Light and Ultraviolet Radiation

Objectives

At the end of this chapter you should:

- understand the adverse effects that visible light and ultraviolet—UV—radiation can have on museum objects;
- be able to identify the items in your collections that are most susceptible to damage caused by exposure to visible light and UV radiation;
- know steps to take to control the lighting and UV radiation levels, and so minimise damage to your collections;
- be aware of the sources of visible light, UV radiation and infrared radiation in a museum, gallery or library; and
- be aware of the need for different lighting levels for the different areas of the museum, gallery or library.

Introduction

Light is necessary in museums, galleries and libraries: for viewing exhibitions, for reading and research, and for curatorial and collection management work.

All common light sources, such as the sun, light bulbs and fluorescent tubes, also give out other forms of radiation, to varying degrees. The most significant of these are UV and infrared radiation.

Light and UV radiation are potentially the most damaging forms of energy present in museums, galleries and libraries, and the damage they cause is cumulative. So when lighting an area where important or valuable works are housed, it is essential to take steps to minimise the potential for damage. We must also provide a safe and comfortable working and viewing environment for people.

Achieving both will nearly always involve some sort of compromise. To determine the type and extent of compromise required, it helps to have a basic understanding of light and UV radiation and how they affect various materials, as well as knowing what types and levels of illumination are required for various activities.

Why worry about light and UV radiation?

Although we could not do without light in museums, galleries and libraries, it is important to remember light is an environmental factor that contributes to the deterioration of our valued collections.

It is vital to be aware that visible light is often accompanied by:

- UV radiation, which can cause more damage faster than visible light; and
- infrared radiation, which heats materials.

When light and UV radiation fall on an object, they deliver bundles of energy to that object. As a result, various chemical reactions can take place, depending on the amount of energy delivered. These reactions are called photochemical reactions. In some cases it is very easy to see the effects of these reactions: try leaving a piece of newsprint in the sun for a few hours and examine the results. The paper becomes discoloured—yellowed. It often feels different as a result. However, most changes caused by photochemical reactions are not as quick as this nor as obvious; so it is difficult to know they are occurring. Nevertheless their effects can be devastating and ongoing.

Light causes extreme and irreversible damage to many materials, most notably organic materials—those that derive from plants and animals. In a museum, gallery or library, these will include furniture, textiles, prints, books, drawings, manuscripts, wallpaper, dyes and inks, feathers and fur.

For example, UV radiation and visible light:

- set off chemical changes in paper and textiles, which weaken and discolour them; and
- cause inks, dyes and pigments to fade, and so seriously affect the aesthetic quality of many items.

Infrared radiation is less energetic than UV radiation and visible light. It:

- heats materials and can cause them to expand, leading to mechanical stresses; and

- can also cause chemical changes to progress more rapidly. As a result, infrared radiation can increase the destructive effects of visible light and ultraviolet radiation.

CAUTION:

Once started, photochemical reactions can continue even after the exposure to light or UV radiation has stopped. This means the deterioration of objects does not stop when the objects are placed in the dark.

What materials are most sensitive to damage?

Some materials are much more susceptible than others to damage through photochemical reactions. Some detailed examples are given below. These illustrate the extent and types of damage which are often found. You will probably recognise some of the problems.

Textiles

Light and UV radiation are the greatest enemies of textiles. Colours will become pale and dull, and the fabric will become fragile and will split readily.

This piece of silk brocade has been folded back on itself to show the degree of light-damage to one side of the item.

Photograph courtesy of Artlab Australia reproduced with permission of the Art Gallery of South Australia

Textiles produced in the 19th century require particular care. The aniline dyes, which were first manufactured and became popular around this time, are particularly susceptible to fading, especially the purples, blues and greens.

Watercolour pigments

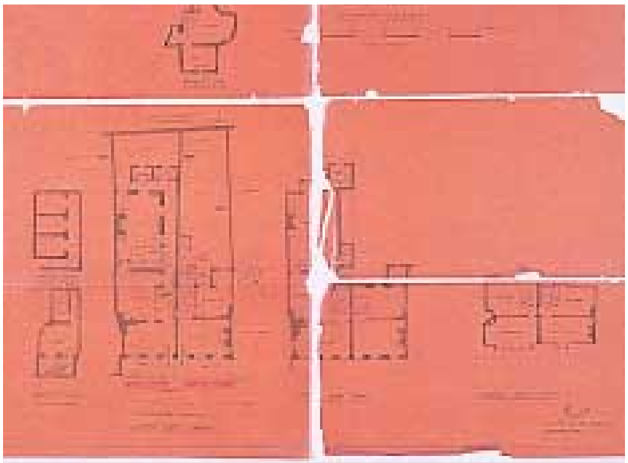
Pigments of plant or animal origin, that is organic pigments, tend to be more sensitive than others.

Photochemical action in pigments has severely altered the appearance of many watercolours. For example, Hooker's Green is a pigment mixture that was widely used for foliage in botanical illustration and landscape watercolours. It is made up of the reasonably durable Prussian Blue mixed with Gamboge, a yellow pigment made from gum from a Cambodian tree. Gamboge is sensitive to photochemical action and fades, leaving the foliage blue.

Many of these sensitive pigments were also used in oil paintings; but because the pigment layer is usually thicker, and the oil medium offers more protection, the effects are less obvious.

Paper

Mass-produced, cheap, modern papers are made from untreated wood pulp. These contain lignin, the substance in trees that gives them their strength. Lignin is very reactive and is susceptible to photochemical deterioration. As lignin breaks down it produces yellow–brown substances, as seen when newspaper is left in the sun, as well as acids.



This paper is severely damaged; it is discoloured and very brittle.

Photograph courtesy of Vicki Humphrey

The acids produced can then attack the paper fibres, making them short, and the paper brittle.

The photochemical deterioration of paper is an example of a reaction that continues even when the paper is no longer exposed to light or UV radiation.

Moderately sensitive materials

Although not all materials are as sensitive to photochemical reactions as those listed above, most are affected by light and UV radiation to some extent.

Materials that are moderately sensitive to light and UV radiation include:

- oil paintings;
- bone and horn; and
- furniture.

Therefore, it is important to consider the lighting conditions under which you store, display and use valuable items, as well as the length of exposure they get.

Can the damage be prevented?

Damage to objects and collections cannot always be totally prevented, but the rate of deterioration can be limited and slowed:

- by exposing objects to light only when necessary;
- by making sure the light is not too bright; and
- by eliminating UV radiation.

It is important to realise that protecting your collections from the damage caused by light and UV radiation may involve reassessing collection and management policies, and taking a different approach to the display of collections.

Select and control the light

Avoid displaying, using and storing items in direct sunlight. Wherever possible, eliminate daylight completely.

If daylight is a major light source for your museum, gallery or library, take steps to diffuse and filter the light. You can:

- use curtains or blinds over windows and skylights; and
- use UV-absorbing plastic films on windows and skylights to eliminate the UV radiation coming into the room from the daylight.

If fluorescent or halogen lights are used, remember:

- some sort of UV-absorbing filter should be used to remove the UV radiation;
- filtering can be used on the lamps or on display cases and frames; and
- UV-absorbing films, acrylic sheets and lacquers are available.

If you have fluorescent light fittings, remember:

- low UV-emitting fluorescent tubes should be used. If you use these, give instructions that the same type of tubes should be purchased when the existing ones burn out; and
- low UV-emitting fluorescent tubes are more expensive than ordinary tubes. It can be tempting to replace these with cheaper and more readily available tubes. If low-UV fluorescent tubes are ever replaced with ordinary tubes, the new ones should be filtered.

If you use incandescent tungsten spotlights or floodlights, remember:

- the intensity of the light is greater the closer the light source is to the object; and
- if the light source is too close to an object, it can cause the temperature to rise, which can lead to damage.

Control light levels by design

Lights should be on only when visitors are viewing a display. You could install switches that turn lights on when people approach particular areas of the display and then turn off after a set period of time.

Covers or curtains can be placed over or in front of a display, for the viewer to move as required. These can be used as part of your exhibition design. Signs explaining why you have curtains will make your audience more aware of the work involved in properly caring for collections.

If your collection includes items that are likely to be damaged by light:

- in an exhibition, try to group them in one area and ensure this area has appropriately low light levels;
- don't keep all items on permanent display; and
- rotate items in the exhibitions, so their annual exposure to light is kept low.

Screens and partitions can be used to create semi-closed areas with lower lighting levels than the general display area. Partitions can provide intimate spaces for exhibits, or create a path through your exhibition.

Arrange display areas so areas with low lighting levels don't appear dark:

- an area with low lighting will appear to be much too dark for viewers who enter from an area that is quite bright—like walking from bright sunlight into a dark room. However, if viewers move through areas in which the lighting levels gradually become lower, their eyes will adjust gradually, and the low lighting level will be quite acceptable for viewing.

Separate areas for separate activities

Wherever possible try to separate different activities into different spaces. For example,

- display, storage and work areas have different lighting requirements, and should be separated;
- items that are not on display should be stored in a separate area, which is lit only when access is required; and
- areas used for reading, for accessioning or for checking the condition of items need higher lighting levels, so people can see well enough and do detailed work. These areas should be separate from storage and display areas.

If it is not possible to separate activities, consider installing dimmer switches, so the lighting levels can be adjusted according to the activity taking place.

CAUTION:

Remember, photocopiers and photographic flashes are sources of intense light—exposure of sensitive items to these should be kept to a minimum.

Light sources in museums, galleries and libraries

Visible light is necessary in museums, galleries and libraries. But, as already noted, it is often accompanied by other forms of radiation that are unnecessary and undesirable.

The major sources of visible light in museums, galleries and libraries—daylight and artificial light produced by incandescent bulbs and fluorescent tubes—are also sources of UV and infrared radiation.

Daylight

Daylight is bright and hot, and contains a high proportion of UV radiation. Ordinary glass, used in windows and skylights, blocks the most damaging, high-frequency, longer wavelength UV radiation. But it does not block the lower frequency range that can still cause damage to sensitive materials.

Daylight is not essential for a display or working environment. You can reduce unwanted UV radiation by careful use of artificial lighting.

Artificial light

There are many types of artificial light sources. Each has advantages and disadvantages:

- incandescent tungsten lamps, in spot or floodlights, have a low UV output, but emit infrared radiation in the form of heat. Therefore, if they are close to items or placed in a closed case, they can cause damage by raising the temperature of the objects;
- fluorescent light tubes are cold, but many emit higher than acceptable levels of UV radiation. However, fluorescent tubes are generally favoured, because they are more cost-effective to run and are longer-lasting than incandescent bulbs; and
- tungsten halide bulbs, which are more efficient than ordinary incandescent bulbs, also give out higher than acceptable levels of UV.

What lighting levels are acceptable?

In order to minimise damage, lighting levels should be kept low. But what is a low level of lighting and what is too high?

In considering appropriate levels of lighting, take into account the following factors:

- how sensitive the materials are to damage by visible light and UV radiation; and
- the activities that take place in the area being considered.

Keep in mind that the amount of damage caused by photochemical reactions depends on the energy of the radiation as well as the amount of radiation that falls on the material for the whole time it is exposed.

Guidelines for lighting levels, UV levels and length of exposure to light for materials of different sensitivities have been developed. An outline of the guidelines follows with further explanation in the next section.

For sensitive materials

Note: Sensitive materials include items such as textiles and watercolours.

- The brightness of the light should be no greater than 50 lux.
- The exposure in one year should be no greater than 200 kilolux hours.
- The UV content of the light on sensitive materials should be no greater than 75 µW/lm—microwatts per lumen—and preferably below 30 µW/lm.

For moderately sensitive materials

Note: Moderately sensitive materials include items such as oil paintings and furniture.

- The brightness of the light should be no greater than 250 lux.
- The exposure in one year should be no greater than 650 kilolux hours.
- The UV content of the light should be no greater than 75 µW/lm—microwatts per lumen—and preferably below 30 µW/lm.

Non-sensitive materials

Note: Non-sensitive materials include items such as stone and metal.

- Objects that are not particularly sensitive to light should still be protected.
- Do not unnecessarily expose them to very high lighting or UV levels.

Remember also that many objects are made from composite materials and may contain small amounts of sensitive materials.

What do these levels mean?

To get an idea of what the guideline levels for the brightness mean, it is useful to compare them to recommended lighting levels for more familiar areas where other activities take place. Lighting designers recommend:

- desktops in reference library reading rooms should be lit to 500 lux;
- drawing boards in drawing offices should be lit to 750 lux;
- car showrooms should be lit to 500 lux;
- domestic kitchen work surfaces should be lit to 300 lux;
- cinemas, at seat level, should be lit to 50 lux; and
- conservation laboratories in galleries and museums should be lit to 2000 lux.

It is clear that the use of a particular area contributes to what is an acceptable level of illumination for that area.

For example, items in conservation laboratories can be exposed to bright light, because conservators must see clearly what they are doing to carry out delicate treatments, and because they will not be exposed to that intensity of light for extended periods of time.

Lux? Kilolux hours? μW/lm? Help!

Lux, kilolux hours and microwatts per lumen are units for measuring different qualities of light. They can be explained quite simply.

Lux:

- Is the unit which indicates the intensity to which a surface is lit, or the brightness of the light.
- The closer the light source is to the surface being lit, the higher the lux value will be, that is the greater the intensity of light.
- So if we want to lower the intensity of light falling on an object we can simply move it further away from the light source. For example, if the brightness or intensity of light falling on a object is measured at 100 lux when the object is 1 metre away from the light source, we can alter that intensity to 25 lux by moving the object to a distance of 2 metres from the light source.

Kilolux hours:

- Is the unit which indicates the exposure to light over a period of time.
- Take the example of an historic costume on permanent display in a museum. The museum is open 5 days a week for 5 hours a day all year round and while the museum is open, the costume receives light to an intensity of 200 lux. In a year the costume is exposed to:

  5 x 5 x 52 x 200 lux hours = 260000 lux hours or 260 kilolux hours

- This could be brought to within the levels recommended in the guidelines by adjusting the intensity of light falling on the costume and/or reducing the display time. For example, if the intensity of light was lowered to 50 lux and the costume was on display for only 6 months of the year, the total annual exposure would be significantly altered:

  5 x 5 x 26 x 50 lux hours = 32500 lux hours or 32.5 kilolux hours

μW/lm, Microwatts per lumen:

- Are the units which indicate the amount of UV energy in the light coming from a light source.
- Microwatts are a measure of energy; lumens measure the quantity of light from a particular light source.
- This measurement is constant for a light source and does not alter if the readings are taken at a greater distance from the source.
- If we want to lower the UV content of the light, we can use absorbing filters on windows or on fluorescent tube fittings, or we can install lights that give out only small amounts of UV radiation. Above all we must try to exclude sunlight.

Special instruments can be purchased to measure light and UV levels. The intensity of light on an object is measured with a lux meter and the UV content of the light is measured with a UV meter.

Measuring light and UV radiation

Measuring lux

The device used to measure the brightness of light falling on an object is a lux meter.

A lux meter

Photograph courtesy of Artlab Australia

The meter is held close to the object, facing the light source. It measures the number of lumens, that is, the quantity of light of all wavelengths per square metre.

When setting up your exhibitions, it is handy to have a lux meter. By moving it to different distances from the light source, you can determine a suitable position for the object in relation to the light.

Measuring microwatts per lumen

The amount of energy in the ultraviolet band can be measured using a UV meter/monitor.

This device measures the amount of ultraviolet light energy in each lumen of light.

Measuring the UV content of light can be useful in determining whether or not you have a problem. For example, a conservator taking UV readings in an art centre in the far north of South Australia expected very high UV content. The building is not in a sheltered position and the principle light source is sunlight. The readings, however, were low, because the building has Perspex windows instead of glass. Perspex does not allow as much UV radiation to pass through it as glass. Because the Perspex develops static electricity, it attracts the red dust which surrounds the building. This also helps to reduce UV radiation passing through the windows. In this case, a problem was expected, but did not in fact exist.

UV Monitor

Photograph courtesy of Artlab Australia

Measuring infrared energy

Infrared energy can be measured using a simple thermometer. Infrared light causes objects to heat up. So by measuring the rise in temperature with a thermometer placed near the object and directly exposed to the light, we can get an indication of the quantity of infrared energy.

MORE ABOUT LIGHT AND UV RADIATION

Light and UV radiation are types of energy

Light and UV radiation are forms of radiant energy. They are part of what scientists call the electromagnetic spectrum.

Energy can be defined as the capacity for doing work. The greater the amount of energy available, the more work that can be done. If this work is a chemical reaction leading to deterioration of an object, then the more energy available, the greater the damage that will result.

What is light?

Attempts to understand the nature of light and to adequately describe it have involved scientific experiments and debate over many centuries which are still continuing to this day. This work has led to our present knowledge of the nature of radiant energy and the existence of the electromagnetic spectrum.

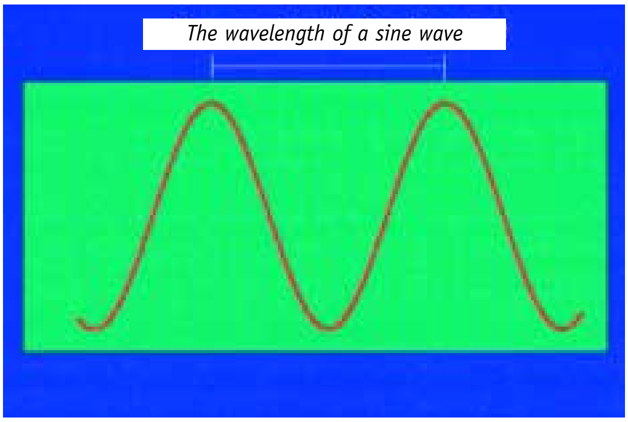
However, to understand light and its effects on objects, we don't need to be physicists! A basic description of radiant energy and the electromagnetic spectrum is adequate for our purpose.

In the mid-19th century it was accepted that light consists of waves. Then, at the turn of the 20th century, light was described as a stream of tiny particles because the wave model did not fully account for some properties of light where it behaves like discrete solid matter—albeit invisible.

To this day, both models are considered correct. Though what light is precisely—wave or particle—let alone what it looks like, is still a mystery.

Nonetheless, light is a form of electromagnetic radiation and travels in waves and as particles, delivering discrete energy in bundles or quanta called photons.

A closer examination of the wave model of light provides information necessary for a more complete understanding of visible light and UV radiation. The sine wave shown below gives us a basic visual aid for the definition of some important terms and will be used to introduce some concepts regarding radiant energy.



The energy in the diagram is travelling horizontally. As it travels, it moves in a wave motion passing through peaks and troughs. The distance between the peaks of the waves is called the 'wavelength' and is measured in nanometres—nm.

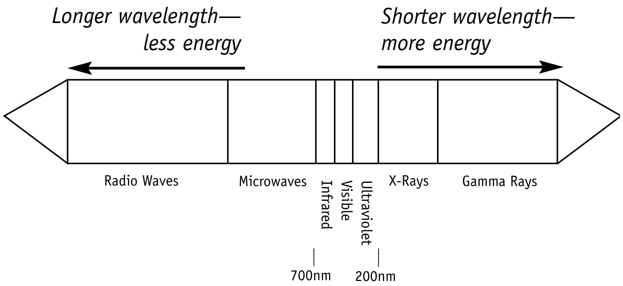
There is a mathematical relationship between the amount of energy transmitted and the wavelength of the radiant energy—namely, they are inversely proportional. In other words, the longer the wavelength the less energy transmitted, and the shorter the wavelength the more energy transmitted.

This is true for the entire electromagnetic spectrum.

The electromagnetic spectrum

The light visible to humans is electromagnetic radiation with wavelengths ranging from approximately 400–700 nm.

But this is only a very small part of the electromagnetic spectrum. The full spectrum has wavelengths ranging in excess of several hundred metres to less than a billionth of a metre. The spectrum is broken into ranges according to the amount of energy transmitted and, therefore, the effect they have on matter.

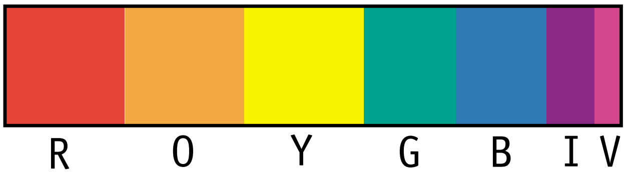


The electromagnetic spectrum with some indicative wavelengths

If you keep in mind that the longer the wavelength, the less energy that is transmitted, we can see:

- radio waves do not transmit as much energy as gamma radiation; and
- infrared radiation is less energetic than UV radiation. The higher energy transmitted by UV radiation is known to be harmful to humans, causing sunburn and skin cancer.

Visible light is further categorised into a spectrum of red, orange, yellow, green, blue, indigo and violet light. We see these distinct colours because the different wavelengths have different energies, and so affect our eyes in different ways.



The visible spectrum

Within the visible light range, the violet/blue end of the visible spectrum is more energetic and so more harmful than the red wavelengths. This has implications for museums, galleries and libraries in the choice, for example, of luminaires—light sources—for exhibitions.

How does the energy cause damage?

When electromagnetic energy encounters matter, such as items in a museum, gallery or library, it is readily converted to mechanical, chemical or electromagnetic energy of a different frequency.

Depending on the amount of energy being carried by the waves electromagnetic energy can:

- cause the object to heat up;
- initiate simple chemical reactions; and
- produce complex chemical reactions called photochemical reactions. If these reactions produce deterioration, it is called photochemical deterioration.

Photochemical deterioration

In the museum environment, photochemical reactions are most likely to be initiated by UV radiation and the higher energies of visible light, that is, 320–500 nm. UV radiation nearly always accompanies visible light, because it is produced by the sun and by some common luminaires, such as fluorescent tubes and tungsten halide bulbs.

Photochemical reactions are rarely isolated or short-lived. For example:

- sometimes a new substance, which forms as a result of the initial photochemical reaction, has sufficient energy to also react with the original substance and produce further chemical change. This is called a ‘chain reaction because the light produces not just one chemical change but a whole series of them; and
- if this happens while the object is still exposed to light, a whole range of chain reactions will occur at a rapid pace.

You should be aware that the amount of damage depends not only on the wavelength of the light, but also on the amount of light that falls on the material for the whole time it is exposed.

And remember that some of these chemical reactions continue after the exposure has stopped. The deterioration reaction does not stop when the material is placed in the dark. Light damage is cumulative.

Examples of typical deterioration of artefacts because of photochemical reactions include:

- dyes fading and changing colour. This is perhaps the most obvious damage caused by light and UV radiation. It can also be seen that the radiation has its greatest impact on the surface of the object, for example, dyes on the exposed side of a carpet will fade, while dyes on the unexposed side appear to retain their original colour;

The areas protected from light, for example, in the armpit of this dress, have not faded.

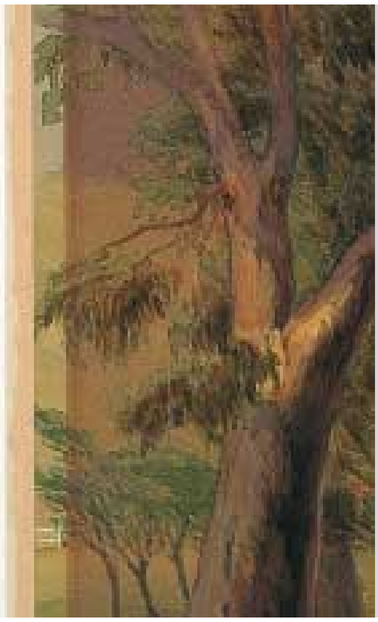
Photograph courtesy of Artlab Australia

- watercolours fade and change colour. This is often noticeable only when the watercolour is removed from its mount. The edges of the work, which have been covered by the mount, often seem to have stronger colour than the part of the work that has been exposed;

The pigments on the very edge of this watercolour have not faded because they have been protected by the mount.

Photograph courtesy of Artlab Australia

- paper yellows. When prints are removed from their mounts, you may see light-coloured paper at the edges that have been protected by the mount, while the exposed paper has become yellowed or even brown;



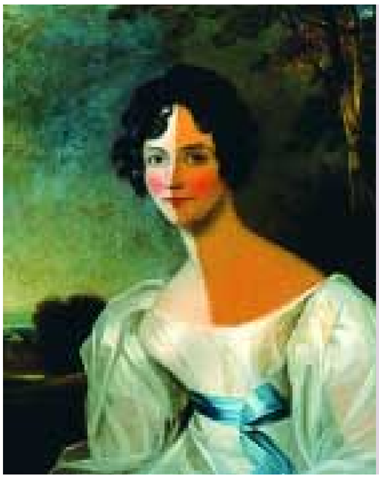
The areas of paper that have been exposed to light have discoloured badly; in contrast to the area at the edge which has been protected by the mount.

Photograph courtesy of Artlab Australia

- paper becomes brittle. The cellulose molecules break down. This can be caused by photochemical reactions in the actual paper fibres or by photochemical reactions involving other materials in the paper or used with the paper. These materials break down because of the production of acids in the reactions. These acids attack the paper fibres and this continues even when the paper is no longer exposed to the radiation;

- textiles deteriorate and discolour. Silk, wool and cotton are all affected by light and UV radiation. But the reactions they undergo are different, because of their differing chemical compositions. Cotton will react in a similar way to paper because both are cellulose-based; it will darken and become brittle. Wool and silk are made up of proteins, and behave differently from cellulose-based materials. Both wool and silk are bleached by visible light, and will yellow when exposed to UV radiation; and

- oil paintings change. This can include the yellowing of varnishes and an increase in the transparency of paints. Changes can also involve complex interactions between the oils, the pigments and the varnishes.



A painting during treatment. You can clearly see the extent to which the varnish had discoloured.

Photograph courtesy of Artlab Australia, reproduced with permission of Skipper Garnthan

Deterioration of museum objects caused by photochemical reactions is inevitable. However, there is much that can be done to minimise this. By being aware of the sources of harmful radiation, museum staff can take positive steps to eliminate it or reduce it significantly.

Sources of light and UV radiation

There are two common ways of making light. One way is to heat something until it glows. This is the principle used for incandescent bulbs. Heating the tungsten element causes it to emit or give out light. The other way to make light is to excite something electrically so that it fluoresces. Fluorescent light tubes and television screens are examples of this method.

Light from heat

When an object is heated, it gives out light. A hot object emits a broad spectrum of light. However, the frequency and wavelength at which most of the light is emitted depends on the temperature of the object. The hotter the object, the shorter the wavelength of the energy emitted. That is, the hotter the object, the greater the energy emitted.

Observing a piece of metal in a very hot flame will demonstrate this relationship. For example, when the metal starts to heat up, it will initially glow a dull red colour. As it becomes hotter, the colour will become a brighter red, then yellow—the frequency is increasing, the wavelength becoming shorter and more energy is being transmitted. This continues, and the metal glows blue and eventually white.

Incandescent light bulbs

Incandescent light bulbs consist of a filament of tungsten metal suspended between two electrodes inside a sealed glass bulb. The bulb is filled with an inert gas to prevent the tungsten from burning up when it gets hot. When an electric current flows between the electrodes, the tungsten is heated.

The operating temperature of incandescent light bulbs is about 2,500°C. At this temperature tungsten emits most of its light in the infrared range. This is why light bulbs get so hot. But less than 10 per cent of the energy used to power a light bulb is converted into visible light, meaning they are not very efficient. A much smaller amount of power is converted into UV radiation, making incandescent light bulbs a low emitter of UV radiation.

Tungsten halide bulbs

Tungsten halide bulbs operate at a much higher temperature than incandescent light bulbs, usually at about 3,500°C. They emit more light in the visible range, and so are brighter light sources than ordinary incandescent bulbs. They also emit more UV radiation than incandescent light bulbs.

The sun

The sun also emits light because it is a hot object. Its surface temperature is approximately 6,000°C. At this temperature, the sun emits not just heat, but also a tremendous amount of light at higher frequencies and shorter wavelengths than an incandescent light bulb.

Overall, the sun emits about 9 per cent of its light in the UV range, 41 per cent in the visible light range and 50 per cent in the infrared range.

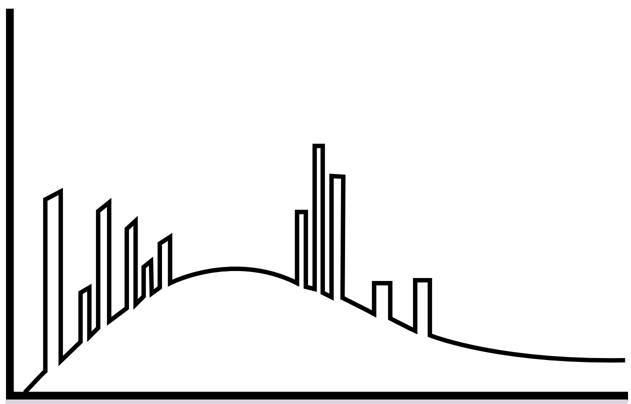
Fluorescence

Fluorescent lights work because some materials fluoresce, that is, they absorb radiation at one frequency and then give it out at another frequency.

The materials used in fluorescent lights are known as phosphors. Different phosphors are selected for use in fluorescent tubes, depending on the specific frequencies of the light they emit.

The inside of the tube is coated with the selected phosphors. A gas inside the tube becomes excited when the electric current is switched on. The excited gas emits light, which is absorbed by the phosphors and re-emitted at a different frequency.

The sharp peaks of a fluorescent spectrum are made up of light emitted by both the phosphors and the gas. The material becomes hot during this process, so that it also emits some light in the same way as hot objects.



The spectrum of light from a fluorescent light tube is composed of a continuous curve caused by thermal—hot object—emission, with sharp peaks corresponding to strong fluorescent light emission at specific wavelengths. The position of the fluorescent peaks depends on the phosphors selected for the fluorescent tube.

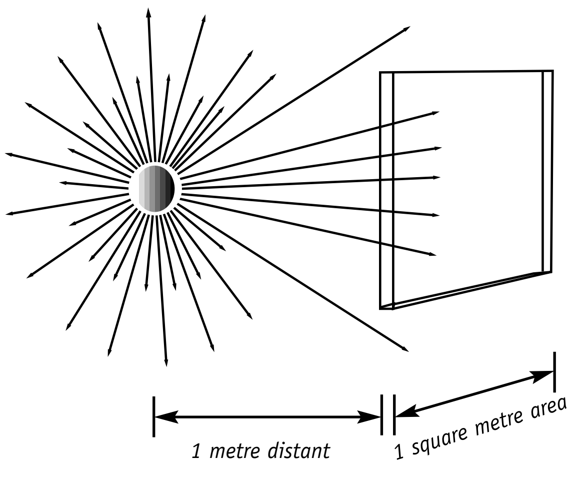
The main advantage of fluorescent lights is that they are very efficient at converting electrical energy into light. This is because most of the power goes into generating light at a few specific frequencies, rather than generating energy over a wider range of frequencies, as incandescent bulbs do. This means that fluorescent lights do not waste energy-producing infrared radiation or heat, as incandescent lights do. Fluorescent lights are therefore cooler and cheaper to run, and last longer.

By selecting particular combinations of phosphors, lighting manufacturers can determine the type of light a fluorescent tube emits. This characteristic is an important consideration when choosing your light source. If fluorescent lighting is to be used in museums, galleries and libraries, care must be taken to select only those types of tubes which emit very little ultraviolet light.

The brightness of light

From experience, we know that the closer we stand to a light bulb the brighter it seems. This is a simple consequence of geometry.

Light spreads out in all directions from its source, rather like a ripple on a pond. The farther away we are from the source, the more spread-out the light is and so it becomes dimmer.



Brightness is expressed as the number of lumens passing through a given area. The brightness of the light an observer sees, therefore, depends on how many lumens catch their eye. For convenience, this area is defined as one square metre and the name given to this unit is lux.

Lux = lumens/sqm

The mathematical law that describes the radiating behaviour of light is the inverse square law. This law states the brightness of the light decreases according to the square of the distance from the source. For example:

- if the observer is 1 metre away from a light and sees a brightness of 100 lux, then at 2 metres distant they will see a brightness of only a quarter — $\frac{1}{2 \times 2}$ — of this, or 25 lux; and
- at 3 metres, they will see a brightness of a ninth — $\frac{1}{3 \times 3}$ — or 11 lux.

The inverse square law is useful to help determine the placement of lighting in a museum, and has important outcomes for the wellbeing and longevity of the art and valuable objects.

Additional information about the units used to measure light

In order to control the effects of light in a museum, gallery or library, it is useful to measure properties such as:

- the brightness or intensity of the light;
- the composition of the light and whether UV radiation is present; and
- how much energy is contained in the light.

Brightness or intensity has already been discussed in some detail; but some of the other units used to measure light may need further explanation.

Watts are the amount of energy that falls on an object per second. This should not be confused with the wattage rating of a light bulb, which is a statement of how much electrical energy goes into the bulb to make it work, not how much light energy comes out.

Lumens are the units that measure luminous flux, that is the amount of light given out by a light source. A 100 watt incandescent bulb, for example, emits about 1200 lumens.

Because light is composed of different wavelengths—or energies—we often need to know the distribution of energy amongst the different wavelengths. This is what we are doing when we measure the UV content of light falling on an object.

So a measurement from the UV meter of 50 microwatts per lumen indicates there are 50 units of energy in the UV wavelength band in every unit of light being monitored.

If you have a lighting problem and don't know how to deal with it, contact a conservator. Conservators can offer advice and practical solutions.

For further reading

Brill, Thomas B., 1980, *Light, Its Interaction with Art and Antiquities*, Plenum Press, New York.

Gardner, Carl, & Hannaford, Barry, 1993, *Lighting Design—An Introductory Guide for Professionals*, The Design Council, London.

The Chartered Institute of Building Services Engineers, 1994, *Lighting for Museums and Art Galleries—LG8 1994*, The Chartered Institute of Building Services Engineers, London.

Thompson, Paul & Wallace, Jim, 1994, *Exhibition Installation & Lighting Design,* Art on the Move, Perth.

Thomson, Garry, 1994, *The Museum Environment*, 3rd edn, Butterworth-Heinemann, Oxford.

Self-evaluation quiz

Question 1.

Which of the following statements are true?

a) Light is necessary in museums, galleries and libraries.

b) Light does not cause damage.

c) Light levels that are appropriate for people working are fine for objects too.

d) UV radiation can be very damaging.

Question 2.

Which of the following statements are true? Visible light:

a) causes extreme and irreversible damage to organic materials;

b) is often accompanied by UV radiation and infrared radiation;

c) can cause fading of dyes;

d) can lead to the discolouration of paper and cotton fabric;

e) all of the above.

Question 3.

List the following types of light or radiation in this order: from the most energetic to the least energetic, that is, the most damaging to the least damaging.

a) Infrared radiation.

b) Green light.

c) UV radiation.

d) Yellow light.

e) Blue light.

Question 4.

Which of the following materials are considered to be very sensitive to light?

a) Stone.

b) Oil paintings.

c) Textiles.

d) Watercolour pigments.

e) Natural history specimens, such as feathers and fur.

Question 5.

Preferred light sources for museums, galleries and libraries are:

a) fluorescent tubes;

b) sunlight;

c) low-UV emitting fluorescent tubes;

d) tungsten incandescent bulbs.

Question 6.

If you rely a lot on daylight in your museum, gallery or library you should:

a) try and eliminate all direct sunlight;

b) let the sun shine in as it produces a lovely summery atmosphere;

c) use curtains and blinds over windows and skylights to diffuse the light;

d) use filtering films on your windows to eliminate the UV radiation from the light coming into the room.

Question 7.

You can take steps to reduce light damage by:

a) moving objects further away from the light source to reduce the brightness of the light;

b) installing dimmer switches on lights;

c) reducing the length of time that items are on display;

d) grouping light-sensitive items in low-light areas;

e) turning off lights if people are not viewing the display;

f) all of the above.

Question 8.

What is the name of the unit which is used to measure the intensity or brightness of visible light?

a) Lumen.

b) Lux.

c) Microwatts.

d) Kilolux hours.

Question 9.

'Microwatts per lumen' is a measure of:

a) daylight;

b) light from a fluorescent tube;

c) the amount of UV energy in a light source;

d) the distance between an object and the light source.

Question 10.

What is the recommended maximum light level for the display of a watercolour?

a) 75 lux.

b) 250 lux.

c) 650 kilolux hours.

d) 50 lux.

Question 11.

What is the recommended maximum light level for the display of an oil painting?

a) 75 lux.

b) 250 lux.

c) 650 kilolux hours.

d) 50 lux.

Question 12.

What is the exposure, in kilolux hours, of a costume displayed for 11 weeks in a museum which is open for six hours a day, six days a week and where light falling on the costume has been measured as 150 lux?

a) 69,300.

b) 59.4.

c) 59,400.

d) 69.3.

Answers to self-evaluation quiz

Question 1.

Answer: a) and d) are true. b) and c) are false. Light can be very damaging and there is often a need to compromise between accommodating people's needs and the needs of valuable items.

Question 2.

Answer: e).

Question 3.

Answer: c), e), b), d) and a).

Question 4.

Answer: c), d) and e). Oil paintings are considered moderately sensitive and stone is considered non-sensitive.

Question 5.

Answer: c) and d).

Question 6.

Answer: a), c) and d).

Question 7.

Answer: f).

Question 8.

Answer: b).

Question 9.

Answer: c).

Question 10.

Answer: d).

Question 11.

Answer: b).

Question 12.

Answer: b).