Understanding Huygens principle & verifying laws of light propagation: a mathematical approach

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Background and motivation:

- Huygens principle forms a basis for explanation of wave optics and laws of reflection and refraction. It is introduced at NCERT (National Council for Educational Research and Training) physics textbook at Class XII.

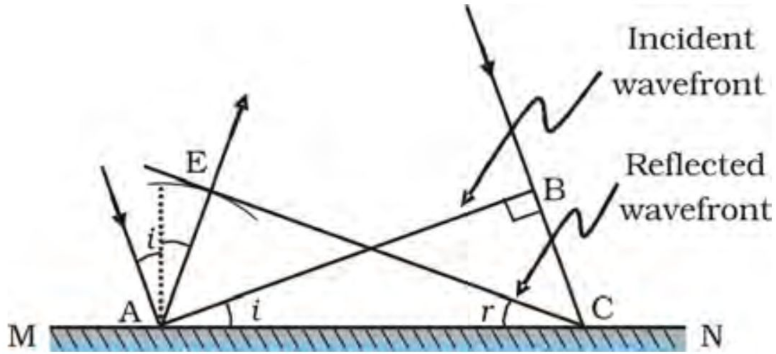

Fig.1: Geometrical representation in laws of reflection proof

Source: *Class XII NCERT Physics textbook*

In derivation of these laws, the textbook geometrical representation begins with a readymade & static construction, which does not offer visualization of the growth of the wavefront. Thus, does not build an entire picture required for the proof.

Learning objectives in our design intervention on Geogebra platform was to enable students:

- Understand the terms: phase of the wave, wavefront, ray in relation to wavefront in geometrical representation.
- Construct spherical wavefront at later instant of time.
- Understand cylindrical and plane wavefront.
- To enable student to verify laws of reflection using Huygens Principle.

GeoGebra platform: dynamic, useful features for visualisation geometries, manipulate the mathematical representations of various entities.
Classroom intervention: 2 online sessions of 90 minutes each, ~50 students.

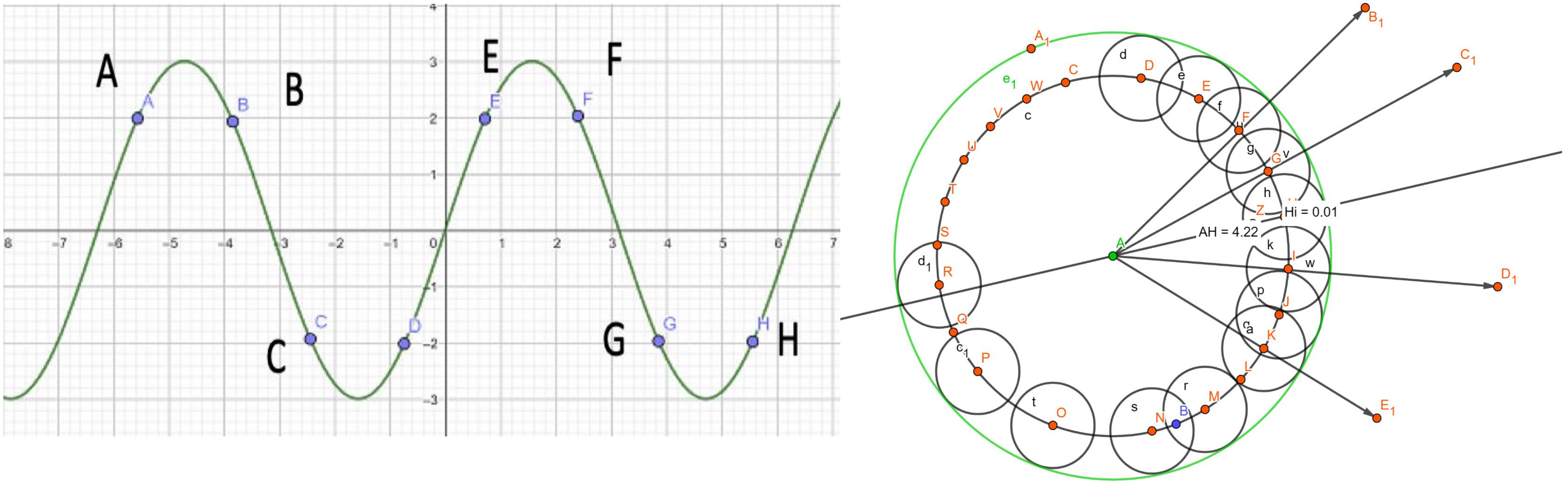

Fig. 2: Visualizing concepts of ‘phase’ & ‘spherical wavefronts’ on Geogebra

- ➢ Stepwise construction allows student to understand the relation between radii of spherical wavefronts from different points on a given wavefront and phase.
- ➢ The radii of the spherical wavefronts are taken equal so that the forward tangent collects all the points that are at same phase in turn gives rise to new wavefront.

Geogebra's dynamic platform allows construction of the wavefront from scratch, right from the incident waves and reflecting surface (see fig. 3), followed by incident and reflected wavefronts.

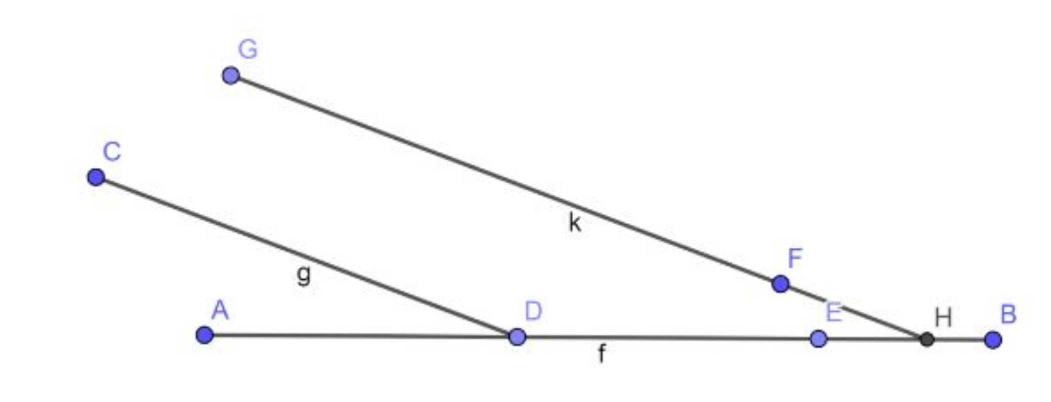

Fig. 3: Beginning the construction for verifying law of reflection using Huygens principle. Segments CD and GH represent 2 parallel incident rays, on a plane reflecting surface denoted by segment AB.

Alongside the GeoGebra construction, mathematical proof (consistent with the textbook) was parsed and students' feedback about the intervention was sought. A discussion with this such evolving construction can provide clarity to their understanding about Huygens principle. Further they are used to prove and verify laws of reflection

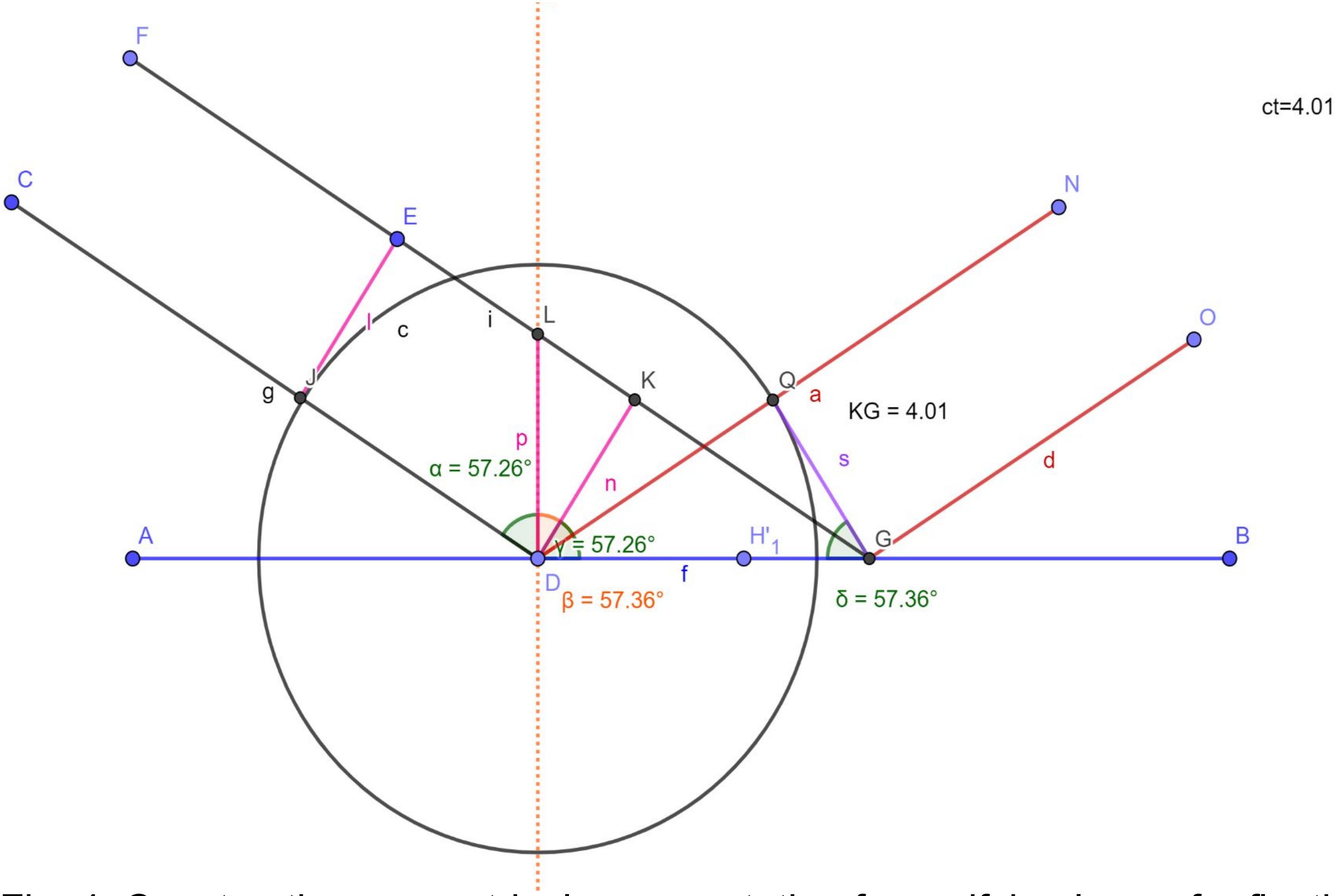

Fig. 4: Constructing geometrical representation for verifying laws of reflection using Huygens principle.

Key observations:

- ❑ Students could visualize and comprehend the time evolution of the wavefronts, something not possible to achieve in textbook static representation.
- ❑ Some added activities by varying different parameters, such as angle of incidence, and observing its effects on the construction can be included.

Future work:

In our pilot interventions, we are positive that mathematical discourse embedded alongside the geometric construction on Geogebra is useful to understand Huygens principle, and verify the laws of refraction. More studies in classroom are needed to report our observations in a systematics manner.

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