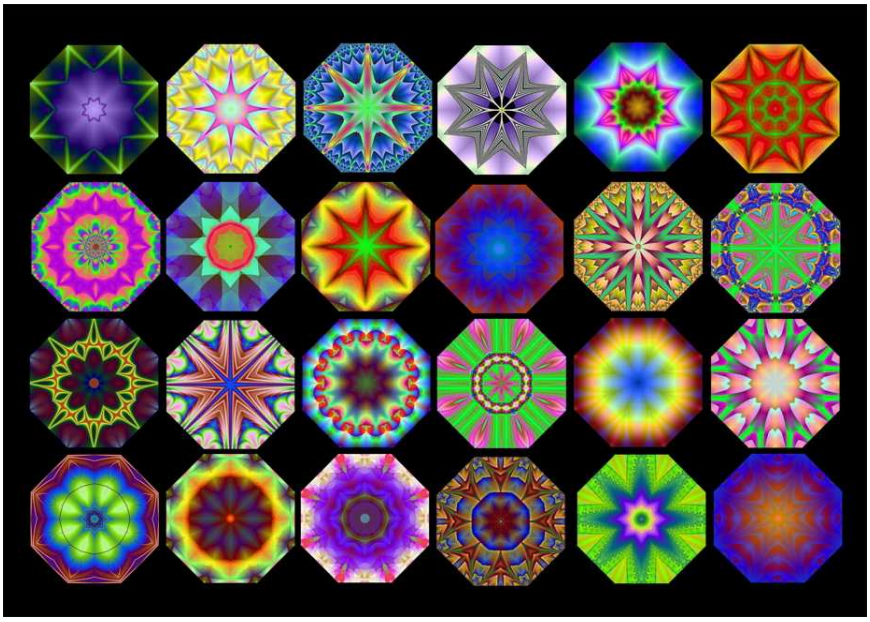
Ophthalmology Series

Self-tests

in

Optics and Refraction



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First Edition

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PUBLICATION

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Optics and Refraction

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Cover:

Kaleidoscopes. This optical device was invented in 1816 by Sir David Brewster, a Scottish writer, inventor and academic. He derived the term "kaleidoscope" from the Greek words, kalos (beautiful), eidos (form) and scopos (viewer). Originally conceived as a scientific tool, the kaleidoscope gained wide popularity as an amusement and avenue for artistic expression. The device uses intersecting mirrors to increase the images of objects placed inside a tube.

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Introduction

Optic and refraction play an important part in the education of ophalmologists. With the advances achieved in cataract surgery and refractive surgery, an understanding of optic and refraction is more important than ever in the understanding of visual rehabilitation in patients.

This book contains multiple choice questions and short answer questions in testing the knowledge of the trainee ophthalmologists. It is recommended the book is used in conjunction with a textbook of optic and refraction such as Clinical Optics by A. R. Elkington, Helena J. Frank, Michael J. Greaney by Blackwell publishing. The last section of the book contains essential steps in clinical refraction for ametropia.

The book is useful for ophthalmologists in-training in Malaysia as well as those who are taking the ophthalmology qualifying examination such as FRCOphth (Fellowship of the Royal College of Ophthalmologists) and FRCS (Fellowship of the Royal College of Surgeons).

C.C.N.
C.L.L.
N.C.T.
M.A.S.
November, 2007.

Contents

Test your basic knowledge of clinical optics

1. What is the minimal angle of resolution of an eye with a 6/6 acuity?

2. How far away can an eye with 6/6 visual acuity read the 6/24 lines?

3. What is the Snell's law of refraction?

4. What is the apex angle in degrees of a 10 dioptres prism made of glass?

5. The nodal point of a thin lens is at the intersection between the _____ and the _____.

6. The refracting power of a cylindrical lens is at _____ degrees to the axis.

7. The image produced by a negative lens is _____, _____ and _____.

8. A focimeter measures the _____ of a lens.

9. A decentration of 10 mm from the optical centre of a +5 dioptre lens produces a prismatic effect of _____ prism dioptres.

10. A X8 loupe has an equivalent power of _____ dioptres.

11. A lens of +10 dipotres fully correct an hyperopia and now the lens is moved forward 10mm, what is the new lens power needed to correct the hyperopia?

12. In trifocals the intermediate lens usually has _____ power over the distance correction.

13. The LTF stands for _____ when considering tints.

14. Relative spectacle magnification =

15. Which combination make up 1.00 Jackson cross cylinder?

Answers

1. One degree of arc.

2. 24 metres.

3. Snell's law (law of refraction) = the incident and refracted rays and the normal to the surface at the point of incidence lie in the same plane and the ratio of the sine of the angle of incidence i to the sine of the angle of refraction r is a constant for any two media. This constant is called the relative index of refraction ie. sine i / sin r = refractive index.

4. 10 degrees.

5. Principal axis, principal plane.

6. 90**.**

7. Virtual , erect and diminished.

8. Back vertex power.

9. 5.

10. 32.

11. +9 dioptres

    To calculate this you need to use the formula for lens effectivity which is

    Dn = Do/1-dDo where Dn = the new power
    Do = the old lens power
    d = difference in the location (in meters), -ve if it is moved forward and +ve if it is moved backward.

    The formula shows that moving a plus lens forward increases its effective power and therefore a weaker plus lens is needed to maintain the same effectiveness.

12. half the power.

13. Luminance transmission.

14. Actual size corrected with spectacle / size seen by the emmetropic eye

15. +0.50DS/-1.00DC
    The two cylinders are 90 degrees to each other and therefore it is not necessary to designate the axis.

I. Properties of light

1. With regard to optical radiation:

a. the wavelengths of visible light lie between 400nm and 780nm
b. ultraviolet A has a shorter wavelength than ultraviolet C
c. the shorter the wavelength the higher the energy of an individual quanta (photon)
d. the human lens is better at absorbing shorter than longer wavelengths
e. eclipse burn is caused by infrared radiation

2. The following are true about colour vision:

a. deuteranomaly is more common than deuteranopia
b. blue pigment gene is found on chromosome X
c. red-green defect is common in acquired optic nerve disease
d. blue-yellow defect is common in glaucoma
e. blue cone is more sensitive to shorter wavelength than green cone

3. In colour vision testing:

a. the Farnsworth-Munsell hue 100 test contains 84 colour discs
b. the colours of the Farnsworth-Munsell hue 100 test differs in hue and saturation
c. Ishihara test plates are designed mainly for congenital red-green colour defects
d. Ishihara test plates cannot be used by pre-verbal children
e. Lanthony New Colour Test is only suitable for adults

4. With regard to light scattering:

a. it does not occur in vacuum
b. it is proportionally to the wavelength of the light
c. vitreous is best viewed with light of short wavelength as it scatters more
d. the cornea scatters about 10% of the incoming light
e. it is responsible for poor vision in corneal oedema

5. The following equipment are used in fluorescein angiography:

a. a fundus camera with optics similar to direct ophthalmoscope
b. a blue excitation filter
c. a green barrier filter
d. a rotating prism
e. a binocular microscope

6. The following are true about indocyanine green angiography (ICG):

a. indocyanine green has a larger molecule than sodium fluorescein
b. indocyanine green emits light in the infrared range
c. ICG is better at visualizing the choroidal vasculature than sodium fluorescein angiography because it has a higher protein binding and only partially absorbed by the retinal pigment epithelium
d. ICG is best imaged with photographic film
e. ICG should be avoided in patients with seafood allergy

7. Regarding diffraction:

a. it is best explained with the wave theory of light
b. it occurs when there is an obstruction to the light
c. both constructive and destructive interference occurs
d. it increases with longer wavelength
e. it prevents the formation of a point image from a point source

8. The Airy's disc:

a. is formed by diffraction
b. contains a central bright disc that receives 90% of the luminance flux
c. is surrounded by concentric light and dark rings
d. is proportional to the wavelength of the light
e. is proportional to the diameter of the pupil

9. The following tests are used in testing the vision of pre-verbal children:

a. Log MAR
b. STYCAR
c. Catford drum
d. Cardiff card
e. Sheridan-Gardiner tests

10. Regarding visual acuity:

a. it can be represented by a reciprocal of the minimum angle of resolution
b. it varies with the region of the retina
c. it is affected by general illumination
d. it is affected by the colour of the test objects
e. it is affected by the time of exposure

11. Pinhole:

a. if less than 1mm diameter, impairs the image quality
b. abolishes the need for the eye to focus
c. increases the depth of focus
d. increases the depth of field
e. improves ametropia of less than 6 D

12. Contrast sensitivity:

a. measures the eye's sensitivity to light
b. is inversely proportional to contrast of image
c. can be measured with Snellen's chart
d. can be measured with VISTECH
e. may be reduced following LASIK

13. The following are true about birefringence:

a. they have two refractive indices
b. they split a unpolarized light into two polarized lights
c. polarimetry uses the birefringence of the nerve fibre layer to quantitate its thickness indirectly
d. it is used in pleoptics to produce Haidinger's brushes
e. amyloid when stained with Congo red produces birefringence

14. In stereoscopic vision testing:

a. corresponding retinal areas in both eyes are stimulated
b. the grading is based on the least horizontal disparity of retinal image that evokes depth perception
c. in normal person, the value is about 60 seconds of arc or better
d. amblyopia is unlikely if the stereoacuity is better than 250 seconds of arc
e. the TNO test can give stereoacuity from 450 to 15 degrees of arc

15. The following refers to the amount of light arriving at a given point:

a. illuminance
b. brightness
c. shininess
d. irradiance
e. radiance

I. Properties of light – Answers

1. a.T b.F c.T d.T e.T

Visible light contains wavelengths between 400 and 780nm. Ultraviolet A has wavelength of 315-400nm whereas ultraviolet C 200- 280nm. Thus in order of increasing wavelengths: ultraviolet C, ultraviolet B, ultraviolet A; visible light; infrared A, infrared B and infrared C. The lens is very efficient at absorbing ultraviolet than infrared light. The thermal burn in eclipse burn is caused by infrared light.

2. a.T b.F c.T d.T e.T

Deuteranomaly is the most common type of congenital colour defect and is found in 5% of the male population. It occurs when the normal middle-wavelength (ie. green) cone photopigment is replaced by one that has a peak sensitivity at a longer wavelength (ie. red). Deuteranopia refers to absent of the middle-wavelength ie. green cone.

Blue pigment gene is found on chromosome 7 whereas red and green pigment gene on chromosome X. Red-green defect is seen in acquired optic nerve disease, cone dystrophy and Stargardt's disease. Blue-yellow defects are seen in most retinal dystrophy. Blue-yellow defect is found in glaucoma and autosomal dominant optic neuropathy.

3. a.T b.F c.T d.F e.F

Farnsworth-Munsell hue 100 test contains 84 colour discs to be arranged in order of closest colour match with the reference colours at each end. The colours only differ in hue with same brightness and saturation. Ishihara test plates are mainly for congenital red-green colour defect. Wavy lines are used in Ishihara plates for illiterates or children. Lanthony New Colour Test can be used in children.

4. a.T b.F c.T d.T e.T

Scattering occurs due to the presence of particles within a medium and does not occur in vacuum. Scattering is inversely proportional to the wavelength of the light ie. the shorter the wavelength the more the scattering. Vitreous is best viewed with short wavelengths such as blue or green light as they scatter more within in the vitreous. Normal cornea scatters about 10% of incoming light which increases with oedema.

5. a.F b.T c.T d.F e.F

Sodium fluorescein absorbs blue light light of 465-490nm and releases fluorescent yellow-green light (520-530nm). The fundus camera has optics similar to indirect ophthalmoscope.

6. a.T b.T c.T d.F e.F

Indocyanine green has a larger molecule than sodium fluorescein and more firmly bound to the serum protein. It is therefore allow better view of choroidal vasculature. It emits light in the infrared range which is better imaged with digital videography than photographic film. ICG contains iodine and should be avoided in patients allergy to other radiographic contrast dye. Seafood allergy is related to protein and not iodine and therefore not a contraindication.

7. a. T b.T c.T d.T e.T

Diffraction is best explained with the wave theory of light. It occurs when light passes through the edge of an obstacle such s the pupil. Both constructive and destructive interference occur. Diffraction depends on several factors: the wavelength of the light, shorter wavelength causes less diffraction than a longer one and the shape and size of the obstacle for example a smaller pupil causes more diffraction than a large one. Rather than a point image, a point source is converted by diffraction into a diffraction pattern.

8. a.T b.T c.T d.T e.F

The Airy's disc is a diffraction pattern when light passes through the edge of an obstacle. It contains a bright central disc ie. Airy's disc that receives about 90% of the luminous flux. This disc is surrounded by concentric light and dark rings. The radius of the disc is proportional to the wavelength of the light but inversely proportional to the pupil size.

9. a.F b.T c.T d.T e.T

10. a.T b.T c.T d.T e.T

11. a.T b.T c.T d.T e.F

Pinhole allows a single ray of ray to enter the eye and therefore abolishes the need for focusing. It can improves ametropia up to 4D. If too small ie. less than 1mm in diameter, the image quality is impaired due to diffraction.

By reducing the effective pupil diameter, pinhole increases both the depth of focus and the depth of field. The depth of focus which is the distance in front and behind the focal point or retinal over which the image may be focused without causing reducing in sharpness beyond a certain tolerable amount. The depth of field is the distanceover which an object may be moved without causing a sharpness reduction beyond a certain tolerable amount. Both are inversely proportional to the diameter of the pupil.

12. a.F b.T c.F d.T e.T

Contrast sensitivity tests the ability of the eye to detect luminance contrast. It is the reciprocal of the minimum perceptible contrast. It gives an evaluation of the detection of objects usually sinusoidal gratings on a chart or generated on an oscilloscope display of varying spatial frequencies an d of variable contrast. The letters on Snellen's chart are of high contrast and not useful for contrast sensitivity testing. VISTECH can be used to measured contrast sensitivity, it consists of a chart containing five horizontal rows, each with nine circular patches of sinusoidal gratings. The gratings are either vertical or 15 degrees to the right or to the left.

13. a.T b.T c.T d.F e.T

Substance with birefringence properties will split incident unpolarised light into two polarized beams travelling different directions. Therefore, they are said to have two different refractive indices.

Polarimetry uses the birefringence of the NFL (nerve fibrelayer) to quantitate its thickness indirectly. The change in the polarization of light as it passes through the NFL, or “retardation,” is measured and linearly correlated to the NFL thickness.

Pleopitcs used to produce Haidinger's brushes requires the use of polarized light.

Amyloid such as those seen in lattice dystrophy has birefringence property when stained with Congo red.

14. a. F b.T c.T d.T e.T

In stereoscopic vision, disparate retinal elements within Panum's fusional areas in the two eyes are stimulated giving rise to depth perception. The grading is based on the least horizontal disparity of retinal image that evokes depth perception. The unit is seconds of arc.

The normal individual has a stereoacuity of 60 seconds of arc or better. Amblyopia is unlikely if the stereoacuity is better than 250 seconds of arc.

The various tests for stereoscopic vision include:

- Titmus test: 3000 to 40 seconds of arc
- Frisby test: 600 to 15 seconds of arc
- TNO test: 480 to 15 seconds of arc
- Lang stereotest: 1200 to 550 seconds of arc

15. a. T b.F c.F d.T e.F

Illuminance and irradiance are terms used to refer to the amount of light arriving at a given point. Radiance refers to the amount of light leaving a certain point.

II. Reflection

1. Regarding reflection:

a. it always occurs when light travels from one medium into another
b. the incident ray and the reflected lie in the same plane
c. the angle of incidence is always equals to the angle of reflection
d. diffuse reflection occurs when light is reflected from a regular surface
e. catoptric images are images reflected from the surfaces of the eye

2. The image of an object formed by reflection at a plane surface has the following properties:

a. the image is upright
b. the image is laterally inverted
c. the image is real
d. it is located along a line perpendicular to the reflecting surface
e. it is as far behind the surface as the object is in front of it

3. The following are true about reflection on a mirror:

a. the focal length of a concave mirror is half the length of its radius of curvature
b. the focal length of a convex mirror is half the length of the its radius of curvature
c. the image formed by a concave mirror is always magnified
d. the image formed by a convex mirror is always magnified
e. the shorter the radius of curvature of a spherical mirror, the stronger its refractive power

4. For an object situated between the centre of curvature and the principal focus of a concave mirror, the image has the following characteristics:

a. it is erect
b. it is virtual
c. it is real
d. it is magnified
e. the image is found within the centre of curvature

5. For an object situated outside the centre of curvature of a concave mirror, the image has the following characteristics:

a. it is erect
b. it is virtual
c. it is real
d. it is magnified
e. the image is found within the centre of curvature

6. For an object situated within the principal focus of a concave mirror, the image has the following characteristics:

a. it is erect
b. it is laterally inverted
c. it is real
d. it is magnified
e. the image is found within the centre of curvature

7. For an object situated anywhere in front of a convex mirror, the image has the following characteristics:

a. it is erect
b. it is laterally inverted
c. it is real
d. it is magnified
e. the image is found within the centre of curvature

8. The following are true about total internal reflection:

a. it does not occur when light travel from a medium with lower refractive index to one with higher index
b. it occurs when the incident ray exceeds the critical angle
c. it is used in binoculars
d. it explains why the anterior chamber angle can not be visualized with a slit-lamp
e. a contact lens with a lower refractive index than the cornea may be used to visualize the anterior chamber angle

II. Reflection - Answers

1. a.T b.T c.T d.F e.T

Reflection always occurs (to a large or small extent) when a light travels from one medium into another. According to the laws of reflection: the incident ray and the reflected ray lie in the same plane and the angle of incidence is always equals to the angle of reflection.

Diffuse reflection occurs when light is reflected from an irregular surface. Catoptric images are images reflected from the surfaces of the eye.

2. a.T b.T c.F d.T e.T

The image of an object formed by reflection at a plane surface is upright, laterally inverted and virtual. It is located along a line perpendicular to the reflecting surface and is as far behind the surface as the object is in front of it.

3. a.T b.T c.F d.F e.T

The focal length of a spherical mirror be it convex or concave is half the length of its radius of curvature. As the power of a spherical mirror is 2/r where r is the radius of curvature, the shorter the radius of curvature of a spherical mirror the stronger its refractive power. The image formed by a concave mirror is always minified, the image formed by a convex mirror may be magnified or minified depending on the position of the object.

4. a.F b.F c.T d.T e.F

The image is found outside the centre of curvature, inverted, real and magnified.

5. a.F b.F c.T d.F e.T

For an object outside the centre of curvature of a concave mirror, the image is inverted, real, minified ie. reduced in size and the image is found between the centre of curvature and the principal focus of the concave mirror.

6. a.T b.T c.F d.T e.F

The image is erect, laterally inverted, virtual, magnified and found within the concave mirror.

7. a.T b.T c.F d.F e.T

The image is virtual, erect and diminished. It is also laterally inverted and found within the centre of curvature of the mirror.

8. a. T b.T c.T d.T e.F

Total internal reflection only occur when the light travels from a medium with a higher refractive index to one with lower index. It occurs when the incident ray exceeds the critical angle. It is used in binocular and slit-lamps to invert images. To visualize the anterior chamber angle, a contact lens with a higher refractive index than the cornea need to be used to overcome the total internal reflection.

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III. Refraction

1. With regard to refraction:

a. it is a change in direction of light when it passes from one transparent medium into another of different optical density
b. light is deviated away from the normal when it enters an optically dense medium from a less dense medium
c. the velocity of light is changed during refraction
d. the wavelength of the light is changed during refraction
e. the angle of refraction is different for light of different wavelength

2. The following are true about the refractive index of a material:

a. the absolute refractive index of a material is always greater than its refractive index
b. the refractive index of a material is usually measured with ultraviolet light
c. the refractive index of a medium differs for light of different wavelengths
d. the deviation of light increases with the increase in refractive index of the material that it enters
e. a material with high refractive index will reduce the speed of light more than one with lower refractive index

3. With regard to the refractive index of a medium:

a. it is the ratio of sin i to sin r . i is the angle of incidence of the light and r is the refracted angle
b. it can be calculated by knowing the velocity of light in air and its velocity in the medium
c. the cornea has a lower refractive index than the lens
d. the lens accounts for most of the refractive power of a human eye due to its higher refractive index
e. the refractive index of the human lens remains constant throughout life

III. Refraction - Answers

1. a.T b.F c.T d.T e.T

Refraction is defined as a change in direction of light when it passes from one transparent medium into another of different optical density.

Light is deviated towards the normal when it enters an optically dense medium form a less dense medium. The reverse applies.

The velocity of light and the wavelength are changed during refraction. However, the frequency remains the same.

The angle of refraction is different for light of different wavelengths. Light of shorter wavelength is deviated more than one with longer wavelength.

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2. a.T b.F c.T d.T e.T

The absolute refractive index of a material is the velocity of light in vacuum divided by velocity of light in that medium. The refractive index of a material is the velocity of light in air divided by velocity of light in that medium. As light travels faster in vacuum than air, the absolute refractive index of a material is always greater than its refractive index.

The refractive index of a material is different for different wavelength and in general it is usually measured with yellow sodium flame. The refractive index of a medium differs for light of different wavelengths, however, the difference is usually slight. A material with a higher refractive index will deviate the light more and reduce the speed of light more than one with lower refractive index.

The frequency of a light is not change as it travels from one medium into another but the wavelength become shorter.

3. a.T b.T c. T d.F e.F

The refractive index of a medium is calculated using the Snell's law:

$$sin\ i\ /\ sin\ r$$

where i is the angle of incidence of the light and r is the refracted angle of the light.

The refractive index of a medium can also be calculated as:

Velcoity of light in air / Velocity of light in medium.

The refractive index of cornea is 1.370 and that of the non-cataractous lens is about 1.390. However, because the lens is immersed in aqueous with a refractive

index of 1.333, the incoming light refracted by the lens is very much reduced and it only accounts for 1/3 the refractive power of the human eye. The cornea accounts for 2/3 the refractive power of the human eye.

The refractive index of a human lens increases with age due to the development of cataract. In addition, the human lens does not have uniform refractive index being higher in the nucleus (1.400) than the cortex (1.380) in a non-cataractous lens.

IV. Prisms

1. The following are true about prism:

a. its orientation is defined by its apex
b. light is deviated towards the apex
c. light with shorter wavelength is deviated more than light with longer wavelength
d. the angle of the prism apex is called the refracting angle
e. all the ophthalmic prisms are calibrated according to the Prentice's position

2. The image formed by a prism is:

a. erect
b. magnified
c. laterally inverted
d. virtual
e. deviated towards the apex

3. The angle of deviation of a prism is determined by:

a. the refracting angle
b. the angle of incidence of the ray
c. the refractive index of the prism material
d. the width of the base
e. the thickness of the prism

4. The following are true about prisms:

a. they can control torsional diplopia
b. they can control diplopia caused by an eye which is deviated out and up
c. the prism power can be calculated form the refracting angle alone
d. a prism with 2^{Δ} will produce a linear displacement of 2 cm of an object situated at 1 m
e. a prism with 1^{Δ} produce a stronger deviation than one with an angle of apparent deviation of 1^{0}

5. The Fresnel prisms:

a. reduce the weight of conventional prisms
b. are made up of a series of small prisms
c. are usually made up of polyvinyl chloride
d. reduce the visual acuity mainly through light scattering at the groove edges
e. are usually applied to the front of patients' glasses

6. A patient has a 4 $^{\Delta}$ deviation of right over left strabismus. The following prisms may be used to correct the vertical diplopia that this patient is experiencing:

a. 4 $^{\Delta}$ base down over the right eye
b. 4 $^{\Delta}$ base up over the left eye
c. 2 $^{\Delta}$ base down over the right eye and 2 $^{\Delta}$ base up over the left eye
d. 2 $^{\Delta}$ base down over the right eye and 2 $^{\Delta}$ base down over the left eye
e. 1 $^{\Delta}$ base down over the right eye and 3 $^{\Delta}$ base up over the left eye

7. A patient has a 8 $^{\Delta}$ right esotropia. The following prisms can be used to correct the deviation:

a. 8 $^{\Delta}$ base in over the right eye
b. 8 $^{\Delta}$ base out over the right eye
c. 8 $^{\Delta}$ base in over the left eye
d. 8 $^{\Delta}$ base out over the left eye
e. 4 $^{\Delta}$ base out over the right eye and 4 $^{\Delta}$ base out over the left eye

8. The following are true about the prismatic effect of lenses:

a. if the optical centre of a myope lens is moved nasally, a base out prism will be induced
b. if the optic centre of a myope lens is moved inferiorly, a base down prism will be induced
c. if the optic centre of a hyperope lens is moved temporally, a base in prism will be induced
d. if the optic centre of a hyperope lens is moved superiorly, a base up prism will be induced
e. a 2 D base in prism can be produced by shifting the optical centre of a -5.00D myope lens 2 mm temporally

IV. Prisms - Answers

1. a.F b.F c.T d.T e.F

The orientation of a prism is defined by its base. Light is deviated towards the base. Light with shorter wavelength is deviated more than light with longer wavelength by a prism. The refracting angle is the angle of the prism apex. The glass ophthalmic prisms are calibrated according to the Prentice's position ie. with one face of the prism perpendicular to the light ray (eg. trial lens prism) but for plastic ophthalmic prism (eg. prism bar), power in the position of minimum deviation is used.

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2. a.T b.F c.F d.T e.T

The image formed by a prism is erect, virtual and deviated towards the apex.

3. a.T b.T c.T d.F e.F

Three factors determine the angle of deviation: the refracting angle, angle of incidence of the ray and the refractive index of the prism material.

4. a.F b.T c.F d.T e.F

Torsional diplopia can not be controlled with prism. In addition to the refracting angle, the refractive index of the prism is required to calculate the prism power. A prism of 1 prism dioptre is equivalent to one with an angle of apparent deviation of 1/2 degree.

5. a.T b.T c.T d.F e.F

Fresnel prisms reduce the weight of conventional prism and used widely in treating patients with strabismus. They are made up of a series of small prisms. The most common type are made up of polyvinyl chloride. They reduce the visual acuity mainly through chromatic aberrations. They are usually applied to the the back of patients' glasses.

6. a.T b.T c.T d.F e.T

To correct a strabismus, the apex of the prism is pointing in the direction of the deviation and the base in the opposite direction. Therefore a patient with a right over left strabismus ie. right hypertropia and/or left hypotropia can be corrected with a base down prism over the right eye or a base up prism over the left eye. The power of the prism can be split between the two eyes. In such cases, the orientation fo the prisms is opposite for the two eyes.

7. a.F b.T c.F d.T e.T

As mentioned in answer 6, the apex of the prism should be pointing in the direction of the deviated eye to control the diplopia. Therefore, the prism should be base out over the right eye or the left eye (unlike vertical strabismus, the base orientation of the prisms in horizontal strabismus are in the same direction). If the prisms are divided between the two eyes, the prism dioptre should be 4 with base out over each eye.

8. a. T b. F c. F d.T e.F

A myope (concave) lens can be regarded as two prism placed apex to apex.

Decentring a myope lens temporally induces a base in prism; nasally induces a base out prism, inferiorly a base up prism and superiorly a base down prism.

The reverse is true for a hyperope (convex) lens.

Using the Prentice rule:
Prism dioptre = distance from the optic centre (cm) X dioptre power of the lens.
The induced prismatic effect is 1D.

V. Spherical lenses

1. The vergence power of a lens is dependent on:

a. its dispersive power
b. vergence power of each surface
c. thickness of the lens
d. the wavelength of the light
e. the medium on either side of the lens

2. The following are true about the focal lengths of spherical lenses:

a. the first focal length always has the same length as the second focal length
b. the first focal length of a convex lens is to the right of the lens
c. the first focal length of a concave lens is to the right of the lens
d. the second focal length of a convex lens has a positive sign
e. the second focal length of a concave lens has a negative sign

3. The following are true about magnification by the lens:

a. the linear magnification of an object is defined by the distance of the image from the principal point divided by the distance of the object from the principal point.
b. angular magnification is more important than linear magnification in determining the image size falling on the retina
c. a tall object situated far away may be perceived as having the same size as a smaller one close to the eye
d. magnification of the depth of the image along the optical axis is known as axial magnification
e. if the image is situated at infinity, its size is the same as its object size

4. The magnifying glass:

a. increases the angle subtended by the image of a near object
b. has an angular magnification which is traditionally defined as angle subtended by the image divided by the angle subtended by the same object placed 25 cm from the eye
c. has an angular magnification equal to M/4 where M is the power of the lens in dioptres
d. is used to produce erect virtual image for the normal user
e. has a small field of vision

5. The increasing prismatic effect of the more peripheral parts of a spherical lens is responsible for:

a. ring scotoma
b. chromatic aberration
c. spherical aberration
d. jack-in-the-box effect
e. image distortion

V. Spherical lenses - Answers

1. a.F b.T c.T d.T e.T

The vergence power of a lens is affected by the vergence power of each surface, thickness of the lens and the medium on either side of the lens. The later explain why cornea has a stronger refractive power than lens in human eye although its refractive index is less. The wavelength of the light also affects the vergence power of the lens.

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2. a.F b.F c.T d.T e.T

The first focal length has the same length as the second focal length only if the media on either side of the lens are the same. The first focal length of a convex lens is to the left of the lens whereas that of the concave lens is to the right of the lens.

By convention, the second focal length has a positive sign for convex lens and a negative sign for concave lens. As lenses are designated by their second focal lengths, a convex lens is also called a plus lens and a concave lens a negative lens.

3. a.T b.T c.T d.T e.T

Image magnification can be defined in various ways:

- Linear magnification is the quotient of the image height divided by the object height.
- Axial magnification is the magnification of the depth of the image along the optical axis.
- Angular magnification is the quotient of the angle subtended by the image divided by the angle subtended by the object.

4. a.T b.T c.T d.T e.T

The magnifying lens increases the angle subtended by the image of a near object placed in the primary focal plane of a plus lens. For such a magnifier, the magnifying power is traditionally defined as the quotient of the angle subtended by the image divided by the angle subtended by the same object placed 25 cm from the eye. The magnifying power is calculated to be M/4 where M is the power of the lens in dioptres.

5. a.T b.F c.T d.T e.T

The increasing prismatic effect of the more peripheral parts of a spherical lens is responsible for:

- spherical aberration
- ring scotoma
- jack-in-the-box effect
- image distortion so that a thick plus lens gives a pin-cushion effect and a thick minus lens gives a barrel effect.

VI. Astigmatic lenses

1. The following are true about the cylindrical lens:

a. it has two meridian of curvature
b. it has no power along its axis
c. it can be used to measure phoria
d. it causes meridian magnification or minification at 90^0 to its axis
e. it forms a focal line parallel to its axis

2. The following are true about the Maddox rod:

a. when the cylindrical lenses within the rod are vertical, a vertical line is seen by the eye when it views a distant white spot through the rod
b. when the cylindrical lenses within the rod are horizontal, a horizontal line is seen by the eye when it views a distant white spot through the rod
c. light incident in the meridian at 90^0 to axis of Maddox rod is seen as a white line
d. it is used to measure phoria for both near and distance
e. it can be used to measure cyclotorsion

3. Irregular astigmatism:

a. occurs when there are many radii in one meridian
b. can be corrected with spectacle
c. is usually corneal in nature
d. can be caused by different indices of refraction in different portions of the crystalline lens
e. can be treated with laser refractive surgery

4. The following prescription has oblique astigmatism:

a. PL / -2.00X45
b. +1.00 / -0.25 X85
c. +1.25 / +1.00X175
d. -4.00 / -0.25X35
e. -5.00 / -1.00X130

5. The following prescription has against-the-rule astigmatism:

a. +1.00 / +0.25 X 180
b. +1.00 / -025 X 180
c. +1.00 / -0.25 X 90
d. +1.00 / -0.25 X 135
e. -1.00 / +0.25 X 90

6. In against-the-rule astigmatism:

a. the horizontal meridian has more power than the vertical meridian
b. a minus cylinder at 180^0 will correct the astigmatism
c. a plus cylinder at 180^0 will correct the astigmatism
d. the astigmatism may be reduced with clear corneal incision at the temporal side during cataract surgery
e. the visual acuity is less affected than with-the-rule astigmatism

7. Simple astigmatism occurs when:

a. one image is focused on the retina and the other is in front of the retina
b. one image is focused on the retina and the other is behind the retina
c. both images are in front of the retina
d. both images are behind the retina
e. one image is in front of the retina and the other is behind the retina

8. The following are true about the conoid of Sturm:

a. it is the three-dimensional image form by a spherocylindrical surface
b. images at the end of the conoid are lines
c. images at the centre of the conoid are circle
d. the circle of least confusion is within the conoid of Sturm
e. the length of the conoid of Sturm increases if the differences between the two foci of a spherocylindrical surface increases

9. The following are true about the spherical equivalent:

a. it is located at the circle of least confusion in the conoid of Sturm
b. it is midway between the dioptric powers of the two cylindrical lenses that make up the astigmatic lens
c. it can be used to calculate if the eye is essentially emmetropic, myopic or hypermetropic
d. it is used to choose intraocular lens during biometry
e. it is calculated by adding the spherical power to half the cylindrical power

10. Jackson's cross cylinder:

a. does not blur the image when placed before an emmetropic eye
b. does not change the interval of Sturm according to the position of the Sturm
c. does not alter the spherical equivalent of an ametropic eye
d. is used to check the axis of the cylinder subjectively
e. is used to check the power of the cylinder subjectively

11. The following are true about Jackson's cross cylinder:

a. it is used to check the axis of the cylinder before the power
b. the power of the cylinder is twice that of the sphere and of opposite sign
c. a 0.50D cross cylinder has a total cylindrical power of 0.50D
d. a 0.50D cross cylinder has a net spherical power or spherical equivalent power of 0
e. a 0.50D cross cylinder can be written up as +0.25DS/-0.50DC

VI. Astigmatic lenses - Answers

1. a.F b.T c.T d.T e.T

A cylindrical lens has one plane surface and the other with curve surface. It has no power along its axis. Its power is 90 degrees to the axis and the lens forms a focal line parallel to its axis. It is used in Maddox rod for the measurement of phoria.

2. a.F b.F c.F d.F e.T

When the cylindrical lenses within the rod are vertical, a horizontal line is seen by the eye when it views a distant white spot through the rod. A horizontal line is seen when the lenses are vertical. Light incident in the meridian at 90 degrees to axis of Maddox rod is focused in front of the eye which is too close for the eye to see as a line. Maddox rod is used to measure distant phoria and Maddox wing for near phoria. Double Maddox rod can be used to measure cyclotorsion.

3. a.T b.F c.T d.T e.T

Irregular astigmatism occurs when principal meridians are not at 90 degrees to each other. It is commonly corneal in nature and caused by scar but it can also be lenticular in origin caused by different indices of refraction in different portions of the crystalline lens. Spectacle can not correct irregular astigmatism. It is treated by substituting a new surface and this can be achieved with a contact lens usually RGP lens, corneal graft or laser surgery.

4. a.T b.F c.F d.T e.T

By oblique astigmatism, we mean that the axis of the correcting cylinder is other than near 90 degrees or 180 degrees (other than with or against the rule astigmatism).

5. a.T b.F c.T d.F e.F

In against-the-rule astigmatism, the plus cylinder is at 180 degrees and the minus cylinder is at 90 degrees. In with-the-rule astigmatism, the plus cylinder is at 90 degrees and the minus cylinder is at 180 degrees.

6. a.T b.F c.T d.T e.F

In against-the-rule astigmatism, the horizontal meridian has more power than the vertical meridian. A minus cylinder will correct the astigmatism if placed at 90 degrees or alternatively a plus cylinder can be used which is placed 180 degrees.

Temporal incision will reduce against-the-rule astigmatism. The visual acuity is less affected in with-the-rule astigmatism than against-the-rule astigmatism.

7. a.T b.T c.F d.F e.F

Simple astigmatism occurs when one of the images is on the retina. Simple myopic astigmatism occurs when one image is on the retina and the other in front of the retina. Simple hypermetropic astigmatism occurs when one image is on retina and the other is behind the retina. Compound myopic astigmatism occurs when both images are in front of the retina. Compound hypermetropic astigmatism occurs when both images are behind the retina. Mixed astigmatism occurs when one image is in front of the retina and the other behind the retina.

8. a.T b.T c.T d.T e.T

9. a.T b.F c.T d.T e.T

The circle of least confusion of the conoid of Sturm is located at the focal point of the spherical equivalent lens. However, the spherical equivalent is not midway between the dioptric powers of the two cylindrical lenses that make up the astigmatic lens.

The spherical equivalent of a sphero-cylindrical lens can be calculated as follows:
Spherical equivalent = sphere + (cylinder/2)
It can be used to find out if an eye is emmetropic, hypermetropic or myopic.
It is used in biometry to choose the intraocular lens.

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10. a.F b.F c.T d.T e.T

Placed before an emmetropic eye, the cross-cylinder blurs the image. Placed before an ametropic eye, the cross-cylinder does not alter the spherical equivalent, but it will enlarge or contract the interval of Sturm, blurring or clarifying the image, as it increases or decreases the net astigmatic ametropia. The cross-cylinder is used for subjective refinement of axis and power of cylinder after placing the best available estimate of refraction before the eye (retinoscopy, astigmatic dial test, or previous refraction).

11. a.T b.T c.T d.T e.T

It is used to check the axis of the cylinder before its power. The power of the cylinder is twice that of the sphere and of opposite sign. A 0.50D cross cylinder has a total cylindrical power of 0.50D. A 0.50D cross cylinder has a net spherical power or spherical equivalent power of 0. A 0.50D cross cylinder can be written up as +0.25DS/-0.50DC or -0.25DS/+0.50DC. Axis is not specified.

VII. Optical prescriptions and lenses

1. The following transpositions are correct:

a. PL / -2.00 X 180 = -2.00 / +2.00 X 90
b. +2.00 / -0.50 X 60 = +2.50 / +0.50 X 150
c. -1.25 / +0.75 X 4 = -0.50 / -0.75 X 86
d. +7.00 / -2.00 X 78 = +5.00 / +2.00 X 168
e. -0.25 /-3.00 X 50 = -3.25 / +3.00 X 140

2. When transposing +3.00/-1.00X 90 to the base curve -5.00, the correct answer should be:

a. +8.00 DS/-5.00DC axis 180/-6.00DC axis 90
b. +8.00 DS/-5.00DC axis 180/-6.00DC axis 180
c. +8.00 DS/ -5.00DC axis 90/-6.00DC axis 180
d. -2.00DS/ -5.00DC axis 90/-6.00 DC axis 90
e. -2.00DS/ -5.00DC axis 180/-6.00DC axis 90

3. The following are true about the identity of an unknown lens when viewed through a cross made up of two lines crossed at 90:

a. there is no distortion of the cross if the lens is spherical
b. an astigmatic lens always causes distortion of the cross
c. 'scissors' movement of the cross when the lens is rotated suggests the lens is astigmatic
d. if the cross moved in opposite direction to the lens, the lens is likely to be concave
e. displacement of the line on cross suggests the presence of prism within the lens

4. Regarding the Geneva lens measure:

a. it can only be used to measure crown glass
b. it measures the base curve of a lens
c. it makes use of the principle that the total power of a thin lens is equal to the sum of its surface power
d. it can be used to measure the thickness of a lens
e. it can be used to measure the diameter of a lens

5. The focimeter:

a. contains a convex collimating lens
b. contains a collimating lens that converge the incoming light
c. uses green light to eliminate spherical aberration
d. contains a telescope system for viewing
e. gives a ring of dots if the lens has no cylindrical power

6. The focimeter can measure:

a. back vertex power of the lens
b. prism
c. axis of the cylinder
d. optic centre of the lens
e. refractive index of the lens

7. Regarding tinted lenses:

a. the lenses always change colour with light
b. they work by either absorbing the light or reflecting the light
c. transmittance curve of a tinted lens measures the percentage of light transmission for each wavelength
d. the protective goggles used in laser room are made up of tinted lenses
e. lenses with solid tint have uniform light absorption throughout

8. True statements about anti-reflective coatings include:

a. the principle of destructive interference applies to anti-reflective coatings
b. the thickness of the coating is a quarter of the wavelength of the incident light
c. they cause the lenses to grow dark in bright light
d. they absorb ultraviolet light
e. they can only be used on plastic lenses

9. Photochromic lenses:

a. usually have a more rapid darkening process than lightening process
b. give different tints according to the wavelengths
c. tend to become darkened with repeated use
d. that made of glass usually employed organic photochromic compounds
e. tend to darken more rapidly if the environmental temperature is low

VII. Optical prescriptions and lenses - Answers

1. a.T b.F c.F d.T e.T

To transpose an astigmatic lens, first add the spherical and the cylindrical power and then alter the sign of the cylinder power and finally add 90 degrees to the existing axis. If the axis is more than 180 degrees, takes 180 degrees from the total degrees to get the new axis. Therefore question b should be +1.50 / +0.50 X 150 and c should be -0.50 / -0.75 X 94.

2. a.T b.F c.F d.F e.F

The steps for toric transposition is as follow:

i. Make sure the cylinder has the same sign as the base curve

ii. Obtain the required power of the spherical surface by subtracting the base curve power from the spherical power. Here the result is +3-(-5) = +8.00DS

iii. Specify the axis of the base curve and this axis is 90 degrees to that of the required cylinder. The result in this case is: -5.00DC axis 180.

iv. Finally add the required cylinder to the base curve power with its axis. The result is -5 (-1.00) = -6.00DC axis 90.

3. a.T b.F c.T d.F e.T

If the axis of the astigmatic lens coincide with the cross lines, there is no distortion. However, if the lens is rotated against the cross, scissors movement of the cross always occurs. If the cross moved in opposite direction to the lens, the lens is convex. A prism has no optical centre and therefore one line of the cross is always displaced regardless of the lens position.

4. a.F b.T c.T d.T e.T

The Geneva lens measure is calibrated for crown glass but can be used for other materials with a correction factor. It measures the base curve of lens and makes use of the principle that the total power of a thin lens is equal to the sum of its surface power. It can be used for lens diameter or thickness measurement.

5. a.T b.F c.F d.F e.T

The focimeter contains a convex collimating lens but the light passing through it are rendered parallel. Green light is used to eliminate chromatic aberration.

6. a.T b.T c.T d.T e.F

A focimeter is used to measure the vertex power of a lens, the axes and major powers of an astigmatic lens and the power of a prism. For spectacle lens, the back surface of the lenses is placed against the rest so that the back vertex power is measured .

7. a.F b.T c.T d.T e.F

Tinted lenses may be of fixed colour or photochromic (the colour changes with light). They work by either absorbing the light or reflecting the light. Transmittance curve gives the performance of the lens.Laser protective goggles are tinted lenses.

Light absorption in a lens with solid tint depends on the thickness of the lens; therefore, the absorption is higher in area where the lens is thicker.

8. a.T b.T c.F d.F e.F

Anti-reflective coatings do not change the colour of the lens. They use the principle of destructive interference to reduce the reflection. The thickness of the coating is a quarter of the wavelength of the incident light. The coatings can be used on either glass or plastic. The coating materials are made by metal oxides.

9. a.T b.T c.T d.F e.T

Photochromatic lenses change colour in the presence of light and the process of darkening is more rapid than the process of lightening. The tint that develops depends on the wavelengths of the light. Silver halide is used in glass and organic photochromic compounds are used in plastic. With constant use, the lens eventually become darkened. Darkening tends to occur more rapidly in low temperature because heat reduces the effect of light on photochromic lenses.

VIII. Aberration of optical system

1. The following are true about chromatic aberration:

a. it results from the fact that longer wavelength is deviated more than shorter wavelength.
b. it does not occur with light of same wavelength
c. it results from the dispersive power of a material
d. it is dependent on the refractive index of a material
e. it can be reduced by combining crown and flint glass

2. Duochrome test:

a. uses letters or numbers of different colours against the same background
b. uses blue and red colours
c. is sensitive to changes in refraction of 0.25D or less
d. is useful in myopic patients to avoid undercorrection
e. can not be used in colour blind patients

3. Spherical aberration in human eye is reduced by the following:

a. the anterior surface of the cornea is flatter peripherally than centrally
b. the cortex of the lens has a higher refractive index than the nucleus
c. the lens has variable anterior surface curvature
d. the retina has a radius of curvature which is shorter centrally than peripherally
e. the vitreous reduces spherical aberration

4. The following are true about spherical aberration:

a. it is responsible for reduced vision in dilated pupil
b. it results from the prismatic effect of the peripheral parts of a spherical lens
c. light passing through the periphery of a spherical lens is deviated more than those through the paraxial zone of the lens
d. it can be reduced by using a lens with less dispersive power
e. it can be reduced with a doublet

5. Oblique astigmatism

a. occurs when light passing through the lens obliquely
b. is more troublesome the higher the power of the lens
c. is most troublesome in the reading section of the varifocal glasses
d. is worse with meniscus lenses than biconvex or biconcave lens
e. of spectacle can be reduced with pantoscopic tilt

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6. Best form lenses is used to reduce:

a. chromatic aberration
b. oblique astigmatism
c. spherical aberration
d. coma
e. glare

7. Oblique astigmatism in the eye is reduced by:

a. aplanatic curvature of the cornea
b. the vitreous
c. the variable refractive index of the lens
d. the spherical surface of the retina
e. the peripheral retina has less resolving power than the central retina

8. The following are true about image distortion through strong lenses:

a. it is mainly the result of chromatic aberration
b. it is mainly the result of spherical aberration
c. pin-cushion distortion occurs with high minus lens
d. barrel distortion occurs with high plus lens
e. it can be reduced by getting the patient to use contact lenses

9. True statements about higher order optical aberrations of the eye include:

a. it can be detected with wavefront analysis
b. it can be measured with with aberometer
c. it can not be corrected with spectacles
d. it can be corrected with contact lenses
e. it can be corrected with corneal ablation

VIII. Aberration of optical system - Answers

1. a.F b.T c.T d.F e.T

Chromatic aberration results from the dispersive power of a material and results from the fact that different wavelength deviates differently when passing through an optical medium (refraction). Longer wavelengths such as red deviates less than shorter wavelengths such as blue. Chromatic aberration is independent of the refractive power of a material. Reduction of chromatic aberration can be achieved by combining different materials in the optical system to reduce the aberration such as crown and flint glass.

2. a.F b.F c.T d.F e.F

Duochrome test is a subjective test using the principle of chromatic aberration. It uses letters or numbers of the same colour usually black against different backgrounds: red and green. It is sensitive changes in refraction of 0.25D or less. It is useful in myopic patients to avoid overcorrection which can cause the eye to accommodate and thereby causing eyestrain.

3. a.T b.F c.F d.F e.F

Spherical aberration is reduced by the following in human eye:

- the anterior surface of the cornea is flatter peripherally than centrally
- the nucleus of the lens of the eye has a higher refractive index than the lens cortex
- the presence of iris reduces light coming from the peripheral lens
- the retinal cones are more sensitive to light entering the eye paraxially than to light entering obliquely

4. a.T b.T c.T d.F e.T

Spherical aberration is the result of prismatic effect of a spherical lens. A convex lens can be looked upon as a series of prism placed base to base and the prismatic power gets progressively stronger towards the centre. The reverse applies to concave lens. A dilated pupil causes blurred vision mainly due to chromatic aberration. The dispersive power of a lens is related to chromatic aberration. It can be reduced with a doublet.

5. a.T b.T c.T d.F e.T

Oblique astigmatism is worse with stronger lens, biconvex or biconcave lens (as against meniscus lens) and in the reading section of the varifocal glasses. It can be reduced by using meniscus lens and pantoscopic tilt of the spectacles.

6. a.F b.T c.T d.F e.F

Best form lenses are lenses that have been made to reduce both spherical and oblique aberrations.

7. a.T b.F c.F d.T e.T

The aplanatic curvature of the cornea reduces oblique astigmatism. The astigmatism is also reduced by the spherical surface of the retina so that the circle of least confusion fell on the retina. The peripheral retina has less resolving power than the central retina.

8. a.F b.T c.F d.F e.T

Image distortion through strong lenses is caused mainly by spherical aberration. Pin-cushion distortion occurs with high plus lens and barrel distortion occurs with high minus lens. Contact lens can reduce this problem in aphakia and high myopes.

9. a.T b.T c.T d.F e.T

High-order aberrations are ones that cannot be corrected by simple spherocylindrical systems, such as spectacles or contact lenses. They are caused by minute misalignments of the eye's optical components and include, in order of visual significance, spherical aberration, coma, higher-order astigmatism, and others. They can be detected with wavefront analysis performed with an instrument called aberometer. Theoretically, an ablation that removes aberrations increases visual contrast and the spatial detail of images seen by the eye.

IX. Refraction by the eye

1. In the schematic eye of Gullstrand:

a. the human model eye is based on the principal of thick lenses
b. the eye is about 24.0 mm in axial length
c. the nodal points lie on either side of the posterior surface of the lens
d. the nodal points coincide with the principal points
e. the cornea contributes 2/3 to the power of the eye

2. In the reduced eye of Listing:

a. the refractive power is stronger than that of the schematic eye of Gullstrand
b. the whole eye is regarded as a single refractive surface
c. the second focal point lies on the retina
d. the nodal point lies at the posterior surface of the lens
e. the principal plane lies at the anterior surface of the lens

3. The back vertex power:

a. is the reciprocal of the back vertex distance
b. of a convex meniscus lens can be calculated from its second focal length
c. of a convex meniscus lens is stronger than its front vertex power
d. gives the equivalent power of a lens
e. is used to grade spectacle lenses

4. The following definitions are true for accommodation:

a. the far point of distinct vision of an emmetropic eye is at infinity
b. the near point of distinct vision refers to clear near vision when maximum accommodation is used
c. range of accommodation is the difference in dioptric power between the eye at rest and the fully accommodated eye
d. dynamic refraction refers to the dioptric power of the accommodated eye
e. static refraction refers to the dioptric power of a resting eye

5. Regarding accommodative convergence / accommodation ratio (AC/A):

a. the eye could not accommodate in the absence of convergence
b. the normal range of AC/A is 3:1 to 5:1
c. the interpupillary distance needs to be known if the ratio is to be calculated using the gradient method
d. the heterophoria method of calculation gives a lower value than the gradient method
e. esotropia with high an AC/A ratio has a larger angle of deviation for near than for distance.

6. The catoptric images :

a. are formed at the refracting interfaces of the eye
b. can be used to measure the ocular accommodation
c. are all virtual images
d. are all erect images
e. are made up of 2 images produced by the cornea and 2 images by the crystalline lens

7. The first image of the captoptric image can be used for:

a. measuring ocular deviation in strabismic patient
b. keratometry
c. measuring accommodation
d. measuring corneal thickness
e. measuring anterior chamber depth

IX. Refraction by the eye - Answers

1. a.T b.T c.T d.F e.T

The schematic eye of Gullstrand is based on the principal of thick lenses. The eye has an axial length of 24.40mm. The first and second principal planes are located 1.35mm and 1.60mm from the corneal apex respectively; nodal points are located 7.08mm and 7.33mm from the corneal apex, and thus straddle the back surface of the lens. The complete eye has a refractive power of 58.64, cornea contributes 43.05D and the lens 19.11D.

2. a.F b.T c.T d.T e.F

The power is the same for the reduced eye and the schematic eye. In Listing's reduced eye, the principal plane lies in the anterior chamber.

3. a.F b.F c.T d.F e.T

The concept of back vertex power is used in the calculation of a thick lens. The back vertex power is the reciprocal of the posterior vertex focal length expressed in dioptres. The posterior vertex focal length is different from the focal length of a thick lens. In the case of a convex meniscus lens, the posterior vertex focal length is shorter than both the second focal length and the anterior vertex focal length. As a result, in a convex meniscus lens, the back vertex power is stronger than its front vertex power.

The equivalent power of thick lens is calculated from the two surface powers and a correction for vergence change due to lens thickness. Spectacle glasses are graded according to its vertex power because its back vertex power is the one that is used to correct the ametropia.

4. a.T b.T c.F d.T e.T

Range of accommodation refers to the distance between the far point and the near point. The difference in dioptric power between the eye at rest and the fully accommodated eye is called the amplitude of accommodation.

5. a.F b.T c.F d.F e.T

The eye can accommodate in the absence of convergence. However, in normal daily life a patient with normal binocular vision will convergence when he/she accommodates. The normal ratio is 3:1 to 5:1. The AC/A ratio can be calculated using either a heterophoria method in which the interpupillary distance needs to be known or the gradient method in which the interpupillary distance needs not be measured. The heterophoria method tends to give a higher ratio than the

gradient method. Esotropia due to high AC/A ratio tends to be worse for near than distance and can be corrected with bifocal glasses to reduce the accommodation or recession of medial recti.

6. a.F b.T c.F d.F e.T

They are also called the Purkinje-Sanson images. The images are formed at 4 surfaces: the anterior (image 1) and posterior (image 2) corneal surfaces and the anterior (image 3) and posterior (image 4) lenticular surfaces. The first three images are erect and virtual whereas the last one is inverted and real. The first image is used for keratometry and images 3 and 4 are used for accommodation.

7. a.T b.T c.F d.T e.F

Hirschberg's test made use of the first captoptric image which is located on the anterior corneal surface for measuring ocular deviation. This image is also used for keratometry. The distance between the first and the second images is used to measure the corneal thickness. The depth of the anterior chamber is between the second and the third image. Accommodation is the thickness between the third and the fourth images.

X. Optics of ametropia

1. The following are true about myopia:

a. the second principal focus lies behind the retina
b. the presence of posterior staphyloma suggests axial myopia
c. axial myopia may be caused by the cornea having too strong a refractive power
d. nucleosclerosis is a cause of index myopia
e. high myopia may be treated with clear lens extraction

2. The following are true about hypermetropia:

a. the second principal focus lies in front of the retina
b. accommodation is used to achieve normal vision
c. aphakia is a form of hypermetropia
d. patients require reading glasses earlier than the normal population
e. patients who has hypermetropic refraction following cataract surgery will have problem for both near and distant reading

3. The following are true about hypermetropia:

a. manifest hypermetropia is the strongest plus lens the eye can accept for clear distant vision
b. latent hypermetropia is the residual hypermetropia masked by ciliary tone and involuntary accommodation
c. latent hypermetropia can be unmasked by cycloplegic refraction
d. falcultative hypermetropia refers to hypermetropia that can not be overcome by accommodation
e. absolute hypermetropia cannot be overcome by accommodation

4. With regard to astigmatism:

a. regular astigmatism has the principal meridians at 90^0 to each other
b. oblique astigmatism occurs when the principal meridians do not lie at 90^0 to each other
c. irregular astigmatism is seen in patients with keratoconus
d. astigmatic eye produces an image known as a Sturm's conoid
e. astigmatic image can not be fully corrected with a spherical lens

5. Regarding the images form by astigmatic eyes:

a. rays in all meridians are focused behind the eye in compound hypermetropic astigmatism
b. ray from one meridian is focused on the retina while the other is focused behind the retina in simple hypermetropic astigmatism
c. rays in all meridians are focused in front of the eye in compound myopic astigmatism
d. ray from one meridian is focused on the retina while the other is focused in front of the retina in simple myopic astigmatism
e. ray from one meridian is focused in front of the retina and the other behind the retina in mixed astigmatism

6. Anisometropia:

a. occurs when the two eyes have different refractive errors
b. of more than 1D in hypermetropic patients can usually be controlled through accommodation of the more hypermetropic eye
c. is a common cause of amblyopia in patients with uncorrected low myopia
d. of recent onset may be caused by the development of posterior subcapsular cataract
e. may result from unilateral central serous retinopathy

7. With regard to the pin-hole:

a. the vision through the pin-hole is usually worse in patient with macular disease
b. it may allow presbyopic patients to read comfortably without glasses correction
c. failure of the vision to improve to 6/6 with pin-hole always indicates the presence of macular diseases
d. too small a pin-hole can affect vision through interference
e. it can improve vision in patients with posterior subcapsular cataract.

8. The stenopaeic slit:

a. can be used to find the principal axes of astigmatism
b. is an elongated pinhole that reduces blur resulting from ametropia in the meridian perpendicular to the slit
c. gives a clear vision when held at 90^0 with a +2.00DS and at 180^0 with a -1.00DS, the cylindrical power required is -3.00DC at 90^0
d. gives a clear vision when held at 90^0 with a +2.00DS and at 180^0 with a -1.00DS, the lens required to correct the vision is +2.00 /-3.00 X 180^0
e. can be used to find the best position for optical iridectomy in a patient with corneal scarring

9. True statements about the correcting lens include:

a. when a correcting lens is moved forward in a hypermetrope the image is moved forward
b. when a correcting lens is moved forward in a myope the image is moved backward
c. the effectivity of the lens is increased in a myope if the correcting lens is moved backward
d. the effectivity of the lens is increased in a hypermetrope if the correcting lens is moved forward
e. a hypermetrope with early presbyopia may be able to read clearly by pushing his glasses closer to his eyes

10. The following are true:

a. the back vertex distance is the distance between the back of a correcting lens and the cornea
b. the back vertex distance is not required if the correcting lens is less than 5 dioptre power
c. the contact lens for a myope is usually stronger than the glasses
d. the contact lens for a hypermetrope is usually stronger than the glasses
e. contact lens magnifies the image in a patient with axial myopia

11. Relative spectacle magnification:

a. is defined as the ratio of corrected image size to uncorrected image size
b. is 1.0 in axial ametropia if the correcting lens is placed at the anterior focal point
c. is 1.0 in index or refractive ametropia if the correcting lens is placed at the anterior focal point
d. is about 1.33 in aphakia corrected with spectacle
e. is 1.0 in aphakia corrected with contact lens

12. Regarding the correction of aphakia with glasses:

a. there is an increasing image magnification as the correcting glasses is moved forward from the position of the natural crystalline lens
b. reduction in visual field is a common problem
c. “pincushion” distortion of the visual field
d. ring scotoma of aphakia is created by the prismatic effect of the lens
e. using head turning rather than eye movement to change gaze direction can prevent 'Jack-in-the-box' phenomenon

13. Intraocular lens calculation:

a. is more affected by an error in axial length calculation than keratometric measurement
b. most commonly used in the preoperative clinic is derived from theoretical formulas
c. uses a lower A constant for anterior chamber than posterior chamber lens
d. is affected by the velocity of the ultrasound through the cataract
e. is affected by the absence of crystalline lens

14. The SRK formula for IOL calculation

a. the SRK formula is not accurate for eye shorter than 22mm
b. the SRK formula is not accurate for eye longer than 24.5 mm
c. the SRKII is a more accurate formula than SRK
d. the SRK II uses a higher A constant than SRK
e. the SRK-T is a more accurate formula than Hoffer Q for eye shorter than 21mm

15. The crystalline lens:

a. has an in-situ effective power of +15.00D
b. contributes more power than the cornea towards the refraction of the eye
c. if extracted without implant can correct myopia who needs spectacle correction of -15.00D
d. has a longer radius of curvature anteriorly than posteriorly
e. has an uniform refractive index

X. Optics of ametropia – Answers

1. a.F b.T c.F d.T e.T

In myopia, the second principal focus lies in front of the retina. Myopia may be classified into axial myopia (in which the eye is abnormally long as in high myopia which can produce staphyloma) or refractive (index) myopia in which the refractive power of the eye is increased as in keratoconus and nucleosclerosis.

2. a.F b.T c.T d.T e.T

The second principal focus of hypermetropia lies behind the retina. Accommodation is used to correct the hyperopia to certain extent. They require reading glasses earlier than the normal population. Aphakia is a form of hypermetropia. Following cataract surgery, the accommodative ability of the eye is lost. Therefore, if the patient is render hypermetropic, the vision will be blurred for distant and near. This is the reason why most patients are made slightly myopic so that they can achieve a reasonable vision without glasses for distance.

3. a.T b.T c.T d.F e.T

Four terms are used to define hypermetropia:

- Manifest hypermetropia refers to the strongest plus/convex lens that the patient can accept for clear distant vision.
- Latent hypermetropia is the remaining hypermetropia masked by the ciliary tone and involuntary accommodation. It can be unmasked by cycloplegic refraction.
- Facultative hypermetropia refers to hypermetropia that can be overcome by accommodation.
- Absolute hypermetropia refers to hypermetropia in excess of the amplitude of accommodation.

4. a.T b.F c.T d.T e.T

Regular astigmatism has the principal meridians at 90 degrees to each other. Oblique astigmatism also has its principal meridians at 90 degrees to each other but they do not lie near to 90 or 180 degrees.

Irregular astigmatism occurs when the principal meridians are not at 90 degrees to each other. An image known as Sturm's conoid is produced by an astigmatic eye; such image can only be corrected with a spherocylindrical lens.

5. a.T b.T c.T d.T e.T

The definitions of the terms are correct.

6. a.T b.F c.F d.F e.T

Anisometropia refers to different refractive errors between the two eyes. Anisometropia of more than 1D in hypermetropic patients can not be controlled with unilateral accommodation because accommodation is a binocular process. Therefore the image in one eye is often blurred and is a cause of amblyopia. On the other hand, anisometropia in low myope does not usually cause amblyopia because the near vision is normal. Unilateral nucleosclerosis and not posterior subcapsular cataract can lead to index myopia. Central serious retinopathy can cause hypermetropic shift.

7. a.T b.T c.F d.T e.F

Pin-hole is used to improve the vision of patients with ametropia in the range of +4 to -4. High ametropia may not improve with pin-hole.

Patients with macular disease, posterior subcapsular cataract or central corneal scar may have worse vision with pin-hole. If the hole on the pin-hole is too small, interference of light can affect the visual acuity.

8. a.T b.T c.T d.F e.T

Remember that the power of cylinder is 90 degrees from the axis. The cylinder power required in question b is either -3.00 at 90 degrees or +3.00 at 180 degrees. The lens required is either +2.00 / -3.00 X 90 or -1.00 / +3.00 X 90.

9. a.T b.F c.T d.T e.F

The image is moved forward when a correcting lens is moved forward irrespective if the lens is concave or convex. The effectivity of the lens is increased in hypermetrope when the lens is moved forward (which is expected of a convex lens) but in the case of the myope, the effectivity of the lens is decreased if the lens is moved forward as the lens fails to achieve its expected function which is to move the image backward.

A hypermetrope with early presbyopia may be able to read clearly by moving his glasses away from the eyes.

10. a.T b.T c.F d.T e.T

The position of the correcting lens affect its effective power. The back vertex distance is important if the power of the correcting lens is more than 5 dioptres. The contact lens for a myope is usually weaker than the glasses but for a hypermetrope it is usually stronger than the glasses. Contact lens magnifies the image in a patient with axial myopia.

11. a.F b.T c.F d.T e.F

Relative spectacle magnification (RSM) is defined as the ratio of corrected ametropic image size to emmetropic image size. The definition in 'a' is spectacle magnification. In axial ametropia if the correcting lens is placed at the anterior focal point, the RSM is 1.0. In index or refractive ametropia if the correcting lens is placed at the anterior focal point, the RSM is >1.0 for hypermetropia and <1.0 for myopia. Aphakia is an index/refractive ametropia and the RSM is about 1.33. With contact lens, the RSM approaches unity but still measures about 1.1. In order to achieve RSM = 1, a secondary lens implant is the treatment of choice.

12. a.T b.T c.T d.T e.T

There is an increasing image magnification as the correcting glasses is moved forward from the position of the natural crystalline lens. Therefore, aphakia is best corrected with either contact lens or secondary lens implant.

The problem with aphakic glasses include:

- large image magnification
- "pin-cushion " distortion of the visual field
- a ring scotoma, which has the "jack-in-the-box" effect of objects
- suddenly appearing from the edge of the scotoma.
- reduction of visual field

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13. a.T b.F c.T d.T e.T

In the SRK formula, the axial length is multiplied by 2.5 whereas the keratometric multiplied by 0.9. Therefore, a difference in the axial length has a greater effect on the IOL calculation than the keratometry. The most commonly used formula is empirical formulas using regression analysis. A lower A constant is used for the anterior chamber than one in the posterior chamber. The velocity of ultrasound through the lens can affect the IOL calculation and this velocity of ultrasound varies according to the density and type of cataract. It is important to set the ultrasound to phakic, pseudophakic or aphakic during biometry as the ultrasound travels at different speed through these variables.

14. a.T b.T c.T d.F e.F

SRK formula is used for IOL calculation. However, it is not accurate for eye less than 22mm or longer than 24.5mm. SRK II and SRK-T are more accurate than SRK. The SRK II uses adjusted A constant depending on the length of the eye. For eye with an axial length shorter than 21mm, Hoffer Q is preferable.

15. a.T b.F c.F d.T e.F

The crystalline lens has a power of +19.00D but within the eye it contributes only +15.00D. If extracted without implant it can be used to correct myopia who needs spectacle correction of between -18.00 and -20.00DS. The anterior lens surface is less curved than the posterior lens surface. The lens has different refractive indexi within its substance; the nucleus tends to have higher refractive index than the cortex.

XI. Presbyopia

1. The onset of presbyopia depends on:

a. the size of the pupil
b. task required
c. sex of the patients
d. the refractive state of the patients
e. amplitude of accommodation

2. Presbyopia occurs as a result of:

a. loss of elasticity of the sclera
b. sclerosis the lens fibres
c. reduced elasticity of the lens capsule
d. reduced anterior movement of the lens
e. reduced contraction of the ciliary muscle

3. The following are true about accommodation:

a. it decreases with age
b. in order to focus an object at a distance of 25cm, an emmetropic eye needs to use 4D of accommodation
c. in order to focus an object at a distance of 25cm, an eye with -3.00D needs 2D of accommodation
d. in order to focus an object at a distance of 25cm, an eye with +2.00D needs 6D of accommodation
e. for comfortable near vision one-third of the accommodation should be kept in reserve

4. The following are true about an emmetropic patient has an amplitude of accommodation of 6D:

a. the near point is 33 cm
b. in order to achieve comfortable reading he will need to keep 2D of his accommodation in reserve
c. if the patient is emmetropic, he will require glasses for comfortable reading at 25cm
d. if the patient is myopic, he will require glasses for comfortable reading at 25cm
e. if the patient is hypermetropic, he will require glasses for comfortable reading at 25cm

5. With regard to bifocal glasses:

a. Franklin design involves attaching a supplementary lens to the surface of a distance lens of the same refractive power
b. fused bifocals involves the use of lenses with different refractive indexes
c. it used for children with accommodative esotropia
d. the problem of prismatic jump is related to the power of the lenses
e. the near visual point of the bifocals is usually inferior and nasal to the distance visual point

6. The following can be used to reduce prismatic jump in bifocal glasses:

a. adding base down prism to the distance portion
b. adding base-up prism to the reading section
c. moving the optical centres of the lens near the junction of the two portions
d. using executive glasses
e. pantoscopic tilt

7. Varifocal lenses:

a. are also called trifocal lenses
b. have no visible interface between the distance and near portions
c. do not produce the prism jump seen in conventional bifocal glasses
d. often produce significant aberration at the periphery of the intermediate portion
e. of the soft designs are better than the hard designs for prolonged VDU works

XI. Presbyopia – Answers

1. a.T b.T c.F d.T e.T

Presbyopia is the age-related loss of the ability to comfortably sustain the accommodation necessary for clear near vision.

Its onset is dependent on:

- the amplitude of accommodation
- task required
- refractive state of the patients (earlier with hypermetropia than myopia)
- size of the pupil (small pupil has a pin-hole effect)
- latitude where patient lives (onset is earlier in the tropical than temperate countries)

2. a.F b.T c.T d.F e.T

Presbyopia is multifactorial and is believed to result from poor ciliary muscle contraction with age and age-related sclerosis and loss of elasticity of the lens fibres and the lens capsule.

3. a.T b.T c.F d.T e.T

A child has about 14D of accommodation which decreases with age. In order to focus an object at a distance of 25cm, an emmetropic eye needs to use 4D of accommodation. For an eye with -3.00D, only 1D is needed. In an eye with +2.00D, 6D of accommodation is required (the accommodation is the sum of the patient's refractive state + 4D). For comfortable near vision, one-third of accommodation should be kept in reserve.

4. a.F b.T c.F d.F e.T

The near point for this patient is 1/6 = 0.17m=17cm. For comfortable reading, one third of his accommodation should be kept in reserve which is 2D in this patient. Therefore, he has 4D of accommodation for use. If he is emmetropic, the 4D of accommodation is adequate for an object at 25cm. If he is myopic, the amount of accommodation required will be less but if the he is hypermetropic, the amount of accommodation needed will be greater than 4D and plus lens will be needed.

5. a.T b.T c.F d.T e.T

The Franklin design is a split bifocals in which a distance lens is mounted on a near lens. The cemented designs involves attaching a supplementary lens to the surface of a distance lens of the same refractive power. Fused bifocals is made by

heat-fusing a near portion made of flint glass into a depression on a crown glass with a lower refractive index.

Bifocals are used for children with convergence excess esotropia but not in high myopes. The problem of prismatic jump is related to the power of the lenses as well as the distance between the distance of the interface from its optical centre.

6. a.F b.T c.T d.T e.F

Image jump can be reduced by moving the optical centres towards the junction of the two portions as in the executive glasses. Alternatively, a base up prism can be incorporated into the reading section.

Pantoscopic tilt is used to reduce astigmatic aberration.

7. a.F b.T c.T d.T e.T

Varifocal glasses has three sections: distance, intermediate (for VDU or working at arm length) and near (for reading). Varifocal or progressive lenses have no visible interface between the distance and near portions unlike bifocal or trifocal lenses. There is a power progression corridor (intermediate portion) which reduces the image jump seen in bifocal glasses; however on either side of the corridor aberration or astigmatism induced can become intolerable.

The soft designs have wider progressive corridor and therefore bigger intermediate portion for VDU work.

XII. Contact lenses

1. The power of a contact lens is determined by its:

a. thickness
b. posterior curvature
c.diameter
d. oxygen permeability
e. refractive index

2. The following are true about a contact lens with the following numbers 8.9/13.8/-4.25:

a. the contact lens has a base curve of 8.9 mm
b. the contact lens has a diameter of 8.9 mm
c. the power of the contact lens is 13.8 D
d. the base curve of the contact lens is 13.8 mm
e. the contact lens has a power of -4.25 D

3. The base curve of a contact lens:

a. refers to its posterior central curvature
b. is usually measured in dioptres
c. is measured with a radiuscope
d. determines its movement with blinking
e. for a particular patient is chosen according to the central keratometry measurement

4. With regard to contact lenses:

a. they are usually tinted to make them more visible for handling
b. only rigid gas permeable contact lens can correct astigmatism
c. tear lens can neutralize astigmatism
d. truncation of a contact lens is used to prevent lens rotation
e. piggyback contact lens involves the use of two soft contact lenses one above the other

5. Compare with spectacles, the contact lenses:

a. increase the field of vision
b. magnify images in hypermetropia
c. minify images in myopia
d. reduce aneisokonia
e. reduce optical aberration

6. Compared with glasses, the contact lenses:

a. increase the amount of convergence needed in myopes
b.increase the amount of accommodation needed in myopes
c. decrease the amount of convergence needed in hypermetropes
d. decrease the amount of accommodation needed in hypermetropes
e. cause eyestrain in presbyopic patients at an earlier age

7. The following are true about corneal warpage:

a. corneal oedema is a feature
b. it refers to a change in the corneal curvature associated with contact lens wear
c. it is more common with rigid gas permeable contact lens
d. it interferes with the result of biometry
e. it is a reversible condition

8. With regard to contact lenses:

a. three and 9 o'clock staining is more common with soft than RGP lens
b. bacterial corneal ulcer is more common with soft than RGP contact lens
c. soft contact lens is more suitable for occasional wear than RGP lens
d. giant papillary conjunctivitis is more common with soft contact lens than RGP lens
e. ptosis is more common with RGP than soft contact lens

9. A contact lens wearer complains that his vision is blurred immediately after blinking. Slit-lamp examination reveals excessive contact lens movement. To reduce the movement, you may:

a. increase the oxygen permeability of the contact lens
b. decrease the diameter of the contact lens
c. increase the thickness of the edge of the contact lens
d. increase the base curve of the contact lens
e. reduce the wearing time

XII. Contact lenses - Answers

1. a.T b.T c.F d.F e.T

The power of a contact lens is determined by its:

- anterior curvature
- posterior curvature
- thickness
- refractive index

2. a.T b.F c.F d.F e.T

The numbers represent base curve/diameter/power respectively.

3. a.T b.F c.T d.T e.T

The posterior surface of a contact lens determines its fitting relationship with the cornea. Known as the base curve or central posterior curve, its dimensions are usually expressed in mm radius of curvature and sometimes in dioptic power. The radiuscope is the traditional instrument used by practitioners and laboratories to measure the radius of spherical base curves.

The base curve determines how tight the lens is fit to the cornea and hence its movement with blinking. To choose a base curve for a particular patient, central keratometry measurement is used.

4. a.T b.F c.T d.T e.F

Tint in contact lenses make them more visible for easy handling. Both rigid gas permeable spherical contact lens and soft spherical contact lens can correct astigmatism. However, because the soft contact lens conform to the shape of the cornea, there is little tear lens ie. the tear film between the cornea and the posterior surface of a contact lens to allow neutralization of high astigmatism. Soft spherical contact lens can correct up to 1.00D of lens.

Soft contact lens with toric surface can be used to correct higher astigmatism. Truncation involves cutting off the lower part of the spherical lens and prevent lens rotation. Piggyback contact lens involves the use of two lenses, the soft contact lens provides the fitting surface for the rigid gas permeable lens.

5. a.T b.F c.F d.T e.T

Spectacle magnifies and minifies images in hypermetropia and myopia respectively. As contact lenses tend to return the images to near normal size, the images are minified in hypermetropia and magnified in myopia.

Aneisokonia ie. differences in image size is reduced with contact lenses. Contact lens allows the patient to look through the optical centre in all direction of gaze, and optical aberration is reduced compared with spectacles.

6. a.T b.T c.T d.T e.T

Because of the prismatic effect of glasses with reading (base in in myopes and base out in hypermetropes), the myopes need less convergence and accommodation than when using the contact lenses, the converse is true for hypermetropes. Because of the additional accommodation and convergence required, contact lenses can cause eyestrain in presbyopic at an earlier age.

7. a.F b.T c.T d.T e.T

Corneal warpage refers to change in the corneal curvature associated with contact lens wear. Corneal oedema is absent. It is commoner with rigid gas permeable contact lens than soft contact lens. The result is reversible. Biometry or refractive surgery should be avoided until the cornea returns to its normal shape otherwise the results of the measurement or surgery will be inaccurate.

8. a.F b.T c.T d.T e.T

Three and 9 o'clock staining is a common complication of RGP and is caused by peripheral corneal desiccation. It is believed to be initiated by excessive upper lid margin sensation, leading to abortive blinking, which in turn initiates a cascade of events that include drying and accumulation of mucous debris on the surface of the lens, limited lens movement, loss of the lens edge tear meniscus, and desiccation of the exposed cornea. Rigid gas permeable (RGP) contact lens has a smaller diameter than the cornea. The soft contact lens typically has a diameter than extends beyond the limbus.

Bacterial corneal ulcers, although rare, are potentially the most devastating complication of contact lens wear. Their occurrence is more common in soft lens wearers, and extended wear increases the incidence 10- to 15-fold.

RGP usually requires a period of wear to get use to and occasional wear may be uncomfortable for the patient.

Giant papillary conjunctivitis is more common with soft than RGP lens. It is thought to be caused by deposits of denatured proteins. Ptosis is more common

with RGP lens. It is thought to be related to the way the RGP lens is removed ie. temporal stretching of the lids combined with forceful lid closure.

9. a.F b.F c.T d.F e.F

To reduce the lens movement, you may increase the contact lens diameter, decrease the base curve of the contact lens or increase the thickness of the contact lens.

XIII. Optics of low visual aids

1. The following may be used as low visual aids:

a. text scanner
b. closed circuit television
c. high-add bifocal
d. convex cylinder lens
e. telescope

2. The disadvantages of using optical magnifying glasses for low visual aids include:

a. reduced depth of focus
b. reduced visual field
c. reduced contrast
d. objects need to be placed far away
e. unsteadiness of images if the objects are not held steady

3. The following are true about convex lens for low visual aids:

a. the object is placed at its focal point
b. the image produced is virtual
c. the image is erect
d. the field of vision obtained is decreased if the user moved away from the lens
e. the field of vision obtained is reduced if the diameter of the lens is reduced

4. The following are true about the Galilean telescope:

a. it is made up of two convex lenses
b. the distance between the two lenses is the sum of the focal length
c. it is usually lighter than the astronomical telescope
d. it is usually shorter than the astronomical telescope
e. the image produced is usually dimmer than that seen by the naked eye

5. The image produced by a Galilean telescope is:

a. laterally inverted
b. upright
c. real
d. at infinity
e. magnified

6. The following are true about the Galilean telescope:

a. it is invented by Galileo
b. the objective lens usually has a much lower power than the eye piece
c. the magnification can be calculated by using the the formula M=fo/fe (where fo is the focal length of the object and fe the focal length of the eye piece)
d. it is useful for viewing faint stars at night
e. it magnifies by increasing the angle subtended by the object at the eye

7. The following may be used as visual aid for patients with significant visual field loss due to advanced glaucoma:

a. concave lens
b. inverted Galilean telescope
c. astronomical telescope
d. prism with the base towards the area of scotoma
e. mirror mounted on glasses

XIII. Optics of low visual aids - Answers

1. a.T b.T c.T d.F e.T

The following optical devices may be used for low visual aids:
- High-add bifocal
- Prismatic half-frame spectacle
- Head-mounted magnifier
- Hand-held magnifier
- Stand magnifier
- Spectacle-mounted telemicroscope
- Closed-circuit television (CCTV)
- Text scanner, enlarged font on computer monitor
- Convex cylindrical magnifying lens

2. a.T b.T c.F d.F e.T

Disadvantages of optical magnifying glasses includes: reduced depth of focus, reduced visual fields, objects need to be placed near the eye and unsteadiness of images if the objects are not held steady.

3. a.F b.T c.T d.T e.T

The object is placed between the focal length and the lens.

The image is magnified and erect. The field of vision is dependent on the size ie. diameter of the lens and the distance between the eye and the lens (the greater the distance between the lens and the eye, the smaller the visual field).

4. a.F b.F c.T d.T e.T

Galilean telescope is made up of a convex objective and a concave eye-piece? lens. The separation between the lenses is the difference between the their focal lengths and for this reason is usually shorter than the astronomical telescope (separation is the sum of the focal lengths) and also lighter due to the shorter distance. The image produced is usually dimmer than that seen by the eyes because light is reflected and absorbed as it passes through each lens.

5. a.F b.T c.F d.T e.T

The image produced by a Galilean telescope is at infinity, virtual, upright and magnified.

6. a.F b.T c.T d.F e.T

Despite the name it is not invented by Galileo. It is usually made up of a lower power plus objective lens and a high power minus eyepiece lens. The magnification can also be calculated using Fe/Fo where Fe is the dioptre power of the eyepiece and Fo the power of the objective lens. Compare with the astronomical telescope, Galilean telescope is not efficient in gathering light and therefore not suitable for viewing distant faint stars. The angle subtended by the object at the eye is increased and hence magnification.

7. a.T b.T c.F d.T e.T

There are two optical ways which can help patients with constricted visual fields: minification and image relocation. Minification of image allows the remaining functional retina to process more information and this can be achieved with concave lens or inverted Galilean telescope.

Image relocation relocates visual information from the scotoma closer to the area of functioning visual field. This has the effect of minimizing the size of the eye or head movement required to detect the visual object. This technique typically uses prisms placed nasally and temporally with the base in the direction of the scotoma but can also use mirrors.

Lastly, the non-optical way involves making the patients aware of the spatial area to be processed ie. behavioural approach and this involves increasing the efficiency of eye movements.

XIV. Optical instruments

1. The direct ophthalmoscope:

a. gives an angular magnification of 15X
b. gives a real erect image
c. makes the disc of a myope appears larger than that of a hypermetrope
d. makes the disc of a hypermetrope larger than that of an emmetrope
e. is better than indirect ophthalmoscope in detecting diabetic maculopathy

2. When using a direct ophthalmoscope, the field of view:

a. is about 6 degrees
b. is smaller than that through an indirect ophthalmoscope
c. is larger in an eye dilated with mydriatic
d. is larger in a myope compared with a hypermetrope
e. is larger when the observer moves towards the patient

3. The image formed by an indirect ophthalmoscope:

a. is upside down
b. is real
c. is laterally inverted
d. is not affected by the refractive state of the patient
e. is formed between the observer and the condensing lens

4. In indirect ophthalmoscopy, the field of view is affected by:

a. size of the patient's pupil
b. size of the observer's pupil
c. diameter of the condensing lens
d. power of the condensing lens
e. the refractive state of the observer

5. The advantages of indirect ophthalmoscope over direct ophthalmoscope include:

a. binocular view
b. larger field of view
c. higher magnification
d. erect image
e. the instrument is smaller size

6. Regarding the condensing lenses used in indirect ophthalmoscope:

a. it is usually aspheric to reduce aberration
b. the image formed is located at or near the first principal focus of the condensing lens
c. the stronger the condensing lens used the higher the angular magnification
d. the stronger the condensing lens used the larger the field of vision
e. when deliver laser photocoagulation through the condensing lens, the stronger the condensing lens the larger the laser spot magnification

7. During indirect ophthalmoscopy:

a. observer needs to accommodate to see clearly
b. image size in emmetrope remains the same irrespective of the position of the condensing lens
c. image size in myope increases when the condensing lens moves towards the eye of the patient
d. image size in hypermetrope decreases when the condensing lens moves towards the eye of the patient
e. image from myopic retina always falls within the second principal focus of the condensing lens

8. The following are true about the retinoscope:

a. two mirror systems are used: the plane mirror and the convex mirror
b. in the UK, most retinoscope gives a plane mirror effect when the condensing lens is moved down the shaft of the instrument
c. scissors shadows are usually seen in patient with widely dilated pupil
d. the speed of the reflex increases as the neutralization point is near
e. a myope who accommodates excessively during retinoscopy will result in a more myopic refraction

9. When using the plane mirror technique during retinoscopy:

a. a 'with' movement is neutralized with a plus lens
b. an 'against' movement is neutralized with a minus lens
c. a 'with' movement always indicates hypermetropia
d. an 'against' movement always indicates myopia
e. the neutral point occurs when the patient's far-point coincides with the observer's nodal point

10. The keratometer:

a. uses the cornea as a convex mirror in the measurement of corneal curvature
b. measures only the central 3 mm of the cornea
c. can be misleading in patients who have had corneal transplantation
d. doubles the central image to overcome the effect of eye movement
e. is more important in fitting soft contact lens than rigid gas permeable contact lens

11. The following are true about the keratometer:

a. in the Javal-Schiøtz instrument, the object size is fixed
b. in the Javal-Schiøtz instrument, each step of the mire is equivalent to 1/2 a dioptre
c. Wollaston prism is used in Javal-Schiøtz instrument
d. von Helmholtz instrument uses rotating glass plates to double the size of the image
e. the power of the cornea is equal to 337.5 divided by the radius of curvature in mm.

12. The slit-lamp:

a. is a low powered binocular compound microscope
b. contains prisms that shorten and invert the image
c. incorporates Galilean telescopes that are used to magnify the image
d. visualizes vitreous best with blue light
e. can be used to perform Watzke's sign

13. The following are true about the techniques used in slit-lamp:

a. uncoupling of the microscope and light source is needed in sclerotic illumination
b. specular illumination is best for visualizing the endothelium
c. the light and the microscope are co-axial in retroillumination
d. lateral illumination is best for visualizing the anterior capsule
e. diffuse illumination is best for visualizing iris atrophy

14. The Hruby lens:

a. is a powerful biconcave lens
b. gives a virtual, erect and diminished image
c. is useful for laser photocoagulation of the retina
d. requires a coupling solution in order to visualize the retina
e. forms retinal image between the lens and the observer

15. Regarding the indirect lens

a. 90D has a larger angular magnification than a 78D
b. 90D has a larger field of view than a 78D lens
c. superfield has a larger angular magnification than a 78D
d. panfundoscope gives a larger field of view than a 90D
e. panfundoscope gives a real erect image

16. The optical pachymeter (pachometer):

a. can be used to measure the corneal thickness as well as the anterior chamber depth
b. uses images I and II of Purkinje-Sanson's images to measure the corneal thickness
c. is more precise than ultrasound pachymeter
d. gives a thicker corneal measurement in the early morning than in the afternoon
e. can be used to decide if the ocular pressure recorded is spuriously high

17. The OCT (optical coherence tomography):

a. uses reflection of infrared light to obtain retinal image
b. provides a three-dimensional picture of the retina
c. can give resolution as small as 10 micrometer
d. can be used to detect subtle macular oedema
e. can be used instead of fluorescein angiography in deciding if a diabetic patient requires macular laser

18. Regarding the autorefractors:

a. which are currently available on the market show large variation in accuracy
b. Scheiner double-pinhole principle are used in all modern autorefractors
c. modern autorefractors are useful in checking binocular muscle balance
d. accommodation and the size of the pupil can affect the accuracy
e. photoscreening uses a polaroid camera to screen children at risk of refractive amblyopia

XIV. Optical instruments

1. a.T b.T c.T d.F e.F

The direct ophthalmoscope gives an angular magnification of 15X. The image formed is virtual and erect. The size of the optic disc when viewed through a direct ophthalmoscope is larger in myope than emmetrope which in turn is larger than in hypermetrope. Diabetic maculopathy is better detected with indirect ophthalmoscope.

2. a.T b.T c.T d.F e.F

The field of view refers to the retina that can be seen through the ophthalmoscope. It is about 6 degrees with a direct ophthalmoscope and 25 degrees through an indirect ophthalmoscope. The field of view is increased if the pupil is dilated and when the observer moves towards the patients. It is larger in hypermetrope than emmetrope which in turn is larger than in a myope.

3. a.T b.T c.T d.F e.T

The image formed by the indirect ophthalmoscope is real and inverted (both vertically and laterally). It is situated between the observer and the condensing lens. The image formed is affected by the refractive state of the patient but not to the same extent as with direct ophthalmoscope.

4. a.F b.T c.T d.T e.F

The field of view in indirect ophthalmoscopy is affected by:size of the observer's pupil diameter of the condensing lens ie. the larger the diameter, the greater the field of view the power of the condensing lens, a higher power gives a smaller magnification but greater field of view. The size of the patient's pupil affects the field of illumination.

5. a.T b.T c.F d.F e.F

Direct ophthalmoscope has the following advantages over indirect ophthalmoscope:

- easily portable
- image not inverted and
- larger magnification

On the other hand, indirect ophthalmoscope has the following advantages:

- binocularity
- higher field of view and the presence of teaching mirror

6. a.T b.F c.F d.T e.T

Aspheric lens is used to reduce aberration during indirect ophthalmoscope. The image formed is located at or near the second principal focus of the condensing lens.

The stronger the condensing lens used the lower the angular magnification but the larger the field of vision. However, the laser spot magnification increases the stronger the condensing lens used.

7. a.T b.T c.F d.F e.T

The image is formed 40 to 50 cm from the observer's eye and therefore accommodation is needed. The image size in emmetrope remains the same irrespective of the position of the condensing lens. In myope, the image size increases when the condensing lens moves away from the eye and decreases when the lens moves towards the eye of the patient. The reverse is true for hypermetrope.

The image from myopic retinal always falls within the second principal focus of the condensing lens, whereas that of the hypermetrope eye always falls outside the second principal focus of the lens.

8. a.F b.T c.T d.T e.T

The two mirror systems used are: the plane mirror and the concave mirror. In the UK, most retinoscope used gives a plane mirror effect when the condensing lens is moved down the shaft of the instrument. Scissors shadows result from a difference in refraction with the different zone of the pupil and is most commonly seen in dilated pupil. The speed of the reflex increases as the neutralization point is near. Excessive accommodation gives a myopic shift and therefore the result of refraction will be more minus.

9. a.T b.T c.F d.T e.T

With the plane mirror technique, plus lens is used to neutralize with movement and minus lens for against movement. While an against movement always indicates myopia, a with movement may be seen in myopic patient if the myopia is less than the dioptric value of the observer's working distance (for example at a distance of 2/3 m, a with movement is seen if the myopia is less than -1.50D. The neutral point occurs when the patient's far-point coincides with the observer's nodal point..

10. a.T b.T c.T d.T e.F

The keratometer uses the first Purkinje-Sanson's image. It measures only the central 3 mm and can be misleading in patients who had had radial keratectomy or corneal transplant. To negate the ocular movement, the central image is doubled during keratometry. Keratometry is important for contact lens fitting but more so for rigid gas permeable contact lens than soft contact lens.

11. a.F b.F c.T d.T e.T

In the Javal-Schiøtz instrument, the object is varied to give a fixed image size. Each step of the mire in Javal-Schiøtz instrument is equivalent to 1 dioptre of corneal power. Wollaston prism is used to double the image formed by reflection on the cornea. von Helmoholtz instrument uses rotating glass plates to double the image size. The power of the cornea is equal to 337.5 divided by the radius of curvature in mm.

12. a.T b.T c.T d.T e.T

The slit-lamp is a lower powered binocular compound microscope. It contains prisms that shorten the instrument and inverts the image. Galilean telescopes are used to achieve magnification. The vitreous is best viewed with blue and green light as it scatters more and allow vitreous to be better visualized. The slit-lamp can be used to detect the presence of macular hole using the Watzke's sign.

13. a.T b.T c.T d.F e.F

In sclerotic illumination, the light and the microscope are uncoupled and the light is focused on the limbus at 3 or 9 O'clock. It is a useful technique for visualizing fine corneal opacity. Specular illumination is useful for viewing endothelium.

In retroillumination, the light and the microscope are co-axial and it is best for visualizing iris atrophy and iris transillumination as in pseudoexfoliation syndrome and pigment dispersion syndrome.

Diffuse illumination is best for viewing the anterior capsule.

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14. a.F b.T c.F d.F e.F

The Hruby lens is a powerful plano-concave lens which gives a virtual, erect and diminished image. It is difficult to master and the image is too small for reliable photocoagulation. Coupling solution is not required as the lens does not come into contact with the eye. It is held with the concave side towards the patient. The image is formed within the eye.

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15. a.F b.F c.F d.T e.F

78D gives a larger angular magnification than 90D or superfield. Both 90D and superfield has the same angular magnification. The field of view is larger in a 78D than a 90D because the 78D has a larger diameter. The superfield has a larger field of view than 78D or 90D but smaller than panfundoscope. The panfundoscope gives a real inverted image.

16. a.T b.T c.F d.T e.T

Optical pachymeter can be used to measure both corneal thickness and the anterior chamber depth. Images I and II of Purkinje-Sanson images are used to measure the corneal thickness. Whereas II and III are used for the anterior chamber depth. Ultrasound pachymeter is more precise than optical pachymeter. The cornea tends to be thicker early in the morning on waking than during the day because of evaporation. A thicker cornea is associated with a higher ocular pressure reading. Correction can be done if the corneal thickness is known.

17. a.T b.F c.T d.T e.F

The OCT works along the same principle as ultrasound scan but uses infrared light instead. It gives a two-dimensional picture of the retina and can have resolution as small as 10 micrometer. It can be used to detect macular oedema such as following cataract surgery or diabetic retinopathy. While it can detect subtle macular oedema in diabetic maculopathy, it does not show the leakage point or the integrity of the capillary network. Therefore, fluorescein angiography is still needed to detect the leakage point in difficult cases and the presence of macular ischaemia.

18. a.F b.F c.F d.T e.T

The currently available autorefractors show little variation in accuracy. Scheiner double pinhole principle are used in some autorefractors but not all. Infrared optometers are also used. Binocular muscle balance cannot be measured with autorefractors. The accuracy of autorefraction is affected by the pupil size and accommodation. Photoscreening with a polaroid camera can be used to detect ametropia in children.

XV. Laser

1. The following are properties of laser:

a. it is entirely monochromatic
b. all the photons are in phase
c. all the photons have the same wavelengths
d. the waves of light are parallel
e. the distance between the mirrors within a laser tube is a multiple of the wavelength of the light emitted

2. The following are true about the modes of laser output:

a. both Q-switched and mode-locked mode increases the laser energy by compressing the energy in time.
b. mode-locked produces more power than either continuous or Q-switched mode
c. the duration of a pulse of laser produced by mode-locked mode is shorter than that of Q-switched mode
d. in Q-switched mode, a shutter is placed inside the laser tube to limit energy loss
e. laser from continuous mode has a constant power and is measured in watts

3. Regarding the Nd-YAG laser:

a. it emits infrared radiation
b. it is invisible
c. doubling its frequency makes it suitable for retinal photocoagulation
d. it is usually mode locked when used to treat the eye
e. it is used to create iridotomy

4. Regarding argon laser:

a. it produces a wavelength of between 488-514nm
b. argon blue laser is the preferred choice during photocoagulation
c. the xanthophylls in the macular absorbs argon green better than argon blue laser
d. a white burn is the end point during panretinal photocoagulation.
e. a higher energy is required for lighter than pigmented fundus

5. The following laser investigations can be used to monitor the progression of glaucoma:

a. confocal microscopy
b. laser interferometry
c. confocal scanning laser tomography
d. scanning laser polarimetry
e. laser Doppler flowmetry

6. True statements about laser safety include:

a. laser with output energy of 5mW or more is damaging to the eye
b. lasers of class 3a and above are detrimental to human eye
c. argon laser used for retinal photocoagulation is class 3b laser
d. the eye is more sensitive to laser damage than the skin
e. safety goggles are not necessary for visitors during YAG capsulotomy

XV. Laser

1. a. F b.T c.T d.T e.T

Laser is virtually monochromatic but not entirely so. It is coherent i.e. photons have the same wavelengths and in phase and collimated ie. the light waves are parallel. The laser tube contains two mirrors and the distance between them is a multiple of the wavelength of the light emitted.

2. a.T b.T c.T d.T e.T

There are three modes of laser: continuous, Q-switched and mode-locked. Laser from continuous mode has a constant power and is measured in watts. Q-switched and mode-locked increases the energy by compressing the energy in time and the energy is best measured in joules. Mode-locked laser compresses the laser more than Q-switched laser and therefore produces more energy.

3. a.T b.T c.T d.F e.T

Nd-YAG produces an infrared radiation with a wavelength of 1064nm. Another laser He-Ne is used to produce the red aiming beam. Doubling its frequency makes it suitable for photocoagulation. It is usually Q-switched when used to treat the eye. It is used to treat posterior capsular thickening following cataract surgery and create iridotomy for narrow angle glaucoma.

4. a. T b.F c.F d.F e.T

Argon laser can produce both blue and green light. The new argon laser limits the emission to green light which is not absorbed by the macular xanthophylls and therefore less damaging to the macula of both the patients and the doctors. During photocoagulation, the laser should just blanch the retina instead of heavy or white burn which increases the risk of visual field loss and reduced dark vision. Argon laser is well-absorbed by melanin and a pigmented fundus requires less power than a light fundus.

5. a. F b.F c.T d.T e.F

Confocal microscopy is used to study the cornea. Laser interferometry tests the potential visual acuity of a patient with dense cataract. Laser doppler flowmetry measures retinal capillary blood flow. Laser scanning polarimetry measures the thickness of the retinal fibre layer and can be used to monitor the progression of glaucoma. Confocal scanning laser tomography gives the topographic map of the optic nerve head and can be used to monitor glaucoma damage.

6. a.T b.F c.T d.T e.F

The International Safety Classification of Lasers divides the lasers into 4 groups. Group 3 is subdivided into 3a and 3b. Class 3b and above is damaging to the eye and their powers are 5MW and above. All lasers used in ophthalmology are classed as 3b and above. Safety goggles should always be worn by people in the vicinity.

XVI. Practical clinical refraction

1. During clinical refraction:

a. accommodation results in a more myopic prescription
b. the visual acuity is measured binocularly for distance and near
c. occlusion is recommended for patient with nystagmus to reduce the ocular movement
d. a high minus lens over the non-examining eye of a patient with bilateral congenital nystagmus can reduce the nystagmus
e. recent wearing of gas permeable lens may give erroneous results

2. The following tests depend on binocular vision:

a. Maddox rod
b. Maddox wing
c. Worth's four dots test
d. Duochrome tests
e. Bagolini's test

3. Fogging:

a. reduces or eliminates accommodation
b. brings the image behind the retina
c. uses strong plus lenses
d. is achieved by adding minus sphere power to plus corrections
e. is achieved by reducing minus sphere power in minus corrections

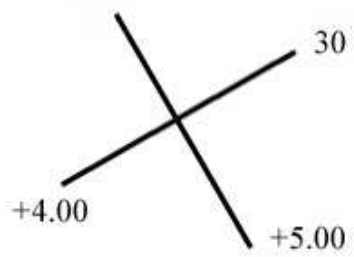
4. In objective refraction:

a. accommodation is stimulated if the patient stared at the light from the retinoscope
b. 'with' motion occurs in high myope if the sleeve of the retinoscope is placed in the plano mirror position
c. 'against' motion occurs in hypermetrope if the sleeve of the retinoscope is placed in the concave mirror position
d. movement of the reflex increases as the neutralization point is near
e. the power of the working distance lens in dioptres is proportional to the working distance in metres

5. Using minus cylinder during refraction :

a. avoids stimulation of accommodation in young hypermetropic patients
b. may overcorrect hypermetrope in the elderly
c. may overcorrect hypermetrope in cycloplegic refraction
d. may undercorrect myope patients
e. is a major cause of spectacle intolerance

6. The following is the power cross of a patient examined at 2/3 meters (before correcting for the working distance):



a. when a streak retinoscopy is used to neutralize the eye at 30^0 the power of the lens needed is +4.00
b. if the patient were to accommodate the power cross will have a higher plus power
c. if a +5.00DS lens is placed in the trial frame; a -1.00DC is required to neutralize the eye at 120^0
d. the corrective lens can be +2.50/+1.00 X 30
e. the corrective lens for this patient if the working distance is 1/2 m can be +3.00/-1.00X 120

7. In subjective refraction:

a. the spherical power should be tested before the cylinder
b. the axis of the cylinder should be verified before the power
c. Duochrome test should be only performed when the spherical power is corrected to within 1 D of emmetropia
d. if the letters against the green background appear clearer on the Duochrome test, more plus correction or less minus correction is indicated.
e. Maddox rod test is useful in patients with manifest squint

8. The interpupillary distance:

a. can be measured using the corneal reflex
b. can be measured by noting the distance between the nasal limbus of one eye and the temporal limbus of the other
c. used in making spectacle is 1 mm less than the anatomical interpupillary distance
d. for a patient with accommodative esotropia is the distance between the two corneal reflexes without spectacle correction
e. for a patient with intermittent exotropia is the distance between the two corneal reflexes when the two eyes are in primary position

9. A 42 year-old myopic man recently changes his glasses and find them uncomfortable despite having a visual acuity of 6/6 in both eyes. The following may be responsible:

a. over-correction of myopia
b. onset of presbyopia
c. change of lens form
d. change of axis
e. decentration of the lens

10. Regarding refraction in children:

a. myopia is more common than hypermetropia
b. refractive amblyopia can occur if there is more than 1.5 dioptre of hypermetropic anisometropia
c. increased accommodation is used by children to overcome uncorrected hypermetropia
d. myopia tends to progress as the child grows older
e. correction of hypermetropia can reduce exophoria

XVI. Practical clinical refraction - Answers

1. a.T b.F c.F d.F e.T

Accommodation causes myopic shift.

The visual acuity is examined uniocularly for distance and near.

Occlusion of one eye in congenital nystagmus worsens the nystagmus. Fogging with a high plus lens is recommended.

Contact lens especially gas permeable lens can cause corneal warpage give false refractive results.

2. a.T b.T c.T d.F e.T

Duochrome does not require binocular vision.

3. a.T b.F c.F d.F e.T

Fogging is used to reduce or eliminate accommodation. It brings the image in front of the retina so that accommodation blurs the image further. It is achieved by adding a limited amount of plus sphere power to plus corrections or by reducing minus sphere power in minus corrections. The end point is the most plus power, or least minus power, that gives the best vision.

4. a.T b.F c.T d.T e.F

In objective refraction, accommodation is reduced by getting the patient to look at the distance or using cycloplegic drug. 'With' motion occurs in hypermetrope and 'against' motion occurs in high myope if the sleeve of the retinoscope is placed in the plane mirror position. The reverse occurs if the sleeve of the retinoscope is placed in the concave mirror position. The power of the working distance lens in dioptre is inversely proportional to the working distance in metres.

5. a.T b.T c.T d.F e.F

The use of minus cylinder in young hypermetrope prevents stimulation of accommodation but may overcorrect hypermetrope in the elderly and when performing cycloplegic refraction.

6. a.F b.F c.T d.T e.T

The power is 90 degrees from the axis and when the retinoscopy is used to neutralize the eye at 30 degrees, the required power will be +5.00D.

Accommodation causes a myopic shift resulting in a lower plus power during refraction.

The working distance lens is -1.50 for 2/3 metres and -2.00 for 1/2 metres.

7. a.T b.T c.T d.T e.F

The spherical power should be verified before the cylinder and the axis of the cylinder should be verified before its power. Maddox rod is used to check muscle balance for distance.

8. a.T b.T c.T d.F e.T

The interpupillary distance is important to avoid decentring the optical axis which can cause spectacle intolerance. The distance is shorter for reading than distant glasses. For a patient with accommodative esotropia, it is important to have the eyes in primary position before measuring the interpupillary distance. This can be achieved with either the correcting lenses in place or using cover test.

9. a.T b.T c.T d.T e.T

Onset of presbyopia may make reading difficult especially if the patient is over-corrected. Myope tends to be less tolerant of a change in lens form and axis of the cylinder. Decentration of the lens causes prismatic effect.

10. a.F b.T c.T d.T e.F

Hypermetropia is more common than myopia amongst UK children. It is recommended that hypermetropic anisometropia of more than 1D should be corrected because of the risk of refractive amblyopia. Increased accommodation is used by children to overcome uncorrected hypermetropia; as accommodation is associated with convergence accommodative esotropia can result. As children grow older, the axial length of the eye increase leading to more myopia. Correction of myopia can reduce exophoria due to stimulation of accommodation.

XVII. Refractive surgery

1. The refractive state of the eye may be altered by:

a. paralysing the ciliary muscle
b. changing the depth of the anterior chamber
c. removing the vitreous
d. increasing the thickness of the lens
e. changing the axial length of the eye

2. Monovision:

a. refers to the use of one eye for distant vision and the other for near
b. is mainly reserved for presbyopic patients
c. requires one eye to be made hypermetropic and the other myopic
d. reduces visual acuity
e. reduces stereopsis

3. The following are contraindications to refractive surgery:

a. age less than 21
b. keratoconus
c. discontinuation of gas permeable lenses wear for less than ten weeks
d. tilted disc
e. irregular astigmatism

4. Photorefractive keratectomy:

a. uses excimer laser made up of ultraviolet radiation
b. uses thermal energy for reshaping the corneal contour
c. corrects myopia by flattening the central cornea
d. causes more stromal scar in high myope than low myope
e. is less predictable for high myope than low myope

5. LASIK is superior to photorefractive keratectomy in that it :

a. is a less painful procedure
b. gives a faster visual rehabilitation
c. can treat a higher myopia
d. has less complication
e. has less myopic regression

6. LASIK:

a. is contraindicated in patients with thin cornea
b. involves the use of microkeratome
c. involves the creation of a complete circular flap
d. can be repeated by lifting the flap created if further refinement is necessary
e. causes less scarring than photorefractive keratectomy

7. The side-effect of LASIK include:

a. reduced corneal sensation
b. inaccurate biometry if the patient requires cataract surgery in later life
c. tear film abnormality
d. erroneously high intraocular pressure with applanation tonometer
e. glare

8. Radial keratotomy:

a. is an irreversible procedure
b. weakens the cornea
c. is used to reduce the refractive power of the cornea
d. is used to increase the refractive power of the cornea
e. flattens the central cornea

9. Radial keratotomy:

a. involves incisions with depth which are at least 80% of the corneal thickness
b. has a greater effect the deeper the incision
c. has a greater effect the longer the cut
d. has a greater effect the smaller the central zone
e. is more predictable than LASIK in treating myopia

10. Temporal corneal incision during phacoemulsification has the following advantages:

a. easier access to the eye
b. reduced incidence of endophthalmitis
c. less surgically induced astigmatism
d. increased surgical view
e. decreased incidence of epithelial downgrowth

11. The following are true about astigmatic keratotomy:

a. the incision is placed perpendicular to the steepest meridian
b. it causes coupling
c. the nearer the incision to the centre the greater the reduction of astigmatism
d. if astigmatic keratotomy were performed for a phakic patient, the site of incision should be based on the corneal topography
e. astigmatic keratotomy can be carried out either as a transverse or arcuate incision

12. The advantages of arcuate incision over transverse incision in astigmatic keratotomy include:

a. more uniform relaxation of the cornea
b. cutting a more uniform thickness of the cornea
c. the entire length is at the same distance from the calculated central zone
d. actual incision length is about 10% longer than a linear incision spanning the same number of degrees
e. reduced risk of post-operative keratitis

13. When a tight suture is placed radially in the cornea, the following may occur:

a. the cornea adjacent to it is flattened
b. the curvature of the cornea along that meridian is increased
c. the curvature of the cornea at 90^0 to that meridian is decreased
d. the effect on corneal curvature is increased if the suture is deep
e. the effect on corneal curvature is increased if the suture is nearer the centre of the cornea

14. The following are true about intrastromal corneal ring:

a. it can be used to treat myopia
b. it can be used to treat hypermetropia
c. it is made up of PMMA
d. it is a reversible procedure
e. it involves the use of keratome

15. The following involves the use of donor cornea:

a. epikeratophakia
b. keratomileusis
c. keratophakia
d. lamellar keratoplasty
e. penetrating keratoplasty

16. In a patient who has had vitreoretinal surgery:

a. buckling causes a hypermetropic shift
b. buckling induces astigmatism
c. cataract formation is a common complication with macular hole surgery
d. injection of air into the vitreal cavity of a phakic patient causes a myopic shift
e. injection of air into the vitreal cavity of an aphakic patient causes a a hypermetropic shift

17. The effect of silicone oil in an eye include:

a. reducing the hypermetropic power of an aphakic eye
b. causes a myopic shift in a phakic eye
c. increases the speed of ultrasound passing through it
d. band keratopathy
e. glaucoma

XVII. Refractive surgery - Answers

1. a.T b.T c.F d.T e.T

Paralysing the ciliary muscle will reduce the plus power of the lens and make the patient less myopic or more hypermetropic. Changing the depth of the anterior chamber will alter the effectivity of the lens and hence the refractive power.

Vitreous is made up of 99% water and its removal does not significantly affect the refractive index of the vitreous, unless the vitreous space is filled with silicone oil or gas.

Increasing the lens thickness increases its refractive power.

The axial length of the eye is one of the factors that determine the ocular refractive power.

2. a.T b.T c.F d.T e.T

Monovision uses one eye for distant vision and the other for near (usually the non-dominant eye). It is reserved for presbyopic patients. One eye is made emmetropic and the other myopic. However, 50% of patients have problems with monovision. As the patient can not use both eyes, the visual acuity and the stereopsis are reduced.

3. a.T b.T c.T d.F e.F

Before refractive surgery is carried out, it is important to make sure that the corneal topography is stable. Therefore, it is contraindicated in children and young adults whose refractive error has not stabilized and also patients who has recently worn contact lenses in which the corneal topography may be affected by warpage.

Keratoconus is associated with thin cornea and refractive surgery may accelerate the progression.

4. a.T b.F c.T d.T e.T

Photorefractive keratectomy uses excimer laser that works by breaking the molecular bonds. It reduces myopia by reducing the corneal curvature. It is more effective for low myope. Stromal scar is more common in high myope.

5. a.T b.T c.T d.F e.T

As LASIK does not expose raw corneal surface at the end of surgery it is less painful. It can also treat a higher myopia, causes less scarring and has less myopic regression. However, because a flap need to be created, it has a higher potential risk.

6. a.T b.T c.F d.T e.T

Thin cornea is a contraindication to LASIK. Cutting the cornea too deep or treating a patient with thin cornea may give rise to cornea ectasia. Microkeratome is used to create a flap which has a hinge. Excimer laser is used to treat the stroma underneath the flap. It causes less scarring than photorefractive keratectomy.

7. a.T b.T c.T d.F e.T

Reduced corneal sensation and tear film instability are side-effects of LASIK. Glare may result from scarring or too small an optic zone. Biometry can be inaccurate unless correction of the corneal topography is taken into account. LASIK gives rise to a thinner cornea and may give an erroneously low intraocular pressure with applanation tonometer.

8. a.T b.T c.T d.F e.T

Radial keratotomy involves cutting the cornea radially and this gives rise to gaping of the wound and flattening of the cornea. It is used to treat myopia and astigmatism but not hypermetropia. The refractive power of the cornea is reduced. A cornea which has had radial keratotomy is at an increased risk of rupture during blunt trauma along the incision line.

9. a.T b.T c.T d.T e.F

The depth of radial keratotomy is typically between 80-90% in depth. Its effect is greater if the cut is deeper, longer and the central zone smaller. It is less predictable than LASIK and the refraction takes longer to stabilize.

10. a.T b.F c.T d.F e.F

Temporal incision has the advantages of easier access to the eye as the brow is not interfering with manipulation of the instruments. And as the central cornea is further from the temporal limbus than the superior limbus, the induced astigmatism is less. The other advantages do not apply.

11. a.T b.T c.T d.F e.T

Astigmatic keratotomy is placed perpendicular to the steepest meridian. Coupling is a problem and it is defined as steepening of cornea at 90 degrees perpendicular to the meridian that has been flattened by the incision though not to the same degree. The nearer the incision to the central zone, the greater the effect. However, it carries the risk of glare and irregular astigmatism if the incision is made too near the centre of the optical zone. It is generally advised that the incision is made 6-7mm from the centre of the cornea.

Astigmatism in a phakic eye may be due to cornea and/or lens. Corneal topography only provide information on corneal astigmatism. It is important to obtain the refraction result to understand the total astigmatism.

12. a.T b.T c.T d.T e.F

Both transverse and arcuate keratotomy can be used in astigmatic keratotomy. The advantages of arcuate incision over the transverse incision include: more uniform relaxation of the cornea cutting through a more uniform thickness of the cornea, the entire length is at the same distance from the calculated central zone also the acute incision length is about 10% longer than a linear incision spanning the same number of degrees.

Keratitis is a complication but is not related to the type of incision performed.

13. a.T b.T c.T d.T e.T

A tight suture flattens the cornea adjacent to it but increases the corneal curvature along that meridian. The curvature of the cornea at 90 degrees from it is decreased due to coupling. A deeper suture and one nearer the centre of the cornea has more effect on the corneal curvature.

14. a.T b.F c.T d.T e.F

Instrastromal corneal ring is used to flatten the cornea and thereby reduces its refractive power. It is used in the treatment of myopia. The ring is made up of PMMA. The ring is inserted following the creating of a tunnel. It can be reversed by removing the ring.

15. a.T b.F c.T d.T e.T

Epikeratophakia involves the suturing of a pre-shaped donor corneal stroma to the surface of the host cornea.

Keratomileusis involves the use of microkeratome to remove a lamella of anterior corneal stroma which is reshaped on a cryolathe and replaced.

Keratophakia involves the use of keratome to lift a lamella of anterior stroma and this is replaced over a shaped lenticule of donor corneal stroma.

Lamellar and penetrating keratoplasty are partial thickness and full thickness corneal grafts respectively.

16. a.F b.T c.T d.T e.T

Buckling increases the length of the eye and hence a myopic shift. Buckling if placed asymmetrically can induce astigmatism. Gas used in macular hole often induces cataract. Air or gas injected into the eye increases the refractive power of the back surface of a phakic eye and causes a myopic shift. In aphakic eye, the air increases the diverging power of the back surface of cornea and causes a hypermetropic shift.

17. a.T b.F c.F d.T e.T

Silicone oil has a higher refractive index than the crystalline lens and causes the posterior surface of the lens to become a diverging rather than a converging interface. As a result, a hypermetropic shift occurs. In an aphakic eye, the silicone oil acs as a converging interface and causes a myopic shift. Hence, the hypermetropia caused by aphakia is reduced by silicone oil. Silicone oil reduces the speed of ultrasound and will therefore gives a erroneously longer axial length. Band keratopathy and glaucoma are known complications of silicone oil.

Test your basic knowledge of clinical refraction

1. Retinoscopy is used to determine ___ the refractive state of the eye.

2. There are two types of retinoscope: ____ and ____ retinoscope. The ___ retinoscope projects an oblong streaks into the patient's eye and is therefore easier than the __ retinoscope in determining an astigmatic error.

3. During retinoscopy, the movement of the reflex is observed. If the reflex moves in the same direction as the retinoscope, this is called with movement and we add ___lenses and the eye is ___ at this working distance.

   If the reflex moves in the opposite direction to the retinoscope, this called against movement and we add ____ lenses and the eye is ____ at this working distance.

4. A retinoscope is made up of a light source, a condensing lens and a mirror. Although the image on the patient's retina moves in the same direction as the retinoscope light is moved on the patient's eye. This image ie reflex will appear to the observer to move in either the same direction ie. with or in the opposite direction ie. against.

   Two factors affect the movement of the reflex and there are:
   a. _____
   b. _____

5. In retinoscopy at the end point (also called neutrality), the pupil of the patient is suddenly filled with light and ____ motion is observed.

   Neutrality of the reflex occurs when the far point of the patient's eye coincides with the nodal point of the examiner's eye.

6. An examiner working at 67cm (2/3 m) will observe an against motion when refracting a -2.00D myopic patient (without any lenses being placed in front of the patient). When refracting the same eye at a working distance of 50cm he observes neutrality. When the examiner moves to 40 cm he will observe ____ of the eye.

7. So far the movement of the reflex applied to divergent light from the retinoscope. If the light is convergent when it strikes the eye, all relative movements are reversed.
   Therefore, with convergent light from the retinoscope, a with movement indicates that the eye is ____ at the working distance and an against movement indicates that the eye is ____ at the working distance.

8. The vergence of the light can be changed in streak retinoscope. In the UK, the light emergences from the retinoscope with the handle down is ____ and is ____ with the handle up.

9. The examiner can select any distance at which to work, but in general 67 cm or 50 cm is used depending on the length of the examiner's arm.

   If using 67cm, neutrality without lenses means that the eye is 1.50 D ___ and an emmetropic eye requires ____ lens for neutrality. Therefore the total power must be adjusted by ____ if using 67cm.

   If the working distance is 50 cm, the total power found at neutrality must be adjusted by substracting ____.

10. Using the streak retinoscope with the handle down, a with movement is observed without lenses at the working distance of 67cm.

    There are three possibilities:

    a. myopia of less than ____
    b. ____
    c. ____

11. An against motion is observed with a streak retinoscope (handle down) at a distance of 67cm. The patient is ___ and he requires a lens greater than ___.

12. As neutrality is approached, the reflex becomes ____, ____ and ____. When the refractive error is neutralized, the pupil is suddenly filled with light.

13. One can verify the neutral point by moving forward a few cm and then backward a few cm. As he moves forward (with the handle down), there would be ___ motion and as he moves backward, there would be ___ motion.

14. The final refractive power is adjusted for the working distance. If the working distance is 67cm, the net retinoscopy will ___ D less hypermetropic or more myopic than that obtained from the retinoscopy.

15. When the retinoscopy reveals +2.00-1.75 X 180 at working distance of 67cm, the final refraction will be ____. This cylinder portion of the correction is ____.

    If the retinoscopy reveals neutralization at +0.50 -1.00 X 90 at 50cm, the final refraction will be ____.

16. During retinoscopy, you may neutralize one meridian with sphere and the other with the cylinder; or alternatively you can use spheres to neutralize the two meridians.

    Example 1:
    If you are working at a distance of 67cm, and you find that with the streak at 90 degrees +2.00 D sphere neutralized the reflex; with the streak at 180 degrees (with the sphere in place) a -2.00D cylinder neutralizes the reflex. The patient's final refraction is ____.

    Example 2:
    Your working distance is 50cm, and you find that with the streak at 45 degrees, -1.00D sphere neutralized the reflex, with the streak at 135 degrees (with the streak in place a -1.50 D cylinder neutralizes the reflex. The patient's final refraction is ____.

17. You may use sphere to neutralize both axis.

    Example 1:
    With the streak at axis 45 degrees a -3.00D lens neutralizes the reflex
    With the streak at axis 135 degrees, a +2.00 lens neutralizes the reflex.
    The result of the retinoscopy is ____ /-5.00 X 45.
    If the working distance is 67cm, the final refraction is ___.

    Example 2:
    With the streak at axis 90 degrees, a +3.00D lens neutralizes the reflex
    With the streak at axis 180 degrees, a +6.00D lens neutralize the reflex
    The result of the retinoscopy is +6.00 /____X 90.
    If the working distance is 67 cm, the final refraction is ____

    Example 3:
    With the streak at axis 45 degrees, a -1.00 D lens neutralizes the reflex.
    With the streak at axis 135 degrees, a -2.00D lens neutralizes the reflex.
    The result of the retinoscopy is -1.00D/ -1.00 X ____.
    If the working distance is 67 cm, the final refraction is ____.

18. In patients with dilated pupil, the reflex in the periphery of the pupil may be opposite in motion to that in the central area of the pupil. This results from the difference in _____ of the lens periphery. To gain an accurate result, only the _____ should be regarded.

Test your basic knowledge of clinical refraction

1. Objectively

2. Streak and spot; streak; spot.

3. Plus; hypermetropic; minus; myopic.

4. The working distance; refractive state of the patients.

5. No.

6. With.

7. Myopic; hypermetropic.

8. Divergent; convergent.

9. Myopia; +1.50D; 1.50D; 2.00D.

10. -1.50D; emmetropia or hypermetropia.

11. Myopic; -1.50D.

12. Faster, brighter and thinner.

13. With; against.

14. 1.50D.

15. +0.50 -1.75 X 180; unchanged; -1.50 -1.00 X 90.

16. Example 1: +0.50 -2.00 X180 (after taking away 1.50D).
    Example 2: -3.00D -1.50D X135 (after adding -2.00D).

17. Example 1: +2.00; +0.50 -5.00 X 45.
    Example 2: -3.00; +4.50 -3.00 X 90.
    Example 3: 135; -2.50 -1.00 X 135.

18. Refractive power; central portion.

Steps in clinical refraction

In refraction, the examiner detects ametropia with retinoscope and subjective refraction. The following are summary of the steps taken for refraction. A form for recording the findings is given at the end of the steps.

Summary of the steps for refraction

1. History of relevant.

2. Objective refraction

3. Subjective refraction:
- *check spherical power*
- *checkcylinder axis*
- *check cylinder power*
- *check spherical power*

4. Duochrome and binocular balance test

5. Near vision.

6. Muscle balance tests (Maddox tests: rods and wing).

1. Take a brief history:
   - ❖ Age of the patient.
   - ❖ Occupation and hobby.
   - ❖ Does the patient wear spectacle.
   - ❖ Any previous eye surgery including cataract and strabismus surgery.
   - ❖ History of diabetes and glaucoma.

The history is important as it will give you an idea if:

- ❖ The patient has normal vision ie. if you could achieve 6/6 vision.
- ❖ Need to check Duochrome or binocular balance tests. Aphakic, pseudophakic and patients over 50 have no or little accommodation making the tests\unnecessary.

2. Record the unaided vision in both eyes and put on the trial frame and adjust the distance.

3. Retinoscope both eyes and make sure you keep the same distance through out and facing the patient perpendicularly.

Tips:

- You need to know your working distance before the examination. Find out how long your arm is and this will give a rough area of the working distance. Avoid changing the working distance as this may give an inaccurate results. (Working distance of 1/2m = +2.00D; 2/3m = +1.5D and 1m = +1D)

Working distance (D) = 1/ (working distance in metre)

- It is also important to be facing the patient perpendicularly otherwise the retinosocopy may give spurious astigmatic results. Learn to refract with both hands so that you refract the patient's right eye with your right hand and right eye and the patient's left eye with your left hand and eye.

4. Check the axis and power needed to neutralize each meridians. You can either neutralize the ametropia with two spherical lenses or use a spherical lens and a cylinder lens. To do the later, the spherical lens is left in place after one meridian has been neutralized. This has the advantages of avoiding the need for drawing up the power cross and simplify the calculation (however, some examiners may ask for the power cross durin the examination.)

Tips:

- If the reflection of the pupil is difficult to see, the patient may have either high refractive error, the room light is too bright or the there are media opacity such as cataract.

- Do not waste valuable time using small increment of +/-0.25 D of either spherical or cylindrical power to neutralize the ametropia. Use an increment of +/-0.50 or 0.75D until the movement changes direction then chooses the lens of an opposite sign.

- One common mistake during refraction is to confuse the axis. This happen more commonly with neutralization with two spherical lenses then with a spherical and a cylindrical lens. Remember that when the streak is moved up and down, it is the vertical meridian that is neutralized and the axis is 180^0. When the streak is moved sideway ie. left to right, the horizontal meridian is neutralized and the axis is 90^0. (see the questions at the end to test your understanding).

5. Take away the working distance and check the subjective refraction. Begin with the spherical power.

   Asked the patient to look at the Snellen chart and present the patient with two choices (+/-0.25D) and ask which one appear clearer. Repeat the process until the patient finds the two choices are equivalent.

> Tips:
> - ❖ It is important to give clear instruction. There is a tendency for the myopes to choose stronger minus lens. 'I am going to give you two choices lens 1 and 2. Tell me which of the lenses are better or there are no differences.' If the patient goes for the minus lens, ask ' Are the letters clearer or are there just smaller and darker?' If the letters are smaller and darker don't add the minus lens.

6. Continue with subjective refraction by checking the cylinder axis and power. If vision is 6/9 or better refer patient to circles on the white background and use the cross cylinder (0.50 which gives +/- 0.25). If vision is 6/12 or less use the 1.00 cylinder (which gives +/- 0.50)

   i. Check cylinder axis.

   Hold handle parallel to trail frame cylinder axis. Rotate the cross cylinder and ask 'I am going to give you two choices. Tell me which one make the circle rounder or more circular. Position 1 or position 2?' If a selection is made, rotate the trail frame cylinder axis towards the negative preference (assuming a negative cylinder is used otherwise rotate it towards the positive preference) and repeat until the two positions appear similar. This is the correct cylinder axis.

   ii. Check cylinder power.

   Hold the handle at 45^0 to the trail frame cylinder axis such that the cross cylinder axes are superimposed as the handle is rotated.' Which is better 1 or 2?' If better with the negative cylinder axis superimposed increase the power of the negative cylinder. If better is reported with the positive cylinder side superimposed, decrease the power of the negative cylinder in the trail frame. Repeat until equality is reported in 1 and 2. This is the correct cylinder power.

> Tip:
> - ❖ If cylinder is changed by 0.50D, change spherical power by 0.25 to maintain best vision. For example extra -0.50D, add +0.25D to the sphere.

7. Complete the subjective refraction by referring back to the letter chart and check the spherical power again (Remember to give maximum positive sphere equal to best visual acuity and minimum negative sphere).

8. Duochrome test. This will tell if the patient has been given too much minus or too much plus in the spectacle correction. Ask the patient to look at the letters in red and green background and comment which colour appear clearer. If the green ones appear clearer, there are too much minus power so take away the minus power. If the red ones are clearer, there are too much plus power take away the plus power. The test is not accurate if the patient accommodates.

9. Binocular balance procedure is performed. In monocular refraction one aims to obtain the maximum positive correction with the accommodation fully relaxed. However, if the eye not being examined accommodates behind the cover, then the maximum correction will not be achieved. Binocular balancing is a check for this small amount of accommodation. The most likely adjustment to the spherical correction therefore is a small addition of positive power. It is not needed if the patient is above 50 (due to loss of accommodation) or pseudophakic.

   There are several methods of achieving binocular balancing. The prism dissociation test is the classic test but often confusing for the patient. A better and less confusing test is described in b.

   a. Prism dissociation balance.

   Fog the eyes (with the correcting lenses in place) using +0.75DS lenses. Place a 3 dioptre base up prism in the right trial frame and a 3 dioptre base up prism in the left trial frame. A single line of 6/12 is projected on the wall. The patient will perceived two lines (the right eye will see the lower line and the left eye the top). If the two eyes are balanced, the two lines will be equally blurred. Otherwise, add minus to worse eye or plus to better eye until each image is equally blurred. Once the balance between the two eyes are achieved, the prisms are removed. The fogging lenses are reduced simultaneously from the two eyes in step of 0.25. The end point is reached when the best vision (6/6) is achieved with the lowest minus or the highest plus spheres.

   b. With the patient binoculary viewing a block of letters at a 6 m distance.

   Add +0.25 D binocularly. The patient should report a slight blur of the 6/6 letters. Add an additional +0.25D binocularly. The patient should now eport that the 6/6 letters are badly blurred. Add a third +0.25D binocularly. The patient should report that the 6/6 letters are completely blurred out. If the 6/6 letters can still be easily readable with +0.75D added to the binocular subjective finding, the patient's accommodation was not completely relaxed during the subjective examination. However, if the 6/6 letters are blurred out with only +0.25D, it is possible that too much plus has been added in the subjective examination.

10. Check the near add. While one may use the age to decide on the amount of adds given, a more satisfactory result will depend on how far the patient wishes to read.

11. Check the muscle balance for distance and near.

Use the Maddox rods for distant muscle balance test. The Maddox rods consists of a set of parallel cylindrical glass rods used in testing for heterophoria. With the correction in the trial frame. Place the Maddox rods in the right frame and ask the patient to look at a white spot in a dark room. A vertical red line will be seen through the right eye when the striations are orientated horizontally and a horizontal red line seen when the striations are orientated vertically. Ask the patient to comment on the position of the line with respect to the white dot. Use the prism to bring the line so that it passes through the centre of the dot. This is the amount of heterophoria.

Tip:

- ❖ Ask patient to comment on position of line as soon as it is seen, line often moves with time. The same applied to Maddox wing. The tests measures both tropia and phoria. You may want to perform a quick cover test before the start of this test for any tropia.

Use the Maddox wing to test the near heterophoria. The white arrow indicates the amount of horizontal phoria and the red arrow the vertical phoria.

Candidate name:

Candidate number:

Name of Patient:

Age:

Relevant medical history:

Occupation or hobbies:

Right **Left**

Visual acuity:

Retinoscopy findings

Subjective refraction:

Muscle Balance

Final prescription:

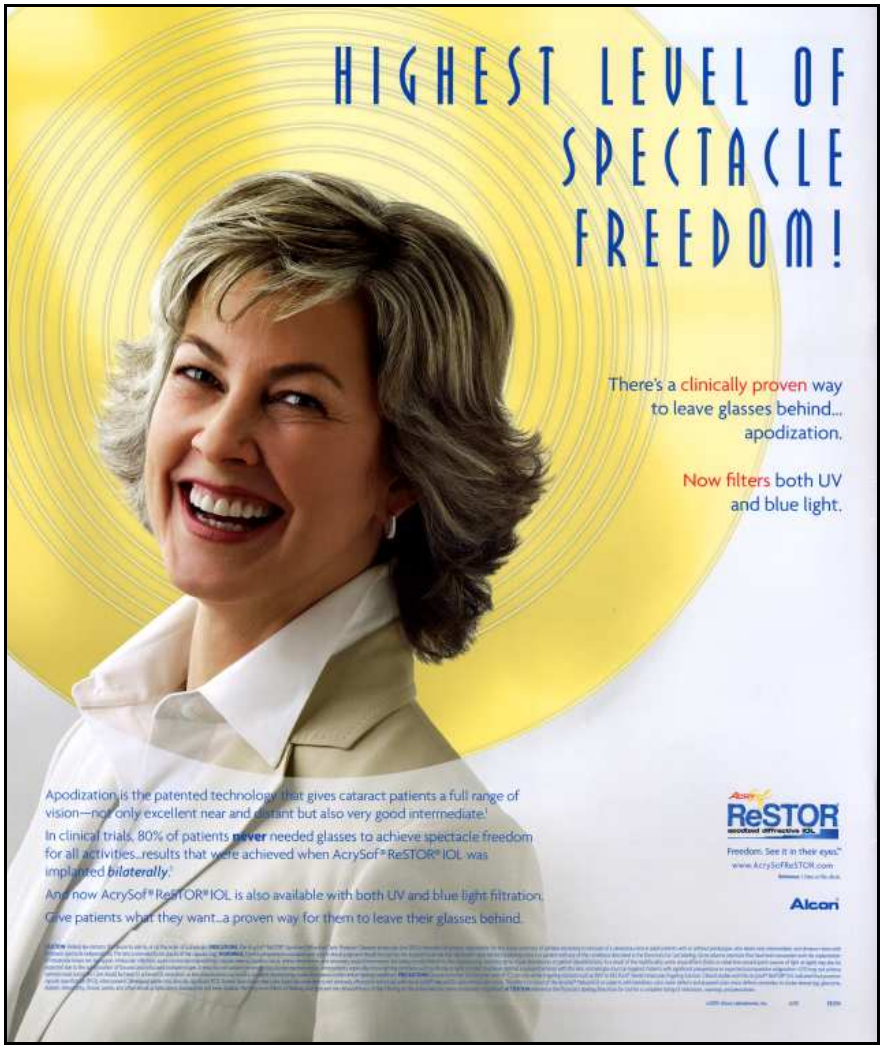
Right eye

	Sph	Cyl	Axis	Prism	Base	VA
Distance						
Near						

Left eye

	Sph	Cyl	Axis	Prism	Base	VA
Distance						
Near						

Others relevant information (e.g. BVD)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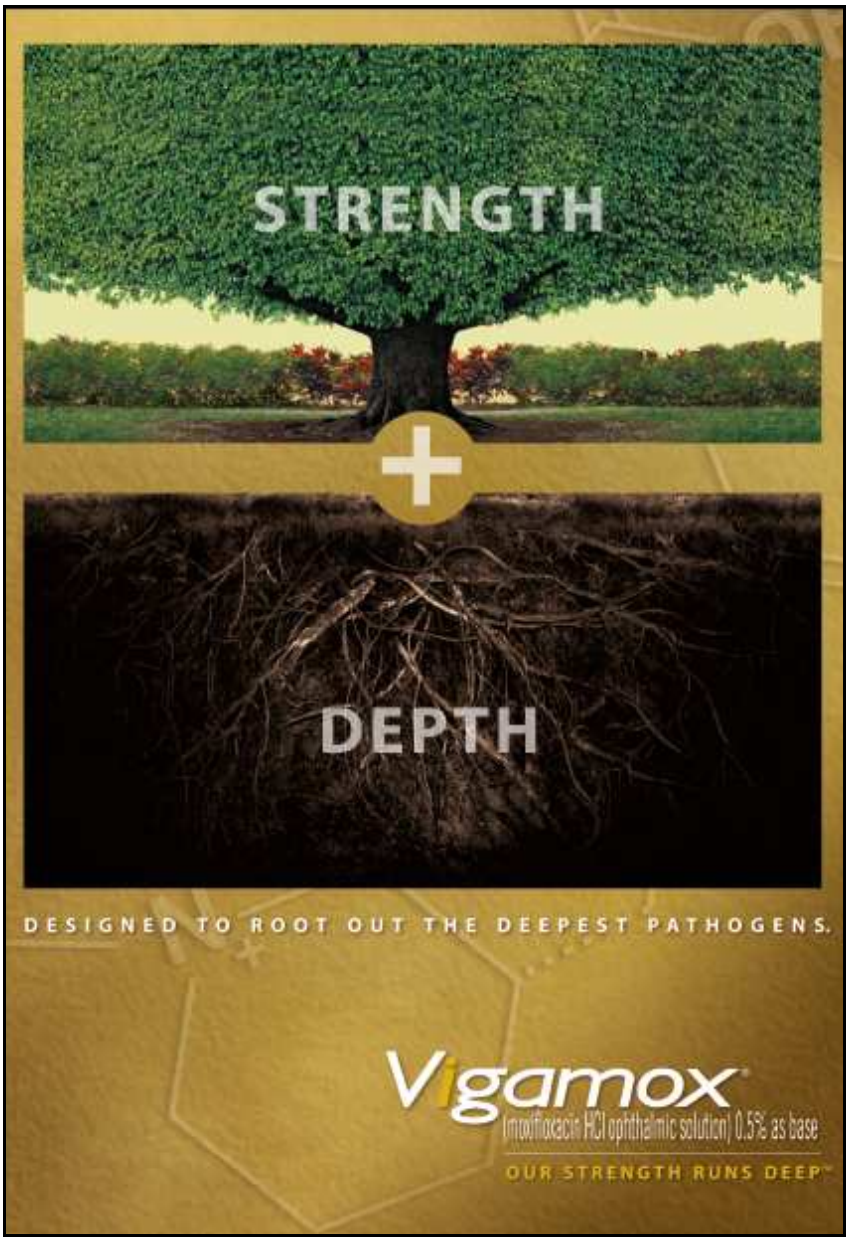
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