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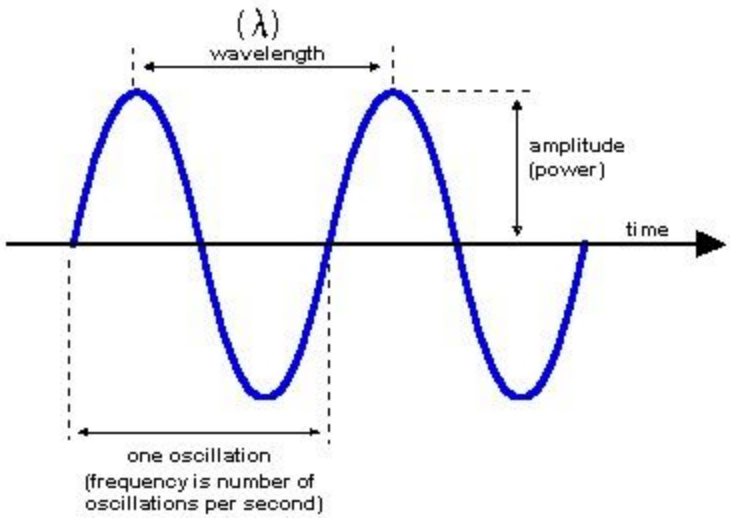
Light

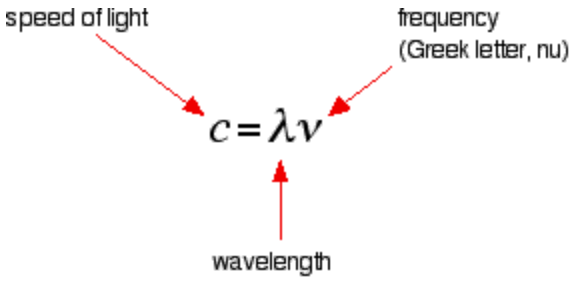
Many kinds of waves exist, such as sound waves and water waves. Visible light is also a wave. More specific light is an electromagnetic wave. All waves can be described in terms of the basic physical properties frequency and wavelength.

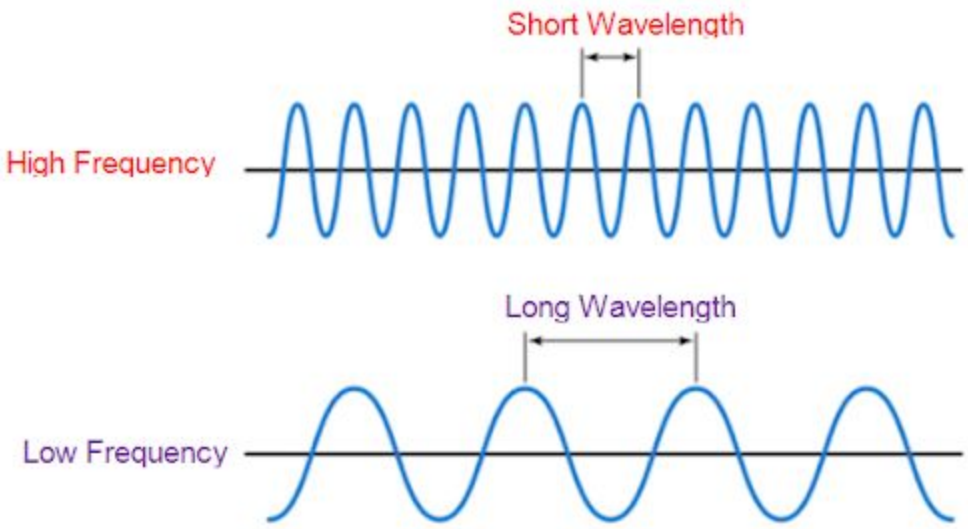
Wave: A wave can be described as a disturbance that travels through a medium from one location to another location.

Now, let's talk about wave:



- **frequency**: number of waves passing from a point per second
- **The wavelength** λ is the distance between 2 consecutive crest or trough.
- **period**: time it takes for one wave cycle to complete.(1 wave ko complete hone mai jo time lagta hai usse wave ka period bolte hai)
- **Wavenumber** : It is defined as the number of wavelengths per unit length.





Extra knowledge about period of the wave:

Period refers to the time that it takes to do something. When an event occurs repeatedly, then we say that the event is periodic and refer to the time for the event to repeat itself as the period. The period of a wave is the time it takes to make one complete cycle(crest and trough).

As an example of the distinction of frequency and period, consider a woodpecker that drums upon a tree at a periodic rate. If the woodpecker drums(hitting) upon a tree 2 times in one second, then the frequency is 2 Hz.

Each drum takes time half a second, so the period is 0.5 s. If the woodpecker drums upon a tree 4 times in one second, then the frequency is 4 Hz; each drum(hit) takes one-fourth a second, so the period is 0.25 s. If the woodpecker drums upon a tree 5 times in one second, then the frequency is 5 Hz; each drum takes one-fifth a second, so the period is 0.2 s.

Do you observe the relationship? Mathematically, the period is the reciprocal of the frequency and vice versa. In equation form, this is expressed as follows.

$$\text{period} = \frac{1}{\text{frequency}} \qquad \text{frequency} = \frac{1}{\text{period}}$$

Electromagnetic Wave or Radiation

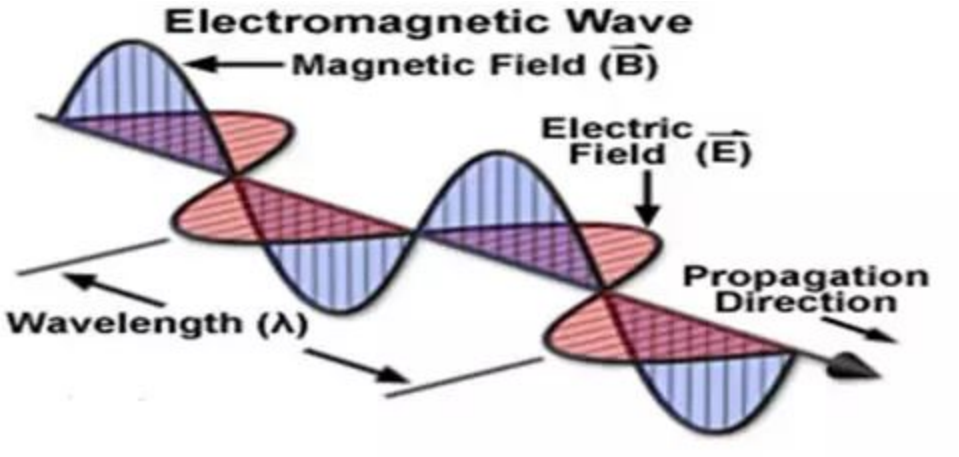
(***radiation** is the emission or transmission of energy in the form of waves or particles)

Electromagnetic consist of 2 words, electro means electric field and magnet means magnetic field.

When electrically charged particle moves under accelaration, alternating electrical and magnetic fields are produced and transmitted. These fields are transmitted in the forms of waves called electromagnetic waves or electromagnetic radiation.

Few properties of electromagnetic waves:

1. **The oscillating electric and magnetic fields produced by oscillating charged particles are perpendicular to each other and both are perpendicular to the direction of propagation of the wave.**



2. Unlike sound waves or water waves, electromagnetic waves do not require any medium and can move in vacuum.
3. There are many types of electromagnetic radiations,these electromagnetic radiations have different wavelength(or frequency) and when these electromagnetic waves are arranged according to their wavelength(or frequency) they make electromagnetic spectrum.
4. All electromagnetic waves travels with speed of light.

Always remember: Electromagnetic waves are produced by oscillating charge particle.

Question:1

After running, Jane checks her pulse. She realizes that her heart is beating rapidly, approximate four beats every second. What is

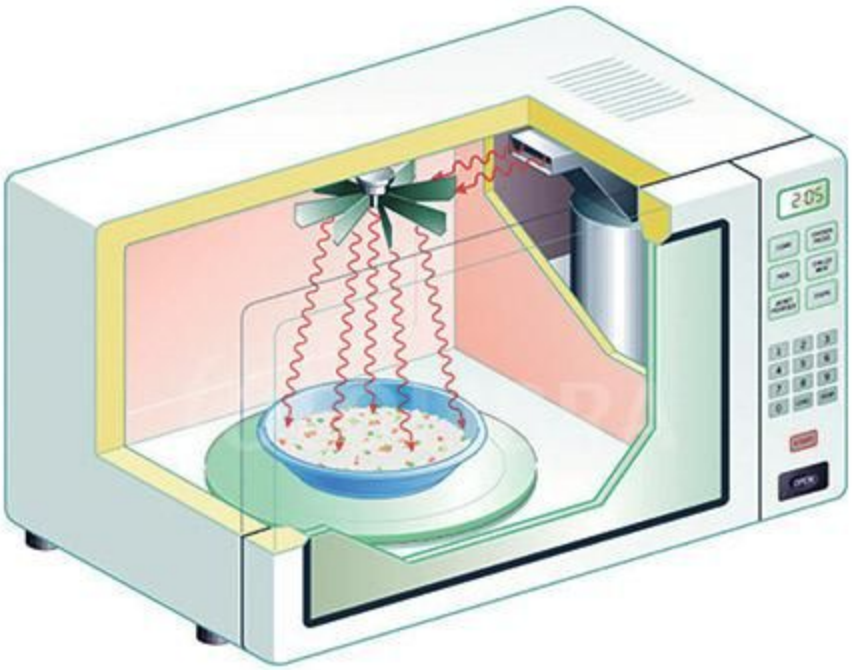
the period and frequency of her heart rate?

Question:2

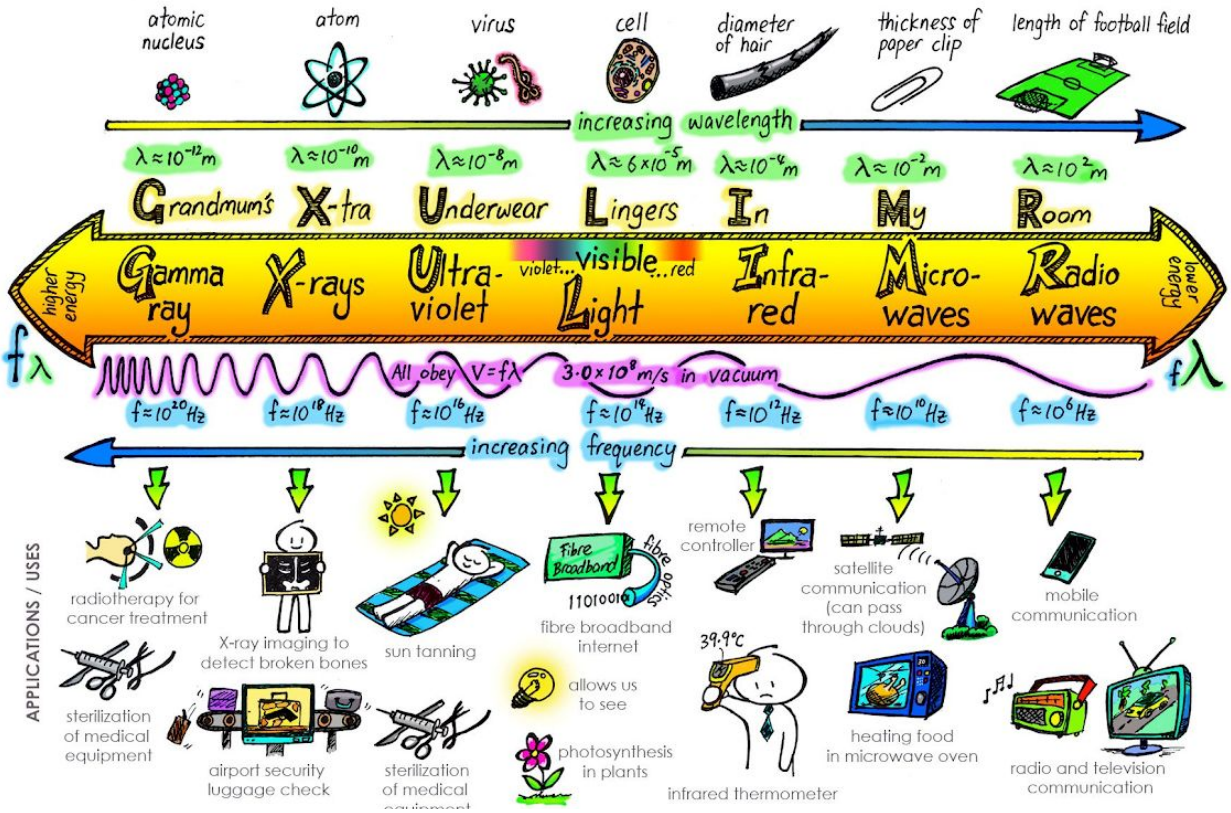
On a sunny day, You picked up your grandpa radio and tuned to 98.3 on FM radio.This radio station broadcasts at a frequency of 98.3 MHz(1MHz =10^6 Hz). If the broadcast is an electromagnetic wave, then what is its wavelength?

a) 6.02m
b) 5.25m
c) 0.33m
d) 3.02m

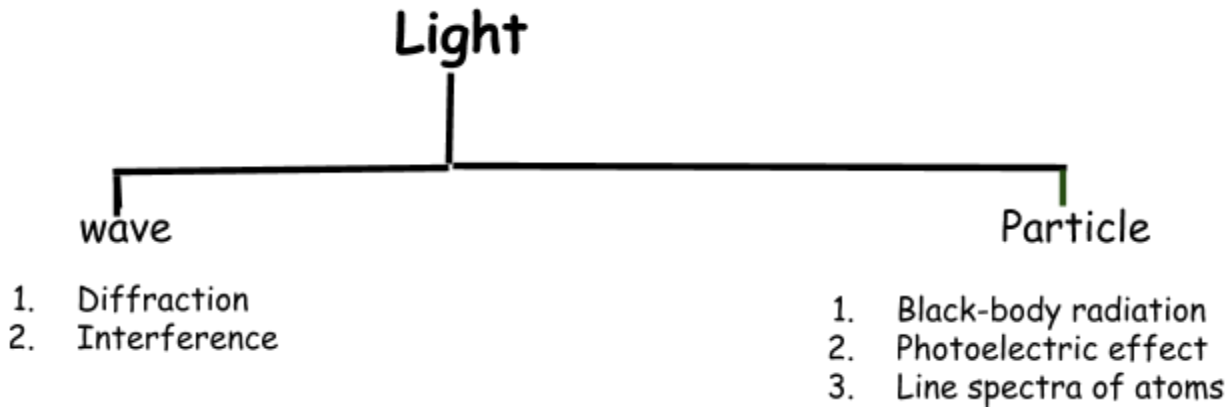
3. A microwave oven (commonly referred to as a microwave) is an electric oven that heats and cooks food by exposing it to electromagnetic radiation in the microwave frequency range.A microwave oven heats food by passing microwave radiation through it .Microwave radiation used in oven has a wavelength of 12.2 centimetres.
Find out the frequency microwave radiation.



Electromagnetic Spectrum



Gamma rays(γ) have highest energy so high frequency and low wavelength.



Diffraction and Interference are two experiments that suggest that light is made up of waves.
(We will study about these two experiments in class XII)

There are experiments and observations that suggest that light is made up of particles not wave.

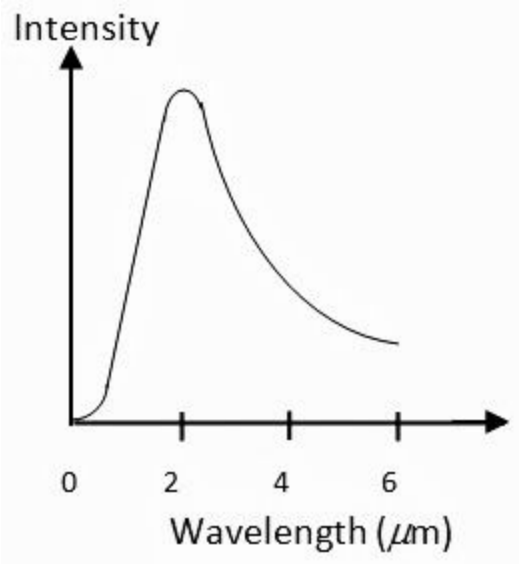
1. **black -body radiation**
2. **photoelectric effect**
3. **line spectra of atoms**

Black-body Radiation:

Black body: A blackbody is a body which absorbs all the radiation falling on it.

Black body radiation: all the radiation(wavelength) emitted by the black body is known as black body radiation.

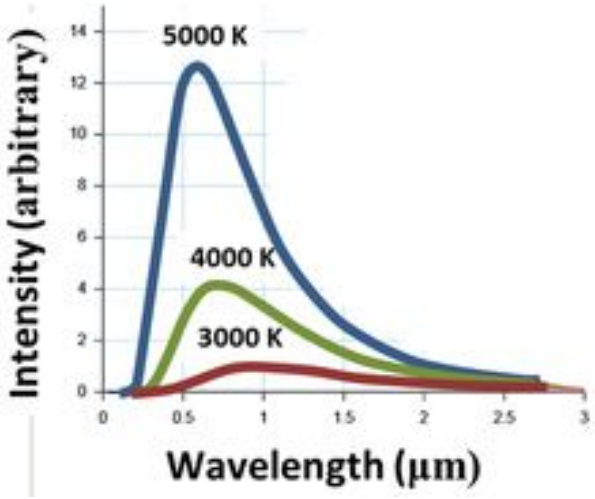
When a body is heated it emits radiation. This radiation contains electromagnetic waves of all wavelengths. But there are few wavelengths whose intensity is higher than the other wavelength. (As shown in the graph)
(for e.g. jab hum iron ko heat krte hai toh usse sarre colour ki radiation nikalti hai toh hume sirf red color hi kyon dekhta hai???
Reason: iron se saare color ke radition nikal rhe but aur dusre colour ki intensity kaam hai lekin red color ki intensity jayda hone ki wajah se humari eyes sirf red color ko percieve(dekhna) kr pati hai.



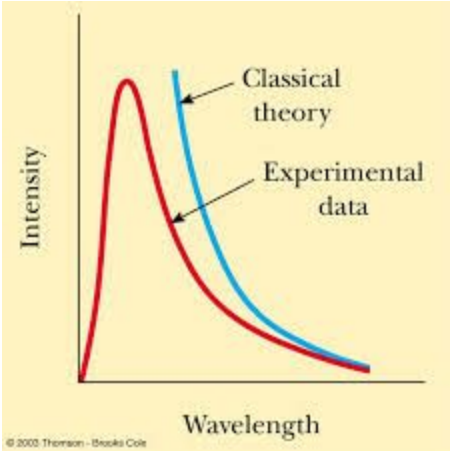
On increasing the temperature graph shift towards lower wavelength region.
That's the reason iron change its colour from red(Long wavelength) to blue(short wavelength) on further increase in temperature.

<u>Simple words:</u>

Jab hum temperature increase krte hai toh graph kaam wavelength ki taraf shift hone lagta hai.
Isliye jab hum iron ko heat krte hai toh phle woh red(Long wavelenth) hota hai aur fir uska color change ho jata blue(short wavelength)



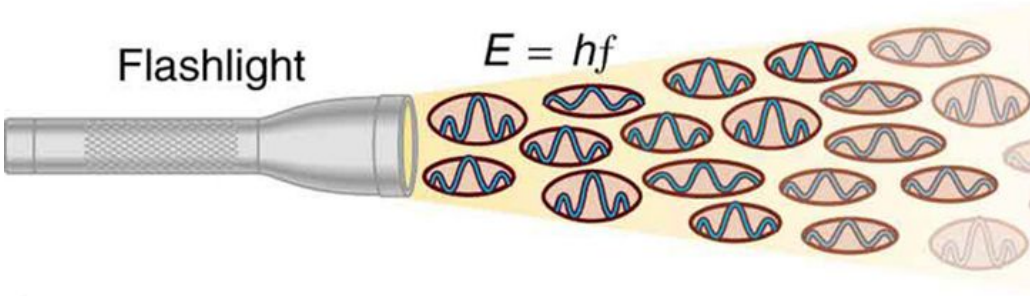
But experimental data was different from the calculation done by the classical theory(That assumes light as wave).



Experimental data (or black body radiation) was explained by Planck by assuming light that light is made up of packets called quanta.

Planck's Quantum theory of light

According to planck's light is absorbed or emitted in the form of packets of energy. These packets are known as quanta.(1 packet = Quantum)



Simple words:
Light waves ki form mai nhi aati wo chote-chote energy ke packets mai aati hai. Aur ek energy k packet ko hum quantum bolte hai and bahut sare energy packets ko hum quanta bolte hai(plural).

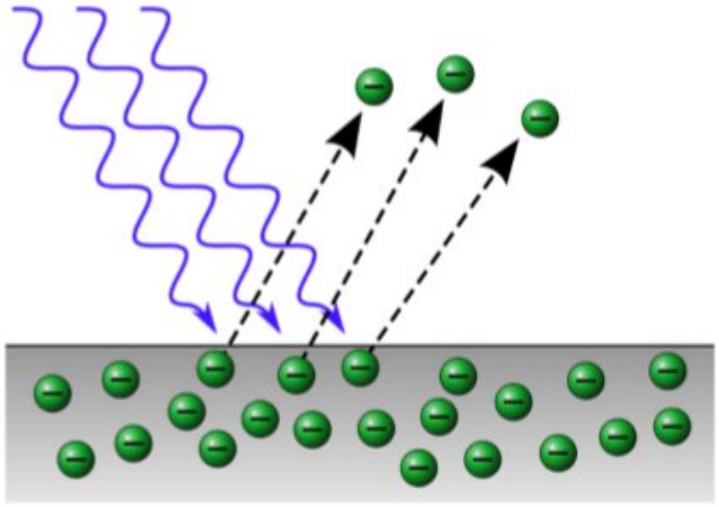
Energy of quantum

v is the frequency of the light(radiation)
h= 6.62607015 × 10^{-34} joule second.
E is the energy of the quantum

$$E = hv$$

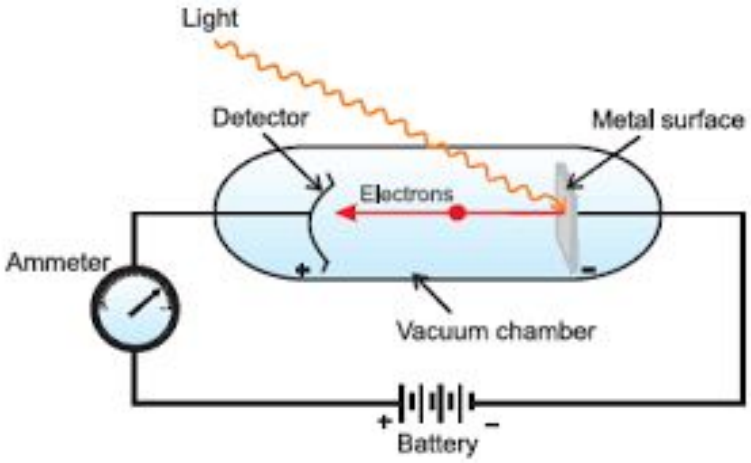
Photo-electric effect

Immediate ejection of electrons from a metal's surface when the light of suitable frequency falls on the metal surface is known as photoelectric effect.



Under the right conditions, light can be used to eject electrons from a solid material. This phenomenon, known as the photoelectric effect, occurs when some types of electromagnetic radiation are shined on certain kinds of matter.

Experimental setup:



Experimental results:

1. Electrons are ejected from the metal surface as soon as light strikes on the metal surface.(matlab jaise hi hum light dalte hai,electron ek dum tabhi niklne start ho jate. Electrons ko niklne mai time nhi lagta)

2. Number of electron ejected is directly proportional to the intensity of light(intensity means brightness)
   Agar light ki brightness jyada hogi toh jyada electron metals se niklenge.

3. For each metal, there is a minimum frequency below which photoelectric effect is not observed.
   That minimum frequency is known as threshold frequency.

Threshold frequency(v_0): minimum frequency of the light required to eject an electron from the metal.

Simple words:

Kisi metals se electron nikalne k liye hume ek minimum energy(or frequency) chahyiye rhegi(us energy ko work function aur minimum frequency ko threshold frequency bolte hai). Agar light ki energy work function se kam hui toh electron nhi nikelga.

4. **If frequency of light is greater than the threshold frequency. ($v>v_0$)**

On increasing the frequency of light kinetic energy of electron increase.

Simple words:

Agar hum light ki frequency increase krenge toh electron speed bhi increase krti hai. Lekin ek condition hai light ki frequeny, thresold frequency se jyada honi chihye nhi toh electron niklega hi nhi.

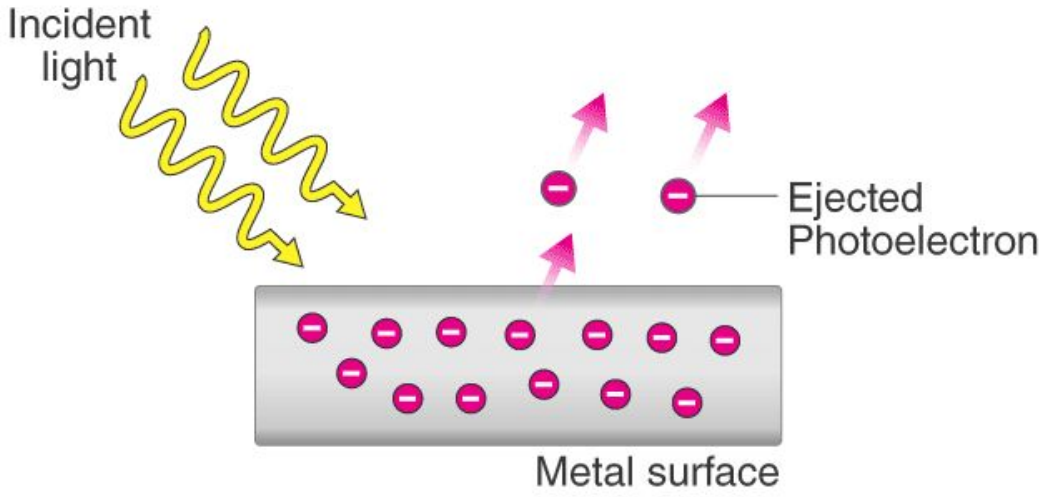
Photoelectric effect Explanation:

When a photon of sufficient energy strikes an electron in the atom of the metal, it transfers its energy to the electron during the collision and the electron is ejected.

minimum energy required to eject the electron is $h\nu_0$ (also called work function, W_0 .

Jab photon metal ke electron se collide krta hai toh apni energy ko electron ko transfer kr deta hai, electron iss energy ko 2 kaam k liye use krta hai

- **Metal se bhar nikalne k liye (iss energy ko work function bolte hai)**
- **Bachi hui energy kinetic energy mai chali jati hai(matlab bachi hui energy se electron apni speed increase krta hai)**



$$h\nu = h\nu_0 + \frac{1}{2} m_e v^2$$

Greater the energy possessed by the photon, greater will be transfer of energy to the electron and greater the kinetic energy of the ejected electron.(But photoelectric current will be the same if increase the energy or frequency of the light)

Agar photon ki energy jyada hai toh jo extra energy hogi wo electron ki kinetic energy mai chali jyegi(electron ki speed increase ho jygi agar hum higher energy(or frequency)ki light metal p dalenge toh.(ek baat dhyan rkhna electron same hi niklenge{toh current bhi same hi rhega} bas unki speed increase hogi)

If intensity of light is high it means it contains a larger number of photons as a result the number of electrons ejected is also larger as compared to light of weaker intensity .
(Photoelectric current will increase with increase in intensity of light)

Agar hum light ki intensity increase krte hai toh uska matlab hota hai ki hum jyada photon daal rhe hai aur agar jyada photon honge toh jyada electron niklenege.(iska matlab intensity increase krne se photoelectric current increase ho jata hai)

Note: Humesha light ki frequency meta ki thresold frequency se jyada honi chihye tabhi photelctric effect hoga(matlab electrons niklenge) nhi toh kuch nhi hoga..chaheaap kitni bhi intensity badha lo!!!!!!

Har ek metal ki alag alag thresold frequency hoti hai.

Let's start with simple and interesting Questions:

Question-1:

A black light is a lamp that emits ultraviolet light. It is used to attract the insects.Insects are attracted to the UV light, which they are able to see, and are then electrocuted by the device.

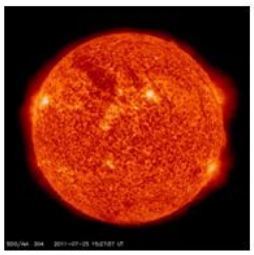
If the wavelength of black light is 350nm. What will be the frequency of black light? Find out the wavenumber and Time period also.

Question-2

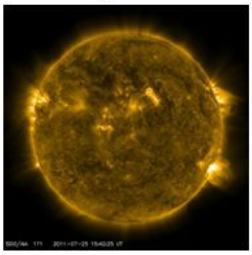
The intensity of a colour in black body radiation depends upon the temperature.Black body radiation from stars helps us to determine their temperature.

Out 3 stars shown below which one is the coolest star ?

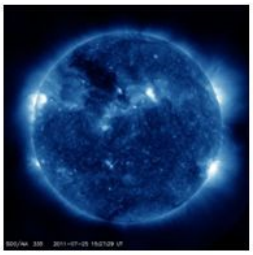
Red star



Yellow/white star



Blue star



Question-3

Red colour of light have wavelength = 700nm.

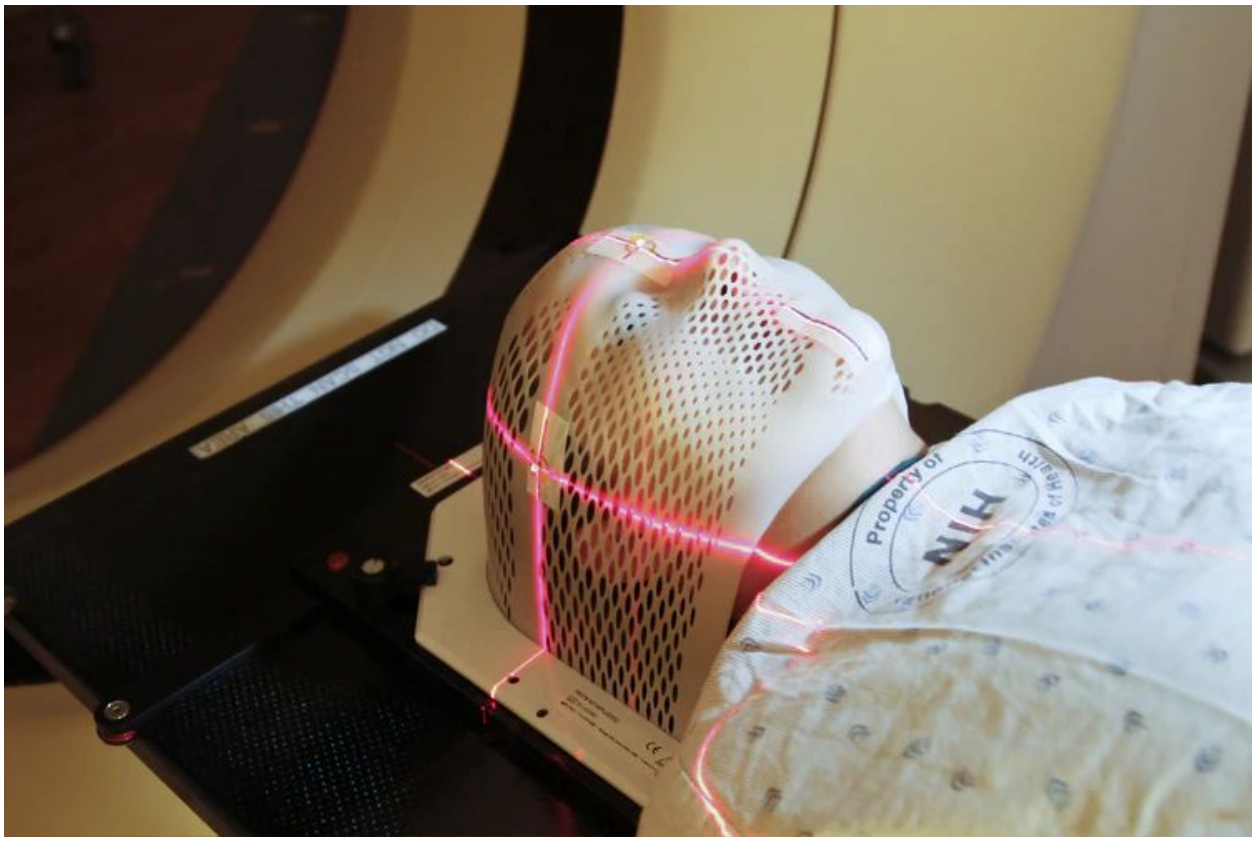
What will be the frequency of the red color light.

What will be the energy of the quanta coming from the red light?

Question-4

Radiation therapy uses high-energy particles or waves, such as x-rays, gamma rays, electron beams, or protons, to destroy or damage cancer cells.

Calculate the energy of 100000 quanta used to destroy the cancer cell. if the radiation used has frequency= 5×10^{23} Hz.



Question-5

The photo-cell is the most ranging of applictions of the photoelectric effect. It is most commonly found in solar panels. it works on the basic

principle of light striking the cathode which causes the emmision of electrons, which in turn produces a current.

A photon of wavelength 200 nm strikes on metal surface, the work function of
the metal being 2.13 eV. Calculate (i) the energy of the photon (eV), (ii) the kinetic
energy of the emission, and (iii) the velocity of the photoelectron
(1 eV= 1.6020 × 10–19 J).

Some easy questions:

Q-1. As the wavelength of the radiation decreases, the intensity of the black body radiations _____

a) Increases
b) Decreases
c) First increases then decrease
d) First decreases then increase

Q-2. The radiations emitted by hot bodies are called as _____

a) X-rays
b) Black-body radiation
c) Gamma radiations
d) Visible light

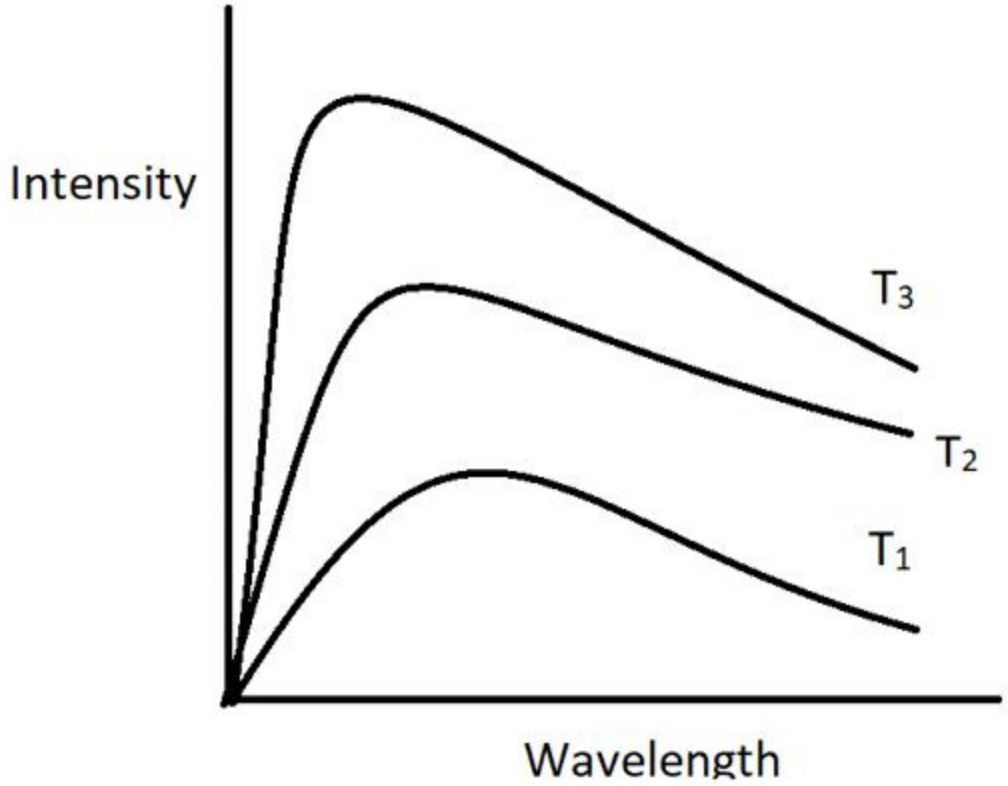
Q-3. An iron rod is heated. The colors at different temperatures are noted. Which of the following colors shows that the iron rod is at the lowest temperature?

a) Red
b) Orange
c) White
d) Blue

Q-4. A black body is defined as a perfect absorber of radiations. It may or may not be a perfect emitter of radiations.

a) True
b) False
Answer: b
Explanation: A black body is defined as the one which is a perfect absorber as well as a perfect emitter of radiations. Such a body would absorb all the radiations falling on it and would emit all of them when heated.

Q-5 From the figure, what's the relation between T1, T2, and T3?



a) T1 > T2 > T3
b) T3 > T2 > T2
c) T3 > T1 > T2
d) T2 > T1 > T3

Q-6. Electromagnetic wave theory of light could not explain Black Body radiations.
a) True

b) False

Q-7. How does the intensity affect the photoelectric current?

a) As intensity increases, the photoelectric effect increases

b) As the intensity increases, the photoelectric effect decreases

c) As the intensity decreases, the photoelectric effect becomes twice

d) No effect

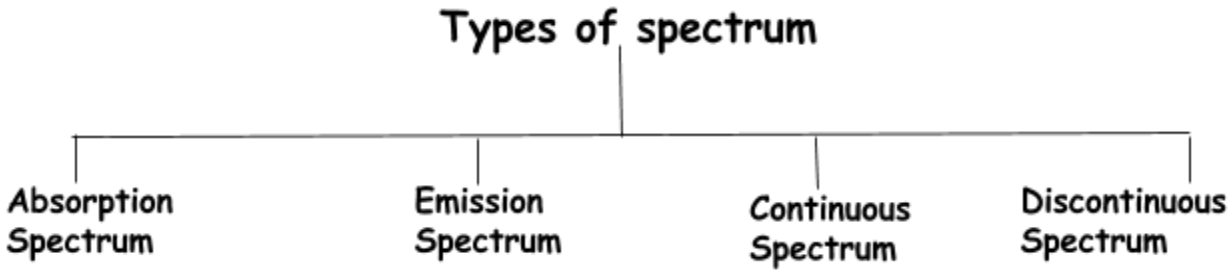
Q-8 Light of wavelength 3500 Å is incident on two metals A and B. Which metal will yield more photoelectrons if their work functions are 5 eV and 2 eV respectively?

a) A
b) B
c) A & B
d) C

Spectrum

Spectrum ka matlab hota hai kisi bhi cheez ko ek order mai arrange krna. Yahan hum baat kr rhe hai radiation ke spectrum ki. Toh agar hum radiation(waves) ko wavelength ya frequency ki hisab se arrange kr dete hai toh us arrangement ko hi spectrum bolte hai.

Arrangement of radiation(wave) according to their wavelength or frequency.



Continuous spectrum or Continuum spectrum

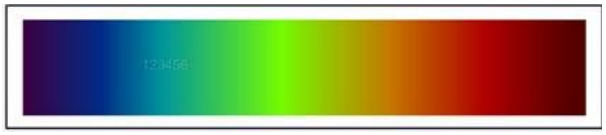
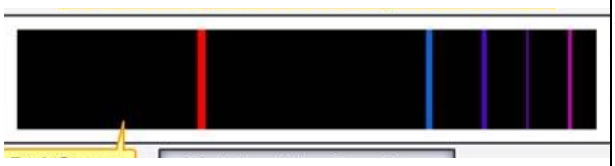
A spectrum having no breaks or gaps throughout its wavelength range is known as continuous spectrum.

A continuous spectrum is produced when all the colors of a rainbow (from red to violet) are present. If all the seven colors are present with no gaps between them, it makes a continuous spectrum.

Discontinuous spectrum or line spectrum

A spectrum that includes some, but not all of the wavelengths in the specified range.

Some differences between continuous and line spectrum

Continuous Spectrum	Line Spectrum
Continuous spectra contain no observable gaps.	There are huge gaps between lines.
Continuous spectrum contains all the wavelengths of a given range.	Line Spectrum: Line spectrum contains only a few wavelengths.
	

Emission spectrum

The spectrum of radiation emitted by a substance that has absorbed energy is called an emission spectrum.

Jab hum kisi cheez ko energy dete hai usse jo radaition niklega uske spectrum ko hum emission spectrum bolenge.

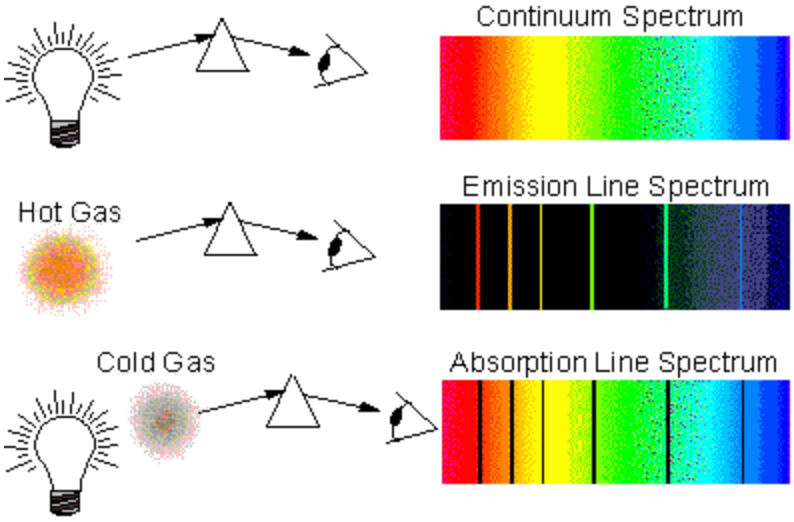
Niche figure mai dekho bas kuch hi colour ki line dekh rhi hai baaki sab black hai. Jo colour line wo us substance n emit ki hai

Absorption Spectrum

An absorption spectrum is a spectrum that takes place when light passes through cold and dilute gases.

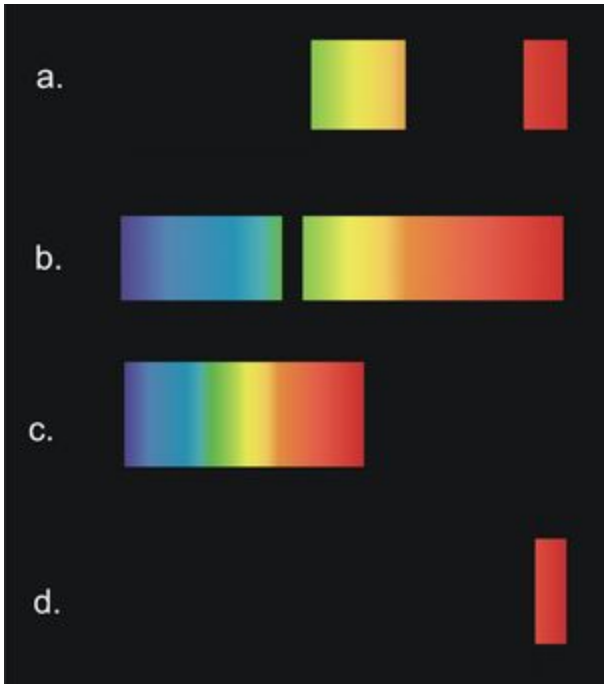
Jab hum kisi substance(generally gas) ko bina energy diye usse radiation pass krte hai,toh substance wavelenth absorb kr lega aur hume jo spectrum milega usko hum absorption spectrum bolenge.

Niche figure mai dekho absorption spectrum mai kuch black line hai uska matlab wo wavelength substance n absorb kr li.



Question-1

Choose which one the following spectra is continuous or discontinuous.



Question-2

Decide whether each of the following statements is true or false.

(a) White light has a wavelength of 760 nm.

(b) Iron's atomic spectrum is an example of a discontinuous spectrum.

(c) Hydrogen's atomic spectrum is an example of a continuous spectrum.

Question-3

Fill in each of the following blanks with the words "must", "may" or "does not".

(a) A continuous spectrum between 300 nm and 500 nm _____ contain light with a wavelength of 356 nm.

(b) A continuous spectrum between 1000 cm and 1.50 m _____ contain light with a

wavelength of 1.234 m.
(c) A discontinuous spectrum between 234 mm and 545 mm ____ contain light with a wavelength of 300 mm.

Question-4

Choose the correct word in each of the following statements.
(a) A continuous spectrum between 532 nm and 894 nm contains light of every wavelength (greater than/less than) 532 nm and (greater than/ less than) 894 nm.
(b) A discontinuous spectrum between 532 nm and 894 nm does not contain and light of every wavelength between 532 nm and 894 nm (including/may have) light with a wavelength of 650 nm.