

The Exposure Pizza

Robert Stone - February 2024

There are three camera settings that can be adjusted to get a properly exposed image. These are *Aperture*, *Shutter Speed*, and *ISO*, commonly referred to as the 'Exposure Triangle'. According to Wikipedia, a triangle is used extensively in architecture because "a triangle will not change shape unless its sides are bent, extended or broken." Photographers tend to get bent or broken by the exposure triangle because it's often taught with all the unfamiliar technical language of optics and geometry. Like the Bermuda Triangle, people venture in and get lost.

A rigid triangle does not give you an intuitive feel for how these three items interact. Most sites show a lot of fixed-size triangles with no way to visualize how change in one component affects the others. Changes in the triangle's angles (or sides) simply distort the shape. The *dynamics* are not clear or obvious.

I prefer the Exposure Pizza model. The whole pizza represents a combination of values that gives you a correct exposure. The pizza will always have 3 slices, one for each of the three settings. No matter the size of individual slices, they always cover the full pizza. The dynamics are simple: if one slice gets smaller, then one or both remaining slices must get larger, and *vice versa*.

Here's an example pizza: The camera LCD / light meter tells me that f/2, 1/100s at ISO 100 is correct. Since ISO 100 is the base (lowest) ISO for my camera, its slice is small.

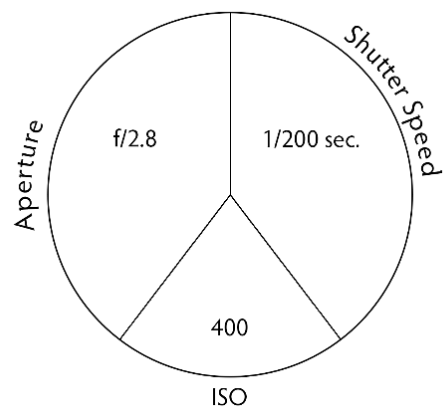
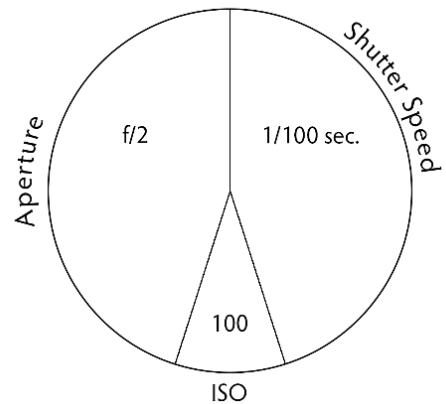
Now, if I want a faster shutter speed and slightly more depth-of-field, I can set the ISO to 400 (2 stops more sensitive). The camera's exposure meter will tell me that it's 2 stops over exposed. To get back to a correct value, I can make the aperture smaller by 1 stop (f/2.8) and the shutter speed faster by 1 stop (1/200s).

The pizza now looks like this; the ISO slice got bigger. The shutter speed and aperture slices got smaller. The 2 stops increase in ISO was compensated by using a shutter speed 1 stop faster and reducing the aperture by 1 stop.

The pizza will always be round and always have the same area. The different sizes of the slices will better represent their part of your exposure decision. Many different values for aperture, shutter speed and ISO can give you the correct exposure.

The pizza is the exposure.

A camera usually has a built in light meter that shows or points to '0' when it thinks the exposure is correct. If the pointer says '+1' it may be one stop over-exposed, or '-1' if under-exposed by one stop. If it is not pointing to '0', your slices might need adjusting!



The Three Pizza Slices

<i>ISO</i>	The sensitivity of film to light, or signal amplification for digital sensors.
<i>Shutter Speed</i>	How long (or short) the sensor or film is exposed to light.
<i>Aperture</i>	The size of an adjustable opening in the lens: the diaphragm.

ISO - The sensitivity of film to light, or signal amplification for digital sensors.

With digital photography, you use a dial or menu option to change the ISO value. Increasing ISO does not really change the sensor's sensitivity to light; it simply amplifies the voltage data from the sensor's photosites. High ISOs also produce a grain effect in digital photography similar to that of high ISO film. In general, you will keep ISO as low as possible for less noise in the image.

Shutter Speed - How long (or short) the sensor or film is exposed to light.

Of the three, only shutter speed is reasonably intuitive. Faster shutter speeds 'freeze' subject motion; slow shutter speeds can smooth moving water. It is easy to review test frames to see if your chosen shutter speed gets the job done, then adjust if necessary.

Shutter speed can be critical to making images. I like my waterfall images to show enough blur in the moving water to emphasize flow, yet not so slow that I lose texture. I usually start with a shutter speed of 1/5 second, with the camera on a tripod. Wildlife and sports photographers often want tack-sharp images and so choose faster shutter speeds.

Aperture - The size of an adjustable opening in the lens: the diaphragm.

Aperture, or f/stop, is the most difficult to get an intuitive understanding. Smaller apertures yield deeper depth-of-field (DOF), exactly what I want in my landscapes. But changes in DOF are nearly impossible to evaluate in-camera. The lens stays wide open even when making changes to aperture, so you always see a bright but 'shallow' version. If your camera has a DOF Preview menu option or button, the viewfinder may get too dark to see the effect well.

The image you see on your camera's LCD is a medium size and quality JPG that's quick to produce. The camera will be applying some color correction and sharpening; these limit your ability to use the LCD to truly evaluate how DOF sharpness changes with aperture. In fact, DOF changes with the size of the final image and the LCD is just too small.

I rely on cell phone applications to choose the aperture that provides the DOF I want. I have a series of documents on my website dedicated to depth-of-field if you wish to explore that subject more deeply. But for this document, we want to explore the concept of Exposure.

Exposure Pizza Dynamics

The pizza is the exposure! You can set any value for each of the three slices. As long as the light meter in your camera points to '0', all the possible combinations of ISO, Aperture and Shutter Speed will work! But as a photographer, you will 'pre-visualize' your image and have some definite ideas about each of the proper pizza slice values. Here's an example...

I love to photograph waterfalls. After composing the image, I start with a shutter speed of 1/5 sec. Generally, the resulting image shows smooth flow yet retains good detail in the water. Since the shutter speed is relatively long, that slice is large. The ISO slice or the aperture slice must be smaller. (Or maybe both will be slightly smaller.)

Next, I use depth-of-field tables on my smart phone to set a suitable aperture. This aperture must result in sharpness in-depth across the whole image. This will generally be a small aperture, perhaps f/11.

With 2 of the pizza slices set, I now need to adjust the ISO setting so that the camera's exposure meter is centered or points to '0'. Our shutter speed is slow, allowing light to enter the camera for a fairly long time. But the intensity of the light entering the camera is reduced by the small aperture. Sometimes, the ISO does not need to be adjusted but on cloudy days I may need to increase ISO to center the needle. On a sunny day, I may need to add an ND filter to the front of the lens to avoid diffraction at smaller f/stops.

The lesson here is that you, the photographer, adjust the size of the pizza slices to get the image you want. I often set aperture first to make my landscape images sharp from front to back. I then set a low ISO to avoid noise in the image. Shutter speed is set last to get the proper exposure. For a landscape with no waterfall, shutter speed may not be important.

The 'exposure' we are establishing must reflect the give-and-take among the three pizza slices as adjustments are made. Here's a way to think about it.

A 'Mental Model'

My wife waters her small garden plants using a one gallon watering can. She fills it in the kitchen sink, turning the faucet on full for about one minute. Sometimes, the faucet isn't open all the way, and it takes longer. Makes sense, doesn't it? Turning the faucet handle opens the valve; the bigger the opening in the valve, the faster the water flows and the less time it takes to fill the bucket.

If we wanted to use numbers to describe this, we would say that wide open, the water flows at 1 gallon per minute or, 1 gpm. If the water was flowing at ½ gallon per minute, or ½ gpm, it would take 2 minutes to fill the bucket. If the water flows at ¼ gallon per minute, ¼ gpm, it takes 4 minutes to fill the bucket. A little table with these numbers looks like this:

Rate	Time	Rate x Time
1 gpm	1 minute	1 gallon
½ gpm	2 minutes	1 gallon
¼ gpm	4 minutes	1 gallon

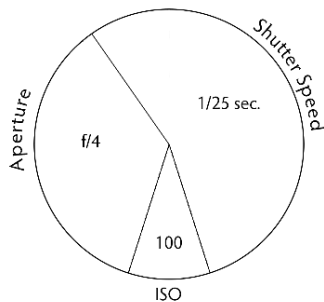
Note these two things: 1) If the water flows fast, it flows for a shorter time. If it flows slowly, it flows for a longer time. 2) All three combinations of flow and time fill the bucket with the same amount of water. If you multiply flow rate and fill time on each row you get the same 1 gallon. We could call this number the 'Fill Value' or FV.

Your camera sets the aperture so light enters as a flood or trickle by changing the size of the diaphragm opening. With a small aperture, a trickle, say $f/16$, the shutter has to stay open longer. A wider aperture, a flood, say $f/2.8$, requires a faster shutter speed.

Increasing ISO has the effect of telling the camera that there is more light by amplifying the voltages on the sensor. In this FV model, this suggests that the bucket is smaller and can be filled with less water. But high ISO values generally mean reduced dynamic range and more noise in shadows. For this reason, I like to keep my ISO as low a possible and start shooting at my camera's lowest ISO, 100, then increase if necessary. That said, modern de-noise in Adobe and third party apps is very good and higher ISO values less of a problem.

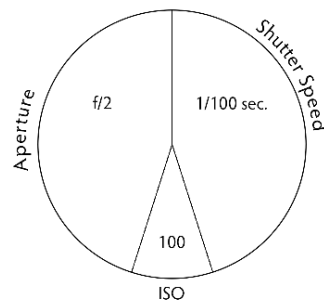
Reciprocity

Here are some pies that show the reciprocal relationship of aperture and shutter speed at the same ISO. This is called *reciprocity*.



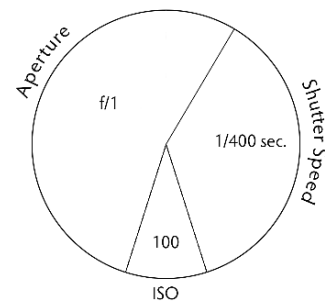
Photographer chooses
2 stops smaller aperture
2 stops slower shutter

$f/4 @ 1/25s$



Camera Suggests
f/2
1/100 sec.

$f/2 @ 1/100s$



Photoghrapper chooses
2 stops larger aperture
2 stops faster shutter

$f/1 @ 1/400s$

The whole pizza is the same exposure but note how the cut line between the aperture slice and shutter speed slice moves as they are adjusted. The photographer has simply selected complementary values for shutter speed and aperture that she wants! The camera's exposure needle stays firmly on the '0'. Choosing a higher ISO causes the camera to believe there is more light in the scene. Higher ISO can mean smaller apertures or faster shutter speeds, or a little of both. Look back at the two pizzas on the first page.

Exposure Value (EV)

If we wanted to get particularly geeky, and we do, we could adopt an Exposure Value (EV) system like the Fill Value (FV) above. A single number could represent all the combinations of aperture, shutter speed and ISO that result in the same exposure. The camera could have an EV dial, then as the photographer makes changes to one pizza slice, the camera automatically adjusts the other slices. (Some older Konica and Aires film cameras actually did have an EV ring on the lens that coupled aperture and shutter speed. Using it proved awkward and was later dropped.)

But wait! There really is an Exposure Value¹ system, and it's in your camera's firmware! It's hidden behind the camera's 'automatic' modes: Auto, Program, Aperture Priority, Shutter Priority, and Auto ISO. It also gets involved in Manual mode. You just never see the EV values. This table explains the details.

EV Automatic and Manual Modes

Mode	How it works
AUTO Fully Automatic	The camera does everything! You cannot change the aperture, shutter or ISO. (White balance may also be set to auto.) All 3 slices may be changing size; your camera may not even show the ISO, shutter speed or aperture values!
P : Programmed P* Option	The camera controls the size of the aperture and shutter speed slices, but the user's selected ISO slice stays the same. On my Nikon Z cameras in P mode, the rear knob allows changing aperture and shutter speed to keep a constant EV. The LCD display changes from P to P* when settings do not match the automatic values. (Since the exposure is the same, I like to use this feature to quickly step through all the equivalent f/stops and shutter speeds as part of a lens test on a tripod-mounted camera.)
S : Shutter Priority Tv or Time Value	User sets the desired shutter speed, so the shutter slice size remains constant. The camera adjusts the aperture slice to accommodate changes in scene light. User can change white balance and ISO. This is commonly used by sports photographers.
A : Aperture Priority Av or Aperture Value	User selects the desired aperture, so the aperture slice stays constant. The camera adjusts the shutter speed slice according to light levels. User can change white balance and ISO. This is commonly used by portrait and landscape photographers.
Auto ISO	User sets aperture and shutter speed; their slices stay the same size. The camera adjusts the ISO slice as needed. User can change white balance. Essentially, Manual with Auto ISO.
M Fully Manual	User sets all three slices: aperture, shutter speed and ISO. The camera won't complain about 'wrong' settings, but it uses the EV system to point that needle to '0' if the exposure is correct, or the number of stops over or under exposed!

There is one more thing we need to consider; the camera is reading the amount of light in the scene! With this luminance value, the camera's EV firmware uses the ISO, aperture and shutter speed settings to automatically set the camera's exposure pointer. In the automatic modes, that pointer stays locked on '0'. The pointer, or '0', might not even be displayed! As you make changes in these modes, the camera compensates immediately.

When EV Values Go Wrong

Understanding the Exposure Pizza relies on the idea that the camera is using its built-in light meter and EV firmware to figure out the correct exposure. It sets a pointer or numeric indicator to '0' when the ISO, aperture and shutter speed give a correctly exposed image. But sometimes, it's wrong!

¹ The EV system defines EV 0 as ISO 100, f/1, 1 sec. Scenes with more illumination have higher EV numbers. EV 20 would be a scene 20 stops brighter; 1/1000 sec @ f/32: 10 stops faster shutter speed, 10 stops smaller aperture. Check this link for details: [Exposure value - Wikipedia](#).

Before exploring when a camera's automatic setting does not give the best results, it's worth noting that the Auto modes on modern cameras are exceptionally good! Camera EV systems are trained on thousands of sample images. This is baked into the camera's chip system. My old Nikon D200, released in 2005, based its 'matrix' auto-exposure system on over 300,000 sample images! (Nikon doesn't provide this info anymore. I expect the number to be much larger now.) If you are working with a new camera, don't be afraid of automatic modes!

Back in the day, this was called Machine Learning; now it's called AI for Artificial Intelligence. Once you understand how the EV system works, operating your camera exclusively in Manual mode becomes simple, and an older form of AI: Actual Intelligence.

The light meter wants to average all the luminance values in the scene. This 'correct' EV is the same as if you metered the luminance of a middle grey card under the same lighting conditions². But the camera doesn't really understand the image, it only understands patterns of light. Some scenes do not average well. Winter landscapes with lots of white will result in snow looking muddy grey. At a concert, a spotlighted performer will get over exposed as the camera tries to give more exposure to the near-black background.

The camera has knowledge, not intelligence.

You will have several clues when this is happening. The live and review images on your LCD will clearly show the problem! A drab, grey landscape, or a bright white, washed-out performer will be obvious. If your camera has a histogram option, either 'live' while shooting, or part of the after-shot review on the LCD, use it! The grey landscape histogram will show a peak in the middle with lots of empty space in the dark and light areas. The concert performer image will have a tall peak pushed to the right, bright side of the histogram. (On some cameras, the histogram displays are optional; check your manual!)

What do you do when the Auto modes are getting it wrong? You use the exposure compensation button on the camera. This button typically has the +/- symbol on it. Hold that button down and use a dial to add '+' more exposure to the snow scene, or lower '-' the exposure for the performer. Check your manual for this! Stay in your chosen automatic mode, take test shots, and adjust +/- to get the desired result.

Tip! This type of exposure compensation often stays in effect until you cancel it, even after you turn the camera off! Be sure to reset when done. As a clue, your camera will likely show the +/- icon on the LCD when it's active. Double check often!

There is one other situation where the EV system goes wrong. Film does not respond to long exposures the same way as a digital sensor; extra time has to be added to longer shutter durations. This *reciprocity failure* is also known as Schwarzschild's Law, first scientifically documented by

² Large format cameras have no built-in light meter; photographers typically use a grey card and hand-held light meter to determine aperture and shutter speed settings.

physicist Karl Schwarzschild³ as part of his work in astronomical photography.

Final Comments

I started my involvement with photography in 1970 with a Nikon FTN. I used a 4x5 view camera for about 10 years. Both of these were all manual, all the time! ISO (then ASA) was constant for the whole roll of 35mm film or box of 4x5 sheet film. ISO changes were rare, except for some artistic purposes. The reciprocal nature of f/stop and shutter speed at the same ISO is deeply engrained into my personal firmware.

I never found the idea of representing exposure as a triangle to make any practical sense. But changing the size of pizza slices has real world meaning! We all understand the size of a slice!

The Exposure Pizza really helped me understand exposure and reciprocity. I hope it works for you too!

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³ This is the same Karl Schwarzschild that solved Einstein's equations of General Relativity for a spherical, non-rotating mass, and lead to the derivation of the Schwarzschild radius, or event horizon, of black holes. [Karl Schwarzschild](#)