Polarizers

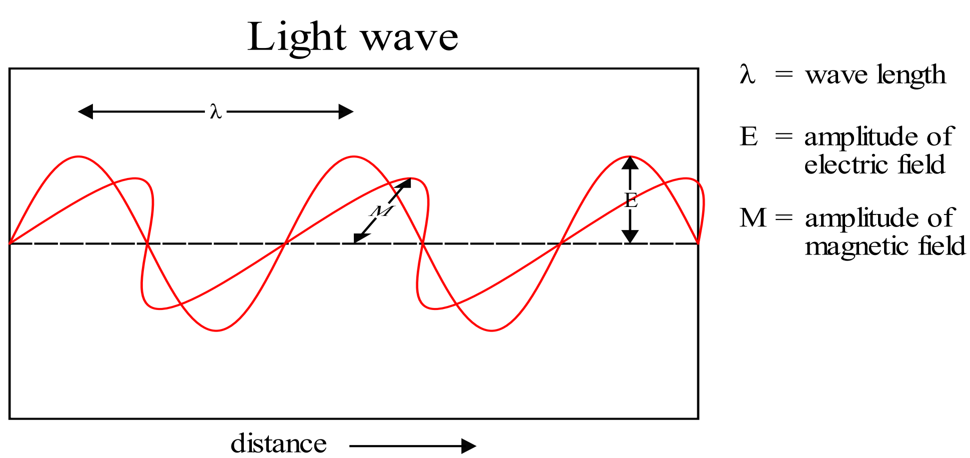
Robert Stone Ver. 3.0 March 2024

Polarizers are a mainstay of landscape photography. They darken skies, remove reflections, and increase the saturation of colors. As you rotate the filter, the effect gets stronger, then goes back to normal. This is easily seen in the camera's viewfinder or LCD screen and allows the photographer to make artistic choices easily. It's often said that the filter is polarizing and un-polarizing the light, but this is not true. Knowing the underlying science of polarizers will give you a precise understanding of what the polarizer is doing, what subjects are appropriate, and when the polarizer will be effective. To understand this filter, you need to understand a bit about light.

Light Waves*

Light is a form of electromagnetic energy and can be thought of as a wave (a light ray) or a particle (a photon). Physicists call this the "wave-particle duality". In photography and human vision, only the electric component of light is important. It directly interacts with the electrons in atoms and molecules. Most biological tissues are not sensitive to magnetic fields, so we are blind to them. (However, many migratory animals and birds have specialized iron containing organs that allow them to sense the Earth's magnetic field.)

How polarizers work is best understood using the wave theory of light. Light is a transverse wave; it vibrates perpendicular to the direction of movement. A familiar example of a transverse wave is the circular up-and-down ripples that move away from a stone dropped into a calm body of water.



What is Polarization?

A single light wave has a specific direction of vibration. But on its journey from the sun, natural light passes through all the layers of the sun's atmosphere (photosphere, chromosphere, corona, and heliosphere), then *scatters* off ions, atoms, particles, and clouds in the Earth's atmosphere. It also *reflects* off surfaces to reach your camera. Both scattering and reflection change the direction of vibration for the light ray. Thus, the world is illuminated by a bazillion individual light rays, all

* For an animation of light and polarization visit YouTube channel 3Blue1Brown: Some Light Quantum Mechanics.

vibrating in different directions. This illumination is said to be unpolarized, but ‘random’ or ‘incoherent’ would be more accurate.

After light passes through a polarizing filter, it is composed of rays that vibrate in the same direction. This is called polarized light. When you turn a polarizer, you are choosing the polarization angle of the light that will reach the camera’s sensor or film. The polarizer does not create the polarization; it simply subtracts some of the incoherent light rays. Because they subtract light, polarizers always require a corresponding adjustment to your camera’s exposure settings. In fact, all photographic filters work by subtraction, removing some component of light.

Linear Polarizers

The linear polarizer[†] contains a thin film material composed of long-chain polymers all oriented in the same direction. (For camera filters, this thin film is sandwiched between two layers of optical quality glass. Plastic is used in cheap filters and light weight sunglasses.) Light rays whose electric field vibrates in the same direction as the polymer are absorbed by the filter; light waves vibrating perpendicular to the polymer pass through.

If you stack two linear polarizers, you can change the amount of the light passing through them by rotating one of the filters. The maximum effect is obtained when the long chain molecules are at right angles (90°). This is how variable neutral density filters work! (Pay attention to the ‘gotcha’ moments of polarizers mentioned later.)

In an optics lab, the first filter is called the *polarizer*. It simply provides a stream of polarized light. The second filter is called the *analyzer*. The polarizing filter you place on your lens acts like the analyzer. If turning the analyzer lightens or darkens the incoming light as you rotate it, we know that light has somehow been ‘pre-polarized’.

The polarizer is actually a “polarization angle selection” filter.

With this hint, we now know how the polarizer works its magic: some natural light is polarized *before* it reaches your camera. When turned, the filter on your camera blocks or passes this naturally polarized light. The two causes of natural polarization are *Scattering* and *Reflection*.

Scattering

As light passes through the atmosphere, its electric field interacts with electrons in nitrogen and oxygen atoms in the air. These scatter blue wavelengths strongly, and is why the sky is blue. The scattered light is strongest at right angles to the inbound rays.

The greatest sky-darkening effect of the polarizing filter is 90° from the direction of the sun.

Just after sunrise and before sunset, the ‘Golden Hour’ light is composed of predominantly warm colors. Light coming from the sun at the horizon has traveled through far more scattering atmosphere than when the sun is overhead. Most of the blue wave lengths have been scattered away!

[†] The modern linear polarizing filter was invented by Edwin Land. Polyvinyl alcohol polymers doped with iodine are embedded in a thin film that is stretched to align the molecules. He formed the Polaroid Corporation to manufacture these filters. He later invented the Polaroid Camera, also known as the Polaroid Land Camera.

Before dawn and after dusk, the 'Blue Hour', the sun-illuminated sky overhead is still scattering lots of blue light. Blue hour skies can be darkened with a polarizer because of scattering. Polarizers can also reduce haze in distant subjects, which is scattering by particulates.

Reflection

Light reflected by most materials is polarized to some degree. Wearing polarized sunglasses when driving removes glare from wet road surfaces, and the reflection of items on top of your dashboard. For landscape photographers, the usual reflections are from water, wet surfaces and leaves.

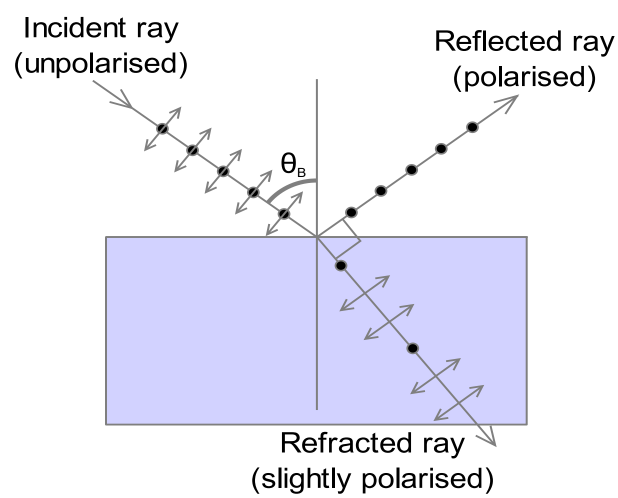
The amount of polarization in the reflected light depends on the angle at which the light wave hits the surface. For each material there is one angle at which 100% of the reflected light is horizontally polarized. All of the light reflected at that angle can be blocked by your polarization selection filter!

Brewster's Angle

The angle of reflection where the reflected light is 100% polarized is known as Brewster's Angle, formally explained by the Scottish physicist Sir David Brewster in 1815.

The vertical angle shown as θ_B is Brewster's Angle. This angle varies slightly from one material to the next, but 55° is a useful value when you start to compose and evaluate an image. Although Brewster's Angle is precise for different materials, the effect is strong for all materials between 40° and 60°.

For me, it is easier think of Brewster's Angle as the horizontal angle between the reflecting surface and the camera, or about 35° (90° - 55°).



The effect of a polarizing filter is strongest at Brewster's Angle,
but photographically significant between 40º and 60º.

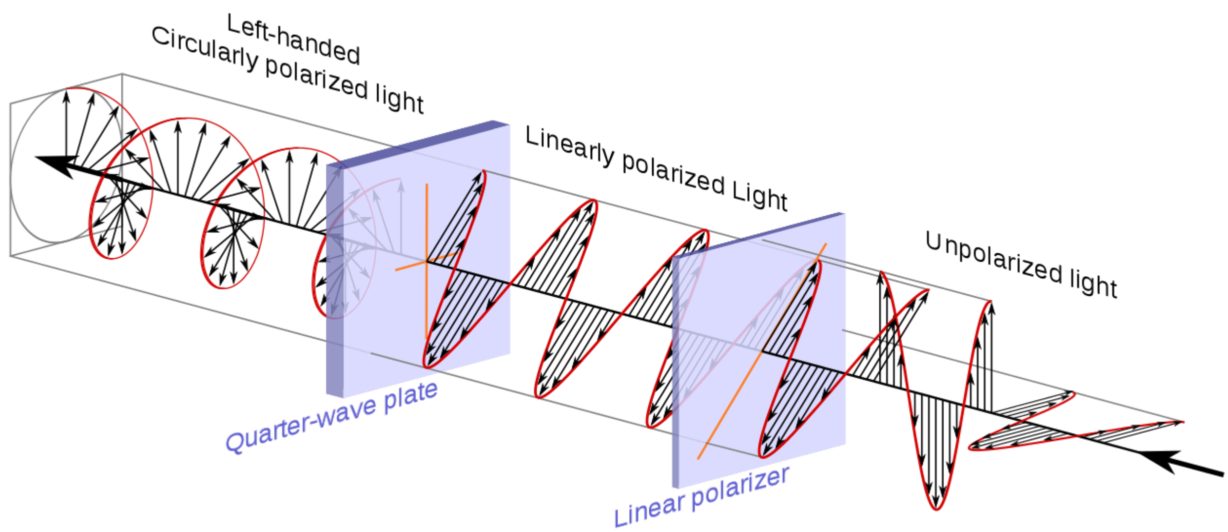
Circular Polarizers

All modern auto-focus digital cameras now require circular polarizers. Single Lens Reflex (SLR) cameras have their autofocus unit inside the camera body, and light is reflected into this unit using mirrors. If linear polarized light were to enter the system, the intensity of the reflected light in the autofocus unit might change across the image, and auto-focus could fail!

It is not clear if modern, mirrorless cameras need circular polarizers; linear polarizers may work. But there may be issues with reflection from the sensor surface coatings; some photosites are used for focus detection and distributed across the whole sensor.

How Circular Polarizers Work

With a circular polarizer (CP or CPOL), light first passes through a linear polarizer, then passes through a second filter‡ which causes the direction of the light's electric component to rotate. Since light entering the CP filter first passes through a linear polarizer, the visual effects are identical to the simple linear polarizer.



Light entering the CP filter from the right first passes through a linear polarizer, then through a quarter-wave plate. The quarter-wave plate is also a thin film material.

Most of the light that leaves the filter will not be subject to the Brewster's Angle effect when it is reflected into the autofocus unit.

You can see the variable neutral density effect with CP filters; just hold them face-to-face. The light has to pass through them sequentially.

Using a Polarizer in Practice

Many photographers like to preview the effect of a polarizing filter before mounting it to the lens. Simply look through the CP filter *from the camera side*, then turn to evaluate the strength of the effect. This is very important for reflections, which have a dominant plane of polarization. Sky effects can be seen from either side, but camera side works best.

have very I often use a setting that only partially removes reflections. The full effect may create too many empty black shadows. Find the best Brewster's Angle effect for your composition.

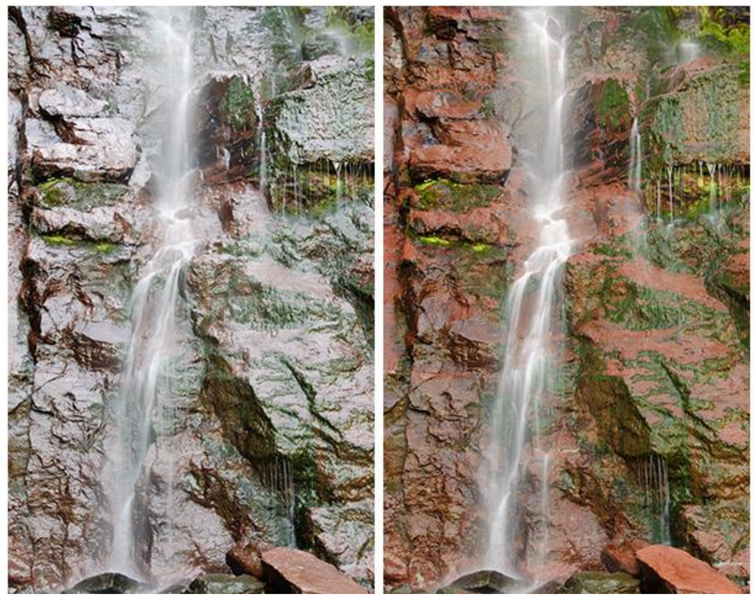
If the effect is minimal, skip the polarizer to avoid the loss of about 2 stops of light. Otherwise, mount the filter on the lens and position the camera.

Always preview the effect of your circular polarizer by viewing from the camera side!

‡ This filter is a 'quarter-wave plate'. See this Wikipedia article about wave plates.

Note that polarizers can do double-duty as neutral density filters! Even if you do not need the polarization effect you may find them useful to achieve a slower shutter speed. Some CP manufacturers are even bonding their polarizing material to 3 stop or 6 stop ND filters. This minimizes the possibility of vignetting when more than one filter is needed.

These images show how important a working knowledge of polarizers can be. This is the wet rock face of Kaaterskill Falls in upstate New York. There was no filter used to make the left image.



No filter on the left, circular polarizer on the right.

On the right, a circular polarizer was used. The image was visually evaluated while turning the filter until the maximum effect was seen. The filter is not polarizing or unpolarizing light, only blocking light reflected at Brewster's Angle.

Brewster's Angle also works on the waxy top surface of most leaves. You cannot set the angle of the polarizer for each leaf of course, but the polarizer does remove reflections from many. More of the underlying colors come through and more saturation achieved. Wet leaves are particularly well emphasized!

This effect of polarizers cannot be easily replicated in Photoshop!

Metals are a special case. Metals are good electrical conductors; they interact strongly with the electric field of the light wave. Polarizers may have little effect on light reflected from bare metals. In real life, bare metal may be clear-coated, waxed or painted and some polarization effects may be seen. Don't overlook the possible use of polarizers for reflections from metals.

'Gotcha' Moments

Rainbows - Rainbows are formed by the internal reflection and refraction of light inside raindrops. These internal reflections are close to Brewster's Angle. At one orientation, the polarizer can totally remove a rainbow. When you see a double rainbow, light in the secondary rainbow has been through two reflections inside the raindrop. Both are close to Brewster's Angle. The position of the colors in the rainbow will be reversed, but the polarization problem still exists! This is generally not the effect you want, so double check before photographing rainbows. You may choose to *not* use a polarizer!

Sky - Panoramas with a broad swath of sky will show dramatic differences in the saturation of the color blue across the sky when a polarizer is used. The sky will be very dark at 90° from the sun, and almost colorless near or opposite the sun. This is generally to be avoided as it looks seriously unnatural. I have used polarizers effectively when there is just a small patch of blue sky showing.

But now you can 'Select Sky' and evenly darken blue skies in Lightroom, Photoshop or Adobe Camera Raw. (You can also easily replace a sky, but this raises ethical issues for me.)

I watched a YouTube video recently where the photographer explained that he was going to use a polarizer for woodland images because the sun was at a 90° angle from the direction of the subject. But some leaves in a woodland image will always be reflecting at Brewster's Angle no matter the position of the sun. The 90° rule is for sky only!

Water - For water features and wet rocks, rotating the polarizer will give the visual effect of removing reflections from flat surfaces, or moving reflections on curved surfaces. Use a rotation that reveals patterns and textures that you want in the final image. Partial effects may be perfect!

This wide-angle image was made at Jordan Pond looking toward The Bubbles at Acadia National Park. The camera is pointed downward, so the surface of the foreground water is near Brewster's Angle of 55° from vertical. The reflections from the surface of the water in the foreground have been eliminated by the polarizer. Hidden textures of the bottom of the pond are revealed. The Brewster's Angle effect slowly diminishes as the angle of view changes toward the horizon; rotating the CP filter will not have any effect on the water out there.

This tidepool image was made at Hunters Beach, Acadia National Park. As the polarizer was rotated, the reflection of the sky appeared to move from the top surfaces of the small stones to their edges. The rotation was chosen visually to maximize the colors and textures at the top of the most colorful stones.

Conclusion

That was a lot of technical information! Here's the take-home information.

- ✓ The polarizer on your lens does not polarize or un-polarize the light; it only passes or blocks naturally polarized light.
- ✓ Polarization in nature is caused by scattering (the sky) or reflection (water, wet surfaces, leaves).
- ✓ Scattering in the sky is strongest at 90° from the sun.
- ✓ Reflected light can be totally blocked at Brewster's Angle but the effect is strong between 40° and 60°.
- ✓ Both reflected and scattered light can be selectively blocked by turning your polarizer.

When making images, take the time to previsualize these effects before threading the filter on your lens. Simply look through it from the camera side. Do this at all the locations where you might position your camera. Rotate as necessary to see the difference between fully passed and fully blocked light. In between values might offer a finer balance of light and dark tones.

Now you know how a polarizer works! You will recognize situations where using the polarizer will be effective, and how to evaluate its effects on tonality.

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Another physics tip … using a faster shutter speed in astrophotography does not freeze the motion of the stars. It freezes the rotation of the Earth. 😉

Polarizers beyond photography

If you place two circular polarizers face-to-face, then rotate one of them, you will produce the same effect as the variable neutral density filter! Unfortunately, they cannot be threaded together. But in a pinch, you might be able to handhold a large CP backwards in front of one on a tripod mounted camera / lens.

Most sunglasses use linear polarizing filters. The glasses you get at 3D movies are circularly polarized; the lenses are polarized in opposite directions, so each eye sees a slightly different image which your brain then interprets as depth.

If you wear sunglasses while making images, be sure to test for interference with the display on your smart phone or camera. Be sure to check both the LCD and electronic viewfinder! Note that many digital displays use polarization to control pixel brightness. My polarized driving sunglasses block the GPS display on my car. Geesh!

It is also interesting to look at the various digital displays you might have at home with both sunglasses and your camera's CP filters. Computer displays, cell phones and televisions make good subjects. Have fun with the science!