MODULE 1 COLOUR, PIGMENTS AND DYES

UNIT 1 COLOUR AND ITS FEATURES

CONTENTS

1.0 INTRODUCTION

Electromagnetic radiation is characterised by its wavelength (or frequency) and its intensity. When the wavelength is within the visible spectrum (the range of wavelengths humans can perceive, approximately from 380 nm to 740 nm), it is known as "visible light". Most light sources emit light at many different wavelengths; a source's *spectrum* is a distribution giving to its intensity at each wavelength. Although the spectrum of light received by the eye from a given direction determines the colour sensation in that direction, there are many more possible spectral combinations than colour sensations. Therefore, one may formally define a colour as a class of spectra that gives rise to the same colour sensation, although such classes would vary widely among different species, and to a lesser extent among individuals within the same species. In each such class, the members are called *metamers* of the colour in question.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- explain the history of colour
- define colour
- identify the different kinds of colour
- explain why objects appear the colour they are

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.
3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Definition of Colour

Colour is simply defined as the light of different wavelengths and frequencies.Light, however, is just one form of energy that we can actually see that is made up of photons.

4.2 History of Colour

Some of the early studies and theories about light were done by Aristotle. He discovered that by mixing two colours, the third is produced. He did this with a yellow and blue piece of glass, which when brought together produced green. He also discovered that light travels in waves. Plato and Pythagoras also studied light. In the 10th century, Al-Haytham researched into colour and his findingsinspired Newton. During the Middle Ages, Paracelsus reintroduced the knowledge and philosophy of colour using the power of the colour rays for healing along with music and herbs. Unfortunately, he was hounded throughout Europe and ridiculed for his work. Most of his manuscripts were burnt, but now he is thought of, by many, to be one of the greatest doctors and healers of his time. A man, it would seem, very much ahead of his time. Not only do we now use Colour Therapy once again, but, his other ideas, using herbs and music in healing, can also be seen reflected in many of the complementary therapies now quite in commonplace.

A pioneer in the field of colour, Isaac Newton, in 1672 published his first, controversial paper on colour, and forty years later, his work 'Opticks'. Newton passed a beam of sunlight through a prism,when the light came out of the prism it was not white but was of seven different colours: Red, Orange, Yellow, Green, Blue, Indigo and Violet. The spreading into rays of these colours was called ‘dispersion’ by Newton and he called the different coloured rays the ‘spectrum’. He discovered that when the light rays were passed again through a prism, the rays turned back into white light. If one ray was passed through the prism it would come out the same colour as it went in. Newton concluded that white light was made up of seven different coloured rays.

4.3 Where Does Colour Comefrom?

Colour comes from light. We can see seven main colours of the Visible Spectrum. The retinas in our eyes though have three types of colour receptors in the form of cones, we can actually only detect three of these visible colours – red, blue and green. These colours are called additive primaries. It is these three colours that are mixed in our brain to create all of the other colours we see. The wavelength and frequency of light also influences the colour we see. The seven colours of the spectrum all have varying wavelengths and frequencies. Red is at the lower end of the spectrum and has a higher wavelength but lower frequency than that of violet at the top end of the spectrum which has a lower wavelength and higher frequency.

To physically see this, we need a prism. When light from the sun passes through a prism, the light is split into the seven visible colours by refraction. Refraction is caused by the change in speed experienced by a wave of light when it changes medium.

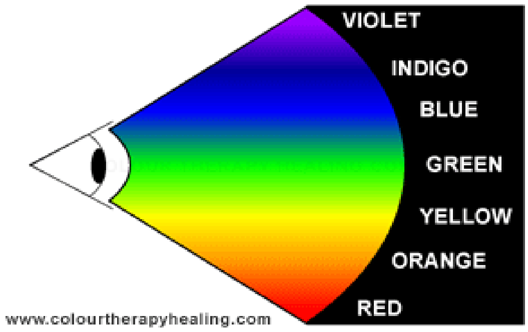


Fig. 1.1 Colours of Visible Spectrum
Source: www.colourtherapyhealing.com

4.4 Electromagnetic Waves and Visible Spectrum

The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation.The electromagnetic spectrum of an object is the characteristic distribution of electromagnetic radiation emitted or absorbed by that particular object. The electromagnetic spectrum extends from below frequencies used for modern radio through to gamma radiation at the short wavelength end, covering wavelengths from thousands of kilometers down to a fraction of the size of an atom. The long wavelength limit is the size of the universe itself, while it is thought that the short wavelength limit is in the vicinity of the Planck length, although in principle the spectrum is infinite and continuous.

Generally, electromagnetic radiation (EM) is classified by wavelength into radio wave, microwave, infrared, the visible region we perceive as light, ultraviolet, X-rays and gamma rays. The behaviour of EM radiation depends on its wavelength. When EM radiation interacts with single atoms and molecules, its behavior also depends on the amount of energy per quantum (photon) it carries.

The diagram below shows what small part of the whole electromagnetic visible spectrum light actually forms.

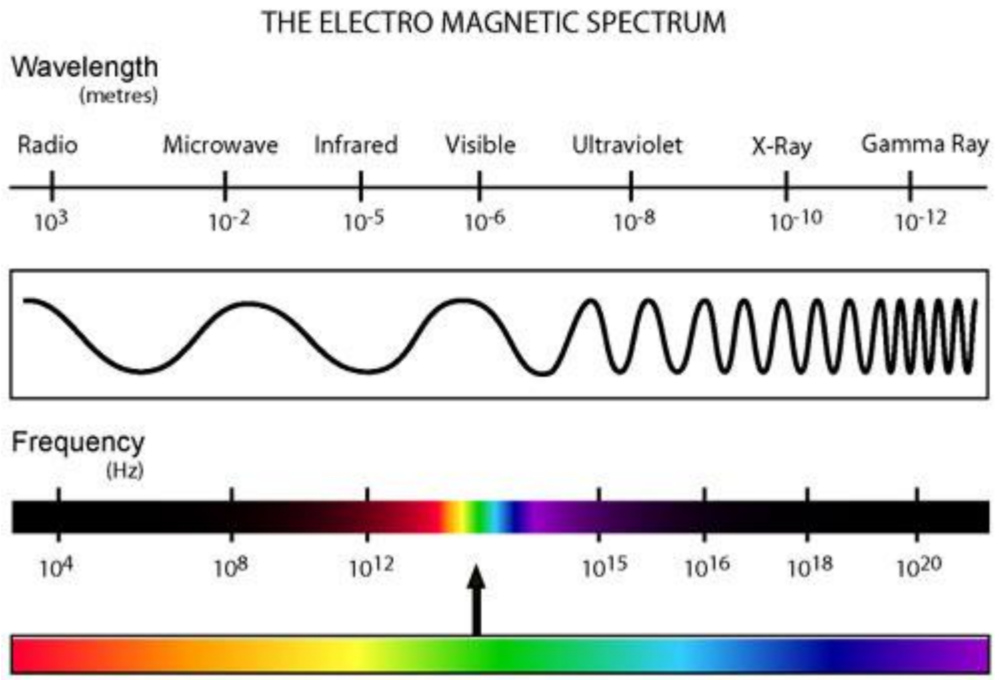


Fig.1.2 Nature of Electromagnetic Radiation
Source: www.colourtherapyhealing.com

The amount of energy in a given light wave is proportionally related to its frequency, thus a high frequency light wave has a higher energy than that of a low frequency light wave.

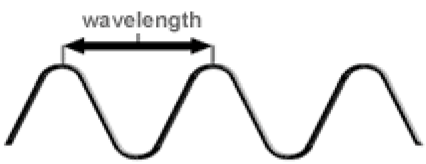
E= hv where E= Energy; h=Planck' constant; v= velocity of light

SELF ASSESSMENT EXERCISE 1

i. Explain briefly the origin of colour.
ii. Highlight the content of visible spectrum.

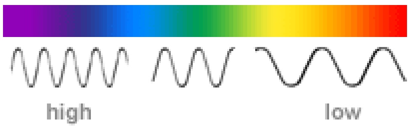
4.5 Wavelengths and Frequencies of Colour

Each colour has its own particular wavelength and frequency. Each colour can be measured in units of cycles or waves per second.If we can imagine light traveling in waves like that in an ocean, it is these waves that have the properties of wavelength and frequency. A wavelength is the distance between the same locations on adjacent waves.



Each of these waves has a different wavelength and speed of vibration. Together they form the electromagnetic spectrum. Light travels in waves.

The frequency of a wave is determined by the number of complete waves or wavelengths that pass a given point each second. All light travels at the same speed but each colour has a different wavelength and frequency. It is these different wavelengths and frequencies that cause different colours of light to be separate and visible when passing through a prism. This can be compared to the radio waves which have different frequencies and wavelengths in which certain stations can only be listened to at a particular frequency or wavelength. So, colour blue, for instance, - can only be visible at a particular frequency and wavelength range. The higher thefrequency ofa colour, the closer the waves ofits energy.



Higher frequency colours are violet, indigo, and blue while the lower frequency colours are yellow, orange and red. A high frequency light wave has a higher energy than that of a low frequency light wave.

4.6 Properties of Colour

Each colour has its own properties with its own wavelength and frequency. Although white could be said to be a colour, it is generally not included in the scientific spectrum as it is in fact made up of all the colours of the spectrum, but it is often being referred to as a colour.

Table 1.1: Colour and Relative Property

Colour	Wavelength Range (nm)	Frequency Range (THz)
Red	700-635	430-480
Orange	635-590	480-510
Yellow	590-560	510-540
Green	560-490	540-610
Blue	490-450	610-670
Violet	450-400	670-750

(Frequency = Terahertz (one trillion cycles per second); **Wavelength** = Nanometers

One meter equals 1,000,000,000 nanometers. One nanometer is about the length of ten atoms in a row)

4.7 Colour Perception

We see colour with the sensors in the retina of the eye called rods and cones. The rods are sensitive to low light and the cones, which require a greater intensity of light, are sensitive to colour. The message is passed to the optic nerve and then on to the brain.

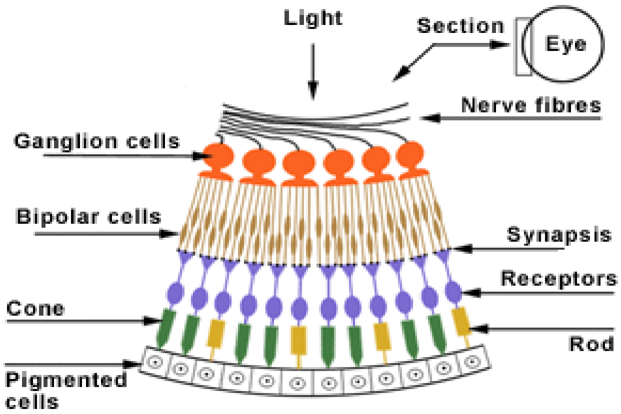


Fig. 1.3 Colours and Eyes
Source: www.colourtherapyhealing.com

The eye picks up colour and light by the rods and cones. It is the *Cones* that detect colour. Each cone contains one of three pigments sensitive to either redgreen or blue. There are about 120 million rods and about 6 to 7 million cones in the human eye.Rods are more sensitive than the cones but they are not sensitive to colour, they perceive images as black, white and different shades of grey. More than one thousand times as sensitive, the rods respond better to blue but very little to red light.

Each pigment absorbs a particular wavelength of colour. There are short wavelength cones that absorb blue light, middle wavelength cones that absorb green light, and long wavelength cones that absorb red light. When we observe a colour that has a wavelength between that of the primary colours red, green and blue, combinations of the cones are stimulated. An example could be that yellow light stimulates cones that are sensitive to red and green light. The result is that we can detect light of all colours in the visible spectrum.

People who suffer fromcolour blindness have less numbers of particular cones than normal, so they get confused with colours. If we lose our eye sight, the body adapts and receives colour rays through the skin. It takes time for the body to adapt, but it has been shown that people, who are blind, can differentiate between different colours.

4.8 Why are Objects the Colour they are?

Everything we can see has a colour. Around us, in our homes, at work, in nature, in space - it is universal; everywhere has a colour, of some sort. The colour of anything we observe depends upon a few factors. Firstly - *Everything* is made up of electrons and atoms. Different materials, objects and items have a different make up of atoms and electrons. Any object, by its nature, will, when exposed to light, do one of the following: reflect or scatter light (reflection and scattering), absorb light (absorption), do nothing (transmission) and refract light (refraction).

4.8.1 Reflection and Scattering

A lot of objects reflect light to some degree, but something that is particularly reflective, has more free electrons that are able to pass from one atom to another with ease. The light energy that is absorbed by these electrons is not passed onto any other atoms, instead, the electrons vibrate and the light energy is sent out of the material at the same frequency as the original light coming in. Smooth surface reflect light while rough surface scatter it and the angle of incidence is always equal to angle of reflection.

4.8.2 Absorption

When something appears to have no reflection or is opaque, then the incoming light source frequency is the same as, or very close to the vibration frequency of the electrons in the given material. The electrons of the material absorb the energy of the light source, and because the light is absorbed, the material or object appears opaque - it has very little or no reflection.

4.8.3 Transmission

This occurs when the energy of the incoming light is either much lower or much higher than the energy or frequency required to making the electrons in the particular material vibrate. As a result of this, the electrons in an object that appears to be transparent, instead of capturing the light energy, allows the light wave pass through the object/material unchanged, thus the object/material is transparent to that frequency of light.

4.8.4 Refraction

If you have ever put a straw in a drink, then you may have noticed that the straw appears to be bent under the water. The reason for this is ***Refraction***. If the energy of the incoming light is the same as the vibration frequency of the electrons in the material, the light is able to go deep into the material and causes small vibrations in the electrons. These vibrations are passed on to the atoms by the electrons, and in turn they send out light waves at the same frequency as the incoming light. Although this happens extremely quickly, some of the light that is inside of the material slows down, but the frequency of the light outside the material remains the same. The result of this is that the light inside the material is bent. The angle of the distortion (refraction) depends upon how much the material is able to slow down the light, in this case as in the image above water.

A good example as to why objects possess a particular colour is shown in thepicture below (of ripe tomatoes).Tomatoes appear to be red because when ripe, tomatoes contain a carotenoid known as "Lycopene".Lycopene is a bright red carotenoid pigment, a phytochemical found not only in tomatoes but also other red fruits.Lycopene absorbs most of the visible light spectrum, and being red in colour, Lycopene reflects mainly red back to the viewer, and thus, a ripe tomato appears to be red.

Fig. 1.4 Tomato and its Colour
Source: www.colourtherapyhealing.com

Another example is the green leaf or green grass whichuses Chlorophyll to change light into energy. Because of its nature and chemical makeup, Chlorophyll absorbs the blue and red colours of the spectrum and reflects the green. The green is reflected back out to the viewer making the grass and leaves appear green.

SELF ASSESSMENT EXERCISE2

i. Explain in detail why objects possessa particular colour.
ii. Mention the relationship between colours and the eyes.
iii. What is colour perception?

5.0 CONCLUSION

Colour comes from light which resides mainly in the visible region of the electromagnetic radiation. This should not be interpreted as a definitive list – the pure spectral colours form a continuous spectrum, and how it is divided into distinct colours linguistically is a matter of culture and historical contingency.(Although people everywhere have been shown to *perceive* colours the same way). A common list identifies six main bands: red, orange, yellow, green, blue, and violet. Newton's conception included a seventh colour, indigo, between blue and violet – but most people do not distinguish it, and most colour scientists do not recognize it as a separate colour; it is sometimes designated as wavelengths of 420–440 nm. The *intensity* of a spectral colour may alter its perception considerably; for example, a low-intensity orange-yellow is brown, and a low-intensity yellow-green is olive-green.

6.0 SUMMARY

In this unit, you have learnt that:

- colour comes from light which is the visible portion of the electromagnetic radiation
- there are seven different kinds of colours namely: red, orange, yellow, green, blue, indigo and violet
- the *intensity* of a spectral colour may alter its perception considerably; for example, a low-intensity orange-yellow is brown, and a low-intensity yellow-green is olive-green
- the colour of anything we observe depends on what happened on exposure to light source
- any object, by its nature, will, when exposed to light, do one of the following: reflect or scatter light (reflection and scattering), absorb light (absorption), do nothing (transmission) and refract light (refraction).

7.0 TUTOR-MARKED ASSIGNMENT

i. Explain the concept of colour.
ii. What are factors that determine whatthe colour of objects are?

iii. Examine the concept of colour perception.

8.0 REFERENCES/FURTHER READING

Bailey, Alice A. (1995). *The Seven Rays of Life*. New York: Lucis Publishing Company.

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UNIT 2 TYPES OF COLOURS

CONTENTS

1.0 INTRODUCTION

The science of colour is sometimes called *chromatics*. It includes the perception of colour by the human eye and brain, the origin of colour in materials, colour theory in art, and the physics of electromagnetic radiation in the visible range (that is, what we commonly refer to simply as *light*). The familiar colours of the rainbow in the spectrum – named using the Latin word for *appearance* or *apparition* by Isaac Newton in 1671 – include all those colours that can be produced by visible light of a single wavelength only, the *pure spectral* or *monochromatic* colours.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- identify the different types of colour
- describe the constitution of each type of colour
- produce colour combination
- determine the kind of colour that best suits a particular environment
- enumerate the use to which colours are subjected

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.
3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Types of Colours

There are basically three types, namely primary, secondary and tertiary colours

4.2 Primary Colour

Contrary to popular belief, there are actually two methods of producing colours. They are the **Additive and Subtractive Colour.** To create all the colours of the rainbow, both processes use primary colours, which are colours that cannot be created by mixing other colours.

4.2.1 Additive Primary Colours

Additive colours are colours that are associated with emitted light directly from a source before an object reflects the light. These colours are red, green and blue. These are the colours we are probably most familiar with that are associated with television, and computer displays. If all three of the additive colours were combined together in the form of light, they would produce white. Some examples where additive primary colours are used include television, theatrical lighting and computer monitors. The additive colour theory was first described by James Clark Maxwell in the mid 1800s. When equal amounts of red, green and blue light are combined, they produce white light. By adding the colours together to produce white, we call these additive colours. Red, green and blue are the *"primary" colours* of white light. This is called colour by addition and is a direct way to prove that all of these three colours do indeed come from white light.

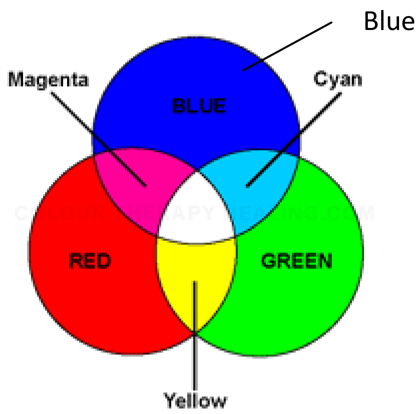

Figure 2.1 primary colours of white light

4.2.2 Subtractive Primary Colours

Subtractive colours are colours that are associated with reflected light. In this case the subtractive colours are blue, red and yellow. These are the colours we are probably most familiar with as primary colours in school. These colours are associated with the subtraction of light and used in pigments for making paints, inks, coloured fabrics, and general coloured coatings that we see and use every day. If all three of the subtractive primary colours are combined together, they will produce black. By adding the colours together to produce black, we call these subtractive colours.

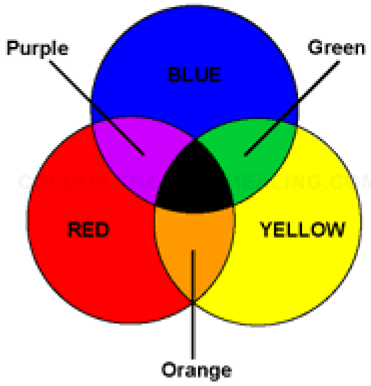

Figure 2.2 subtractive primary colours

The subtractive primary colours used in the printing process are cyan, magenta and yellow. Black is also used. All printing processes use subtractive colours in the form of cyan (blue), magenta (red), yellow, and sometimes black. This is known as CMYK for short (cyan, magenta, yellow, black) the K stands for black in the printing process. These colours: cyan, magenta and yellow are a set of subtractive primaries and are commonly used by printers. They are commonly referred to as the 'printing primaries'. It is difficult to achieve a good black from just these colour pigments so printers sometimes also use black. The reason that printers use this set of primaries as opposed to the painting primaries of blue, red and yellow, is that they yield far better results. If you are using these colours for painting however, you will find that mixing them is far less intuitive than when mixing the painting primaries.

Some examples where subtractive primary colours are used: textiles, clothes, furnishings, printing, paints and coloured coatings.

SELF ASSESSMENT EXERCISE 1

i. What is colour?
ii. Differentiate between additive and subtractive primary colours

4.3 Secondary Colours

If two of the primary colours are mixed together, a **secondary colour** is created. As more colours are mixed, the selection of colours grows. **The following colours can be created:**

- **Violet/Purple** – mixing of Blue and Red
- **Orange -** mixing of Red and Yellow
- **Green -** mixing of Blue and yellow
- **Black -** mixing of Blue, Red and Yellow

These colours that are created from mixing the primary colours are called *secondary colours*.

4.3.1 Additive Secondary Colours

Secondary additive colours are produced by mixing two additive primary colours together. The additive primary colours are red, green and blue. When these additive colours are mixed, they produce three secondary colours. These are: cyan, magenta and yellow.

4.3.2 Subtractive Secondary Colours

Secondary subtractive colours are produced by mixing two subtractive primary colours together. The additive primary colours are red, green and blue. When these subtractive colours are mixed, they produce three secondary colours. These are: Violet/purple, Orange and green.

4.4 Tertiary Colours

Tertiary colours are combinations of primary and secondary colours. There are six tertiary colours; red-orange, yellow-orange, yellow-green, blue-green, blue-violet, and red-violet. An easy way to remember these names is to place the primary name before the other colour. For instance, the tertiary colour produced when mixing the primary colour blue with the secondary colour green, is called 'blue-green"

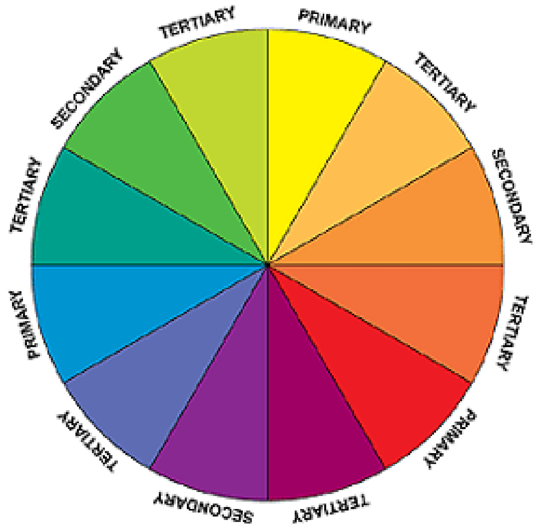

Fig.2.3 **Formation of Colours**
Source: www.colourtherapyhealing.com

4.5 Colours in the Home

There are many variations of the basic colours. The paler versions, which are sometimes more appropriate for covering the walls within our homes, give us the same qualities as the bold colour but in a gentler way. When decorating an area - the complementary colours, and their variations, should be remembered and combined with our main choice of colour by way of soft furnishings, pictures etc.

It is also helpful to take in to account the aspect of a room. For example, should you require a calming atmosphere in a north facing room, which may well be one of the colder rooms in your house, remember to use some warm colours (i.e. variations of the warm colours of yellow, orange and red) to avoid the room feeling colder.

4.5.1 Using Colours in the Home

When using colour in the home environment, we all have our own personal choices. A Particular colour choice can help towards providing a specific 'feeling' for a space. Below are some suggested uses of colour in the home, workplace and various environments, and the effects these colours can produce.

Table 2.1: Colours, Features and Uses

Colour	Effect	Suggested Area of Use
Violet	• Calming for body and mind. • Good for meditation and prayer. • Enhances purpose and dignity. • Heightens our awareness and helps us to give our very best. • Purifying.	• Places of worship • Entry areas to clinics and hospitals • Festival areas • Pale violet in bedrooms.
Indigo	• Sedative • Helps to open up our intuition • The colour of divine knowledge and the higher mind.	• Not suitable for areas for entertainment but for more 'quiet' places • Bedrooms • Treatment rooms • Some people find indigo is helpful for studying so this colour could be used as part of the decor of a library or study.
Blue	• Calming, relaxing and healing • Not as sedating as indigo. Also the colour of communication.	• Any rooms except those used for physical activity or play.
Green	• Balancing, harmonising and encourages tolerance and understanding.	• Depending upon the shade, can be used for most areas • Useful for any rooms except those used for physical activity or play. It can be used with other colours/colour as well to avoid the balance and harmony becoming more like total inactivity and indecision.
Yellow	• Stimulates mental activity • Promotes feeling of confidence • Helpful for study as it helps us to stay alert.	• Activity rooms • Entrance halls • Not for bedrooms as yellow can interfere with sleep since it tends to keep our minds "switched on" • Not ideal for areas of possible stress.
Orange	• Warming and energizing • Can stimulate creativity • Orange is the colour of fun and sociability.	• Any activity area and creative areas • Not ideal for bedrooms or areas of possible stress.
Red	• Energizing, exciting the emotions • Stimulates appetite.	• Any activity area but red needs careful choice of tone and depth and the space in which it is to be used as it can make a

		space look smaller and can be claustrophobic or oppressive. However, used well, red and its variations can make a space feel warm and cosy. Often used in restaurants.
Magenta	• Magenta is the eighth colour in the colour spectrum and is a combination of red and violet, it combines our earthly self and spiritual self, thus balancing spirit and matter. • It is uplifting and helps us to gain a feeling of completeness and fulfillment.	• Lecture spaces • Chapels halls etc • Not ideal for play rooms or activity rooms
White	• White contains all the colours. It emphasises purity and illuminates our thoughts, giving us clarity.	• Any room, but it can be a little intimidating to some. Needs to be broken up with another colour or with plants/ornaments/pictures etc.
Black	• Black used with another colour enhances the energy of that second colour • Black gives us the space for reflection and inner searching.	• Not ideal as a single colour, but when used with care,can enhance and complement other colours in almost any situation.
Pink	• This colour soothes and nurtures • It helps to dissolve anger and encourages unconditional love.	• Ideal for a baby's or child's bedroom.
Turquoise	• Cool and calming and good for the nervous system and immune system.	• Any room except it is not ideal for activity areas.

SELF ASSESSMENT EXERCISE 2

Distinguish between secondary and tertiary colours

5.0 CONCLUSION

There are basically three types of colours: namely primary, secondary and tertiary colours. In addition, both the secondary and the tertiary colours arise through combinations of some primary colours.

6.0 SUMMARY

In this unit, we have learnt that:

- Additive colours are colours that are associated with emitted light directly from a source before an object reflects the light. These colours are red, green and blue.
- **Subtractive e**colours are colours that are associated with reflected light. By adding the colours together to produce black, we call these subtractive colours.
- the colours that are created from mixing the primary colours are called Secondary Colours
- if the secondary colours are mixed, they produce what are called Tertiary Colours
- useof colour in the home, workplace and various environments to produce aesthetic, psychological or healing.

7.0 TUTOR-MARKED ASSIGNMENT

i. Write short notes on the followings
   (a) Primary colours
   (b) Secondary colours
ii. In a tabular form, compare and contrast the nature and the uses of violet, magenta and blue colours

8.0 REFERENCES/FURTHER READING

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UNIT 3 PIGMENTS

CONTENTS

1.0 INTRODUCTION

Both dyes and pigments appear to be coloured because they absorb some wavelengths of *light* preferentially. In contrast with a dye, a *pigment* generally is insoluble, and has no affinity for the substrate. Some dyes can be *precipitated* with an inert salt to produce a *lake pigment*, and based on the salt used they could be aluminum lake, calcium lake or barium lake pigments.

2.0 OBJECTIVES

By the end of this, you should be able to:

- define what a pigment is
- identify types of pigments and their structure
- differentiate between the known pigments

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.
3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Definition of Pigments

Pigments are generally coloured, organic or inorganic solid powder, and usually are insoluble. They are not affected physically or chemically in the substrate in which they are incorporated. Pigments can give a full range of colours.

4.2 Features of Pigments

The pigments are versatile colouring agents that come with all round features to give credence to their suitability in a variety of mediums. Some of the striking features are:
Excellent light and weather fastness:

- A good baking stability that makes them suitable for automotive and other industrial paints
- High tinting strength
- Good over spray fastness when applied in paints
- Gives heat stability of around 300° C in the case of Polyolefins Plastics
- Excellent solvent resistance properties
- Easily dispersible
- Consistency and uniqueness of shades.

4.3 Types of Pigments

a. Inorganic Pigments: Those pigments that are made up of mineral compounds are known to be Inorganic Pigments. These minerals are mainly oxides, sulphides of one or more metals. To impart colours in different compounds, inorganic pigments are applied.

b. Organic Pigments: In organic pigments, the molecules are made of carbon atoms along with hydrogen, nitrogen or oxygen atoms. Organic pigments can be subdivided into two viz. Natural organic pigments and Synthetic organic pigments.

c. Metallic pigments: Obtained from the ores of metal

4.3.1 Natural and Synthetic Organic Pigments

i **Natural Organic Pigments-** Pigments of this category are derived from animal and plant products. The use of these pigments is rare due to their poor light fastness property.

ii **Synthetic Organic Pigments-** Pigments of this category are carbon based and are often made from petroleum products. Under intense pressure or heat, carbon base molecules are manufactured from petroleum, acids, and other chemicals and synthetic organic pigments have been formulated from these molecule. Most of the synthetic organic pigments except carbon black are not stable and they will wear away at the time of use as a pigment.

Table 4.1: Comparison between Natural and Synthetic Organic Pigments

Natural Organic Pigments	Synthetic Organic Pigments						
Miscellaneous: e.g. Rose-Madder, Bone Black, Carbon Black	Quinacrid-ones	Phthaloc-yanines	Peryl e-nes	Pyrrol es	Ary-lamides	Metal Complexes: e.g. Transparent Yellow, New Gamboge	Miscellaneous: e.g. Dioxazsine - in Danthrone.

4.4 Differences among Types of Pigments

Table 3.2: Property of various Kinds of Pigments

Property Behaviour	Inorganic Pigments	Classical Organic Pigments	Specialty Organic Pigments	Organic Dyestuffs
Opacity	Usually high	Translucent to Transport		Very Transparent
Colour Strength	Low to moderate	Considerably stronger than Inorganic Pigments		Strongest
Dispersability	Usually Good: Often Abrasive	Adequate	Poor to good	Not required; Soluble
Heat Resistant	Usually 500^0 F; Some 200^0 C	150^0 C- 300^0 C	200^0 C- 300^0 C	250^0 C- 350^0 C
Migration resistance	Excellent	Moderate - Good	Good - Outstanding	Very Poor - good
Light Fastness (on a Blue scale	6 to 8	2 to 6	6 to 8	2 to 7
Weather resistance	Outstanding for selection	Insufficient	Excellent for Selection	Good for selection

Source: www.dyespigments.com

SELF ASSESSMENT EXERCISE 1

i. What do you understand by the word pigment?
ii. List the kinds of pigments you know

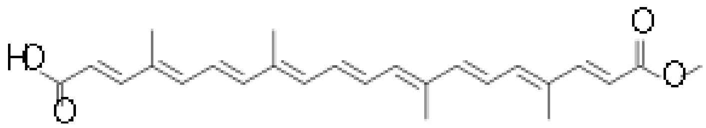
4.5 Natural Pigments

Different types of natural pigments are found in different kinds of natural sources. Some of these pigments are obtained from insects/animals and others are obtained from plants. Other pigments belong to cosmetics and have affinity to all such foods and drugs which require colour additives. Natural pigments are good for use in the shower gel, bath bombs, bath salts, shampoo, soap, lotion and in many more other products. These pigments have good quality of bleed protectiveness in soap and these are also water dispersible. But, these pigments do not have high intensity in light.

4.5.1 Kinds of Natural Pigments

4.5.2 Annatto Natural Pigments

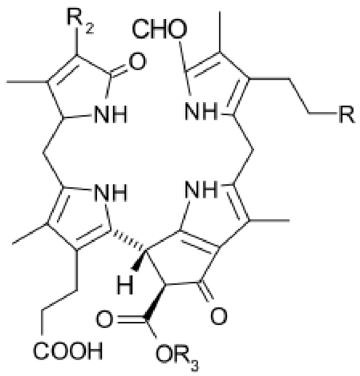
Annatto natural pigments have reddish-orange colourant. This colourant is derived from seeds of Achiote trees. Annatto pigments are given 'annatto' as a name because these pigments are derived from Annato shrubs. The concentration of annatto pigments in the annatto shrubs, vary from place to place. When the foodstuffs require hues of yellow to orange, annatto based pigments are used. The main food items in which annatto dyes are used are: in making cheese (around 50%), fish processing (around 20%), confectionery (around 10%), dairy products except cheese (around 20%). Bixin is the major *carotenoid* of annatto



Bixin

4.5.3 Plant Pigments

Chlorophyll is responsible for the green colour of flowering plants. Acetone is required for the extraction of plant pigments. Calcium carbonate must be present for stimulating the extraction process. Any other mild alkali can also be used for the extraction of plant pigments. The alkali is used during the extraction process to neutralize the acid which liberates from the plant tissues.



Chlorophyll

4.5.4 Carotenoid Pigments

Carotenoid pigments e.g. β-carotene, have colour range from yellow to red. Mixture of acetone and hexane in the 1:3 ratios is used for the extraction of carotenoid pigments. The acetone fraction containing the extracted carotenoid pigments is removed with water. To remove the hexane residue, the mixture is treated with activated MgO_2 in diatomaceous earth column.

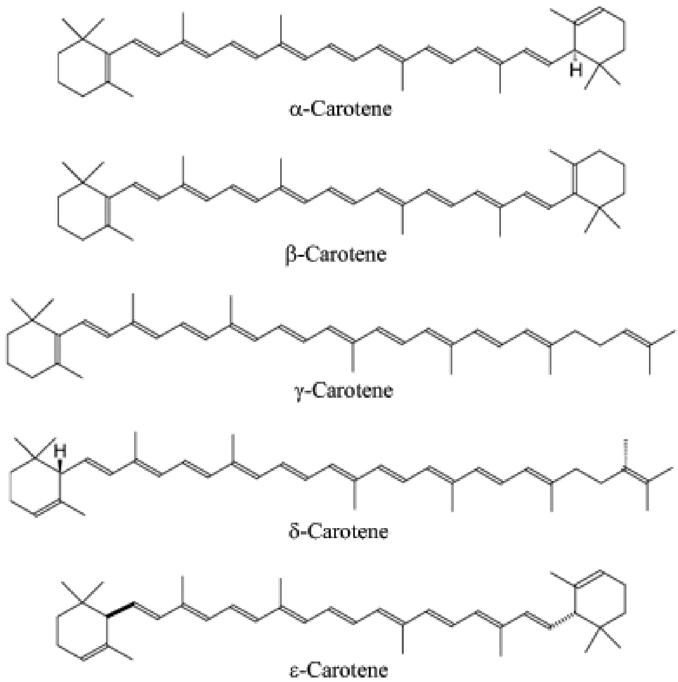
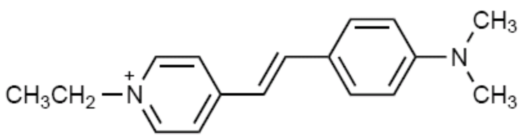


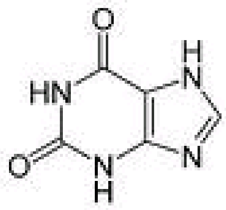
Figure 1. Chemical structure of carotene series.

4.5.5 Betalain Pigments

Betalains are another type of colour pigments which are also derived from plants. These pigments are present in two forms. The first is β-cyanin having purple-red colour and are present in high concentration. The second is β-xanthine which is yellow in colours which are obtained in low concentration. These pigments can easily be extracted from plant tissues with water as they are highly soluble in water. The extracted water is then mixed smoothly with ethyl alcohol in 1:1 ratio. The use of ethanol in the mixture is to reduce the enzymatic action; otherwise the pigments will be degraded.



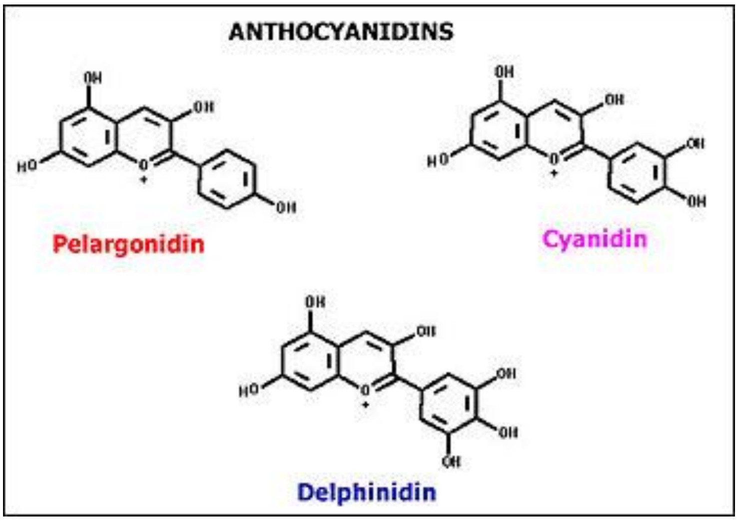
Cyanin



Xanthine

4.5.6 Anthocyanin Pigments

Anthocyanin pigments are coloured pigments and these are found in abundance in plant kingdom. The colours imparted by these pigments are blue, red and purple. The colour of fruits and flowers are also due to the colour impartation of these pigments. Anthocyanins are soluble in water and their extraction from the plant parts is also easy. Slightly acid mixed water is required for the extraction of these pigments.



4.6 Limitations of Natural Pigments

1. Natural pigments are produced by traditional methods.
2. These pigments have lower intensity in comparison to synthetic pigments.
3. To obtain the same depth like synthetic pigments, natural pigments require large quantities of raw materials.
4. These pigments are not efficient for colouring of the synthetic clothes.
5. To ensure adequate wash and light fastness, these pigments require application with different metallic mordants.
6. Application with few mordants like alumina and iron has adverse effects on the environment.
7. The liquid waste of natural pigments contains heavy metals which is much more than the desired limit.

4.7 Factors affecting the selection of Pigments

Factors affecting the choice of a pigment depend on application. The following broad factors can be taken as a guide:

- Hiding efficiency
- Colour
- pH value
- Bulking value
- Density
- Refractive index
- Hardness
- Oil absorption

SELF ASSESSMENT EXERCISE 2

i. Mention four limitations of natural pigments
ii. Give the names and structures of three common pigments

5.0 CONCLUSION

Pigments have been known since ages to impact positively as coloured substances made of both natural and synthetic materials. There are several factors to be taken into consideration when working with a pigment.

6.0 SUMMARY

In this unit, we have learnt that:

- pigments are generally described as insoluble colour materials
- there are different kinds of pigments, both natural and synthetic forms
- these natural pigments are made of diverse chemical structures which affects their colouring properties.

7.0 TUTOR-MARKED ASSIGNMENT

i. Differentiate between natural and synthetic pigments
ii. Mention four limitations of natural pigments
iii. With structural examples, explain
    a. Betalain pigments
    b. Anthocyanin pigments
    c. Carotenoid pigments

7.0 REFERENCES/FURTHER READING

Brunello, F. (1973).*The Art of Dyeing in the History of Mankind*.Neri Press: Vincenza.

www.dyepigments.com

UNIT 4 ORGANIC, INORGANIC, AND METALLIC PIGMENTS

CONTENTS

1.0 INTRODUCTION

There are a number of pigments available today. In fact, after the advent of synthetic pigments there has evolved various types of pigments that are suited to particular needs and types of industries.

2.0 OBJECTIVES

By the end of this unit, you should be able to know:

- the different types of pigments
- discuss the features of each type of pigments
- identify the differences and similarities between types of pigments

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you

are satisfied that you have done your best to get all the answers.

3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Definition of types of Pigments

Inorganic Pigments: Pigments that are made up of mineral compounds are known as Inorganic Pigments.

Organic Pigments: Organic Pigments are not usually found in nature. That is the reason why a majority of these pigments are chemically synthesized. They contain carbon and come with relatively low levels of toxicity, not providing any major environmental challenge.

Industrial Pigments: These are based on their industrial application.

4.2 Organic Pigments

Raw materials include coal tar and petroleum distillates that are transformed into insoluble precipitates. Traditionally organic pigments are used as mass colourants. They are popular in plastics, synthetic fibres and as surface coatings-paints and inks. In recent years the organic pigments are used for hi-tech applications that include photo-reprographics, opto-electronic displays and optical data storage.

4.2.1 Categories of Organic Pigments

a. Monoazo Pigments
b. Diazo Pigments
c. Acid and base dye Pigments
d. Phthalocyanine Pigments: Some of the striking features which makes it a very useful for a variety of applications are the following: Light fastness, tinting strength, covering power, resistance to the effects of alkalies and acids and good stability
e. Quinacridone Pigments: The following are important features of these pigments; outstanding light fastness, excellent bleed and heat resistance, bright and vibrant tones, very good tinting value along with working properties and high transparencies
f. Other polycyclic Pigments

4.2.2 Key Features of Organic Pigments

a. Very good stability to solvents, light, heat, and weathering
b. Good tinctorial strength
c. Cost effectiveness
d. Consistency and unique shades
e. Completely non-toxic
f. Very bright, pure, rich colors
g. Organic pigments shows good color strength

SELF ASSESSMENT EXERCISE 1

i. Mention the source of organic and inorganic pigments
ii. Mention three of the characteristics of organic pigments

4.3 Inorganic Pigments

Inorganic pigments may be obtained from vivid naturally occurring mineral sources or minerals which have been obtained synthetically. They are of the type mineral-earth but generally are metallic oxides or synthetics. Pigments that are of the type Mineral-earth are very simple and naturally occurring coloured substances. The preparation process is also simple and consists of the steps of washing, drying, pulverizing and mixing into a formulation. Inorganic pigments are available in the market in different forms. These different forms are powder, pastes, slurries and suspensions. The Inorganic Pigments are again divided into two sub types.

4.3.1 Natural Inorganic Pigments

Natural inorganic pigments are the earth colours in natural form like ochers, umbers etc. These colour pigments are extracted from the earth bed, Iron oxide and hydroxide which are present in the soil. These two compounds are responsible for the colouration of these colour pigments. Clay, chalk and silica are also present in these pigments in varying quantity.

The types of Natural Inorganic Pigments are:

(i) **Azurite-** Actually these kind of natural inorganic pigments are copper carbonates having greenish blue shading. Over a very long period, azurite has been used as a pigment. But, often these pigments have been replaced by synthetic pigments or used to paint the expensive ultramarine as under paintings.
(ii) **Red earths-** These pigments are the most diverse kind of natural inorganic pigments. These are made from clay and they have a

large amount of iron oxide. The colour varies from dull yellow to dull deep yellow or from dull orange to dull red or from dull dark brown to dark brown.

(iii) **Yellow earths-** These are natural earth containing silica and clay. These pigments are present in hydrous form of iron oxide. These pigments also contain gypsum or manganese carbonate. All over the world, these pigments are available and have been used from the prehistoric period.

4.3.2 Synthetic Inorganic Pigments

Synthetic inorganic pigments are manufactured in the laboratory. These pigments consist of metallic compounds like manganese violet; cobalt blue etc. Synthetic inorganic pigments can also be produced by the replication of the natural earth colours like mars, red or yellow. As these pigments are manufactured in the laboratory, so they are found in pure form having fine particles.

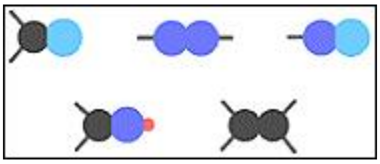
Table 4.1: Refractive Index of some of the very Popular Class of Inorganic Pigments;

Pigment	Refractive Index
TiO_2 (rutile)	2.71
TiO_2 (Anatase)	2.55
Antimony Oxide	2.20
Zinc Oxide	2.01
Calcium Carbonate	1.65
Fumed Silica	1.45

Source: www.dyespigments.com

Synthetic organic pigments are mainly derived from some selective elements atoms. These are as follows:

Chromophore is a pair or group of atoms which creates a complex and dynamic clouding of the electrons within the respective electron shells in single atom or more than one atom. These chromophores are responsible for the colour creation phenomena of the pigment's molecules.



4.3.3 Shortcomings of Inorganic Pigments

Colour that comes from inorganic pigments is comparatively less bright. These pigments also seemed to be less rich and pure than the organic pigments. As these pigments have low tinting strength so a large number of pigments are required to produce the desired effects.

4.4 Differences between Organic and Inorganic Pigments

The differences between organic and inorganic pigments are based upon three principal factors.

i. Molecular structure of the pigments:

Carbon chains or carbon rings are always present in the molecules of the *Organic Pigments*. As carbon element is associated with nitrogen and sulphur elements of the same class of the atomic table, so, sometimes in the molecules of the organic pigments, the atoms of nitrogen and sulphur are also found along with the carbon atoms.

Examples: Azo, Phthalocyanine, Diazo and Anthraquinone pigments.

However, in the molecules of the *Inorganic Pigments*, the cations of metal are found in an array form with the non-metallic anions. This arrangement does not allow these pigments to dissolve in the solvent and plastic. Examples: Iron oxide, yellow, black, red and tan pigments.

ii. **Sources**:

The main sources of organic pigments are plants and plant products.

iii. **Exposure**:

Inorganic pigments are considered better over their organic counterparts. These inorganic pigments can withstand the impact of sunlight and chemical much better. .They have also good opacity and thus can protect other objects by preventing light. These pigments also increase rash inhibition, abrasion resistance and rigidity to the molecules. These pigments are available at low cost in respect to the organic pigments. They are also durable.

Table 4.2: The Differences between Organic and Inorganic Pigments

Particulars	Inorganic Pigments	Organic Pigments
Source	Minerals	Chemically refined oil
Color	Often dull	Bright
Dyeing/Coloring Strength	Low	High
Opacity	Opaque	Transparent
Light fastness	Very good	Vary from poor to good
Solubility	Insoluble in solvents	Have little degree of solubility
Degree of safety	May be unsafe	Usually safe
Chemical Stability	Often sensitive	Usually good
Cost	Moderate	Mostly too expensive

Source: www.dyespigments.com

4.5 Metallic Pigments

Nowadays, metallic pigments are a very popular category of pigments, as a further classification. Metallic pigments can be of two types:

(i) **Aluminium Pigments**: Aluminium pigments are further divided into two categories namely leafing grade and non-leafing grade. The aluminum pigments are produced from aluminium that has purity in the range of 99.3-99.97%. The particle has lamellar shape with 0.1-2 µm in thickness and diameter of 0.5-200 µm. These pigments found use in automotive topocoats. Some of the preferred applications of Aluminium pigments are the following:

i. Corrosion protection coats
ii. Reflective paints
iii. In Marine paints (covering coats)
iv. Roof coatings
v. In Heat-proof and highly heat-resistance paints
vi. Chrome effect paints
vii. Aerosols

(ii) Zinc Pigments: Zinc Pigments come in two forms of powder and dust. Usually the zinc dust is finer as compared to powder and is spherical in shape. The dust also has a light coating of zinc oxide.

Table 4.3: Zinc Pigments along with their Applications

Zinc Pigments	Application
Zinc dust	Chemical applications Metallurgical applications
Zinc phosphate	Active ingredient in domestic cleaning products
Zinc oxide	Agricultural applications Rubber industry Brick kilns Ceramics

Source: www.dyespigments.com

5.0 CONCLUSION

There a number of pigments in the world today that have serve mankind in various applications. The use to which pigments are put depends on a number of factors. The presence of chromophores that absorbs light of certain wavelength is the most striking feature of individual pigments.

6.0 SUMMARY

In this unit, you have learnt that:

- natural organic pigments are abundant in nature and consist of carbon and some other elements
- inorganic pigments are obtained from naturally occurring mineral sources or minerals which have been obtained synthetically. They are of the type mineral-earth but generally are metallic oxides
- synthetic inorganic pigments are manufactured in the laboratory These pigments consist of metallic compounds like manganese violet, cobalt blue
- metallic pigments are primarily composed of aluminium and zinc

7.0 TUTOR-MARKED ASSIGNMENT

i. Differentiate between organic and inorganic pigments
ii. Write short notes on the following
   a. kinds of natural inorganic pigments
   b. Application of aluminium pigments
   c. Categories of organic pigments

8.0 REFERENCES/FURTHER READING

Lyles, J.N. (1990). *The Art and Craft of Natural Dyeing*. Knoxville:University of Tennessee Press

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UNIT 5 THE LINKAGE BETWEEN PIGMENTS AND DYES

CONTENTS

1.0 INTRODUCTION

Both dyes and pigments appear to be coloured because they absorb some wavelengths of *light* preferentially. In contrast with a dye, a *pigment* generally is insoluble, and has no affinity for the substrate. However, there has been an interchange of usage between the two. Pigment dyeing is a comparatively recent addition.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- state what makes a dye
- identify the types of dyes
- differentiate between a dye and pigments
- explain how dyes work.

3.0 HOW TO STUDY THIS UNIT

4. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
5. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.

6. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.

Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

3.0 HOW TO STUDY THIS UNIT

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3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Definition of Dyes

A dye can generally be described as a coloured substance that has an affinity for the substrate to which it is being applied. The dye is generally applied in an aqueous solution, and may require a mordant to improve the fastness of the dye on the fiber.

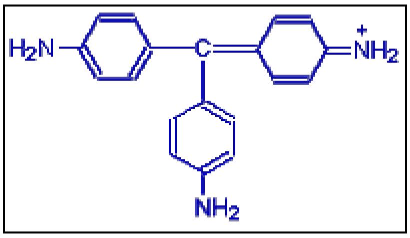
4.2 Features of Dyes

At the very basic level, the use of colour in identifying individual components of tissue sections can be accomplished primarily with dyes. Although there are other means, Dyes are however, the largest group that can easily be manipulated to our liking. Dyes are applied to numerous substrates for example to textiles, leather, plastic and paper in liquid form. One characteristic of dye is that the dyes must get completely or at least partially soluble in what it is being put to. The rule that we apply to other chemicals is similarly applicable to dyes also. For example, certain dyes can be toxic, carcinogenic or mutagenic and can be hazardous to health.

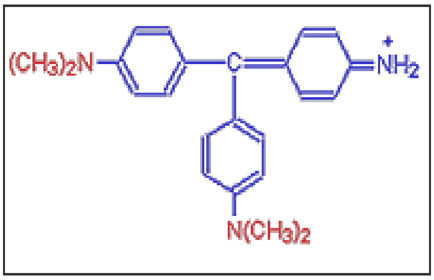
4.3 How Can the Colour of the Dyes be Altered?

The answer lies in the modifiers. Colour modifiers like methyl or ethyl groups can actually alter the colour of dyes. They do so by altering the energy in the delocalised electrons. It has been found that by addition of a particular modifier there is a progressive alteration of colour. An example can be given for methyl violet series.
The following step explains what happens to the colour of the dyes when modifiers are added

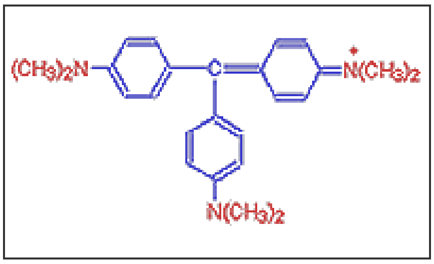
Step A: When no methyl group is added, the original dye *Pararosanil* as it is called is red in colour.



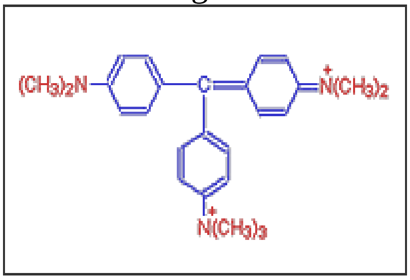
Step B: As four methyl groups are added, reddish purple dye *Methyl Violet* is got.



Step C: With the addition of more methyl groups a purple blue dye *Crystal Violet* is obtained. It has in it six such groups.



Step D: Further addition of a seventh methyl group the dye that is got is called *Methyl green.*



4.3.1 What Gives Dyes Solubility and Cohesiveness?

The answer to this riddle lies in substance called Auxochrome. Auxochromes have the abilty to intensify colours. It is a group of atoms which attaches to non-ionising compounds yet has to ionise. Auxochromes are of two types, positively charged or negatively charged.

—OH	—NHR	—Cl	—Br
$—CH_3$	$—NO_2$	$—NR_2$	—COOH
$—NH_2$	$—SO_3H$		

SELF ASSESSMENT EXERCISE 1

i. What is a dye?
ii. What are the basic features of a dye

4.4 Dyeing and Fabric

This is an application of dyes with respect to the fabrics.

Table 5 .1: Types of Dyes and Fabric

Group	Application
Direct	Cotton, cellulosic and blended fibres
Vat dyes	Cotton, cellulosic and blended fibres
Sulphur	Cotton, cellulosic fibre
Organic pigments	Cotton, cellulosic, blended fabric, paper
Reactive	Cellulosic fibre and fabric
Disperse dyes	Synthetic fibres
Acid Dyes	Wool, silk, paper, synthetic fibres, leather
Azoic	Printing Inks and Pigments
Basic	Silk, wool, cotton

Source: www.dyespigments.com

4.5 Conventional Pigment Dyeing System

There is a challenge in pigment dyeing. In the process of pigment dyeing no actual chemical reaction takes place between the dye and the fabric. Instead, what happens is that the pigments get seated on the fabric with the help of binders.

Pigments are not soluble in water and show no affinity for fibre. So, conventional dyestuff-based dyeing conditions are not feasible for pigment dyeing. To come to terms with such limitations, a new kind of pigments have been formulated for use in fibres. These are maintained in a stable dispersion in the medium of water by anionic surfactants. This type of pigment is known as pigment resin color (PRC), primarily used in printing. Some of the popular pigments used in fabrics are given here.

a. Yellow colour: Acetoacetic acid anilide pigments
b. Red: Azoic pigments
c. Blue or green: Phthalocyanine pigments

A typical process of pigment dyeing for cellulosic textile materials consists of padding the textile materials with a dye bath. The dye bath contains anionic or neutral colour dispersions of pigments. Along with the pigments it also contains anionic binders, acid-liberating catalyst, anti-migrating agents, and other types of additives. Then, the textile materials are dried at high temperatures, this cures the film-forming binders and pigment colours firmly on the textiles.

4.6 Differences between Dyes and Pigments

The major differences between the Dyes and Pigments are highlighted below

Table 5.2: Differences between Dyes and Pigments

Points of Difference	Dyes	Pigments
Solubility	They are soluble	Pigments are colourants that are insoluble in water and most solvents
Number	Available in large number	Comparatively lesser in number
Product resistance	Lower as compared to pigments	Very high
Light fastness	Lower Dyes are very much vulnerable. Lights destroy coloured objects by breaking open electronic bonding within the molecule	Traditionally pigments have been found to be more lightfast than dyes
Size	Dye molecules are comparatively smaller it's like comparing a football (pigment) to say a head of a pin (dye)	Pigment particles are about 1-2 microns in size. (1 micron =1/1000 meter). It means that the particles can be seen under a magnifying glass
Bonding	Taking the example of dyeing a wood surface, the dye and the substrate (wood) that is dyed are chemicals that have certain features called functional groups. At the level of molecules these groups serve as open pockets of electrostatic charges (+ or -). The functional group in dyes, serve as a point for attaching the dye to the wood	Taking the example of a wood surface pigment requires the help of a binder for gluing. As it is an inert substance which is merely suspended in a carrier/binder
Structure during the application process	During application process there is a temporary alteration in the structure of the dyes	During application, pigments have the capacity to retain its particulate or crystalline structure
Imparting of	Dyes can only impart colour	Pigments impart colours by

Colours	by selective absorption	either scattering of light or by selective absorption
Combustible properties	Taking the example of a candle making process, if the candles are dyed it is easily combustible and can be applied throughout the candle	In the example of a candle making as pigments are coloured particles, they tend to clog a wick when burned. This makes them undesirable for a candle if it is coloured throughout and used for burning
Chemical Composition	Usually the dyes are organic (i.e. carbon-based) compounds	While pigments are normally inorganic compounds, often involving heavy toxic metals
Longevity factor	The dye based printing inks do not last as long as the pigment inks	In case of ink based printing prints made with pigments last longer
Printing on substrates	Compatible with almost all the substrates that needs to be dyed	Owing to the physical makeup of the pigment inks the range for suitable substrates are limited
Colour gamut	Taking the case of printing inks, dye based inks offers a wide variety	As compared to dye-based inks, pigment inksets somewhat lags behind, on the same paper stock

Source: www.dyespigments.com

5.0 CONCLUSION

It could be seen that dyes and pigments are not the same, though they may be similar in some cases. Interestingly, pigment can be dyed too. Certain chemical modification explains the reason behind the dyeing processes.

6.0 SUMMARY

In this unit, you have learnt that:

- a dye can generally be described as a coloured substance that has an affinity to the substrate to which it is being applied
- dye is generally applied in an aqueous solution, and may require a mordant to improve the fastness of the dye on the fiber
- the functional group in dyes, serve as a point for attaching the dye to the wood

- inthe process of pigment dyeing no actual chemical reaction takes place between the dye and the fabric.

7.0 TUTOR-MARKED ASSIGNMENT

i. What are auxochromes? Mention four kinds of auxochrome
ii. In a tabular form, mention five differences between dye and pigment

8.0 REFERENCES/FURTHER READING

Industrial Dyes, Chemistry, Properties, Applications; Edited by Klaus Hunger (2003). Wiley-VCH.

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UNIT 6 APPLICATION OF DYES AND PIGMENTS

CONTENTS

1.0 INTRODUCTION

Modern dyes serve more than just being pretty. They have become indispensable tools for a variety of industries. Today various dyes are manufactured to meet the requirements of various industries. Dyes are available in various forms. Examples are dry powders, granules, pastes, liquids, pellets, and chips. Today the role and application of pigments have increased. There would hardly be any industry left where dyes and pigments do not play any substantial role. The challenge is now to discover pigments that are capable of not only long-lasting applications but also are environmentally safe.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- identify the various applications of dyes and pigments
- describe the economic importance of dyes and pigments

3.0 HOW TO STUDY THIS UNIT

1. You are expected to read carefully, through this unit at least twice before attempting to answer the self-assessment questions or the tutor marked assignments.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all the answers.
3. Share your difficulties with your course mates, facilitators and by consulting other relevant materials particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do better.

4.0 MAIN CONTENT

4.1 Application of Dyes and Pigments

From acting as colourants for plastics, textile dyeing industries and the highly sophisticated biotechnology industry, dyes are touching lives everywhere. Dyes and pigments are also used by industries for inks and tinting. Other industries, where dyes are used in a variety of products include paper and pulp, adhesives, art supplies, beverages, ceramics, construction, cosmetics, food, glass, paints, polymers, soap, wax, biomedicine etc.

4.2 Overview of the Important Applications of Pigments

- Paints- A diversified application in the whole gamut of paints that include decorative and protective coatings, in paints that are oil and resin based, automotive finishes, emulsion paints, distempers etc.
- Printing inks- Pigments are used in all kinds of printing inks that includes inks for printing metal foils, lacquers etc.
- Pigment finishes for leather and textiles: Colouration application for popular textiles such as polyesters, nylon etc
- Colouration of Plastics- Pigments are used in host of plastic applications that includes poly vinyl chloride (PVC), rubber and synthetic polymers, urea-formaldehyde (U-F) and melamine-formaldehyde moulding powders polystyrene, nylons, polyfins, phenol-formaldehyde (P-F), acrylonitrile-butadiene-styrene resins (ABS).

SELF ASSESSMENT EXERCISE 1

Give a brief account of the industrial application of dyes and pigments.

4.3 Industrial Application of Dyes and Pigments

4.3.1 Colourants for Plastic Industry

Colour selection is one of the vital things to be considered in the plastics industry. Colour is an integral part of the plastic material and it should not be considered as an afterthought. The whole system of colouring has to deal with using what is called a total systems approach. No doubt the colour enhances the part's functionality, but it has also the potential to degrade certain material properties like impact strength, if not properly applied. The colourants that are used in the plastic industries are the dyes and pigments. Both dyes and pigments exhibit colour through the process of visible light absorption and scattering. Typically colour formulations generally have four colourants. Black and white areused basically to control the value and Chroma, while two coloured pigments or dyes are applied to establish the Hue. The resulting colour that is achieved is governed by the laws of subtractive mixing, the same law that is used in printing and painting.

4.3.2 Cement Industry

Over the years, people have generated interesting effects by mixing cement and pigments in different ways and in different proportions. Concrete is derived from cement. For about last one century, pigments have been used with concrete to give them different colours. When pigments are mixed with concrete, then actually, these pigments tint the colour of the paste portion of the concrete.

To ensure a long lasting cement colour shade, the pigment that is being used in the cement, must have a good quality. These pigments (colour) are made from both natural and synthetic iron oxide, cobalt, titanium dioxide and chromium oxide. From iron oxide pigments, red, black and yellow colour can be obtained. From cobalt pigments, blue colour can be obtained. White colour and green colour can be obtained from titanium dioxide and chromium oxide respectively. Other colours like buffs, brown, tans, coppers, oranges, chocolates and many other colours can be obtained from the blends of the red, black and yellow coloured iron oxide pigments. These coloured pigments are: water-wetable, lightfast, alkali resistant and will not negatively affect the firmness and strength of the cement. But, one thing we should remember about the concentration of these pigments in the cement. This concentration should be within the range of 10% of the weight of the cementation ingredients.

4.3.3 Ceramic Industry

The applications of different pigments on ceramics are brought in different forms. These applications are as follows:

- **In Coating Ceramic Materials; Ceramic Glaze; Frits-**By formulating these coating applications of pigments on ceramics, the end users get attractive looking products with more durability and utility.
- **In Glaze development-** One of the applications of pigments on ceramics is to develop leading glazes for various whiteware ceramics. These include sanitary ware, tile, dinner ware etc.
- **In preventing Ceramics Corrosion and colour fading-** In this process, by applying pigment coating and protective layer with other kind of chemicals, the corrosion of the metals can be prevented. The lasting effect of colours also increases.

For enforcing the different applications on ceramics, various kind of special pigments are available. How much of which pigment will be used depends upon the desired colour intensity. But, the quantity of pigments that is used for these applications can vary from 1% to 10%. This variation does not make any noticeable impacts on the substances. Enamel (colourful) can be produced by colouring the melt during manufacturing. Enamel can also be generated by mixing colouring stains during the milling process.

4.3.4 Colourants for Security Printing

In view of the ever increasing threats of the cases involving forgery and fraud being committed in the financial institutions involving currency, both dyes and pigments play a vital role in giving cutting edge solutions to detect and prevent such fraud. Here we will discuss about the fluorescent dyes as well as about the luminescent pigments as applied in security applications.

Considerable research over the last decade or more on the study of fluorescence has borne fruits in the form of development of new fluorescent dyes. These security dyes are now applied increasingly in the very sensitive area of security printing. The fluorescent dyes are providing ways to create and apply effectively controlled”signatures“. The United States Pharmacopeia (USP) of these dyes is that they are customized and are printed as patches on different kinds of surfaces. Each of them has a signature element that is able to identify the patch as authentic. As the different dye formulas are able to vary their fluorescence characteristics in various repeatable ways, as a result unique signatures can be achieved. A very popular Example of a dye that is used in security printing is that of Coumarin.

Coming now to *Luminescent pigments,* these days a new range of luminescence has been developed that are either excited by ultraviolet (UV) or infrared (IR) or applied in security printing applications. Here a few specific uses of the luminescent pigments in the security printing are discussed.

- Security Printing and prevention of counterfeiting- Security marks and features that are not visible under normal light are made with *Luminescent pigments*. They cannot be duplicated even by the ultra sophisticated photocopiers. They can be easily verified using a very simple Ultra violet light or a luminescence sensor. That is the reason why security printing of stamps, checks, credit cards, licenses etc are done with *Luminescent pigments.*

- Brand Protection and Security of Products- In applications that involve product security, luminescent pigments are used in making tamper evident seals for pharmaceuticals and other products. When it comes to brand protection, luminescent pigments and fluorescent dyes are used for proprietary invisible security marks and features which gets printed on products, packaging and labels.

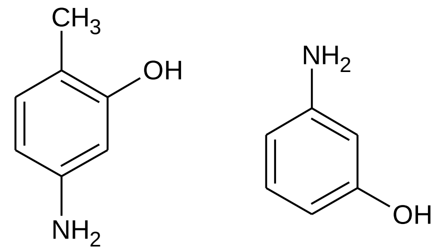
- Property Identification and Prevention of loss- As the invisible security marks created by luminescent dyes are not visible under normal conditions, do not deface the property and cannot be removed they are an ideal forensic tool.

SELF ASSESSMENT EXERCISE 2

Describe in detail, the application of dye or pigment in a security and printing industrial.

4.3.5 Colourants for Cosmetics Industry

Dyes have found a wide variety of uses in the cosmetics industry. Be it the hair dyes or lipsticks or nail polish shampoo everywhere there is wide use of dyes. Most of the commercial hair dye formulas available now are complex that use bountiful of ingredients and the formulas also differ considerably with manufacturers. The dye chemicals that are used in making hair dyes usually consist of amino compounds, like 4-amino-2-hydroxytoluene and m-Aminophenol. Pigments of metal oxides, like titanium dioxide and iron oxide, are also used.



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In the category of decorative cosmetics, the majority of colours used are pigments. It is the inorganic pigments that are popular with cosmetics but are subject to purity levels of heavy metals. The range of inorganic pigments used in cosmetics is generally made up of various chemical types. A few of the popular ones are provided in the table.

Table 6.1: Applications of Pigments

Pigments	Features and applications
Iron Oxides	Three basic shades: black, yellow and red, finds use in liquid foundations, face powders, and blushers.
Chromium Dioxides	Shades range from dull olive green, to a blue green, or bright green, finds use in most categories of cosmetic preparations but prohibited for use in lip products in the USA.
Ultramarines	Shade range from bright blue to violet, pink and green also, not allowed for lip products in the USA.
Manganese Violet	Shade is purple.
Iron Blue	Colour is dark blue, used in a wide range of applications.
White Pigments Titanium Dioxide Zinc Oxide	White pigments have a wide use in all cosmetics, they show extremely good covering power, are almost totally inert also extremely stable to heat and light.
Mica	Mica gives a natural translucence when used as face powders and powder blushers.

Source: www.dyespigments.com

In addition to this some types of organic pigments are also used along with water soluble and oil soluble dyes in the cosmetics application.

Some examples of water soluble dyes are given here.

Table 6.2: Examples of soluble dyes

Dye	Colours
Carotene PS 300	
Annato Hydrosouble	
Carmin of Cochineal	

Table 6.3: Colour of some Dyes

Dye	Colours
Carotene PS 300	Medium yellow
Annato Hydrosouble	Sand
Carmin of Cochineal	Orchid

4.3.6 Dyes in Medicine

Dyes are now an important ingredient in medical tests. Many of the tests that are carried out on patients use dye to get accurate results. One such example is that of Fluorescein angiography. Fluorescein angiography derives its name from fluorescein, the dye that is used very successfully for carrying out tests. Angiogram is a very valuable test that gives information about the circulatory system.

4.3.7 Colourants for Agriculture Industry

Primarily there are three main types of agricultural industries that use the dye. They are the crop protection industry, fertilizer industry and the seed dressing industry. The purpose of the dye used here is for colouring of agricultural chemicals or in the identification process of agricultural chemicals. The basic selection criteria depend upon the following:

- Colour strength of the particular dye
- Dye colour
- Colour stability
- Compatibility of the dye with the particular agent

(i) Fertilizer Industry: Fertilizers are often added with colouring to differentiate between qualities and to avoid any type of errors in application. Fertilizers are also coloured for purely marketing purposes. Usually water based pigment is often used in the diluted form and is sprayed onto the fertilizer or sometimes incorporated into a melt.

(ii) Crop Protection Industry: Use of colourants in crop protection agents of the type insecticide and fungicides helps to clearly demarcate treated areas from the untreated ones. In addition, the dye stuffs also help in promoting safety in the handling techniques. Colouring of pesticides or herbicides is generally done by mixing chromatic pigments with dry powder formulations of the agents. Milori blue is a very popular pigment, which goes well with viticultural fungicides. Other categories of pigments include lithol rubine, heliogen blue etc., Dyes used in the crop protection industry are Solvent dyes, Acid dyes or Basic dyes.

(iii) Seed Dressing Industry: The main objective of colouring the seed dressings is used for marking and a warning reference. To avoid any sort of confusion and making sure that it does not end up being used as fodder. The most important colourant used here is red with typical concentrations of 600 ppm.

4.3.8 Paper Industry

Over the years Paper makers have used dyes. Seeing the growth in the paper industry it can be safely assumed that Dyes for paper industry has a very promising future. Given below is a comprehensive list of the various grades of paper that are open to dyeing.

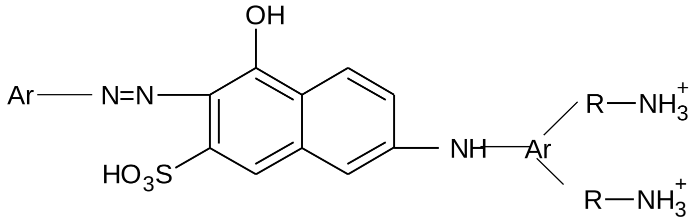
- Writing and printing paper
- Tissue - Facial, toilet, towel, napkin
- Copier papers
- Boards/Cover papers
- Decorative laminated paper
- Packaging grades - corrugated case stuff
- Envelope grades
- Specialty papers like, label, laundry tag, posters

The dyes that are used include sulphur dyes and cationic direct dyes. Other than these two popular options, acid dyes and basic dyes are also used. Sulphur dyes are reduced alkaline solutions.

Coming to the Cationic Direct Dye, some features which make them suitable towards use in paper are:

- An extended conjugation
- A planar molecular structure
- An excess of positive charge over the negatively charged surface groups

A typical structure of a cationic direct dye is given here.



Ar = Aromatic

R = Aliphatic

4.3.9 Pigments in Paints Industry

Pigments are the colouring elements present in the paints. They have a very special place in the paints industry. The paints industry uses them from a broad array, which includes specialty pigments to manufacture paints for a variety of applications. Ranging from automobiles to buildings to hardware the list is virtually endless.

The paints that employ the wide variety of pigments can be broadly classified according to application into two types. They are colourants for the industrial applications and architectural/decorative applications respectively. The pigment types are:

(i) **Earth colour Pigment-** Earth colours are derived from natural sources and are inorganic in nature (i.e. metal oxides). Examples that can be given of earth colours are: ocher, umber, terra di siena, bolus, swedish red etc.

(ii) **Mineral Pigments-** Mineral pigments comprise synthetic inorganic pigments. They include among others chrome oxide green, titanium dioxide, iron oxide yellow, red, brown and black, ultramarine blue, nickel-titanium yellow etc. One of the disadvantages of mineral pigments is the toxicity and ecological imbalance.

(iii) **Plant Colour** Pigments- Plant colours are sourced from natural organic pigment found in plants. Examples of plant colours can be given of indigo, alizarin red, woad, reseda, alkanna violet and saffron.

(iv) **Synthetic Pigments-** Synthetic Pigments are the most widely used artificial organic pigments and dyes. They give the advantage of synthesisation of almost any shade, especially of pure colour tones and gives dazzling visual effects. Examples are: azo, dioxazine and phthalocyanin.

4.3.10 Wire and Cable Industry

In the Wire and cable industry, various types of pigments are used to colour polyolefins. Mainly they are employed for Wire Identification Methods. As in cables, it can be seen that the colouring done on the outer layer is governed by a different set of requirements as from the inner layers. Pigments that are used in the wire and cable industries are of two types inorganic and organic. Newer alternatives that are coming in to the market are known as the "mixed-phase metal oxide" pigments. Examples can be given of, yellow nickel titanates and blue and green cobalt aluminates. A relatively new entrant is the brilliant yellow bismuth vanadate. Organic pigments are also used but are not as popular because they are more difficult to disperse than inorganic ones leading to possible loss in mechanical strength.

Table 6.4: Common Pigments and Applications

Pigment	Colour	Application
Titanium dioxide	White	Used in variety of resins
Zinc sulphide	White	Wide use
Iron oxides	Red, yellow, brown, and black	Wide use
Lead chromates and lead chromate molybdates	Colours can include bright yellow and orange	Good use
Cadmium	Comes in reds, yellows, oranges and maroons	Excellent for engineering resins
Chromium oxides	Green	Shows good heat and light fastness, variety of uses
Ultramarines	Comes in blue, pink and violet shades	Works in a wide gamut of resins

Source: www.dyespigments.com

5.0 CONCLUSION

It could be seen that the use to which dyes and pigments are employed is endless. These vary from cosmetic industry to paper making. They have added value to our day to day living.

6.0 SUMMARY

In this unit, we have learnt that:

- from acting as colourants for plastics, textile dyeing industries and the highly sophisticated biotechnology industry dyes are touching lives everywhere
- pigments have diversified application in paints, textile, printing
- wide variety of options applicable for the usage of dye and pigment.

7.0 TUTOR- MARKED ASSIGNMENT

Describe in detail, the application of dye or pigment in the following industries:

i. Paper making
ii. Cosmetic
iii. Security printing
iv. Wire and cable

8.0 REFERENCES/FURTHER READING

Buxbaum,G. (1998). *Industrial Inorganic Pigments*. VCH, Weinheim.

Klaus Hunger, Peter Mischke, Wolfgang Rieper, Roderich Raue, Klaus Kunde, Aloys Engel "Azo Dyes" in Ullmann's Encyclopedia of Industrial Chemistry (2005). Wiley-VCH, Weinheim.