Name:_____Date:_____PD:_____

ROLE (CIRCLE ONE): CAPTAIN MANAGER RECORDER REPORTER QC

POGIL: What factors affect wave speed?

WHY:

Mechanical waves are waves that require a medium in which to travel. If one watches an ocean wave moving through the medium (ocean water), one can observe that the crest of the wave moves from one location to another over a given interval of time. The **speed** of that wave refers to the distance a wave covers in a given amount of time. Sometimes, a wave encounters the end of a medium and the presence of a different medium. What variables affect the speed at which a wave travels through each medium?

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MODEL 1: WAVE SPEED ON 2 STRINGS WITH DIFFERENT TENSIONS

Trial	Tension of String (N)	Frequency (Hz)	Wavelength (m)	Speed (m/s)
1	2.0	4.05	4.00	16.2
2	2.0	8.03	2.00	16.1
3	2.0	12.30	1.33	16.4
4	2.0	16.2	1.00	16.2
5	2.0	20.2	0.800	16.2
6	5.0	12.8	2.00	25.6
7	5.0	19.3	1.33	25.7
8	5.0	25.5	1.00	25.5

1. In Model 1, what is the medium of the waves? (HINT: What are the waves propagating on?)

2. In the experiment represented by the data in Model 1, what property was held constant for Trials 1-4?

3. In Trials 1-5, a wave generator was used to make waves with different frequencies through an unchanging medium. The effect of different frequencies on the wave's speed was recorded.
   a. What was the Independent Variable?
   b. What was the Dependent Variable?

4. Summarize the results of Trials 1-5. As frequency increased, what happened to wavelength? Wave speed? ***Use quantitative data to support any claims you make.***

5. What can account for the small differences in Wave Speed in Trials 1-5?

6. In Trials 6-8, the same experiment was repeated, but the medium was changed to a string with a tension of 5.0N. The effect of different frequencies on the wave's speed was recorded.
   a. What was the Independent Variable?
   b. What was the Dependent Variable?

7. Summarize the results of Trials 6-8. As frequency increased, what happened to wavelength? Wave speed?
Use quantitative data to support any claims you make.

8. What can account for the small differences in Wave Speed in Trials 6-8?

9. Compare the data for wave speed in Trials 1-5 to the data for wave speed in Trials 6-8. What is the effect of increasing the tension in the medium on the wave's speed?

10. If you repeated the same experiment with a string that has a tension of 10N, what would you expect to happen to the speed of the wave? Why?

READ THIS:

Waves travel at different speeds in different media. In fact, the speed of a wave is determined by the properties of the material, or the medium, through which it travels. A medium can be any form of matter, such as air, water, or steel. Wavelength and frequency do ***not*** change the speed of a wave—it is determined solely by the nature of the medium. Think about it—even though instruments play notes with different frequencies, they all reach your ears at the same time. That's because they're all traveling through the same medium: air. Wavelength and frequency may vary, but speed stays constant in the same medium.

MODEL 2: SPEED OF SOUND IN DIFFERENT MEDIA

MEDIUM	TEMP (°C)	STATE	STRENGTH OF BONDS	ELASTICITY	DENSITY (g/cm^3)	v (m/s)
Air	0	gas	weak	small		331
	100	gas	weak	small		386
Helium	0	gas	weak	small		880
	100	gas	weak	small		940
Water	25	liquid	medium-strong	medium		1490
	99	liquid	medium-strong	medium		1535
Methyl Alcohol	25	liquid	medium	medium		1140
	100	liquid	medium	medium		1185
Aluminum	25	solid	strong	large	270	5100
	100	solid	strong	large		5145
Gold	25	solid	strong	large	1900	2560
	100	solid	strong	large		2605
Vulcanized Rubber	25	solid	strong	very small		54

12. According to Model 2, as the temperature of a substance increases, what happens to the speed of sound in that medium?

13. Support your answer to number 12 with data from Model 2.

14. Think about the difference between objects of different temperatures **at the molecular level.** Propose a **molecular-level** explanation for why the relationship you determined in question 12 exists.

15. According to Model 2, how does the state of matter of a substance affect the speed at which sound can travel through a medium? Explain.

16. **Elasticity** is the property of a substance that causes it to regain its original shape after being deformed, such as by a wave propagating through it. Substances with a high elasticity quickly return to their original shape, while substances with a low elasticity take a long time to regain their original shape. The state of matter of a medium, which is related to the strength of its chemical bonds, has a large impact on that substance's elasticity. Propose an explanation, **at the molecular level,** of how elasticity of a material affects the speed at which sound waves can travel through the medium. (HINT: Think about what's happening to the molecules of a substance as a longitudinal wave travels through.)

17. Compare the speed of sound in Aluminum and Gold at 25°C.

a. How are the properties of Aluminum and Gold similar?

b. How are the properties of Aluminum and Gold different?

c. According to the data in Model 2, in what way does density affect the speed of sound in a medium?

d. Density is the amount of mass per unit volume of a substance. Considering the definition of density, propose a **molecular-level** explanation for how density affects the speed of a wave in a medium.

READ THIS:

The speed of any wave depends upon the properties of the medium through which the wave is traveling. There are 3 essential types of properties that affect wave speed – temperature, elastic properties, and density.

1. *TEMPERATURE*: The speed of sound in dry air at 0 degrees Celsius is about 330 m/s each degree increase above 0 degrees Celsius, the speed of sound in air increases by about 0.6 m/s because warmer air has faster moving molecules, so they bump into each other more often and can transmit a pulse in less time than in cold air.
2. *ELASTICITY*: Elasticity is the ability of a material to change shape in response to a force, and then return to its original shape. A material such as steel will experience a very small deformation of shape (and dimension) when a stress is applied to it. Steel is a rigid material with a high elasticity. On the other hand, a material such as putty is deformed easily; when a force is applied to the putty, it changes its shape easily. Putty is not very elastic. In general, solids are most elastic, followed by liquids and then gases. For this reason, longitudinal sound waves travel faster in solids than they do in liquids than they do in gases. $v_{solids} > v_{liquids} > v_{gases}$
3. *DENSITY*: Density of a medium is an example of an inertial properties, which are those properties related to the material's tendency to be sluggish to changes in its state of motion. The greater the density of the medium, the less responsive it will be to the interactions between neighboring particles and the slower the wave will be. As stated above, sound waves travel faster in solids than they do in liquids than they do in gases. However, within a single phase of matter (i.e., if we are ONLY talking about solids, or ONLY talking about liquids), the inertial property of density tends to be the property that has a greatest impact upon the speed of sound. A sound wave will travel faster in a less dense material than a more dense material.

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18. Normal room temperature is about 20 degrees Celsius. How fast would sound travel in air of this temperature?

19. Will sound travel faster in putty or steel? Why?

20. In old Western movies, you'll often see cowboys put their ears to the ground in anticipation of someone approaching on horseback. Why do you think they do that?

21. Many people think that inhaling helium makes your vocal cords move faster, thus producing a higher frequency voice temporarily. While your vocal cords do not move faster, you DO sounds funny after inhaling helium. Using what you know from Model 2, why do you think inhaling helium makes your voice higher?