THE APPLICATION OF THE UNREAL QUANTUM YIELD THEORY TO THE SAFE ILLUMINATION OF TWO-DIMENSIONAL WORKS OF ART

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Abstract - Two methods of applying the Unreal Quantum Yield Theory to the illumination of works of art are described. In the first a system of focussed light emitting diodes is used and in the second a more elegant system uses a colour transparency of the work of art. Several problems of application, encountered during trial, are enumerated and solutions described.

1 Introduction

Light can be considered as either a waveform or as quanta of energy. Over the years it has been given many other attributes. Thom Garryson of the National Gallery called it "..illuminating.." Some Feller called Robert referred to light as "..brilliant and enlightening.." and Jim Hanlan of Queen's University called it "..a sensation that everyone must experience at least once in their lifetime..". (Some simply refer to it as less filling, and with only 4% alcohol, an enjoyable alternative to regular ale.) Because light is energy, it can be a causative agent. Plants grow, people tan or sun-burn depending upon the extinction coefficient of their skin and the location of the process (*eg.* Florida vs. Yellowknife), eyes see, skin cancer exists, coloured works of art fade. This paper will deal only with the last of these photochemically induced processes.

The Stark-Einstein Law (1) implies that the efficiency of processes which follow the act of penetration can be measured by the concept of quantum yield. This is defined by:

$$\emptyset = \frac{\text{number of molecules undergoing a particular change}}{\text{number of quanta absorbed}} \quad \ldots 1$$

Light can penetrate an object and be absorbed which we will define as absorbtion, or it can be reflected off the surface of an object, which we will define as reflection.* It is apparent from equation 1 that if zero quanta are absorbed, then we have a division by zero which we all know to be against all the laws of mathematics (2), and will also result in an error 31 on a Hewlett-Packard 9836C computer, error 47 on an Apple 2E, *etc.* We can easily take this unreal situation - division by zero - and apply it to a real situation - the fading of coloured works of art.

Given the situation that the number of quanta absorbed by a coloured surface is zero we have an unreal situation and there cannot be a quantum yield. This is the principle of the Unreal Quantum Yield Theory. In fact, the mere mention of quantum yield here is against the LAW. In our particular case, the quantum yield of the photochemical process of colour fading is unreal, thus colours do not fade when division by zero occurs as in equation 1. With this premise in mind let us examine the real situations when zero quanta of light energy are absorbed, thus leading to a theoretically unreal situation. One example is when there is no light - the object is in pitch darkness. If no light is incident on the surface of the object then, by various mathematical manipulations and transformations, it can be deduced that there can be no light absorbed (or no light reflected for that matter). This leads to an unreal situation (division by zero) and there is no fading of colours. In reality, this real situation is quite unreal. Imagine a museum or art gallery kept in complete darkness. Really now!

2 A Practical Solution

After much reflection the author believes he has found a real solution that is practical and effective, and which would lead to the unreal situation of division by zero in equation 1. When an object is lit, the light can either be absorbed or reflected. The less significant processes of transmission, scattering, gloss, sheen, *etc.* have been omitted for simplicity. Let us examine which part of the light spectrum is being absorbed and which part is being reflected by the illuminated object. The answer to this lies in the colour of the object. Indeed, the colour of an object is determined by what wavelengths are reflected off its surface and subsequently reach the cones of the human eye. All the wavelengths absorbed by the object contribute nothing to its colour, other than to cause it to fade, which we do

* The reader should not confuse this definition of reflection with another popular version: a thought, idea, or opinion formed as a result of meditation. The author has often been asked whether a connection exists between the two and the only evidence that he has found which suggests that there may well be a connection is the popular caricature of a light bulb over the head of a person with an idea, which in effect would produce reflection off the surface of the person's head and reflection inside their head.

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not want. The solution to the fading problem is no doubt quite evident: illuminate a colour with only that part of the light spectrum that is being reflected in the first place. Thus, no light is absorbed, division by zero occurs, which is unreal, and there is no real fading - simple and ingenious.

Consider the simplest case: a painting in which only the colour black has been used. The spectral reflectance curve of the colour black is shown in Fig.1. Black reflects nothing and absorbs everything. Consequently, in order to reduce the number of absorbed quanta to zero, all the wavelengths of the light illuminating this painting should be removed. This can be easily achieved by placing a black filter over the light source. It has been recently suggested to the author that removing the light bulb from the fixture or switching off the light might also work, but more research is required before these two methods can be recommended.

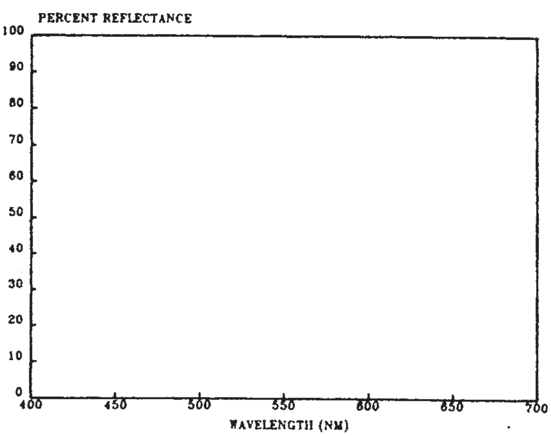

Figure 1 Spectral reflectance curve for the colour black. All wavelengths in the visible region are completely absorbed.

The next level of difficulty is a painting in which only the colour white has been used. Since white reflects all of the wavelengths incident on its surface, as shown in Fig.2, then none of the wavelengths should be removed from the light source. Although this is much more difficult to do than removing all the wavelengths, the author has found that a plain piece of glass works well, to a first approximation.

We can now be daring and skip a few levels of difficulty such as light grey, medium grey, dark grey, combinations of white and black, combinations of greys and white and of course the elusive off-white. As an example we shall consider Leonardo's *Mona Lisa*. A colourimetric and spectroscopic analysis of the image indicates that there exist at least 2,476 different colours in the *Mona Lisa*

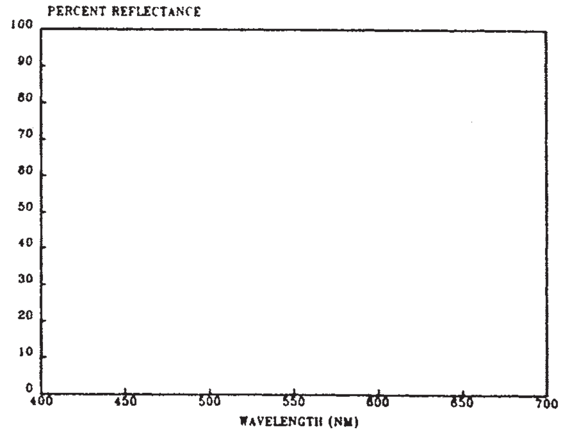

Figure 2 Spectral reflectance curve for the colour white. All wavelengths in the visible region are completely reflected.

painting. Each different colour must be illuminated by light of the same colour in order for the Unreal Quantum Yield Theory to apply.

The application of high technology was first considered. An array of 2,476 high efficiency light emitting diodes (LEDs) was prepared on a circuit board roughly the same shape and size as the *Mona Lisa*. Each LED was fitted with a special lens to focus its light on the painting and a colour filter to transmit only those wavelengths that would be reflected from the colour in question. Needless to say, the fabrication of this illuminating panel was both time-consuming and extremely complex. Each LED must be individually focussed onto the painting. In practice this was never perfectly achieved and the *Mona Lisa* appeared considerably blurry under this theoretically safe light. The effect was similar to gazing through an opalescent acrylic panel. The cost of the components was also considered to be somewhat high ($3.79 for each LED, $47.98 for each of the precision lenses, and $12.49 per filter - total cost of the illuminating panel was $159,107.76). Obviously a simple and less expensive solution was needed.

Again, after much reflection, the author conceived an amazingly novel yet effective solution. It consists of illuminating the painting with a 35mm slide projector and a colour slide of the painting - simple, ingenious and brilliant. Thus, each colour receives exactly those wavelengths that it will reflect. (For sake of simplicity, the effect of metamerism has been omitted.) In essence we have the safest light possible for a coloured work of art. Furthermore, light intensity on the object is no longer a consideration; no more 150 lux maximums.

3 Testing the Solution

In theory, the Unreal Quantum Yield Theory can easily be shown to apply to the fading of coloured works of art. Nevertheless, it was thought necessary to test its performance in the laboratory. The Louvre were not prepared to lend us the *Mona Lisa* for these tests but they were gracious enough to send us a nice coloured postcard of the painting for our experiments. An experiment was designed in which selected colours would be monitored for fading at regular intervals during exposure under our theoretically safe light, *ie.* a colour slide projection of the painting onto the postcard. Obviously not all 2,476 colours could be monitored and so the test was restricted to 892 colours considered to be the most important ones in the *Mona Lisa* composition. The effective intensity on the work of art was about 25,000 lux. This was determined by brightness contrast measurements rather than by normal light intensity measurements.

The results are shown in Fig.3. As can be clearly seen, none of the colours experienced any fading even after 40,000 hours. The unusually high reading for colour 375 at 15,000 hours is most likely due to experimental error, although further tests of this particular colour will be undertaken to confirm this. Thus, laboratory testing once again agrees with theoretical predictions and *vice versa*.

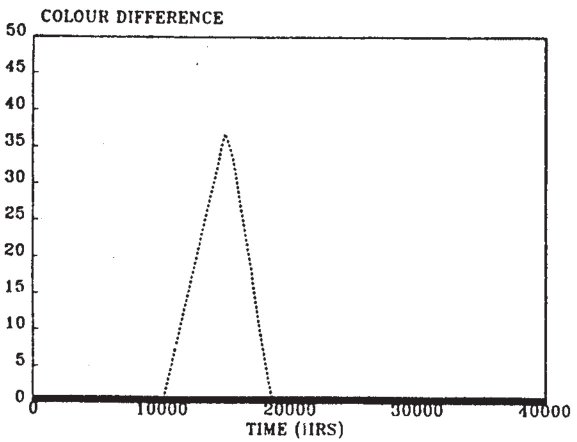

Figure 3 The colour difference of 892 colours during exposure to 25,000 lux of safe light. The curves clearly show that none of the colours faded - the unusually high reading for colour 375 being due to experimental error.

4 The Solution in the Real World

The transitory phase from the laboratory to the real world is difficult for any new discovery, but it is especially so for an unreal theory. Yet, after only 17,520 hours (2 years) since the development of this procedure, numerous little problems have already been resolved and the technique is becoming more popular every 24 hours (day). It would be useful at this point to mention some of these problems and the way they have been resolved.

The first problem was to devise a method that would ensure continuous proper alignment of the light beam on the painting. We need not mention the disastrous effects that this could lead to (but we will): for example, poor colour rendering, increased fading, excessive eye strain, devalued works of art, irritated artists and curators and, last but certainly not least, one unemployed conservation scientist. The solution was borrowed from the electronics industry: a small glob of red coloured epoxy adhesive (preferably one that will not yellow with time) is placed in one corner of the projector thus preventing any movement occuring. A small note with the words "Calibrated at the factory - do not tamper with setting" compliments the red glob.

Another problem that soon became apparent was the fading of the colour slide itself. This was easily rectified by placing an ultraviolet absorbing filter in front of the projector's light source, thus preventing any occurence of colour fading whatsoever.

One minor problem that has occured with the technique (and one the author believes to be completely unrelated to the technique) was the mysterious disappearance of some 50 oil paintings from the New Winchester Art Gallery in Old Winchester. This art gallery was one of the first institutions to utilize this technique on a large scale. Recently, it was discovered that the 50 oil paintings lit with this new technique had been stolen and the only things remaining were the frames and white canvas in place of the original images. Even the discovery of the theft was by accident. It was only when the gallery's conservator wished to remove one of the paintings for restoration that it was discovered missing. A subsequent examination confirmed that the other 49 works of art were also missing. It is not known when the theft occurred. In fact, if it were not for that conservator the disappearance might still be unknown to the art gallery.*

* Rumours have circulated recently that one well-known gallery, which had converted all its lighting installations to the system described here, has placed all its paintings in storage and is now exhibiting only the frame and a white canvas.

5 Conclusion

The application of the Unreal Quantum Yield Theory to the safe illumination of two-dimensional works of art is but one more example of science benefitting conservation. Based on the unreality of division by zero and its extrapolation to an unreal quantum yield of fading, a technique has been developed to ensure the complete stability of colours present in paintings. An ingenious and simple method of ensuring no quantum absorbtion has been shown to be most effective. Minor drawbacks and problems have been corrected as a result of intensive field testing. The author is convinced that this is a viable approach to the illumination of works of art.

6 Acknowledgement

The author wishes to extend his appreciation to a colleague, Sai N. Test, for bringing to his attention the unreality of division by zero in a real context.

7 References

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2. Khan U. Kaunt, *Elementary Arithmetic for Grade Two*, 1,2,3, Publishers Inc., 1907

RAY LAFONTAINE was born in a hospital at 1.47am and weighed in at 7lbs, 12ozs, which makes him a featherweight. He crawled for one year and then played for four. He joined a school where he sometimes studied. After he graduated he went to a local bar and got drunk. Later he specialized in research. He is best known for his work and is the author of many famous publications, including "Humidity is Relative", "The Fading of Clear Substrates and White Pigments", "The Damaging Effect of Moonlight on Works of Art", "The Use of Hydrochloric Acid for Buffering Display Cases", "The Reversibility of Varnish Removal", "Accelerated Ageing: Is It Good for You?", "Volatile Emissions from Artifacts and Their Effect on Museum Visitors" and his most recent treatise "The Conservation and Restoration of Donkey Kong and Other Video Games". *Author's address: 8M0 A1K, Canada, Ontario, Ottawa, Road 0301 Innes, Institute Conservation Canadian.*

Résumé - On décrit deux méthodes pour utiliser la Théorie du rendement quantique non-réel pour l'éclairage des oeuvres d'art. Premièrement, on utilise un système de diode émetteur de lumière convergée. Deuxièmement, un système beaucoup plus élégant est utilisé; il s'agit de la projection d'une diapositive de l'oeuvre sur l'oeuvre. Quelques problèmes éprouvés durant les essais sone énumérés, ainsi que les solutions apportées.

Auszug - Zwei Anwendungsmethoden der irrealen Quanten Theorie in der Beleuchtung von Kunstwerken sind beschrieben. Bei der ersten wird eine Zweielektrodenröhre benutzt, die gebündeltes Licht ausstrahlt, während eine zweite ein eleganteres System darstellt, das sich Farbdias von Kunstwerken bedient. Verschiedene Probleme der Anwendung, die sich während der Versuche herausstellten, werden aufgezahlt, und etwaige Lösungen beschrieben.