Clinical Visual Optics (OPTO 223)

Dr Salwa Alsaleh

Week I
Introduction to the course and the Physics of light.

About the course

This course aims to develop your theoretical and practical understanding of light and its role in vision, electrophysiology of vision and interaction between light and the human eye.

By the end of this course, you will be able to :

1- Understand the nature of light

2- Know the most important physical properties of light

3- Photometry and illuminances and their measurements.

4- Refraction and absorption of light

5- Describe the interaction between the light and the human eye

6- The role of light in vision.

7- Threshold frequency of seeing curve

8- Understand the basic notions in photochemistry and electrophysiology of vision.

9- Define the spatial phenomena

10- Understand the temporal phenomena.

Course references:

The recommended references for this course, besides these lecture notes are:

- Elmsley, H. ` Visual Optics’ Vol I (1948) and II (1972).
- Consweet, T.N. ` Visual Preception’ (1970)
- Michaels, David D. *Visual optics and refraction: a clinical approach*. CV Mosby, 1985.

Course Plan

* We will have a total of 14 lectures, of 2 contact hours.

- The mid-term exam will be in the 9th week.
- The final exam will be in the 15th week

Course instructor

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- The website is the main method of communication, you'll find all course material there, my contact info and office hours.

Outline of week I

In this lecture, we shall address the following topics:

- What is light ?
- Spectrum of light
- Propagation of light
- Interaction between light an matter

Why understand light ?

In order to appreciate how the eye works, what the different parts of the eye do, and what happens when there are problems with vision, it helps to know a few simple things about the nature of light, including:

1- **What <u>is</u> Light** (wavelengths and colours)

2- **Non-spectral colours** (i.e. colours that don't correspond to a specific wavelength of light, incl. white, black and greys)

3- **Propagation of light** (usually in straight lines while traveling through any one medium, e.g. air.)

4-**Re-direction of light at surfaces** (absorption, reflection, scattering or refraction) explaining why light travels away from most illuminated objects in many different directions, hence in most cases some light from all objects in a person's 'field of view' reaches his or her eyes, except perhaps for very dark objects.

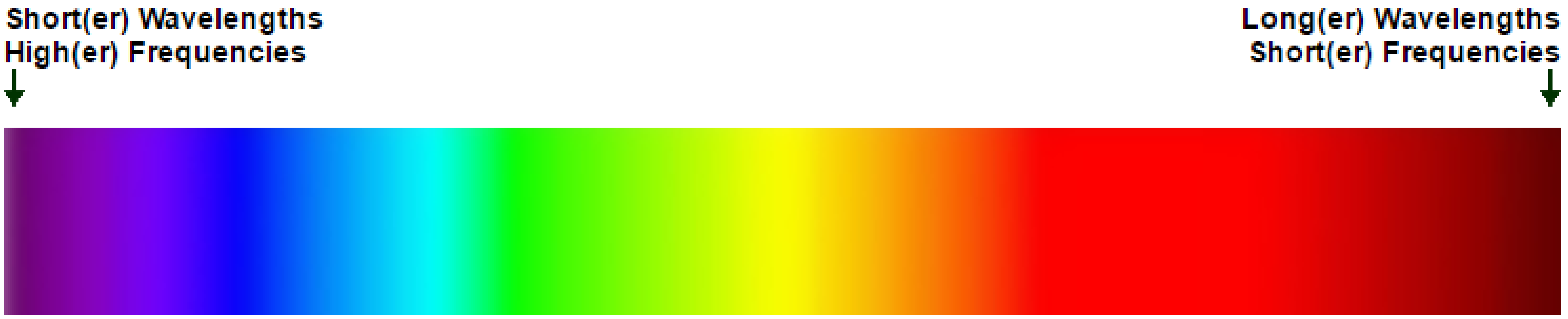
What is light ?

- **Light** is a form of energy.
- The word **light** is commonly used to refer to the **visible spectrum**, i.e. the range of wavelengths (sometimes referred to by their corresponding frequencies) that, together, form the **visible** part of the **electromagnetic spectrum**. 'Visible' means something that can be seen using the human eye, as opposed to 'invisible' things that cannot be seen by the human visual system on its own*.

- The visible part of the electromagnetic spectrum ranges (in wavelengths) from **380 nm** to **750 nm.**
- Each wavelength corresponds to light of **one colour** so the visible spectrum range of wavelengths would look something like the block below if they were all lined-up in order of increasing wavelength with each wavelength appearing only once.

Spectrum of light

- The expression '*visible* spectrum' means the range of electromagnetic energy that most people (i.e. those with "normal" vision) can **see with the naked eye**. This is just a small part of a much wider range of energies, many of which we cannot see but some of which are used in other ways, e.g. radio waves, microwaves, ultra violet (UV) light, infra-red (IR) radiation, X-Rays, and other wavelengths such as those used in various types of scanning and imaging equipment. These other types of electromagnetic energy have wavelengths that are either less than 380 nm or more than 750 nm. (One nm = 10^{-9}m)



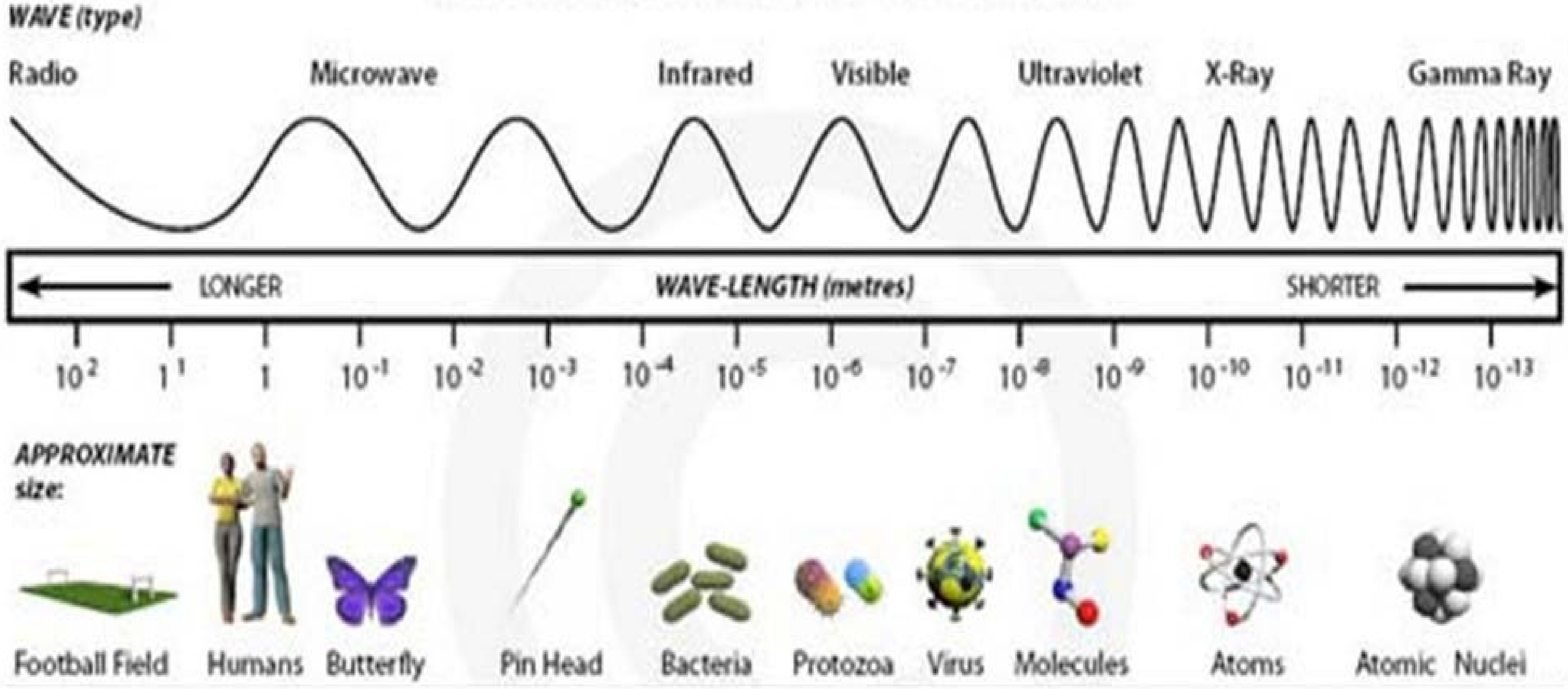
Above : Colours of the visible spectrum

Relation between the speed of light c, the wavelength of light λ and the frequency f.

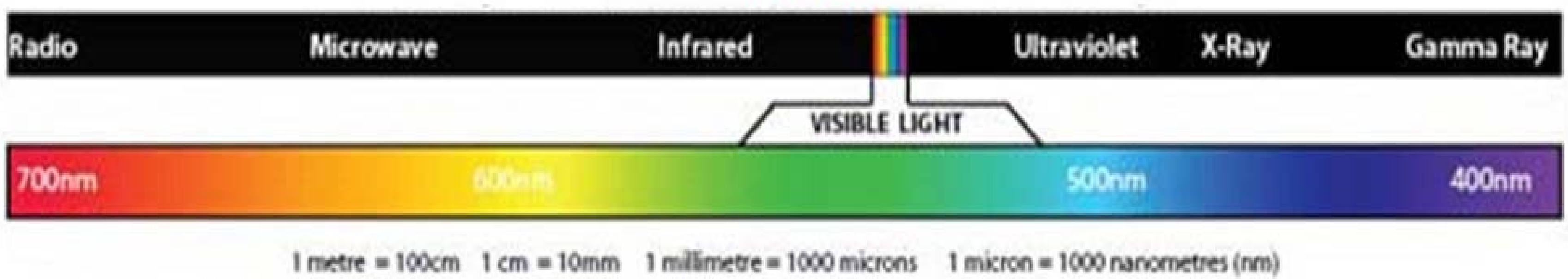
$$c = \lambda f$$

Notice that since c is a constant, the wavelength is inversely proportional to the frequency.

THE ELECTRO MAGNETIC SPECTRUM



The Visible Spectrum is a VERY tiny part of the full Electromagnetic Spectrum. All these wavelengths are emitted by the SUN.



What is 'White Light' ?

- Given that light only exists as single wavelengths corresponding to the colours in the range shown above, what is 'white light' ?
- '**White Light**' or 'the colour white' is the way humans perceive and refer to our experience of receiving an **approximately equal quantity of all the wavelengths** (i.e. colours) in the visible spectrum from an area or object. We describe and refer to such objects or regions as 'white' e.g. a sheet of white paper, a bright white moon (in certain atmospheric conditions) and the colour of a dove.

- The statement 'white is not a **spectral color**' means that it does not correspond to a single wavelength in the visible spectrum, i.e. the colour range represented above. Instead, white is the way we perceive an approximately equal presence of all colours while black is the absence of light / colour such that all colours / wavelengths are (equally) lacking. Shades of grey also correspond to *approximately the same energy from a wide range of wavelengths (colours) of light in the visible range*, but in decreasing quantities of light energy along a scale from:
- **White** - Lots of 'light energy' (luminance) in the form of approximately equal amounts of light of each (or most) of the many different wavelengths of 'visible light', corresponding to different 'colours', reaching the eye / brain, to
- **Black** - No 'light energy' or an imperceptibly small quantity of 'light energy' (luminance), if non-zero then in approximately equal amounts of the range of wavelengths of 'visible light', corresponding to different 'colours' reaching the eye / brain.

Propagation of light

- The word '**propagation**' is sometimes used in scientific contexts to mean '**travel**' or '**movement**'. It is used in optics, which is the study of the physics of light and other forms of electromagnetic energy, in the context of describing energy moving ('propagating') in 'waves’.

Light is generally considered to travel through air in **straight lines**, only changing direction when it is reflected, scattered, or passes from one type of substance (called a **medium**) to another. For example, light **changes direction** slightly when it moves from air into water, or from air into glass, or vice-versa. This change in the direction of travel of light is due to **refraction**.

Note: There are some situations in which light travels in curves rather than in straight lines - as explained by the physics of diffraction and interference. However, for the simple cases of describing image formation within the eye and the manifestation and correction of short-sight and long-sight, it is sufficient to think of rays of light traveling through any one medium, such as air or water, in a series of straight lines.

What happens when light reaches the surface of an object ?

- Light travels (propagates) from many different **sources**, including from large and powerful sources of illumination such as the **sun** or the main **lights in a room**. It is also reflected and scattered from many and various objects that are not *sources* of light - meaning that the light did not start at (originate from) that object but arrived at it from somewhere else, then left it again, perhaps in a different direction.

- **Eventually, light reaches the surfaces of physical objects**, e.g. it could come from a lamp in a light fitting in the ceiling of a room (the *source* of the light), propagate through the *air* in the room (a '*medium*' through which the light passes) until it reaches a surface such as a table or other item of furniture.
- When light reaches an object it can do one or some combination
of **absorption**, **reflection**, **scattering** or **refraction**
.

Interaction between light and matter

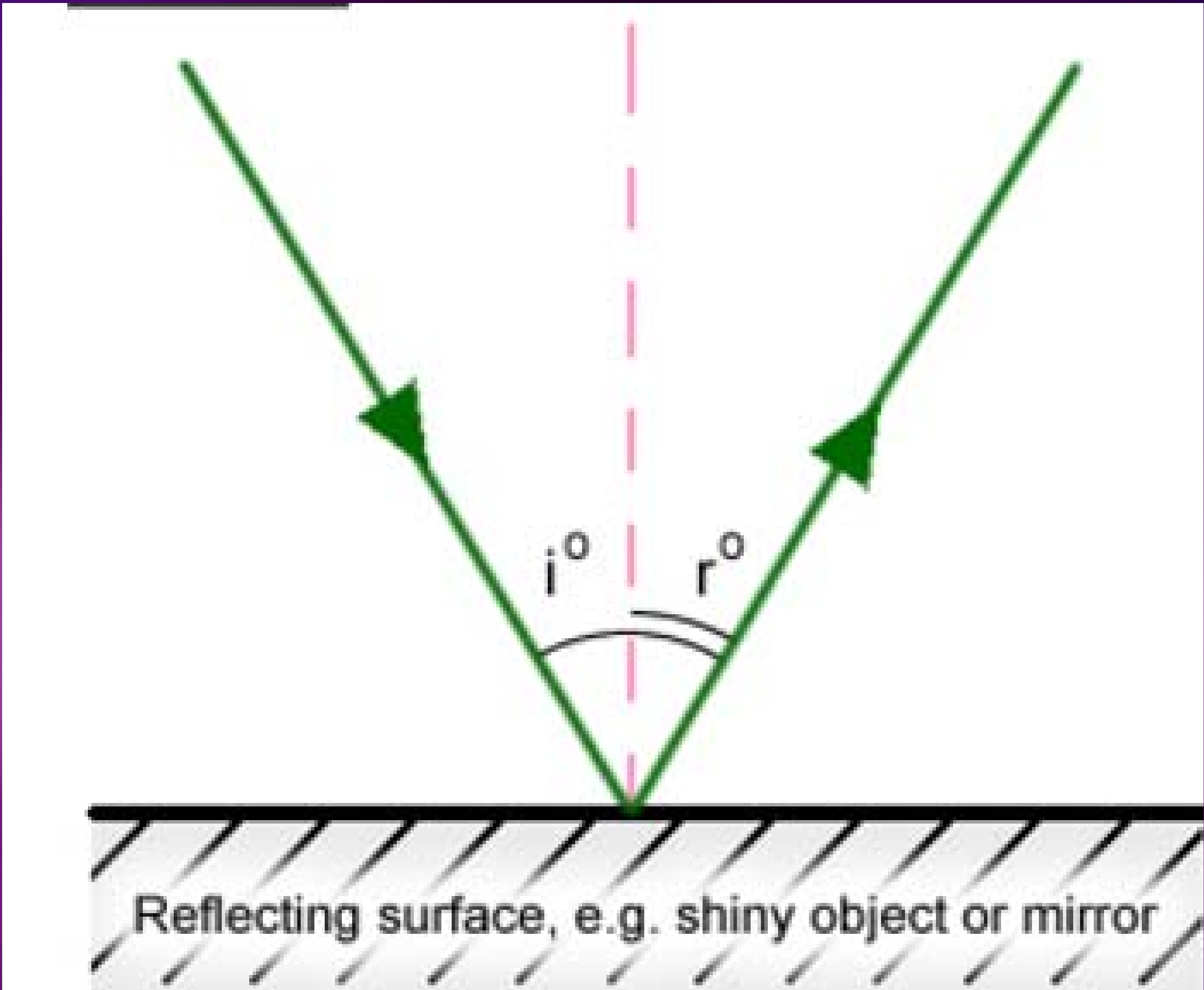
First **Absorption**

Light energy goes into the object itself. Because the light goes into the object rather than leaving the surface of the object - *and then some of that light entering the eye* - the object is not "*seen*" as very bright. Instead, it is perceived to be dark (meaning that little light is traveling from that object into the eye). However, the object might still be obvious to a viewer, e.g. a dull matt-black object would still be seen if observed on a clean white surface. In that case the contrast makes the presence of the dark object obvious.

In general, dark objects are move likely to absorb light energy, while objects that are light (in colour) are more likely to reflect or scatter the light energy they receive.

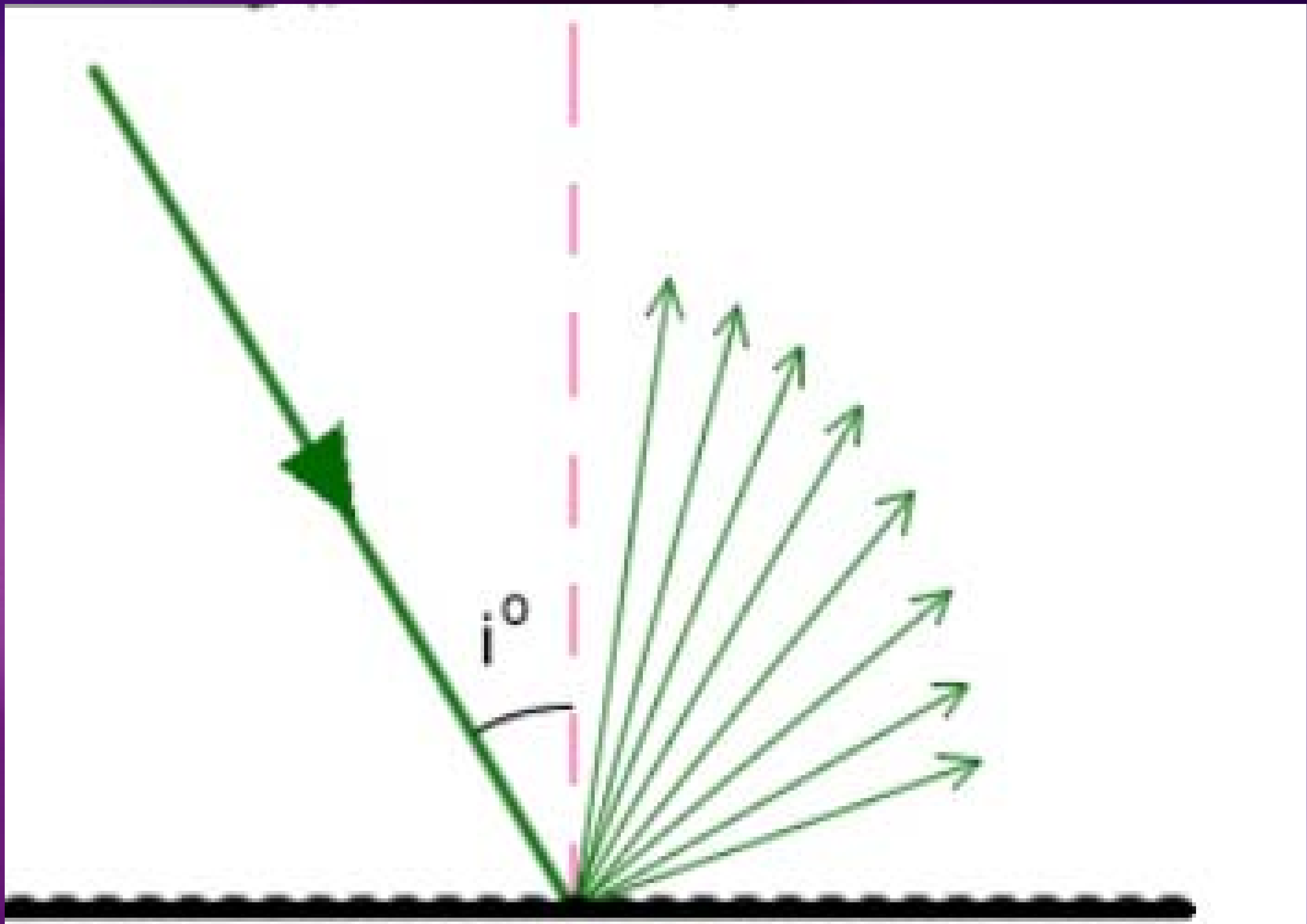
- Second **Reflection:** Light reaches the surface of a very shiny object and 'bounces' off the object in the same way as a hard ball would bounce off an even flat surface (e.g. as in the game of snooker).
- That is, **reflected** light leaves the surface of an object at one particular angle relative to the angle from which it reached that surface.

- <u>Law of Reflection</u>:
- **Angle of incidence = Angle of reflection** (i.e. the same angle)



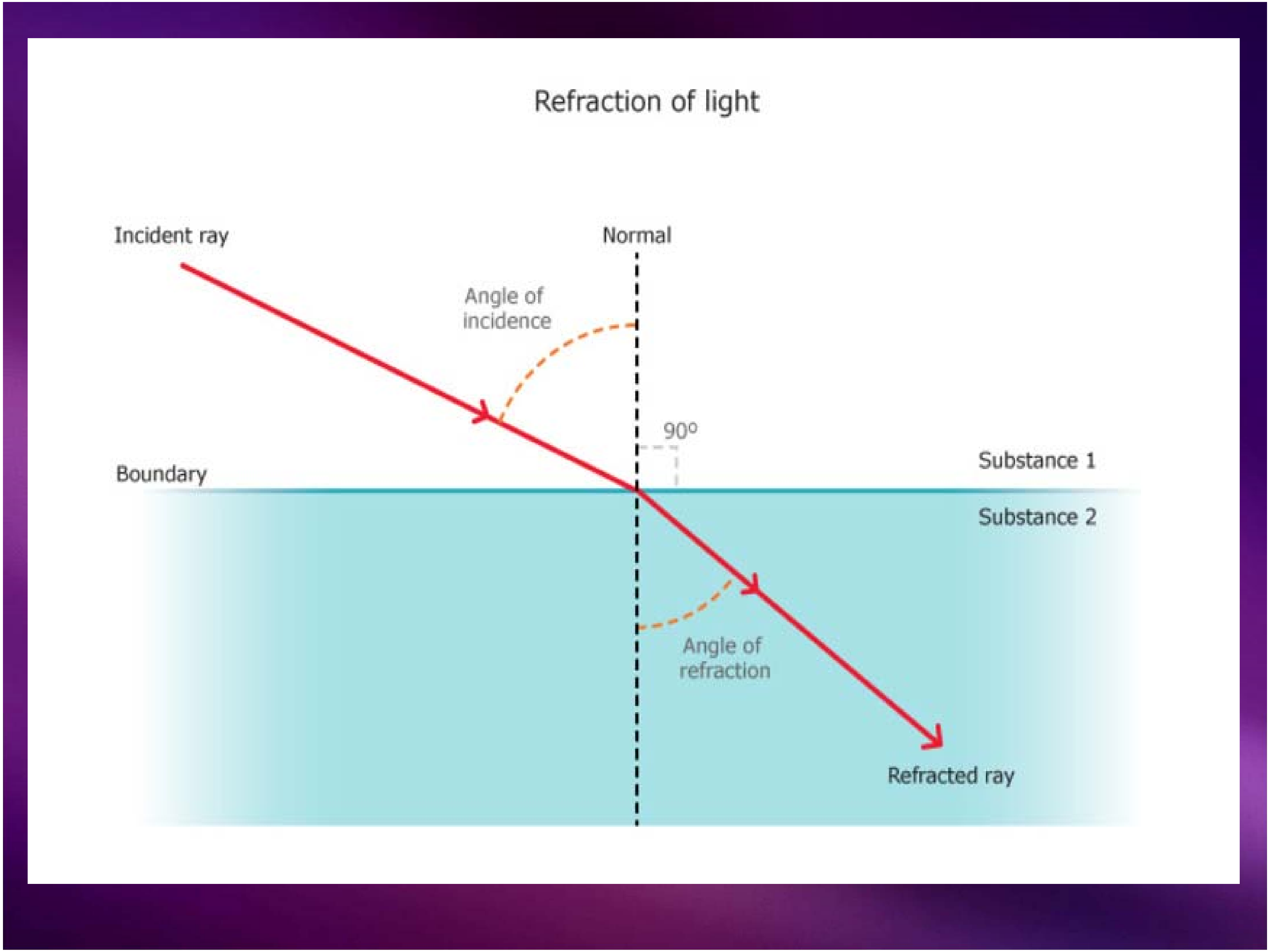
Reflection follows the "Law of Reflection", which is:
the angle of incidence (i^0) = the angle of reflection (r^0)

- Third **Scatter :** On reaching the surface of an object, light leaves that surface **not** in any one particular direction, but in many directions spread over a wide range of angles. This applies particularly to non highly-polished surfaces, such as paper, or walls painted matt white.
- Scatter is the most common of these possibilities when visible light is incident on ordinary everyday solid/opaque objects.



Scattering surface, i.e. not highly polished, typically light colour, matt texture

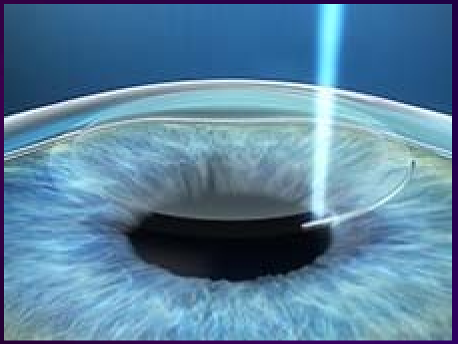
- Forth **Refraction:** This is another case of light <u>entering the object</u> instead of <u>leaving the surface of the object</u>.
- **Refraction** only applies to objects that light can pass <u>through</u>, such as blocks of glass or plastic, windows, water, and spectacles. It is mentioned here for completeness.
- In the context of explaining how light reaches a person's eye from objects in the real world in front of him or her, refraction is less important that the other possibilities described above.
However, **refraction** plays an important role in the eye and visual system for <u>other reasons</u>, such as focusing images onto the retina.


Refraction of light
Incident ray
Normal
Angle of incidence
90º
Substance 1
Boundary
Substance 2
Angle of refraction
Refracted ray

In summery

- In simple terms, the same object, e.g. a cube, is more like to:
- **Absorb light** - if it has an opaque **matt (non-shiny) black** surface
- **Scatter light** - if it has an opaque **matt (non-shiny) white** surface
- **Reflect light** - if it has a shiny finish e.g. **mirror surface**
- **Refract light** - if it is **transparent** to the wavelength of light that reaches its surface (e.g. if it consists of colourless glass and is illuminated by visible light e.g. a green laser beam) and the light reaches the surface of the object within a certain range of angles.

An extra bit



<u>LASER in ophthalmology:</u>

The word LASER is an abbreviation for , **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. It is a special kind of light that has unique physical properties, including:

1- LASER is monochromatic, with exactly one wavelength.

2- It is coherent , i.e. each light ray " photon" has the same phase as the rest in the bundle. Hence it can produce an intense heat/ energy n a focused reigion.

These properties allow LASER to burn, coagulate evapourate , and dispute. Making it very useful in medicine, particularly ophthalmology.

Lasers used in ophthalmology

Type	Atomic environment	Effect produced
Argon	Argon gas	photocoagulation
Krypton	Krypton gas	Photocoagulation
Diode	Diode crystal	Photocoagulation
Nd: YAG	A liquid dry or a solid compound of Yt-Al garnet+neodymium,	Photodisruption
Excimer	Helium and fluorine	Photoablation
Diode pumped Nd YAG	Diode and Nd: YAG crystal	Photocoagulation

End of lecture

Extra reading for this week include:

Polarisation of light (Application in Opth.)

Florescence and Phosphorescence

More on LASER in Opth.

Have a nice week !