Spectroscopy

contents

- Introduction
- Electromagnetic radiation
- Various terms
- Absorption spectroscopy
- UV/visible spectroscopy
- Applications

- Spectroscopy is the study of the interaction between electromagnetic radiation and matter. The matter can be atoms, molecules or ions

spectrometer

Spectrometer is something which can be used to measure the presence of particular compound or particle in a molecule

Spectrum...

- Spectrum is a plot of the amount of light absorbed by a sample versus the wavelength of the light
- The amount of light absorbed is called the absorbance

Electromagnetic radiation

- EM is a form of energy that is all around us
- EM is a form of energy and has both electrical and magnetic characteristics
- Electricity and magnetism were once thought to be separate forces
- **James clerk maxwell** developed a unified theory of electromagnetism
- The study of electromagnetism deals with how electrically charged particles interact with each other and with magnetic fields

Electromagnetic radiation

- Electromagnetic radiation is a form of energy and has both electrical and magnetic characteristics

- The electric and magnetic fields in n electromagnetic wave oscillate along directions perpendicular to the propagation direction of the wave

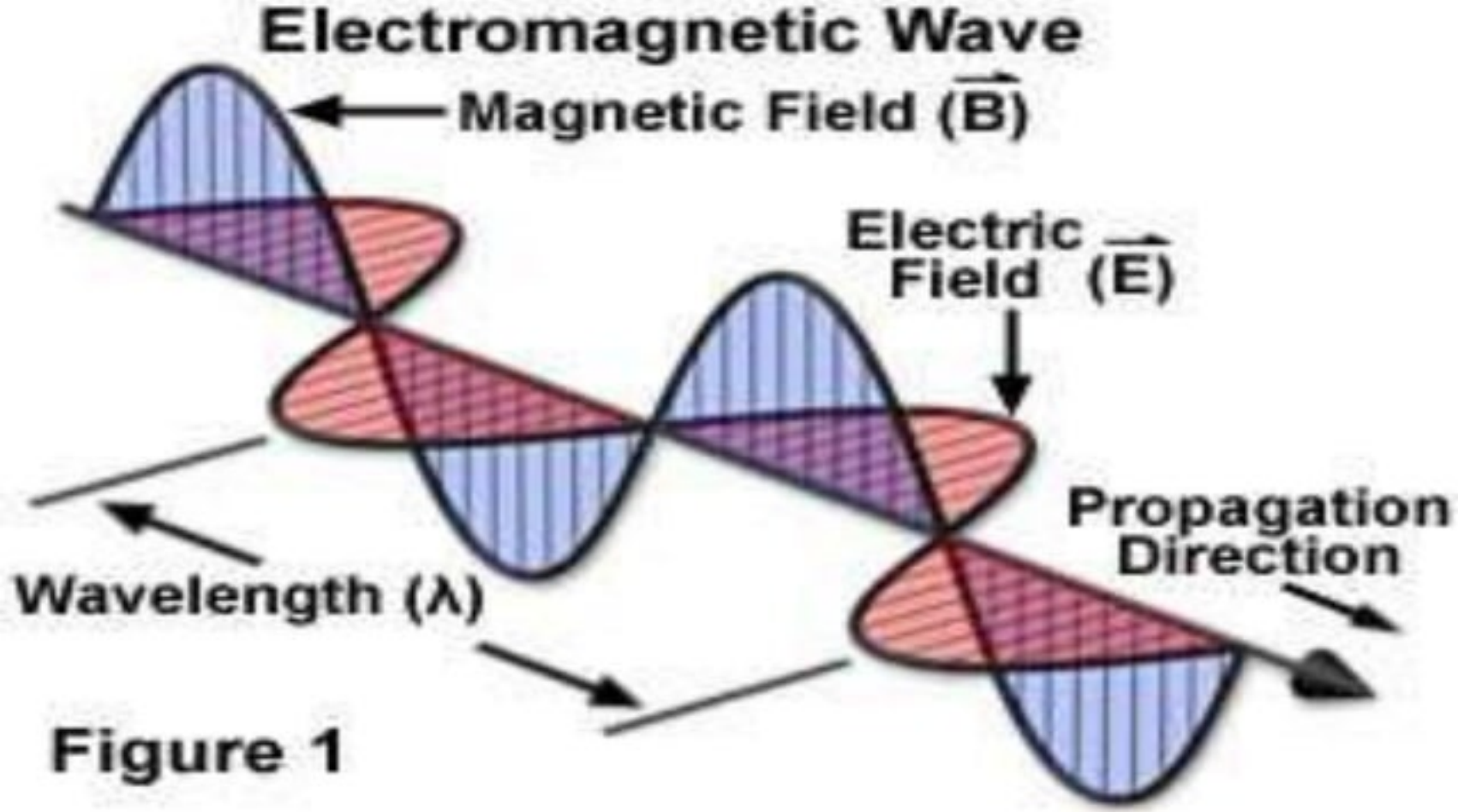

Electromagnetic Wave
Magnetic Field (B)
Electric Field (E)
Propagation Direction
Wavelength (λ)

Figure 1

Electomagnetic spectrum

- A short wavelength means that the frequency will be higher because one cycle can pass in a shorter amount of time according to the **university of wisconsin**
- Similarily a longer wavelength has a lower frequency because each cycle takes longer to complete

Various terms...

- **Frequency :-**

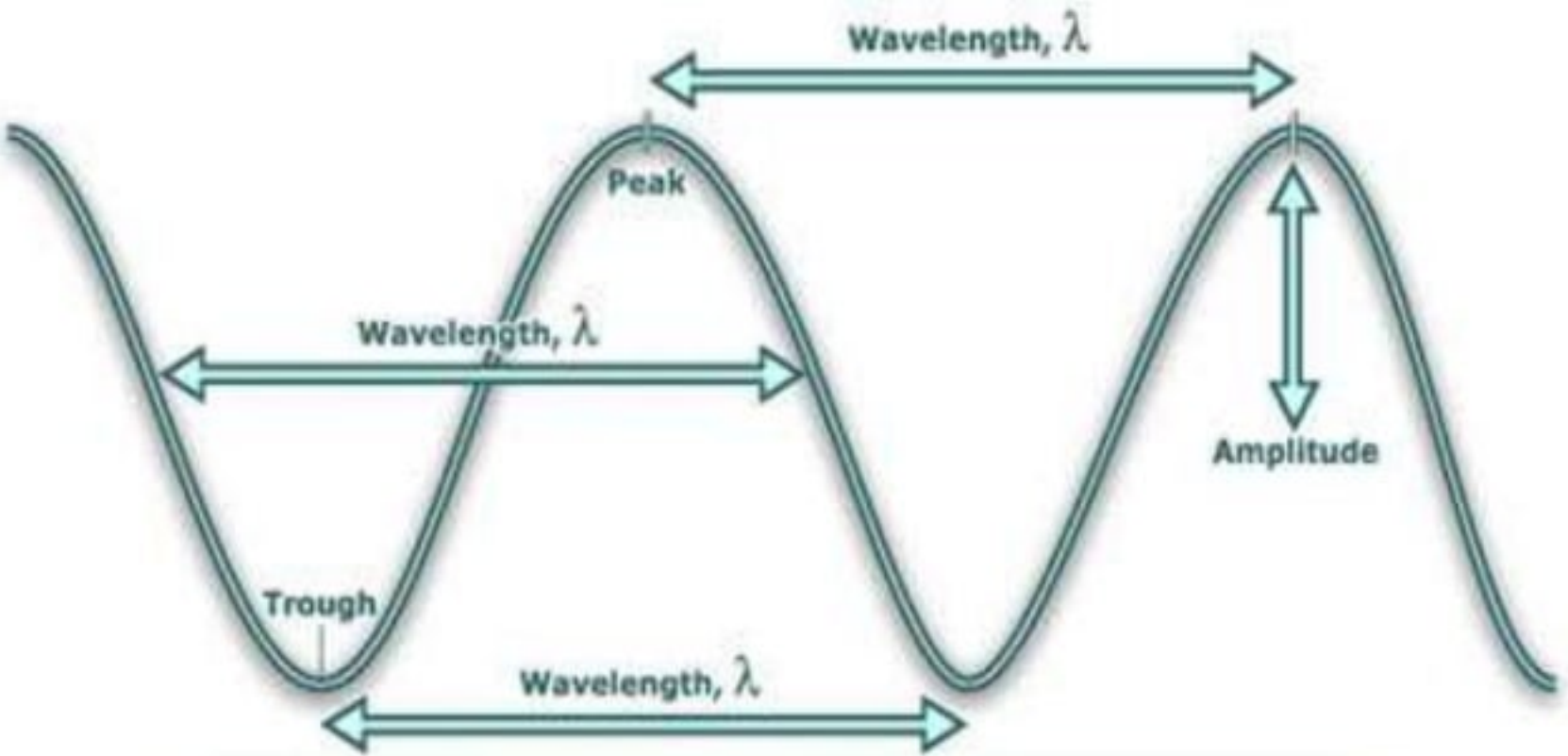
number of waves produced each second (measured in Hz).

- **Wavelength (λ) :-**

the distance between two successive waves (measured in m).

- **Amplitude :-**

is the maximum distance a wave extends beyond its middle position.



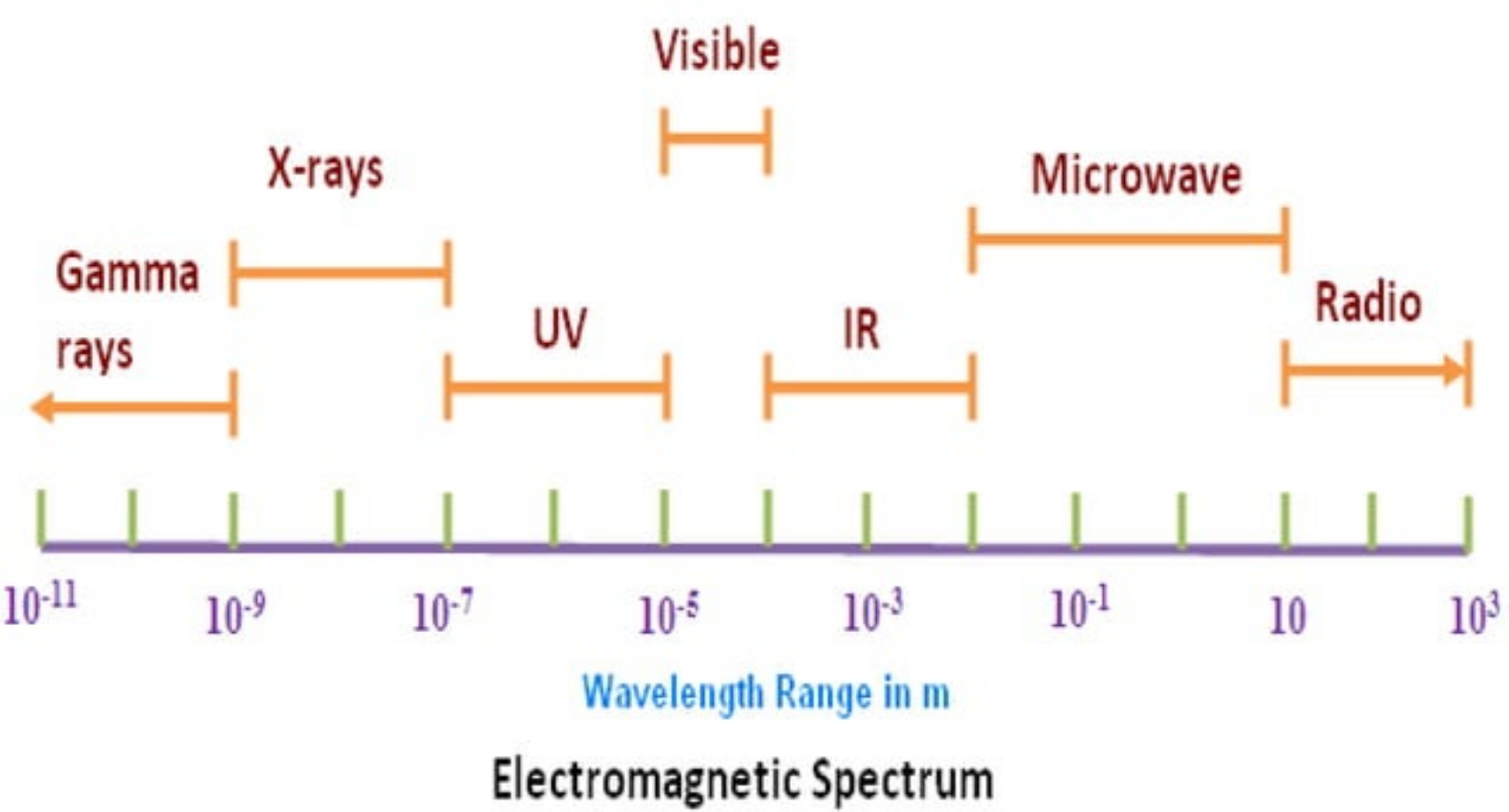
Speed of wave, **v** = frequency, **f** x wavelength, λ

Electromagnetic spectrum

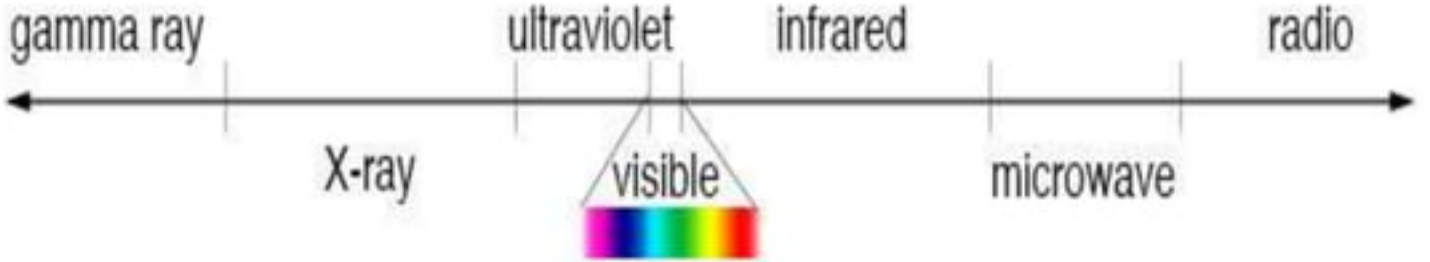
- Electromagnetic spectrum ranges from very short wavelenth (gamma rays) to very long wavelenths(radio waves)
- The visible region of the spectrum extends approximately over the wavelenth range 400-700nm
- The shorter wavelenghts being the blue end of the spectrum and the longer wavelength the red

Electromagnetic spectrum

- The wavelength between 400 and 200nm make up the near ultraviolet region of the spectrum
- The wavelength above 700nm to approximately 2000nm the ultraviolet region

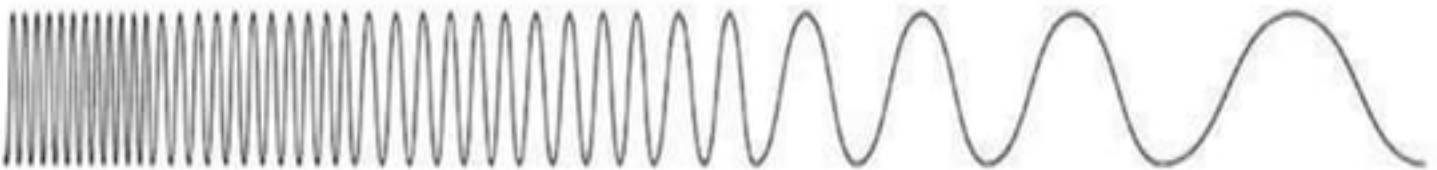


Electromagnetic Spectrum

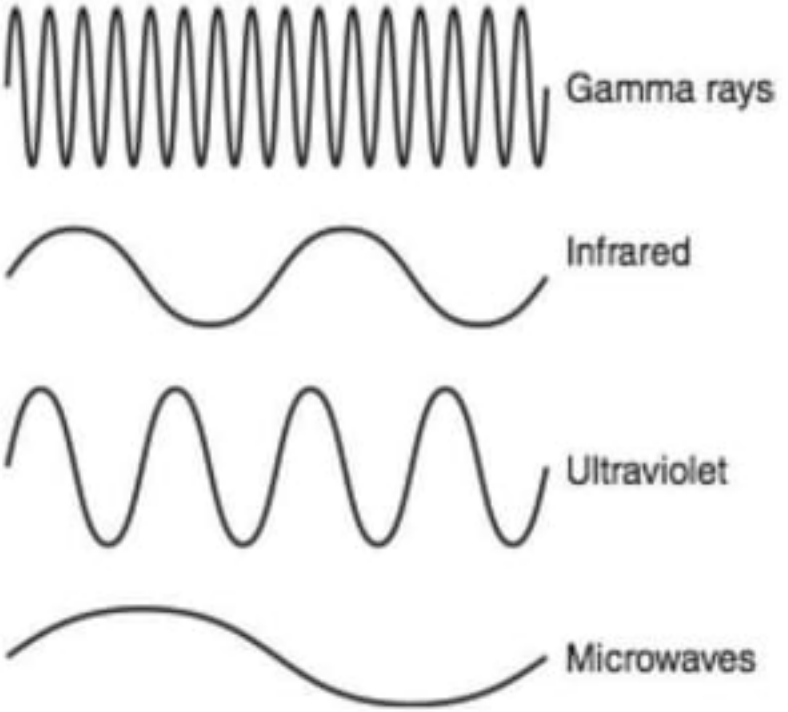


shorter wavelength
higher frequency
higher energy

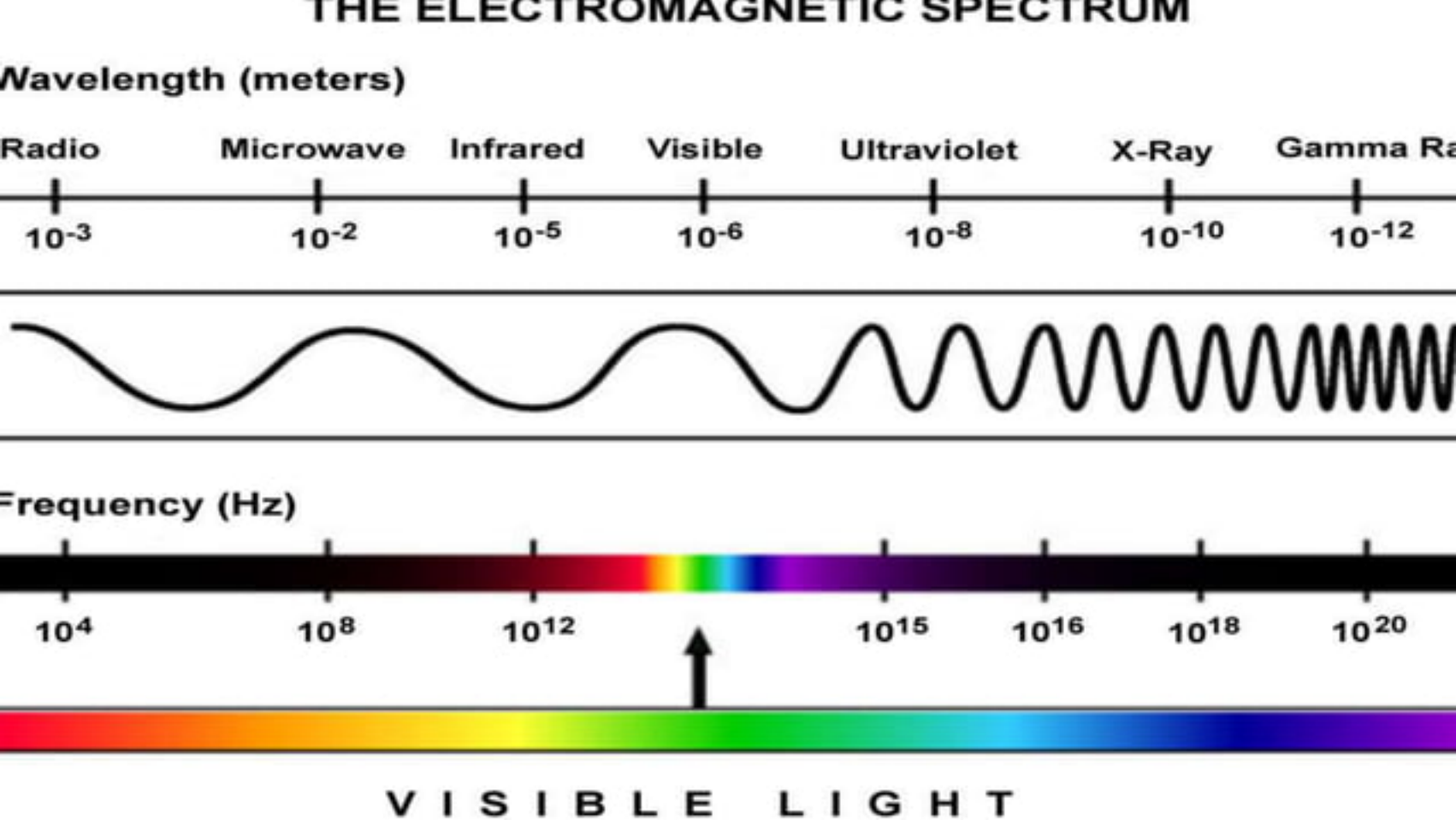
longer wavelength
lower frequency
lower energy



The diagram below shows four waves that represent four different types of electromagnetic radiation: gamma, infrared, ultraviolet rays, and microwaves. The wavelengths shown below are relative but not to scale.



Which kind of wave has the greatest frequency?


THE ELECTROMAGNETIC SPECTRUM
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-Ray
Gamma Ra
10-3
10-2
10-5
10-6
10-8
10-10
10-12
Frequency (Hz)
104
108
1012
1015
1016
1018
1020
VISIBLE LIGHT

Interaction of electromagnetic radiation

With matter

- The nature of the interaction between radiation and matter may include-
    1. absorption
    2. emission
    3. scattering
- They help in the study of matter with respect to
    1. qualitative study
    2. quantitative study

Interaction with matter...

- The effect of electromagnetic radiation on interaction with matter depends on energy associated with the radiation
- Very energetic radiations (UV and x-ray) may cause an electron to **be ejected from the molecules**
- Radiation in the infrared region of the spectrum have much less energy they can cause **vibrations in molecules**

Interaction with matter...

- **Microwave radiation** is even less energetic than infrared radiation it can neither induce electronic transition in molecules nor can it cause vibrations it can only cause molecules to rotate

- **Ultraviolet, visible** - electronic transitions
- **Infrared** - molecular vibrations
- **Microwave** - molecular rotation

Types of spectroscopy

- When radiation meets matter, the radiation is either scattered, emitted or absorbed

- so they are of three types

  1.absorption spectroscopy

  2.scattering spectroscopy

  3.emission spectroscopy

Absorption spectroscopy

- In absorption spectroscopy an electromagnetic radiation is absorbed by an atom or molecule

Which undergoes transition from a lower energy state to a higher energy or excited state

- Absorption occurs only when the energy of radiation matches the difference in energy between two energy levels

Scattering spectroscopy…

- Scattering spectroscopy measures certain physical properties by measuring the amount of light that a substance scatters at certain wavelenths .

- One of the most useful applications of light scattering spectroscopy is **RAMAN SPECTROSCOPY**

Emission spectroscopy:

- Atoms or molecules that are excited to high energy levels can decay to lower levels by **emitting radiation**
- The substance first absorbs energy and then emits this energy as light
- Emission can be induced by sources of energy such as flame or electromagnetic radiation

Principles of absorption spectroscopy…

Lamberts law:

- It states that when monochromatic light passes through a transparent medium, the intensity of transmitted light decreases exponentially as the **thickness of absorbing material increases**

Beer's law:

- It stats that the intensity of transmitted monochromatic light decreases exponentially as the **concentration of the absorbing substance increases**

Beer-lamberts law...

- The Beer-Lambert law states that the amount of light absorbed by a substance dissolved in a fully transmitting solvent is directly proportional to the concentration of the substance and the path length.

Spectrophotometer...

- A spectrophotometer is an instrument that measures the amount of light absorbed by a sample.
- used to measure the concentration of solutes in solution by measuring the amount of the light that is absorbed by the solution in a cuvette placed in the spectrophotometer .

Parts...

- Light source
- A monochromator
- Sample holder(cuvvette)
- Light detector

Light source…

- The function of the light source is to provide a sufficient of light

- The light source typically yields a high output of polychromatic light over a wide range of the spectrum.

Tungsten Lamp

- Tungsten Halogen Lamp, it is the most common light source used in spectrophotometer.
- This lamp consists of a tungsten filament enclosed in a glass envelope,
- with a wavelength range of about 330 to 900 nm, are used for the visible region. It has long life about 1200h

Tungsten-Halogen Lamp

Hydrogen / Deuterium Lamps

- For the ultraviolet region, hydrogen or deuterium lamps are frequently used.
- their range is approximately 200 to 450 nm.
- Deuterium lamps are generally more stable
- and has long life about 500h.
- This lamp generates continuous or discontinuous spectral.

Xenon flash lamps

- 1)Their range between (190nm - 1000 nm)
- 2) Emit both UV and visible wavelengths
- 3) Long life
- 4) Do not heat up the instrument
- 5) Reduce warm up time


XENONFLASHTUBES.COM

Monochromator

- Monochromator Accepts polychromatic input light from a lamp and outputs monochromatic light.
- Monochromator consists of three parts:
- I) Entrance slit
- II) Exit slit
- III) Dispersion device

Dispersion devices

- Dispersion devices causes a different wavelength of light to be dispersion at different angles monochromators used for function.
- **Types of dispersion devices :**
- **Prism**:- is used to isolate different wavelength .
- If a parallel beam of radiation falls on a prism , the radiation of two different wavelength will be bent through different angles.
- Prism may be made of glass or quartz.
- The glass prisms are suitable for radiation essentially in the visible range
- whereas the quartz prism can cover the ultraviolet spectrum also.
- It is found that the dispersion given by glass is about three times that of quartz.

Filter

- Filters separate different parts of the electromagnetic spectrum by absorbing or reflecting certain wavelengths and transmitting other wavelengths.
- **Absorption filters:-**

are glass substrates containing absorbing species that absorb certain wavelength.

- **Interference filters:-**

are made of multiple dielectric thin films on a substrate.

- They use interference to selectively transmit or reflect a certain range of wavelengths.

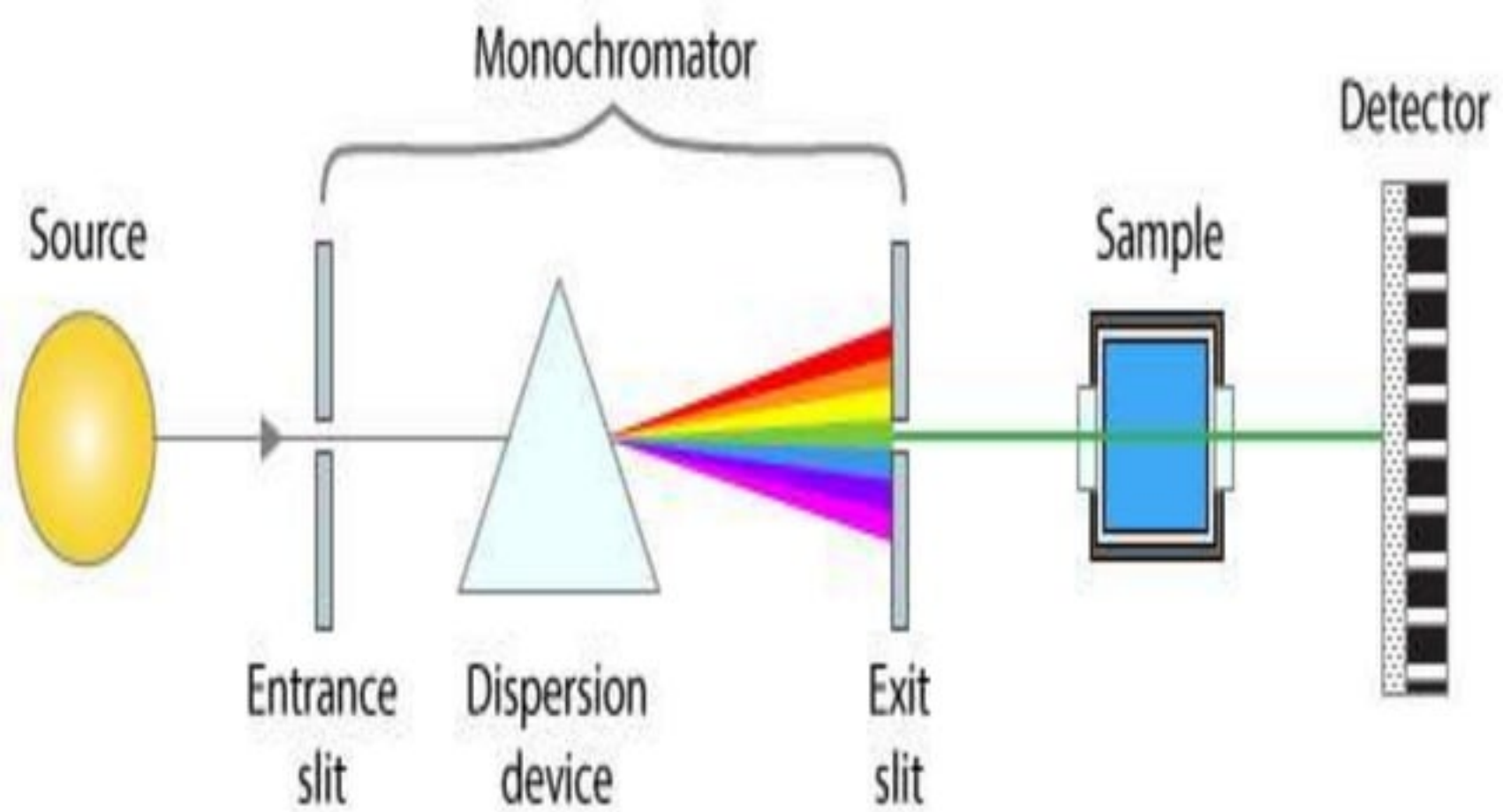
Absorption cells(Cuvettes)

- A cuvette is a kind of cell (usually a small square tube) sealed at one end
- made of Plastic, glass or optical grade quartz
- designed to hold samples for spectroscopic experiments.
- Cuvette should be as clear as possible, without impurities that might affect a spectroscopic reading

Why should we use quartz cuvettes for measuring absorbance in the UV range and plastic cuvettes in the visible range?

Why the cuvettes have two forsted sides?


Frosted Glass
Regular Glass

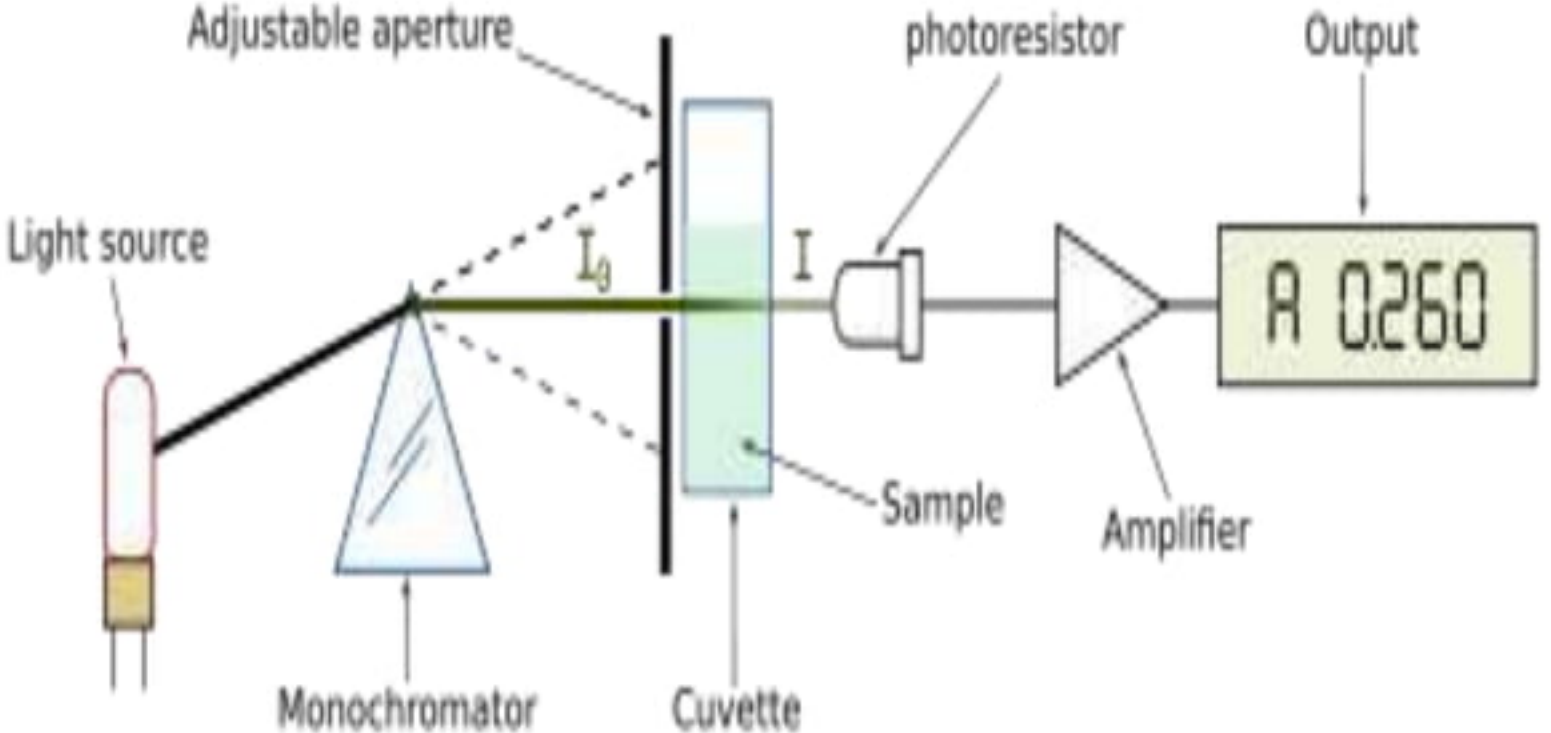

Monochromator
Detector
Source
Sample
Entrance slit
Dispersion device
Exit slit

Types of spectrophotometer

- There are two classes of spectrophotometers:
    1. Single beam spectrophotometer
    2. double beam spectrophotometer

Single beam spectophotometer

- The single beam spectrophotometer was **the first invented**,
- all the light passes through the sample.
- In this case, to measure the intensity of the incident light, the sample must be removed so all the light can pass through.
- This type is cheaper because there are less parts and the system is less complicated.
- **low cost,**
- **high Sensitivity ,** because the optical system is simple.
- The disadvantage is that an appreciable amount of Time elapses between taking the reference and Making the sample measurement

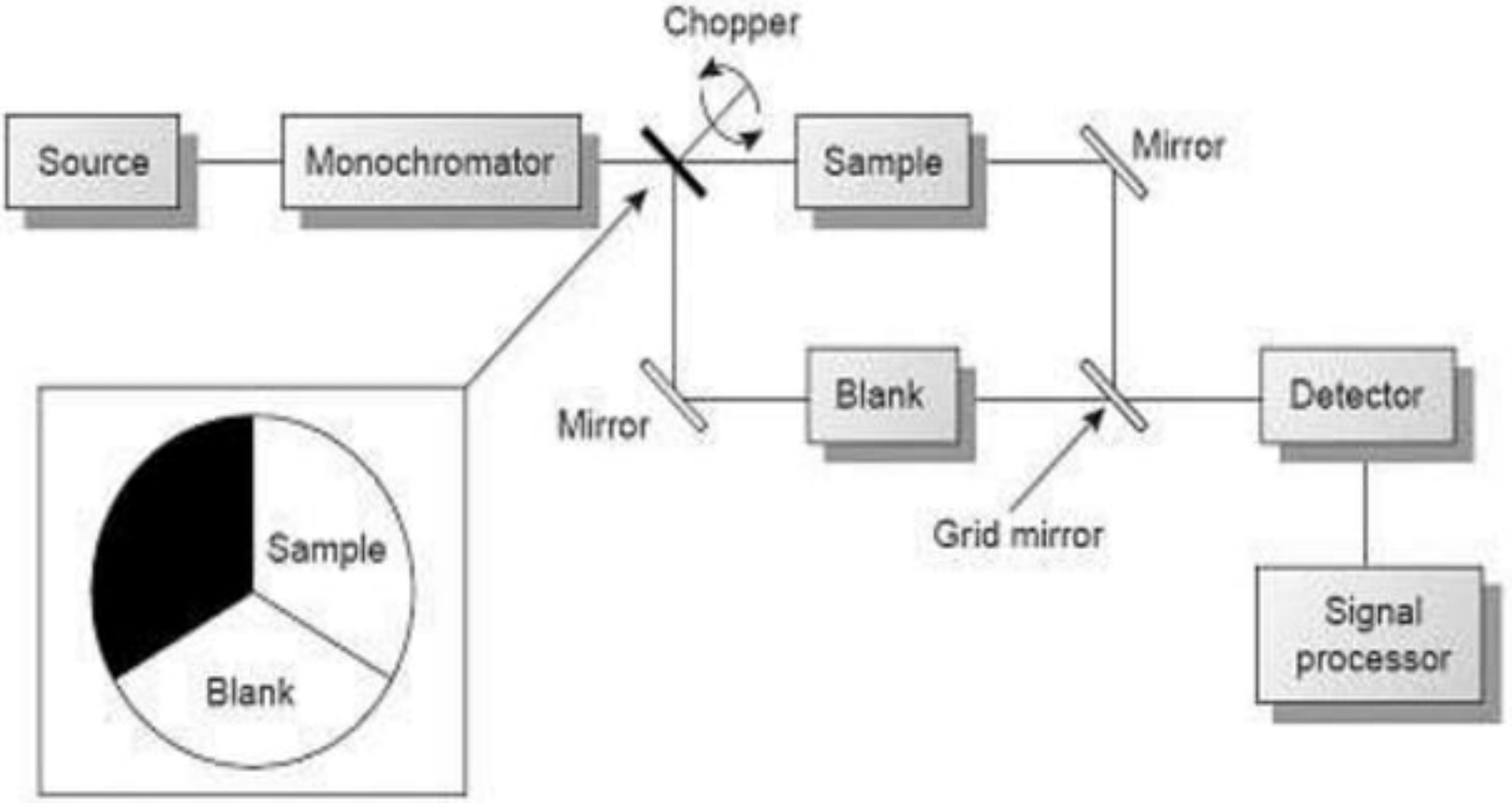

Adjustable aperture
photoresistor
Output
Light source
I_0
I
A 0.260
Sample
Amplifier
Monochromator
Cuvette

Double beam spectophotometer

- The double beam instrument design aims to eliminate drift by measuring blank and sample virtually simultaneously.
- A chopper alternately transmits and reflects the light beam so that it travels down the blank and the sample optical paths to a single detector.
- high stability because reference and sample are measured virtually at the same moment in time.
- The disadvantages are

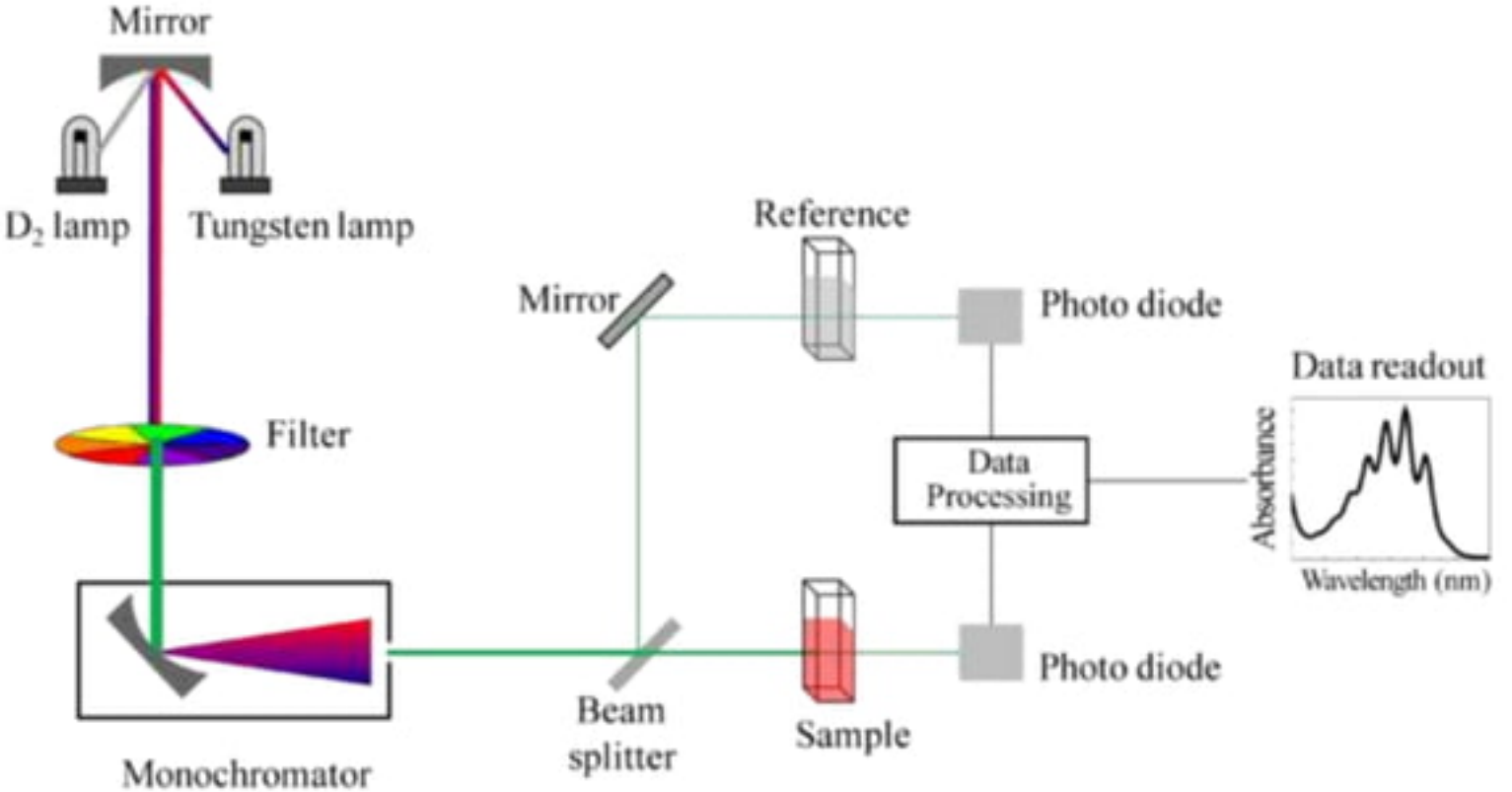
  higher cost,

  lower sensitivity


Chopper
Source
Monochromator
Sample
Mirror
Mirror
Blank
Detector
Grid mirror
Signal processor
Sample
Blank

Split beam spectophotometer

- The split beam spectrophotometer is similar to the double beam spectrophotometer but it uses a beam splitter instead of a chopper.
- Thus blank and sample measurements can be made at the same moment in time.
- Spectra are measured in the same way as with a double beam spectrophotometer.
- The advantage of this design is good stability,.


Mirror
D2 lamp
Tungsten lamp
Filter
Monochromator
Mirror
Reference
Photo diode
Beam splitter
Sample
Photo diode
Data Processing
Data readout
Absorbance
Wavelength (nm)

Beam splitter and chopper

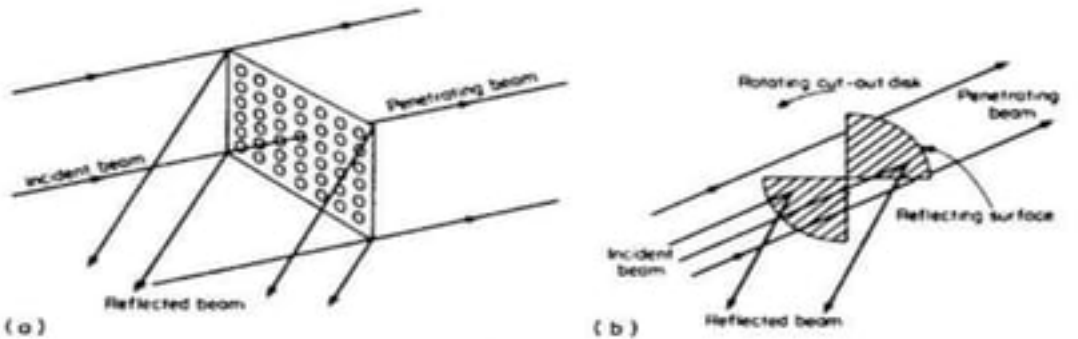


Figure 2.29 (a) Plate beam splitter. (b) Rotating disk beam splitter (or *chopper*).

What is the difference between colorimeter and spectrophotometer

Difference between colorimeter and spectrophotometer

Colorimeter	Spectrophotometer
Colorimeter is the **general type**	Spectrophotometer is the specific type.
Both of them measure color and intensity of color through light.	
Basic method of operation is similar for all instruments.	
colorimeter utilizes a **three color source** (Red, green, and blue) generated by either a **color wheel** with **colored filters** or, sets of **specially designed LEDs**.	Spectrophotometer utilizes either a **diffraction grating** or **prism** in the sensor
Colorimeter is limited to the **visible light** only with WL 400-700 nm	spectrophotometer can be extended to x-ray, UV light, infrared and radiofrequencies

Colorimeter - Spectrophotometer

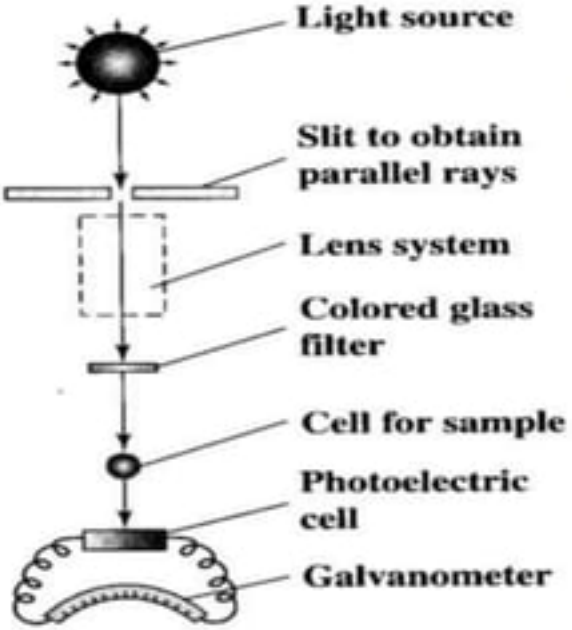


Figure 11.3
Schematic diagram of a photoelectric colorimeter.

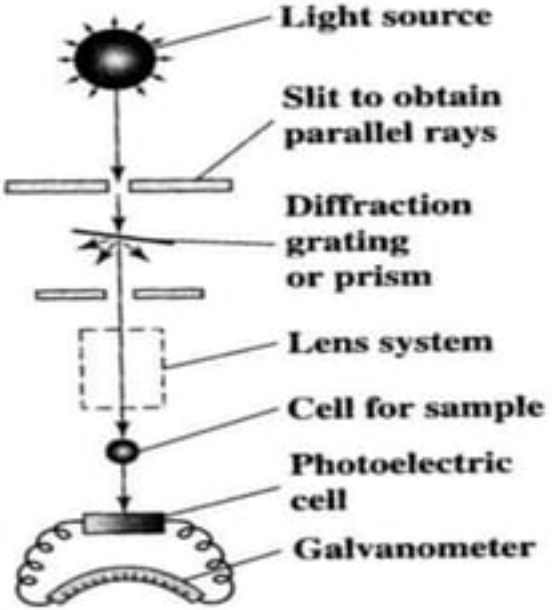


Figure 11.5
Schematic diagram of a spectrophotometer.


ANY
questions?


Thank You