkvision.com/imagedetail/eye-resolution.html
http://www.photoxels.com/tutorial_white-balance.html
http://www.go-photo.com/photography-skills/flash/flash-basics/