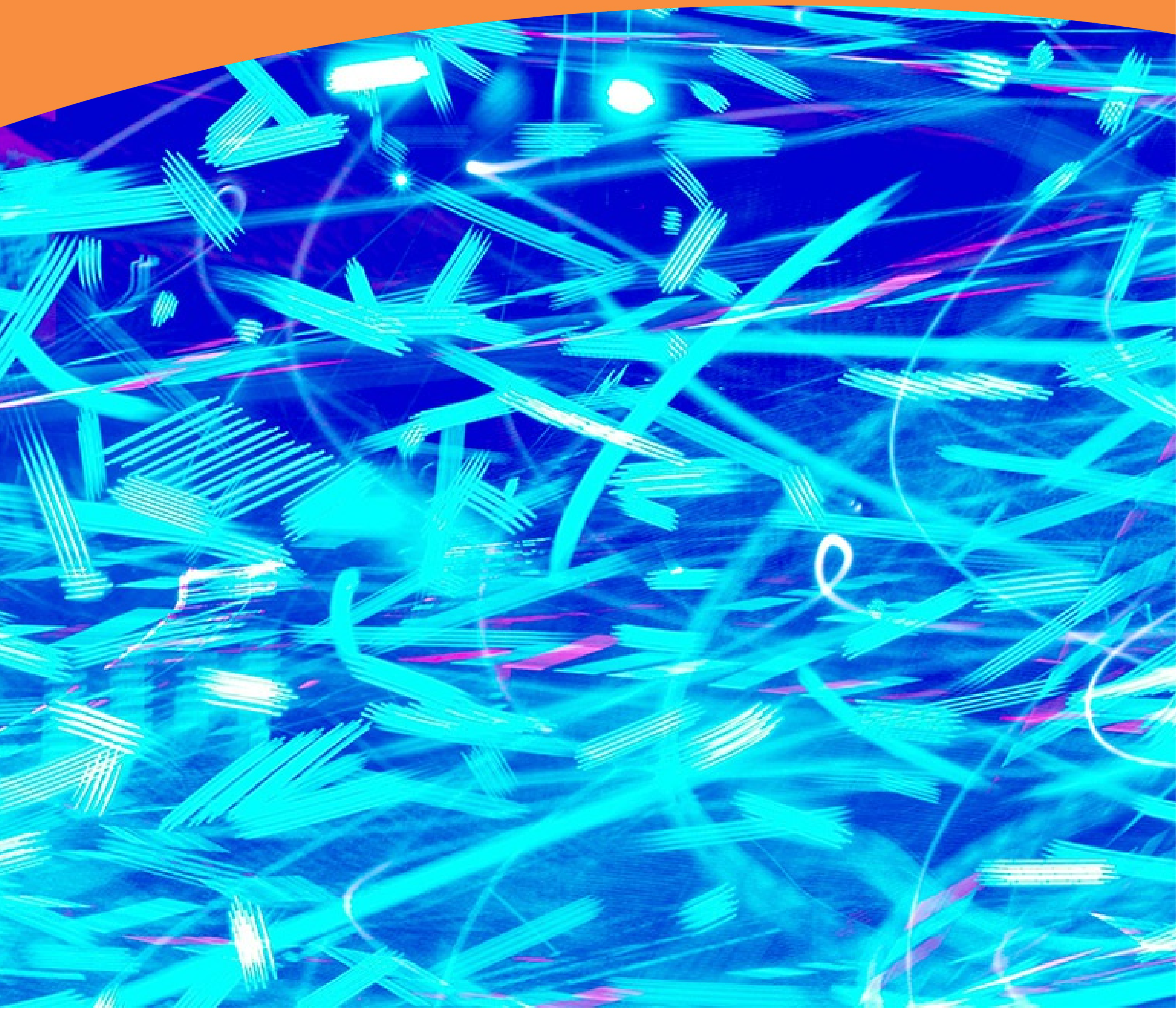
Ultraviolet light and its uses

David Cycleback



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ULTRAVIOLET LIGHT AND ITS USES

Ultraviolet light and its uses
1st edition

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ABOUT THE AUTHOR

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1 INTRODUCTION

1.1 INTRODUCTION TO BOOK

This book is an introduction and beginner's guide to ultraviolet light (UV) and its many and varied practical uses. This guide covers the elemental basics of ultraviolet and fluorescence, shows many practical and interesting uses of ultraviolet light that you can do, and gives a survey of its uses in more advanced areas including medicine, science and industry. It includes links to further online readings, image galleries and videos, along with quizzes and short assignments that can be done as part of self study or a class. I consider a good introductory text to be a springboard to further study, and the final assignment has the student reporting on an area not covered in this book or reporting in more detail on an area that is covered.

Ultraviolet is a range of light invisible to human eyes. While it cannot be seen, UV is useful to humans in a wide range of areas. Astronomers study UV to understand stars and planets. Medical doctors use UV light to identify and treat ailments. Geologists use UV to identify gems and minerals. Collectors and museum specialists use UV to identify fake and altered art and artifacts. Forensic scientists use UV in criminal investigations. Civil engineers use UV to purify water and air. Artists use UV to make glow in the dark art. The list goes on and on.

As you will see, one of the keys to ultraviolet light is that it makes some materials fluoresce, or glow in the dark. This fluorescence ranges in color and brightness, and helps people identify and study materials. This fluorescence is also what allows people to make glow in the dark arts and exhibits.

While this is an introductory guide and blacklights are commonly used in many areas, I was surprised to discover that many advanced scientists and research professors know little about ultraviolet and its common applications. I thus half-jokingly call this a book for beginner to research professor.

While a primer hardly intends to *cover it all*, even the total beginner reading this book can learn how to do things such as identify modern reprints of paper antiques, make glow in the dark art, authenticate currency and licenses, double check the identity of gems and minerals, and make invisible security markers for valuable heirlooms.

1.2 SAFETY PRECAUTIONS

The safety precautions needed for using UV light are given in detail throughout the book, but it is prudent to start with a quick introduction. If used properly and prudently, UV light is safe.

This book discusses using both blacklight (longwave, UVA) and shortwave (UVC, germicidal) lights.

Blacklight is relatively safe, and in fact sunlight and artificial lights give off some UVA. The key is to not stare directly at the light, just as you should not stare at any light source.

UVC is more dangerous. You should not look directly at the UVC light source, should wear protective clothing or UVC protecting sunblock and glasses or goggles for extended use, preferably glasses or goggles that also protect the sides of the eyes.

Many users of this book will use only the safe blacklight, and it has the most practical uses. But, as said, if proper care is taken, both kinds of UV light are safe to use.

Figure 1: UV protecting glasses with side protection

1.3 ACKNOWLEDGMENTS

I am thankful for the input and assistance from Professor Paul Mac Berthouex (University of Wisconsin-Madison Civil and Environmental Engineering Department), Dr. Catarina Amorim (Linacre College, Oxford University), Sandra C. Rudd, April R. Meyers (MA. mathematics education) and Professor Dale F. Rudd (University of Wisconsin-Madison Chemical and Biological Engineering Department).

2 WHAT IS ULTRAVIOLET LIGHT?

This chapter gives the background to the nature and categories of ultraviolet and other light.

2.1 INTRODUCTION TO THE NATURE OF ULTRAVIOLET LIGHT AND LIGHT

Ultraviolet, or UV, is a form of light, or electromagnetic radiation, that is invisible to humans. Ultraviolet makes up a small section on the entire electromagnetic radiation spectrum, most that is invisible to humans. As shown below, the entire electromagnetic radiation spectrum also includes infrared light, x-rays, gamma rays, radio waves and the visible light we see.

All the types of electromagnetic radiation are made up of the elementary particles called photons, which are 'energy packets' that have no resting mass and move at the speed of light in a vacuum. Photons are described by quantum mechanics theory and uniquely exhibit the qualities of both particles and waves. In some ways they act like super fast moving subatomic particles, and in some ways they act like waves. They can 'shoot like bullets,' yet also spread out like ripples in a swimming pool. All the rays in the spectrum can be bent, reflected and refracted like visible light.

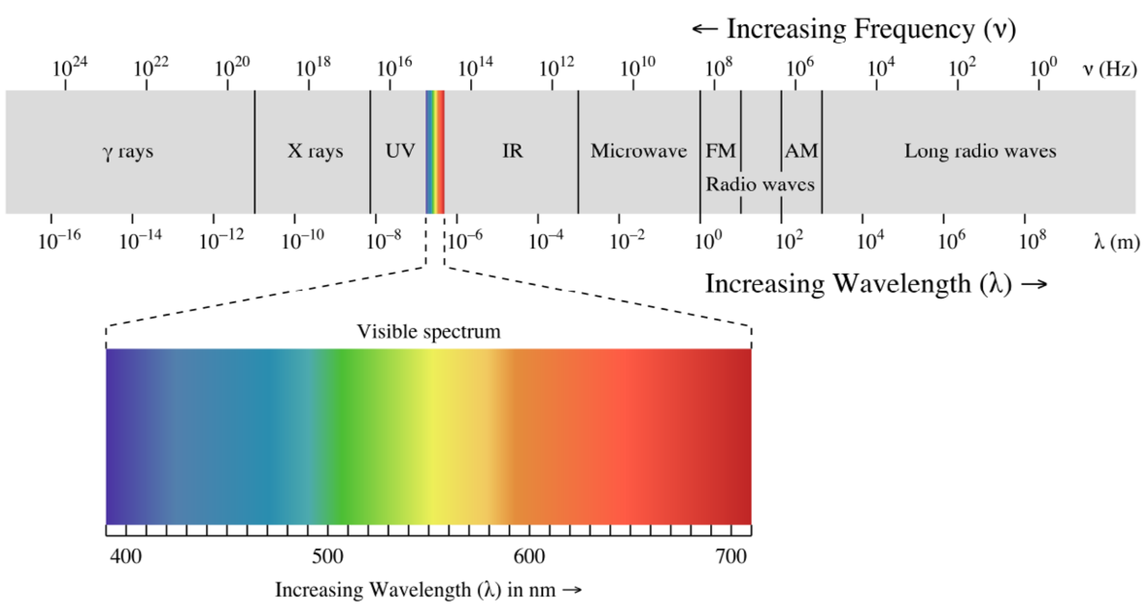


Figure 2: Electromagnetic radiation spectrum (courtesy of Wikipedia.org)

Light and electromagnetic radiation are commonly categorized by the wave quality and measured in wavelengths, and that is how the electromagnetic spectrum above is categorized.

The wavelengths continually increase from left to right on the electromagnetic spectrum. The shortest gamma rays, on the furthest left on the spectrum, have wavelengths shorter than the width of a hydrogen atom, while the longest radio waves, on the farthest right of the spectrum, are longer than the width of the earth.

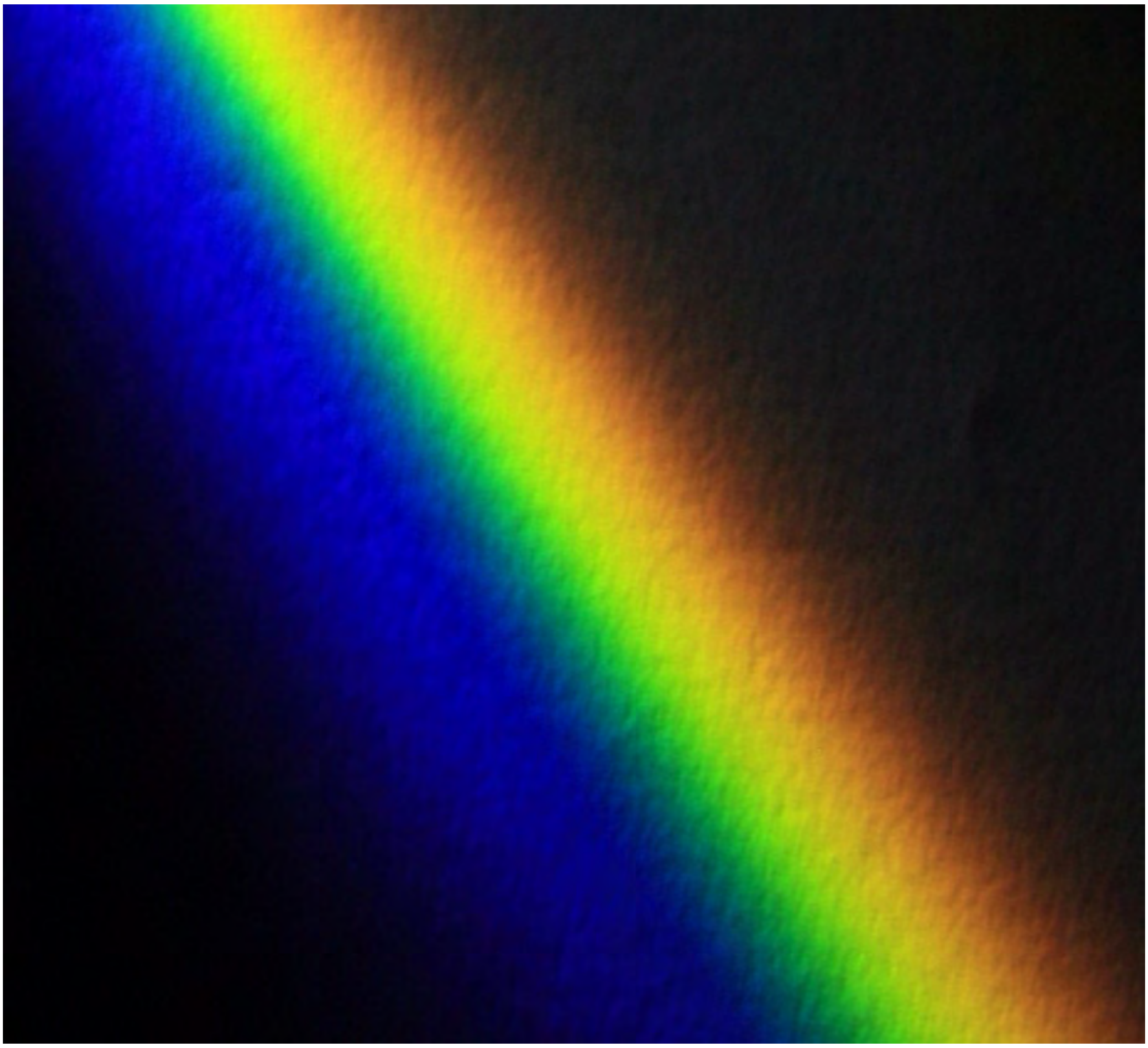


Figure 3: The visible light section of the spectrum as spread out through a prism. From left to right are violet, blue, green, yellow, orange and red. The invisible ultraviolet light is just to the left of violet, and the invisible infrared is just to the right of the red.

The wave frequency increases the opposite of the wavelengths. The shorter the wavelength, the higher the frequency. Gamma rays have short wavelengths and high frequency, while radio waves have long wavelengths and low frequencies.

The energy of the radiation in the spectrum decreases left to right, with gamma rays having the highest energy and radio waves having the lowest.

Ultraviolet, which is in between x-rays and the color violet on the visible light spectrum, can be referred to by many names, including *ultraviolet light, ultraviolet radiation, ultraviolet electromagnetic radiation, ultraviolet rays* or *simply ultraviolet* or *UV*. I mostly use the term ultraviolet light in this text and book title simply because this book is an introduction and 'radiation' tends to scare people new to the area. However, realize that the visual light and colors we see are also radiation. Though the word often has has general public associations with sci fi monster movies and atomic bomb fallout, radiation can be as harmless as, well, the colors blue and yellow.

Ultraviolet literally translates to 'beyond violet,' with ultra being Latin for 'beyond' or 'past.' Infrared, just on the other side of the visible light, translates to 'beyond red,' or 'beyond the the other side of visible light,' with infra meaning the same as ultra.

2.2 THE DIFFERENT CATEGORIES OF ULTRAVIOLET, INCLUDING BLACKLIGHT

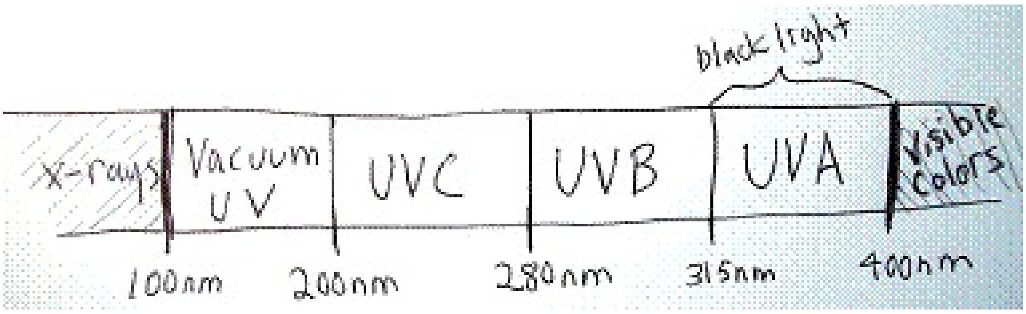


Figure 4: Categories of ultraviolet

Ultraviolet light itself is commonly divided into subcategories, also usually defined by the wavelengths. Length of the wave, or wavelength, is measured from crest to crest, though you can also measure it bottom to bottom.

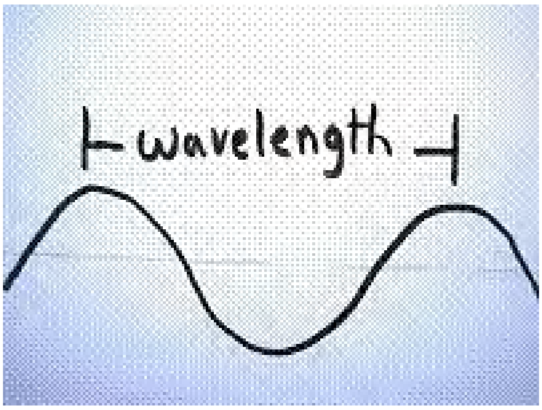


Figure 5: Measuring wavelength

The most common ultraviolet categories you will see are called UVA (also known as longwave UV and blacklight), UVB (a.k.a. mid-wave UV) and UVC (a.k.a. shortwave UV and germicidal light).

Common names:

UVA = longwave UV = blacklight
UVB = midwave UV
UVC = shortwave UV = germicidal light

Ultraviolet wavelength is commonly measured in nanometers, abbreviated as nm. A nanometer is one billionth of a meter, or one millionth of a millimeter. A human hair is roughly 30,000 nm thick.

One will occasionally find light represented in Angstroms (A), which is one tenth (1/10th) of a nanometer. An easy conversion.

1 nanometer (nm) = 10 Angstroms

1 Angstrom = 0.1 nanometer

The following are the wavelengths in nanometers (nm) for UVA, UVB and UVC:

UVA (longwave, blacklight) = 320 to 390s nm

UVB (mid-wave)= 280–315 nm

UVC (shortwave, germicidal) = 200–280 nm

Most blacklights, including the one you use for this book, are in the 380s–390s nm range. This is just a tad longer in wavelength than visible violet light.

Most UVC germicidal lamps are 254nm.

Other names and ranges of UV light:

** Near UV: 400 nm – 300 nm (This includes blacklight, and blacklight is sometimes called Near UV)
** Far UV: 200 nm – 122 nm
** Vacuum UV: 200 nm – 10 (Vacuum UV light is absorbed by air and must be used in a vacuum.)
** Extreme UV: 121 nm – 10 nm

3 YOUR FIRST TOOL FOR THIS GUIDE: A BLACKLIGHT

This chapter introduces the longwave ultraviolet light tool, commonly called a black light.

3.1 THE BLACKLIGHT

Blacklight = UVA = longwave UV = 320–390s nm

Along with other ranges of ultraviolet and their uses, this book shows you how to use a blacklight, also known as a longwave UV or UVA light. This chapter tells you how to buy the correct kind of blacklight.

As discussed previously, there are different kinds of ultraviolet light. The most common kinds are UVA, UVB/midwave and UVC/shortwave. The type of ultraviolet light you want to purchase here is the UVA, or longwave ultraviolet light. These are commonly advertised as and called "blacklights." For this section, do not buy shortwave or UVC. UVC lights are commonly marketed for germicidal purposes. UVC light and its specialty uses are discussed later in this book.

You will be happy to know that the UVA/blacklight is the most inexpensive and easiest to find ultraviolet light on the market.

3.2 BUYING YOUR BLACKLIGHT

There are many places to buy a good blacklight. You can pick up cheap ones from amazon.com and ebay.com. Some science, hobby and rock shops sell them.

Blacklights come in many styles and powers. This includes screw in bulbs and large and small flashlights. I own a small flashlight style and a screw in bulb. Both were inexpensive and serve different purposes. The bulb screws into a standard light socket and the flashlight can carried around in my pocket.

So long as the light gives off blacklight, the style is up to you.

Figure 6: A popular blacklight style

The above flashlight is good for authenticating art, currency and such. They take batteries and can be carried around most anywhere.

Figure 7: Pocket-sized LED blacklight

The above pocket sized LED and other high powered black lights are good for rock hunting and general inspection, and are also good for examining art, collectibles and currency. It uses batteries, so you can take it anywhere. This is my personal favorite.

Figure 8: Blacklight light bulb

Screw in blacklight light bulbs such as the above are especially good for art and crafts displays such as posters, paintings and clothes. This type of light works well for inspecting art, but is not so portable as the flashlights. They look like a regular screw in visible light fluorescent light bulb except the bulb is black not white.

Be careful when purchasing screw in blacklights, because many are not ultraviolet. Make sure it specifically mentions that it is UV or makes things glow in the dark. Most UV light bulbs are fluorescent. Many incandescent 'blacklight' bulbs are not ultraviolet. The non-UV incandescent light bulbs are inexpensive, so if you pick the wrong one you won't be throwing away lots of money.

As you may want to stick to only UVA blacklight for many of the practices in this book, names for lights you want to avoid include *UVC, shortwave ultraviolet* and *germicidal.* These lights are usually much more expensive than the cheap blacklights, so the price itself can be an identifier.

3.3 QUIZ QUESTIONS

1) On the wavelength spectrum, ultraviolet is in between visible light and
   a) x-rays,
   b) infrared or
   c) radio waves?
2) Light with a wavelength of 220 nm is UVA, UVB or UVC?
3) Blacklight is the common nickname for UVA (longwave ultraviolet), UVB or UVC (shortwave ultraviolet)?
4) In nanometers (nm), what is the general range for longwave (also known as UVA and blacklight)?
5) Which type of UV is the more dangerous: UVA (longwave) or UVC (shortwave)?

4 HOW TO USE YOUR BLACKLIGHT

This chapter show how to use a blacklight to test the fluorescence of materials.

4.1 HOW TO USE YOUR BLACKLIGHT

Once it is plugged in or the batteries popped in, most blacklights are as easy to use as normal flashlights. The blacklight works in the dark, the darker the better. When using them, first allow your eyes to adjust to the dark. Then shine the blacklight around and you will find things that fluoresce. Most blacklights emit a small amount of visible light so that you know that it is on.

When you are later examining specific objects – such as a photograph, stamp or currency – it is best to examine them against something that does not fluoresce. If the background gives off light it may affect the results.

4.2 SAFETY OF BLACKLIGHT

You will be happy to know that UVA or blacklight is the safest type of the ultraviolet light. The light you will use is just shorter in wavelength than visible light. In fact, regular sunlight contains UVA light, so you are exposed to it on a daily basis.

While blacklight is not of great danger, reasonable care should still be taken. Do not stare directly at the light source, exactly as you should not stare directly at the sun or a regular light bulb. If you want to take extra precaution, there are UV blocking glasses and glasses/goggles. Regular glass eyeglasses block UVC and UVB, but, unless specially treated, not UVA.

4.3 TEST YOUR BLACKLIGHT AROUND THE LAB, OFFICE OR HOUSE

In the dark, go around your home or office and see what things fluoresce and what do not. Common around the house things that fluoresce include:

White paper
Some cloth and threads. You may find threads that fluoresce yellow, orange, blue and other bright colors.
Laundry detergent

Tennis balls
Some glass and plastics. Plastics can fluoresce a variety of bright colors.
Some things will fluoresce so brightly you can almost read by them!

Figure 9: Vaseline under blacklight

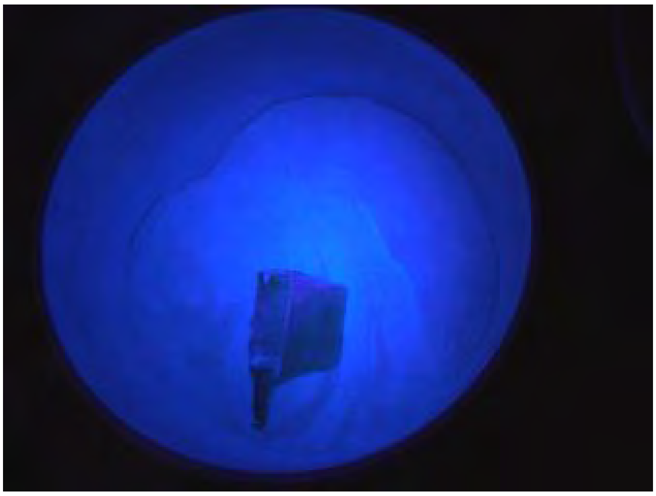


Figure 10: Laundry detergent in tub under black light

Figure 11: Bar of soap under blacklight

4.4 ASSIGNMENT

Make a list of 8 different things and their fluorescence, including brightness and color. If possible take pictures with your digital camera or phone. What things have little or no fluorescence?

5 ULTRAVIOLET LIGHT FREQUENTLY ASKED QUESTIONS

This chapter answers common questions about ultraviolet light.

5.1 WHERE DOES ULTRAVIOLET LIGHT COME FROM?

The common natural source of UV light is the sun. The sun gives off UVA, UVB and UVC light. UVC does not reach us on the earth's surface, because it is blocked by the earth's atmosphere. This is good, because UVC exposure is dangerous to humans and other animals. One concern about the depletion of the earth's ozone layer is that more UVC will be allowed to hit earth.

Distant suns and planets give off UV light, some that make it to earth's surface and much that is blocked by our atmosphere.

Humans manufacture UVA, UVB, UVC and other ranges of UV light for industrial, commercial and scientific purposes. The human-made UV products include the blacklights used in this book, suntan lamps, germicidal lamps used to sterilize, and currency counterfeit detectors.

5.2 HOW WAS UV DISCOVERED?

Ultraviolet light was discovered in 1801 by scientist Johann Wilhelm Ritter, a year after William Herschel discovered infrared light. These were ranges of light invisible to human eyes to be discovered.

Herschel, a German-British astronomer, discovered infrared while testing light for his observations of the sun. To his surprise, when he passed sunlight through a prism, spreading the white light into the rainbow of colors, the invisible area just beyond red was warm. Infrared is associated with heat. After further tests, he concluded that there was an invisible light beyond the color red.

After learning that Herschel had discovered a form of light beyond the color red, Rittner experimented to see if invisible light also existed beyond the color violet, on the opposite side of the visible light spectrum. After using a prism to spread sunlight into the rainbow of visible colors, he discovered that silver chloride turned dark in the invisible area just beyond violet. Silver chloride is used in much photography, as it turns dark under sunlight. This showed that an invisible form of light existed beyond the violet end of the spectrum.

LInks to Wikipedia biographies of RItter and Herschel:

Johann Wilhelm Ritter
William Herschel

5.3 WHY CAN'T WE SEE ULTRAVIOLET LIGHT?

Because we can't.

Whether eyes, ears or human-made machines, all devices have limits to what they can detect. The human eyes have lenses that block ultraviolet light, and this is important because over time UV can damage the eyes. In rare cases where the lens is missing or removed during eye surgery, the human can see ultraviolet light as a white-ish light. However, in the vast majority of cases, humans cannot see ultraviolet light.

There are other physical limits to human sight. We cannot make out detail that is too small or far away. We use optical aids such as binoculars and microscopes to aid our sight. We cannot see or see clearly objects that move too fast. A hand waved by our eyes looks blurred. A speeding bullet is invisible. Sight variations exist amongst humans. Some humans see colors better than others, see better at night and make out details others can't.

Though you cannot see either, you can physically detect ultraviolet and infrared light. Infrared light is warm or hot and ultraviolet light can give you a suntan.

For further reading on this topic:

An article on other physical limits of human sight:
http://www.cycleback.com/eyephysiology.htm

An article about how the colors of Claude Monet's paintings changed after eye surgery:
http://www.skepticalartist.com/2013/06/25/claude-monet-and-ultraviolet-light-did-the-master-impressionist-painter-have-UV-supervision/

5.4 ARE THERE ANIMALS THAT CAN SEE ULTRAVIOLET LIGHT?

Yes.

Being self-centered, humans define visible light as the light that humans can see. However, numerous other animals can see light that we cannot see. Snakes can detect infrared light, while geese, butterflied, goldfish, eagles and many mammals can see ultraviolet light. The goldfish can see both UV and IR.

Non-human animals have different than human vision, including in clarity and the colors. Some animals have better vision than humans, some worse and some just different. While butterflies cannot see the detail we see, their color vision is perhaps the most advanced of any animal. And many animals have other senses that are superior to ours. While a bloodhound has worse eyesight than humans, their sense of smell is many times better than ours. Scientists say that the bloodhound's sense of smell is comparatively more sophisticated and advanced than the human's eyesight. And bloodhounds are used by police departments to find lost humans that humans cannot find.

Non-human animals and ultraviolet light is an area of continuing research. There are numerous way to discover what colors they can see, including studying the optical systems of dead and sedated animals. In the case of reindeer, they sedated several of the animals, shined ultraviolet light in their eyes and saw that it made optical nerves react.

Of animals that are known to be able to see ultraviolet light, there is speculation about how and why it aids them. The following are examples of how ultraviolet vision is useful:

Reindeer are able to see UV absorbing urine of their predators and their food staple, lichen. As these substances absorb the UV, they will appear dark against the UV reflecting winter landscape.

Some flowers have patterns in ultraviolet light that are invisible in human visible light. This allows UV seeing butterflies and bees to be better able to find the flowers, including in dim light.

The sex of some butterflies is clear by the patterns on the wings in the UV spectrum, but the males and females look identical in our visible spectrum.

For further reading on this topic, click on the below links:
https://askabiologist.asu.edu/colors-animals-see
http://blog.zoo.org/2012/01/ultra-awesome-ultraviolet-eyesight-in.html

An article about how and why animals have been genetically made to fluorescence:
http://theweek.com/articles/464980/7-genetically-modified-animals-that-glow-dark

Video about reindeer and ultraviolet light
https://www.youtube.com/watch?v=kKedY2D84yc

Video on flowers and bees
https://www.youtube.com/watch?v=N1TUDFCOwjY

Many scorpions fluoresce under blacklight. The following youtube video shows this and gives a theory as to why scorpions fluoresce:
https://www.youtube.com/watch?v=1d3WPceJrRM

5.5 WHAT BLOCKS ULTRAVIOLET LIGHT?

UVC (shortwave) is blocked by many things including the atmosphere (all UVC on earth is from human made devices), glass and most cloth. UVC is dangerous, but happily easy to block.

Normal glass blocks UVB (and UVC) but not UVA. Glass and plastics have to be specially treated or coated to block UVA, and many sunglasses and glass for art frames are. The longwave UV (UVA) can penetrate light colored clothes, which is why experts say you should wear dark colored or specially made UV protectant clothes in the sun. Longwave/ UVA can penetrate writing paper, but is blocked by most cardboard, especially if it is dark on one or both sides.

5.5.1 ASSIGNMENT: TEST WHAT BLOCKS ULTRAVIOLET LIGHT

Using your blacklight (and shortwave UVC light if you have one), make a list of materials that do or do not allow the light to shine through.

To do this, first find something that fluoresces brightly under the UV light. Then put a material (cloth, paper, glass, plastic, other) between the UV light source and the item. If the object on the other side still fluoresces, the in between material lets the UV light through. If the object on the other side does not fluoresce, the in between material blocks the UV light.

If you have both a longwave and shortwave light, you will find that some materials block the shortwave but not the longwave.

This is a good practical skill to have. You will often want to know how UV protectant are glass, clothes and plastics, whether for wearing clothes or glasses in the sun or lab, or for protecting framed art or memorabilia that can fade in UV light. As glass blocks UVB and UVC but not always UVA, this test with a blacklight will tell you if that picture frame or cabinet glass will protect your art and collectibles from all three forms of UV. Many artworks, photographs and other valuables fade and discolor over time under UV exposure both from the sun and artificial lights.

5.6 HOW DOES BLACKLIGHT MAKE THINGS FLUORESCE?

I will start this answer with a look at visible light colors. With visible light colors – the colors we see during our normal lives –, the color of the object is defined by the color it reflects back, or the color most dominantly reflected back, when visible white light is shined on it. White light is all the colors shined at once. Objects can have different perceived colors under different color lights (a white ball will appear red under red light and blue under blue light), but humans define an object's color by the color under white 'natural' light. If the object completely absorbs the light it is is opaque and black and if the light passes through the object it is transparent. If an object, say a green tinted wine glass, is transparent except for the tinge of green, most of the light passes through the object except for some green light that is given back.

With ultraviolet fluorescence, we are not shining visible light, but an invisible light and observing what, if any, visible color the shined upon material gives back. The fluorescence, or visible light that is emitted from a material when ultraviolet is shined on it, happens at the atomic level. When you are shining ultraviolet on an object, you are testing its atomic makeup. And, in fact, chemists and physicists can identify the chemicals makeup by studying and measuring this fluorescence.

Just as with visible light, heat and x-rays, ultraviolet is a form of energy. When ultraviolet is shined on a material – whether the material is glass, plastic, cloth, mineral or paper – energy is being added to the atoms of the material. The atoms can only hold this extra energy for a short amount of time before having to give it off. The atoms give off the energy in a different form than received and in a longer wavelength. For fluorescent materials, the atoms receive the light energy in one wavelength, but give the energy off as visible light (a longer wavelength). What form(s) of energy the atoms gives off is dependant on the makeup of the atoms.

Some materials give off no visible light under ultraviolet light. In a darkened room this material will remain dark.

Duly note that materials can be fluorescent under other forms of light, including x-rays and visible light lasers that shine a color of shorter wavelength.

5.6.1 PHOSPHORESCENCE: AFTERGLOW

Phosphorescence is closely related to fluorescence. As with fluorescent materials, phosphorescent materials give off visible light when excited by shorter wavelength light. However, while fluorescent material quits emitting light when UV light is turned off, phosphorescent material continues to glow. The extra duration varies from phosphorescent material to phosphorescent material. Sometimes phosphorescent material gives off light for a fraction of a second longer, while other material emits light for hours or even days. The phosphorescence can be caused by UV light, but also visible light of shorter frequency visible colors and x-rays. As with fluorescence, the color, brightness and duration of the phosphorescence is caused by the atomic make up of the material.

As with fluorescent material, the added energy of UV or other light excites the atoms in phosphorescent material, raising the electrons to a higher orbital. While the electrons move back to their normal orbital right away with fluorescent material, it takes longer with phosphorescent material. Thus, the phosphorescent glow lasts longer.

Further reading on this topic:
Boundless.com quantum physics article explaining fluorescence

A video explaining the science of fluorescence:
https://www.youtube.com/watch?v=CcssdJf0pKQ

A bit off topic to the book, but a more detailed article to read if you want to read more how objects get their color in visible light:
http://www.zmescience.com/science/physics/what-gives-colour/

5.7 HOW DO THEY MAKE BLACKLIGHTS?

Just as there are different kinds of lightbulbs that give off visible light, there are many different kinds of lights that give off blacklight. Blacklights are usually simply variations on regular lights. The most common blacklights are fluorescent, incandescent and LED (light emitting diodes).

The following looks at some of the most common different kinds of visible lights and the blacklights variations.

5.7.1 VISIBLE LIGHT INCANDESCENT LIGHT

Figure 12: Visible light incandescent light bulb

The **incandescent visible light** is the traditional screw into the light socket that people have used for years and years. It is the light bulb Thomas Edison invented.

The incandescent light is comprised of a filament, a base (the metal screw in end) and the glass bulb. The filament is a thin wire inside the bulb the electricity goes through. The electricity heats up the filament to a degree that it gives off the light that we see. A bad side effect of the incandescent light bulb is it gives off a good amount of heat, as anyone who's burned her fingers while unscrewing a lightbulb can attest. This also shows that it is an inefficient user of electricity and energy, giving off useless heat.

Incandescent blacklights cover a normal visible incandescent bulb with Wood's light. Wood's light lets through blacklight while blocking most visible light. These are not quite as good at producing blacklight as the fluorescent version and, as with all incandescent lights, get hot. Wood's glass is named after it's inventor, American physicist Robert Wood (read his wikipedia biography).

5.7.2 VISIBLE LIGHT FLUORESCENT LIGHT

Figure 13: Visible light fluorescent light

Many homes and offices use fluorescent lights. They usually give off whiter than incandescent light, make a hum and do not give off heat. They are often in long or 'curlicue' tubes.

A visible light fluorescent light has a glass tube filled with mercury and argon gas. Electricity going through the bulb causes the gas to give off ultraviolet light. The ultraviolet light hits phosphors coating the inside of the bulb, causing the phosphors to give off the visible light we see.

Fluorescent blacklight. Many blacklights are fluorescent. These use a different type of phosphor to coat the inside the bulb. It also covers the tube or bulb with the dark blue or purple Wood's glass. Wood's glass blocks out all but the blacklight.

5.7.3 LIGHT EMITTING DIODES (LED)

Light Emitting Diodes (LEDs) are semiconductor chips that can be designed to emit different ranges of light, including the visible colors, infrared and blacklight. Visible light LEDs are used in many products, including stop lights, LED flashlights, car and computer lights. Many television and VCR remote controls have LED infrared lights. Some blacklights sold to hobbyists, including small flash lights, are LED.

Figure 14: Visual light LED flashlight, with the diodes seen in the front

5.8 QUIZ

1) Name an animal that can see ultraviolet light. Name an animal that can see infrared.
2) Explain a way being able to see ultraviolet light is useful to an animal. Can you think of a possible use not listed in the text? Would being able to see ultraviolet and infrared be useful to humans? If so, how?
3) Why is it good that the earth's atmosphere blocks shortwave/UVC light?
4) How does phosphorescence differ from fluorescence?

6 PRACTICAL AND INTERESTING USES FOR YOUR BLACKLIGHT

This chapter looks at some practical and interesting areas where you can use your blacklight.

6.1 INVISIBLE INK PENS AND SECRET MESSAGES AND SECURITY

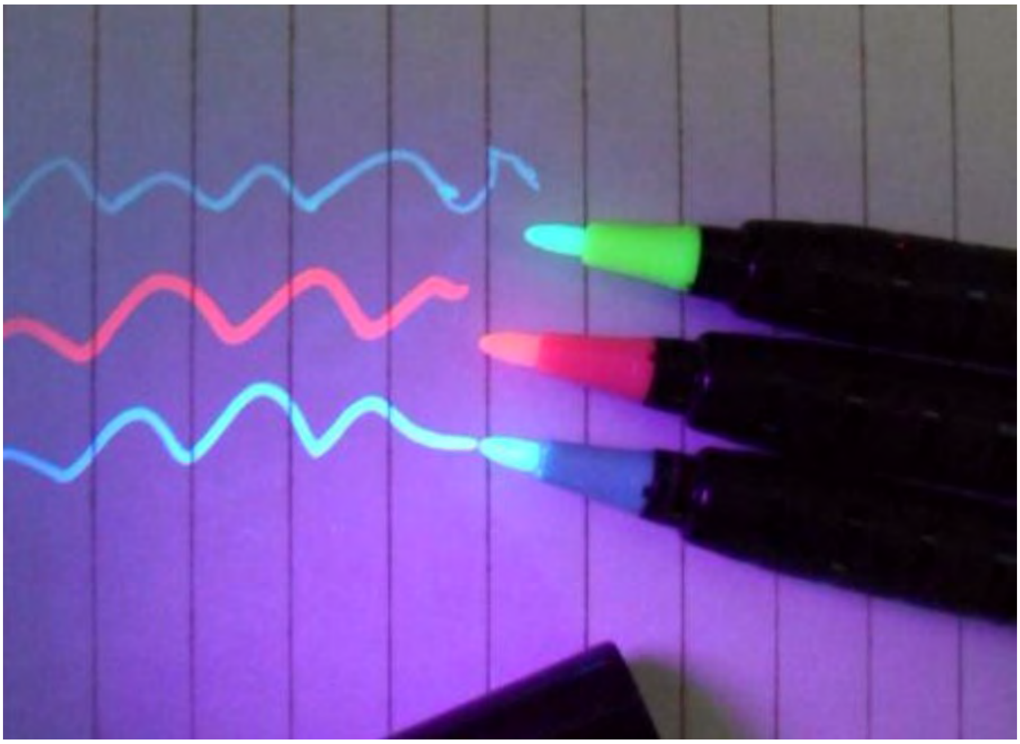


Figure 15: Invisible ink pens and writing under blacklight

A useful, fun and inexpensive tool is the invisible ink pen. Looking similar to regular felt tip pens, they write with ink that is invisible in daylight but that fluoresces brightly in the dark under UV light.

UV ink pens are widely available online, including at amazon.com and eBay. Many sellers of blacklights sell the pens. You can also buy multipacks of pens in different colors. You might be able to pick up some UV ink pens when you buy your blacklight. I have even found inexpensive invisible ink pens with little blacklights built in.

People use invisible ink pens for a wide variety of purposes, including writing secret notes in diaries and to friends, and, as described in a later chapter, making glow in the dark sketches and art.

Invisible ink is often used to secretly mark objects for later identification. This includes vases, paintings, prints and documents. A family might mark the bottom of valuable heirlooms in case of theft or ownership dispute. You might write your name or serial number on the back of a painting. This will aid in showing it was yours in case of loss, theft or identity dispute. If the marking was written in visible ink, a thief may simply scratch it off or mark over it. With invisible ink the same thief will likely have no idea the item is marked.

An online seller or brick-and mortar-store of car parts or dolls may have a problem with customers returning damaged goods not actually purchase from the seller. If the seller puts an invisible ink mark on the back of the items before sale she can be sure that the customer is returning the original item.

6.2 UV INK HAND STAMPS FOR DANCE CLUBS, BARS AND CONCERTS

You can buy UV ink and ink pads for your rubber hand stamps. These can be used for secret marking, the same as with UV ink pens. Dance clubs and concerts often stamp the hand of patrons with invisible ink. This allows the patron to leave and return, while allowing the club to catch those trying to sneak in without paying.

Figure 16: For identification purposes, Major League Baseball put a UV fluorescent stamp on the ball Barry Bonds hit for his record 73rd home run in 2001.

Link: An interesting online article on the invisible ink marking of baseballs

6.3 AUTHENTICATING DRIVER'S LICENSES, CREDIT CARDS AND SIMILAR

Most state drivers licenses have authenticating markings that are invisible except under backlight. Others cards and licences also have UV fluorescent markings. This includes credit cards and passports. Check them out yourself.

Alterations to these licenses can often be detected with a blacklight, as the added paper, glue or other material can stand out from the rest of the license and other untampered licenses. If the alterations are visually hidden by lamination, the new lamination will often hide the fluorescent markers and the lamination itself will often fluoresce differently from other, original licenses.

6.4 CHECKING THE CLEANLINESS OF KITCHENS, LABS AND BATHROOMS

Under blacklight, otherwise invisible stains on sinks, tabletops, bathroom floors and the like can fluoresce under blacklight. They often fluoresce yellow.

Blacklights are used to check the cleanliness of motel and hotel rooms, public bathrooms and restaurant kitchens.

6.5 FINDING RATS AND MICE

As rat and mice urine fluoresce under blacklight, exterminators and scientists trace the rodents with blacklight. You will often see the pest exterminator carrying a blacklight. I have seen two television comedies where a pest exterminator used a handheld blacklight: *King of the Hill* and *King of Queens*.

7 BLACKLIGHT IN EXAMINING ART, MEMORABILIA, ARTIFACTS AND COLLECTABLES: INTRODUCTION

Figure 17: Antique painting

Blacklight is an invaluable tool for collectors, dealers, auctioneers, forensic scientists and museum workers in examining art, artifacts and collectibles. It is used to identify materials and alterations, help date items, and identify fakes, forgeries and reproductions. Many collectors and dealers own a simple, inexpensive blacklight for such purposes.

The next chapters shows several areas where blacklight is of assistance in this area.

8 IDENTIFYING MODERN REPRINTS AND FORGERIES OF PAPER ART, MEMORABILIA AND ARTIFACTS

This chapter shows how blacklight is used to identify many modern fakes on antique paper items.

Figure 18: This movie poster is easily identifiable as a reprint with a blacklight.

8.1 BLACK LIGHT AND OPTICAL BRIGHTENERS

A blacklight is effective in identifying many, though not all, modern papers and cardstocks. This allows the collector, dealer, forensic scientist and museum expert to identify modern reprints and fakes of antique trading cards, posters, photographs, programs, documents and other paper memorabilia. Many people buy a blacklight specifically for this purpose. The infamous Hitler Diaries and Man Ray photograph forgeries were discovered as fakes because blacklight showed that the paper and other materials were too modern.

Starting in the late 1940s, manufacturers of many products began adding *optical brighteners* and other new chemicals to their products. Optical brighteners are invisible dyes that fluoresce brightly under ultraviolet light. They were used to make products appear brighter in normal daylight, which contains some ultraviolet light. Optical brighteners were added to laundry detergent and clothes to help drown out stains and to give the often advertised `whiter than white whites.' Optical brighteners were added to plastic toys to makes them brighter and more colorful. Paper manufacturers joined the act as well, adding optical brighteners to many, though not all of their white papers stocks starting before 1950. Optical brighteners were added to photopaper about 1955.

A blacklight can identify many trading cards, posters, photos and other paper items that contain optical brighteners. In a dark room and under blacklight optical brighteners will usually fluoresce a very bright light blue or bright white. To find out what this looks like shine a recently made white trading card, snapshot or most types of today's printing paper under a blacklight. If paper stock fluoresces very bright as just described, it almost certainly was made after the mid 1940s. It is important to note that not all modern papers will fluoresce this way as optical brighteners are not added to all modern paper. For example, many modern wirephotos have no optical brighteners. This means that if a paper does not fluoresce brightly this does not mean it is necessarily old. However, with few exceptions, if a paper object fluoresces very brightly, it is modern.

Figure 19: Valuable 1880s tobacco card is shown to in fact be a worthless modern reprint under blacklight (right).

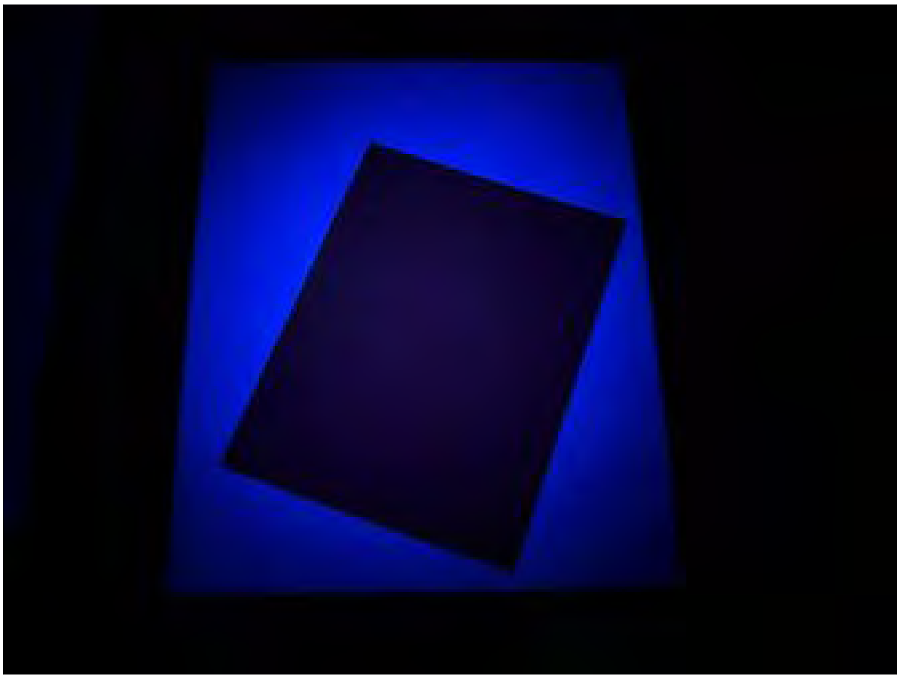


Figure 20: A piece of 1930s vintage paper on top of a larger piece of 1990s white paper.

The beauty of this blacklight test is you can use it on items where you are not an expert. You may be no expert on 1920s German Expressionist movie posters, World War I postcards or American Revolutionary War era etchings, but you can still identify many modern reprints of those items.

8.2 TIPS FOR BETTER RESULTS

A blacklight must be used in a dark room, the darker the better. Take a minute or three to let your eyes get adjusted to the dark. The paper memorabilia being examined should be on something that does not fluoresce. Something that does not fluoresce will appear black under blacklight. If your background fluoresces too brightly, it can be hard to judge the fluorescence of the memorabilia.

It is best for the memorabilia to be removed from any glass, plastic sleeve or other holder. The holder itself can fluoresce or otherwise mask the memorabilia fluorescence. Shine the blacklight on all sides of the memorabilia. Some trading cards and photographs have coatings on one side that mask the fluorescence.

For comparison purposes, you may wish to have a shard of modern computer paper that fluoresces brightly. Between the black table and bright shard, you will have a range on the spectrum for comparison.

8.3 FURTHER READING

Wikipedia article on the Hitler Diaries, including mention of how UV found the paper to be modern:
https://en.wikipedia.org/wiki/Hitler_Diaries

Article on the Man Ray forgeries including how UV was used to identify the paper as modern:
http://www.artnet.com/magazine/news/robinson/robinson12-2-97.asp

Article on fakes of famous photographer Lewis Hines:
http://www.theatlantic.com/magazine/archive/2003/06/too-much-of-a-good-thing/302751/

9 IDENTIFYING COUNTERFEIT US CURRENCY

This chapter gives visual light and blacklight methods used to help authenticate American and other currency.

9.1 OVERVIEW AND METHODS

There are numerous methods used for identifying counterfeit United States currency bills, including the use of visual light inspection, infrared and blacklight. Note that this section is only a brief and general introduction. Currency is regularly changed and updated by the US Government, and it is likely that there will be changes within a few years of the publication of this guide. Newly issued currency does not make old currency disappear. Old currency is floating around for many years. If you find a 1930 US $1 bill it is valid currency.

Counterfeits vary in quality, but the following techniques should help identify most counterfeits. The following looks at specific techniques of counterfeit detection. It is important to understand that a single correct quality authenticate a bill. For example, some counterfeiters bleach genuine $1 bills and make them into fake $20 bills. That the paper itself is genuine does mean that these fakes authentic.

Pay attention to your currency

Observe your bills before you get counterfeits. Look at the printing, the Presidential portrait, examine the details, get a feel for the paper. A common way a counterfeit bill is found suspect is that it looks and feels "off," different from other bills. The image may look funny and unclear, the color may be off, the paper may feel different.

Real bills have high quality, detailed printing. Check the details and lines in the portrait and in the background lines. The detail in reprints is often lacking and muddled.

Figure 21: Closeup details on US currency bill

Compare a suspect bill to known genuine bill of same denomination and year. Again compare the feel and general look. Compare specific, close up details, such the President's eye or the points on a seal. Compare all the designs and text. Again, remember that the design and text changed and changes over the years on genuine bills, so you want to compare bills from the same year.

Take into consideration that there can be natural differences between genuine bills. One genuine bill can be crisp and unused, while another genuine bill can be worn, wrinkled and dirty. This is why comparing to numerous bills is a good idea.

Blacklight test #1: fluorescent vertical bands.

Some recent currency above the $1 denomination has vertical bands that fluoresce under blacklight. Under normal visible light, the bands can be seen when the bill is held up to a light. The presence of these is very strong evidence of authenticity.

Fluorescence of bands:

$100 Pink/Orange
$50 Yellow
$20 Green
$10 Red
$5 Blue

Figure 22: The blacklight fluorescent band on a US $20 bill

Blacklight test #2:

Authentic currency does not have optical brighteners in the paper. Many, but not all, counterfeits are made with normal paper and will fluoresce brightly. One has to be careful with this test, because many laundry detergents contain optical brighteners. Bills can fluoresce if they were accidentally run through the wash.

Visible light watermarks. Modern higher currency bills have a visible light watermark to the side of the bill. The authentic watermark is not seen until it is held up to a light. It will be a smaller portrait of the president on the bill or the currency number, and can be seen when viewing from both sides.

Figure 23: US $5 bill held up to the light, showing '5' matermarks

Figure 24: US $20 bill with matching Andrew Jackson portrait and watermark

Fibers in the paper. Some modern currencies have thread-like fibers of different colors in the paper. Some counterfeits will look like they have the threads, but close examination under a microscope or high magnification shows the fibers real on a real currency.

Microprinting: Microprinting is very, very small text that appears in some parts of some but not all currency. It is readable under magnification and very hard to reproduce in a counterfeit. In most counterfeits, the microprinting will be all blurred under magnification.

Color shifting ink on higher than $5 currency: On modern higher currency, there is a distinct color shifting ink used on the front right. It has a metalicy finish and is used on two right symbols. It changes color, from green to black, when you change the angle of the bill. This is hard to duplicate in counterfeits.

Minute multi-color dot pattern as identifier of counterfeits. When you examine a genuine bill under good magnification, you will see the images, lettering and design are comprised of solid monotone lines and marks. Some, but not all, counterfeits are identified by a minute multi-color dot pattern in the printing. Many digital computer prints will have this pattern.

Raised notes. Some genuine notes are altered to give them a high denomination. For example, a forger may take a $1 bill and paste '$10' on the corners. This is identifying by knowing which presidents appear on which bills. George Washington appears only on a $1. Also, the correct denomination is spelled out just below the President's portrait.

Paper testing pen. There are inexpensive commercially available pens that test the paper. Genuine currency is fiber based, while some counterfeits are on wood based paper. Common computer paper is wood-based. The pen contains iodine that makes a black stain on wood-based paper, but not on fiber-based. The black stain shows that the bill is counterfeit. Realize that some counterfeits are made on fiber-based paper, including bleached genuine currency, so the pen won't identify all counterfeits. Many foreign currencies are on fiber based paper, so the pen will work with the European Euro. Mexican Peso, Argentine Peso, Indian Rupee, Greek Drachma, German Mark, French Franc, British Pound, Russian Ruble, Japanese Yen and numerous other paper currency.

9.2 VIDEOS OF OTHER CURRENCIES

Check other nation's currencies to see if they have ultraviolet markers. Many do.

The following youtube video shows the Euro and British Pound under blacklight
https://www.youtube.com/watch?v=nxXeuuOmnPY

The following video shows various currencies under blacklight
https://www.youtube.com/watch?v=R8O_uUgr8XA

10 HOW TO IDENTIFY RESTORATION AND ALTERATIONS IN ART, ARTIFACTS AND COLLECTIBLES

This chapter shows how blacklight is helpful in identifying otherwise invisible alterations.

Figure 25: Restoration to a ceramic is easily visible under blacklight

10.1 OVERVIEW AND METHODS

Blacklight is helpful in identifying many types of restoration and alteration to paintings, prints furniture, photos, vases and more. These items can be altered by the addition of paper, glue, paint, varnish and/or other material. Items are typically restored to fix damage and make things appear in better condition. It is illegal to sell an altered or restored artwork or item without disclosing the work. However, many sellers are dishonest.

As the added material often fluoresces differently than the rest of the item, the restoration can often be identified under blacklight.

To identify alterations, one should also look for visual light differences in texture, gloss, and opacity. When an art print is put at an angle nearing 180 degrees to a light, the added paint, ink or paper will often have a different texture and gloss from the rest of the card surface. The added material also may be physically raised from the rest of the surface. You might be able to feel the relief with your fingertip.

Figure 26: Added paint on an altered print, easily identifiable at sharp angle to desk lamp in visible light

Opacity is the 'see through' effect when you hold an item up to a light. If material is added to a poster or print, it will often appear darker than the rest of the translucent collectible.

The backs and insides of items often reveal restoration – for examples, the back of a pin may reveal solder and the inside of a desk drawer may reveal the original color.

Some dealers and collectors remove autographs from baseballs for aesthetic or financial reasons. For example, a single signed Joe DiMaggio baseball can be worth more than the same ball with the bat boy's signature beneath. There is one or more companies that will remove autographs. While the removal may be difficult to see under normal daylight, the restoration shows up under blacklight.

10.2 FORGERIES AS ALTERATIONS

In some cases, forgeries are alterations. For example, a inexpensive trading card or stamp may be changed into a rare and valuable variation by changing text. In driver's license forgeries, the forgery may be a genuine license that has had the name or age altered with paper and glue. Many kids want their license to say they are old enough to drink alcohol. In many cases, these changes are identified by the above mentioned techniques.

In a few cases, the forger covered the entire altered trading card in a clear substance to try to cover up the handiwork. The substance however gives the card a different gloss and blacklight fluorescence than other cards in the issue. A collector did not notice the actual altered text of one card, but noticed the card had a distinctly different gloss than his other cards from the same set. Closer examination by an expert revealed the alteration.

11 EXAMINING CLOTH

This chapter shows how blacklight is used to identify modern, faked and altered cloth items.

11.1 OVERVIEW

Many expensive collectibles and artifacts are cloth or partially cloth. This includes baseball caps worn by famous players, military uniforms displayed in museums and rare teddy bears. Some expert collectors and examiners of valuable cloth items use blacklight to help judge age and check for restoration. An example is a collector checking to see if the nameplate and number are original to a sporting jersey. Another example is a collector putting a stuffed teddy bear under blacklight to see if the tags and stitching are modern.

11.2 OPTICAL BRIGHTENERS AND MODERN CLOTH

As with paper, optical brighteners have been added to much cloth made after World War II. Used to make bright colors brighter and stain resistant, the optical brightened clothes will fluoresce a bright white or bright blue/white under blacklight. The optical brighteners will typically indicate that the cloth was made after World War II. Many so-called antique patches, hats and shirts are identified as being modern reproductions – or at least altered or restitched after World War II – due to the presence of the presence of optical brighteners. For example, collectors of World War II military patches know that many fakes fluoresce brightly under blacklight.

Figure 27: Under blacklight, an antique embroidery is shown to be modern by the bright fluorescence.

Figure 28: Under blacklight, the white parts of this modern Japanese kimono fluoresce brightly.

As many cloth items are made from a variety of cloths and threads, the optical brighteners will often appear only in parts. For example, most of a modern baseball cap might not fluoresce, but the emblem, stitching and/or laundry tag might. As with paper and cardstock, cloth and thread that does not fluoresce brightly does not mean it is not modern. In fact, most dark cloth does not contain optical brighteners no matter what year it was made.

It is important to note that many laundry detergents have optical brighteners, which can throw off examination results. If an antique shirt was washed in the washer, it may have optical brightener residue from the detergent.

An interesting sidenote is that police sometimes find bodies at the bottoms of lakes or rivers due to the UV fluorescence of the clothes.

11.3 ALTERATIONS TO CLOTH ITEMS

Examiners and collectors identify alterations on new and old cloth by looking for clear differences in UV fluorescence. If a stuffed doll was patched up with a new cloth of the same color, the alteration often can be identified by fluorescence difference between the patch and the rest of the doll. This comparison and judgment requires experience both with examining cloth, and the dolls, jerseys or whatever is being examined.

In some cases, modern alterations are not identified by the added cloth but by the new stitching. On an antique shirt, optically brightened thread will reveal the modern stitching. It is striking how much the thread can stand out.

12 PAINTINGS AND PAINT

Blacklight is used to examine paintings and antique painted items. This is an area where you should have personal experience shining your blacklight on many painted items, due to the subtleties and exceptions to any rule. Research on trends in specific kinds of paints and painted items is an area that can still be worked on (by you, if you are so inclined)

As with paper items, optical brighteners in the paper, canvas and sometimes the paint will often reveal a painting to be modern. A catch is a couple of 1700s paints can fluoresce brightly.

Many antique collectables such as toys and iron banks were painted. In general, the original antique paint will have little fluoresce, while modern paint will have more fluorescence. This can help identify reproductions, repainted and repaired items. Also, original antique paint tends to fluoresce the same color in black light as in visible light, while modern paint tends to not.

For old paintings, blacklight can help identify alterations and added signatures. An added modern signature to an old varnished oil painting will often stand out due to its fluorescence and will often appear to float above the rest of the paintings. Alterations will often also stand out due to difference in fluorescence. Alterations can often also be seen in visible light, including by close inspection, changes in gloss and by holding the painting up to a bright light (opacity).

Duly note that there is a masking varnish used to hide restoration by absorbing the UV. However, the masking varnish is easily distinguished from original antique varnishing on old oil paintings. The masking varnish is noticeably greasy, with a greenish tint and has a perfect surface texture. Old varnish has surface streaks as it was added brush stroke by brush stroke.

13 A STANDARD TECHNIQUE FOR IDENTIFYING TRADING CARD REPRINTS: DIRECT COMPARISON

This chapter shows methods for using blacklight and visual light is used to identify reprints and forgeries of paper stock items.

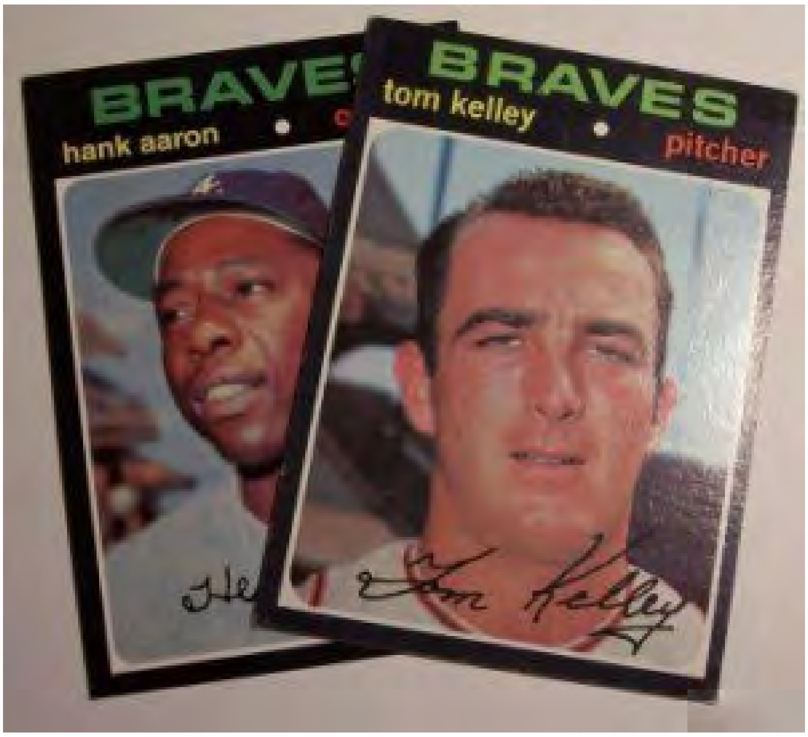


Figure 29: The 1971 Topps baseball cards in this picture look good. However, the Hank Aaron card on the left is a reprint. In subsequent pictures you will see how the cards differ in distinct ways.

13.1 OVERVIEW AND METHODS

A standard and often highly effective way to detect trading card counterfeits and reprints is by directly comparing in visual and blacklight the card in question with one or more known genuine examples. Granted, it is uncommon for the collector to already own duplicates, especially if it is an expensive 1933 Goudey Babe Ruth or 1965 Topps Joe Namath. However, good judgment is often made when comparing a card to different cards from the same issue. Comparing the Ruth to a bunch of Goudey common cards and the Namath to a handful of other 1965 Topps.

A valuable 1909 T206 Ty Cobb baseball card, and even a hundred thousands dollar T206 Honus Wagner, was printed on the same sheet as T206 commons. The printers did not bring out special cardstock and VIP inks for the superstars. When you are studying the qualities of T206 commons, you are also studying the qualities of the rare and ultra expensive T206 Wagner.

In nearly all cases, counterfeits and reprints are significantly different than the real card in one and usually more than one way.

Before examination, the collector should be aware of variations within an issue. A genuine 1956 Topps baseball card can be found on dark grey or light grey cardboard. While the 1880 Old Judges are usually sepia in color, pink examples can be found. The examiner must also take into consideration reasonable variations due to aging and wear. A stained card may be darker than others. An extremely worn or trimmed card may be shorter and lighter in weight than others in the issue. A card that has glue on back will allow less light through when put up to the light. The collector will often have to make a judgment call when taking these variations into effect. This is why having experience with a variety of cards is important.

The following is a short list of things to look at. You are welcome to add your own observations to the list.

Visible light obvious differences: This can include text or copyright date indicating the card is a reprint, major size difference, wrong back. Many of these problems are obvious even in an online scan.

If you are experienced with an issue, perhaps you have collected 1933 Goudeys for the last few years, most reprints and counterfeits within that issue will obvious. They simply will look bad or be printed on a different type of card stock than you're used to examining.

Blacklight Test. Studying the degree and color of fluorescence under a blacklight is an unbeatable tool for comparing ink and cardboard. If you spread out in the dark a pile of 1983 Topps, with the exception that one is a 1983 OPC (the Canadian version of Topps, with the same basic design), the OPC will be easy to pick out with blacklight. The OPC is made out of a different card stock and fluoresces many times brighter than the Topps stock. This is the way it often works for reprints and counterfeits. Reprints and counterfeits were made with different cardstock and often fluoresce differently than the genuine cards. The reprint may fluoresce darker, lighter or with a different color. In some cases, a reprint and an original may fluoresce the same, but in most cases the blacklight will identify the reprints with ease.

Visual light appearance of card stock and surfaces: This includes color, texture, feel, etc. The correct gloss is hard to duplicate on a reprint, and most reprints will have different gloss than the originals. Make sure to check both sides. A T206 and 1951 Bowman, for examples, have different textures front versus back. Make sure to check the thickness, color and appearance of the card's thickness or edge. The edge often shows the cardstock to be different.

Figure 30: The reprint 1971 Hank Aaron has an different gloss (shiney) and coloring than the original card.

Visible Light Opacity: Opacity is measured by the amount of light that shines through an item, or the 'see through' effect.

Cardstock and ink vary in opacity. Some allow through much light, some allow none, while the rest will fall somewhere in between. Most dark cardboard will let through little if any light. White stocks will usually let through more. While two cardboard samples may look identical in color, texture and thickness, they may have different opacity. This could be because they were made they were made in different plants, at a different time and/or were made from different materials.

Testing opacity is a good way to compare cardstock and ink. The same cards should have the same or similar opacity.

Figure 31: When held to a normal desk lamp, the reprints lets through much more light than the original

Opacity tests should be done with more than one card from the issue. Comparisons should take into consideration variations due to age, staining, soiling and other wear, along with known card stock variations in the issue. It must be taken into consideration that normal differences in ink on the card will affect opacity. If one genuine card has a darker picture (a dark uniformed player against dark background), it should let less light through than a genuine card from the same set with a lighter picture (a white uniformed player against a light sky).

13.2 OPTIONAL ASSIGNMENT

This chapter showed how these tests are done with trading cards. If you wish, think about what other possible collectibles these types of tests could be done with and find out if they are useful.

14 ART GLASS

Blacklight is a useful tool in judging the identity and age of art glass vases, figurines and more.

Figure 32: Highly sought after Lalique glass

Different types and ages of glass can fluoresce different colors, and the color of fluorescence can be helpful in identification. As there are variations and exceptions, the fluorescent colors should be used only as a general guide. The expert collector and dealer also looks at the visual color, physical nature, style, visible stamps, provenance, weight, etc.

The following are a few examples of glass and blacklight fluorescence:

Lalique art glass

The Frenchman Rene Lalique produced some of the finest glassware. Lalique art glass from before 1945 typically fluoresces yellow and sometimes peach, but different colors after.

Marbles

Many 1800s marbles fluoresce, some bright green and yellow. Many believe post WWII marbles to do not fluoresce.

Uranium glass

Uranium glass is a popular form of yellow-green glass, including the highly popular vaseline glass. Under blacklight genuine vintage and modern uranium glass fluoresces an easy to identify bright green. Glass that resembles but is not uranium glass fluoresces differently, including peach, orange or less bright lime green.

Figure 33: Uranium glass vase fluorescing bright light green under black light

Uranium glass under blacklight video:
https://www.youtube.com/watch?v=yLzVij5iGKY

Modern reproductions of Burmese Art Glass

Old Burmese art glass tends to fluoresces a bright yellow, while modern reproductions usually do not.

American colorless pressed glass

Antique American colorless pressed glass fluoresces brightly. Modern reproductions do not.

14.1 ASSIGNMENT

From the previous chapters on collectables and materials post some UV pictures and explanations. Examples can include photos showing how UV shows restoration or alteration, how a modern reprint fluoresces brightly, how the blacklight authenticates a currency bill, other. Show and explain one or two different things.

15 MAKING FLUORESCENT ART, DESIGNS & CRAFTS

This chapter shows how artists use ultraviolet light.

With a blacklight and fluorescent materials, you can make all sorts of glow in the dark arts and crafts. This includes sketches, wall hangings, sculptures, mobiles and halloween costumes. This chapter shows various techniques and ideas. You can expand on these ideas and come up with your own inventions. Your imagination is your only limit.

Figure 34: Sketch on cardboard in invisible ink.
The sketch is only visible in the dark under blacklight.

15.1 ART FROM INVISIBLE PEN INK AND OTHER MATERIALS

Those inexpensive UV ink pens are great for drawing sketches and designs on paper, cardboard, wood and other surfaces. Though the UV ink does fluoresce on normal white paper, you may find it best to draw on material that does not fluoresce. This is particularly true if you want something to stand out on its own in the dark – a skeleton sketch for Halloween for example.

Of course one should be careful what one writes one, in particular if it is not yours. The ink may or may not be easy to remove or cover over. Writing a design on a disposable plastic toy or shard of writing paper is one thing. Writing on mom's silk scarf or your friend's hallway wall without permission is another. Also, it only makes sense that you don't want to be writing on areas that people eat or drink from, such as the face of plates. Use common sense.

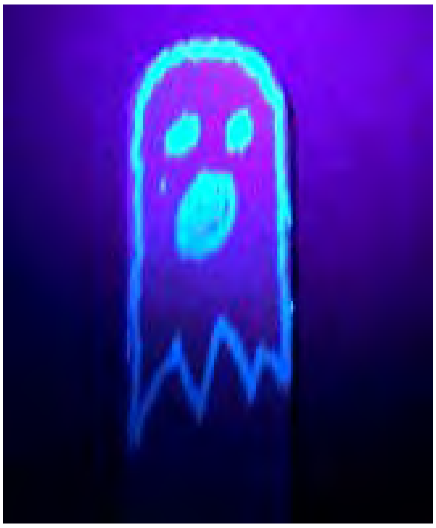


Figure 35: Ghost drawn on on tongue depressor

You can also use other fluorescent materials, such as paper, granular laundry detergent and other assorted materials and objects you find around the house. You can cut optically brightened paper into designs, make collages, fold them into dolls, figures and mobiles, combine them with your pen ink and glued on laundry detergent. There is also fluorescent paint and inks of different colors, including paints especially made for human skin. If you do not have face paint, you can use vaseline, which fluoresces brightly.

One of the neat things with UV art is you can have the design change when the visible light is on versus off (and the blacklight on). For a sketch you can use a regular ballpoint pen or pencil for the daylight picture, then have invisible ink for a different image when the lights are off. You can have a daylight scene on your bedroom mobile and a night design for when you go to bed. For example, the daylight scene can show robins and the sun, while the night scene can show bats and owls. UV designs in your room, such as stars on your ceiling, will not show up until night and the ultraviolet light is on.

Go online and image google *ultraviolet fluorescent portraits* to see some wild images.

The below videos shows murals that change light to dark:
https://www.youtube.com/watch?v=ytaapz5NpxA
https://www.youtube.com/watch?v=ATFVVf10oEg

15.2 BLACKLIGHT THEATER

Using blacklight fluorescent costumes, props and makeup, blacklight theater involves many amazing spectacles including plays, pantomimes and dances. An example of how it can be done is where a human wearing non-fluorescent clothing holds a fluorescent prop, so all the audience sees is the prop moving around. The human can also wear a fluorescent costume. The variations are endless, and the the exhibitions are usually accompanied by music. The below links show some examples. You can search for others:

https://www.youtube.com/watch?v=L02oHLVi1EA
https://www.youtube.com/watch?v=rpJE5FmEy6E
https://www.youtube.com/watch?v=H_eQ6IKUEAU

15.3 UV PHOTOGRAPHY

People take ultraviolet photographs for art, hobby and scientific purposes.

There are two different basic methods of ultraviolet photography. One is to take normal visible light photographs of fluorescent items, such as you have already been doing. Make something fluoresce under blacklight, then photograph that.

The second, more technically advanced method is to have a camera that detects and photographs ultraviolet light. This is called 'reflected UV photography.' Cameras, including digital cameras, normally have lenses that block ultraviolet light. When the inside lens is removed, the camera can photograph ultraviolet light.

The same can be done with infrared photography. Infrared photography in particular is a popular art form and is also often used in forensic science and art examination. I have an infrared camera, which simply is a converted standard digital camera. I bought it already converted. The images download onto my computer the same as with a regular digital camera.

Reflected ultraviolet photography is not used as often as infrared photography, but is gaining in popularity.

Infrared and reflected ultraviolet photography are useful for studying how animals who see different light. We get an idea of what they see.

The following are links to more reading on the topic of UV reflected photography.

http://petapixel.com/2013/04/19/a-beginners-guide-to-UV-reflectance-in-photography/
http://www.naturfotograf.com/UV_IR_rev01UV.html
https://www.lifepixel.com/galleries/UV-ultraviolet-photography-gallery
http://photographyoftheinvisibleworld.blogspot.com/2011/01/simple-tutorial-for-reflected-UV.html

15.4 ASSIGNMENT

Make and photograph a blacklight fluorescent art, sketch, mobile, collage or other design. Explain what you did and what materials you used. Not only have you made a fluorescent work of art, you have made an ultraviolet art photograph.

16 SHORTWAVE/UVC LIGHT

This chapter introduces the use of the shortwave ultraviolet light.

Some people using this book may wish to use a UVC/shortwave light. Many readers will only need the UVA blacklight, but the UVC is used in some specialty areas including stamp collecting, and gem and mineral identification.

16.1 BUYING A UVC LIGHT

You can buy handheld UVC lights. There are also lights that shine both UVA and UVC light. I have one of these UVA/UVC lights, pictured below, and it works well. It has two lenses, one that emits UVA and the other UVC. You can find these on amazon and ebay. They are more expensive than UVA blacklights, but not too expensive.

Figure 36: A popular style of UVA/UVC light by Raytech. One lens shines UVA, the other UVC

16.2 SAFETY

UVC is more dangerous than UVA and, in fact, is used as a germicide. You should not expose it to your skin (UVC does not go through clothing). You should not use it for unnecessary periods of time, and you should avoid looking directly at the light. It might be wise to invest in a pair of UVC protective glasses or goggles. Normal glass in eyeglasses blocks UVC light and most UVB, but not UVA. So wearing glasses will protect you from UVC, but UVA blocking glasses will be even better. Also, goggles will protect the sides of your eyes, which is important. Remember that, even when you are shining the light away from you, the UVC can reflect off of material.

If you take due precautions and keep safety on your mind, UVC light is safe, and many collectors and hobbyists use it without harm.

16.2.1 TEST THE ULTRAVIOLET PROTECTION OF YOUR SUNSCREEN

Must sunscreen blocks UVB and UVC, but not always UVA. Some, called full spectrum, block all three. To test your sunscreen – especially if you want to use sunscreen protection when you use ultraviolet light – , apply a small area of sunscreen to a brightly fluorescent piece of computer paper and wait for the sunscreen to dry. Then shine UVA and UVC light on the paper. If the sunscreen blocks the ultraviolet light, the area where the sunscreen was applied will appear dark. I did this with my sunscreen and discovered it blocked all three.

The following are two common areas where UVC, along with UVA, is used.

16.3 GEMS AND MINERALS IDENTIFICATION AND DISPLAY

Many though not all gems and minerals fluoresce under ultraviolet light. While there are many qualities that identify a gem and mineral – including visual color, shape, hardness, visual light tests and streak colors – the ultraviolet fluorescence color and brightness is a useful aid in identifying gems and differentiating real from fake valuable gems. Some gems and minerals fluoresce different colors in UVA versus UVC light. Some minerals fluoresce so brightly and colorfully that a hobby is to collect and display them under UV. Natural history and geology museums often have fluorescent mineral exhibits.

The following links give list UV colors for gems and minerals:

gems:
https://www.realorrepro.com/article/Black-light-and-gemstones

minerals:
http://www.gemstones-guide.com/Ultra-Violet-Fluorescence.html
http://www.galleries.com/minerals/property/fluotabl.htm

Video of the Sterling Hill Mining Museum in New Jersey USA and its fluorescent minerals:
https://www.youtube.com/watch?v=VhM7RcGGt4I

16.4 FLUORESCENT AND PHOSPHORESCENT POSTAGE STAMPS

Many postage stamps fluoresce and even phosphoresce in various and often bright colors and different patterns. Though some older stamps also naturally fluoresce, in modern times these qualities were intentionally added as an aid for the automatic machine sorting of mail. Before then, letters were time-consumingly sorted by hand. The fluorescent and phosphorescent marking help the UV-detecting sorting machines place the letters in the right position and identify the stamps and postage.

Stamps that have this fluorescence or phosphoresce markings for machine sorting are called *tagged*, and stamps without are called *untagged*. There are all sorts of colors and variations, even within a particular stamp. A particular stamp can sometimes come tagged and untagged, and tagged in different patterns. Many stamp collectors avidly collect tagged stamps and search for rare variations. A collection of fluorescent and phosphorescent stamps can display almost as well as fluorescent and phosphorescent minerals.

Blacklight makes some stamps fluoresce and phosphoresce, while shortwave is needed for some. In cases, the colors and patterns will change longwave to shortwave. This means the brightness, color and/or pattern will be different in longwave than it is in shortwave. This is a great help for authentication and forgery detection.

The following shows some tagged stamps.

Figure 37: This stamp has the fluorescent marking, or 'tagging,' only around the edges.

Figure 38: This stamp is fluorescent except for a bar in the middle. Other examples of this stamp have the bar in different areas.

Figure 39: This stamp has the fluorescent tagging everywhere except for the edges. This stamp can also be found untagged.

17 ULTRAVIOLET LIGHT IN SCIENCE, INDUSTRY AND MEDICINE

The following are a few examples of how various ranges of ultraviolet light are used in more advanced areas.

17.1 IRRADIATION, PURIFICATION AND STERILIZATION

UVC light, typically at 254 nanometers, is used to irradiate, purify and sterilize water, air, food, sewage, laboratories, office buildings, pools and aquariums. In industry and science the process is called Ultraviolet Germicidal Irradiation (UVGI).

Direct and long enough exposure to UVC light can kill, amongst other things, anthrax, typhoid, e. coli, tuberculosis, salmonella, hepatitis, algae and fungi.

There are limitations to UVC as a germicide. There must be direct exposure to the light for it to work. This means that in a lab or building there may be areas that are missed, and the light cannot penetrate into materials. Because of this, laboratories and medical facilities use UVC in combination with other cleaning and disinfecting methods.

UVC is commonly used to purify circulating air, such as in an office or medical building. While the air is purified at the spot of exposure, the air can get dirty again with circulation.

A positive with UVCI is there is no material waste or toxic runoff, as with bleach and other liquid and dry cleansers. Once the light is turned off, the light is gone.

There are commercially marketed handheld UVC germicidal lights for normal people. They are commonly used by travelers to sanitize hotel and airplane bathrooms, beds, dishes, etc. I've even seen a UVC toothbrush cleaner.

An article on germicidal light use in a hospital:
http://hpac.com/archive/oklahoma-hospital-takes-ultraviolet-germicidal-irradiation-next-level-0

Scientific American article on how UV kills cells:
https://www.scientificamerican.com/article/how-does-ultraviolet-ligh/

17.2 ULTRAVIOLET ASTRONOMY

Ultraviolet astronomy is the observation of ultraviolet wavelengths from celestial bodies. Much of this light, including nearly all UVC, is absorbed by the earth's atmosphere, so the information must be gathered from the upper atmosphere or space via rockets and space stations.

Astrophysicists photograph and study the ultraviolet to identify the chemical makeups, densities and temperatures of the stars, planets and other bodies. This information helps them determine the history and evolution of the galaxies, including the age of stars.

Space looks different in the ultraviolet spectrum, and many stars are only seen, and thus discovered, in this spectrum.

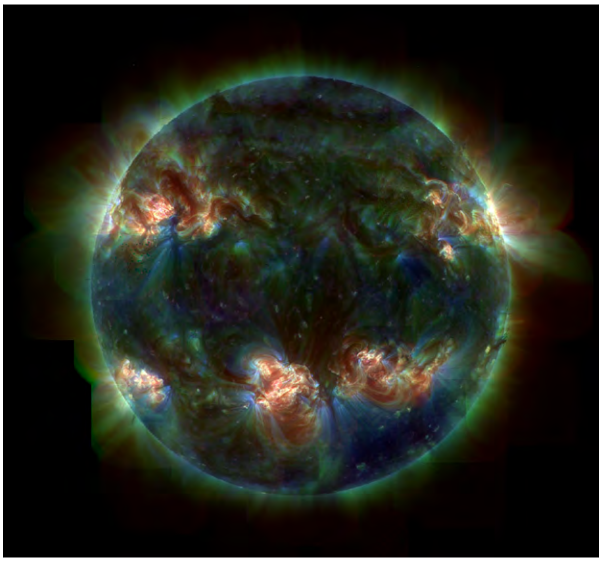


Figure 40: Ultraviolet image of the sun from NASA

Online NASA article:
http://imagine.gsfc.nasa.gov/science/toolbox/emspectrum_observatories1.html

17.3 CRIMINAL SCENE INVESTIGATIONS (CSI)

Police departments and similar institutions use forensic light machines to identify and photograph trace materials at crime scenes. This includes hairs, fingerprints, saliva, semen and gun residue. The machines shine the range of light from ultraviolet to infrared, including many visible colors. Trace and tiny objects and materials that are normally invisible will often appear in one of the light frequencies. The inspectors often also wears colored glasses that help things stand out. The key for with these light machines is to go through the full range of light until something appears. They also use fluorescent powders and liquids to make fingerprints and similar stand out.

These forensic light sources can also be used on questioned documents (contracts, wills, valuable famous person's autographs) to identify alterations and the use of different inks, such as when two pens were used to add text, or writing erased, to make make a forgery. They can also be used to identify alterations to art and artifacts.

These forensic light machines are extremely expensive and the average person will not be able to afford one.

The below link is the description of such a light source by its manufacturer:
http://www.spexforensics.com/applications/category/forensic-light-sources

17.4 HEALTH AND MEDICINE

Ultraviolet carries health dangers and benefits.

Some UV light is beneficial to the body, because it is crucial to produce vitamin D. Vitamin D increases calcium and phosphorus absorption from food and plays an important role in bone development, immune function, blood cell formation and even helps prevent cancer. However, only a little bit of sun exposure a week on your face, hands and arms is sufficient to get your needed vitamin D. You can also get vitamin D by eating fish, eggs and fortified foods such as milk.

Too much sun and its ultraviolet light, however, is bad for you. Overexposure can cause sunburns, skin aging including wrinkles and age spots, harm to the immune system and a higher risk of cancer. It also can damage the eyes both short term and long term.

It is recommended that you reduce your sun exposure by regularly applying a sunscreen that blocks both UVA and UVB, wearing protective clothing and UVA & UVB blocking sunglasses, avoiding the peak sunlight hours of 10am to 4pm and not using tanning beds.

In medicine, ultraviolet has been used to identify and treat a number of diseases. The Dane Niels Ryberg Finsen won the 1903 Nobel Prize for Medicine for his pioneering work with UV phototherapy, in particular for the treatment of lupus vulgaris. The medical use does not eliminate the bad side effects of UV, so treatment must take place under trained supervision.

The following are some conditions and diseases where ultraviolet is used:

> *Rickets* involves the softening and often distorting of children's bones due to lack of calcium. This is often caused by lack of vitamin D. UV light exposure helps cure rickets by helping the body absorb vitamin D. Vitamin D supplements also are commonly used.
>
> *Lupus vulgaris* is a chronic infection of the skin caused tuberculosis bacteria that results in scarring and ulcers on the face and neck. For many years it was treated by exposure to a UVB light, but today it is usually treated with antibiotics.
>
> *Psoriasis* is an autoimmune disease that results in skin sores and scales. Ultraviolet therapy is one of the treatments. A drug is given to the patient to make the skin more sensitive to UV and the skin is then exposed to UVA.
>
> *Vitiligo,* the disease Michael Jackson claimed have, is a loss of skin pigmentation that can be treated by exposure to UVA or UVB.
>
> *Ringworm* is a skin fungus on humans and other animals, including pets. As it fluoresces greenish under UV, it can be identified via a blacklight.
>
> *Ophthalmologists and optometrists* use UV light to help identify the cataracts, abrasions and lesions.

Further reading:

http://www.medicallightassociation.com/?q=node/69
http://www.news-medical.net/health/What-is-Light-Therapy.aspx

17.5 OTHER USES FOR UV

Photolithography. Ultraviolet light is used in printing designs for very small flat surfaces, such as on semiconductor chips.

Curing (instant drying) adhesive, dyes and inks.

WWII airplane safety. During World War II, airplanes used maps written in UVA fluorescent ink. During dangerous battle situations, the navigator could read the map without illuminating the cockpit.

Chemical and compound identification. As the wavelengths and colors emitted under ultraviolet light depends on the chemical and atomic makeup of the material, scientists study the fluorescence, absorption and reflection of ultraviolet, infrared and other lights to identify the chemical makeup of materials.

Flying pest control. Ultraviolet fly traps, or bug lights, are used to kill flying insects. The bugs are attracted to the UV light it emits, and killed with electrical shock.

Tanning booths and lights. These are not safe and should be avoided, but it is UV light that makes you tan.

Photographs development. UV lights are often used to develop photographic images.

18 FINAL QUIZ AND ASSIGNMENT

18.1 FINAL BOOK ENCOMPASSING QUIZ QUESTIONS

1) Which UV light is the more dangerous: UVA, UVB or UVC?
2) Is blacklight UVA, UVB or UVC?
3) Name two animals that can see UV.
4) How does UV light makes things fluoresce?
5) What is the most common natural source of UV light on earth?
6) 200 nm wavelength is UVA, UVB or UVC?
7) What is the frequency range for blacklight in nanometers?
8) Why do astrophysicists use space stations to study ultraviolet light?
9) Give an example how being able to see UV is useful to an animal.
10) Give two areas where shortwave ultraviolet (UVC) is used.
11) Name two medical conditions or diseases that ultraviolet light is used to identify or treat.
12) How does the ability to see ultraviolet light help butterflies?
13) What is the difference between a 'tagged' and an 'untagged' postage stamp?

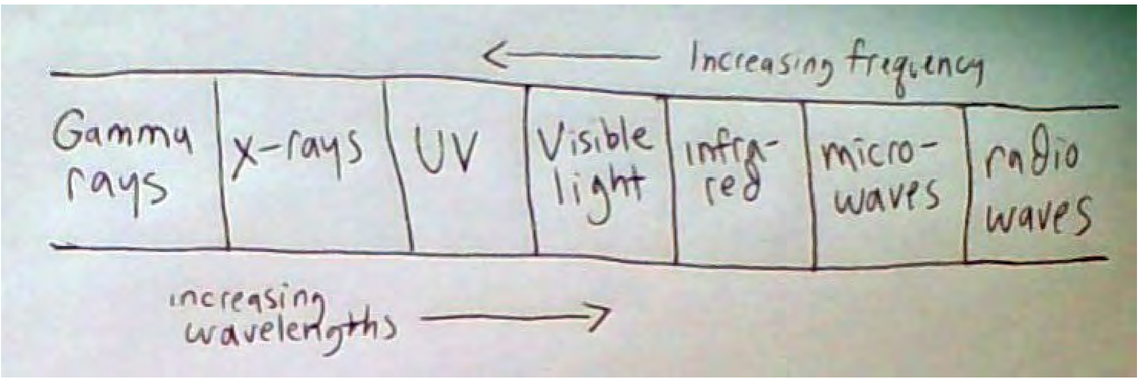
14) How do blacklights help authenticate currency and credit cards?
15) How does blacklight help identify modern paper, such as in reproductions or fakes of antique paper collectibles?
16) How does blacklight help identify alterations or restorations to such things as paintings, vases and movie posters? What other ways can alterations be identified?
17) How did Johann Ritter discover ultraviolet light?
18) Which ultraviolet light is 'germicidal' (kills germs, anthrax, fungi, etc): UVA, UVB or UVC?
19) How does phosphorescence differ from fluorescence?
20) What is blacklight theater?
21) What are two uses of invisible ink pens?
22) Why do governments put fluorescent symbols, marks and/or bands on licenses, passports and currency bills?

18.2 FINAL ASSIGNMENT

Give a short report on some aspect of ultraviolet light. It can be a more detailed extension on a topic already covered in this book – perhaps incorporating the further reading and video links included throughout book –, or a new area not covered. Examples can include your own studies of qualities of fluorescence of materials or collectibles, a short explanation of industrial, medical or scientific use, a further look at animals and ultraviolet light, or a look at the history and techniques of blacklight theater and fluorescent art.

19 A VERY QUICK LOOK AT THE OTHER FORMS OF LIGHT

While this book is about ultraviolet light, this final chapter briefly touches on the nature and uses of the other forms of electromagnetic radiation: gamma rays, x-rays, infrared, microwaves and radiowaves.



19.1 GAMMA RAYS

Gamma rays have the shortest wavelength and the highest energy. They are created by some of the highest temperature events in the universe, including solar flares, supernova explosions and nuclear explosions.

Astronomers use gamma rays to study space, and experimental physicists use gamma rays because they can penetrate materials. Gamma rays are used for irradiation of foods and seeds. In nuclear medicine, nuclear engineers create gamma rays via nuclear fission to make diagnostic imaging such as PET scans.

A brief NASA video on gamma rays

https://www.youtube.com/watch?v=PPlrtgilgK8

19.2 X-RAYS

In between infrared and gamma rays on the wavelength spectrum, x-rays are best known for their use in medicine. However, they can also be dangerous to humans, and physicians must be careful to limit exposure to the patient.

X-ray machines are well known for taking photographs of the insides a patient's body. The x-rays pass through flesh and skin but are blocked by bones, allowing for a photographic image of the bones to be made. The physician can thus see breaks and other internal damage. X-ray machines can also check the insides of baggage at airports and are used by art historians to see through the first layer of a painting or inside an artifact. Chemists and physicists use x-rays to study the chemical makeup of materials and objects, and astronomers study x-rays from space to learn about celestial bodies.

19.3 INFRARED

Infrared is a light that humans encounter daily in the form of heat. Half of the energy given off by the sun is infrared and most of the light given off by an incandescent lightbulb is infrared. Along with convection and conduction, Infrared radiation is one of the three ways heat is transferred.

Infrared is used in many ways in science, industry, medicine and more. There are viewers, goggles and cameras that translate infrared light into visible light viewable on the screens. Night goggles, such as used by the military, help humans see things at night, while infrared photography is a popular art form (image google *infrared photography*). Art historians use infrared to examine art and artifacts. As with x-rays, it can penetrate through the first level of paint to reveal an inside layer of a painting. It penetrates to a different level than x-rays, so artists uses both x-ray and infrared examination to see two different levels inside a painting. Infrared can also allow one to see through cloth, see badly faded writing on ancient artifacts and important documents, and see the foreign material in alterations and restorations.

Other uses of infrared include television remotes, infrared astronomy (like uv astronomy but studying the ir light given off by celestial bodies), meteorology, space heaters, toasters and food lamps (remember that infrared = heat), and to treat medical conditions.

An entertaining video demonstration for kids on infrared and heat:
https://www.youtube.com/watch?v=hwChowiZNyg

Video showing how an infrared viewer finds hidden signatures on paintings:
https://www.youtube.com/watch?v=rWNshrFvl98

Video on night goggles:
https://www.youtube.com/watch?v=CP6wofWfUws

19.4 MICROWAVES

Microwaves are basically high frequency radio waves, Unlike visible light they can freely move through rain, smoke and fog, making them useful for long range purposes such as communications.

Microwaves are used for cooking, weather mapping, radar and satellite communications, cellular phones, television signals and GPS navigation.

Microwave ovens cook by sending the microwave energy to the water in the food. The microwaves heat the water, which heats the rest of the food. Microwaves pass through plastics and ceramic dishes, but reflect off of metal. As we all know, we are not supposed to put metal objects in the microwave oven.

Microwaves do not carry enough energy to damage human DNA, but they can cause burns.

How a microwave oven works:
https://www.youtube.com/watch?v=MqsDPmnPKEk

19.5 RADIO WAVES

Radio waves, which have the longest wavelengths, are used via antennas for the transmission of information. Television, mobile phones, wireless communication and radio all use radio waves. The use of the radio spectrum is legally regulated by many governments. For example, radio stations are allotted specific frequencies.