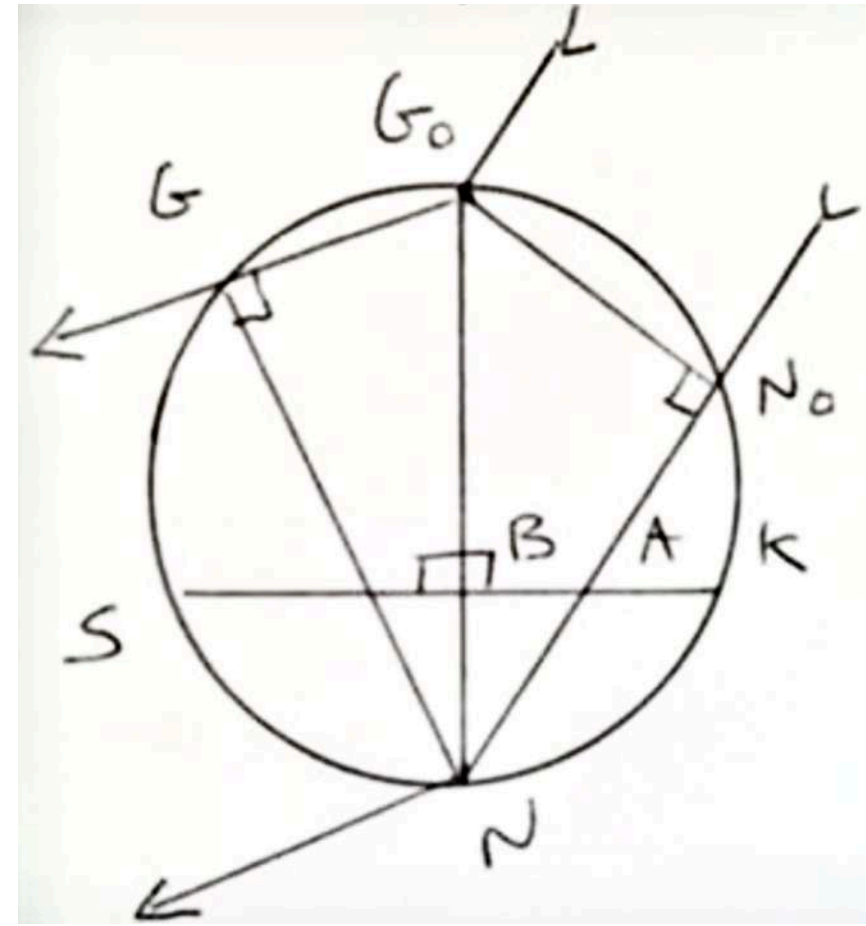
Forward to Geometrical Optics Presentation

Before embarking on a purely geometric approach to ophthalmic optics, I'd like to establish the benefit of this approach with an example problem. I will outline a geometric method of locating a tangential image point from refraction at a plane surface using known triangles to solve for unknown triangles. I expect this will be obviously more accessible to the average ophthalmic optics student than mathematics involving multivariable equations.

Wavefronts turn when one side is slowed more than the other, as would happen if one of your car’s front wheels would brake harder than the other. This is best observed at the beach, where wavefronts from all directions bend, (refract), more parallel to the beach, no matter what direction they might have been traveling in the open ocean.

Wavefront G_oN_o bends, (refracts), into wavefront GN along diameter G_oN when it travels G_oG in the same time it travels N_oN.
As $G_o \Rightarrow N$, $G_oG \Rightarrow NK$,



Therefore, let $G_oG = NK$.
Since equal arcs ~SN and ~KN subtend equal angles,
$\Delta N_oNK \cong \Delta KNA$, and:

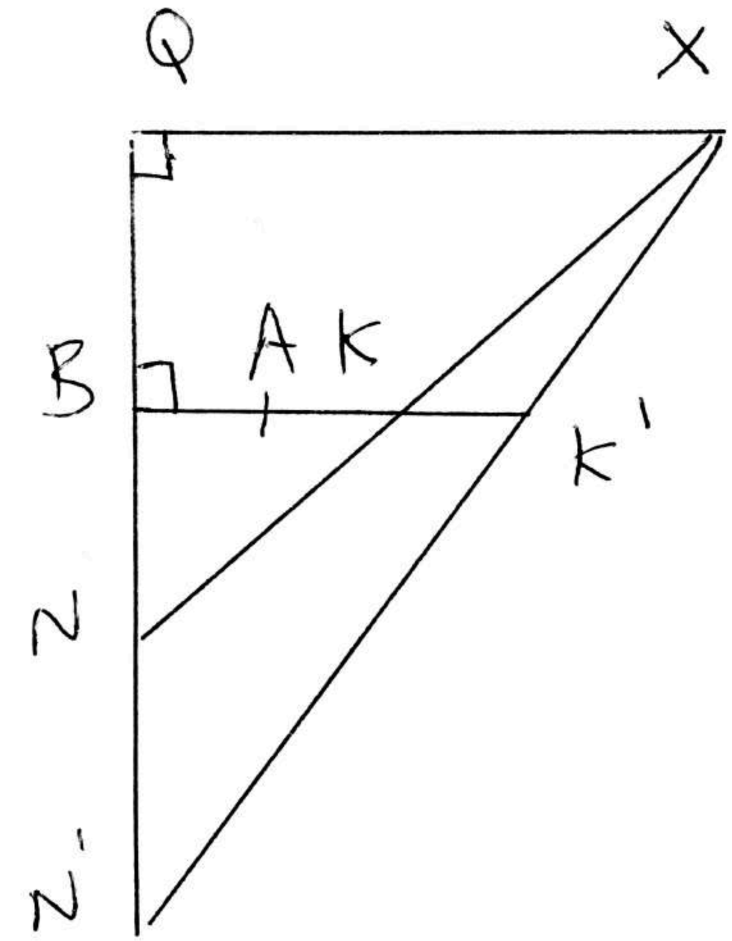
$$\mathbb{R} = NN_o/GG_o = NN_o/NK = NK/NA$$

$\mathbb{R}$, the index of refraction, is therefore a velocity ratio.

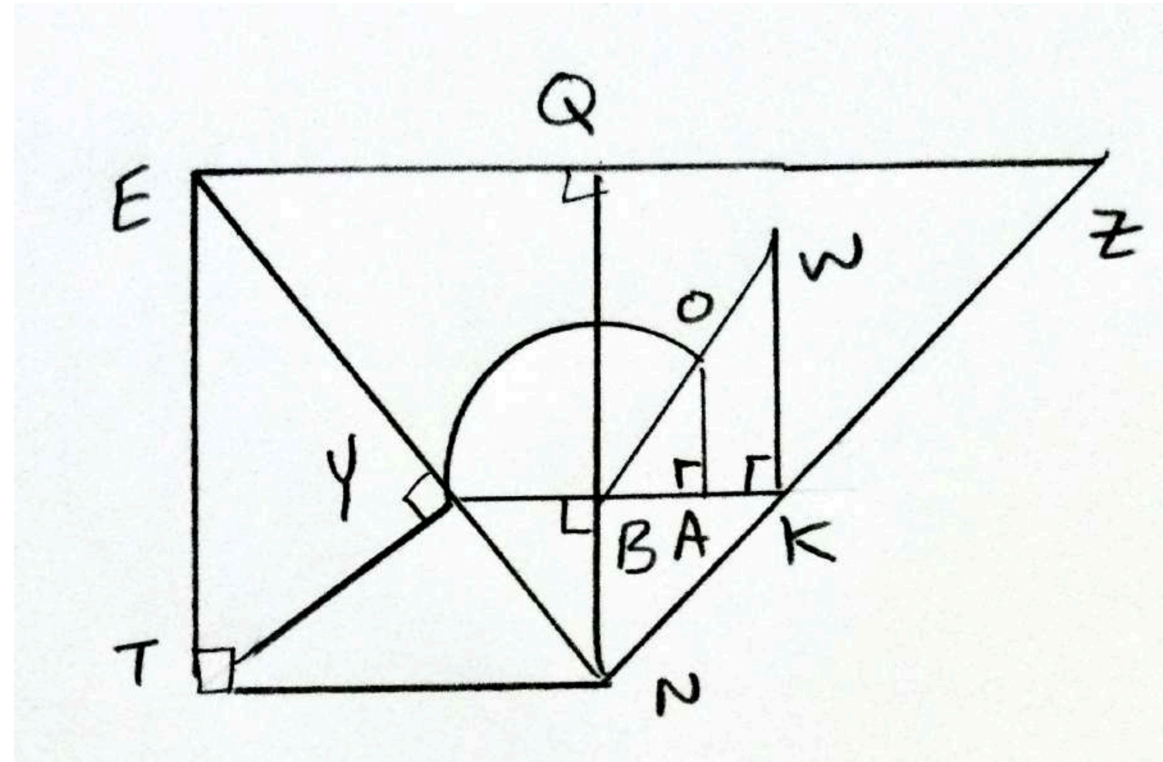
Think of light traveling along an object and image ray as a wave, much like the sound wave traveling from a speaker to a listener. If sound waves reflect off an irregular surface, so that each travels a different distance to the listener, the result is garbled, and unintelligible. However, if a large enough quantity of reflected sound waves travel an equal distance, (at the same speed and thus take the same time), they arrive, “in phase,” and can be understood. They are then, “focused.”

The same would be true if some of the sound waves slowed down, and traveled a proportionately shorter distance; or sped up, and traveled a proportionately longer distance. These waves would be refracted, rather than reflected, and would still be, “focused,” since the speaker could be understood. The information they carried would be, “in phase.”

Section two of this material shows that only *two* object rays from point A can be refracted along a tangential section QBN of a plane surface and projected backwards *as if* to come from a single point X. Unless they are superimposed, they will be out of focus at X because the information they carry will be out of phase.



Section two also shows that these two rays are superimposed when this tangential template can be drawn with these conditions:
$\mathbb{R}$ = NK/NA = OB/OA, and WK = YN.



Under these conditions, Z is therefore the (tangentially) focused image of A.

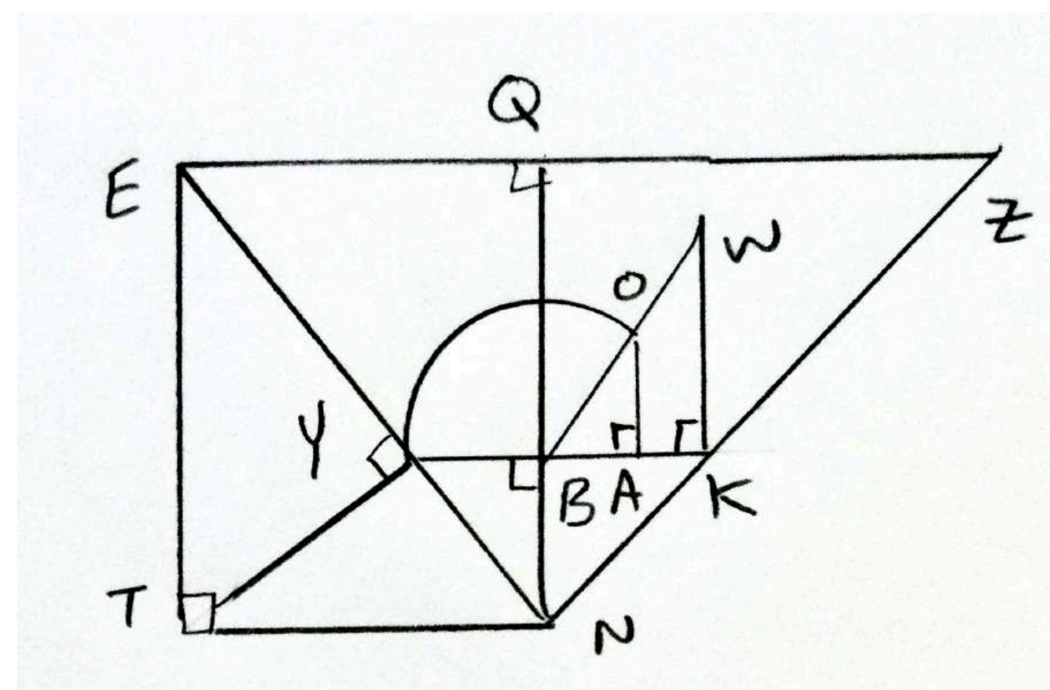
Unlike the tangential refraction just illustrated involving the bundle of rays around the object and image ray that vibrate in the plane represented by the given tangential template, sagittal refraction occurs involving the bundle of rays around the object and image ray that vibrate *perpendicular* to the given template. To visualize how a different sagittal focus and tangential focus can occur along the same image ray, consider the common bellows. Its sides can be compressed an equal or unequal angular amount, and still force air in the same direction, (though with different force).

The bundle of rays vibrating perpendicular to the given template involve equal angles of incidence to the refraction plane, given equal and opposite angular deviations from the object ray.

The bundle of rays vibrating in the given template involve unequal angles of incidence with the refraction plane given equal and opposite angular deviations from the object ray.

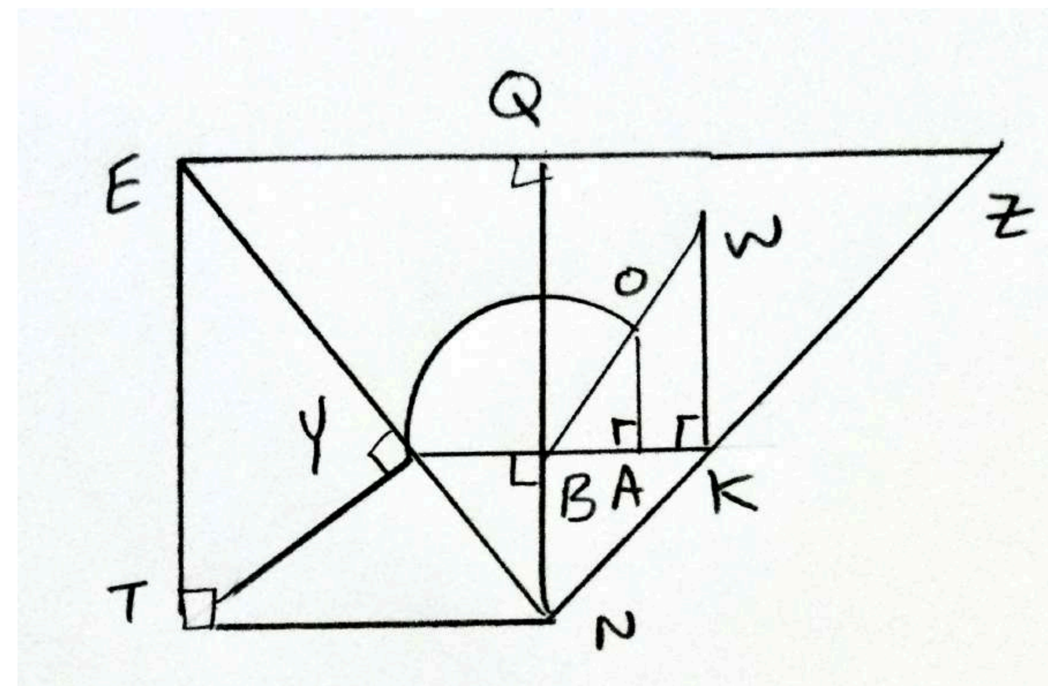
The tangential template allows for an understanding of how each variable of the problem affects others, as well as what is and what is not possible to discover with given variables.

For example, given an object distance AB and ℝ, we can construct ΔBAO by making:
ℝ = OB/OA.

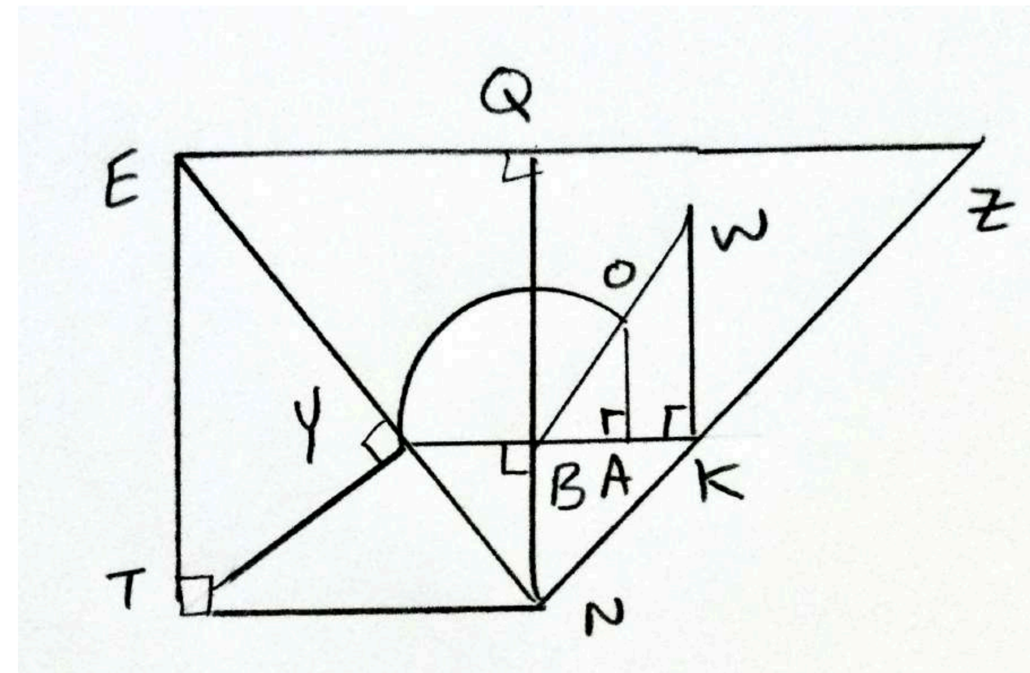


With ΔBAO,
we can find BY by making
BO = BY.

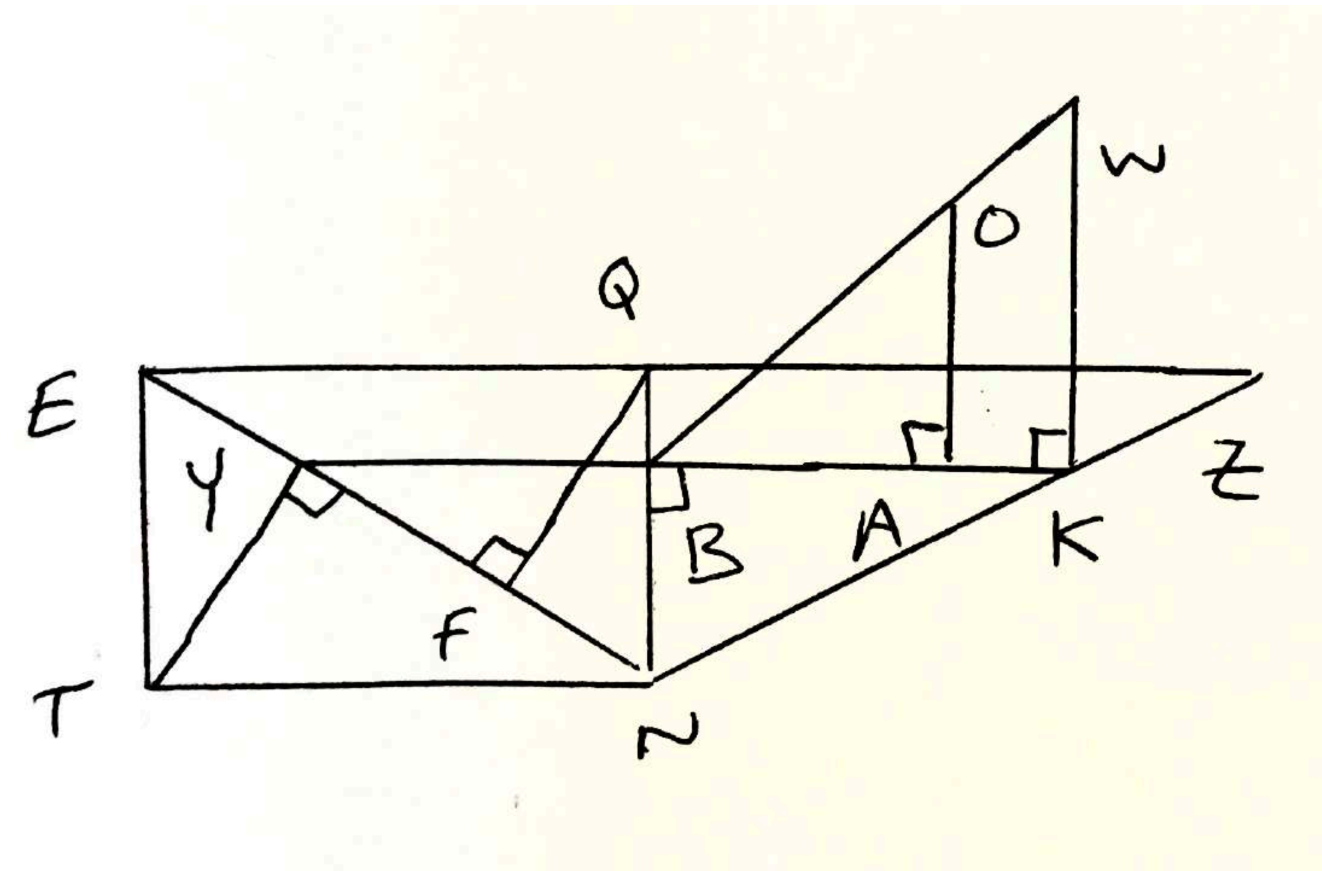
1). For a desired K, we can use ΔBKW to find ΔBNY by making KW = YN, and then find ΔZEN by first finding right triangles ΔNYT and ΔTYE.



2). For a desired N, we can use ΔBNY to find ΔBKW by making YN = KW, and then find ΔZEN by first finding right triangles ΔNYT and ΔTYE.

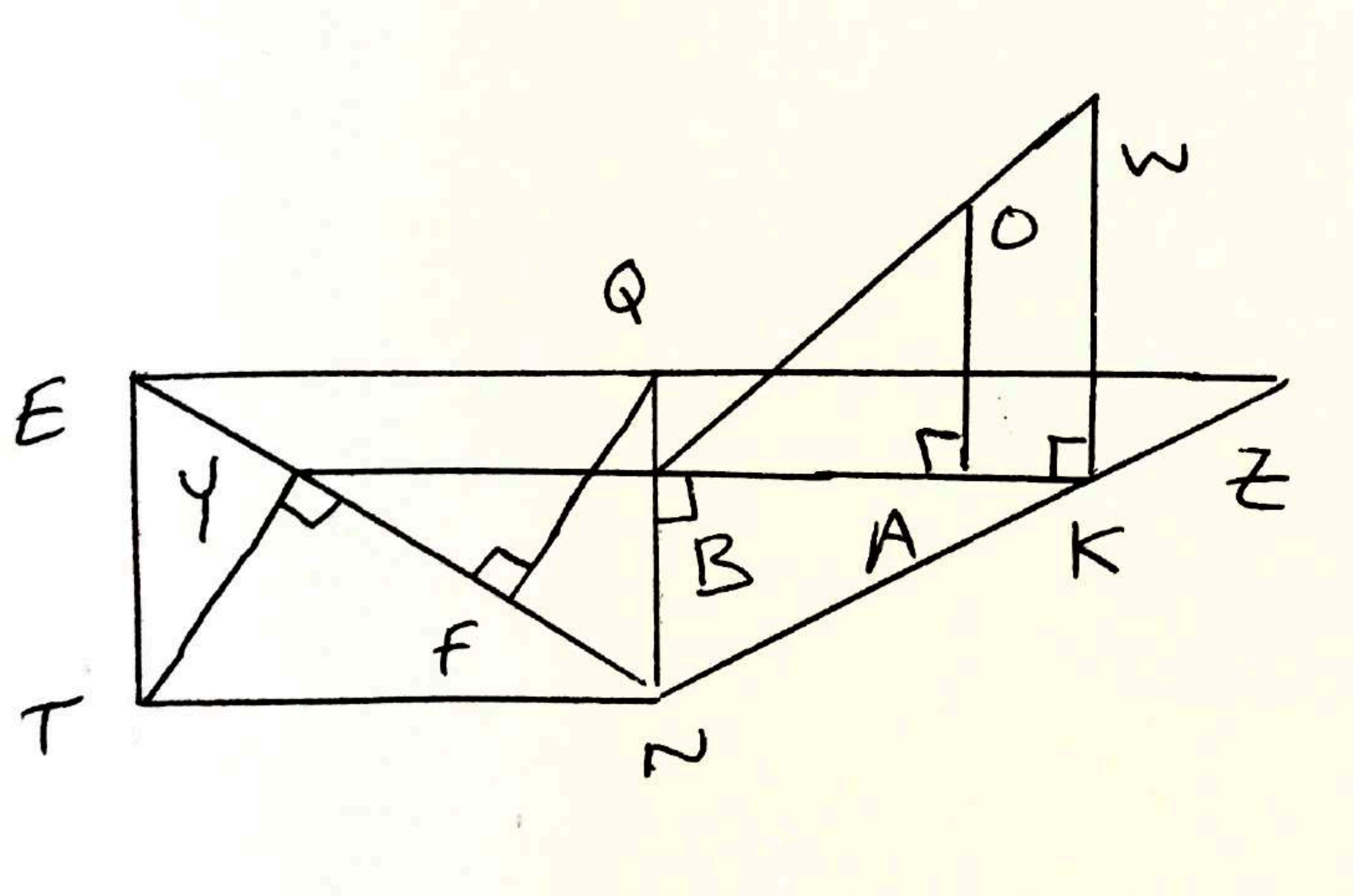


This template works when YE > YN, as shown previously; or when YN > YE, as shown here:



($\mathbb{R}$ = NK/NA = OB/OA; BO = BY; YN = KW)

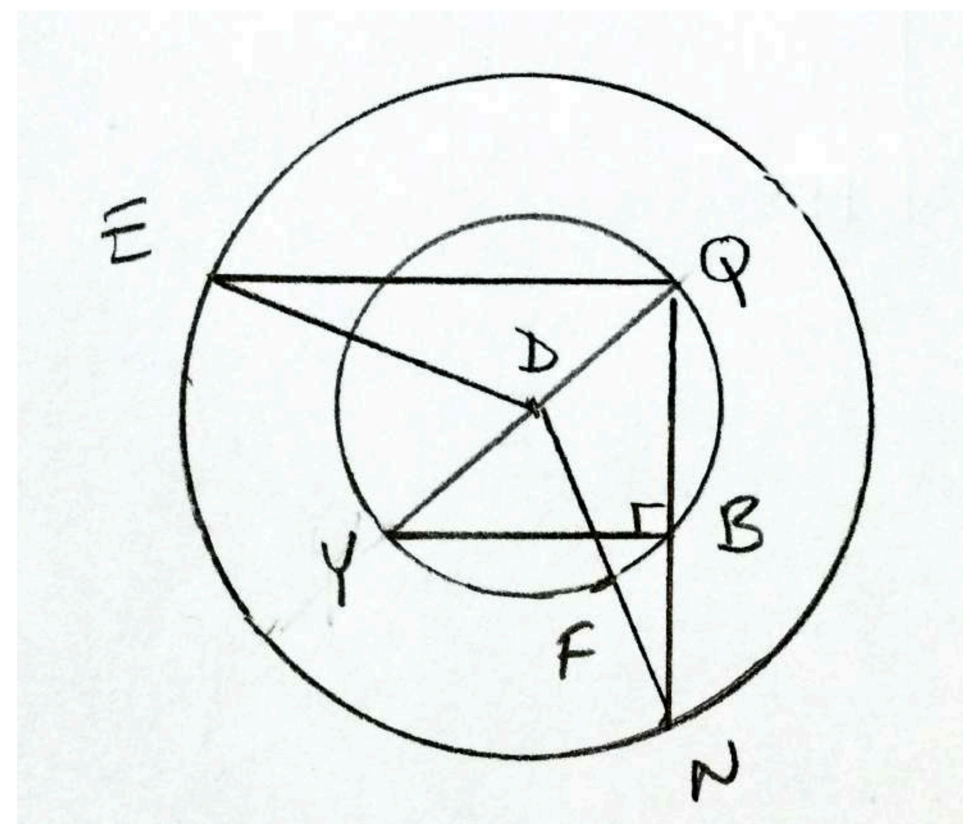
3). Using the template where
YN > YE as the example, for a desired Z, we can use ΔQBY to find ΔBNY.



(ℝ = NK/NA = OB/OA; BO = BY; YN = KW)

A concentric circle around circle ⊙QBY is drawn with its center at the midpoint of hypotenuse YQ, so that line segment YF lies on chord EN.

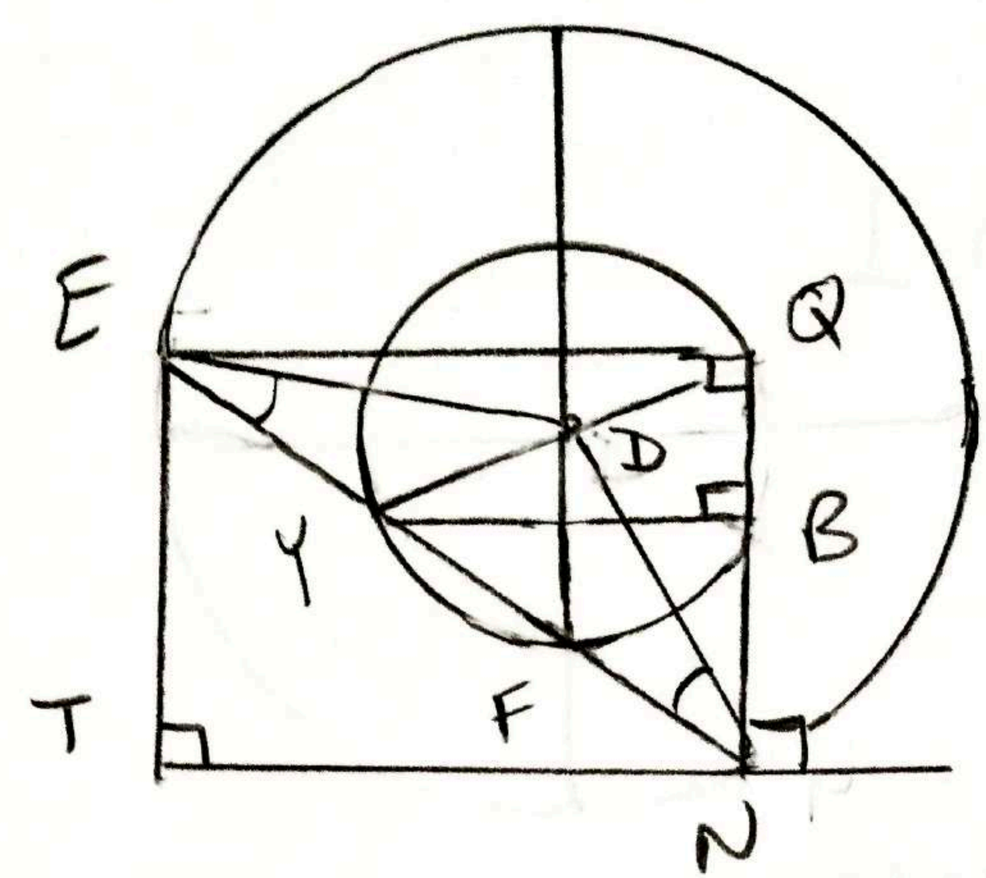
The arc intercepted by ∠DEN equals that intercepted by ∠DNE. Therefore, ∠DEY = ∠DNF.



DY = DF
DE = DN

ΔEDY = ΔNDF
EY = NF

Since QY is a diameter,
∠QFY is a right angle.
This means ∠QFN is
also a right angle,
and since EY = NF,
∠TYE is a right angle.



Note that QZ varies with EN because:
QZ/EN = KB/YN = KB/KW = AB/AO,
which is a constant determined by ℝ.
Therefore, ℝ**,** which determines image ray projection NK given AN, also determines the location of the focused tangential image along NK.