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Museum Lighting

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Abstract

The light so necessary for the viewing of works of art and museum objects can induce chemical reactions which cause deterioration of those objects as evidenced by the fading of dyes and pigments and the embrittlement of paper and textiles. The purpose of this bulletin is to enable museum and gallery staff to become more aware of problems associated with museum lighting and of techniques for minimizing deterioration that may be caused by it.

The bulletin starts with a general description of the nature of light and an explanation of concepts and quantities which are the necessary background to understanding of the problem. Some of the concepts introduced are frequency and wavelength, the electromagnetic spectrum, the black body radiator and colour temperature. The units in which lighting quantities are measured such as the lumen, the foot-candle, the lux and the candela are defined.

The characteristic differences of radiation from different sources such as natural lighting, fluorescent lighting and incandescent lighting and the implications these differences have with respect to photochemical deterioration are examined.

Recommended safe lighting levels are given and practical ways of reducing the levels of light intensity and eliminating the most damaging portion of the radiation are discussed together with psychological considerations relating to the shift in colour temperature as lighting intensities are reduced.

Résumé

La lumière si nécessaire pour voir les oeuvres d'art et les objets exposés dans les musées peut causer des réactions chimiques qui détériorent ces objets, comme en témoignent l'altération des teintures et des pigments et la décomposition du papier et des textiles. Ce bulletin a pour but de sensibiliser le personnel des galeries et des musées aux problèmes relatifs à l'éclairage des oeuvres et aux techniques visant à réduire les dommages qu'il peut causer.

Les premières pages du bulletin contiennent une description générale de la nature de la lumière et une explication des concepts et quantités qui forment la base des données nécessaires à la compréhension du problème. On y présente la fréquence et la longueur d'onde, le spectre électromagnétique, le radiateur à corps noir et la température de la couleur. Les unités de mesure de la lumière, telles le lumen, la bougie-pied, le lux et la candela y sont définies.

On examine les différences caractéristiques de radiation émanant de diverses sources, par exemple l'éclairage naturel, fluorescent ou incandescent et les conséquences qu'amènent ces différences relativement à la détérioration photochimique.

On donne les niveaux d'éclairage acceptables et on discute des méthodes pratiques de réduire les niveaux d'intensité lumineuse et d'éliminer la partie la plus dommageable de la radiation, de même que les considérations psychologiques liées au changement de température de la couleur à mesure que sont réduites les intensités lumineuses.

1. Introduction

The need for museum staff to know something about light and lighting hardly requires justification. Without light nothing can be seen and changes in the quality of light can drastically alter the colour rendition of artifacts. On the other hand, light has certain less desirable properties in contributing to the deterioration of objects. The fading of dyes and pigments is a prime example of this undesirable characteristic. It therefore behoves anyone involved in the display of artifacts to learn something about lighting.

However, it is not easy for anyone without some scientific background to acquire knowledge in this field. Even from the point of view of physics, colour and light are complex subjects with active research still in progress to clarify unresolved points. To compound the difficulty further, colour rendition is not purely physical but there are physiological and psychological dimensions as well. Small wonder then if even the best intentioned throw up their hands when faced with a text book in this field.

This Technical Bulletin addresses itself to people without a scientific background; there are abundant scientific treatises for those who can use them. Our aim here is merely to provide, in as readable a manner as possible, the background necessary to acquire a feel for the subject and to provide a vocabulary sufficient to converse with architects and lighting engineers. That is not to say though that this can be done without some effort on the part of the reader. Some of the definitions will appear somewhat abstract but the learning of a minimum technical vocabulary cannot be avoided.

2. Light and Electromagnetic Radiation

One way that physicists have of describing radiation, such as visible light, is as a wave motion, by which they mean that the electrical and magnetic properties of space change in such a way as to repeat themselves periodically over time and distance much as waves of water radiate out from a pebble dropped into a still pond. The time that expires between the passage of the crest of one wave at a particular spot and the appearance there of the next crest is termed the period. Closely related to the period (in fact the inverse) is the frequency which is the number of waves passing a particular point in one second. Frequency is measured in hertz which is one wave per second. The symbol for frequency is f in this bulletin. The symbol ν is often but not always used for f. The distance between successive crests (or between successive troughs) is called the wavelength, usually measured in fractions of a metre such as a centimetre which is one hundredth (i.e. 10^{-2}) of a metre, a micrometre which is one millionth (i.e. 10^{-6}) of a metre, or a nanometre which is one billionth (i.e. 10^{-9}) of a metre. One also encounters the Angstrom Unit, abbreviated Å, which is one ten-billionth (i.e. 10^{-10}) of a metre. The wavelength is frequently symbolized by the Greek letter λ.

If the number of waves passing a point in one second is f and the length of each wave is λ then, clearly, any particular wave will travel a distance of $f\lambda$ in one second, i.e. the speed or velocity of the wave motion is equal to the frequency multiplied by the wavelength. The speed of all wavelengths of radiation in a vacuum is a constant, approximately 30 billion centimetres per second

(3 x 10^{10} cm/sec.) or 186,000 miles per second. Their velocity is usually denoted by the symbol c, and, for those who like algebra the relation between velocity, frequency and wavelength can be summarized by:

$$c = f\lambda$$

One can see that since c is a constant, the wave length, λ, must increase as the frequency, f, decreases and vice versa. There is a complete spectrum of electromagnetic radiation of different wavelengths from very large to vanishingly small and since each frequency is related to its corresponding wavelength by the above expression it suffices to specify either the wavelength or the frequency in order to completely describe a pure, unmixed radiation propagating in a vacuum. (1)

In Figure I is shown a chart of the major divisions of the electromagnetic spectrum. As the wavelength changes the properties of the radiation change, not sharply as suggested by the schematic representation, but gradually from one major type of radiation to the next. Figure 2 shows that very small portion of the total electromagnetic spectrum which we call the visible region, the wavelengths associated with spectral colours, and portions of the ultraviolet and infrared spectral regions immediately adjacent. For our present purposes we really need concern ourselves only with the band shown in Figure 2.

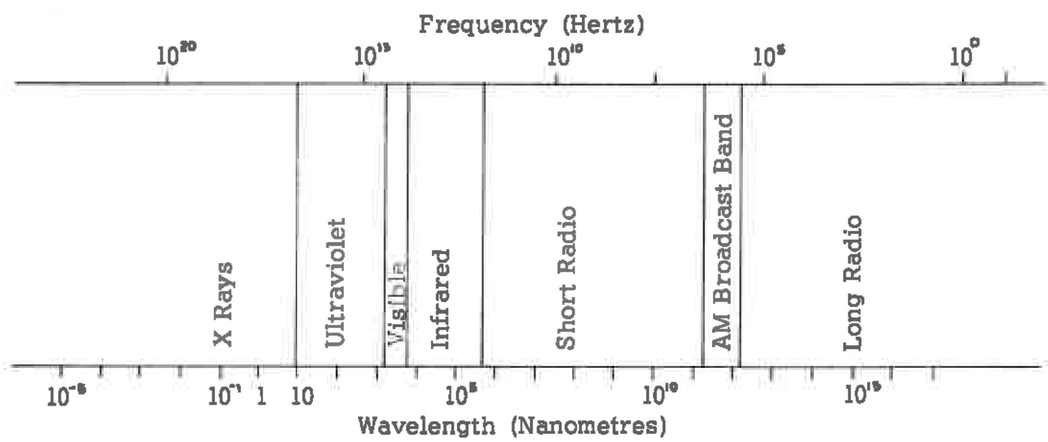

Figure 1 THE ELECTROMAGNETIC SPECTRUM

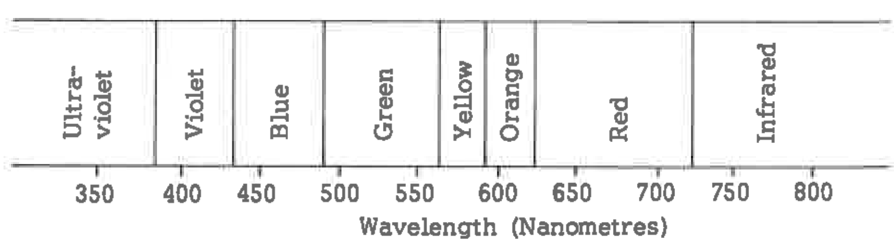

Figure 2 THE VISIBLE SPECTRUM

Object deterioration associated with the IR component of illumination is almost exclusively thermal. The infrared radiation absorbed by molecules causes the temperature of the objects to rise thereby increasing the rate of deterioration. Visible and especially ultraviolet radiation on the other hand is sufficiently energetic to induce photochemical deterioration. To see why this is so we must consider another aspect of radiation, its energy.

In addition to viewing light as an electromagnetic wave motion in space, modern physicists find it useful to consider it as consisting of tiny corpuscles of energy called photons and the amount of energy associated with a photon is given by the expression:

$$E = hf$$

where f is the frequency as before and h is a constant (Planck's constant). The point of this is that as the frequency increases (or in other words as the wavelength decreases) the radiation becomes more energetic. Thus, as we pass from red light through the visible and into the ultraviolet the wavelength becomes shorter, the associated energy greater and the liklihood of photochemical deterioration greater. Fortunately, glass strongly absorbs radiation shorter than 300 to 310 nanometres so that museum objects will not be subjected to the most damaging rays. Nevertheless, radiation between 300 and 400 nanometres must be excluded since it may be damaging to the object. Details of how the deterioration occurs are given below in the section on Photochemical Deterioration.

3. Colour Temperature and the Black Body

When light of one or more wavelengths falls on a white object all wavelengths are reflected with high efficiency. That is why it appears white if white light is the illuminant, red under red light, etc. If a material absorbs virtually all of the visible light incident upon it then there can be no reflection to excite the retina of the human eye and the object appears black. Coloured objects absorb certain wavelengths of light but reflect the rest. A red object, for example, reflects mainly in the red region of the spectrum so if illuminated by white light it will absorb all wavelengths except those in the red portion (>620 nm) which are reflected and the viewer perceives the object as red.

Black objects are efficient absorbers of light. Any stable object, if it is to remain at a constant temperature, must radiate as much energy as it absorbs so a black object must also be an efficient radiator. However, the energy emitted, although equal to the absorbed energy, is not in general associated with the same wavelengths as the incident light. Thus a black object at room temperature absorbs all of the incident light but only emits very long infrared rays which the human eye cannot perceive.

Starting with the fact that a black material is a good radiator, physicists have conceived a theoretical absorber-radiator that they call a black body or perfect radiator. They have derived equations for which graphs can be drawn showing the relative amount of energy emitted at each wavelength by a black body at any temperature. When a body is heated it begins to give off infrared radiation and a hand placed near it feels warm; if further heated it begins to glow red. Subsequent heating results in the emission of radiation of shorter and shorter wavelengths with the object going through stages of dull red, bright red, orange, yellow and finally white and even bluish. The black body behaves in the same way in that there is a definite distribution of the energy associated with each wavelength irradiated, which is unique for each temperature. As stated above, the black body is a theoretical concept but it can be very closely approximated by a special furnace (which can be operated at different temperatures) in which the radiation is emitted through a small porthole. To specify the temperature it is usual to use the so-called absolute temperature expressed in degrees Kelvin. [2] Real objects may more or less closely approximate the behaviour of the theoretical black body at varying temperatures.

In Figure 3 there is a set of curves showing the relative energies of the spectra emitted by a black body at different temperatures. Though the energy at all wavelengths increases with increasing temperature, for convenience in preparing the graph the amount of energy at 550 nm is arbitrarily taken as 100. As may be seen, relatively more radiation of shorter wavelength appears as the temperature is increased, and if one were to view the emitted light it would appear reddish at low temperatures and become whiter and finally bluish as the temperature was raised.

The practical value of graphs for black body radiation such as those in Figure 3 is that they provide a way - not very precise but still a way - to clarify the colour rendering characteristics of different light sources.

We can measure the spectral energy distribution of the light emitted by a tungsten light bulb, say a 100 watt bulb, and compare the graph for it with a set of graphs for a black body at different temperatures. Since the tungsten lamp is not a black body, its graph will not be identical with any of the black body curves. However, it is found that there is a rough accord between the graph for the light bulb and that for a black body at 2860°K. We can then say that the colour temperature of this 100 watt light bulb is 2860°K, that is, the emission spectrum more or less closely approximates that of a black body at a temperature of 2860°K. We

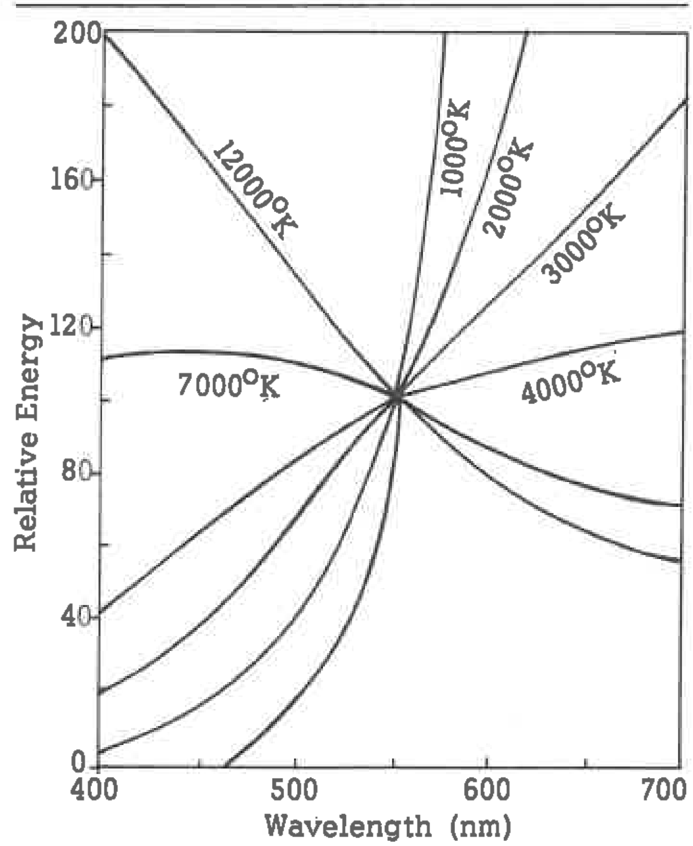

Figure 3 - Relative energy distributions of black body radiators at various temperatures.

could make similar spectral measurements of examples for noon sunlight in summer; this is shown in Figure 4. This diagram illustrates just how rough the correlation is between the graph for the real light source and the black body, particularly at the short wavelength (blue) end of the spectrum. Nevertheless, it does permit us to assign a value to the colour rendering characteristics of the sunlight. Similar

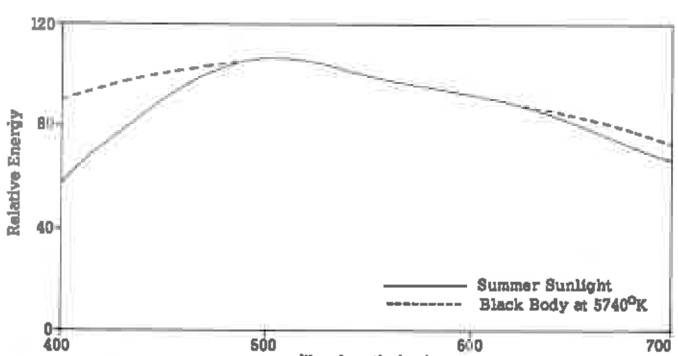

Figure 4 - Energy distribution curves for sunlight as compared with distributions of black bodies of like colour.

experiments will permit us to assign a colour temperature to many other light sources such as a candle, a photoflood lamp, etc. A problem arises though if we attempt to use this method to assign a colour temperature to such light sources as fluorescent lamps, mercury arc lamps, etc. because the distribution in no way resembles the curves for black bodies. As may be seen in Figure 5, the spectral distribution curves for fluorescent lamps have projections or 'spikes' (3) on them, corresponding to very high energy at specific wavelengths, which make them quite unlike those we have seen hitherto and which renders any comparisons if not meaningless, highly artificial. Even a so-called 'daylight' fluorescent tube has an energy distribution completely different from sunlight or from a black body. Fluorescent tubes are assigned the colour temperature of the black body which appears to the human eye to be of the same colour as that of the source in question.

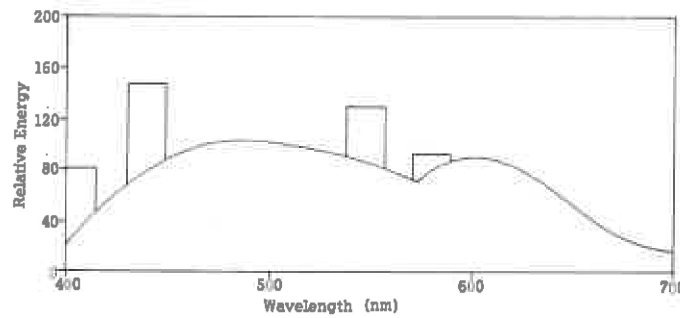

Figure 5 - Spectral-Distribution Curves for 'Daylight' Fluorescent Lamps

Colour temperatures have value in that they do provide a classification of light sources indicative of their colour rendering characteristics. They are particularly useful in colour photography where the matching of films with the light source is required, but they are useful in any situation where one is trying to reproduce the colour rendition of any object in a new environment.

Two possible areas of confusion should be pointed out. First, a higher colour temperature produces an effect opposite to the concept of the warmth of the lighting as used by an artist. That is, the higher the colour temperature the more blue light it contains and therefore the 'colder' the lighting in aesthetic terms. Secondly, colour temperature has nothing whatever to do with the intensity of the illumination. Occasionally one hears people say that a certain illumination is stronger than another because it has a higher colour temperature or that it has a higher colour temperature because its intensity is greater. This is wrong. In essence colour temperature refers only to the proportion of light of various wavelengths produced by a source. Whether the lighting is strong or weak is another matter; quite clearly if the light source is close to an object it will be more strongly illuminated than if the source is distant, but the colour temperature is the same. Similarly one can alter the strength of the light by interposing neutral density filters without changing the colour temperature.

Table 1 lists the colour temperatures of a number of light sources. North sky light under overcast conditions is generally considered to be in the range of 6,500 to 7,500°K.

TABLE 1

Colour Temperature of Various Light Sources

Source	Degrees Kelvin
candle or kerosene lamp	1900
tungsten lamp, 40-watt	2760
tungsten lamp, 60-watt	2790
tungsten lamp, 100-watt	2860
'warm white' fluorescent lamp	3500
'cool white' fluorescent lamp	4500
average noon sunlight	5000
'daylight' fluorescent lamp	6500
lightly overcast sky	7500
hazy blue sky	9000
clear blue sky	25000

Another factor which must be borne in mind is that the percentage of the total radiation energy in the ultra violet region varies from one source to another. With tungsten incandescent lamps it is negligible, less than 1%. For fluorescent lamps it can be from 3 to 7% while with sunlight up to 25% can be ultraviolet. This means that, other things being equal, the potential danger to an object from natural sunlight is greater than that from fluorescent lamps which in turn is greater than that from incandescent lamps.

4. Illumination

One way of measuring the strength of the illumination falling on an object might be to measure the total amount of radiant energy falling on a unit area per second. The units might be microwatts per square centimetre. There are two objections to this. First, the total energy would include ultraviolet and infrared radiations which are not utilized in viewing; meaningful measurements of radiant energy must be restricted to the visible portion of the spectrum. Second, even within the visible region, human vision is not equally responsive to all wavelengths of visible light so any measure of illumination must take this variation into account. The average human eye is much more efficient in viewing light near the middle of the spectrum. In normal daylight vision the eye is most responsive to light in the green portion of the spectrum at 555 nanometres, and less so at longer and shorter wavelengths.

Thus if lights of the same power but of different colours were viewed, the green light would appear much more intense and the red and blue would appear much less intense. This is illustrated in more quantitative fashion in Figure 6 which gives the relative spectral luminous efficiencies for photopic vision. (4)

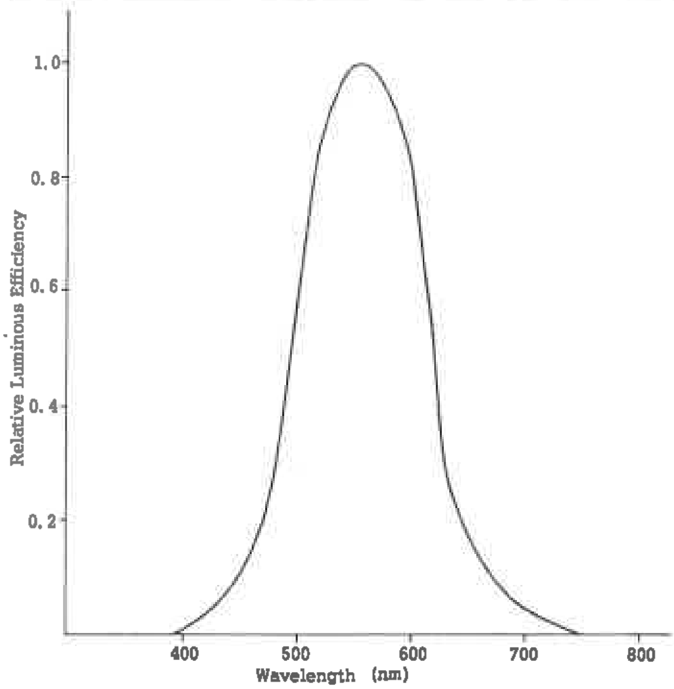

Figure 6 - Standard Relative Spectral Luminous Efficiency Function for Photopic Vision

We must now proceed to a few definitions that may appear somewhat abstract and perhaps even arbitrary, but it is necessary to know the vocabulary and fortunately there are not many terms.

Radiant flux is the radiant energy emitted or received by a surface in a unit of time. It is measured in fractions of a watt, usually microwatts.

Irradiance is the radiant flux divided by the area of the surface in question. It is measured in microwatts per square centimetre.

The radiant flux and the irradiance do not describe the perceived intensity of illumination. However, related to the radiant flux is the luminous flux which is a quantity expressing the capacity of the radiant flux to produce visual sensation. It is evaluated by multiplying the radiant flux for a wavelength by the photopic relative luminous efficiency function for that wavelength, repeating this for each wavelength interval in the visible spectrum and summing all of the products so obtained. The unit of luminous flux is the lumen. The lumen is the luminous flux received on an area of one square foot contained on a sphere of radius one foot (or on an area of one square metre contained on a sphere of radius one metre) from a point source having a uniform luminous intensity of one candela. The candela (formerly candle) is defined as equal to one-sixtieth of the luminous intensity per square centimetre of a black body radiator operating at the temperature of solidification of platinum, the luminous intensity in a given direction being the quotient of the luminous flux in an infinitesimal cone containing the given direction by the solid angle of that cone.

As may have been noticed, the definition given for a lumen was equivalent to saying that the lumen was the luminous flux radiated from a source of one candela per unit solid angle (or steradian) and therefore a source of one candela produces a total luminous flux of 4π lumens.

With the above background it is possible to define illumination or illuminance as the luminous flux incident on the area of a surface divided by that area. The international unit of illumination is the lux defined as one lumen per square metre. It can be visualized as the illumination on the surface of a sphere of radius of one metre when a point source of one candela is at the centre of the sphere. Another common unit of illumination is the foot candle which is defined as one lumen per square foot. Clearly the foot candle represents a greater illumination than the lux; the exact relationship is:

1 foot candle = 10.76 lux

To complete this set of definitions there are a few terms that might arise in discussion with lighting engineers. The specific consumption of a bulb is its electrical power consumption in watts per lumen. The luminous efficiency is the ratio of the luminous flux in lumens to the radiant flux in watts. Occasionally one may encounter the term 'langley' which is the total luminous energy expressed in gram calories per square centimetres per minute. However, as metric units become established, the use of the langley will decline since the joule rather than the calorie is the preferred energy unit. A lambert is the brightness of a perfectly diffusing surface emitting or reflecting one lumen per square centimetre.

5. Illuminance and Related Psychological Factors

In the previous section we have in a rather abstract way defined various lighting concepts. We will now attempt to make the concept of illuminance and the lux a little more concrete-and, also, to indicate certain psychological considerations that must be taken into account in assigning illumination levels in museums and art galleries.

Some feeling for the amount of illumination represented by a lux can be developed by considering some familiar examples. Light from a full moon is somewhat under 0.5 lux. Direct sunlight plus skylight may be as high as 10,000 lux; however, on a dark day the illumination outdoors may be only 1,000 lux. A bare 100 watt bulb provides about 14 lux on a surface 10 feet away. In the author's own office and laboratory area, the illumination varied from 600 to 900 lux. Recommendations have been made by the Illuminating Engineering Society in the United States for illumination for various tasks. Thus 1500 lux is recommended for proofreading; for inspecting manufactured parts 500 lux are recommended for ordinary cases and up to 10,000 lux for very difficult cases; for sewing 5,000 lux have been recommended. These quantities are given only to illustrate what a lux is and no one should attempt to provide such illuminances in exhibition areas of an art gallery or museum. The levels quoted are meant for instances where continuous viewing at a certain level of discrimination is required over long periods; they do not take into account deteriorating effects on the collection.

Actually the human eye is very adaptable. The pupil of the eye will enlarge to accommodate low levels of light and will decrease in bright light. This accommodation is not instantaneous as anyone who has stepped from a bright outdoor location into a poorly lit room, or vice versa, will realize. However, if the museum lighting is arranged sufficiently skilfully so that changes in illumination occur gradually, then it is quite possible to illuminate objects at sufficiently low levels that the possibility of damage to artifacts is minimized yet without causing any discomfort or strain on the viewer.

An important psychological factor has to be taken into account when considering relatively low levels of illumination. If the illuminance is decreased while maintaining the same colour temperature then the light will appear to become colder or more bluish in the aesthetic sense. Conversely, museums or galleries with extensive natural lighting may receive complaints when the colour temperature is high that the lighting intensity is too low although the actual illumination is unchanged. By supplementing the bluish natural light with warmer incandescent light - keeping the overall illumination the same - it is possible to overcome this feeling that the lighting is insufficient or unpleasantly 'cold'.

Thus the conclusion to be reached from the facts is that, as the viewer is brought from a bright location to an area of reduced illumination in the exhibition area, not only should the illumination decrease be gradual but the colour temperature of the light must also be reduced if colour rendering is to be acceptable.

6. Photochemical Deterioration

Not all objects are susceptible to the action of light; stone and metal objects may be quite safe. However, there is a class of materials readily damaged by exposure to light. Included in a list of susceptible objects would be paintings (particularly watercolours), feathers, paper, textiles, leather, etc. Of those which may be damaged not all are equally susceptible. The point is that the bonds between atoms in different molecules may have different strengths and the absorption of light energy may be sufficient to break a bond in one molecule but insufficient in another case. Also, different configurations of atoms absorb energy of different wavelengths so one molecule might absorb light of 560 nm wavelength but another would not. Photochemical change of course can occur only if the molecule absorbs a photon.

Other things being equal, light of shorter wavelength, that is, a higher energy, will be more damaging than light of longer wavelength. As mentioned in an earlier section, the energy associated with a photon depends only on the wavelength of the light. Decreasing the illumination only decreases the number of photons per second reaching the surface but does not alter in any way their individual energies. Therefore, lowering the intensity of light will decrease the rate of photochemical damage but will not completely prevent damage.

Since the eye is insensitive to ultraviolet light and this radiation, being of short wavelength, is potentially capable of great damage, it should therefore be rigorously excluded from museum lighting. Infrared radiation does not contribute to viewing either but causes the temperature of the object to rise. This accelerates any deterioration reactions occurring and for this reason infrared is undesirable in exhibition areas. In order to have acceptable colour rendering it is necessary to have all wavelengths of visible light present and the principle of conservation to be observed here is to keep this illumination low. This will not prevent photochemical deterioration but will minimize it.

The following two paragraphs give in somewhat more detail the steps that may occur in deterioration reactions. They are intended only to indicate the complexity of photo-chemical deterioration by suggesting the complexity of the interaction of illumination, relative humidity, atmospheric components, etc.

The primary photochemical process involves the absorption of a photon by a molecule which makes it more energetic or, in other words, yields an excited molecule. This excited molecule may just show up as heat (the temperature of the object increases); the excited molecule may give off light (it is said to fluoresce); the excited molecule may dissociate (the bonds between atoms may break yielding smaller molecules with different properties); the constituent atoms of the excited molecule may rearrange themselves giving a new substance; or the excited molecule may transfer the energy it has gained to another molecule, say oxygen, making it more reactive than it otherwise would be.

The sequence of reactions leading to deterioration of museum objects may be extremely complex. Thus a dye molecule may capture a photon and become activated. This excited dye molecule can transfer its excess energy to an oxygen molecule which in the activated state could react with a water molecule to form hydrogen peroxide. The latter in turn can oxidize the dye causing it to fade or it might react with the cellulose of the textile fibres forming oxycellulose. Some of these reactions increase in rate with increasing temperatures. In many cases the elimination of moisture or oxygen will essentially halt the photochemical fading of dyes and embrittlement of cellulose fibres. This is however not a recommendation to reduce the relative humidity to very low levels as this will cause other problems.

7. Recommended Lighting Levels

Various scientific studies have been carried out which have permitted estimates of the probable damage per foot candle (so-called D/f. c. values) which have been used to formulate permissible levels of illumination. The experts have not been in complete agreement. (5) However the modern consensus is that the maximum illumination for particularly vulnerable objects such as watercolours, tapestries, etc. should be 50 lux. This is sufficiently greater than the minimum illumination required for adequate colour discrimination (10-30 lux) that a slight unevenness in lighting can be tolerated. For other museum or gallery items a maximum of 150 lux may be permitted, although with especially insensitive materials, as metal or stone, up to 300 lux could be employed for special effects.

The effect of light is cumulative. It has been claimed that many traditional pigments show significant fading after exposure to 80 million lux hours of illumination by daylight fluorescent lighting. Assuming that a museum is lighted 3600 hours per year, this would mean a life expectancy of 70 years at 300 lux, 220 years at 100 lux and 440 years at 50 lux. Particularly sensitive materials as water colour pigments may show fading at only one-eighth of this total exposure, so their lifetime would only be 55 years even at 50 lux.

Since the effect of light is cumulative, particularly sensitive objects should not be on continuous display but should be retired to storage after a period of exhibition.

Illuminated manuscripts are often displayed in cases over which are curtains which the viewer must draw open; this greatly minimizes the exposure such items receive. A similar approach is the use of lighting that the viewer himself must turn on but which automatically switches itself off after a suitable viewing interval.

If a gallery lighting system employs natural lighting, drapes and louvres which close or open automatically to maintain a constant level of illumination can be installed.

8. Control of Ultraviolet Radiation

Beyond the need to control the levels of visible light reaching museum objects, it is mandatory to eliminate as much as possible of the non-visible, ultraviolet radiation. It should always be remembered that the percentage of ultraviolet radiation in natural sunlight is greater than in fluorescent lighting. Incandescent lighting has virtually none. If the exhibition area is unfortunate enough to receive daylight, sensitive objects should not be placed in direct sunlight or strongly lit areas.

Window glass passes ultraviolet radiation in the range of 310 to 400 nm. However, much of this radiation can be removed by reflecting the light from walls painted with titanium dioxide or zinc white pigments. These white pigments are good absorbers of ultraviolet light. The indirect lighting that results from reflection will contain little ultraviolet.

Even better protection is obtained by the use of plastic filters which incorporate various organic compounds with ultraviolet absorbing properties. Plexiglas UF-1 is practically colourless and does not interfere with colour rendering. The Plexiglas UF-3 is somewhat yellow but also a somewhat better ultraviolet absorber. Spectral transmission curves for these materials are given in Figure 7. The slight warming produced by the UF-3 filter may provide the slight compensation often desired, particularly at the lower recommended illumination.

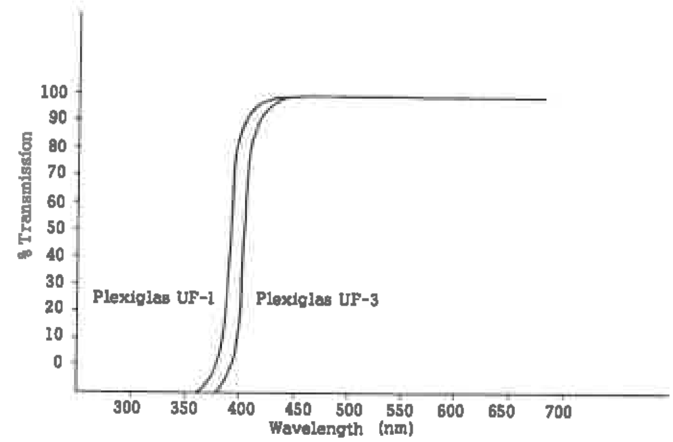

Figure 7 - Spectral Transmission Curves for Plexiglas UF-1 and UF-3

Varnishes are available which also incorporate ultraviolet absorbers. It is possible to coat window glass with such varnish but it is extremely difficult to apply the coating sufficiently uniformly as to be distortion free. The coatings are also liable to deterioration. They can therefore not be recommended in view of the availability of sheet material. Varnishes can be used directly on fluorescent tubes to filter out ultraviolet, but again more convenient sheet plastic is available. These are made in the form of tubes which can be slipped over a fluorescent tube when it is being inserted. Such tubes are available from Canadian sources, one such source being Commercial Plastic and Supply Company, P. O. Box 5146, Station F, Ottawa, Ontario, K2C 0A0. Current prices are in the order of 86¢ to $1. 05 per foot for Comco, Raysfield 403, ultraviolet filter tubes.

In addition to filters a certain amount of common sense is required in the design of installations. Do not install incandescent lamps within display cases where the radiation from them can generate excessive local temperatures. If spotlights are to be employed install them outside display cases. Suitably filtered fluorescent lighting may be installed inside a case with the ballast outside thus avoiding overheating of the display.

9. Meters

In order to ensure that lighting levels are acceptable, especially when the lighting is periodically rearranged, it is necessary to have equipment to measure intensities. Much light-monitoring equipment is far too expensive for the ordinary museum or art gallery and properly belongs in a scientific laboratory. The Canadian Conservation Institute has a spectroradiometer which measures, in absolute units, the spectral energy distribution of a light source over the range 300 to 700 nm. When such information is needed, it is perhaps best to request the Canadian Conservation Institute to make such a survey. C. C. I. also has precision photometers; these cost in the neighbourhood of $1, 200.

Of more concern to curators would be simpler light meters such as a good photographic exposure meter. These, if calibrated in foot-candles, will be satisfactory for measuring the light intensity in the vicinity of artifacts. If such meters are to be of any use they must be capable of reading accurately illuminances as low as 50 lux, i. e. five foot candles. One such meter is the Model LD-300 Spectra Candela footcandle meter made by Photo Research, a Division of Kollmorgan Corporation, Burbank, California. The exclusive Canadian agent is Alex L. Clark, Ltd., 3751 Bloor Street West, Islington, Ontario. The LD-300 is currently available for $110. 95 without a pointer-lock and $130. 95 with a pointer-lock. The pointer-lock is a convenience in that the pointer stays in position after a measurement is made and one can read the value later. This meter has not been checked out by the Canadian Conservation Institute.

With many such meters the 0-20 foot candle range is compressed into the lower part of the scale and care must be exercised in reading the meter.

Notes and References

1. For all practical purposes, light passing through air as a medium has the same properties as those described above in a vacuum. In a more dense medium, such as glass or a pigment particle, different wavelengths will have different speeds.

2. This Kelvin temperature scale is simply related to the more familiar Celsius scale by the addition of 273.15: i.e. degrees Kelvin = degrees Celsius + 273.15.

3. Fluorescent lamps have similar high energy spikes in the ultraviolet region.

4. Photopic vision is normal daylight vision which utilizes the cones of the retina, the maximum efficiency being at 555 nm. For night vision, which utilizes the rods of the retina, the maximum efficiency is shifted to 507 nm. and is termed scotopic vision.

5. R. L. Feller, 'Control of deteriorating effects of light upon museum objects', Museum (Paris), xvii, 2 (1964), 57-98.

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