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 (KEY)

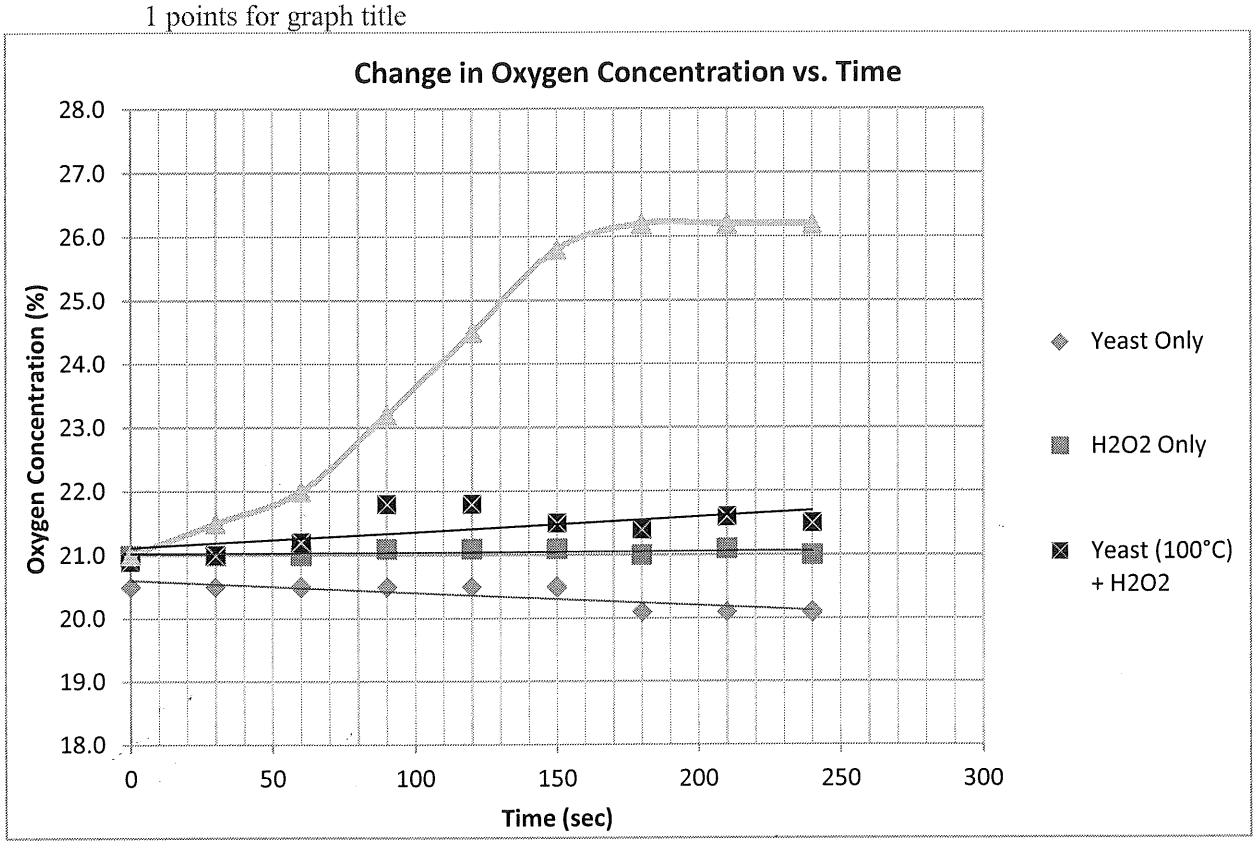
The students recorded the averages for each sample in Table 1, shown below

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 **50 points total**

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.
   21 points: 2 points per axis label
   2 points per axis scale
   3 points per line/curve (1 point for plotting; 1 point for line/curve; 1 point for label)
   1 points for graph title



2013 SCIENCE OLYMPIAD, DIVISION C
REGIONAL COMPETITION
TECHNICAL PROBLEM SOLVING (KEY)

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. **15 points total**

Reaction rate = slope of line = $\Delta y/\Delta x$ (%/second)

(1 pt for equation, 1 point for substituting proper values, 1 pt for units)

Table 2: Reaction Rates

Sample	Reaction Rate	Points
Yeast Only	**~0 %/sec**	**2 pts answer 1 pt for units**
H_2O_2 Only	**~0%/sec**	**2 pts answer 1 pt for units**
Yeast (25°C) + H_2O_2	**~0.017%/sec**	**2 pts answer 1 pt for units**
Yeast (100°C) + H_2O_2	**~0.005%/sec**	**2 pts answer 1 pt for units**

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 points [2 points for answer; 2 points for support/explanation]**

Yeast at 25°C: the slope of the line is greater, meaning the reaction rate is greater. The catalase enzymes in yeast at 25°C are fully functional. The shape of the enzyme/active site is still intact and able to bind to the peroxide molecules. The catalase enzymes in yeast at 100°C have likely been denatured. The heat breaks bonds in the enzyme's structure, altering the shape of the enzyme/active site and preventing the peroxide molecules from binding to it.

4. What was the purpose of the *Yeast Only* and *H_2O_2 Only* trials? Explain your answer. **3 points [1 pt for control/comparison; 1 points for explanation]**

Controls. The *Yeast Only* sample is used to determine if yeast alone generate oxygen. The *H_2O_2 Only* sample is used to see if peroxide breaks down quickly enough when exposed to light and increases the oxygen concentration in the chamber.

5. Why do the *Yeast + H_2O_2* graphs eventually reach a plateau? **2 points**

As the substrate (peroxide) is consumed by the enzyme, the substrate concentration decreases. Eventually, all substrate molecules will have been converted to product, so the reaction rate reaches zero (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.
3 points [1 pt for change in rate/slope OR plateau time; 2 points for explanation]

- The initial reaction rate would be slower (or slope of the line would be lower) than the25°C or 100°C. The enzymes and substrates would move more slowly and collide less frequently, or collide with less energy. Collisions may not be effective enough to overcome the activation barrier.
- The reaction would take longer to plateau because enzymes and substrate are less likely to collide with one another to produce oxygen

7. Identify one source of error in the experiment that may affect the results. Explain how that error would affect the results. **2 points [1 point for identifying <u>one</u> error; 1 point for explanation]**

- Chamber not capped quickly enough—oxygen gas could escape and lower the %
- Chamber not capped tightly enough—oxygen gas could escape and lower the %
- 100°C temperature not held constant throughout experimentation (or yeast mixture allowed to cool)—some enzymes may not have been denatured and were active as the flask cooled
- Volumes in the chambers were not controlled—may affect amount of oxygen gas produced
  - *Yeast Only* had 10mL of fluid
  - *H_2O_2 Only* had 1mL of fluid
  - Both *Yeast+H_2O_2* had 11mL of fluid

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.

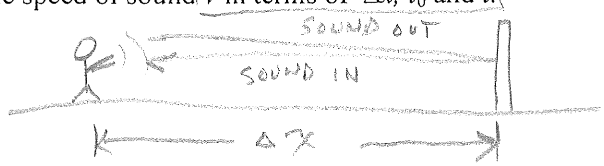
1. What is the presumed speed of sound when employing this method? Assume a distance relationship of 1 mile = 1609 meters, and show your solution below. Express your answer in scientific notation employing the correct number of significant figures.

(5) $\frac{1 \text{ mile}}{5 \text{ sec}}\left[\frac{1609 \text{ m}}{\text{mile}}\right] = 321.8 \frac{\text{m}}{\text{s}} = 3 \times 10^2 \frac{\text{m}}{\text{s}}$

(1) (1) (1) S.F. POWER NOTATION (1) UNITS (1)

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.



(2) 1 FOR INDICATION OF SOURCE & WALL; 1 FOR ΔX LABEL

(5) $v = \frac{d}{t}$, $d = 2\Delta x$ → $v = \frac{2\Delta x}{t - t_0}$

3: (1) FOR INDICATION OF DOUBLING ΔX (FOR SOUND BOTH OUT & BACK); (1) FOR ELAPSED TIME AS $t - t_0$; (1) FOR NO QUANTITIES OTHER THAN ΔX, t, t_0

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} at which this method would still be useful?

(5) either → $v = \frac{d}{t}$ (1) or ⇒ $d = vt$, $d = 2\Delta x$ (1) → $2\Delta x = vt$, $\Delta x = \frac{1}{2}vt$ (1) → $\Delta x = \frac{1}{2}(3\times10^2 \frac{m}{s})(0.1 s)$ (1) same as #1

$\Delta x = 15$ m or $\Delta x = 20$ m (ok) — (1) FOR CORRECT VALUE AND UNIT

(NOTE 20m IS MORE CORRECT FOR S.F.)

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.

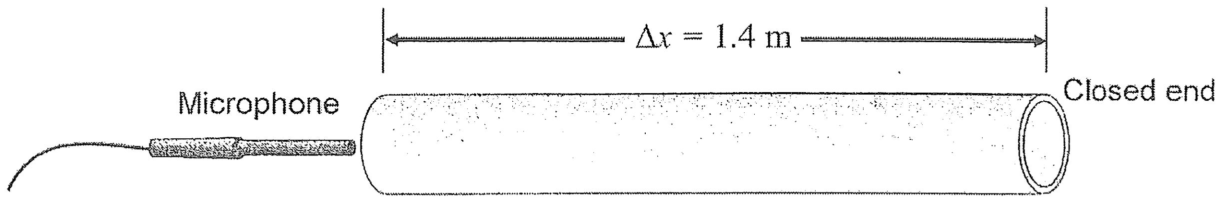
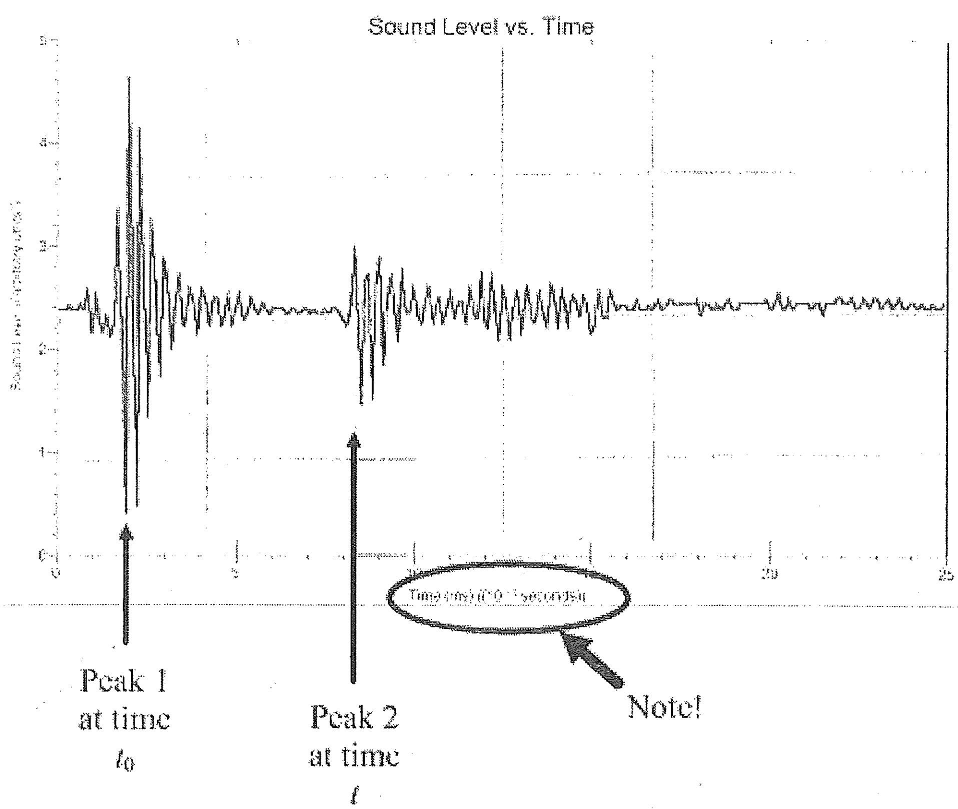
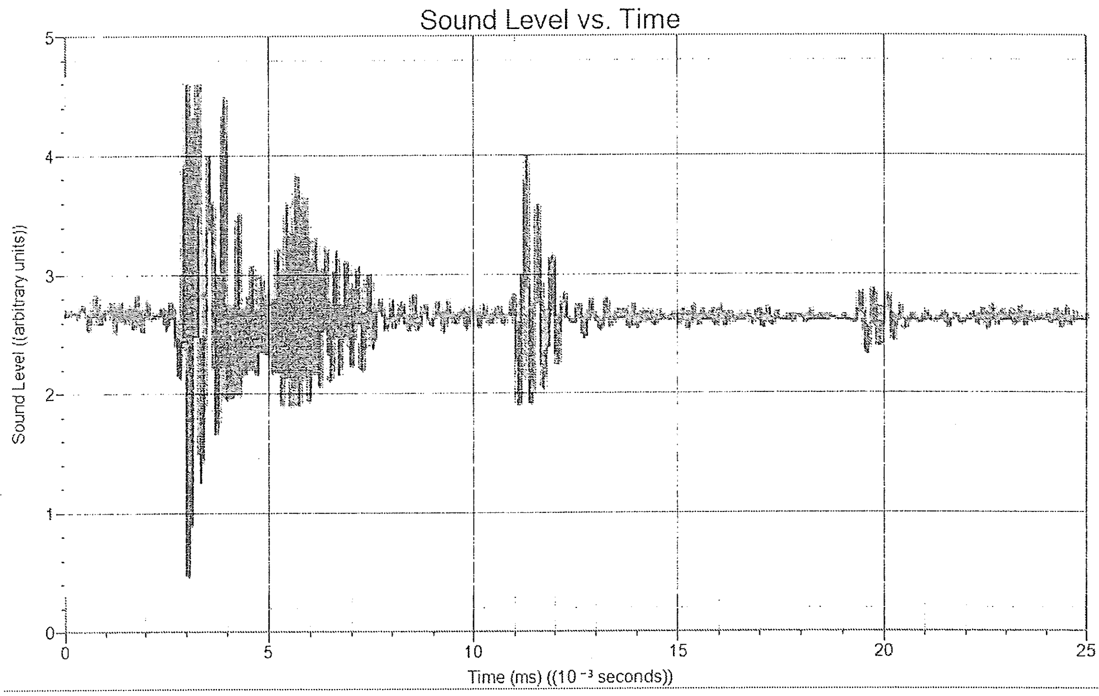
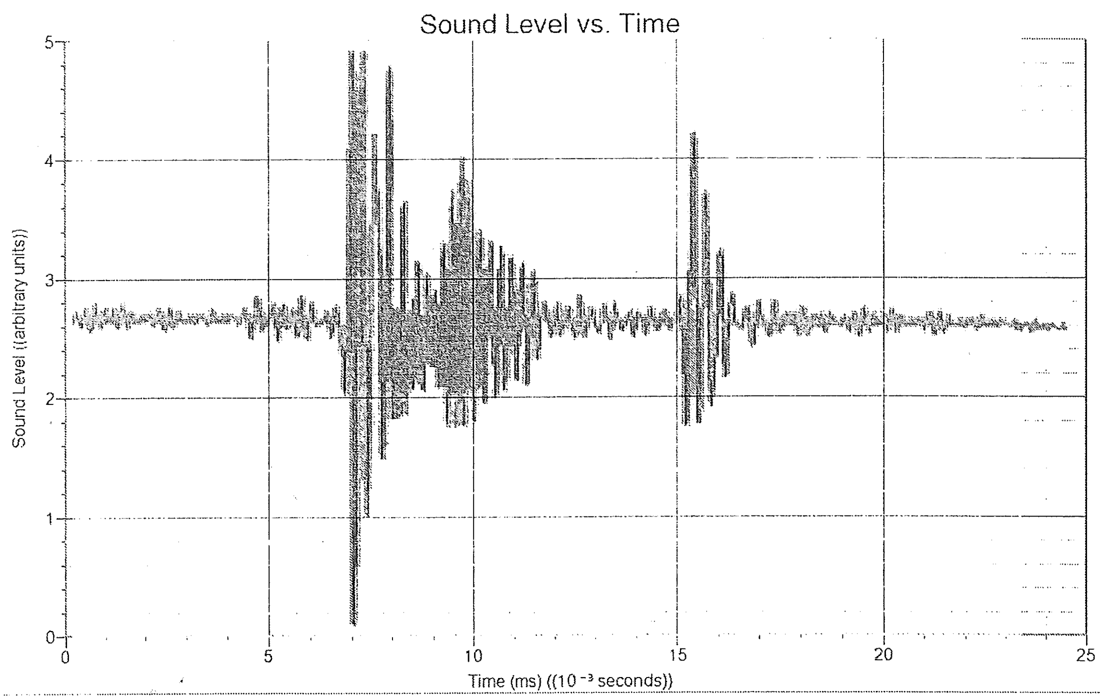


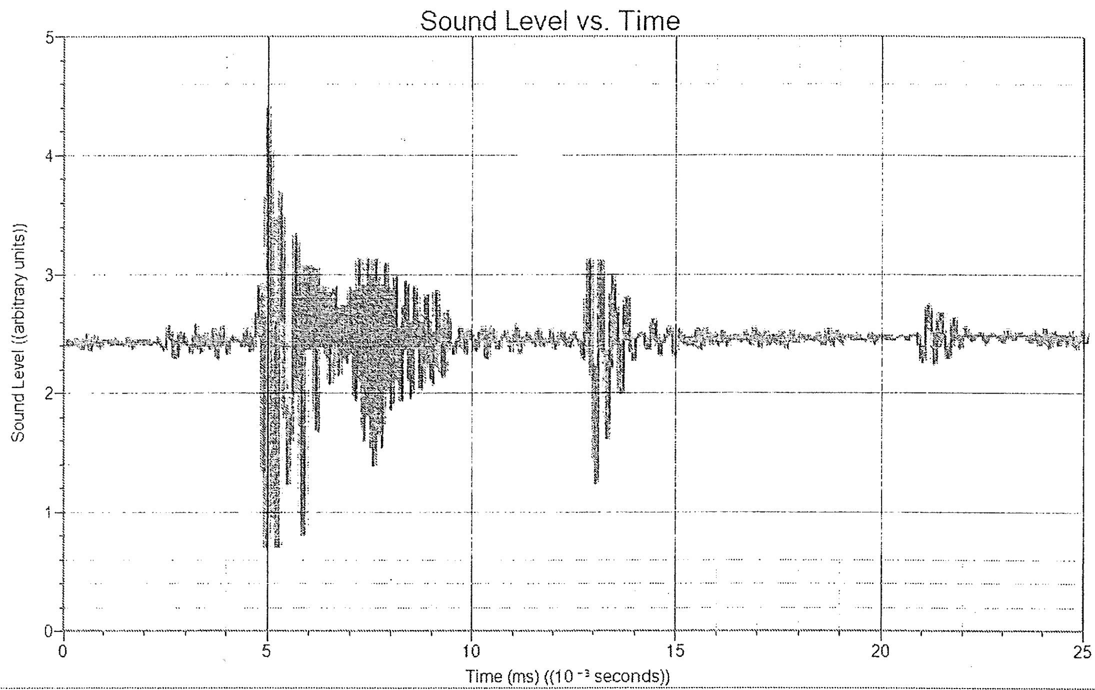
Figure 1

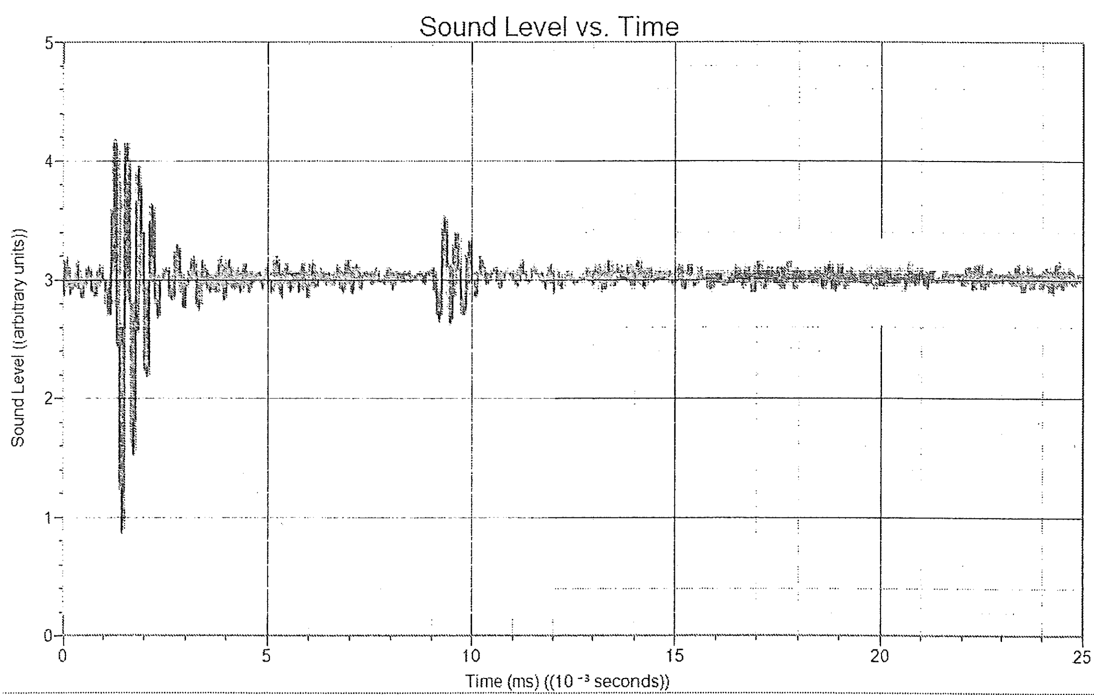
The following three pages provide the graphical data you will evaluate to determine the speed of sound. Note that times are given in milliseconds (10^{-3} s), and that plotted values for sound intensity are arbitrary – only the times between peaks are pertinent. A sample plot is given below:



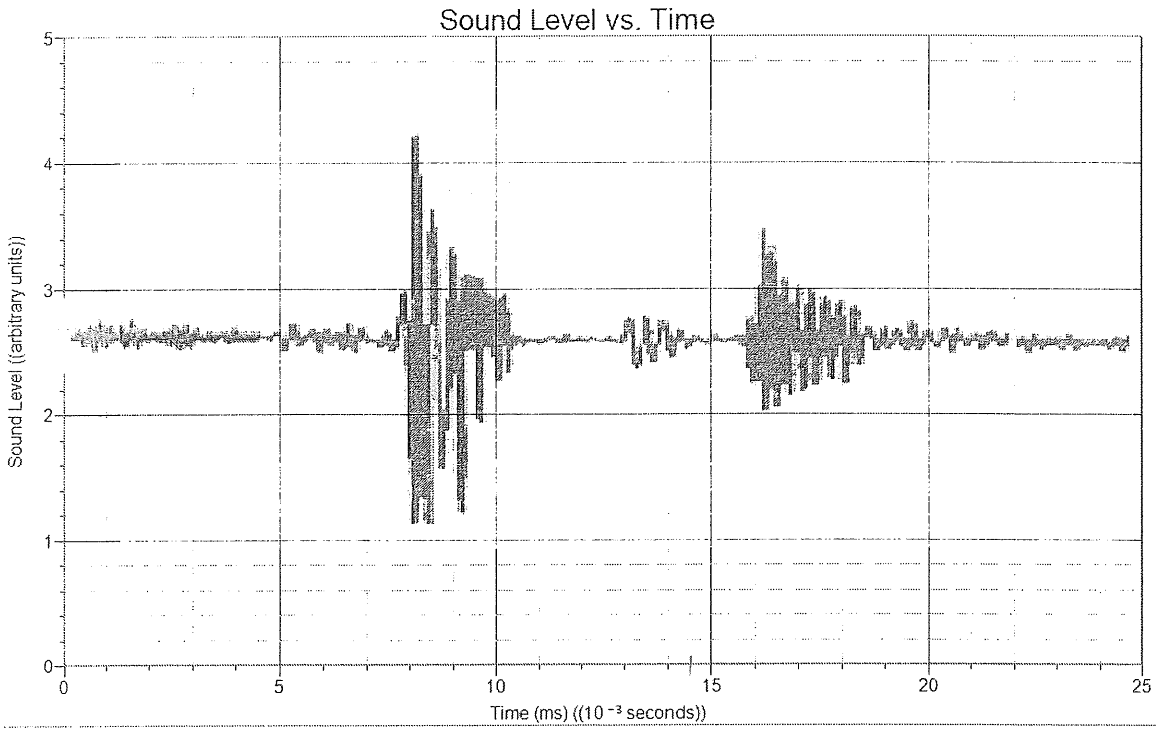

Sound Level vs. Time
Sound Level ((arbitrary units))
5
4
3
2
1
0
0
5
10
15
20
25
Time (ms) ((10 ⁻³ seconds))


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


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

(15)



Length of Tube: 1.4 meters
Temperature of Room 20℃

Data

(4)

Trial	Total Travel Time (s)
1	
2	ALL VALUES
3	8 ms ± 0.5 ms
4	or
5	0.008s ± 0.0005s
Average	

Values around 8 ms or 0.008 s

↑ same

(2) FOR ORDER OF MAGNITUDE (ms or 10^{-3} s)

(2) FOR VALUES $7.5 \le t \le 8.5$

(19)

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.

(6)

4.

T (°C)	Inter-peak Times (ms)	Velocity (m/s)
5	8.16	343 NO ±
10	8.09	346 NO ±
15	8.07	347 NO ±
20	8.00	350 ± 3 m/s
25	7.98	351 NO ±

SOME SLACK ON S.F. IS OK

1 each circled value = (6)
3 points (½) credit for values ≈ 175 m/s
(i.e FAILING TO DOUBLE Δx FOR d)

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

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:

FULL CREDIT FOR 175 ± 2 IF DATA TABLE SHOWS THOSE VALUES

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

SHOWN AS y-INTERCEPT OF BEST-FIT LINE (2)

(5) **341 m/s** → VALUE 341 ± 3 m/s (2)
→ UNITS (m/s) (1)

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

(5) $V = 341\ \frac{m}{s} + \left(0.42\ \frac{m}{s \cdot °C}\right) T$

(1) SHOWN AS f(T)

(1) SAME AS #5 ABOVE

SLOPE ± 0.04 (1)

(2) SHOWN IN SLOPE-INTCPT FORM

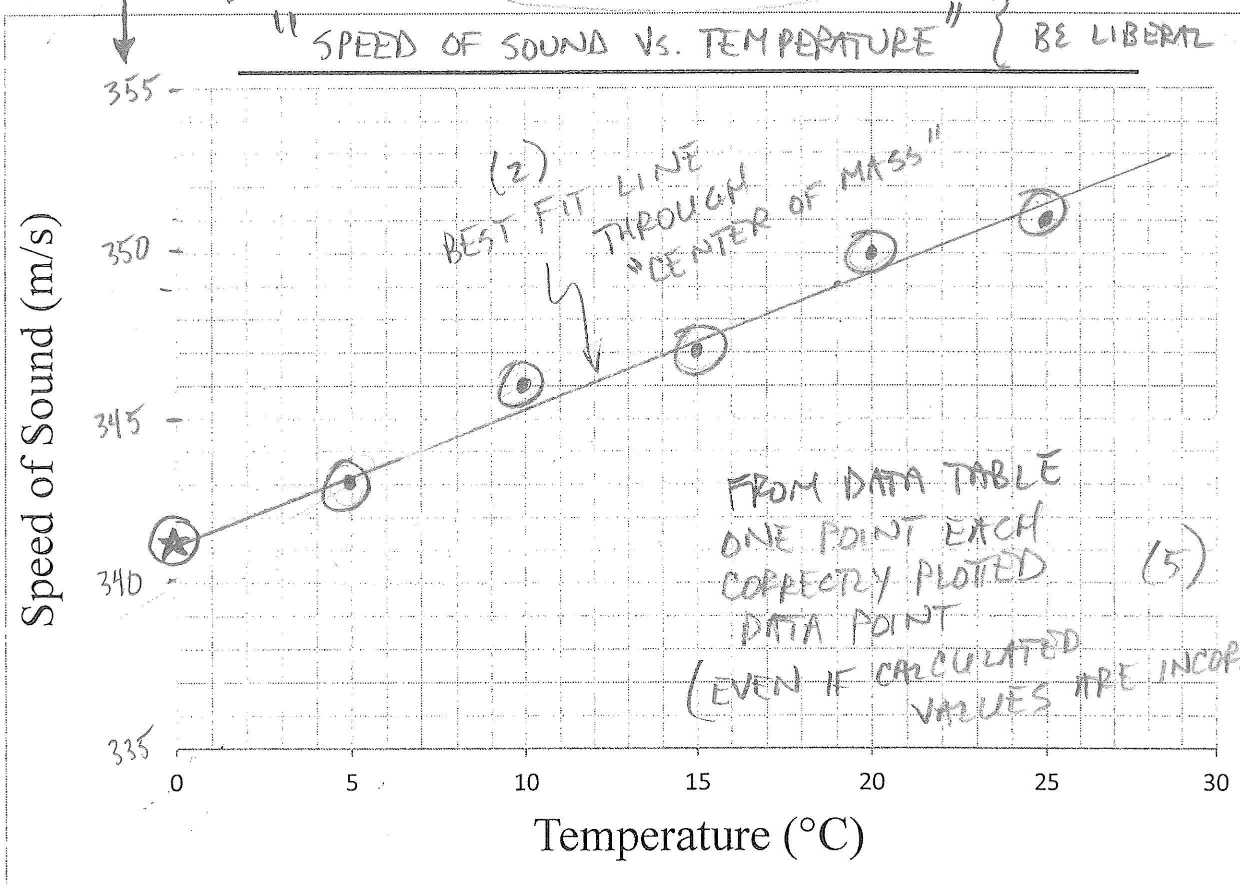
GRAPH

(1) {AXIS SCALED TO APPROPRIATE 20°C RANGE - EVEN IF DATA ARE INCORRECT}

(1) {BLOCKS LABELED EVERY 5}

TITLE INCLUDED (1) {OR SIMILAR — BE LIBERAL}

(5)



✱ TAKE (TOTAL GRAPH POINTS)/2 $\{\frac{10}{2} = 5$ POSSIBLE$\}$