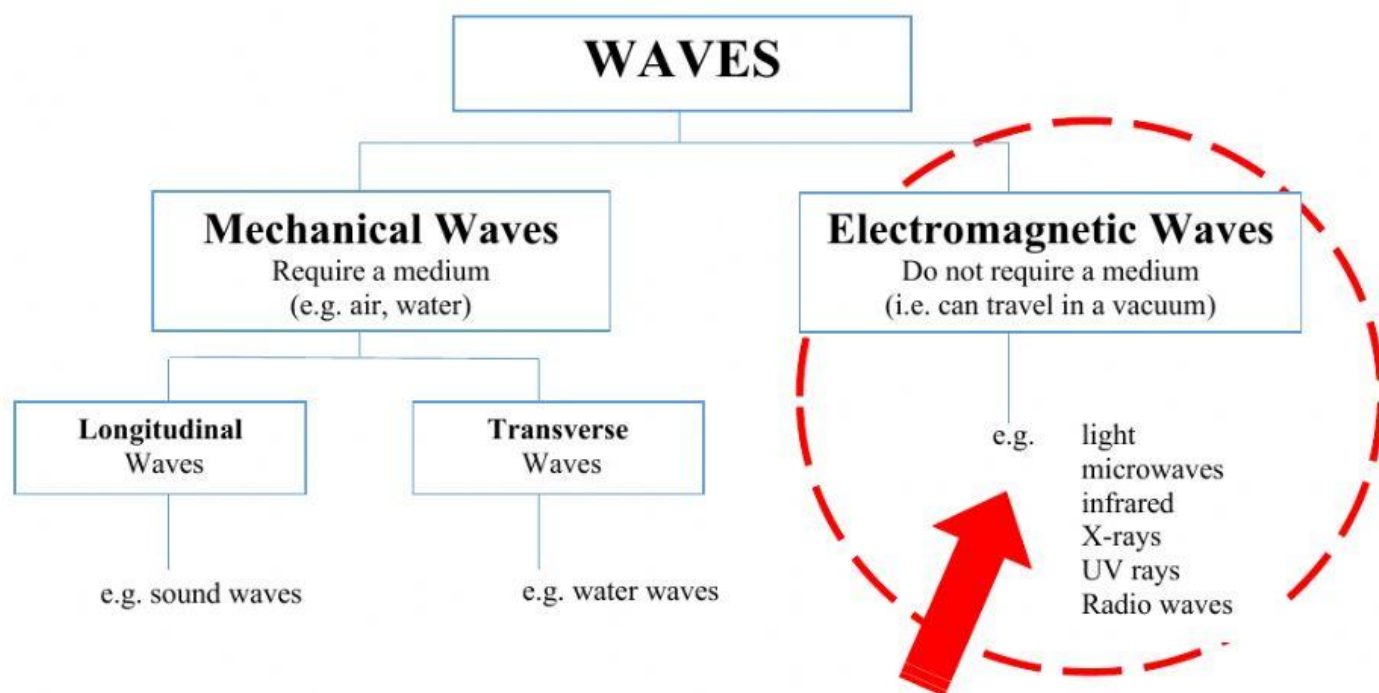
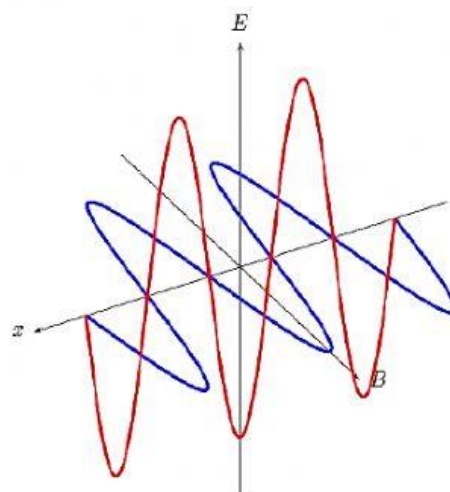


Electromagnetic radiation

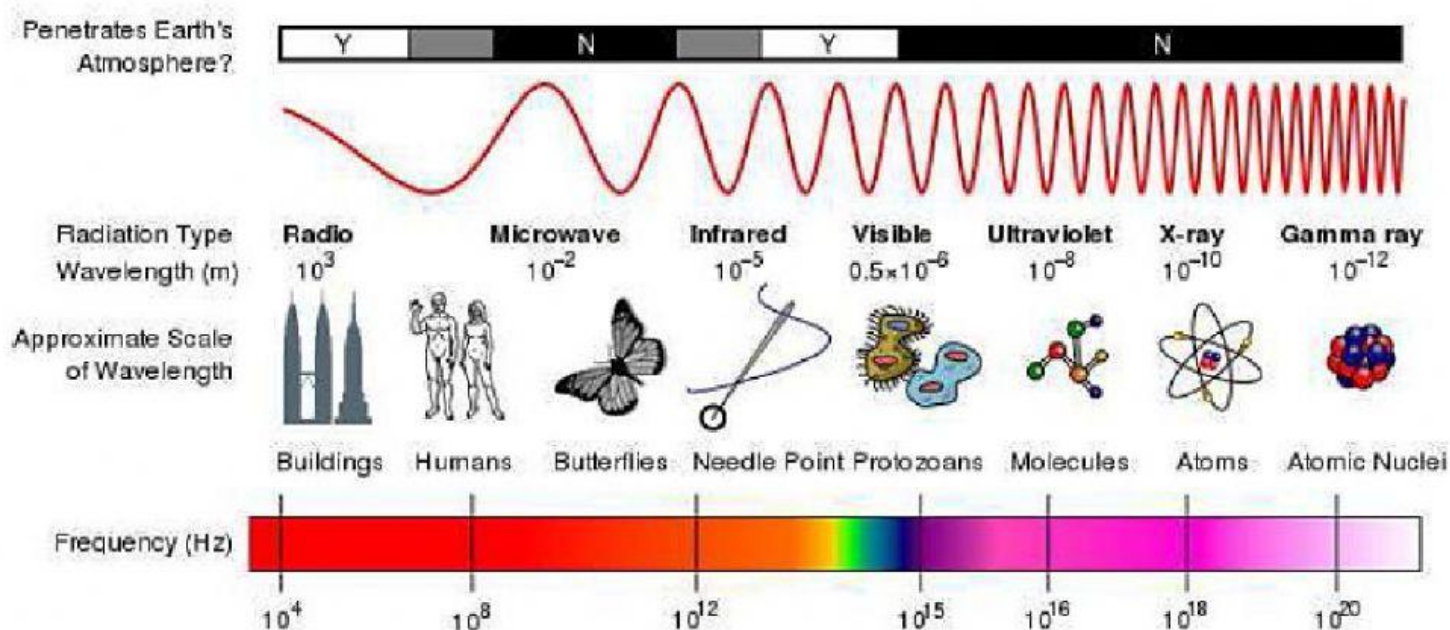
Note: This worksheet is all revision of work done in Grade 10. However, it is necessary to understand this for the section on the Photoelectric Effect which is to follow, and all of this is examinable for Matric. These notes are available in your Physics booklet pg 362-366.



- Electromagnetic waves are caused by an accelerating charge. Whenever charges are accelerated they give off (radiate) energy in the form of electromagnetic waves.
- Electromagnetic waves consist of an electric field and a magnetic field that oscillate (moves back and forth) at right angles to each other.
- When current flows it will produce an electric field which oscillates. This changing electric field produces a changing magnetic field that is perpendicular to electric field; which then produces a changing magnetic field at right angles to it, and so it carries on.



- Electromagnetic waves travel through space at a constant speed of $3 \times 10^8 \text{ m.s}^{-1}$ (symbol used for the speed is c).
- We can arrange the different types of EM radiation in order of frequency or wavelength.
- Longest to shortest wavelength (or from lowest to highest frequency): Radio waves, microwaves, infrared, visible light, ultraviolet, x-ray and gamma rays.



- For calculations with Mechanical Waves we used the formula $v = f\lambda$
- For Electromagnetic Radiation, wave speed is c not v but the formula remains the same:

$$c = f\lambda$$

c = speed of EM waves
($3 \times 10^8 \text{ m.s}^{-1}$)

f = frequency of wave (Hz)

λ = wavelength of wave (m)

Question 1

Calculate the frequency of an electromagnetic wave with a wavelength of $4,2 \times 10^{-7} \text{ m}$.

$$\begin{aligned}c &= f\lambda \\3 \times 10^8 \text{ m} \cdot \text{s}^{-1} &= f \times 4,2 \times 10^{-7} \text{ m} \\f &= \quad \times 10^{14} \text{ Hz}\end{aligned}$$

Question 2

An electromagnetic wave has a wavelength of 200 nm. What is the frequency of the radiation?

$$\begin{aligned}c &= f\lambda \\ \times 10^8 \text{ m} \cdot \text{s}^{-1} &= f \times \times 10^{-9} \text{ m} \\f &= \times 10^{15} \text{ Hz}\end{aligned}$$

Examples of each type of EM radiation: • • •

You need to know the uses for each type of radiation

- **Gamma rays:**

Emitted by radioactive substances (like Uranium and Radium). This radiation can cause mutations, cancer and even cell death.

Uses: kill cancer cells in tumours (radiation), kill bacteria and sterilise medical instruments. Some foods are irradiated by gamma rays to keep them fresh for longer.

- **X-rays:**

Are produced when fast-moving electrons are brought to a sudden stop as they hit a metal target.

Uses: X-rays can pass through skin and flesh, but not through bones and teeth. The differences in penetrating ability are used to create an image on photographic film.

Security checks at airports use X-ray machines to identify objects in luggage.

- **Ultraviolet light:**

the sun emits UV light (but the ozone layer absorbs 97-99%). UV rays cause skin to tan by stimulating a dark pigment called melanin. Over-exposure to UV radiation causes redness, blisters and increases the risk of skin cancer. (sunscreen contains chemicals that absorb the UV rays).

Uses: UV rays are needed to form vitamin D in our skin. Many insects, such as bees and moths and some bird species can see UV light. Bees follow the UV patterns on the flowers to reach the nectar. UV light (also called black light) can be used to attract insects, which are then electrocuted by high-voltage wires near the lamp. Hospitals use UV lights to sterilise equipment, forensics use UV light to look for clues at crime scenes.

- **Visible light:**

The visible spectrum contains seven colours (ROYGBIV).

Uses: We are able to see objects, because they reflect visible light.

- **Infrared rays:**

Infrared rays are given off by hot objects, like heaters or fires. (They radiate from all objects that are warmer than their surroundings).

Uses: conventional ovens use infrared waves to cook food.

Photographers use night-vision cameras when there is not enough

visible light. Police and military use thermal images to “see” in the dark. Infrared light used in remote controls.

- **Microwaves:**

The sun emits microwave radiation, but most of it is blocked by Earth’s atmosphere.

Uses: microwave ovens produce waves that transmit energy to food. Microwaves are also used in satellite communication systems.

(Microwaves are good transmitters because they are not affected by snow, clouds, haze etc.) Telephone messages are transmitted when microwaves are sent from the ground up to communication satellites that are linked around the earth. Television programmes are beamed to television satellites and down to earth again. Radar speed-trapping devices use microwaves to measure the speed of vehicles.

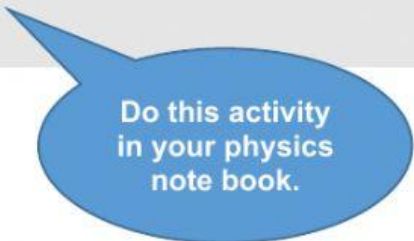
- **Radio waves:**

Radio waves are made by lightning or astronomical objects like stars and galaxies.

Uses: Man- made radio waves are used for radio communication, broadcasting radar and navigation systems.

Exercise 11-1:

1. Arrange the following types of EM radiation in order of increasing frequency: infrared, X-rays, ultraviolet, visible, gamma.
2. Calculate the frequency of an EM wave with a wavelength of 400 nm.
3. Give an example of the use of each type of EM radiation, i.e. gamma rays, X-rays, ultraviolet light, visible light, infrared, microwave and radio and TV waves.



Do this activity
in your physics
note book.

Electromagnetic radiation has the ability to penetrate material such as glass, bone, air and as such can be useful but also dangerous. The ability of EM radiation to penetrate material depends on the amount of energy the radiation has, which is directly linked to its frequency.

You need to be able to indicate the penetrating ability of the different kinds of EM radiation and relate this to their frequency and energy. You also need to be able to describe the dangers of each type of EM radiation.

Penetrating ability:

- *Gamma rays* have the highest frequency of the EM waves (thus highest energy). They are the most penetrative and can pass through most substances (e.g. bone, tissue).
- Lower frequency radiation (*UV, visible light, and infrared* radiation) have less energy. This amount of energy is the right amount to make molecules (in a material) vibrate. These radiations are therefore absorbed more easily, and do not penetrate matter as effortlessly.
- Low frequency *radio waves* have the least energy but can travel long distances without being absorbed. These do not have enough energy to cause molecules to vibrate and so are not absorbed.

Dangers:

- *Gamma rays*: uncontrolled exposure causes mutations, chromosome abnormality and cell death.
- High dosages of *x-rays* can cause tissue to burn and can cause cancer.

- *UV radiation* (from sun) can result in reddening and burning of the skin and ultimately skin cancer.
- *Cell phones and microwave radiation*: Cell phone radiation and health concerns have been raised, because cell phones use electromagnetic waves in the microwave range. It has been suggested (but not yet proven) that there may be a link between brain cancer and cell phones.

Energy of Electromagnetic Radiation

DEFINITION: Photon

A photon is a quantum (energy packet) of light.

- Calculate the energy of a photon using:

$$E = hf$$

OR

$$E = \frac{hc}{\lambda}$$

Where:

Unit for Energy is Joules, J.

h = Planck's constant (see below)

f = frequency of wave (Hz)

c = speed of light ($3 \times 10^8 \text{ ms}^{-1}$)

λ = wavelength of light (m)

DEFINITION: Planck's constant

Planck's constant is a physical constant named after Max Planck.

$$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$$

Example 1

Calculate the energy of a photon with a frequency of $3 \times 10^{18} \text{ Hz}$

$$\begin{aligned} E &= hf \\ &= \boxed{} \times 10^{-34} \text{ J} \cdot \text{s} \times \boxed{} \times 10^{18} \text{ Hz} \\ &= \boxed{} \times 10^{-15} \text{ J} \end{aligned}$$

What is the energy of an ultraviolet photon with a wavelength of 200 nm ?

$$E = h \frac{c}{\lambda}$$

$$\begin{aligned} E &= h \frac{c}{\lambda} \\ &= (6,63 \times 10^{-34} \text{ J} \cdot \text{s}) \frac{\boxed{} \times 10^8 \text{ m} \cdot \text{s}^{-1}}{\boxed{} \times 10^{-9} \text{ m}} \\ &= \boxed{} \times \boxed{} 10^{-19} \text{ J} \end{aligned}$$