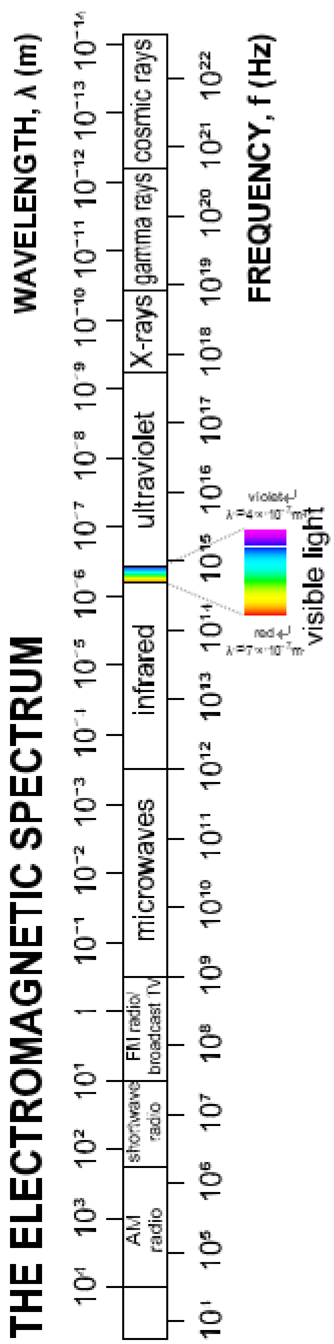
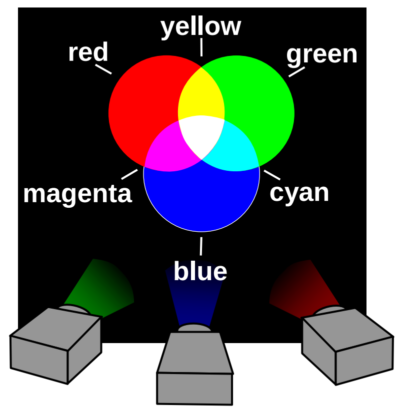
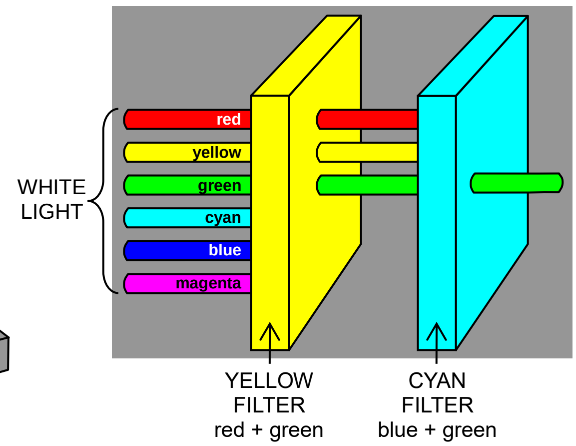
Light & Optics



ADDITIVE NATURE OF LIGHT



SUBTRACTIVE NATURE OF LIGHT

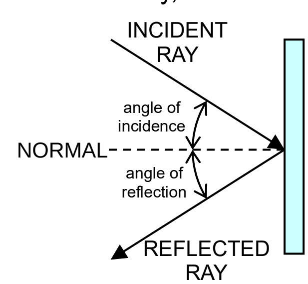


THE COLOUR OF OBJECTS

The colour of an object depends upon the kind of light which it is capable of reflecting to the eye.

A **white** object reflects all colours received.
A **black** object absorbs all rays (colours).
A **red** object reflects red light and absorbs all other colours.

The colour we perceive (for an opaque object) is also dependent on the colour of light incident upon it. For example, a piece of blue cloth under red light appears black since there is no blue light to reflect. Similarly, a red cloth under a blue light appears black.

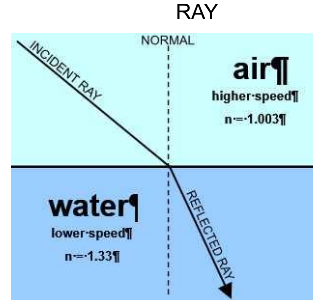


REFLECTION

The **incident ray**, the **reflected ray** and the **normal** (theoretical line perpendicular to the reflecting surface) all lie in the same plane. The angle of incidence equals the angle of reflection.

REFRACTION

Refraction happens when light passes from one transparent medium (with index of refraction n_1) to another (with index of refraction n_2). The light is bent:
→ toward the normal when its speed is lowered ($n_2>n_1$)
→ away from the normal when its speed is increased ($n_2<n_1$)



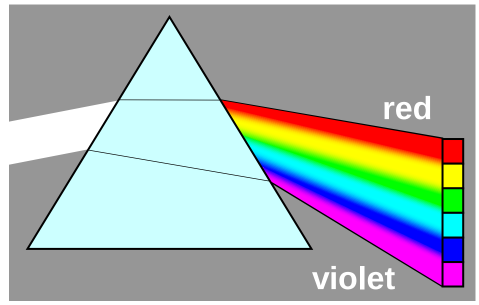
Authored by Gordon Wong

The **index of refraction** for a medium is the ratio of the speed of light in vacuum to the speed of light through that medium:

$n = \frac{c}{v}$, where n = index of refraction, c = speed of light in vacuum (3.00×10^8 m⁄s) and v = speed of light in medium

medium	index of refraction
air	1.003
water	1.33
glass (flint)	1.61
glass (crown)	1.63

Different frequencies of light refract at different angles. This is the principle that allows a prism to split white light into its component colours. High-frequency light (toward the violet end of the spectrum) is refracted more than low-frequency light (toward the red end of the spectrum.



RAY DIAGRAMS — CONVERGING LENS

A **converging lens** is a lens that allows light rays to converge, or focus, when they pass through it. Converging lenses are convex (bulging outwards) on both sides. Converging lenses can create real images and virtual images.

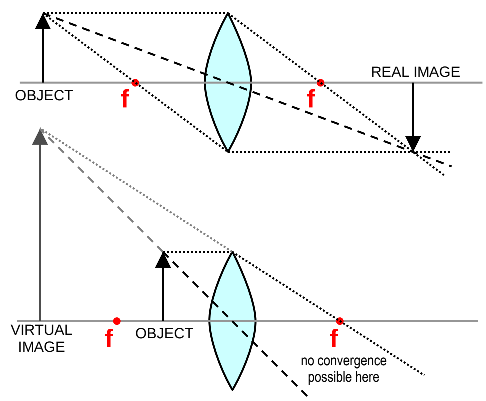
A **real image** is an image created by rays of light reflected directly off the object in the image, converging at the point where the image is. A **virtual image** can only be created with lenses or mirrors, and it's an image that fools your eye into thinking an object exists where it doesn't. The rays of light don't actually converge in one place, but the geometry of the rays makes your eye think they do. Construction of a ray diagram can help us understand virtual images and predict where they'll appear.

A ray diagram is usually constructed using two or three rays: one from the outward tip of an object (usually an arrow) through the centre of the lens, and one (maybe two) through a tip of the lens.

→ Any ray that passes through the exact centre of the lens is not refracted.

→ Any ray that passes through a focal point of the lens is refracted parallel to the axis, and vice versa.

For converging lenses, real images are inverted; virtual ones are not.



FORMULAS

$c = 3.00 \times 10^8$ m⁄s $= f\lambda$

distance-size relationship: $\frac{s_o}{s_i} = \frac{d_o}{d_i}$

lens equation: $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

…where, d_o = object distance, d_i = image distance, s_o = object size, s_i = image size and f = focal length.

EXERCISES

A. What is the colour of the leaves of a plant when seen through a piece of rose-coloured (magenta) glass?

B. What is the colour of a ripe banana seen through a piece of green glass?

C. From the electromagnetic spectrum on the first page, what types of waves have shorter wavelengths than visible light?

D. Which has the longer wavelength, red light or blue light?

E. A converging lens has a focal length of 20.0 cm. If it is placed 50.0 cm from an object, then the image will be:

1) on which side of the lens?
2) real or virtual?
3) how far away from the lens?

F. The focal length in the lens of a camera at a certain setting is 10.0 cm. The fixed distance between the lens and the film is 11.0 cm. If an object is to be clearly focussed on the film, how far must it be from the lens at this setting?

G. What is the focal length of the lens in your eye when you can clearly read a tantalizing physics book 35.0 cm from your eye? The distance from your lens to your retina is 1.91 cm.

H. An object 30.0 cm from a converging lens forms a real image 60.0 cm from the lens.

1) What is the focal length of the lens?
2) If the object is 5.0 cm high, what is the height of the image?

Some tougher problems:

I. Where must an object be placed before a converging lens to produce a real image the same size as the object?

J. An object is placed at the focus of a converging lens. Where will the image be?

SOLUTIONS

A. Blackish, since a magenta filter only lets red and blue light through, not green.
B. Green, since a green filter only allows the green component of yellow light through.
C. ultraviolet, X-rays, gamma rays and cosmic rays D. red
E. (1) opposite the side with the object (2) real (3) 33.3 cm
F. 110 cm G. 1.81 cm H. (1) 20.0 cm (2) 10 cm
I. At 2f, a distance equal to double the focal length.
J. There will be no image. The rays would not converge; they'd be parallel.