Setting the Exposure

Understanding the relationship between aperture, shutter speed and those ISO settings.

Those strange numbers - what do they actually mean?

The moment you pick up a camera, you are confronted by a selection of seemingly meaningless numbers. One set might read 1000, 500, 250, 125, 60 and those are fairly straightforward. Then you come across 22, 16, 11, 8, 5.6, 4 - not quite so straightforward but there *is* a certain pattern. If you look, you'll see that each alternate number in that sequence (ie. 16, 8, 4) is half of the preceding one. This isn't a coincidence but for the time being we are going to ignore it because it isn't particularly important **at this stage**. (The reason is at least partly historical.)

You may also see a 'B' setting - this is short for "the shutter will stay open for as long as you squeeze the bulb that opened it. When you let go, the shutter will close". Imagine how big cameras would have to be if all **that** was on the shutter speed scale!

'B' is actually short for 'Bulb' - which was that rubber thing you used to squeeze to fire the camera shutter way back in the beginnings of the old mechanical shutters.

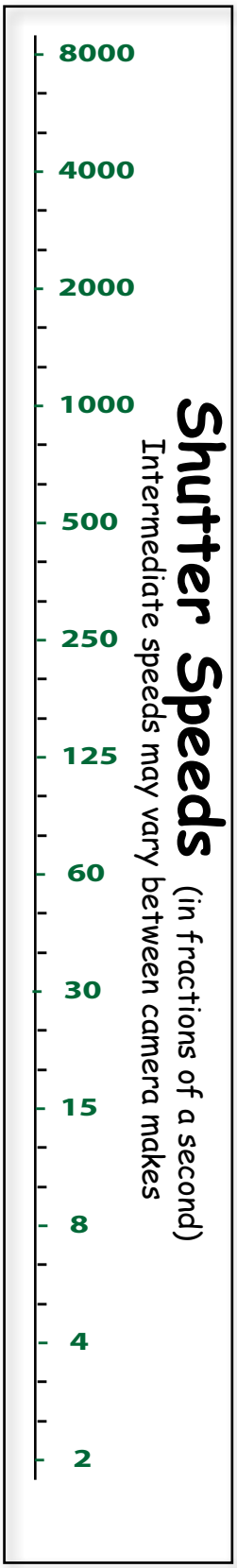
Shutter speeds

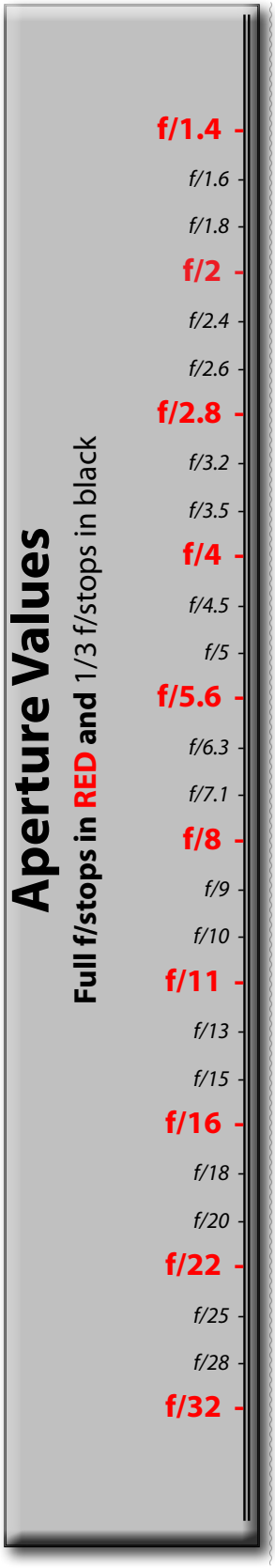
The first set of numbers are shutter speeds and indicate the length of time that light can enter the camera. Nothing more and nothing less than that. The full sequence reads:-
8000, 4000, 2000, 1000, 500, 250, 125, 60, 30, 15, 8, 4, 2, 1 and these are fractions of a second. Because of nothing more than available space, you will hardly ever find them written any way other than as just listed. Correctly speaking (and ever so much more understandable), they should be written as 1/8000th, 1/4000th, 1/2000th, 1/1000th, 1/500th, 1/250th, 1/125th, 1/60th, 1/30th, 1/15th, 1/8th, 1/4th, 1/2nd and 1 whole second - there has just never been enough space on cameras to use the full notation. It takes no great leap of imagination to see that if you take any number in that sequence as your basic setting, if you adjust one number to the left then light enters the camera for half the duration of time and if you take one number to the right, light enters the camera for twice the duration. Each step involves either a doubling or a halving of the time that light is allowed to enter the camera.
You will, especially with modern cameras, come across other numbers which aren't in that sequence. For example, your camera may show the shutter speed as '90'. This, as we have just seen, indicates 1/90th of a second. Naturally, this lets light enter the camera for longer than does 1/125th of a second and shorter than 1/60th of a second. And it really is every bit as straightforward as that. There is a very logical progression with the higher number being a smaller fraction and therefore a shorter time when light can enter the camera. The full list of numbers that you are likely to come across can be found in diagram 1. Just remember that the numbers in the list above are the important ones and that going from one to the immediately adjacent will either double or half the time that light enters the camera.

Aperture settings

1.2, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32, 45, 64. This is the set of numbers which tends to really create confusion. They are just such *strange* numbers. The reason for this is that they aren't just fixed numbers like the shutter speeds but relative to something else. (The explanation is in a panel on page 9). It all gets a bit complicated and very mathematical so let's try and clear it up.

Each of the numbers in the above list is what is called a "full f/stop". Anything in between (like 3.5, 4.5, 6.3, 13 or 18) is a partial f/stop. Did you notice anything about the previous two sentences? Did you see the '/' between 'f' and 'stop'. Oh, yes - it's definitely there for a reason. You'll often find apertures incorrectly written as 'F stop' ,





'f.stop' or any one of a number of other variations. Strictly speaking, the only *correct* way of referring to the aperture setting is 'f/stop'. Why? Because it's a **fraction**. Yep. A fraction, just like the fractions of a second used in the notation for shutter speeds.

Because of various laws of optics; it would be really, *properly*, **seriously** confusing if we just marked the aperture as '2mm hole' or '5½ inch diameter'. Because this would tell us absolutely nothing useful in photographic terms, only in physical terms. What the f/1.4, f/2, f/2.8, etc sequence is telling us is how much light passes through that particular setting. There is no need here to go into all the why's and wherefore's, suffice it to say that a setting of (say) f/5.6 on a 200mm focal length lens **lets in the same amount of light** as does f/5.6 on a 28mm focal length lens. The physical size of the hole is different, but *it lets in the same amount of light*. And that is what we are interested in, the amount of light getting into the camera.

Looking at the sequence in the left hand panel, changing from f/1.4 to f/2 lets half the volume of light into the camera in a given period of time. Changing from f/2 to f/2.8 halves the volume again, and so on all along the scale down to f/64 and even f/128 (which you will probably never, ever see). The size of the hole gets smaller, what the size of the hole happens to be is irrelevant in photographic terms. On any lens, of any focal length, a particular aperture setting or f/number will allow the same amount of light to pass into the camera. That's what the strange numbers mean, the amount of light which can pass through the lens at that aperture setting.

Aha!
We've seen that shutter speeds are fractions and that each full step on that original scale lets in light for either half or twice the time of the adjacent ones. Now we see that apertures are also fractions, and those strange numbers indicate the volume of light entering the camera.

Moving along the aperture scale also changes the volume of light entering the camera by a factor of two. Either twice as much if the number is a bigger fraction (ie ½ is bigger than ¼) or half as much if it is a smaller fraction. Most of the confusion arises because people don't realise that these aperture numbers are fractions. Once that has been explained, then it becomes a matter of basic arithmetic that a setting of f/4 (ie 1/4 of something) is more than f/11 (one-eleventh of that same something) and, of course, lets in a greater volume of light.

Each step on either the shutter speed or the aperture scale either halves or doubles the total amount of light entering the camera. One does it by controlling time and the other does it by controlling volume.

A bit of imagining needed here. Imagine two identical buckets. One is to be filled with a fire hose diameter 6" and the other by a huge teapot with a ½" diameter spout. Which one fills the bucket to the brim first? The fire hose - a large aperture for a short length of time. The teapot, with it's smaller aperture, will still fill the bucket but it'll take a lot longer. Both buckets are still full.

Exactly the same applies with aperture/shutter speed settings. If you follow the instructions on page 4, all will become very clear.

How to use this little scale.

1) Cut this sheet into two parts vertically down the double line.

2) Butt the two newly cut edges together at any point.

3) Read off the selection of shutter speed / aperture setting pairings.

ANY ONE of the pairs formed will give you the same amount of exposure for your photograph. For example (without cutting the sheet up) with the two scales positioned as they are before cutting, you can see that 1/500th second shutter speed with the lens set at f/4 will give you exactly the same exposure level as if you changed the shutter speed to 1/60th second and compensated by also changing the aperture setting to f/11.

Everything works by either doubling or halving the previous setting. It follows, therefore, that if you double one setting and half the other, you get the same overall exposure. You will NOT get the same actual *effect,* because other factors come into play but you will have the same level of exposure.

So: the numbers may look strange but what could be easier than everything working on a factor of 2?

Aperture Values

Full f/stops in RED and 1/3 f/stops in black

Shutter Speeds (in fractions of a second)

Intermediate values may vary from one camera make to another

Aperture Values	Shutter Speeds
	1/ 8000
f/1.4	1/ 4000
f/1.6	
f/1.8	
f/2	1/ 2000
f/2.4	
f/2.6	
f/2.8	1/ 1000
f/3.2	
f/3.5	
f/4	1/500
f/4.5	
f/5	
f/5.6	1/250
f/6.3	
f/7.1	
f/8	1/125
f/9	
f/10	
f/11	1/60
f/13	
f/15	
f/16	1/30
f/18	
f/20	
f/22	1/15
f/25	
f/28	
f/32	1/8
	1/4
	1/2

ISO Settings - either film speed or sensor sensitivity.

You're going to like this - it's another set of figures! Fear not, they're just as straightforward to understand once the fog is cleared out of the way.

ISO100/21° - the **correct** way of writing down how sensitive your media is. It doesn't matter if it's black and white negative film or the latest digital SuperWhizzBang 295SQ with hyper-sensor, all the numbers are doing is telling you how sensitive to light your chosen recording medium is.

Let's go through it stage by stage.

ISO = International Standards Organisation. There isn't actually a lot I can add to that!

100/21° - ah, now we come to the nitty gritty. This is NOT a fraction (sorry); the '/' symbol merely indicates that there are two parts to the formula. The first is an arithmetic scale where a doubling of the number equals a doubling of sensitivity (200 is twice as sensitive to light as 100). The second does no more than repeat this information on a logarithmic scale where a 3° increase indicates a doubling of sensitivity. This is actually a token nod at the old DIN scale used on European films - you are unlikely to come across it on a camera nowadays.

In fact, although it isn't strictly correct, for general usage you could just as easily say ISO100 and leave it at that, without repeating the information. And that is what most cameras do. So nothing to worry about there then. Once again, there are conventions (mainly through convenience as much as anything else) which decree the 'normal' stages of increase in sensitivity. Because of this, you will come across the same numbers time and time again (just as with aperture settings and shutter speeds) - but you will also come across intermediate numbers.

Because of the way in which many digital cameras are configured, there is no indication other than the numerical one as to what sensitivity is set. A very common mistake is to change from '400' to '500' and think that you have greatly increased the sensitivity. The briefest glance at the adjacent table will show that although the numerical increase has been a whopping 100, and the percentage increase has been 25%, in fact you have barely tweaked the sensitivity at all. The very great majority of photographers do not expose or meter their pictures to that degree of accuracy and hence an adjustment like that does almost nothing in real terms. In other words, generally speaking you are wasting your time making so small an adjustment.

In simple terms, if you are going to adjust the sensitivity, do it by an amount which makes a difference - double the ISO number.

Relationship of ISO to aperture and shutter speed settings.

This is all very well, but we now have three different scales to work with. Is it getting complicated yet? Actually, not at all. For the simple reason that all three scales work on the same basic principle - move from one major setting to the next one (ie the coloured numbers) on any one of them and you have either halved or doubled

Abbreviated ISO sensitivity scale
(Arithmetic scale only, logarithmic scale omitted for clarity)

6400
5000
4000
3200
2500
2000
1600
1250
1000
800
600
500
400
320
250
200
160
125
100
80
64
50
40
32
25

the exposure given. The most commonly used way of expressing a change in exposure is in terms of f/stops. Hence we would say that a doubling of the exposure would be 'opening up by one (f/)stop'. Rather obviously, if you actually change the **aperture** to achieve this, you have literally opened up by one f/stop. If you double the length of time for which you open the shutter (say from 1/125th to 1/60th) you have increased the exposure by a factor of two - this is also know as an increase of one f/stop, *even though you have changed the shutter speed and not the aperture.*

When it comes to ISO settings, guess what? Change from ISO100 to ISO200 (ie doubling the sensitivity of the sensor {or film}) and you have effectively increased the exposure by one f/stop. You haven't changed the aperture setting, you haven't changed the shutter speed setting but you've still increased the exposure by one f/stop.

Why? Because no matter what setting you are adjusting, moving one full step in either direction changes the exposure by a factor of two. It either halves or doubles the effective exposure.

Funny numbers? Well, yes they are - and with good reason. But they are nothing to get into a panic over. Grab the aperture setting and one full division change equals a doubling or halving of the overall exposure set. Grab the shutter speed adjustment, same thing. One full division either doubles or halves the overall exposure. Change the sensitivity? Guess what! Yep, same again. Double or half.

Darn it! More funny numbers!

You can skip this section if you are brave - or you can have a bit of history to explain those hitherto unexplained 'film speed' (ie. sensor settings) numbers.

The history bit. English speaking countries finally settled on an arithmetic scale to indicate film speed. 400 is twice 200 which is twice 100. Easy. In line with this, shutter speeds were a simple arithmetic progression (after rationalisation and a tiny bit of tweaking to save on engraving!!) so 1/60th of a second was (roughly) twice as long for the shutter to be open as 1/125th of a second. Two scales, both arithmetic progressions. So easy it's almost laughable - it's the *two times table*!

In Germany, then a very major player in photography, the scientists had more sway and film speed on the DIN (Deutsche Industrie Norm) scale was logarithmic. Lost anyone yet? It isn't actually all that hard to follow; 3° increase in speed indicated a doubling of sensitivity. Hence, to use the 400/100 comparison above, 27°DIN film was four times as sensitive to light as 21°DIN film.

Yawn - boring. Yes, perhaps but it explains two things:-

- Where the /27° part of ISO400/27° comes from (barely relevant in practice now).
- More importantly, it explains why those darned intermediate aperture settings and shutter speeds. The logarithmic scale simply permitted easy definition of intermediate settings.

That these intermediate settings don't translate particularly well into

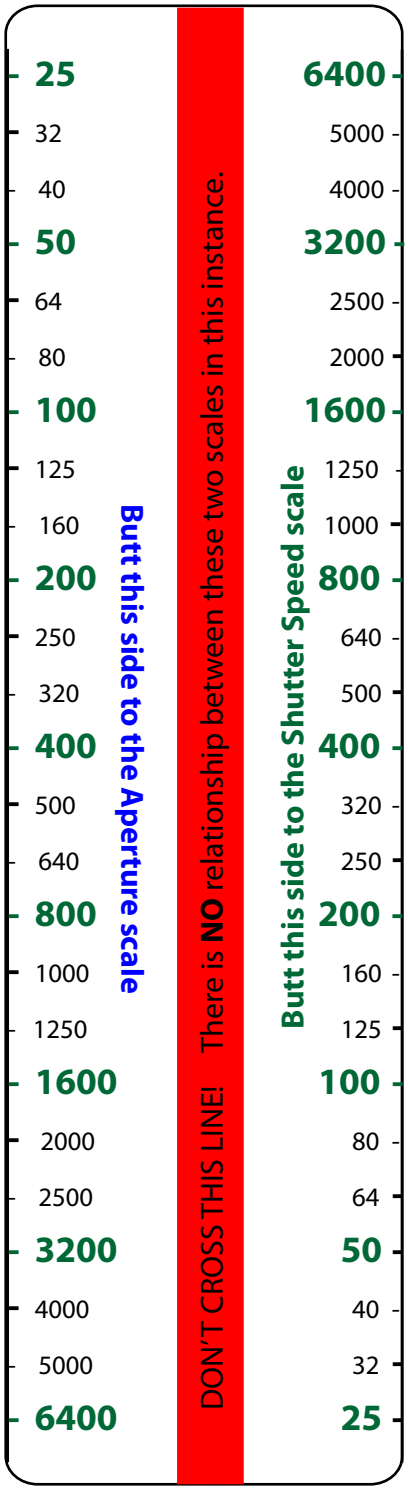
the digital age is unfortunate - they (and particularly the aperture markings) have probably caused more confusion than any other single thing.

All you really need to remember is that on any of the three scales here, the **coloured markings** are the 'normal' ones and the intermediate ones are fractional adjustments.

It's sort of like sitting in a restaurant and ordering a glass of wine. When the waiter brings the wine, do you argue over the drip hanging on the lip of the bottle? Is it yours? Is it the restaurant's? Is it important? Is it relevant?

Intermediate settings are a bit like that. They are there, they could conceivably make a difference (like when the wine costs barrow loads of money), but for most purposes you can forget them at this stage.

To put this into perspective even further, handheld digital exposure meters usually indicate the exposure to 1/10th of an f/stop. Why? Because digital readouts can easily handle 0.10000 readouts but 0.333333 (recurring ad infinitum) are extremely difficult. You could then find yourself in a quandary where the meter says f/5.6 $^{3}/_{10}$ but your lens will only allow a setting of f/5.6 $^{1}/_{3}$. The difference is absolutely minute - one drip of wine in a 175ml glass!



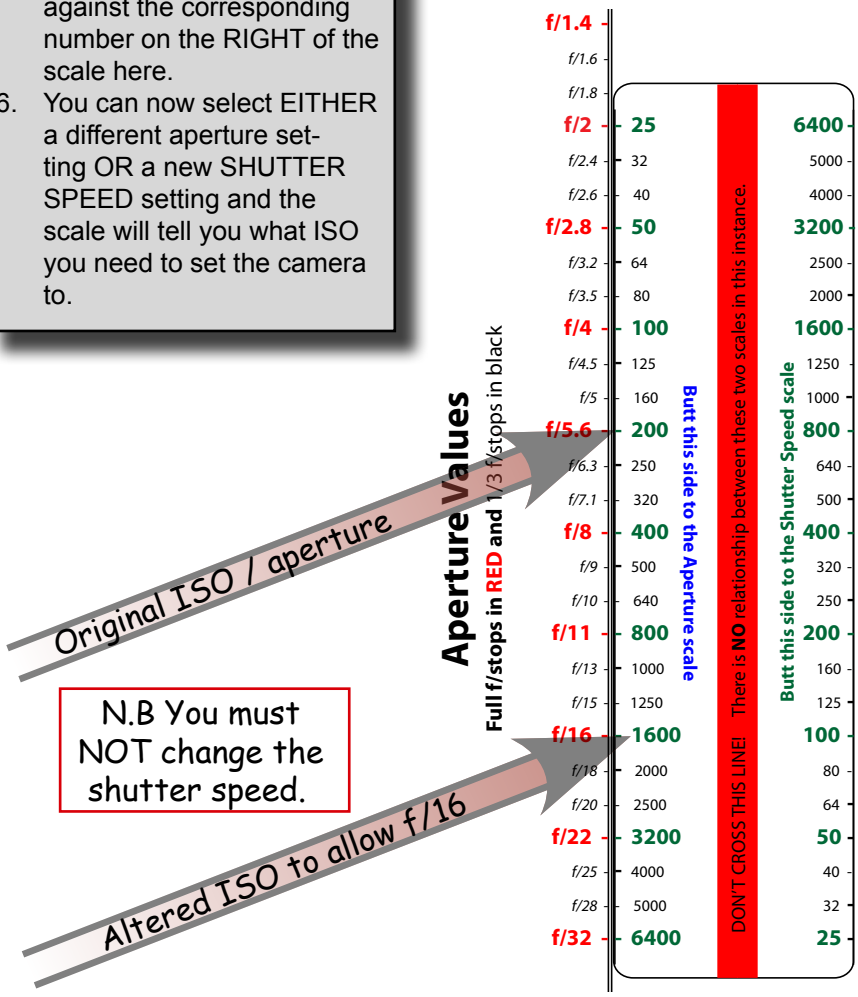
How to use this scale.

VERY carefully!

1. Cut around the black border.
2. FIRST determine the aperture / shutter speed combination using the scale made from page 4.
3. Separate the two halves of the scale made from page 4 and insert the scale here between them.
4. Align your chosen aperture setting against the mark which corresponds to the currently set ISO on your camera.
5. Align the SHUTTER SPEED part of the page 4 scale against the corresponding number on the RIGHT of the scale here.
6. You can now select EITHER a different aperture setting OR a new SHUTTER SPEED setting and the scale will tell you what ISO you need to set the camera to.

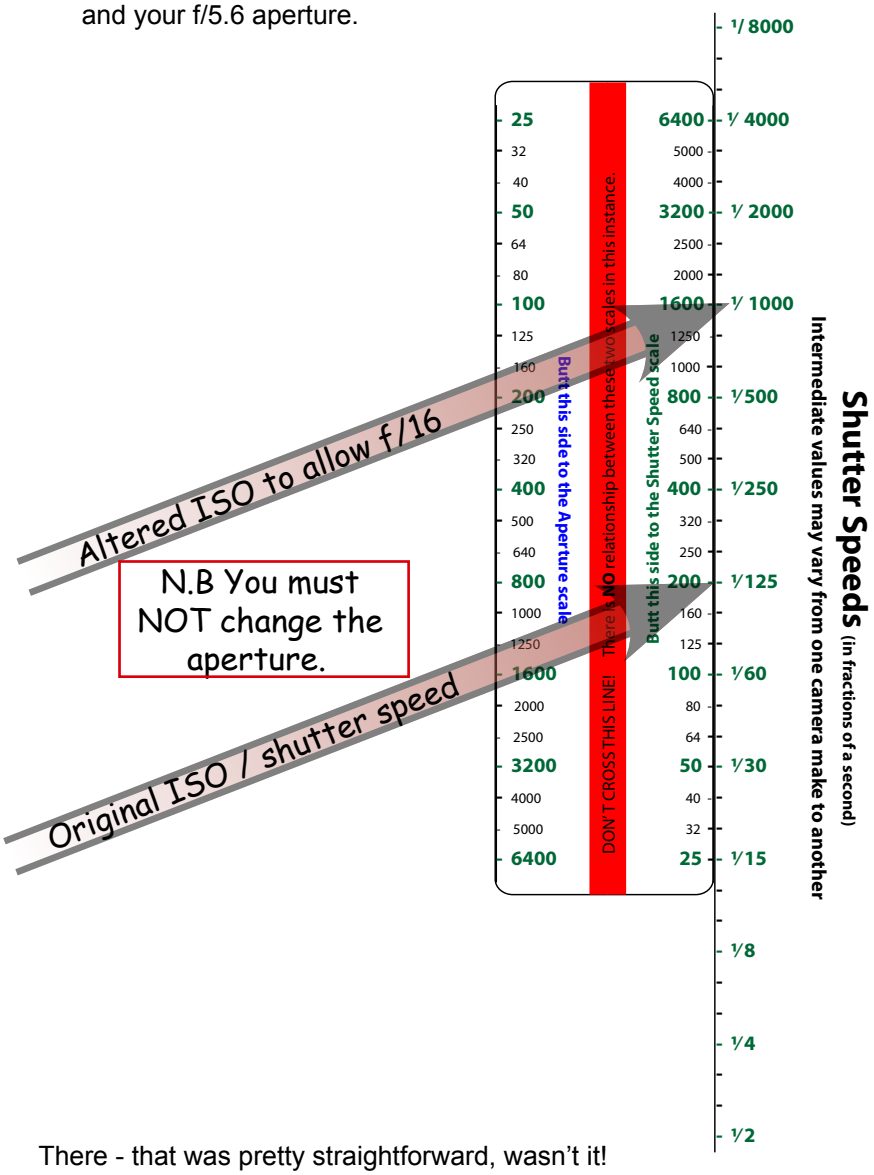
A working example

- Using your camera meter, you have determined that the correct exposure for your subject is 1/125th at f/5.6 with the sensitivity set to ISO200.
- You can't change the light level.
- You want everything in focus and need to use f/16 for the depth of field.
- You have to hand-hold the camera and dare not use less than 1/125th shutter speed.
- Take the LEFT side of page 4 panel. Align ISO200 with f/5.6.
- Look at the ISO setting against f/16 (it should be ISO1600). Setting the camera to ISO1600 and f/16 will still allow you to use 1/125th shutter speed.



Same again - but different

- Using your camera meter, you have determined that the correct exposure for your subject is 1/125th at f/5.6 with the sensitivity set to ISO200.
- You can't change the light level.
- You need to use 1/1000th of a second shutter speed because of rapid subject movement.
- f/5.6 is the maximum aperture of your lens at the focal length you need to use.
- Take the RIGHT side of page 4 panel. Align ISO200 against the 1/125th mark.
- Look at the ISO setting against 1/1000th second (it should be ISO1600).
- Setting the camera to ISO1600 will allow you to use 1/1000th second and your f/5.6 aperture.



There - that was pretty straightforward, wasn't it!

And there, as the saying goes, you have it. Everything you ever needed to know about apertures, shutter speeds and ISO settings.

You don't actually need to know every single value mentioned here, just the main ones. The others are mentioned mainly to fill in the gaps and highlight certain traits (like changing from ISO400 to ISO500) which serve no earthly purpose whatsoever.

All you need to remember is your Two Times Table! What could be more basic than that?

Philip Weston
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(Please manually change the at to the normal symbol @ - this helps me to get your email instead of the spammers' rubbish)

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For those who absolutely **must** know.....

I quietly skirted around telling you what the 'something' was of which the f/number is a fraction. Not that it's secret, just extraneous information at that point.

The f/number actually indicates the physical size of the aperture relative to the focal length of the lens in use. Hence, if your lens focal length is 50mm and the aperture setting is f/4, the actual diameter of the aperture is $^{50}/_{4}$ or 12.5mm. If the focal length changes, then so does the physical size of the hole. What does NOT change is the light passing capability at that f/number. Imagine if someone told you that a rope was "100 long". Useless information. Only when they say "100 feet long" does it have any meaning. So it is with apertures. "I set the lens to 4". Four what, clockwork mice? Once the information is related to the focal length of the lens, ie f/4, it then has some meaning. Otherwise it's just a hole!

You may see zoom lenses marked "18-50mm f/3.5-5.6". At 18mm setting, the aperture can be set to f/3.5 (ie $^{18}/_{3.5}$ or 5.14mm). At the 50mm setting, the physical diameter of the lens you hold will not permit this size hole - the biggest that will fit is $^{50}/_{5.6}$ or 8.93mm (not the $^{50}/_{3.5}$ or 14.29mm which f/3.5 would need). You want a bigger maximum aperture at 50mm? You pay loads more because it needs a bigger construction, even better control of optical quality (more difficult, the shorter the focal length gets) and more glass. That is why the 'professional' fixed aperture (eg. 24-70mm f/2.8) lenses are so much pricier. For direct comparison, one maker's 18-50mm f/3.5-5.6 lens is 62mm diameter at it's widest. The same maker's 18-50mm f/2.8 lens is 85.8mm diameter at it's widest. That's a lot of extra glass and a lot of extra correction of the 15 pieces of glass inside. Guess who pays for that!

And as if that wasn't enough .....

If you want to get really picky, you would find that the f/number isn't the whole story. Oh, no. You see, the f/number is a mathematical formula which relates the size of the hole to the focal length of the lens.

It takes absolutely no account of the light transmitting capability of the glass. If glass transmitted 100% of the light falling on it - it'd be invisible! It isn't, therefore something must make it visible. This something is a combination of reflections from the air/glass surfaces (and don't forget that it is not uncommon for zoom lenses to have 14 bits of glass, or *elements*, inside them) and a small degree of opacity in the glass itself.

If you wanted to be really, *really*, **really** picky, you would need to know the transmission capabilities of the lens unit. Basically, what percentage of the light hitting the front surface actually comes out of the back! This then modifies the f/stop or f/number to become a 't/stop'. No joking - and nothing to do with refreshment breaks either. In all honesty, you will probably never come across this - because despite what we like to think, our exposures are not sufficiently accurate for it to make a difference.

Historical inaccuracies .....

Purely for the sake of brevity, I have taken some tremendous shortcuts in the history of certain things.

Shutter speeds - always at least notionally arithmetic, there were originally quite a few different scales. These were rationalised (thankfully) to give us the logical progression we see today. There are still slight inaccuracies - $^{1}/_{8th}$ second never has and never will be exactly twice $^{1}/_{15th}$ second; likewise $^{1}/_{60th}$ and $^{1}/_{125th}$.

Apertures - let's not even go there! The mathematics were always right, just different people started at different points. The first camera I used had an f/3.5 lens, but the first two markings were f/4.5 then f/6.3. Again, rationalisation has untangled things.

Sensitivity - BS (British Standards), DIN, Scheiner were all logarithmic scales. H & D, ASA (American Standards Association), Weston (meters) were all arithmetic. APEX was ASA expressed on a Log_2 scale. EV, a combination of meter reading plus APEX speed. Thank goodness for the 'dumbing down' to ISO ratings - standardisation rules! OK?