Eye Examination
Principles of optics:

Light rays are (reflected) when they pass from one medium into a medium of a different density, except when they strike perpendicular to the interface.

Convex Lens (عدسات محدبة) focuses light rays (which is called convergence of light rays).

Concave Lens (عدسات مقعرة) diverges light rays (which is called diverges light rays).

Parallel light rays striking a biconvex lens are reflected to a point (principal focus) behind the lens. The principal focus is on a line passing through the centers of curvature of the lens, the principal axis. The distance between the lens and the principle focus is the principal focal distance (focal length).

For practical purposes, light rays from an object that stick a lens more than 6 meters (20 ft) away are considered to be parallel. The rays from an object closer than 6 meters are diverging and are therefore brought to a focus farther back on the principle axis than the principle focus.
Increasing the curvature of a lens will increase its refractive power.

The refractive power of a lens is conveniently measured in **Diopters**,

The number of Diopters being the receptors of the principal focal distance in meters

\[ P = \frac{1}{f} \]

Where **P**: the converging power measured in diopters.

**F**: the focal distance in meters

For example, lens with a principal focal distance of 0.25 meters gas a refractive power of \( \frac{1}{0.25} \), or 4 diopters.

The human eye has a refractive power of approximately 60 diopters at rest.
Eye structures:
The cornea and lens provide the converging power of the eye.

A. Cornea:
The cornea is the avascular, transparent outer surface of the eye.
The absence of blood vessels in the cornea allows light to pass through unhindered.
Because it has no blood vessel, the cornea receives oxygen and nutrients via diffusion through the aqueous humor.
The cornea is responsible for approximately two-thirds of the refractive power of the eye, and its refractive power cannot be altered physiologically.

B. Lens:
Like the cornea, is avascular and transparent.
Unlike the cornea, the refractive power of the lens is under physiologic control.
As individual ages, the lens develops opacities called (cataracts). Normal vision can be restored by surgically removing the opaque lens and replacing it with a plastic lens.
Retinal Image:
In the eye, light is actually refracted
①at the anterior surface of the cornea
②at the anterior and the posterior surface of the lens.
The process of refraction can be represented diagrammatically, however, without introducing any appreciable error, by drawing the rays of light as if all refraction occurs at the anterior surface of the cornea. If all the refractive surfaces of the eye are algebraically added together and then considered to be one single lens, the optics of the normal eye may be simplified and represented schematically as a “reduced eye.” This is useful in simple calculations. In the reduced eye, a single refractive surface is considered to exist, with its central point 17 millimeters in front of the retina and a total refractive power of 59 diopters when the lens is accommodated for distant vision.

\[ P = \frac{1}{f} \]  
since 17 mm = 0.017 meter then \( P = \frac{1}{0.017} \), \( P = 58.8 \) diopters
This true when the object is 6 meter and more
About two thirds of the 59 diopters of refractive power of the eye is provided by the anterior surface of the cornea (not by the eye lens).

The principal reason for this is that the refractive index of the cornea is markedly different from that of air, while the refractive index of the eye lens is not greatly different from the indices of the aqueous humor and vitreous humor.

It should be noted that the retinal image is inverted.

The connections of the retina receptors are such that from birth any inverted image on the retina is viewed right side up and projected to the visual field on the side opposite to the retinal area stimulated. This perception is present in infant and is innate. If retinal image are turned right side up by means of special lenses, the objects viewed look as if they are upside down.

The near response:
When the object distance is less than 6 meters, then some changes occurs to the eye to keep the object image falls on the retina includes. Changes in viewing distance as part of the near triad (the near reflex), consists of:

1. accommodation,
2. miosis,
3. convergence
1. **Accommodation:**

When the ciliary muscle is relaxed, parallel light rays striking the optically normal (emmetropic) eye are brought to a focus on the retina.

As long as this relaxation is maintained, rays from objects closer than 6 meters from the observer are brought to a focus behind the retina, and the objects appear blurred.

The problem of bringing diverging rays from close objects to a focus on the retina can be solved by:

1. increasing the distance between the lens and the retina or
2. by increasing the curvature or refractive power of the lens.

The process by which the curvature of the lens is increased is called **accommodation**.

At rest, the lens is held under by lens ligaments. Because the lens substance is malleable and the lens capsule has considerable elasticity, the lens is pulled into a flattened shape.
When viewing distant objects, the lens is made relatively thin and flat and has the least refractive power. For near vision, the lens becomes thicker and rounder and has the most refractive power. These changes result from the activity of the ciliary muscle that surrounds the lens. The lens is held in place by radially arranged connective tissue bands (called zonule fibers) that are attached to the ciliary muscle. The shape of the lens is thus determined by two opposing forces:

1. The **elasticity of the lens**, which tends to keep it rounded up (removed from the eye, the lens becomes spheroidal),
2. The tension exerted by the zonule fibers, which tends to flatten the lens. When viewing distant objects, the force from the zonule fibers is greater than the elasticity of the lens, and the lens assumes the flatter shape appropriate for distance viewing. The changes during accommodation:
   a. contraction of ciliary muscles,
   b. approximation of ciliary muscles,
   c. relaxation of zonula fibers (suspensory ligaments),
   d. increase curvature of anterior surface of the lens.

Focusing on closer objects requires relaxing the tension in the zonule fibers, allowing the inherent elasticity of the lens to increase its curvature. This relaxation is accomplished by contraction of the ciliary muscle. Unfortunately, changes in the shape of the lens are not always able to produce a focused image on the retina, in which case a sharp image can be focused only with the help of additional corrective lenses.
The ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the third cranial nerve.

In young individuals, change in shape may add as many as 12 diopters to the refractive power of the eye.

Accommodation is an active process, requiring muscular effort, and can therefore be tiring. Indeed, the ciliary muscle is one of the most used muscles in the body.

The degree to which the lens curvature can be increased is, of course, limited and light rays from an object very near the individual cannot be brought to a focus on the retina even with the greatest of effort.

The nearest point to the eye at which an object can be brought into clear focus by accommodation is called the (near point of vision). The near point recedes through life, slowly at first and then rapidly with advancing age, from approximately 9 cm at age 10 to approximately 83 cm at age 60. This recession is due principally to increasing hardness of the lens, with a resulting loss of accommodation due to the steady decrease in the degree to which the curvature of the lens can be increased. By the time a normal individual reaches age 40 to 45, the loss of accommodation is usually sufficient to make reading and close work difficult. This condition, which is known as (presbyopia), can be corrected by wearing glasses with convex lenses.
2. Miosis (or pupillary constriction):
Stimulation of the parasympathetic nerves excites the pupillary sphincter muscle, thereby decreasing the pupillary aperture; this is called miosis. Stimulation of the sympathetic nerves excites the radial fibers of the iris and causes pupillary dilation, called mydriasis.

The size of the pupillary aperture is controlled by two opposing smooth muscles, Sphinctor pupillae (muscle fibers arranged concentrically around the pupil) and Dilator pupillae (muscle fibers arranged radially around the pupil). The sphincter muscle changes its tonus in response to two types of physiologic stimuli:

The pupillary light reflex (or pupillary accommodation reflex) is a reflex that controls the diameter of the pupil. When light is directed into one eye or when an object is close to the eye; the pupil constricts (pupillary light reflex). Thus, the pupillary light reflex regulates the intensity of light entering the eye. A smaller pupil produces a sharper image on the retina.
The pupil of the other eye also constricts (consensual light reflex). Consequently, the light response is sometimes lost while the response to accommodation remains intact (Argyll Robertson Pupil).

The amount of light that enters the eye through the pupil is proportional to the area of the pupil or to the square of the diameter of the pupil. The limits of papillary diameter are about 1.5 millimeters on the small side and 8 millimeters on the large side. Therefore, because light brightness on the retina increases with the square of pupillary diameter, the range of light and dark adaptation that can be brought about by the pupillary reflex is about 30 to 1 (that is, up to as much as 30 times change in the amount of light entering the eye).

3. Convergence:
The gaze of the two eyes shifts toward the center of the head to keep both eyes focused on the objects.
Common defects of the image-forming mechanism (Errors of refraction):
In which distant objects cannot be seen clearly, are caused by variations in the converging power of the cornea, lens or both:

1. **Myopia (nearsightedness)**

   In the nearsighted eye,

   ① the eyeball is too long (antero-posterior distance of the eyeball is too long) or
   ② the cornea is too steep (has too much curvature). As a result, the light entering the eye is not focused correctly on the retina; the focal point is in front of the retina.

   Nearsighted persons have more trouble seeing distant objects as clearly as near objects, and distant objects look blurred (the object can be seen clearly if it is moved closer to the eye).

   This problem is often noticed in school-age children who complain of having trouble seeing the chalkboard.

   In severe myopia; the far point may be only 10 to 15 cm from the eye.

   Because the objects must be brought near to the eye to be seen clearly (i.e. they are able to do fine work without magnifying glasses).

   ① Myopia is said to be genetic in origin.
   ② In human there is a positive correlation between sleeping in a lighted room before the age of two يسبب النوم بغرفة مضاءة في الصغر
   ③ the subsequent development of myopia. In young adults human the extensive close work involved in activities such as studying accelerates the development of myopia.

   This defect can be corrected by glasses with **biconcave lens**, which make parallel light ray diverge.
2. Hyperopia (farsightedness): Farsighted individuals typically develop problems reading up close before the age of 40.

The farsighted eye is usually

1. slightly shorter than a normal eye and

2. may have a flatter cornea (has less curvature). Thus, the light of distant objects focuses behind the retina.

Farsighted persons usually have trouble seeing objects that are close to them and near objects look blurred.

In young age, farsightedness gives rise to no symptoms because the natural accommodation of the eye is strong, correcting mild to moderate degrees of farsightedness.

As age advances the power of accommodation becomes less, the farsighted person starts to find difficulty in seeing first close objects, and later both close and far object. Sustained accommodation even when viewing distant objects can partially compensate for the defect, but the prolonged muscular effort is tiring and may cause headaches after performing close work and blurring of vision. The prolonged convergence of the visual axes associated with the accommodation may lead eventually to squint (strabismus).

The defect can be corrected by using glasses with convex lens, which aid the refractive power of the eye in shorting the focal distance.
3. Astigmatism:
Causes of astigmatism:
1. Corneal: due to an irregularly shaped cornea
2. Lenticular: due to an irregularly shaped lens.
Types of astigmatism:
A. In regular astigmatism: the principal meridians are 90 degrees apart (perpendicular to each other). Regular astigmatism results from an oblong, or egg or football-shaped, cornea; it will be divided into:
1. Myopic astigmatism: One or both principal meridians of the eye are nearsighted. (If both meridians are nearsighted, they are myopic in differing degree.)
2. Hyperopic astigmatism: One or both principal meridians are farsighted. (If both are farsighted, they are hyperopic in differing degree.)
3. Mixed astigmatism. One principal meridian is nearsighted, and the other is farsighted.
It is one where rays that propagate in two perpendicular planes have different foci, so that part of the retinal image is blurred and distorted (for example, a point seen as a line and a line appears to have a halo on either side of it).

B. In irregular astigmatism: the principal meridians are not perpendicular.

Irregular astigmatism causes light to be distorted from the uneven surface of the cornea to produce multiple images from a single object.

To correct for astigmatism, a cylindrical surface is ground with a spherical surface to produce a lens with maximum and minimum refractive powers 90 degrees from each other.
Visual Acuity:
Assessing the subject’s visual acuity is important as it provides a context for other elements of the exam. Visual acuity is typically assessed by a Snellen chart (which can be hand held or mounted) in the clinical environment, but other charts types (e.g. Allen figures, illiterate E charts, Landolt C, etc) are also used.

A pinhole test will improve vision with most refractive errors.

Visual acuity is measured by comparing the person’s ability to see objects at standardized distances. The standard definition of normal visual acuity is 20/20 (US) or 6/6 vision (typically used in Europe & Australia as it refers to meters). Often Snellen Charts will have these values (e.g. 6/6, 6/12, 6/18 etc) along the side.

The chart consists of number of lines of block letters, beginning with a large single letter on the top row.

The number of letters on each row increases moving from top to bottom.

The size of the letters progressively decreases, allowing for more letters on each subsequent line.
the traditional Snellen eye has equal weighting between the black lines and the white space of each letter. Only the letters C, D, E, F, L, N, O, P, T, and Z are used, and the height of the letter is five times the width of the line.

If the eye watches two objects, for example two black dots; it will see them under a certain angle. Obviously, if this angle gets too small, the eye cannot distinguish them from each other. Technically speaking,

1. visual acuity is a measure of the eye spatial resolving power and
2. indicates the angular size of the smallest detail that a person visual system can resolve.

A person with 6/6 (when expressed in meters) normal vision can resolve a spatial pattern where each element within the pattern subtends a visual angle of one minute of arc angle i.e. 1/60th of a degree at the eye (in minutes of arc. One minute, 1', of arc is 1/60°), when viewed at 6 meters away. This represents the minimum angle of resolution (MAR).
In 1863, Professor Hermann Snellen quantitatively the lines by comparison of the visual acuity of person with that of assistant who had perfect vision. Thus (6/60) vision meant that the patient could see at 6 meters what Snellen's assistant could see at 60 meters.

The essence of correct identification of the letters on the Snellen chart is to see the clear spaces between the black elements of the letter. The angular spacing between the bars of the E is 1 minute for 6/6 letter. The entire letter has an angular height of 5 minutes. To calculate the height, X, of a 6/6 letter equation:

\[
\tan(\alpha) = \frac{X \text{ meters}}{6 \text{ meters}}
\]

From this equation \(X = 0.887 \text{ cm}\) for 6/6 and 10 times taller, \(X = 8.87 \text{ cm}\) for 6/60.
Visual acuity examination:
Visual acuity is measured with Snellen's test-types, a series of letters of varying sizes so constructed that the top letter is visible to the normal eye at 60 meters, and the subsequent lines at 36, 24, 18, 12, 9, 6, and 5 meters respectively. Visual acuity (V) is recorded according to the formula:

\[ V = \frac{d}{D} \]

Where:  
- \( d \), is the distance at which the letters are read.
- \( D \), at which they should be read

The patient is normally placed at a distance of 6 meters from the test types (d=6) and each eye is tested separately. The patient reads down the chart as far as he can. If only the top letter of the chart is visible, the visual acuity is 6/60. A normal person should be able to read at least the seventh line, i.e. a visual acuity of 6/6. A person with an uncorrected refractive error may have a subnormal visual acuity, and a rough estimate of his corrected visual acuity may be obtained by asking him to view the chart through a pin-hole aperture. If the visual acuity is less than 6/60, the patient is moved towards the test-types until he can read the top letter.

If the top letter is visible at 2 meters, the visual acuity is 2/60.

Visual acuities of less than 1/60 are recorded as
- 'counting fingers' (CF),
- 'hand movements' (HM),
- 'perception of light' (PL), or
- 'no perception of light' (no PL).
How to know the type of glasses

If the patient wears glasses, the type of lens he is wearing may be determined as follows.

Hold the lens in front of the eye and look at an object through it. Then move the lens from side to side and watch the object. If the latter seems to move in the opposite direction to the lens, the lens is convex محدبة; if in the same direction, it is concave.

In order to tell whether a lens is spherical or cylindrical, look at a straight object through it and then slowly twist the lens round.

If the lens is cylindrical, the object will appear to take up an oblique position. Patients who are astigmatic need cylindrical lenses.

Prescriptions for eyeglasses are measured in diopters. The measurement starts at zero ("plano"), with four quarters to a diopter: 0.25 (a quarter diopter), 0.50 (one half a diopter), 0.75 (3/4 of a diopter), and 1.00 (one diopter). The higher the numbers, the higher (stronger) the prescription.

Here are estimates for the approximate correction needed for each line seen on the Snellen chart:
Color vision:
The Young–Helmholtz theory of color vision in humans postulates the existence of three kinds of cones;
Each cone containing a different photo-pigment
Each cone maximally sensitive to one of the three primary colors
Each cone sensation of any given color being determined by the relative frequency of the impulses from each of these cone systems.
The correctness of this theory has been demonstrated by the identification and chemical characterization of each of the three pigments.
blue-sensitive, or short-wave, pigment: absorbs light maximally in the blue-violet portion of the spectrum.
green-sensitive, or middle-wave, pigment: absorbs maximally in the green portion.
red-sensitive, or long-wave, pigment: absorbs maximally in the yellow portion.
Blue, green, and red are the primary colors
This is all the Young–Helmholtz theory requires
Color blindness
Normal color vision uses all three types of light cones correctly and is known as trichromacy.

People with normal color vision are known as trichromats.

The suffix “– anomaly” denotes color weakness and the suffix “– anopia” color blindness.

The prefixes “prot- red”, “deuter-green” and “tri- blue” refer to defects cone system.

Dichromate
Individuals with only two normal cone systems; the third color category is simply not seen.

Dichromacy can match their color spectrum by mixing only two primary colors.

Dichromacy exists in following forms:

1. protanopia, in which all color matches can be achieved by using only green and blue light (NO red)
2. deuteranopia (most common), in which all matches can be achieved by using only blue and red light (NO green)
3. tritanopia, in which all color matches can be achieved by using only green and red light (NO blue)
Monochromate
Individuals with only one cone system
Monochromate match their color spectrum by varying the intensity of only one.

Anomalous Trichromacy
The different anomalous conditions are
a. protanomaly, which is a reduced sensitivity to red light,
b. deuteranomaly which is a reduced sensitivity to green light and is the most common form of color blindness

c. tritanomaly which is a reduced sensitivity to blue light and is extremely rare.

The effects of anomalous trichromatic vision can range from almost normal color perception to almost total absence of perception of the ‘faulty’ color.

There is general agreement that worldwide 8% of men and 0.5% of women have a color vision deficiency.

The 8% of color blind men can be divided approximately into 1% deuteranopes, 1% protanopes, 1% protanomalous and 5% deuteranomalous.

Approximately half of color blind people will have a mild anomalous deficiency, the other 50% have moderate or severe anomalous conditions.
Color sense
This is most easily tested by the use of pseudo-iso-chromatic plates, the best-known being those of Ishihara Chart. People with defective color vision confuse certain colors.
Pseudo-iso-chromatic plates are so constructed that a person with normal color vision will read one number on a plate, while a person with defective color vision will read a different number on the same plate. Two Ishihara charts:
Right: the normal person reads “74,”
the red-green color-blind person reads “21.
Left: The normal person reads “42.”
In this chart, the red-blind person (prot-anope) reads 2,”
the green-blind person (deuter-anope) reads “4.”
Abnormalities in the field of vision:

A. Damage to the optic nerve: causes loss visual field of one side.

B. Damage to optic chiasm: causes prevent the crossing of impulses from the nasal halves of the two retinas to the opposite optic tract. Therefore, the nasal halves of the retina of both eyes are blinded, which means that the person is blind in both temporal field of vision because the image of the field of vision is inverted on the retina by the optical system of the eye; this condition is called bi-temporal hemi-anopia (or heteronymous (opposite sides of the visual fields) hemianopia (half-blindness).

C. Damage to optic tract: causes denervate the corresponding half of each retina on the same side as the lesion, and as a result, neither eye can see objects to the opposite side of the head. This condition is known as homo-nymous hemi-anopia. Homonymous: same side of both visual fields.

D. Damage to optic radiation or the visual cortex: causes homonymous (same side of both visual fields) hemianopia (half-blindness)
Ophthalmoscope examination of retina (fundoscopic)

I. Optic disk:
1. It is the place where the optic nerve leaves the eye.
2. It is place where the retinal blood vessels enter.
3. It at a 3 mm medial to and slightly above the posterior pole of the globe.
4. There are no visual receptors overlying the disk, and consequently this spot is blind (blind spot).

II. Macula lutea:
1. It is near the posterior pole of the eye.
2. It is yellowish pigmented spot.
3. It contains the fovea centralis: only 0.3 millimeter in diameter which characterized by:
   A. it is a thinned-out, rod-free portion of the retina.
   B. is composed almost entirely of cones and are densely packed, and each synapses to a single bipolar cell which in turn synapses on a single ganglion cell, providing a direct pathway to the brain (1:1:1)
   C. There are very few overlying cells and no blood vessels.
   D. the fovea is the point where visual acuity is greatest. When attention is attracted to or fixed on an object, the eyes are normally moved so that rays coming from the objects fall on the fovea.
III. Blood vessels:
The arteries, arterioles, and veins in the superficial layers of the retina near its vitreous surface can be seen through the ophthalmoscope.

Since this is the one place in the body where arterioles are readily visible, ophthalmoscope examination is of great value in the diagnosis and evaluation of diabetes mellitus, hypertension, and other diseases that affect blood vessels.

The retinal vessels supply the bipolar and ganglion cells,

The receptors are nourished for the most part by capillary plexus in the choroids.

This is why retinal detachment is so damaging to the receptor cell.