Physics: Wave Behavior

9th Grade

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Anchoring phenomenon:

You are part of a team of students who are cleaning up a local waterway. You are wading thigh deep through the water looking for trash to pick up with your "claw".

(I use a simple whiteboard picture for this)

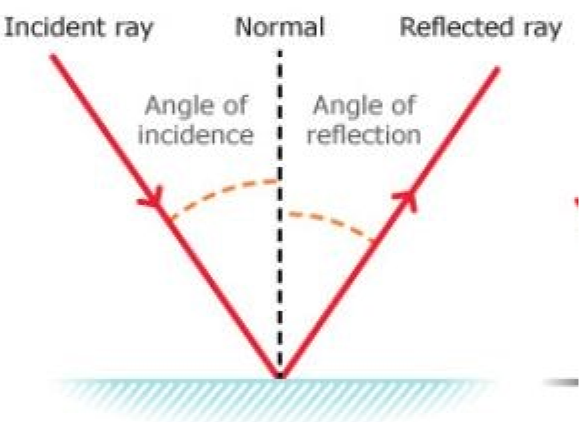
Essential question about phenomenon/for unit:

As you are standing half in/half out of the water, how do you know where to aim your claw in order to successfully pick up the trash?

Big Idea:

If my students understand the relationship between wave speed, wavelength and frequency they would reason about how different types of waves behave as they travel through and between different media because refraction (and reflection) is an important physical event that is used to explain a number of phenomena that are both naturally occurring or used in man made devices.

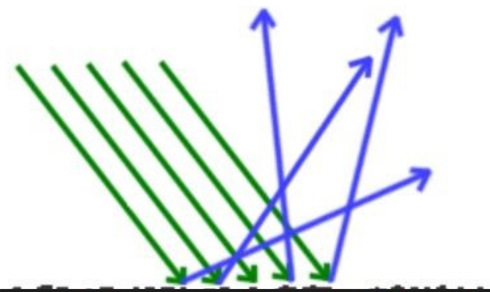
Scientific explanation:

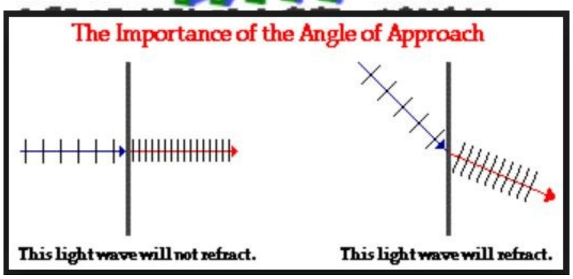


In order for the student to successfully pick up trash they have to account for how the two different media that the light travels through affect how it {the light} behaves and that due to the fact that light travels in a straight line it can have predictable properties.

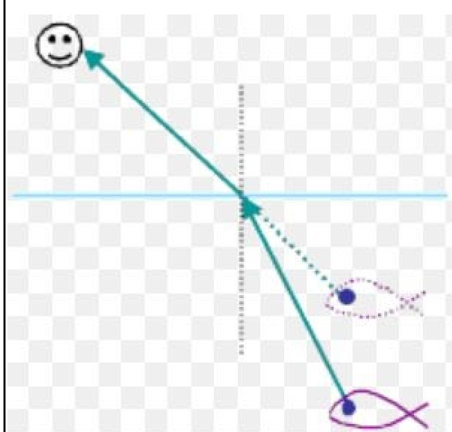
In order for students to see the can it must be illuminated by a light source and that illumination must reflect off of the can and into their eye. When light hits a surface (incident ray) it will reflect off of that surface (reflected ray) at the same angle, but in the opposite direction to that which it arrived at (angle of incidence = angle of reflection). If the reflected ray enters the eye then the student will see the can that was illuminated. Therefore under normal circumstances a student would only need to move into a position where this occurs to see the can. If the reflecting surface is smooth, all of the reflected rays leave at the same angle and direction (allowing clear images to be formed) and this surface can only be observed from one location. If the reflecting object's surface is not smooth, this process is still observed, but the reflecting rays will all leave at different angles (no image will be formed) allowing the illuminated surface to be observed from multiple angles.

Because the light ray that enters the eye travels in a straight line from the can (and not the Sun) the eye “believes” that that is where the ray started and consequently forms an image in the brain based on the starting point of this reflected ray.





However, in order to reach the eye the light must pass through two different media, air and water. As the two media have different densities, the speed that the light travels at is different in each media. The water is more dense, so the light travels slower than in the less dense air. Since the frequency of the light does not change, when the light travels faster in the air it results in increased wavelength. This leads to a corresponding change in wavelength as the frequency of the light wave doesn’t change (this can be shown using the equation wave speed = frequency x wavelength). If the light wave meets the boundary between the two media at a 90 degree angle, there is no change in direction as the entire wave slows down or speeds up at the same time. However should the wave meet the boundary at an angle, one side of the wave will change speeds before the other causing the wave to turn.



All of these principles combined lead to the observed phenomena. When light reflects off of an object underwater, it must leave the water and enter the air (more to less dense media). As a consequence the ray turns towards the boundary before entering the students eye. Due to the brain “believing” that the ray travelled in a straight line from the object it reflected off of, it forms an image that is higher in the water than it really is. Thus when the student reaches into the water with their claw, they will aim above the actual object and miss it.

NGSS *Performance Expectations* addressed in this unit:

Standard	PE	DCI	CCC
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	PS4.A: Wave Properties	Cause and Effect

Summary Table of Activities in Unit

Activity *(Include title, short description, links if applicable)*	***Learning Target*** *(Color code 3-dimensions: Blue = SEP; Orange = DCI, Green = CCC)*	***Evidence Students Could Gain/Key Learning***	***Connection to explain part of the phenomena***
Activity 1: **Initial Model:** Trash Pick-up Model link	Develop a model that shows how light travels from a source, through different media and into our eyes.		Develop initial models using prior knowledge and background from the presented scenario.
Activity 2: **Discrepant Event** 	Does viewing, from one medium, an object in a second one affect where we think the object is?	The student's line of sight is different than how light travels. The can appears to be higher than it actually is. When light enters water from air it will change direction.	The brain believes that an object is viewed along a "line of sight". When looking into a different medium, the eye thinks that the object is not where it really is. A change in medium affects how light waves behave.
Activity 3: **How do we see?**	How does changing the reflecting surface affect how a (light) wave reflects off of that surface?	Students see "rough" surfaces from all directions but "shiny" surface from only one specific vantage point, as evidenced by "mirrored" reflections on a certain group of student's faces.	If the reflecting surface is smooth, all of the reflected rays leave at the same angle and direction (allowing clear images to be formed) and this surface can only be observed from one location. If the reflecting object's surface is not smooth, this process is still observed, but the reflecting rays will all leave at different angles (no image will be formed) allowing the illuminated surface to be observed from multiple angles.

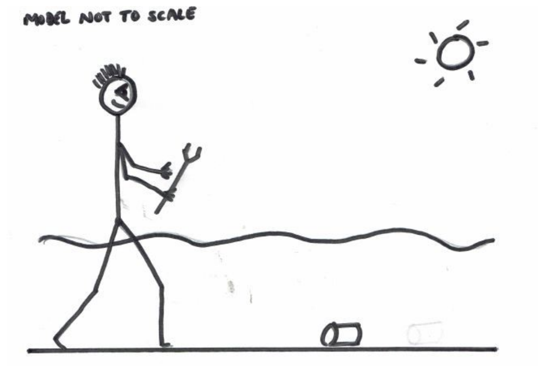
Activity 4: **How does light behave when illuminating surfaces and mirrors?**	What is the relationship between the surface and how light reflects off of it?	Students will observe that light reflects off of all surfaces, but not equally. Students use their understandings from Activity 3 and the first part of Activity 4 to make predictions about and then show that Angle i = Angle r for reflection	Light is reflected off the can at a specific angle, so the eye must be in a specific place in order to see the can.
Activity 5: **Model Revision**			At this point in time, students models will likely show light waves travelling from the sun to the can, reflecting off of it at the same angle it arrived at and going into the eye. They will likely show a line of sight from the eye back to the can to indicate where the person thinks the can is.
Activity 6: **What are waves?**	Identify the two main types of waves, their features and properties.	Difference between longitudinal and compression waves. Specific features of each type of wave. Wave speed (m/s) = Wave frequency (hz) x Wavelength (m)	The speed of the light changes from slower to faster as it leaves the water, resulting in a greater wavelength of light as it leaves the water, since the frequency stays the same.
Activity 7: **Refraction follow-up:** Based on this and this activity.	Does changing media cause light waves to behave differently?	Changing the density of the medium a light wave travels in causes that wave to change direction. Direction change is specific to how the density	When light changes from one water to air it changes direction and bends more towards the water. The change occurs because the light is moving to less dense air, compared to the water. This means that light will

		changes.	change direction away from the air-water interface when entering the water and towards it when leaving. This leads to the eye having a false sense of where the light ray came from, so they think the can is higher than it actually is.
Activity 8: **Sense Making:** **Claim, Evidence and reasoning** Activity – option 1 or option 2	Explain how changing media causes light waves to behave differently?	Why a wave changes speed in difference media and how that leads to a change in direction.	
Activity 9: **Sense Making:** **Online simulation**	Explain how changing media causes light waves to change direction?	Changing the density of the medium a light wave travels in causes that wave to change direction. By viewing the simulation in wave front version students see how the different sides of the wave change at different times.	
Activity 10: **Sense Making:** Use whole class modeling activity (show how marching bands change direction) and teaching/calculations	Why does changing media cause light waves to behave differently?	Why a wave changes speed in different media and how that COULD lead to a change in direction.	
Activity 11: **Model Revision / Student Assessment**	Students show their final understanding by completing model.		Students should be able to show how light leaves a source, is refracted as it changes media (and show the correct direction change), reflects off of an object

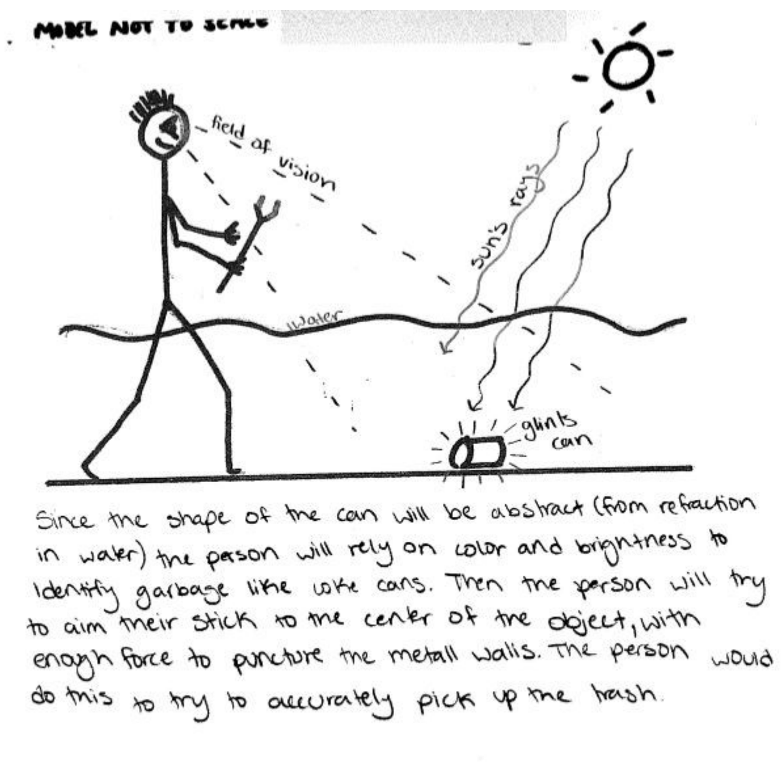
Explanation Application based on this activity	Students use knowledge gained to explain the fish tank discrepant event from activity 2. Students apply knowledge to new, but similar situation by carrying out penny trick activity and writing an explanation.		and enters into the eye. They should also be able to (approximately) show where the person "thinks" the object is relative to its actual position.

Model Template

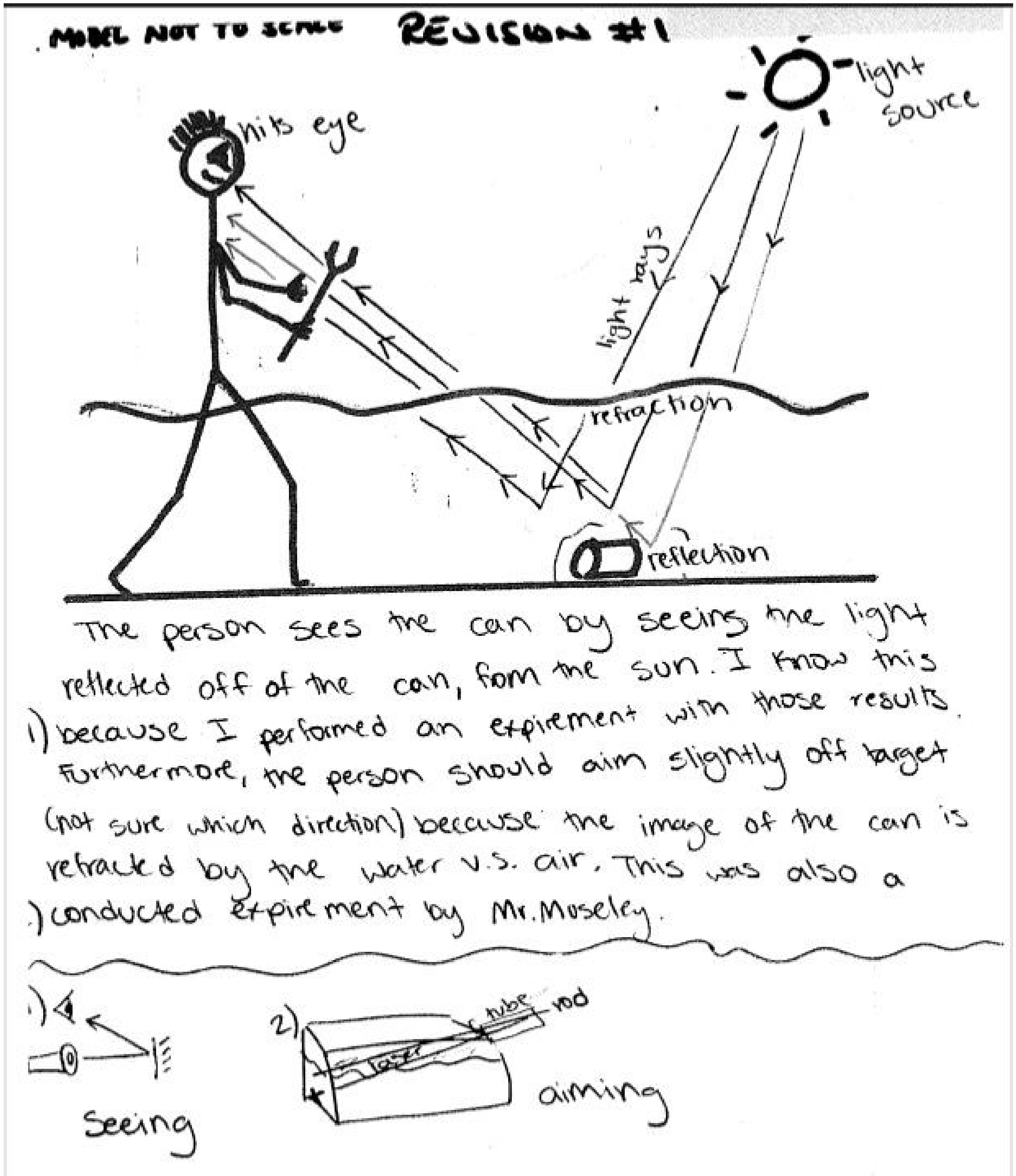
Model Link



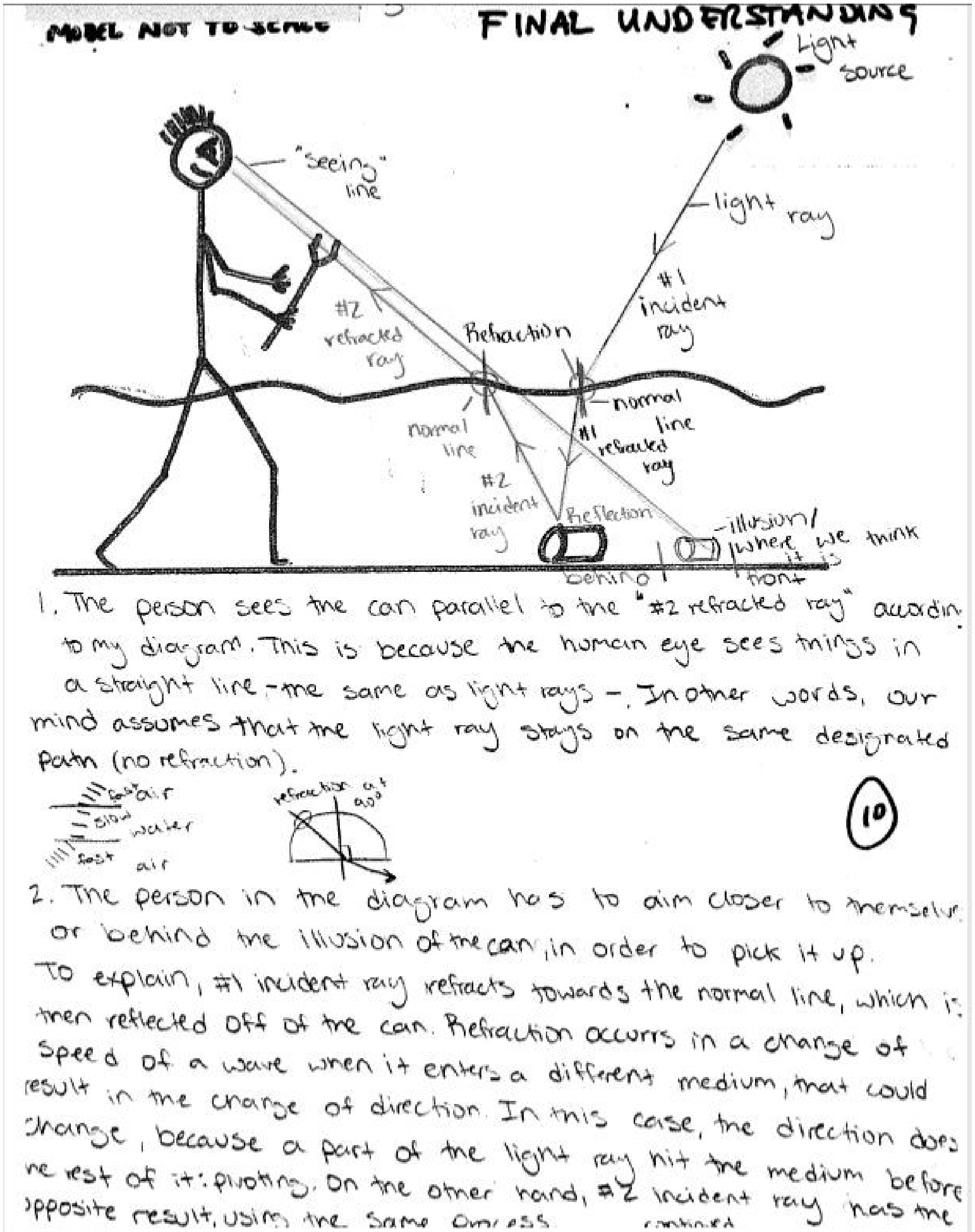
Example of student's initial model.



Example of student's first revision of their model



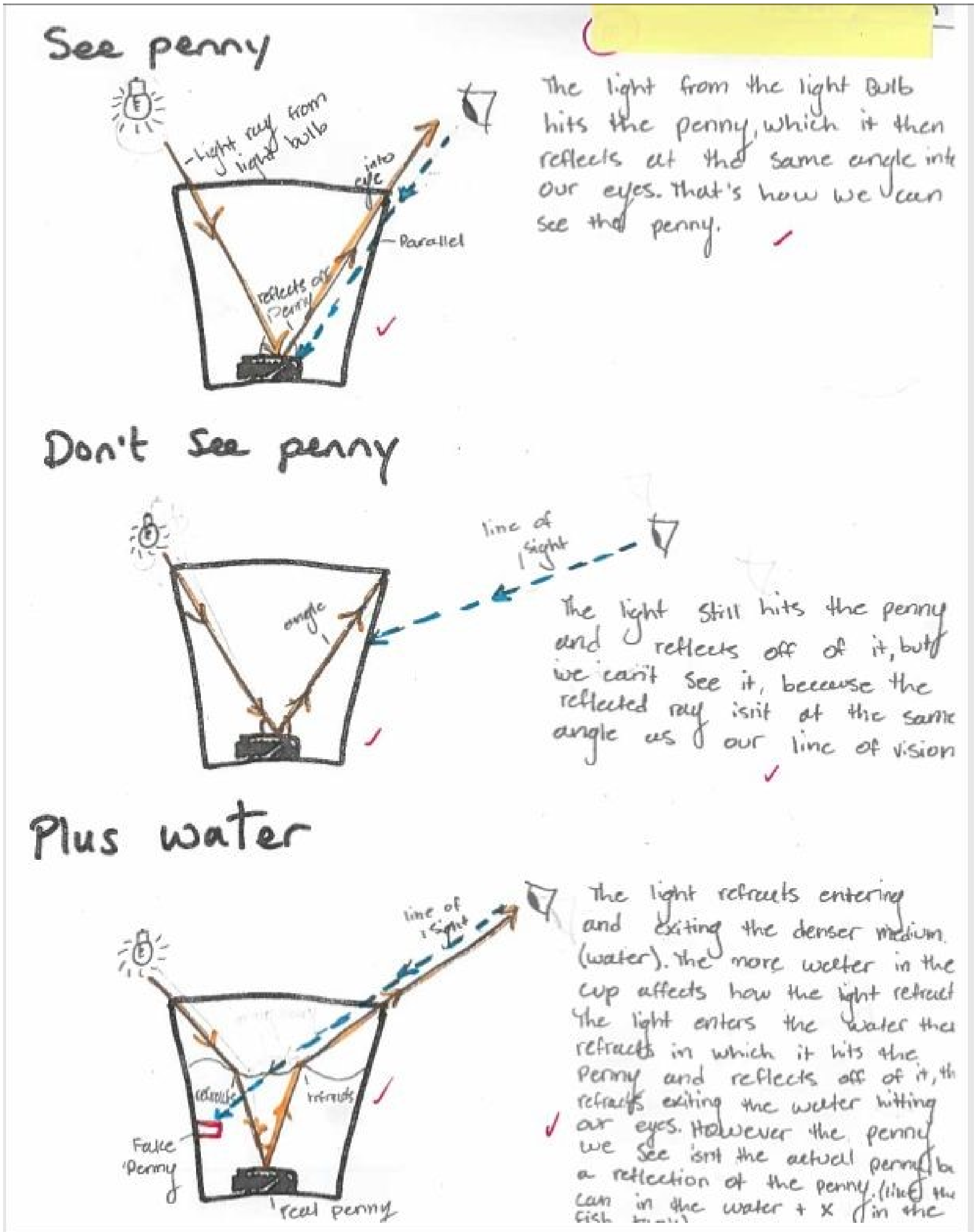
Example of student's final model



1. The person sees the can parallel to the "#2 refracted ray" accordin to my diagram. This is because the human eye sees things in a straight line - the same as light rays -. In other words, our mind assumes that the light ray stays on the same designated path (no refraction).

2. The person in the diagram has to aim closer to themselv or behind the illusion of the can, in order to pick it up. To explain, #1 incident ray refracts towards the normal line, which i then reflected off of the can. Refraction occurrs in a change of speed of a wave when it enters a different medium, that could result in the change of direction. In this case, the direction does change, because a part of the light ray hit the medium before ne rest of it: pivoting. On the other hand, #2 incident ray has the opposite result, using the same process. continued

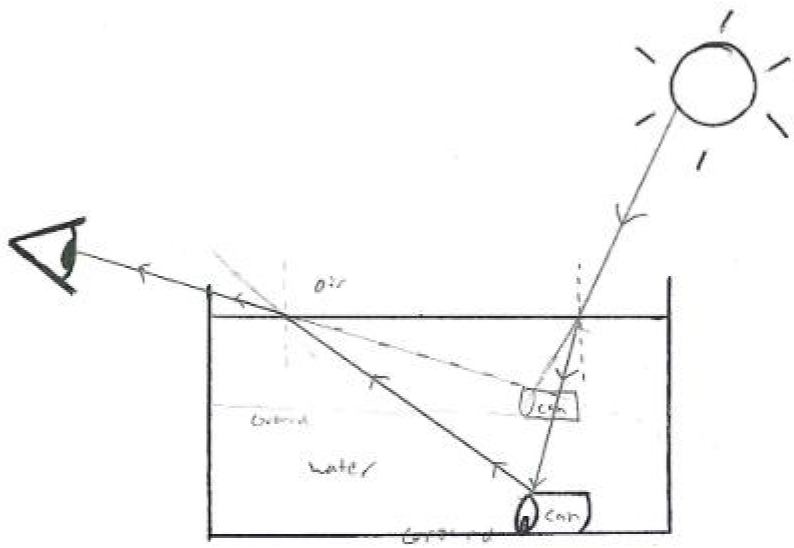
Activity 11 - Assessment example



Activity 11 - Explanation: Example #1

On the diagram below show:

- How the light from the sun allows us to see the can
- Where we think the can actually is (hint – where did the student "spear" actually hit?)



Now explain, using work from our waves unit, why this happens.

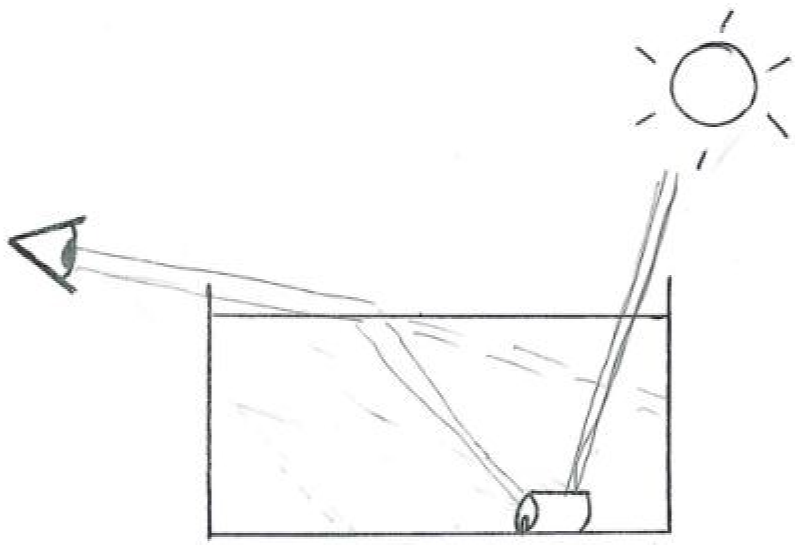
First, what happens, is a light ray from the sun will hit the surface of the water, refracting inwards, towards the normal line of the water, continuing on to hit the can. When the light ray strikes the can, it reflects off its surface and continues on back up towards the surface of the water. At this point, the ray refracts once again, instead away from the normal since it is travelling from a higher to a lower density. This process directs the light into the pupil of the eye, therefore letting us see the can. However, since the human brain interprets light as travelling in straight, undisturbed paths, we are forced to predict that the can lies on the straight path of the refracted ray. This is deceptive however because the straight path of the refracted ray appears shallower than the refracted ray's path is. This makes us misjudge where the can is because our brain falls victim to the incorrect assumption that the light ray travels undisturbed.

Activity 11 - Explanation: Example #2

Fish Tank Phenomena – Student Understandings

On the diagram below show:

- How the light from the sun allows us to see the can
- Where we think the can actually is (hint – where did the student "spear" actually hit?)



Now explain, using work from our waves unit, why this happens.

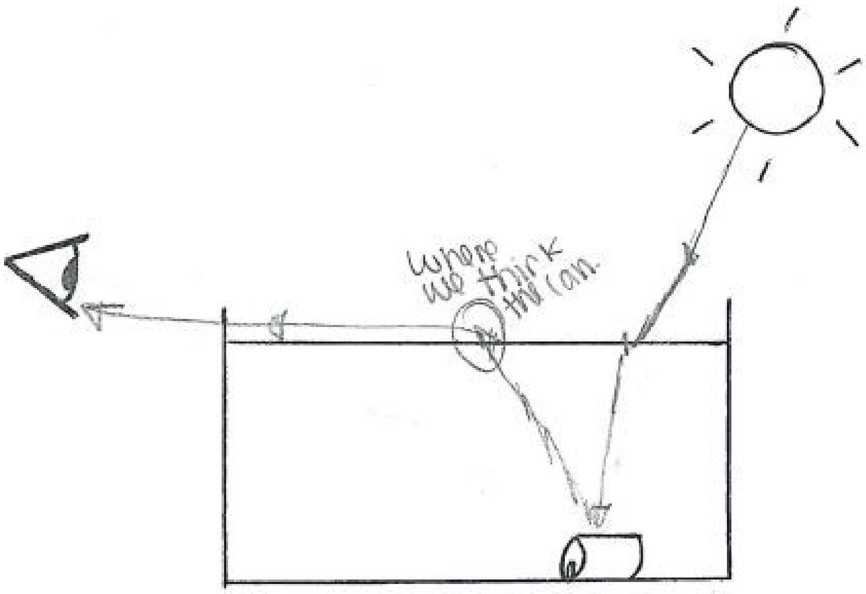
This happens because light bounces off the can and as it moves into the air it travels it retracts away from the normal line making the illusion its smaller than it is.

Activity 11 - Explanation: Example #3

Fish Tank Phenomena – Student Understandings

On the diagram below show:

- How the light from the sun allows us to see the can
- Where we think the can actually is (hint – where did the student "spear" actually hit?)

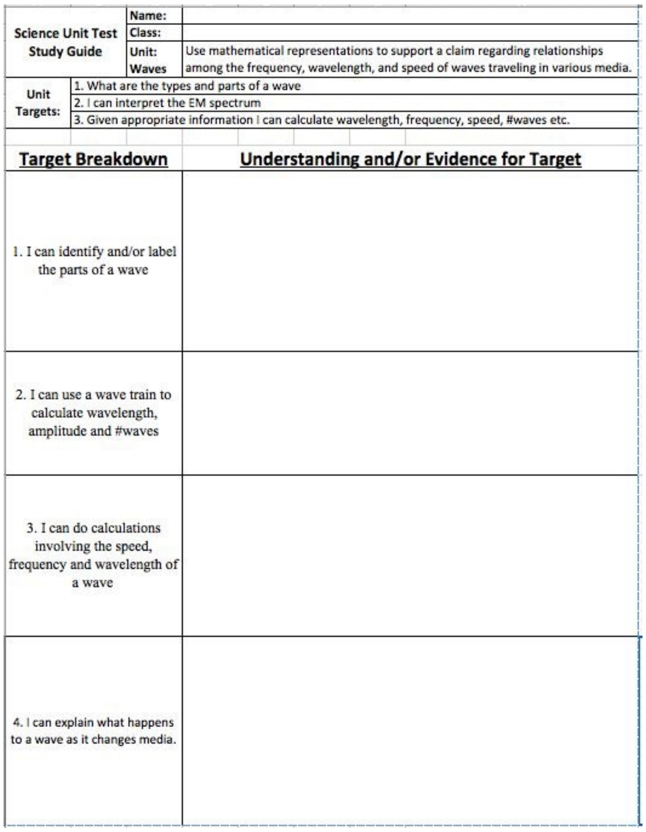


Now explain, using work from our waves unit, why this happens.

this happens because the light comes from the sun, then refracts then hits the can, then goes out of the can and then hits our eye, allowing us to see what the sun is hitting

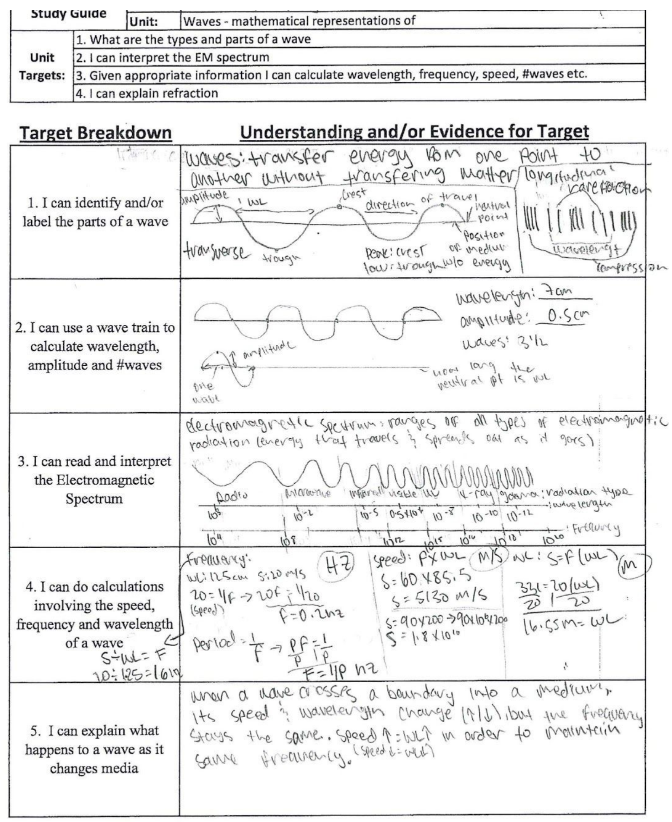
Images of complementary tools

This is a study guide I have used.



Science Unit Test Study Guide	Name:	
	Class:	
	Unit: Waves	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
Unit Targets:	1. What are the types and parts of a wave	
	2. I can interpret the EM spectrum	
	3. Given appropriate information I can calculate wavelength, frequency, speed, #waves etc.	

Target Breakdown	Understanding and/or Evidence for Target
1. I can identify and/or label the parts of a wave	
2. I can use a wave train to calculate wavelength, amplitude and #waves	
3. I can do calculations involving the speed, frequency and wavelength of a wave	
4. I can explain what happens to a wave as it changes media.	



Study Guide	Unit:	Waves - mathematical representations of
Unit Targets:	1. What are the types and parts of a wave	
	2. I can interpret the EM spectrum	
	3. Given appropriate information I can calculate wavelength, frequency, speed, #waves etc.	
	4. I can explain refraction	

Target Breakdown	Understanding and/or Evidence for Target
1. I can identify and/or label the parts of a wave	Waves: transfer energy from one point to another without transferring matter. amplitude, WL, crest, direction of travel, neutral point, position of medium, transverse, trough, Peak: crest, low: trough w/o energy; longitudinal, rarefaction, wavelength, compression
2. I can use a wave train to calculate wavelength, amplitude and #waves	wavelength: 7cm; amplitude: 0.5cm; waves: 3 1/2
3. I can read and interpret the Electromagnetic Spectrum	electromagnetic spectrum: ranges of all types of electromagnetic radiation (energy that travels & spreads out as it goes). Radio, Microwave, Infrared, Visible, UV, X-ray, gamma: radiation type; wavelength; frequency
4. I can do calculations involving the speed, frequency and wavelength of a wave	Frequency: (Hz) WL: 12.5cm S: 20 m/s; F = 0.2 Hz; Period = 1/F; F = 1/P Hz; Speed: F x WL (M/S) S = 60 x 85.5, S = 5130 m/s; WL: S = F(WL) (m) 16.55 m = WL; [illegible]
5. I can explain what happens to a wave as it changes media	When a wave crosses a boundary into a medium, its speed & wavelength change (↑/↓), but the frequency stays the same. Speed ↑ : WL ↑ in order to maintain same frequency. (speed & = WL)

Students used questions 4 and 5 to explain how the light changing from the water ot the air resulted in its speed decreasing, also resulting in a decrease of wavelength, thus giving a false sense of where the can really appeared.