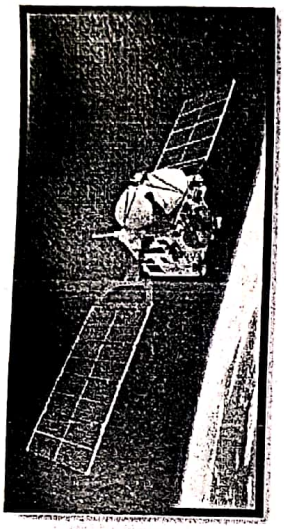
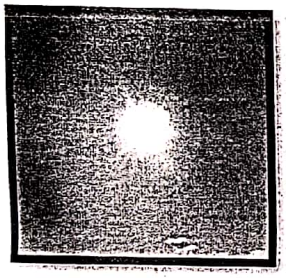
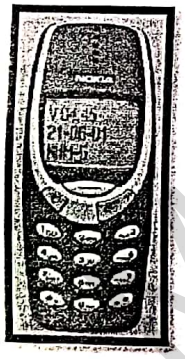
O Level Physics Syllabus Content for CAIE 2019-22 Exams

CHAPTER 15:
ELECTROMAGNETIC SPECTRUM







Syllabus Content

15.1 Dispersion of light
15.2 Properties of electromagnetic waves
15.3 Applications of electromagnetic waves

Learning outcomes

Candidates should be able to:

(a) Describe the dispersion of light as illustrated by the action on light of a glass prism.
(b) State the colours of the spectrum and explain how the colours are related to frequency/wavelength.
(c) State that all electromagnetic waves travel with the same high speed in air and state the magnitude of that speed.
(d) Describe the main components of the electromagnetic spectrum.
(e) discuss the role of the following components in the stated applications:

1. Radio waves – radio and television communications,
2. Microwaves – satellite television and telephone,
3. Infra-red – household electrical appliances, television controllers and intruder alarms,
4. Light – optical fibres in medical uses and telephone,
5. Ultra-violet – sunbeds, fluorescent tubes and sterilisation,
6. X-rays – hospital use in medical imaging and killing cancerous cells, and engineering applications such as detecting cracks in metal,
7. Gamma rays – medical treatment in killing cancerous cells, and engineering applications such as detecting cracks in metal.

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Electromagnetic Spectrum

Electromagnetic spectrum is made of a large family of electromagnetic waves which have these common properties:

- They are transverse waves which transfer energy from one place to another.
- They are a combination of electric and magnetic fields.
- They all travel in vacuum with the speed of light (3×10^8 m/s).
- They all obey the equation: $V = f \cdot \lambda$

  Since V is constant (for a given medium), it follows that the higher the frequency of a wave, the smaller is its wavelength.

- A continuous spectrum contains different colours where the wavelengths are continuously increasing (and frequencies are continuously decreasing). A monochromatic light (like a laser beam) contains one colour only with one definite frequency and wavelength.

Types of Electromagnetic Radiations

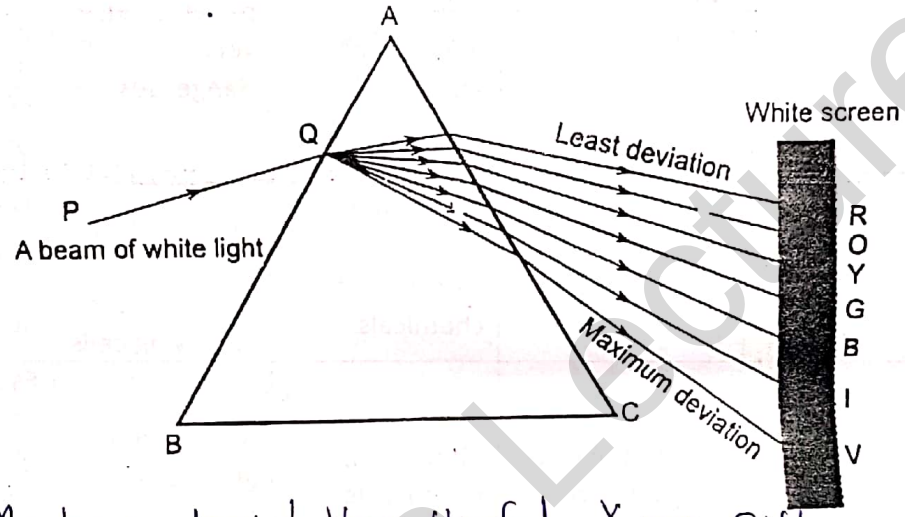
1. ***Gamma Rays:*** *They are produced by radioactive isotopes.* They can be detected by G.M. counter, cloud chamber, or by photographic films.
2. **X-rays** are produced by X-ray tubes. They can penetrate solid objects and effect a film, they are used in hospitals to photograph bones. They are detected by photographic films.
3. **Ultra-violet Rays** are obtained from sunlight and from mercury lamps. They can be detected by a film or by a fluorescent paper. They cause sun-tan and produce vitamins in the skin. An overdose can be harmful, especially to the eyes.
4. **Infrared Radiation** is obtained from sunlight or from a filament lamp. It is characterized by its heating effect. It can be detected by a blackened-bulb thermometer or by a thermopile. All hot objects emit infrared radiation. It is used to dry paint on cars during manufacture, in treatment of muscular pains, an in remote control keypads.
5. **Radio Waves** are radiated from aerials and used to "carry" sound and T.V. links and are also used for cooking because they have a heating effect when absorbed.

Dispersion of Light

Newton discovered the colours of the light spectrum by allowing sunlight (which is white) to fall on a triangular glass prism. The band of colours obtained is a spectrum and the effect is called dispersion.

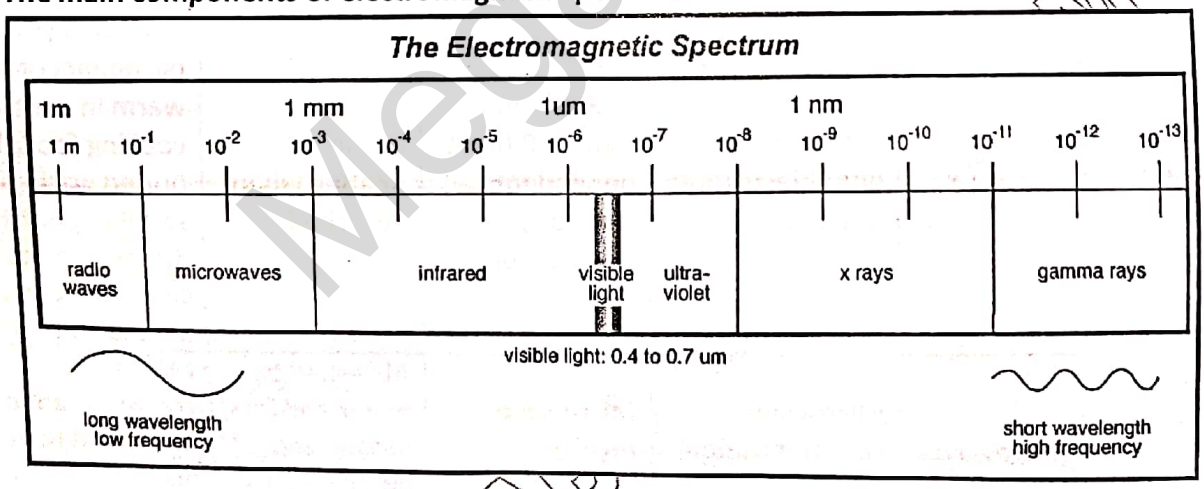
1. Dispersion of light is the separation of white light into its component colours (by using a prism).
2. Dispersion occurs because each colour has a different refractive index.

3. White light spectrum has the following colour:
   Red, Orange, Yellow, Green, Blue, Indigo & Violet.
4. Red light has the smallest refractive index
   Violet light has the greatest refractive index.
5. Red light has the smallest frequency (and longest wavelength) Violet light has the highest frequency (and shortest wavelength), Frequency is inversely proportional to the wavelength.
6. All colours travel with the same speed of light in vacuum (but they have different speeds in material media).
7. There are two extra invisible rays which were detected by their effect on the photographic plates. These are:
   a. Infra-red rays which are detected by their heating effect.
   b. Ultra-violet rays which can produce fluorescence in some materials and can darken photographic films.



Read Monkeys Insist Very Useful X-mas Gifts

The main components of electromagnetic spectrum.



All electromagnetic waves travel at the same speed (3 x 108 m/s) in a vacuum. The speed is the same as the speed of light in a vacuum.

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Summary of the properties and uses of the components of the electromagnetic spectrum

Component	Source	Detectors	Properties	Uses
γ-rays	Cobalt-60	Photographic plate; GM-tube; cloud chamber	very penetrating; very dangerous	Treatment of cancer; γ-camera (images inside the body); finds flaws in metals; sterilizes bandages, prolongs shelf-life of food (eg ice-cream)
X-rays	X-ray tubes	Photographic plate; fluorescent screen	Very penetrating; very dangerous	Treatment of skin disorders; X-ray radiography; study of crystal structures; inspections of welds in steel joints or pipes
Ultraviolet (UV) light	Sun; sparks and arcs; mercury lamps; UV lamps	Photo film; Photo cells; Fluorescent chemicals	Absorbed by glass; causes sunburn; damages and kills living cells	Detects forgeries of signatures; fluorescent tubes; sterilization; sunbeds
Visible light	Sun; hot objects; lamps; lasers	Photo film; photo cells	Refracted by glass lenses, prisms	Essential in photosynthesis and plant growth; in communication systems with lasers and optical fibres
Infra-red (IR) light	Sun; warm and hot objects (fires or people)	Special photo film; LDR (light dependent resistor); photodiode	Causes heating when absorbed	Radiators (keeps occupants of room warm in winter); cooking food; finding buried warm bodies; IR satellite photos reveal diseased crops; television controllers; intruder alarms
Microwaves	Microwave communication dish	Microwave-receiving aerials	Absorbed by water and fats in food and people, hence is dangerous	Microwave communication links (radio and television); microwave cooking; radar communication
Radio	Radio transmitter	Metal aerials; tuned circuits	Induces alternating currents in metal aerials	Radio; TV and satellite communications

Properties of electromagnetic waves

Radiation	Wavelength(m)	Sources	Detectors	uses
Gamma-rays	10^{-12}	Cosmic rays, radioactive substances	Geiger counters, bubble/cloud chambers	Checking welds, killing cancer cells
X-rays	10^{-10}	X-ray tubes	Photographic film, fluorescent screens	Medical/dental inspections analysis of crystal structure
Ultraviolet	10^{-8}	Mercury vapours, the sun	Fluorescent screens/dyes	Forgery detection, sun lamps
Light	10^{-6}	Hot bodies, lasers, fluorescent screens	Photographic film, photodiodes	Chemical special analysis, fibre optics
Infra-red	10^{-4}	Warm bodies, the sun	Blackened thermometers, thermocouples	TV remote control, light vision sights, radiant heaters.
Radio	10^{-2} -10^{-4}	TV and radio transmitters	Aerials	Radio telescope, radar, communications links.

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