Virginia State Science Olympiad Regional Tournament

2013 – Division C
Technical Problem Solving

- You may write your names on this sheet before the event begins.
- Two (2) calculators, one (1) standard-size (8.5"x11") double-sided sheet (*not two one-side sheets*) of paper containing any information, and writing implements may be used. Chemical/splash protection goggles are not required for this test.
- Any other electronic devices are ***not*** allowed for this event; please consult the proctor about a safe location to store these devices for the duration of the event if you happen to carry one; *any team caught with an electronic device during the event will be immediately disqualified*.
- A Tiebreaker is noted on the test. If it fails to break the tie, the team with the first wrong answer starting at the beginning of the test, will be ranked behind teams with correct answers to that point.

- **If you separate the pages of the test, please write your team number on all sheets. It is your responsibility to ensure the pages are put back together in order and stapled when turned in.**

Competitor Names: ______________________________

____

School/Team Name: ______________________________

Team #: __________

2013 SCIENCE OLYMPIAD, DIVISION C
REGIONAL COMPETITION - TECHNICAL PROBLEM SOLVING

MEASURING THE SPEED OF SOUND

Compared to most things studied in physics courses, sound waves travel very fast. The relatively large distances available in open spaces provide an ideal setting for relating distance, time, and the speed of sound. You may be familiar with the "open space" practice of counting the time between a flash of lightning and the resulting thunderclap to estimate the distance to the lightning strike. A typical method is to count seconds between *flash* and *boom* as "1-Mississippi, 2-Mississippi, 3-Mississippi...," and then divide by 5 to determine the distance in miles.

1. What is the presumed speed of sound (in m/s) when employing this method? Assume a distance relationship of 1 mile = 1609 meters, and show your solution below. Express your answer in scientific notation employing the correct number of significant figures.

An "open space" method for determining the speed of sound is based on echoes (reflected sounds). A sound of short duration (like a clap) might be generated at time t_0, travel a known distance Δx from the source to a large, flat surface (like a wall) and reflect, returning at time t to an observer located at the source.

2. In the space below, draw a sketch representing the described physical setting and provide an expression for the speed of sound v in terms of Δx, t_0 and t.

This "echo method," however, becomes less effective as the distance Δx decreases. Because the human ear requires approximately 0.1 second between sound peaks in order to distinguish two sounds as being distinct, there exists a minimum distance Δx_{min} between source/observer and the reflecting surface for which this method can be employed using unaided direct observation.

3. Taking the speed of sound to be that which you determined in Question 1, what is the minimum distance Δx_{min} (in meters) at which this method would still be useful?

To employ this technique over short distances, like those available in a laboratory setting, a faster timing system is required. In this simulated experiment, you will evaluate data collected by a sound probe (microphone) connected to a computer executing data logging/graphing software. As indicated in Figure 1 below, the microphone will be placed next to the opening of a tube that is sealed at its opposite end. When a sound, such as the snapping of your fingers, is generated near the open end of the tube, the computer will collect data from the microphone indicating the time t_0 of the initial sound and the time t of the return trip echo. You will evaluate the graphical results of five trials and use those data to calculate the speed of sound.

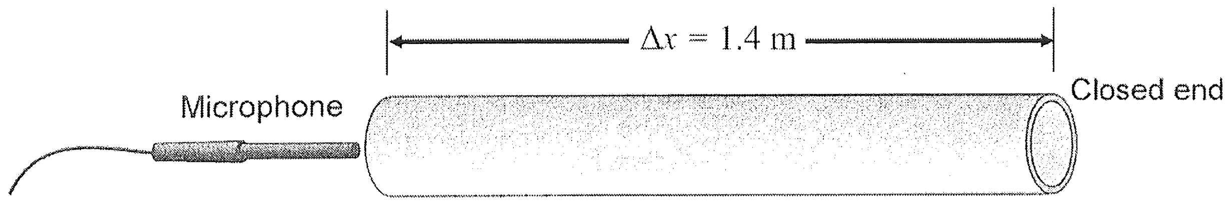
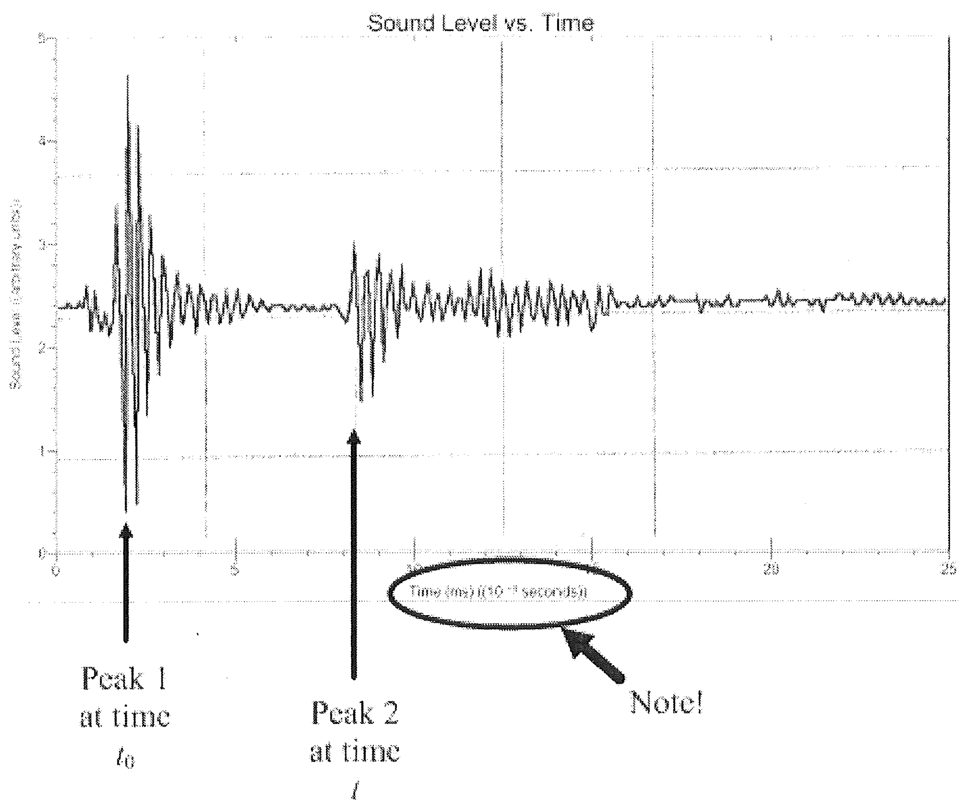
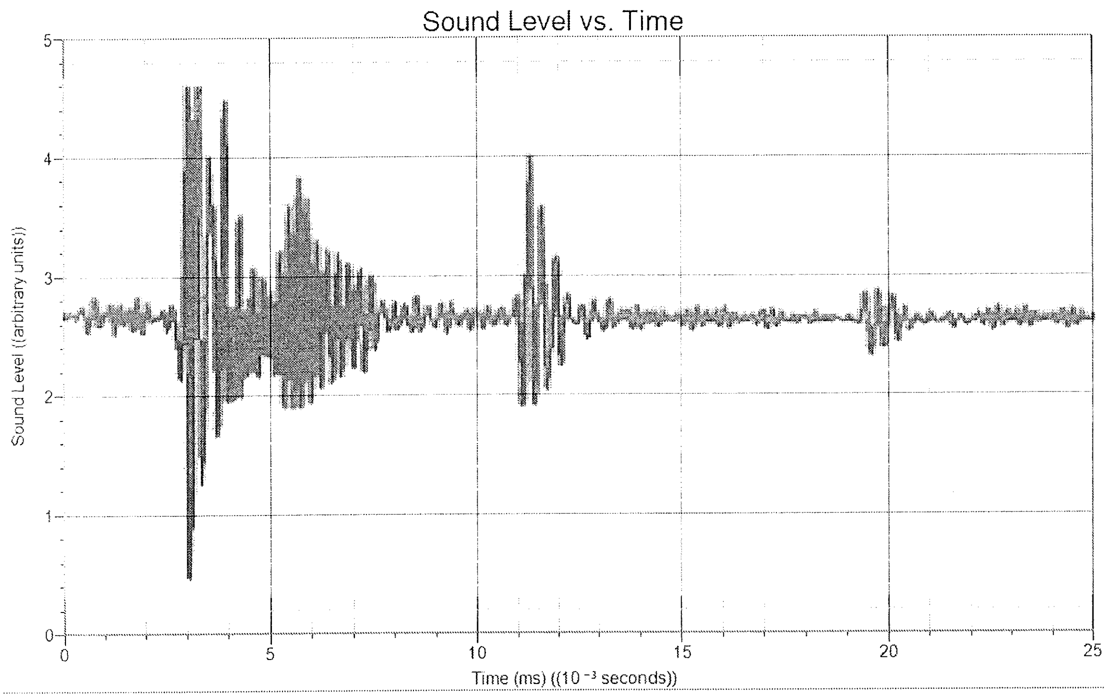
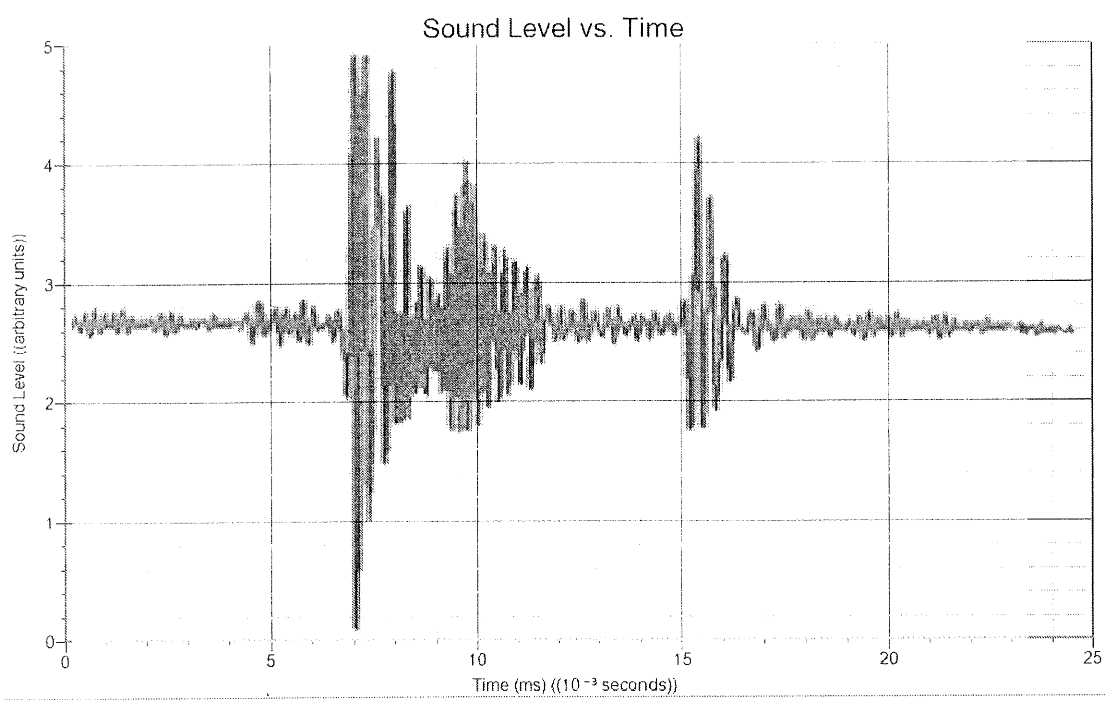


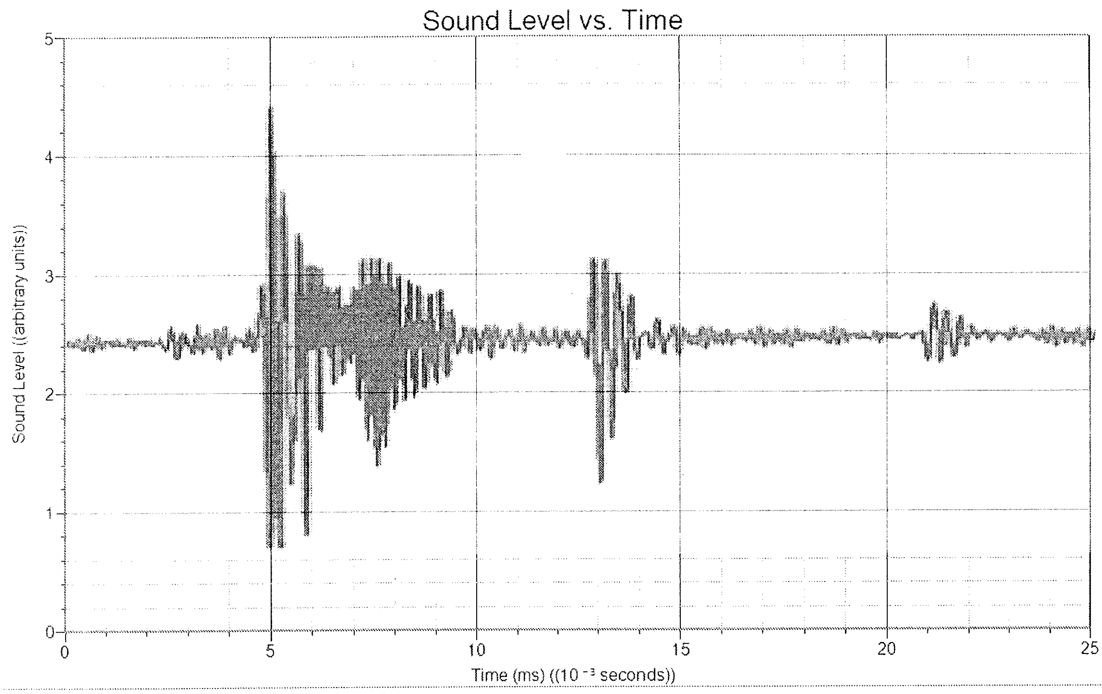
Figure 1

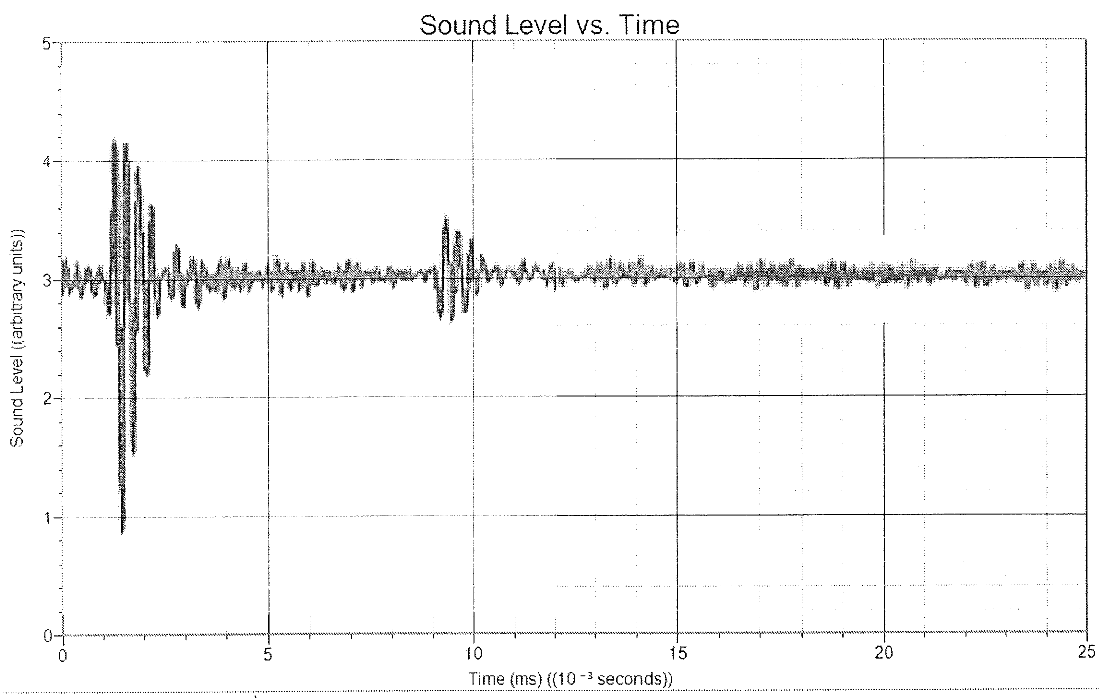
The following three pages provide the graphical data you will evaluate to determine the speed of sound. Note that times are given in milliseconds (10^{-3} s), and that plotted values for sound intensity are arbitrary – only the times between peaks are pertinent. A sample plot is given below:

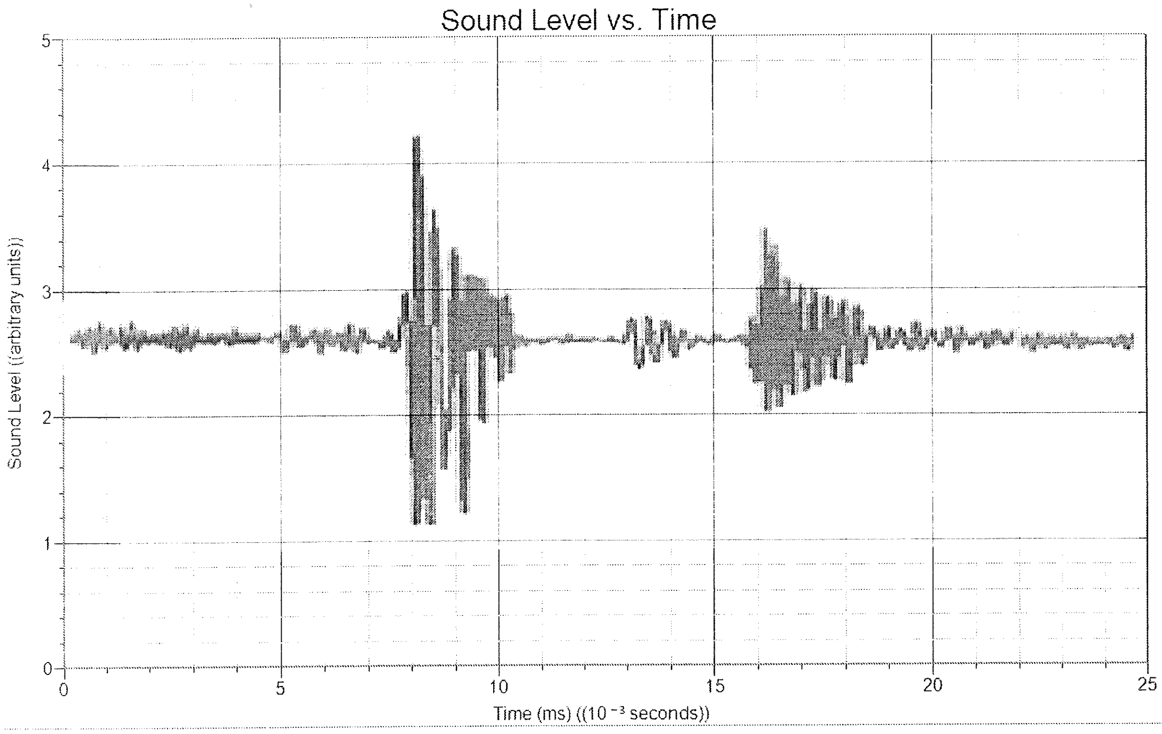



Sound Level vs. Time
Sound Level ((arbitrary units))
Time (ms) ((10 ⁻³ seconds))
0
1
2
3
4
5
0
5
10
15
20
25


Sound Level vs. Time
Sound Level ((arbitrary units))
Time (ms) ((10 ⁻³ seconds))
0
1
2
3
4
5
0
5
10
15
20
25


Sound Level vs. Time
Sound Level ((arbitrary units))
Time (ms) ((10 ⁻³ seconds))
0
1
2
3
4
5
0
5
10
15
20
25


Sound Level vs. Time
Sound Level ((arbitrary units))
Time (ms) ((10 ⁻³ seconds))
0
1
2
3
4
5
0
5
10
15
20
25



Length of Tube: 1.4 meters
Temperature of Room 20℃

Data

Trial	Total Travel Time (s)
1	
2	
3	
4	
5	
Average	

Noting the data given were for a 20°C laboratory, enter in your time and velocity data in the appropriate cells in the table below. Consider, as well, the indicated data for repeated experimentation at varying temperatures. Assuming no other changes in the experimental conditions, complete the table by using these data to calculate the velocity of sound at the given temperatures. Use the space below the chart to show your work.

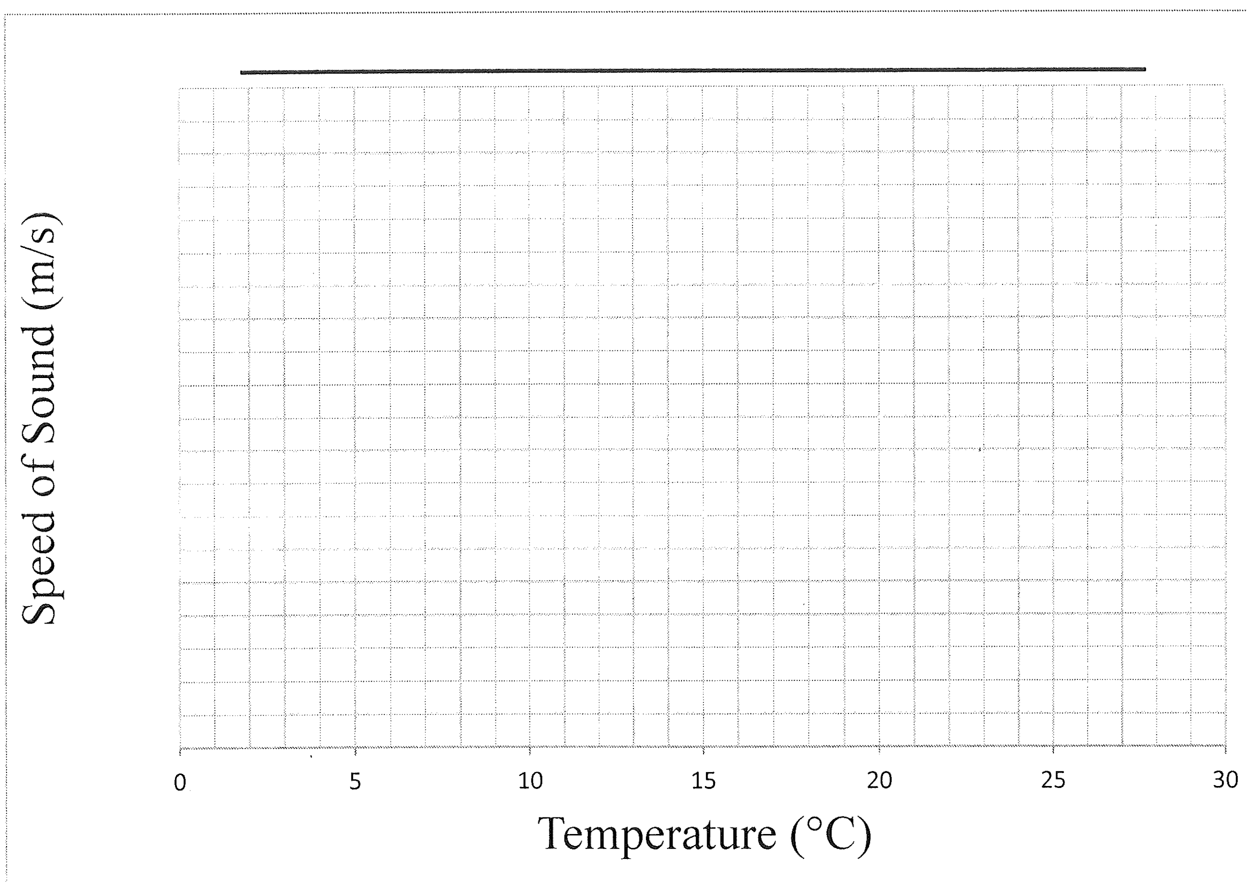
4.

T (°C)	Inter-peak Times (ms)	Velocity (m/s)
5	8.16	
10	8.09	
15	8.07	
20		
25	7.98	

On the graph provided below, assuming each small block to represent 1 m/s, and provide values for the *y*-axis at 5-block intervals that are appropriate to your data range. Plot the calculated velocity vs. temperature values on the graph and give the chart an appropriate title. Then, assuming a linear relationship, construct a line of best fit to determine the following:

5. A reasonable value for the speed of sound at 0°C.

6. An equation for the speed of sound as a function of temperature. (TIEBREAKER)



2013 SCIENCE OLYMPIAD, DIVISION C
REGIONAL COMPETITION

TECHNICAL PROBLEM SOLVING

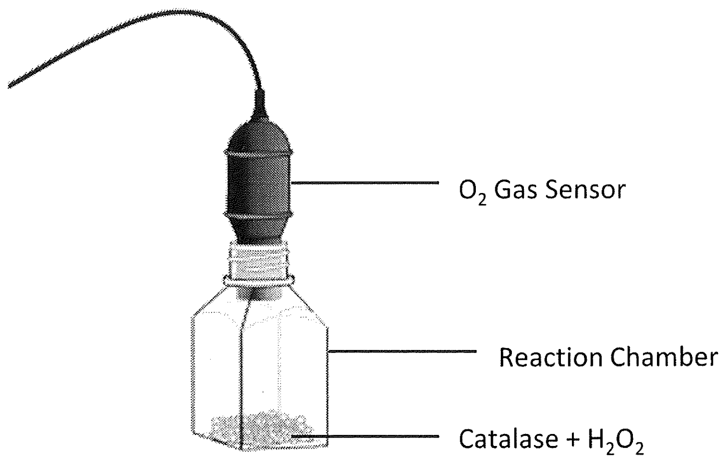
Hydrogen peroxide (H_2O_2) is generated as a by-product in biochemical pathways. However, because this molecule is toxic, many cells produce an enzyme called *catalase* to decompose the peroxide quickly. Hydrogen peroxide will decompose naturally, but the process is very slow without the catalase. The equation below shows the decomposition of peroxide:

$$2H_2O_2\ (aq) \rightarrow 2H_2O\ (l) + O_2\ (g)$$

Students are investigating the rate of peroxide decomposition using catalase from yeast. They design the procedure below:

1. Mix 5g of dried yeast with 250mL of room temperature tap water (25°C) and 1g of sugar in an Erlenmeyer flask. Allow the mixture to sit for 20 minutes to reactivate the dried yeast.
2. Add 1mL of a 3% H_2O_2 solution and 10mL of the yeast mixture to a reaction chamber, and immediately cap the chamber with the gas sensor (shown below). Start the timer on the computer program.

   Note: The sensor is attached to a computer with software that records the percentage of oxygen gas within the chamber.
3. Record the percentage of oxygen gas in the chamber every 30 seconds for 4 minutes.
4. Repeat steps 2 & 3 for a total of three trials.



The students then repeated the procedure using the following samples in the reaction chambers. Three trials were conducted for each sample.

1. Yeast mixture only
2. H_2O_2 only
3. Yeast mixture (100°C) + H_2O_2

Note: For the 100°C yeast mixture, boiling water was used in place of room temperature water. The temperature of the mixture held constant by placing the flask in a boiling water bath.

The students recorded the averages for each sample in Table 1, shown below

Table 1: Average Oxygen Concentrations (%) Measured Over Time (seconds)

Time (sec)	Average Oxygen Concentration (%)			
	Yeast Only	H_2O_2 Only	Yeast (25°C) + H_2O_2	Yeast (100°C) + H_2O_2
0	20.5	21.0	21.0	20.9
30	20.5	21.0	21.5	21.0
60	20.5	21.0	22.0	21.2
90	20.5	21.1	23.2	21.8
120	20.5	21.1	24.5	21.8
150	20.5	21.1	25.8	21.5
180	20.1	21.0	26.2	21.4
210	20.1	21.1	26.2	21.6
240	20.1	21.0	26.2	21.5

QUESTIONS

1. Plot all of the students' data on the grid below. Draw a best-fit line or curve for each data set, and label each line/curve.

2. *Using your graph*, calculate the reaction rate for the first 60 seconds for each sample. Record your answers in Table 2. Show one sample calculation in the space provided. Be sure to include units with all of your answers.

Table 2: Reaction Rates

Sample	Reaction Rate
Yeast Only	
H_2O_2 Only	
Yeast (25°C) + H_2O_2	
Yeast (100°C) + H_2O_2	

3. Which of the samples containing yeast and peroxide decomposed the peroxide fastest? Use the data to support your answer and provide a scientific explanation for why that trial was the fastest compared to the other.

4. What was the purpose of the *Yeast Only* and *H_2O_2 Only* trials? Explain your answer.

5. Why do the *Yeast + H_2O_2* graphs eventually reach a plateau?

6. How would the graph differ if the students combined a yeast mixture at 10°C with peroxide in the chamber? Explain your answer and be specific.

7. Identify one source of error in the experiment that may affect the results. Explain how that error would affect the results.