

### Level 3 –Eclipses (lunar and Solar)

#### Lunar Eclipses:

Lunar eclipses occur when Earth's shadow blocks the sun's light, which otherwise reflects off the moon. There are three types — total, partial and penumbral — with the most dramatic being a total lunar eclipse, in which Earth's shadow completely covers the moon.

Throughout history, eclipses have inspired awe and even fear, especially when total lunar eclipses turned the moon blood-red, an effect that terrified people who had no understanding of what causes an eclipse and therefore blamed the events on this god or that. Below, you'll find the science and history of lunar eclipses.

#### What is a lunar eclipse?

A lunar eclipse can occur only at full moon. A total lunar eclipse can happen only when the sun, Earth and moon are perfectly lined up, anything less than perfection creates a partial lunar eclipse or no eclipse at all. Some understanding of simple celestial mechanics explains how lunar eclipses work.

Because the moon's orbit around Earth lies in a slightly different plane than Earth's orbit around the sun, perfect alignment for an eclipse doesn't occur at every full moon. A total lunar eclipse develops over time, typically a couple hours for the whole event. Here's how it works: Earth casts two shadows that fall on the moon during a lunar eclipse: The umbra is a full, dark shadow. The penumbra is a partial outer shadow. The moon passes through these shadows in stages. The initial and final stages — when the moon is in the penumbral shadow — are not so noticeable, so the best part of an eclipse is during the middle of the event, when the moon is in the umbral shadow.

#### Types of lunar eclipses

**Total lunar eclipse:** Earth's full (umbral) shadow falls on the moon. The moon won't completely disappear, but it will be cast in an eerie darkness that makes it easy to miss if you were not looking for the eclipse. Some sunlight passing through Earth's atmosphere is scattered and refracted, or bent, and refocused on the moon, giving it a dim glow even during totality. If you were standing on the moon, looking back at the sun, you'd see the black disk of Earth

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blocking the entire sun, but you'd also see a ring of reflected light glowing around the edges of Earth — that's the light that falls on the moon during a total lunar eclipse.

**Partial lunar eclipse:** Even a total lunar eclipse goes through a partial phase on either side of totality. During the partial phase, the sun, Earth and moon are not quite perfectly aligned, and Earth's shadow appears to take a bite out of the moon.

**Penumbral lunar eclipse:** This is the least interesting type of eclipse, because the moon is in Earth's faint outer (penumbral) shadow. Unless you're a seasoned skywatcher, you likely won't notice the effect.

### The blood-red moon

The moon may turn red or coppery colored during the total portion of an eclipse. The red moon is possible because while the moon is in total shadow, some light from the sun passes through Earth's atmosphere and is bent toward the moon. While other colors in the spectrum are blocked and scattered by Earth's atmosphere, red light tends to make it through easier. The effect is to cast all the planet's sunrises and sunsets on the moon.



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"The exact color that the moon appears depends on the amount of dust and clouds in the atmosphere," according to NASA scientists. "If there are extra particles in the atmosphere, from say a recent volcanic eruption, the moon will appear a darker shade of red."

### How to watch a lunar eclipse

Lunar eclipses are among the easiest skywatching events to observe. Simply go out, look up, and enjoy. You don't need a telescope or any other special equipment. However, binoculars or a small telescope will bring out details in the lunar surface — moonwatching is as interesting during an eclipse as anytime. If the eclipse occurs during winter, bundle up if you plan to be out for the duration — an eclipse can take a couple hours to unfold. Bring warm drinks and blankets or chairs for comfort.

### Solar Eclipses:

A solar eclipse occurs when the moon gets between Earth and the sun, and the moon casts a shadow over Earth. A solar eclipse can only take place at the phase of new moon, when the moon passes directly between the sun and Earth and its shadows fall upon Earth's surface. But whether the alignment produces a total solar eclipse, a partial solar eclipse or an annular solar eclipse depends on several factors.

**Be careful:** Watching a solar eclipse requires some safety measures. You should never look directly at the sun itself.

### Types of Solar Eclipses:

There are four types of solar eclipses: total, annular, partial and hybrid. Here's what causes each type:

#### Total solar eclipses

The sun's 864,000-mile diameter is fully 400 times greater than that of our moon, which measures just 2,160 miles. But the moon also happens to be about 400 times closer to the sun than the Earth (the ratio varies as both orbits are elliptical), and as a result, when the orbital planes intersect and the distances align favorably, the new moon can appear to completely blot out the disk of the sun.

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There are actually two types of shadows: the umbra is that part of the shadow where all sunlight is completely blocked out and takes the shape of a dark, slender cone. It is surrounded by the penumbra, a lighter, funnel-shaped shadow from which sunlight is partially obscured.

During a total solar eclipse, the moon casts its umbra upon Earth's surface; that shadow can sweep a third of the way around the Earth in just a few hours. Those who are fortunate enough to be positioned in the direct path of the umbra will see the sun's disk diminish into a crescent as the moon's dark shadow rushes toward them across the landscape.

During the brief period of totality, when the sun is completely covered, the corona – the tenuous outer atmosphere of the sun – is revealed. Totality may last longer than 7 minutes, though most total eclipses are usually much shorter. On the average a total eclipse occurs somewhere on Earth about every 18 months.

### **Partial solar eclipses**

A partial solar eclipse occurs when only the penumbra (the partial shadow) passes you by. In these cases, a part of the sun always remains in view during the eclipse. How much of the sun remains in view depends on the specific circumstances.

The closer you are to the path of totality, the greater the solar obstruction. If, for instance, you're positioned just outside of the path of the total eclipse, you'll see the sun wane to a narrow crescent, then thicken up again as the shadow passes you by.

### **Annular solar eclipses**

An annular solar eclipse is similar to total eclipses in that the moon appears to pass centrally across the sun, but it's too small to cover the disk of the sun completely. Because the moon circles the Earth in an elliptical orbit its distance from Earth can vary from 221,457 miles to 252,712 miles. But the dark shadow cone of the moon's umbra can extend out for no longer than 235,700 miles; that's less than the moon's average distance from Earth.

So if the moon is at some greater distance, the tip of the umbra does not reach Earth. During such an eclipse and anyone situated within the path can look to see an annulus, or "ring of fire" around the Moon.

A good analogy is putting a penny atop a nickel, the penny being the moon, the nickel being the sun. An annular eclipse, though a rare and amazing sight, is far different from a total one. The sky will darken . . . somewhat; a sort of weird "counterfeit twilight" since so much of the Sun

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still shows. It is really more of a day, not a night sky; the eclipse is a subspecies of a partial, not total. The maximum duration for an annular eclipse is 12 minutes 30 seconds.

### Hybrid solar eclipses

These are also called annular-total (“A-T”) eclipses. This special type of eclipse occurs when the moon’s distance is near its limit for the umbra to reach Earth. In most cases, an A-T eclipse starts as an annular eclipse because the tip of the umbra falls just short of making contact with the Earth; then it becomes total, because the roundness of the Earth reaches up and intercepts the shadow tip near the middle of the path, then finally it returns to annular toward the end of the path.

Because the moon appears to pass directly in front of the sun, total, annular and hybrid eclipses are also called “central” eclipses to distinguish them from eclipses that are merely partial.

Of all solar eclipses, about 28 percent are total; 35 percent are partial; 32 percent annular; and just 5 percent are hybrids.

### Solar eclipse safety:

It is normally the custom prior to an impending solar eclipse that the mainstream media will provide a variety of warnings and advisories against looking at the Sun with bare eyes, as blindness could ensue. This has given most people the idea that eclipses are dangerous.

Not so!

It’s the Sun that is dangerous. All the time! The sun constantly emits invisible infrared rays that can damage your eyes. Ordinarily, we have no reason to gaze at the sun. An eclipse gives us a reason, but we shouldn’t.

There are safe ways to view an eclipse.

By far, the safest way to view a solar eclipse is to construct a “pinhole camera.” A pinhole or small opening is used to form an image of the Sun on a screen placed about three feet behind the opening. Binoculars or a small telescope mounted on a tripod can also be used to project a magnified image of the Sun onto a white card. The farther away the card, the larger you can focus the image. Look for sunspots. Notice that the Sun appears somewhat darker around its limb. This method of solar viewing is safe so long as you remember not to look through the

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binoculars or telescope when they are pointed toward the Sun; put another way, never look directly at the Sun when any part of its blindingly bright surface is visible.

A variation on the pinhole theme is the “pinhole mirror.” Cover a pocket-mirror with a piece of paper that has a ¼-inch hole punched in it. Open a Sun-facing window and place the covered mirror on the sunlit sill so it reflects a disk of light onto the far wall inside. The disk of light is an image of the Sun’s face. The farther away from the wall is the better; the image will be only one inch across for every 9 feet from the mirror. Modeling clay works well to hold the mirror in place. Experiment with different-sized holes in the paper. Again, a large hole makes the image bright, but fuzzy, and a small one makes it dim but sharp. Darken the room as much as possible. Be sure to try this out beforehand to make sure the mirror’s optical quality is good enough to project a clean, round image. Of course, don’t let anyone look at the Sun in the mirror.

**Never use sunglasses to look at an eclipse!** Sunglasses have very low visible-light transmittance levels, they transmit an unacceptably high level of near-infrared radiation that can cause a thermal retinal burn. The fact that the Sun appears dim, or that you feel no discomfort when looking at the Sun through the sunglasses, is no guarantee that your eyes are safe.

You can safely look directly at the sun when its disk is entirely covered. During those few precious seconds or minutes, the magnificent corona shines forth in all its glory surrounding the darkened sun; a marvelous fringe of pearly white light. It differs in size, in tints and patterns from eclipse to eclipse. It is always faint and delicate, with a sheen like a pale aurora. It has a variable appearance. Sometimes it has a soft continuous look; at other times, long rays of it shoot out in three or four directions. It may stand out from the disk in filmy petals and streamers. But when the sun begins to again emerge into view, the corona quickly disappears and you’ll need to protect your eyes once again.