The table below shows the different waves of the electromagnetic spectrum in order of the increasing wavelengths alongwith their discoverer, source and method of detection.

Electromagnetic spectrum

Name of the wave	Wavelength in nm	Discoverer	Source	Method of detection
Gamma rays	below 0·01	Becquerel & Curie	In cosmic rays, from radioactive substances.	By their large penetrating power
X-rays	0·01 – 10	Roentgen	From a heavy metal target of high melting point when highly energetic electrons are stopped by it.	By the fluorescence produced on a zinc sulphide screen. The photographic film gets affected.
Ultraviolet	10 – 400	Ritter	Sunlight, arc-lamp, spark	By their chemical activity on dyes. Photographic plates get affected. It causes fluorescence.
Visible light	400 – 800	Newton	Sunlight, light from electric bulb, flame, white hot bodies.	Other objects can be seen in its presence.
Infrared waves	800 – 10^6	Hershell	Lamp with thoriated filament, heated silicon carbide rod, red hot bodies	Heating effect is more. The mercury rises rapidly when a thermometer with a blackened bulb is kept in these radiations.
Microwaves	10^6 – 10^{10}	Hertz	Electronic devices such as crystal oscillators	Oscillatory electrical circuit.
Radio waves	above 10^{10}	Marconi	TV and radio transmitters	Aerials of radio and TV receiver.

Approximate ranges of wavelength and frequency

(1) *Gamma rays*–wavelength shorter than 0·1 Å (or $\lambda < 0{\cdot}01$ nm) or frequency above 10^{19} Hz.

(2) *X-rays*–wavelength range 0·1 Å to 100 Å (or $\lambda \approx 0{\cdot}01$ nm to 10 nm) or frequency from 3×10^{19} to 3×10^{16} Hz.

(3) *Ultraviolet rays*–wavelength range 100 Å to 4000 Å (or $\lambda \approx 10$ nm to 400 nm) or frequency from 3×10^{16} to $7{\cdot}5 \times 10^{14}$ Hz.

(4) *Visible light*–wavelength range 4000 Å to 8000 Å (or $\lambda \approx 400$ nm to 800 nm) or frequency from $7{\cdot}5 \times 10^{14}$ to $3{\cdot}75 \times 10^{14}$ Hz.

(5) *Infrared radiations*–wavelength range 8000 Å to 10^7 Å (or $\lambda \approx 800$ nm to 1 mm) or frequency from $3{\cdot}75 \times 10^{14}$ to 3×10^{11} Hz.

(6) *Microwaves*–wavelength range 10^7 Å to 10^{11} Å (or $\lambda \approx 1$ mm to 10 m) or frequency from 3×10^{11} to 3×10^7 Hz.

(7) *Radio waves*–wavelength above 10^{11} Å (or $\lambda > 10$ m) or frequency below 3×10^7 Hz.

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Properties common to all electromagnetic waves

(1) Electromagnetic waves do not require any material medium for their propagation.

(2) They all travel with the same speed in vacuum and air (the speed is 3×10^8 m s^{-1}), and with different speeds in different medium.

(3) They exhibit the properties of reflection and refraction. In refraction, when an electromagnetic wave passes from one medium to the other, there is change in its direction of travel, speed and wavelength, but its frequency remains unchanged.

(4) These waves are not deflected by electric and magnetic fields.

(5) These waves are transverse in nature.

6.5 PROPERTIES AND USES OF DIFFERENT RADIATIONS OF ELECTROMAGNETIC SPECTRUM

(1) Gamma rays

These are the most energetic electromagnetic radiations of wavelength less than 0·1 Å (or 0·01 nm).

Sources : They are obtained in radioactive emissions, when the nuclei of radioactive atoms pass from the excited state to the ground state. They are also present in cosmic radiations.

Properties : Like X-rays, they cause fluorescence when they strike the fluorescent materials such as zinc sulphide. They can easily penetrate through thick metallic sheets (e.g. 30 cm thick iron sheet). Gamma radiations easily pass through human body and cause immense biological damage.

Uses : They are used in medical science to kill cancer cells (*i.e.*, radio therapy) and in industry to check welding.

(2) X-rays

X-rays are obtained from a heavy metal target of high melting point when highly energetic cathode rays (or electron beam) are stopped by it. They have wavelength in the range of 0·1 Å to 100 Å (or 0·01 nm to 10 nm).

Properties : X-rays are chemically more active than ultraviolet radiations. They strongly affect a photographic plate. Like gamma rays, they cause fluorescence in certain materials such as zinc sulphide, etc. They can penetrate through human flesh, but are stopped by the bones.

Uses : ① They are used for the detection of fracture in bones, teeth, *etc.* (*i.e.*, radiography), and ② for diagonistic purposes such as CAT scan in medical science. X-rays are also used ③ for studying atomic arrangement in crystals as well as in complex molecules. ④ X-rays are used by detective agencies to detect concealed precious metals.

(3) Ultraviolet radiations (Actinic rays)

The electromagnetic radiations of wavelength from 100 Å to 4000 Å (or 10 nm to 400 nm) are called ultraviolet radiations. The ultraviolet part of the spectrum was first detected by *Prof. J. Ritter* in 1801.

Detection : (i) When silver-chloride solution is exposed to electromagnetic waves starting from the red to the violet end and then beyond it, it is observed that from the red to the violet end, the solution remains almost unaffected. But just beyond the violet end, the solution first turns violet and then finally it becomes dark brown (or black). It shows that *there exist certain radiations beyond the violet extreme of the visible part, which are chemically more active than the visible light*. These radiations are called *ultraviolet radiations* (or *actinic rays*).

(ii) Ultraviolet radiations can be detected by their chemical activity on dyes and photographic plates.

(iii) The spectrum of ultraviolet radiations is obtained by passing the radiations through a quartz prism in place of a glass prism because glass absorbs these radiations.

Sources of ultraviolet radiations : *The electric arc* and *sparks* give ultraviolet radiations. A *mercury vapour lamp* emits UV radiations, a part of which has ultraviolet radiations along with the visible light. Sun is also a source of ultraviolet radiations, but a large fraction of it is absorbed by the ozone layer present in the earth's upper atmosphere* which protects us from its harmful effects.

Properties of ultraviolet radiations

(i) Ultraviolet radiations can pass through *quartz*, but they are absorbed by glass. Therefore, to obtain the ultraviolet spectrum from its source, a quartz prism is used instead of a glass prism. For the same reason ultraviolet bulbs have an envelope made of quartz instead of glass.

(ii) These radiations travel in a straight line with a speed of 3×10^8 m s^{-1} in air (or vacuum).

(iii) They are usually scattered by dust particles present in the earth's atmosphere.

(iv) They obey the laws of reflection and refraction.

(v) They strongly affect a photographic plate as they are chemically more active than visible light.

(vi) They produce fluorescence on striking a zinc-sulphide screen.

* Due to large pollution, there is depletion of ozone layer which is dangerous for us because exposure to ultraviolet radiations is harmful to us.

Harmful effect of ultraviolet radiations

(v) Ultraviolet radiations cause health hazards like skin cancer if human body is exposed to them for a long period.

Uses of ultraviolet radiations

Ultraviolet radiations are used for the following purposes :

(a) For sterilising air, surgical equipments, etc.

(b) For detecting the purity of gems, eggs, ghee, etc.

(c) In producing vitamin D in food of plants and animals.

(4) Visible light

The electromagnetic radiations of wavelength from 4000 Å to 8000 Å are called visible radiations (or visible light) because in the presence of these radiations, other objects are seen by us. The visible part of the spectrum was discovered by Newton while passing the sun light through a glass prism. The prominent colours of visible light are *violet, indigo, blue, green, yellow, orange* and *red*.

Sources : The Sun, electric bulb, flame and white hot bodies are the main sources of visible light.

Uses : The visible light is used in photography, in photosynthesis and to see the objects around us.

(5) Infrared radiations

These are electromagnetic waves of wavelength in the range of 8000 Å to 10^7 Å (or 800 nm to 1 mm). The infrared part of the spectrum was first detected by *William Hershell* in about 1800.

Detection : (i) If a thermometer having its bulb blackened, is moved from the violet end towards the red end of the spectrum of visible light, it is observed that there is a very slow rise in temperature. But when this thermometer is moved beyond the red extreme, a rapid rise in temperature is noticed. *It means that the part of the spectrum beyond the red extreme of the visible light, although not visible to us, has certain radiations which produce a strong heating effect.* These radiations are called infrared (or heat) radiations.

(ii) A thermopile can also be used to detect the heat radiations. The galvanometer connected with the thermopile shows deflection when infrared radiations fall on the thermopile.

(iii) The spectrum of infrared radiations is obtained by using a *rock-salt prism because a rock-salt prism does not absorb infrared radiations, whereas a glass prism absorbs them.*

Sources of infrared radiations : All red hot bodies such as a heated iron ball, flame, fire, etc. are sources of infrared radiations. The Sun is the natural source of infrared radiations.

Properties of infrared radiations

(i) They travel in *straight lines* like light, with a speed equal to 3×10^8 m s^{-1} in vacuum (or air).

(ii) They obey the laws of *reflection* and *refraction*.

If a source of heat (say, an infrared lamp) is placed at the focus of a parabolic mirror, a parallel infrared beam is obtained.

A *burning glass* (*i.e.*, a convex lens) focuses the more energetic (*i.e.*, short wavelength) infrared radiations obtained from the Sun on a paper due to which the paper chars (or burns).

(iii) They do not affect the ordinary photographic film. However, a specially treated photographic film is affected by them.

(iv) They are absorbed by glass, but they pass through rock-salt.

(v) They are detected by their *heating property* using a blackened bulb thermometer or a thermopile.

(vi) They are scattered less by the earth's atmosphere because of their long wavelength (since intensity of scattered radiation $\propto 1/\lambda^4$). Hence, they can penetrate deep inside the atmosphere even in fog.

(viii) The green house gases such as carbon-dioxide, present in the earth's atmosphere absorb the low energy infrared radiations and keep the earth's surface warm.

Harmful effect of infrared radiations

(i) A high dose of infrared radiations may cause skin burns.

Uses of infrared radiations All

(a) Infrared radiations are used for therapeutic purposes by doctors.

(b) They are used in photography at night and also in mist and fog because they are not much scattered, so they can penetrate appreciably through it.

(c) Infrared lamps are used in dark rooms for developing photographs as they provide some visibility without affecting the photographic film.

(d) They are used as signals during war as they are not visible and they are not absorbed *much* in the medium.

(e) They are used in remote control of television and other gadgets.

(6) Micro waves

Microwaves have wavelength in the range of 10^7 Å to 10^{11} Å (or 1 mm to 10 m) or frequency in the range of 3×10^{11} Hz to 3×10^7 Hz.

Source : These waves are produced by electronic devices such as crystal oscillators.

Uses : They are used for satellite communication, for analysis of atomic and molecular structure, for cooking in microwave-ovens and in radar communication.

(7) Radio waves

These are the waves of longest wavelength amongst all the electromagnetic waves. They have wavelength above 10 m (or 10^{11}Å) or frequency below 3×10^7 Hz. They show all the properties of electromagnetic waves.

Uses : These waves are used mainly in radar communication and also in radio and television transmission.

6.6 DISTINCTION BETWEEN ULTRAVIOLET, VISIBLE AND INFRARED RADIATIONS

Ultraviolet radiations	Visible radiations	Infrared radiations
1. They have wavelength in the range of 100 Å to 4000 Å.	1. They have wavelength in the range of 4000 Å to 8000 Å.	1. They have wavelength in the range of 8000 Å to 10^7 Å.
2. They are invisible.	2. They are visible.	2. They are invisible.
3. They produce no heating effect.	3. They produce slight heating effect.	3. They produce a strong heating effect.
4. They affect photographic plate.	4. They affect photographic plate.	4. They do not affect photographic plate.
5. They cause fluorescence on zinc sulphide screen.	5. They do not cause fluorescence.	5. They do not cause fluorescence.
6. They cause health hazards like skin cancer.	6. They do not affect the body.	6. They do not affect the body, but high dose may cause skin burns.
7. They can pass through quartz but they do not pass through glass. They are absorbed by glass.	7. They can pass through glass. They are not absorbed by glass.	7. They can pass through rock-salt, but they do not pass through glass. They are absorbed by glass.