A short summary of digital photography basics

Exposure

A proper exposure needs adjustment of the following parameters: *A, T, S*, and to some extent *WB.*

<u>Aperture number</u> $A = f/D$, f = focal length, D = diameter diaphragm.
The reciprocal of the aperture, made dimensionless on the focal length.
Usual notation: aperture $D = f/A$, where A = …, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, …
Standardized on powers of $2^{1/2}$; each $2^{1/2}$ doubles the amount of light

Typically	3.5 - 8 for zoom lenses
	1.4 - 22 for fixed lenses
Min *A* (max *D*):	low light conditions
Low *A* (high *D*):	low depth of field (sharpness depth), $A \leq 4$.
Medium *A* (medium *D*):	optically optimal, A = 5.6 - 8
High *A* (small *D*):	large depth of field, $A \geq 8$

Note that the traditional values 5.6 and 22 are historic mistakes. They should have been 5.7 and 23.

<u>Shutter speed</u> $T=1/t$, t = shutter time in seconds, T = … 1, 2, 4, 8, 15, 30, 60, 125, 250, 500, …
The reciprocal of shutter time.
Typically T = 30 - 1000
Normally sufficient for handheld: $T > f_{eq}$ (where $f_{eq} = f$, converted to its 35 mm equivalent; see below)
Standardized on powers of 2, each 2 doubles the amount of light.

Fast *T* (> 500):	freezing motion; from a moving position; long f; good light conditions
Medium *T* (60 - 125):	good light conditions, optimal *A* and optimal *S*.
Slow *T* (< 30):	low light conditions; use tripod; if small *A* or large *S* is not possible.

<u>Exposure value</u> $EV = \log_2(A^2T)$: measures total amount of light that enters the camera

<u>Sensitivity</u> *S* ISO of the chip (CCD) or film = …, 100, 125, 160, 200, 250, 320, 400, …
measured according to ISO in (powers of 2) x 100. Each 2 halves the necessary amount of light.
Automatic selection is usually convenient, but note that the optimal *S* is the lowest (100 or 200).
With higher *S* the quality of the pictures goes, little by little, down, until it is unacceptably muddy for the highest *S*. Only a low *S* warrants a picture of high resolution and high quality jpg. For (very) high *S* this is pointless waste of memory space.

<u>Exposure</u>: If a scene requires, at S = 100 ISO, an exposure value EV = E_{100}, then this can be obtained by any combination of the 3 parameters *A, T* and *S* that satisfy

$$E_{100} = \log_2(100\, A^2T/S).$$

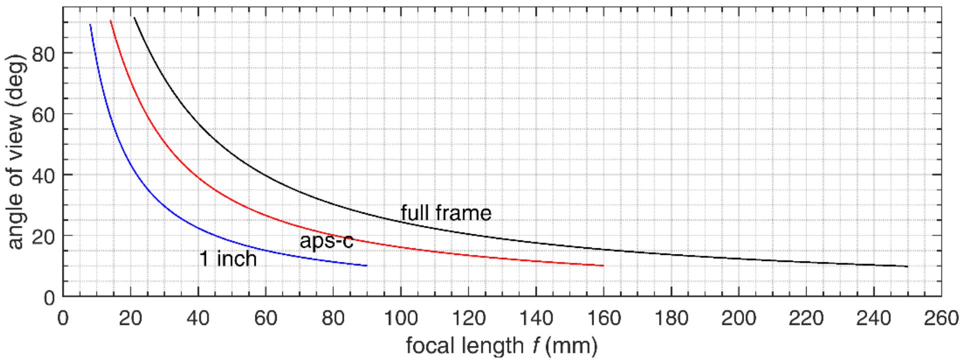
Examples:	5-8 home interiors and offices,	S = 800, A = 4, T = 60
	12 heavy overcast	S = 100, A = 5.6, T = 125
	13 cloudy, no shadow	S = 100, A = 8, T = 125
	14 cloudy sky, hazy sunlight	S = 100, A = 8, T = 250
	15 full sunlight	S = 100, A = 8, T = 500
	16 intense sunlight, beach	S = 100, A = 11, T = 500

<u>White balance</u> *WB* is a multidimensional parameter that represents the visible deviation from what we perceive as *“correct”* white light. By setting the *WB* we can account for the color temperature of bulb lamps (too yellow) and sky (too blue) by comparing with the hue of light radiated from an ideal black-body radiator, or account for color deviations due to e.g. fluorescent light. The automatic setting (AWB) is usually sufficient, except for special cases.

Sensor

The size of the sensor varies from 36x24 mm^2 (full frame) for professional and 23.6x15.7 mm^2 (APS-C) for semi-professional SLR, to 13.2x8.8 mm^2 ("1 inch") and smaller for compact cameras and smart phones. Full frame is to be compared with the standard 35 mm film of non-digital cameras.

The angle of view = 2 arctan($d/2f$) depends on focal length f and sensor diameter d. Although A is a dimensionless number, f and T are not, and the angle of view, equivalent with of a full frame lens of focal length f_F and diameter d_F, is therefore $f = f_F/CF$ mm. ($CF = d_F/d$ is the crop factor.)
For example, the equivalent of standard lens f_F = 50 mm is f = 34 mm for an APS-C sensor, f = 22 mm for a 15 mm sensor, and f = 15 mm for a 10 mm width sensor.



Angle of view vs focal length for various sensors.

To reduce blur due to camera motion, the minimum T for handheld photos (by rule of thumb, $T = f_{eq}$, the 35 mm equivalent of focal length f) is then $T = CF\,f$. That is T = 1.5 x f for 24 mm, T = 2.5 x f for 15 mm, and T = 3.5 x f for 10 mm sensors. For cameras with image stabilization this may be relaxed.

RAW and JPG

The digital information from the sensor may be stored in two ways: (1) *as is,* in so-called RAW-format, to be post-processed afterwards by special software, or (2) as jpg-file, after being processed to correct for geometric lens errors, pixel deficits and color errors, sampled down to the resolution selected, and compressed to jpg-format in the quality selected. (Together with a RAW-version, there is usually a jpg-version stored as well.)

Advantage of RAW: the dynamic exposure range of the RAW-version is a few stops larger than the jpg-version, so unintentional under- or over-exposure is better corrected from the RAW file. After post-processing, any common image format like bmp, tiff, png or jpg may be produced, while the RAW file is left untouched (the changes are stored separately in a log file). Moreover, jpg-compression is not lossless, so information may be lost that cannot be recovered, while with RAW you maintain the full quality of each image at your disposal. The RAW file is sometimes called the digital equivalent of the film negative.

Drawbacks: because RAW files are uncompressed, they take up more memory space than jpg images (2 to 6 times more). They are not typical images and cannot be opened by most image-viewing software. Furthermore, post-processing the RAW files is a lot of work while the jpg-versions are in general quite acceptable, so often the RAW files can be deleted if their jpg-versions are ok.

Note: the fact that geometric errors can be corrected afterwards by software, reduces the number of lens design constraints, making modern lenses far better than their non-digital ancestors.

Automatic settings

<u>AUTO</u>, auto everything (green button): selects reasonable combination of *A, T, S*, and *WB*, possibly with flash. Usually the flash spoils the photo if flash wasn't really necessary. For the photographer who is in a hurry, or with no knowledge whatsoever.

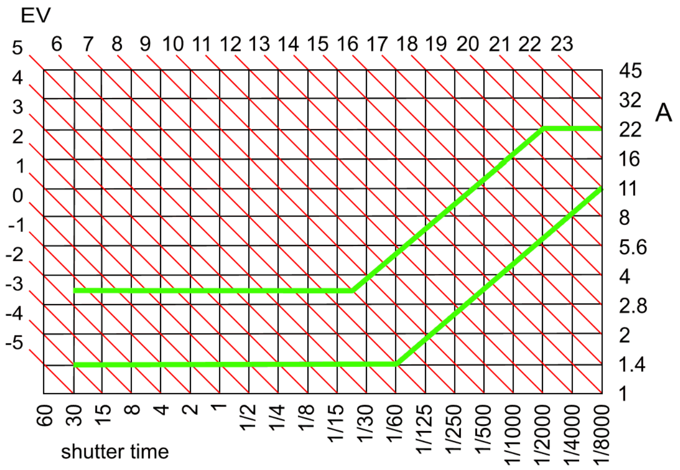
<u>AUTO</u>, auto everything without flash: selects reasonable combination of *A, T, S*, and *WB*, but never flash. For the photographer who knows when flash or tripod should be used.

<u>P, program</u>: selects reasonable *A* and *T*, with preset *S* and WB. Sometimes the program shifts to shorter *t* if *f* is larger (zoom lenses), and sometimes this shift can or should be done manually. Sometimes *S* is automatically adapted at the end of the range where *t* becomes unacceptably long. For the photographer who knows when to flash and what *S* to choose, but doesn't want to worry too much otherwise.

<u>T, shutter priority</u>: selects *A* with preset *T, S* and WB. Sometimes *T* or *S* (or both) is automatically increased when aperture is at maximum. Convenient setting if blur due to motion is to be avoided at all cost.

<u>A, aperture priority</u>: selects *T* with preset *A, S* and *WB*. One chooses for example an optically optimal *A* (5.6 or 8), or a low *A* for portrait or a high *A* for depth of field. Experienced photographers prefer this over shutter priority, but you have to keep an eye on the resulting *T*. Otherwise you end up with a brilliant but blurred picture.

<u>M, manual:</u> The photographer selects *A* and *T* manually. If *S* is adapted automatically, this is still an automatic, and the correct exposure will be obtained. If *S* can only be selected manually, this setting will result in a correct exposure only if the photographer follows, in one way or another, the light meter. *WB* has to be preset (possibly in auto-mode AWB) in all cases.



Exposure chart for *S* = 100 ISO, showing combinations of *A* and *T* leading to the same *EV* (red lines).
The green lines are samples of a P-program mode setting.

Composition

No feet or legs chopped off, unless by intention.
Avoid a sloping horizon, unless by intention.
No unbalanced empty space at top or side.
Consider an underlying pattern in the scene such as visual rhyme, a diagonal, rule of thirds, a surrounding frame of vertical or horizontal lines (tree, wall, etc.)
Avoid undesired elements if they distract the attention: other people, shadow of the photographer, flash mirrored in a window, sticks growing out of heads, ….
Unless intentional (like for a portrait), don't zoom in too closely.

A building or street without people may be just right, but it could also be sterile. Consider including some people, a passing car or bike, or animal.

3 times the same photo doesn't triple your chances of a good picture. Only for a group's photo this may work, if not everybody was alert at the same time. More photos of the same scene is useful only if you make each time the photo as if it was the only one.

Sun in the back gives usually brighter colors, but the picture may become uninterestingly flat. Sun from the side gives more profile and contrast, and is usually ok. Sun from the front (keep your lens clean and dust free!) gives a picture that looks into dark shadows and should be avoided if we want to see faces. However, with a bit overexposure (one or two stops) it may also give beautiful light rays through hair or around the head. Consider HDR (*High Dynamic Range*) to bridge excessive contrast ranges.