Least Time Principle Activity Sheet

Purpose:

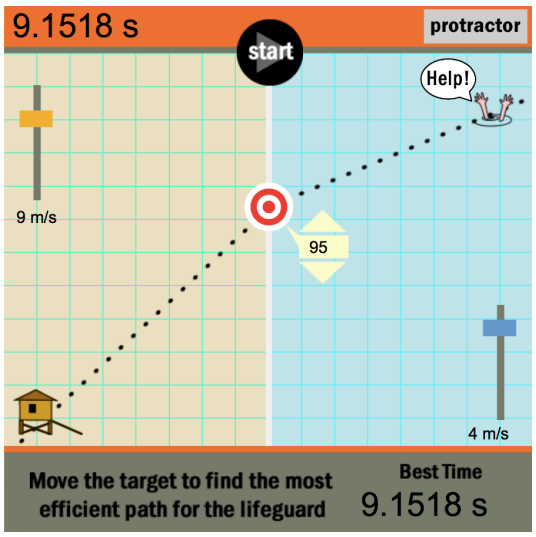
The purpose is to study the relationship between the angles which a light ray makes with the normal as it crosses the boundary between two media and the speed of light in the two media.

Overview:

It has already been learned that a light wave will refract (i.e., bend) as it passes from one medium into another medium. The tendency of a light wave to do this is often explained by the Least Time Principle. This principle states that

> *Of all the possible paths that light might take to get from one point to another, it always takes the path that requires the least amount of time.*

In this activity, you will examine this principle by way of an analogy. The analogy involves a life guard who has become aware of a drowning swimmer in the water. The guard must reach the swimmer in as little time as possible. Since the guard can run faster on sand than she can swim in water, it would make sense that the guard cover more distance in the sand than she does in the water. In other words, she will not run directly at the drowning swimmer. Your task involves determining the optimal entry point into the water in order to reach the drowning swimmer in the least amount of time.



Procedure:

1. Navigate to the web page titled **Least Time Principle** from the Physics Interactives section of the website. Launch the Interactive.
2. Your teacher will assign a set of speed values for the running speed of the lifeguard on sand and the swimming speed of the lifeguard in water. Use the sliders to set the speed values. Record the speeds in the **Personal Data** table.
3. Click/tap on an entry point for the lifeguard to enter the water. Record the time it takes the lifeguard to reach the drowning swimmer if entering the water at this entry point.
4. Pick a different entry point and repeat step 3. Record the time in the **Personal Data** table. Continue the process of picking an entry point and recording the time. Your goal is to be strategic in picking the entry point until you find the *best time* (i.e., least time). Once you're certain you've found the least time, use the protractor to measure the angle of approach (i.e., incidence) and departure (i.e., refraction) at the air-water boundary. Record your values in the **Personal Data** table and the **Group Data** table in the **Data** section.
5. Collect data from other lab groups to fill in the **Group Data** table.
6. Answer the **Analysis** questions and draw the two conclusions in the **Conclusion** Section.

Data:

Personal Data:

Sand Speed: _____ m/s

H_2O Speed: _____ m/s

Entry Point	Time (s)

Least Time: _____ s

$\Theta_{incidence}$: _____ deg

$\Theta_{refraction}$: _____ deg

Group Data

Enter decimals in the cells below.

v_{sand}:v_{water}	v_{sand}/v_{water} Ratio	sin $\Theta_{incidence}$ / sin $\Theta_{refraction}$
9.0 : 4.0		
9.0 : 3.0		
9.0 : 2.0		
8.0 : 4.0		
8.0 : 3.0		
8.0 : 2.0		
7.0 : 4.0		
7.0 : 3.0		
7.0 : 2.0		
6.0 : 4.0		
6.0 : 3.0		
6.0 : 2.0		
5.0 : 4.0		
5.0 : 3.0		
5.0 : 2.0		

Analysis:

1. In which medium is the angle between the path taken and the normal the smallest - the medium with the greatest speed or the smallest speed? _____
2. As the guard crossed from sand (where she was moving fast) into water (where she moved slow), did she turn towards or away from the normal? _____

Conclusions:

1. Using an equation, state the mathematical relationship between the angles of incidence and refraction and the speeds of a light wave in the two media on both sides of the boundary.
2. Given that **n = c/v**, use the equation in Question #1 of the Conclusions and algebraic substitution/manipulation to show how Snell's law is derived. Your steps should be clear, organized and follow-able.