

# Decoding the Snellen's Chart

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## Abstract

This article deals with the basis of visual acuity and the Snellen's Chart. The principles of trigonometry are applied in order to break down the science behind the Chart, and the laws of optics and refraction are used to build back the chart from scratch. The principle behind the construction of each optotype, and using the Snellen's chart in the clinic are explored.

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Conceived in the mind of Dutch ophthalmologist Herman Snellen in 1862, the Snellen's chart is most widely used visual acuity chart in ophthalmology clinics across the globe. Since its conception, the Snellen's visual acuity chart has met a lot of criticism, yet continues to be single most applied method to test a person's vision throughout the world for two main reasons - reproducibility, and ease of usage.

Visual acuity is loosely defined as the ability of the eye to discriminate two adjacent points as distinct. For the eye to make this discrimination, the minimum separation of the two points should be 1' of arc at the nodal point of the lens. The nodal point is roughly located between the anterior 2/3rd and the posterior 1/3rd of the lens.

## Recording Visual Acuity

Visual acuity using the Snellen's chart is recorded as a fraction, separately for each letter. The numerator denotes the distance at which the eye being tested perceives the letter, while the denominator denotes the distance at which a normal eye can perceive the letter.

For example, a vision of 6/60 means that a normal eye can read the letter on the 6/60 even at 60 metres, but the eye that is being tested can read the letter only at 6 metres.

The convention is to check the right eye first, but some schools of thought say that the eye with worse subjective vision should be tested first. Either way, vision in each eye should be tested while the opposite eye is closed, and the patient reads each line on the chart from above downwards.

## Optotypes of the Snellen's Chart

Each letter on the Snellen's chart is called an optotype and each optotype is made of a square-type font. Not all the letter of the alphabet can be printed in such a way as to meet the requirements of the chart, so only a few select letters are used in the common chart: E, C, F, D, O, P, L, N, Z, T. A few other letters are also occasionally found: H, K, R, U, V.

A complex mix of mathematics and optics go into the successful construction of an efficacious Snellen's chart. For the purposes of this article, we will use trigonometry formulas to try and recreate the optotypes of the Snellen's chart. The statement that governs the whole of Optics reads as follows. 'The smallest letter on the chart seen from a particular distance will subtend an angle of 5' at the nodal point.'

We will treat this statement as absolute fact, and use it as the basis of recreating each line of the chart, starting from the largest letter on the chart.

minimum angle of resolution of the eye = 1 arc minute

1 arc minute = 1/60th of a degree

1 degree = 60 arc minutes

According to the statement, at 60 metres, the angle subtended by the 6/60 line would be 5' of arc, with each limb of the letter subtending an angle of 1' of arc.

Therefore, to construct the 6/60 line, we need the dimensions of the letter in usable physical measurements.

Applying the laws of trigonometry,  $\tan\theta = \text{opposite/adjacent}$ ;

$$\tan(5/60) = a/60$$

$$a = 60 \times \tan(5/60)$$

$$a = 60 \times 0.0014544421$$

$$a = 0.08726 \text{ metres} = 8.726 \text{ cm}$$

Therefore, the largest letter has to have a height of 8.726cm. But height is not the only component of the letter. A two-dimensional letter requires a width and a height to work with. Assuming a square type font for all letters, we can say that the letter should have a width of 8.726cm as well.

Or, we can approach this in a different way. We always tend to depict lens having rays falling on it from above and below the equator, but the lens simultaneously refracts rays falling on it from both sides at the level of the equator. Assuming a vertical equator for the sake of argument, these rays from the horizontal limits of the letter also subtend an angle of 5' of arc at the nodal point. Therefore, using the same logic, the width of the letter is the same as the height, seeing as it subtends the same angle at the nodal point from the same distance.

Applying the same method to derive the sizes of all letters of the Snellen's chart, we arrive at these measurements for each of the lines on the chart.

Line	distance in metres	angle subtended at nodal point	height and width of the letter in centimeters
6/60	60	5'	8.726
6/36	36	5'	5.235
6/24	24	5'	3.490
6/12	12	5'	1.745
6/9	9	5'	1.308
6/6	6	5'	0.872

The sizes of each optotype has been derived, and the issue of spacing has to be addressed. Spacing in a visual acuity chart could refer to two things - spacing between individual optotypes in a single line, and spacing between each line on the chart. There are no mathematically predetermined distances between optotypes, either horizontal or vertical, on the Snellen's chart. The spacing between the optotypes are arbitrary, and this is one of the main reasons it has been superseded by the logMAR chart, which follows the Law of Proportional Spacing.

The Law of Proportional Spacing of a Visual Acuity chart says that the space between each optotype should be the same as the size of the optotype in that line, and the space between each line should correspond to the height of the optotypes on the subsequent line down.

### Using the chart in a clinic

Now that we have all the necessary information to construct a Snellen's chart, let us look at the physics behind using it to test vision in the clinic.

We ask the subject to sit at a distance of 6 metres from the Snellen's chart, but the calculations that have gone into constructing the chart have only taken into consideration the point of convergence for each of the optotypes. At 6 metres, however, the angle subtended by the letters in each line will be different, and will gradually decrease from the topmost letter until it reaches the minimum discernible 5' of arc (with each limb subtending 1' of arc).

Therefore, applying the laws of trigonometry again, we set out to find the angle subtended by each line at the testing distance, ie, 6 metres.

Line	height and width of the letter in centimeters	distance in metres	angle subtended at nodal point
6/60	8.726	6	50'
6/36	5.235	6	30'
6/24	3.490	6	20'
6/12	1.745	6	10'
6/9	1.308	6	7.5'
6/6	0.872	6	5'

The angles subtended by each optotype of each line of the chart have been calculated. From this, it quite easy to obtain the angle subtended by each arm of the optotype, if one is interested in doing so.

For the eye to appreciate two adjacent points as distinctly separate, the minimum angle of separation is 1' of arc. When two points are separated physically by a distance that subtends an angle of 1' at the nodal point, these two points are then relayed back into the retina; and are separated by a distance of 4.5 microns on the retina.

### Interpretation of the chart

A visual acuity of 6/24 would mean that the person can see letters that subtend an angle of 20' or more from a distance of 6 metres. The eye is not able to discriminate between points that subtend an angle of less than 20', as compared to a normal eye that should be able to discriminate between points that subtend an angle at 5' of arc.

The various reasons why a person cannot discriminate between two points farther apart than 5' of arc apart due to disease processes are beyond the scope of this article, as it concerns various pathologies of the cornea, lens, retina, and optic nerve.

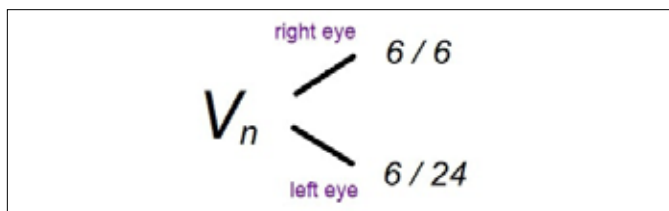


Figure 1: depiction of visual acuity

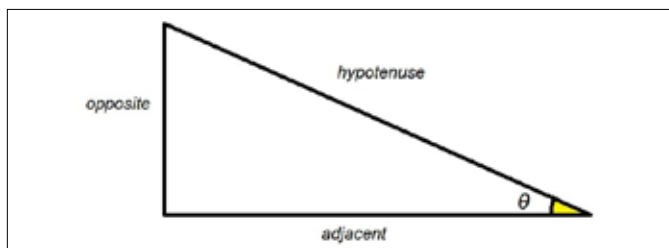


Figure 2: Trigonometry principle used

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

Figure 3: Tan theta

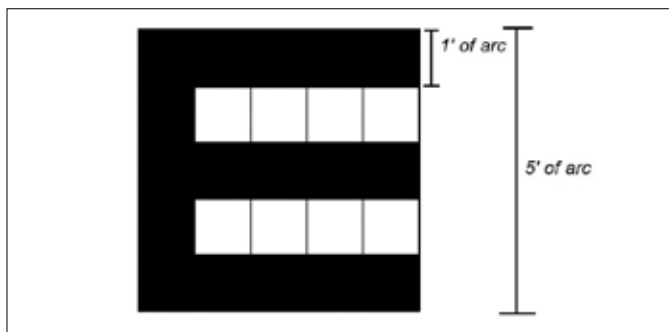


Figure 4: Minutes of arc - Vertical

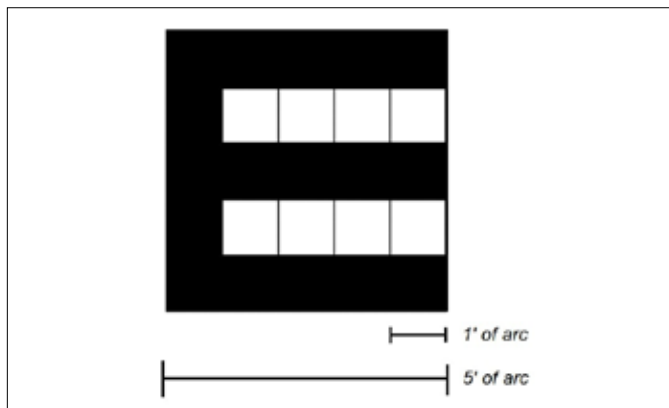


Figure 5: Minutes of arc - Horizontal

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