15 DISPERSION, COLOURS AND ELECTROMAGNETIC SPECTRUM

Dispersion and spectrum of white light

White light consists of a mixture of seven colours. White light can be split into its components by using a prism. These colours listed in the decreasing order of wavelengths are **red, orange, yellow, green, blue, indigo**, and **violet**. Red colour has the longest wavelength while violet has the shortest wavelength. These colours can be recalled easily using the name of a boy ROY G. BIV.

OBJECTIVES

At the end of this topic, students should be able to:

- explain dispersion, obtain the spectrum of white light and recall the colours of the spectrum of white light;
- explain how white light splits into its component colours;
- state the primary and secondary colours of white light;
- explain colour mixing by addition and subtraction; use reflection of light to explain the colours of objects.

Production of impure spectrum

We can split or separate white light into its component colours by passing a narrow beam of parallel light through a triangular glass prism as shown in Figure 14.1. On passing through the glass prism, white light splits into seven distinct colours ROYGBIV.

Dispersion is the splitting of white light into seven pure colours.

The coloured light formed on the white screen is called the **spectrum of white light**.

Spectrum of white light is the pattern or array of colours obtained on the white screen after dispersion of white light.

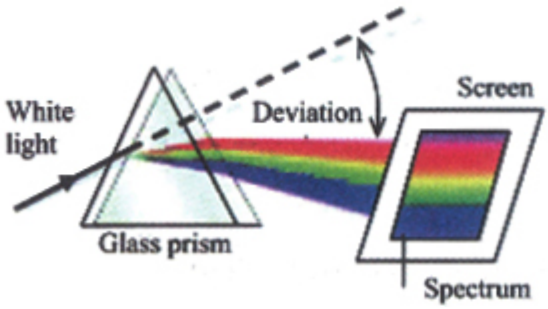

Figure 15.1: Production of impure spectrum by glass prism

The colours of white light obtained in Figure 15.1 are called the **impure spectrum** because the colours overlap. Red colour is deviated least and violet colour is deviated most. Isaac Newton was the first man to split white light and he obtained the spectrum as shown above.

Production of pure spectrum

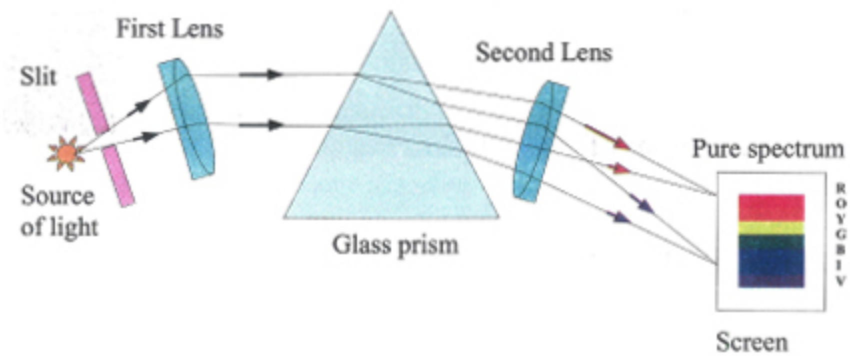

Figure 15.2: Production of pure spectrum

The pattern of colours formed on a white screen when the colours of white light are separated is called **spectrum of white light.** ***A pure spectrum is formed when the colours of white light are completely separated***. To produce a pure spectrum, a glass prism is used to split parallel beam of white light. A converging lens converges each colour to a focus. Coloured patterns formed on the screen are distinct (individual colours do not overlap).

Figure 15.2 shows the arrangement for producing a pure spectrum. It is called a **spectrometer**. A spectrometer consists of:

â€¢ **a collimator** which consists of a bright source of light, a slit and a convex lens. All work together to produce parallel beam of light.

â€¢ **a telescope** to collect and focus the separated coloured light. A screen can replace the telescope.

The parallel beam of light from the collimator is passed through the triangular prism which splits it into seven colours of white light. Each separated colour is brought to a single focus at different spots on a white screen.

The patterns of colours on the screen do not overlap and is called pure spectrum.

The cause of dispersion

A beam of white light consists of seven colours. In air or vacuum, the seven colours travel with the same speed but they travel with different speeds in a medium. *Red light has the longest wavelength in the spectrum of white light therefore, it travels through glass with the highest speed and is deviated least. Violet (the shortest wavelength in the spectrum of white light) is deviated most because it has the lowest speed in glass*. The colours of white light travel at different speeds in glass making it to split into its colours (ROYGBIV).

The amount of bending (deviation) depends on the **colour of light** and the **refractive index** of the medium. The refractive index of glass depends on the colour of light used.

Combining the spectrum to form white light

Newton proved that the colours obtained during dispersion of white light are from the light and not from the glass by the experiment in Figure 15.3.

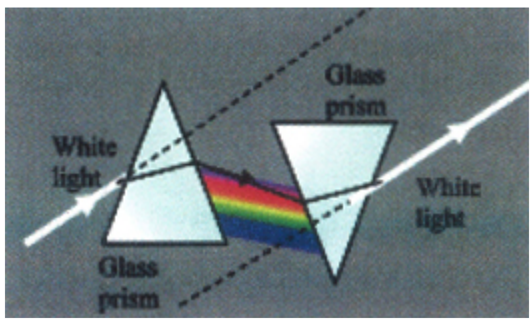

Figure 15.3: Recombination of white light spectrum to form white light

The two prisms are arranged to deviate a beam of light in the opposite directions. The first prism splits the white light while the second prism recombines the colours to form white light. This type of recombination is incomplete as coloured light is observed at the edges of the beam.

Coloured disc

Another way of demonstrating that white light is made up of seven colours ROYGBIV is shown in Figure 15.4. A disc is divided into seven equal sectors of circle. Each sector is painted with one of the colours of white light. When the disc is made to spin at a high speed, the colours recombine to form white colour. These experiments shows that the colours are present in white light and not in the glass.

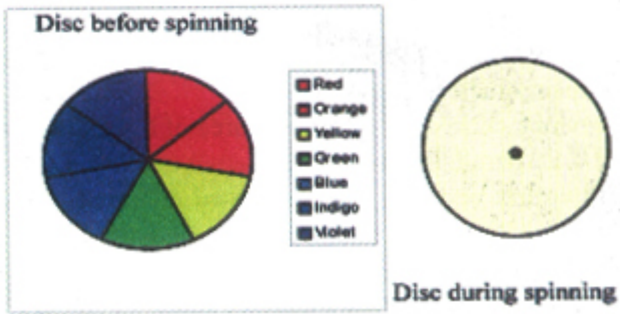

Figure 15.4: Spinning a seven coloured disc at a high speed results in white light

Colours

The colour of each spectrum of white light depends on its **wavelength** or **frequency**. The wavelength of visible light varies from 7 Ã— 10^{-7} m for red light to 4 Ã— 10^{-7} m for violet light. The eyes have the ability to detect light of all colours or wavelength. These colours are divided into two groups: **primary** and **secondary colours**.

â€¢ **The primary colours:** Primary colours are the colours that can be mixed or blended together to form other colours and white but cannot be obtained by mixing other colours. The three primary colours are **red, blue** and **green**.

â€¢ **The secondary colours:** Secondary colours are the colours obtained by mixing two primary colours. Secondary colours are **yellow, magenta** and **cyan**.

Primary colours mixed together	Secondary colour formed
RED + GREEN	YELLOW
RED + BLUE	MAGENTA
BLUE + GREEN	CYAN

The mixing of two primary colours to form a secondary colour is illustrated in Figure 15.5.

Colour additions

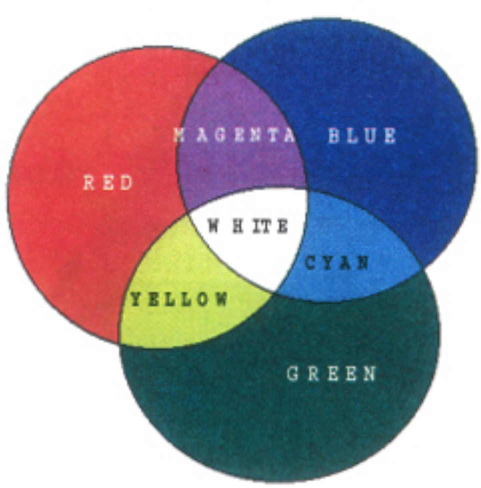

Figure 15.5a: Mixing two primary colours to form a secondary colour

Mixing or overlapping of two primary colours form a new colour called a **secondary colour**. White is produced where the three primary colours overlap or mix. Two colours which mix or add together to produce white light are called **complementary colours**. Complementary colours are shown below; cyan is a complement of red, yellow is a complement of blue and magenta is a complement of green.

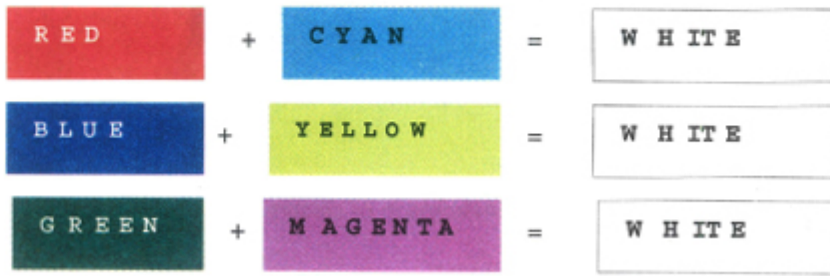

Figure 15.5b: Complementary colours

Primary colours, secondary colours and the pairs of complementary colours (colours which add or mix to form white light) are shown in the colour triangle Figure 14.6. The triangle shows addition of primary colours to produce a secondary colour.

For example: **green + blue = cyan**. The arrow from blue and green both point towards cyan. White light is formed by overlapping or mixing the three colours or by blending a secondary colour with a primary colour directly opposite it. Examples are as follows:

Red + Cyan = White

Blue + Yellow = White

Green + Magenta = White

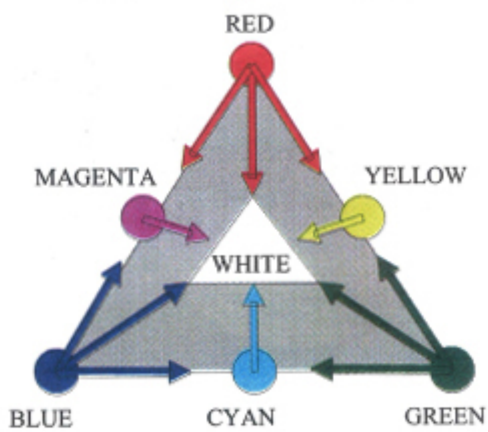

Figure 15.6: Triangle colour addition

Green + Magenta = White

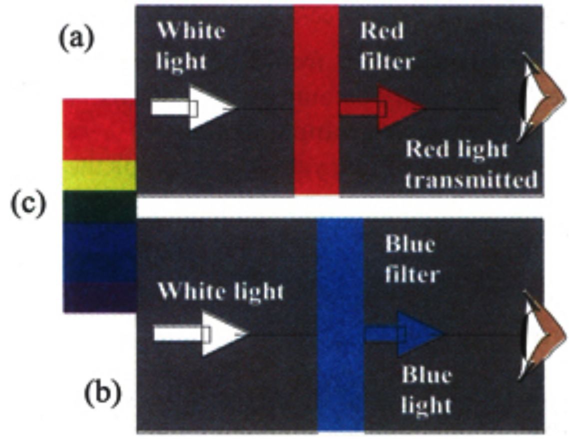

Figure 15.7: Absorption of colours by filters

Absorption or subtraction of colours

Figure 15.7a and b show what happens as white light passes through (a) red filter (b) blue filter. Figure 15.7c represents the spectrum of white light. Study the diagrams and answer these questions:

(i) Which colour do the filters transmit?

(ii) Which colours do the filters absorb?

A filter absorbs other colours except its own colour(s). White light has seven colours, if a beam of white light is passed through a red filter, other colours of white light **(orange, yellow, green, blue, indigo, and violet)** are absorbed. **Red** is the only colour that is transmitted through a red filter. A blue filter absorbs other colours except blue.

Figure 15.8 shows what happens if white light is passed through two filters one after the other.

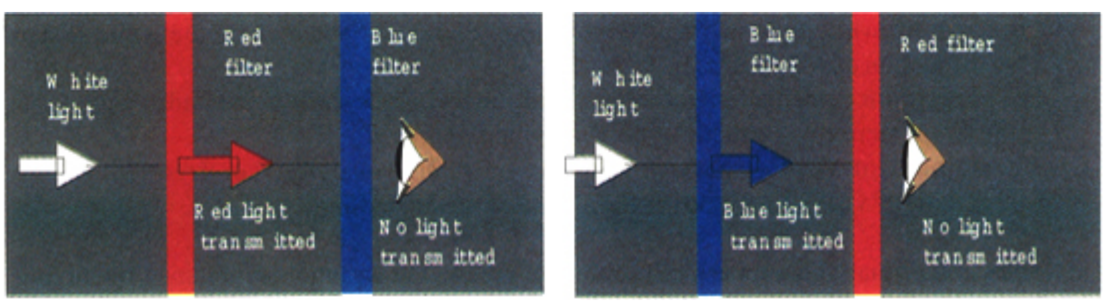

Figure 15.8: Transmission and absorption of colours

The red filter transmits only the red light (colour) and absorbs other colours in white light. The blue filter can only transmit blue light (colour), therefore it absorbs the red light reaching it and no light is transmitted. Red filter will also absorb blue and other colours of white light except red.

Filters with secondary colours can transmit more than one colour. A yellow filter (mixture of red and green) will transmit yellow, red and green lights (colours). What colours will magenta and cyan filters transmit?

Reflection and colours of objects

The colour of an object is the colour of light it reflects. A red object reflects only the red light to the eye; other colours of white light are absorbed. A green surface reflects green light but absorbs other colours of white light. A yellow surface reflects three colours **red, green** and **yellow**. White surface reflects **all** the colours of white light, this why it appears white to the eye. **Black** is not a colour but the absorption of the seven colours of white light. The colour of an object is the one it reflects when illuminated by white light.

If an object is viewed in a dark room illuminated by coloured lights, which it does not reflect, the object looks **black** or **dark**. A blue surface looks **black** when viewed in a dark room lit by green or red light. The blue surface absorbs the red or green colour and therefore appears black.

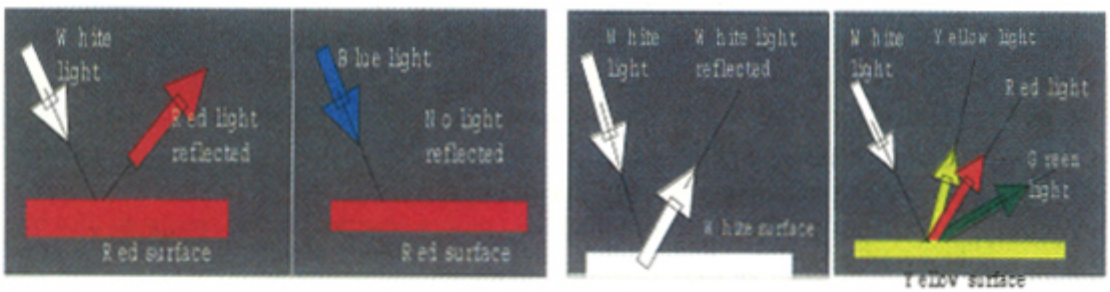

Figure 15.9: Reflection from different surfaces

Summary

â€¢ **White light** consists of a mixture of seven colours namely: **red, orange, yellow, green, blue, indigo, and violet** listed in the decreasing order of wavelength.

â€¢ **Dispersion** is splitting of white light into seven pure colours. Dispersion is caused because each colour of white light travels with different speeds in glass.

â€¢ **Spectrum** of white light is the pattern or array of colours obtained on the white screen after dispersion of white light.

â€¢ **Pure spectrum** is the pattern of colours with each colour clearly separated.

â€¢ **Impure spectrum** is a pattern of colours which overlaps.

â€¢ **The colours of visible spectrum** depend on their **wavelength** or **frequency**. The wavelength of visible light varies from 7 Ã— 10^{-7} m for red light to 4 Ã— 10^{-7} m for violet light.

â€¢ The three primary colours are **red, blue** and **green**. They cannot be obtained by mixing other colours of white light.

â€¢ The secondary colours are **yellow, magenta** and **cyan**. They are produced by mixing two primary colours.

- **Complementary colours** are two colours which mix or add together to produce white light.
- **A filter transmits** light of specific wavelength or a range of wavelengths. The red filter transmits only the red light (colour) and absorbs other colours of white light. A yellow filter (mixture of red and green) will transmit yellow, red and green lights (colours).
- The colour of an object is the colour of light it reflects. A yellow surface reflects three colours **red, green** and **yellow**. It will still appear yellow if viewed in a dark room illuminated by **red, green** and **yellow** lights.
- A white surface reflects **all** the colours of white light, this why it appears white to the eye. White surface will assume the colour of the light which illuminates the room.
- **Black** is not a colour but the absorption of the seven colours of white light.

Practice questions 15a

1. (a) What is **dispersion** of light?
   (b) List the **colours** of white light in the order **decreasing** wavelengths.
   (c) Which colour of white light is **deviated least** and why?
2. (a) What do you understand by the term, **spectrum** of white light?
   (b) Distinguish between **pure** and **impure spectrum.**
   (c) Describe an experiment to produce **pure spectrum** of white light.
3. (a) Describe an experiment to show that white light is made up of mixtures of colours.
   (b) Explain why the colours are separated when a beam of parallel white light is passed through a triangular prism.
4. (a) Explain the terms: **dispersion** and **spectrum** of white light.
   (b) Describe an experiment to show that the colours observed in the spectrum of white light are contained in white light.
   (c) Explain why the violet colour is deviated most when a beam of white light is dispersed by a triangular prism.
5. (a) Name three **primary colours** and explain why they are called primary colours.
   (b) A man wearing a cloth with blue background and red flowers with green leaves enters a dark room lit with
   (i) blue light;
   (ii) red light;

(iii) white light.

Explain with reasons the colour(s) that will be observed in each case.

6. (a) What are **secondary colours**? Give three secondary colours and the two primary colours mixed to obtain each.
   (b) Explain what is meant by **complementary** colours.
   (c) State the complementary colours for the following colours: red, blue and yellow.

Past questions

1. Which of the following colours of light is most deviated when white light passes through a triangular glass prism?
   A. Orange
   B. Green
   C. Indigo
   D. Yellow

WASSCE

2. Which of the following pairs of light rays shows the widest separation in the spectrum of white light?
   A. Green and blue
   B. Orange and indigo
   C. Blue and violet
   D. Red and yellow

WASSCE

3. A sheet of white paper viewed through blue glass appears blue because
   A. blue is primary colour.
   B. the glass absorbs all colours except the blue colour.
   C. it reflects blue colour.
   D. the paper reflects blue colour only.
   E. white is easily absorbed by the glass.

NECO

4. The invisible part of the spectrum of white light consists of
   A. infrared, and ultraviolet only.
   B. infrared, ultraviolet and blue only.
   C. red, orange and green only.
   D. red and violet only.
   E. yellow and indigo only.

NECO

5. A piece of cloth appears green in sunlight. When held in red light, it will appear
   A. green

B. blue
C. red
D. black.

WASSCE

6. Dispersion of white light by a prism occurs because
A. white light consists of a mixture of seven different colours.
B. the refractive index of glass is different for each constituent colour of white light.
C. the speed of each colour of light in the glass is proportional to the refractive index of glass for each colour.
D. the speed of each colour of light in the glass is proportional to the angle of refraction in the prism.

WASSCE

7. When white light passes through a triangular prism, there is dispersion because of
A. diffraction of light.
B. polarization of light.
C. the difference in speed of the components of light.
D. the interference of light waves in glass.

WASSCE

8. (A) What is meant by dispersion of white?
(B) State the colours in the spectrum of white in ascending order of wavelengths.
(C) Which colour is deviated (i) least (ii) most?
(D) Explain why white light is dispersed when it passes through a glass prism.
(E) Describe, with the aid of diagram, how a pure spectrum of white light can be produced on a screen.

WAEC

9. (a) Explain the following physical observations:
(i) A red cap appears red in red light but appears black in blue in blue light.
(ii) A triangular glass prism splits a beam of white light into a band of colours.
(b) (i) Distinguish between a pure spectrum and impure spectrum of white light.
(ii) List the colours in the spectrum of white light in the descending order of wavelength.
(c) (i) What property of light determines the colour of light?
(ii) Define complimentary colours.
(iii) List the primary colours and their corresponding complements.

WASSCE

10. (a) Explain the following terms as applied to ray of light:
   (i) dispersion;
   (ii) deviation.
(b) (i) What is meant by pure spectrum?
   (ii) Using a diagram, describe the production of the spectrum of white light by a triangular glass prism.

WASSCE