Physiology Lessons
for use with the
Biopac Student Lab

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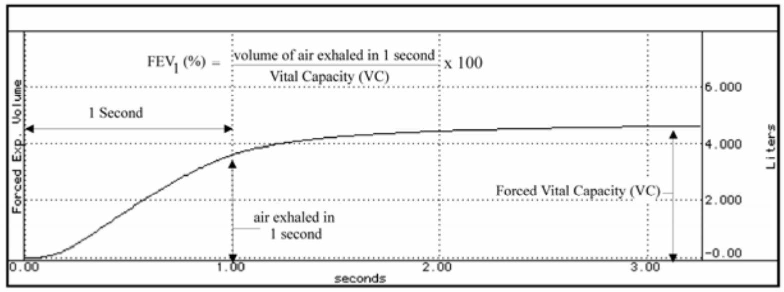
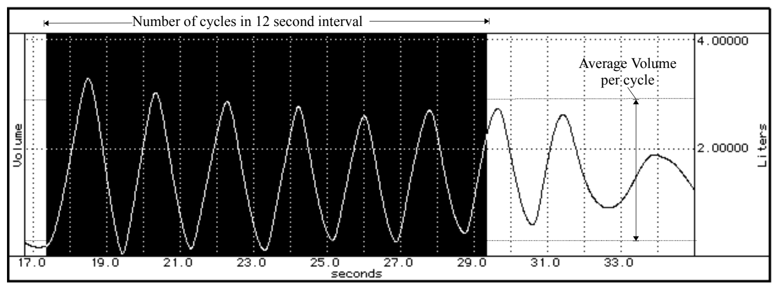
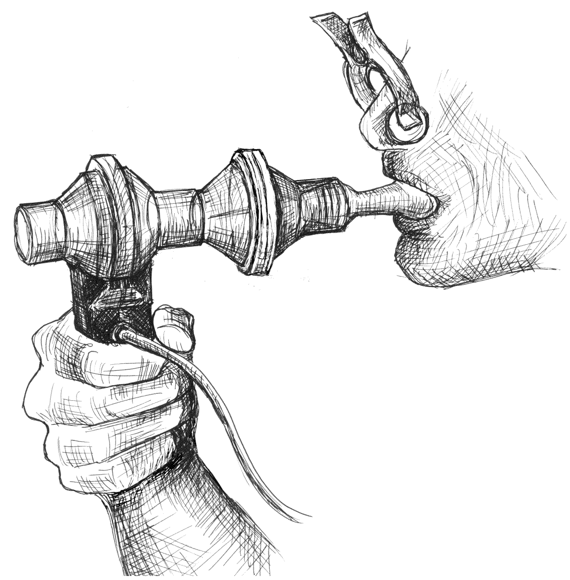
Lesson 13
PULMONARY FUNCTION II
Pulmonary Flow Rates
- *Forced Expiratory Volume ($FEV_{1,2,3}$)*
- *Maximal Voluntary Ventilation (MVV)*





Number of cycles/minute = Number of cycles in 12 second interval X 5

MVV = (Average volume per cycle) X (Number of cycles per minute)



II. EXPERIMENTAL OBJECTIVES

1.) To observe experimentally, record, and/or calculate forced expiratory volume (FEV) and maximal voluntary ventilation (MVV).

2.) To compare observed values of FEV with predicted normals.

3.) Compare MVV values with others in your class.

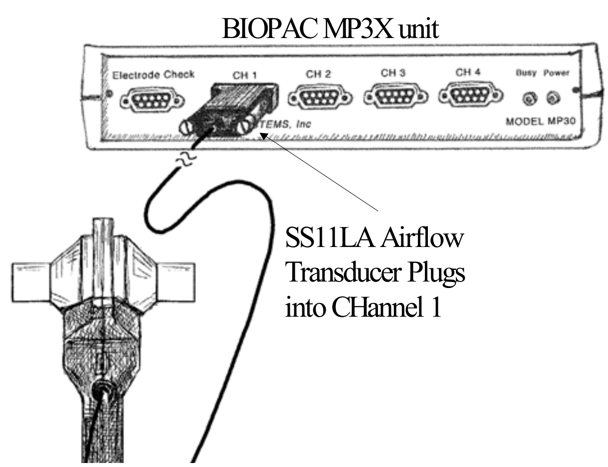
III. MATERIALS

- BIOPAC airflow transducer (SS11LA)
- BIOPAC disposable mouthpiece (AFT2)
- BIOPAC bacteriological filter (AFT1)
- BIOPAC nose clip (AFT3)
- *Optional*: BIOPAC Autoclavable Reusable Mouthpiece (AFT8)
- BIOPAC 0.6 Liter Calibration Syringe (AFT6)
- Clinical Laboratory Scale
- Computer system
- Biopac Student Lab 3.7
- BIOPAC data acquisition unit (MP36, MP35, or MP30 with cable and power)

IV. EXPERIMENTAL METHODS

For further explanation, use the online support options under the Help Menu.

A. SET UP

FAST TRACK SET UP	Detailed Explanation of Set Up Steps
1. Turn your computer **ON**.	The desktop should appear on the monitor. If it does not appear, ask the laboratory instructor for assistance.
2. Make sure the BIOPAC MP3X unit is turned OFF.	
3. Plug the airflow transducer (SS11LA) into Channel 1. 4. Turn **ON** the MP3X Data Acquisition Unit.	 Fig. 13.4

Set Up continues…

5. Place a filter onto the end of the calibration syringe.
6. **Insert** the Calibration Syringe/Filter Assembly into the airflow transducer (Fig. 13.5).

IMPORTANT!
Always insert on the side labeled "Inlet"

The filter is necessary for calibration because it forces the air to move smoothly through the transducer. This assembly can be left connected for future use. You only need to replace the filter if the paper inside the filter tears.

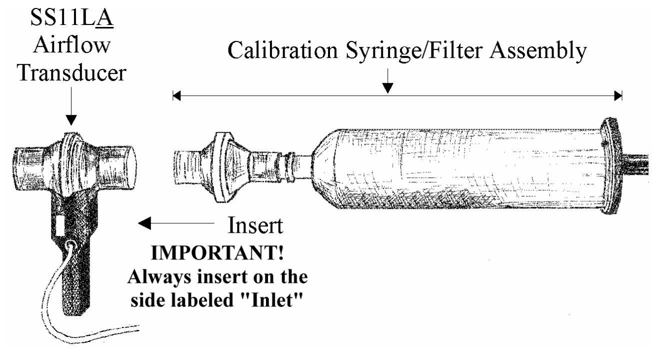


Fig. 13.5

If using **SS11LA** transducer with removable, cleanable head, always insert syringe assembly on the transducer side labeled "**Inlet**" so that the transducer cable exits on the left, as shown in Fig. 13.5.

If using an older **SS11L** transducer with non-removable head, insert syringe assembly into the larger diameter port.

IMPORTANT: If your lab sterilizes the airflow heads after each use, make sure a clean head is installed now.

7. **Start** the Biopac Student Lab program.
8. Choose Lesson 13 (**L13-LUNG-2**).
9. Type in your filename.

Use a unique identifier.

10. Click **OK**.

This ends the Set Up procedure.

END OF SET UP

B. CALIBRATION

The calibration procedure establishes the hardware's internal parameters (such as gain, offset, and scaling) and is critical for optimum performance. **Pay close attention to the entire calibration procedure.**

FAST TRACK Calibration

1. Pull the Calibration Syringe Plunger all the way out and hold the Calibration Syringe/Filter Assembly upright (Fig. 13.6)

Calibration continues…

Detailed Explanation of Calibration Steps

The Airflow Transducer is sensitive to gravity so it needs to be held upright throughout the calibration and recording procedures.

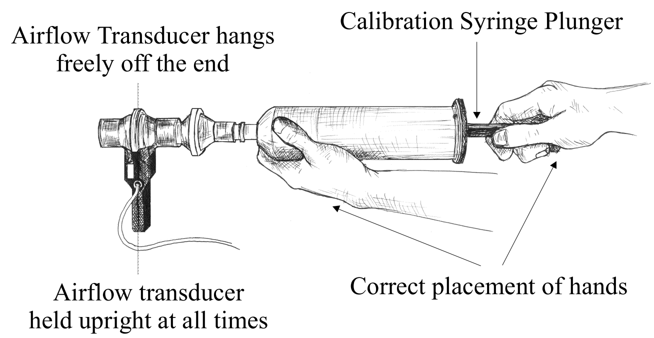


Fig. 13.6

2. Click on the **Calibrate** button.

The first calibration procedure stage will run for 8 seconds and end with an alert box.

IMPORTANT: Leave the plunger extended and hold the assembly steady and upright during the entire calibration procedure. Do not touch the plunger because any pressure at this stage will cause inaccurate results.

3. Prepare for the second calibration stage.

Stage 1 of the calibration procedure ends with an alert box asking if you have read the directions in the journal. Read the directions in Step 5 and/or the journal so that once the second calibration procedure starts, you fully understand the procedures.

4. Click **Yes** after reading the alert box.

Do not click on the **Yes** button until you are completely ready to proceed. When you click **Yes**, the second stage of the calibration procedure will begin, and will run until you click End Calibration.

5. Cycle the syringe plunger in and out completely 5 times (10 strokes).

Hold the syringe assembly as previously shown in Fig. 13.6.

Use a rhythm of about 1 second per stroke with 2 seconds rest between strokes, i.e., push the plunger in for approximately 1 second, wait 2 seconds, pull the plunger out, wait 2 seconds, and repeat 4 more times. Stop the calibration procedure by pushing the **End Calibration** button.

IMPORTANT: Never hold onto the airflow transducer handle when using the calibration syringe or the syringe tip may break.

Note: The calibration procedure may seem a little strange, but is required because of the complexity of the Airflow to Volume calculation. The accuracy of this conversion is aided by analyzing the airflow variations occurring over five complete cycles of the calibration syringe. Additional cycles would also help, but only with diminishing return rates. Five cycles turns out to be an adequate number of cycles, and is an easy number to remember.

6. Click on **End Calibration**.

7. **Check** your calibration data.

At the end of the calibration recording, your screen should resemble Fig. 13.7.

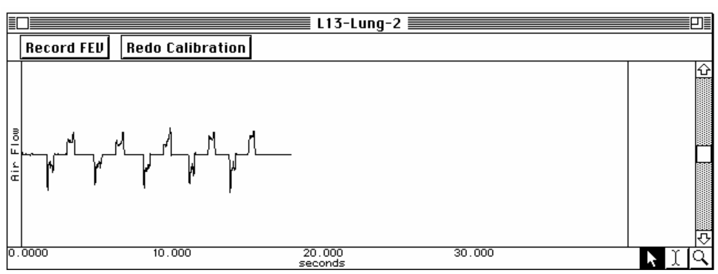


Figure 13.7

- If correct, go to the Recording section.

The first push of the syringe plunger should have resulted in a downward deflection of the data. If your data shows 5 downward deflections and 5 upward deflections, you may proceed to the Data Recording section.

- If incorrect, **Redo Calibration**.

If the first stroke resulted in an upward deflection, you will need to change the calibration assembly by inserting the assembly into the other port of the airflow transducer. Then, you will need to repeat calibration.

If the data shows any large spikes, then you must redo calibration by clicking on the **Redo Calibration** button and repeating the entire calibration sequence.

END OF CALIBRATION

C. RECORDING LESSON DATA

FAST TRACK Recording | **Detailed Explanation of Recording Steps**

1. Prepare for the recording.

In this lesson, you will perform two tests to measure pulmonary flow rates:

Forced Expiratory Volume (FEV)
Maximal Voluntary Ventilation (MVV)

In order to work efficiently, read this entire section so you will know what to do for each recording segment. The Subject should continue to relax while you review the lesson.

Following the procedure precisely is very important, as the calculation from airflow to volume is very sensitive.

Check the last line of the journal and note the total amount of time available for the recording. Stop each recording segment as soon as possible so you don't use an excessive amount of time (time is memory).

Hints for obtaining optimal data:

a) The Subject should wear loose clothing so clothing does not inhibit chest expansion.

b) Always use the noseclip to ensure that there is no loss of air through the nose during recording.

c) The Subject must try to expand the thoracic cavity to its largest volume during maximal inspiratory efforts.

d) During recording of FEV, the Subject should attempt to exhale as quickly as possible into the mouthpiece.

e) During recording of MVV, the Subject should attempt to exhale and inhale as quickly and deeply as possible. Breathing rates should be faster than 60 breaths/minute or greater than 1 breath/second for the best results. The breathing needs to be maintained for 12-15 seconds.

f) Always begin breathing into the airflow transducer before the recording begins and continue breathing into the airflow transducer until after the recording ends.

g) If you start the recording on an inhale, try to end on an exhale, and vice-versa. This is not absolutely critical, but will increase the accuracy of the Airflow to Volume calculation.

h) Always insert on and breathe through the side of the SS11LA airflow transducer labeled "Inlet."

2. Insert a clean mouthpiece and filter into the airflow transducer as described below:

> ***To be safe***, follow this procedure precisely to make sure the airflow transducer is sterile.

IMPORTANT: If your lab sterilizes the airflow heads after each use, make sure a clean head is installed now.

Have the **Subject** personally remove the filter and mouthpiece from the plastic packaging. This mouthpiece will become the Subject's personal mouthpiece. It is advisable to write the Subject's name on the mouthpiece and filter with a permanent marker so they can be reused later.

Recording continues…

- **If** using the **SS11LA** transducer and **sterilizing** the head after each use:

IMPORTANT!
Always insert on the side labeled "Inlet"

If using **SS11LA** transducer and sterilizing the head after each use, insert a disposable mouthpiece (BIOPAC AFT2) or an autoclavable mouthpiece (BIOPAC AFT8) into the airflow transducer on the side labeled "Inlet."

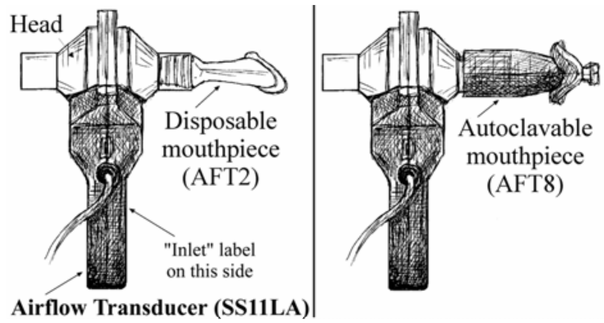


Fig. 13.8 SSLA with sterilized head

- **If** using the **SS11LA** transducer and **not sterilizing** the head after each use:

IMPORTANT!
Always insert on the side labeled "Inlet"

If using **SS11LA** transducer and not sterilizing the head after each use, insert a filter and mouthpiece into the airflow transducer on the side labeled "Inlet."

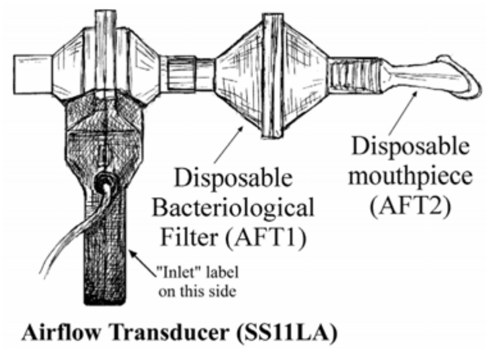


Fig. 13.9 SSLA with unsterilized head

3. Have the Subject apply a personal nose clip, sit upright, and begin breathing through the airflow transducer.

IMPORTANT!
Always breathe through the side labeled "Inlet"

For hygienic purposes, each Subject should be assigned a personal nose clip.

Subject should place his/her personal nose clip on the nose and begin breathing through the Airflow Transducer. As mentioned in the calibration procedure, it is very important to keep the Airflow Transducer upright at all times (Fig. 13.10).

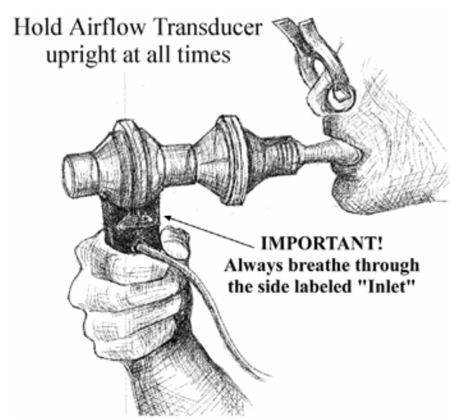


Fig. 13.10

Recording continues…

Segment 1 — FEV

4. Click on **Record FEV**.

5. Perform the following procedure:

   The **Director** should guide the Subject through this procedure.

   a) Breathe normally for 3 cycles

      a) One complete cycle is one inhale *and* one exhale.

   b) Inhale as deeply as you can, then hold your breath for just an instant.

      b) You hold your breath for an instant so that when you are analyzing the data you can see clearly where the exhale began.

   c) Exhale as completely as you can.

      c) Squeeze out all the air you can. You may want to bend over to physically force air out.

   d) Breathe normally for 3 more cycles.

      d) ---

6. Click on **Stop**.

   As soon as the **Stop** button is pressed, the Biopac Student Lab software will automatically convert the air flow data to volume data. At the end of the calculation, just the volume data will be shown on the screen, as shown in Fig. 13.11.

7. Review the data on the screen.

   If all went well, your data should look similar to the figure below, and you can proceed to Step 8.

   ➢ If <u>correct</u>, go to Step 8.

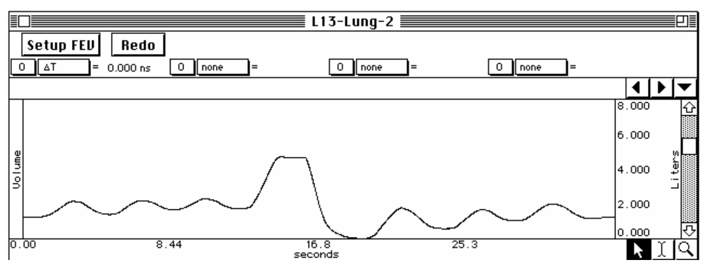


Fig. 13.11

   ➢ If <u>incorrect</u>, click on **Redo**.

   The data would be incorrect if you feel you didn't follow the procedure precisely, or if you can not clearly define the start of **maximal exhale**, and you will need to repeat the recording.

   In this case, you should redo the recording by clicking on "**Redo**" and repeating Steps 4-7. Note that once you press **Redo**, the data you have just recorded will be erased.

8. Use the I-beam cursor to select the area of maximal exhale (must be at least 3 seconds long).

   Use the **I-beam** cursor to select the area of **maximal exhale**. You must start the cursor at the instant of exhale, and by holding the mouse button down, select an area at least 3 seconds in length (refer to Figure 13.12).

   The first measurement box has been set up to read **ΔT (Delta Time),** which is the time between the end and beginning of the selected area. Use the **ΔT** measurement to determine the amount of time you have selected.

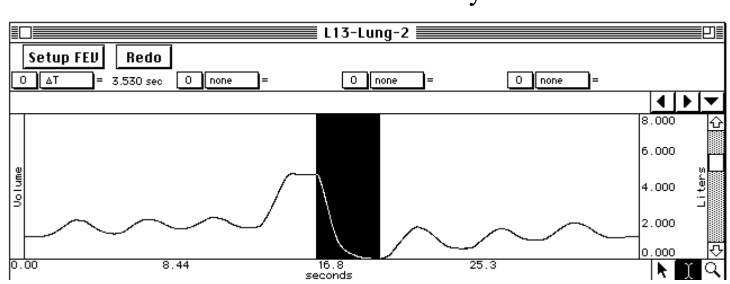


Fig. 13.12

Recording continues…

9. Click on **Setup FEV**.

After you have selected the correct area, click on **Setup FEV**. The program will cut out your selected area, invert it, and paste it into a new channel (Fig. 13.13).

10. Review the data on the screen.
    - If correct, go to Step 11.

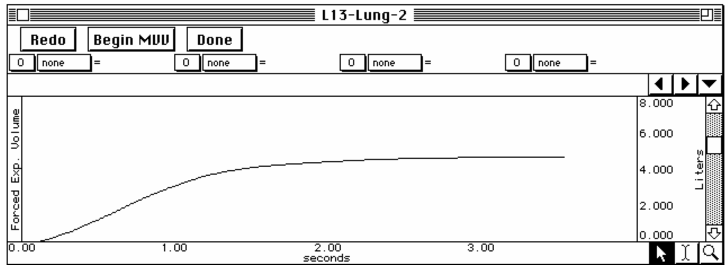


Fig. 13.13

The volume waveform originally recorded will be hidden from view so you can concentrate on the data needed to calculate FEV. The plot shows the cumulative expired volume over time.

- If incorrect, **Redo**.

If after comparing the data obtained to that of Fig. 13.13, you feel the area you selected in Step 7 was incorrect, you may click on the **Redo** button and redo Steps 8-10.

Segment 2 — MVV

11. Click on **Begin MVV**.

The current FEV data on the screen will be automatically saved to disk for later analysis and the screen display will change to include a **Begin MVV** button.

12. Place a noseclip on and begin breathing through the airflow transducer.

It is important that you begin breathing through the airflow transducer before you click on the Record MVV button.

Make sure the air does not leak through the mouthpiece or nose clip.

13. Click on **Record MVV**.

14. Perform the following procedure:

The **Director** should guide the **Subject** through this procedure.

a) Breathe normally into the airflow transducer for 5 cycles.

b) Breathe quickly and deeply for 12-15 secs.

WARNING
This procedure can make the Subject dizzy and light headed. The Subject should be sitting down, and the Director should be watching him/her. Stop if the Subject starts to feel sick or excessively dizzy.

b) For optimal results, the emphasis during the MVV recording should be on **speed**, more than depth of breathing.
   - The best results are obtained at breathing rates faster than 65 breaths/min. At that rate, the Subject is breathing out using maximal effort as in the forced expiration recording.

c) Breathe normally again and continue for 5 more cycles.

Recording continues…

15. Click on **Stop**.

As soon as the **Stop** button is pressed, the Biopac Student Lab software will automatically convert the airflow data to volume data. At the end of the calculation, just the volume data will be shown on the screen (Fig. 13.14).

16. Review the data on the screen.
    - If correct, go to Step 17.
    - If incorrect, click on **Redo**. (If you press **Redo**, the data you have just recorded will be erased.)

If all went well, your data should look similar to the figure below, and you can proceed to Step 17.

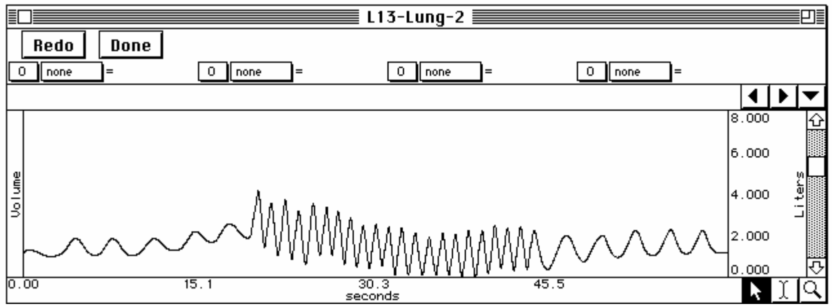


Fig. 13.14

The data would be incorrect if you feel you didn't follow the procedure precisely. In this case, you should redo the recording by clicking on "**Redo**" and repeating Steps 13-16.

17. Click on **Done**.

After you press **Done,** your data will automatically be saved in the "Data Files" folder on your hard drive (with an MVV extension after the filename). A pop-up window with options will appear. Make your choice, and continue as directed.

If choosing the "Record from another Subject" option:

a) You will not need to recalibrate the airflow transducer. For this reason, we recommend that all recordings be completed before you proceed to Data Analysis.

b) Remember to have each person use his/her own mouthpiece, bacterial filter and nose clip.

c) Repeat recording Steps 1-17 for each new Subject.

d) Each person will need to use a unique file name.

END OF RECORDING

V. DATA ANALYSIS

FAST TRACK Data Analysis

1. Enter the **Review Saved Data** mode and choose the correct file.

   Note channel number (CH) designations:

Channel	*Displays*
CH 1	**Volume**

Detailed Explanation of Data Analysis

Enter the Review Saved Data mode.

For the first part of the analysis, choose the data file from the FEV recording (saved with "**FEV-L13**" added to the file name).

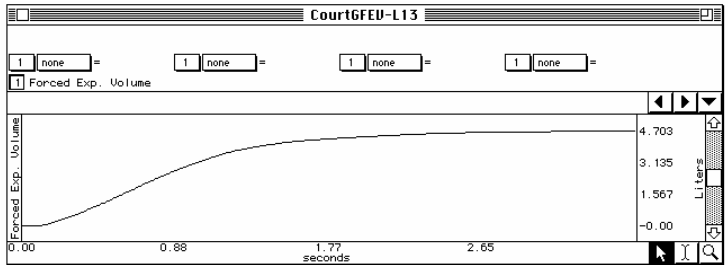


Fig. 13.15

2. Turn Grids ON.

To turn Grids ON, click on the **File** menu, select **Display preferences**, choose **Grids**, select **Show Grids**, and click **OK**.

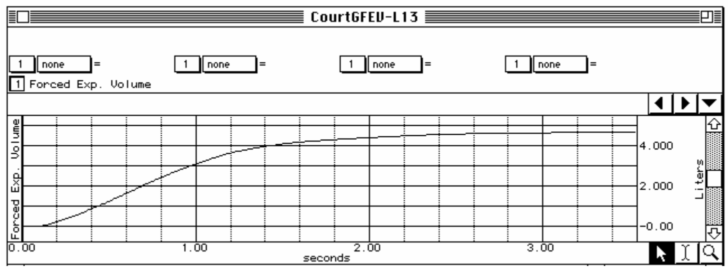


Fig. 13.16 Grids ON

3. Set up the measurement boxes as follows:

Channel	*Measurement*
CH 1	**ΔT**
CH 1	**p-p**

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type, and result. The first two sections are pull-down menus that are activated when you click on them. The following is a brief description of these specific measurements.

> **ΔT:** The Delta **T**ime measurement is the difference in time between the end and beginning of the selected area.
>
> **p-p**: finds the maximum value in the selected area and subtracts the minimum value found in the selected area.

The "selected area" is the area selected by the I-Beam tool (including the endpoints).

4. Use the **I-beam** cursor to select the area from time zero to the end of the recording.

   A

The p-p measurement for the selected area represents the Vital Capacity (VC).

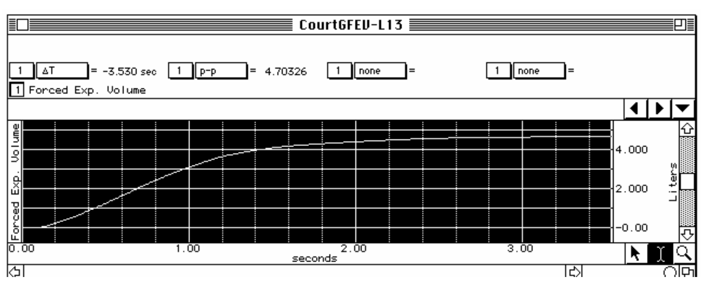


Fig. 13.17

Data Analysis continues…

5. Use the **I-beam** cursor to select the first one-second interval (Fig. 13.18).

   B

The selected area should be from Time 0 to the one-second reading, as displayed in the ΔT measurement. The volume expired in the time interval from 0 to the end of second one (Vol 0-1) is indicated by the **p-p** measurement. Use this volume to calculate FEV_1, which is the % of VC expired in the time interval from 0 to the end of second one.

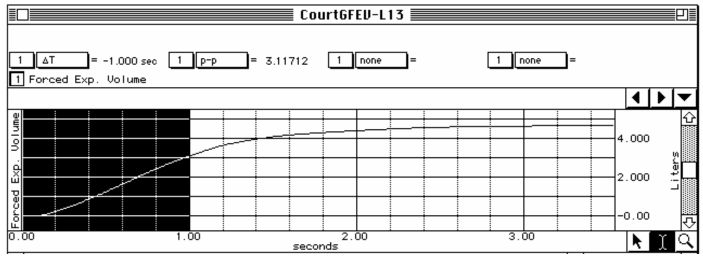


Fig. 13.18 FEV_1

6. Use the **I-beam** cursor to select the first two-second interval (Fig. 13.19).

   B

The selected area should be from Time 0 to the two-second reading, as displayed in the ΔT measurement. The volume expired in the time interval from 0 to the end of second two (Vol 0-2) is indicated by the **p-p** measurement. FEV_2 is the % of VC expired in the time interval from 0 to the end of second two.

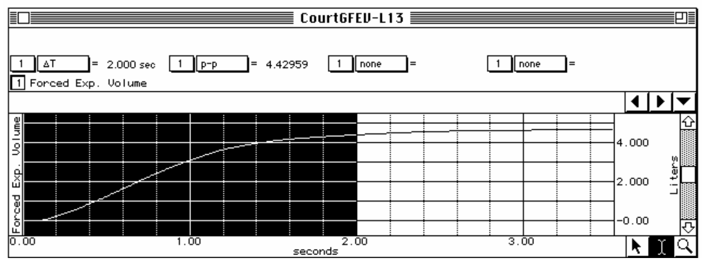


Fig. 13.19 FEV_2

7. Use the **I-beam** cursor to select the first three-second interval (Fig. 13.20).

   B

The selected area should be from Time 0 to the three-second reading, as displayed in the ΔT measurement. The volume expired in the time interval from 0 to the end of three (Vol 0-3) is indicated by the **p-p** measurement. FEV_3 is the % of VC expired in the time interval from 0 to the end of second three.

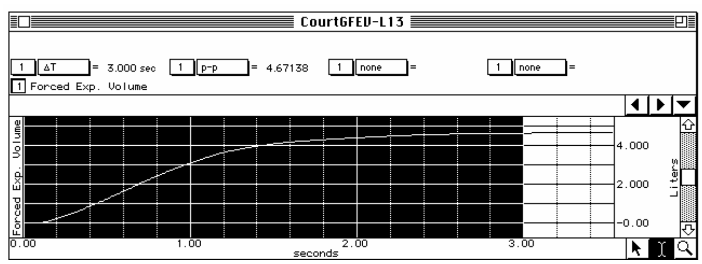


Fig. 13.20 FEV_3

8. Pull down the **Lessons** menu, select **Review Saved Data**, and choose the correct **MVV** file.

   Note channel number (CH) designations:

Channel	*Displays*
CH 2	**Volume**

Re-enter the Review Saved Data mode.

For the second part of the analysis, choose the data file from the MVV recording (saved with "**MVV-L13**" added to the file name.)

Data Analysis continues…

9. Use the **zoom** tool to set up your display window for optimal viewing of the deep, fast breathing segment of the recording (Fig. 13.21).

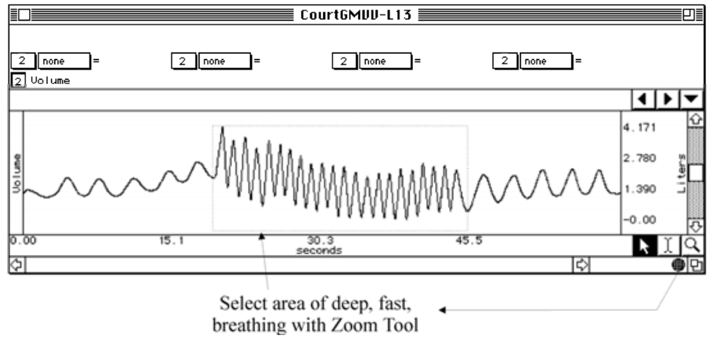


Fig. 13.21

These tools can be used to adjust the data window:

Autoscale horizontal	Horizontal (Time) Scroll Bar
Autoscale waveforms	Vertical (Amplitude) Scroll Bar
Zoom Previous	

10. Set the measurement boxes:

Channel	*Measurement*
CH 2	**ΔT**
CH 2	**p-p**

See the previous definitions of **ΔT** and **p-p**.

11. Use the **I-beam** cursor to select a twelve-second area that is convenient to count the number of cycles in the interval (Fig. 13.22).

C

The example shown in Fig.13.22 is a 12-second interval with about 10.5 cycles. The selected area shows 10 complete individual cycles and one incomplete cycle at the end.

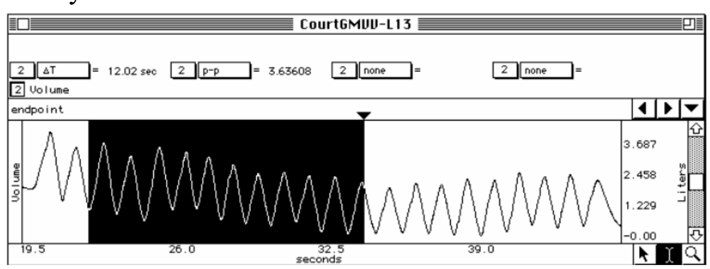


Fig. 13.22

12. Place a marker at the end of the selected area (Fig. 13.23).

To place a marker, click in the lower portion of the marker label region above the endpoint of the selected area. This is important because you will need to identify the region endpoint after you deselect the area. Enter marker text.

13. Use the **I-beam** cursor to select <u>each complete individual cycle</u> in the 12-second interval defined in Step 11. Select one cycle at a time.

C

You need to select <u>each complete individual cycle</u> up to the endpoint of the originally selected area, as indicated by the marker you inserted. If there is an incomplete cycle at the end, do not count it.

Fig.13.23 shows the first cycle of the 12-second interval defined in Fig. 13.22 selected:

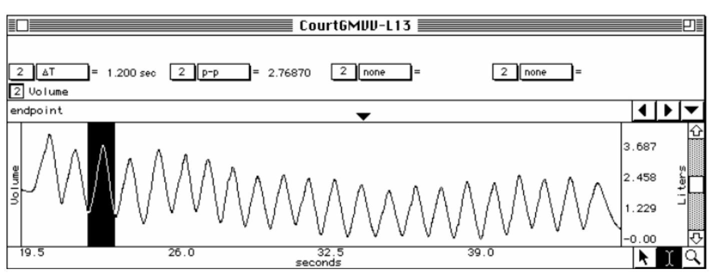


Fig. 13.23

Data Analysis continues…

14. Save or print the data file.	You may save the data to a floppy drive, save notes that are in the journal, or print the data file.
15. Exit the program.	

END OF DATA ANALYSIS

END OF LESSON 13

Complete the Lesson 13 Data Report that follows.

PULMONARY FUNCTION II

Pulmonary Flow Rates

- *Forced Expiratory Volume ($FEV_{1,2,3}$)*
- *Maximal Voluntary Ventilation (MVV)*

DATA REPORT

Student's Name: ______________________________

Lab Section: ______________________________

Date: ______________________________

I. Data and Calculations

Subject Profile

Name______________________ Height______________

Age______________________ Weight______________

Gender: Male / Female

A. Vital Capacity (VC)

CH 1 **p-p** measurement: ____________

B. Comparison of FEV_X% to Normal Values

Table 13.2

Time Interval (sec)	**Forced Expiratory Volume (FEV) [p-p]**	**Vital Capacity (VC)** *from A*	**FEV/VC** *calculate*	**(FEV/VC) x 100 = %** *calculate*	= **FEV_x**	*Averages for reference*
0-1				%	FEV_1	83%
0-2				%	FEV_2	94%
0-3				%	FEV_3	97%

C. MVV Measurements (Note, all volume measurements are in liters)

1) Number of cycles in 12-second interval: ______

2) Calculate the number of respiratory cycles per minute (RR):

RR = Cycles/min = Number of cycles in 12-second interval x *5*

Number of cycles in 12-second interval (from above): ______ x 5 = ______**cycles/min**

3) Measure each cycle

Complete Table 13.3 with a measurement for each individual cycle. If the Subject had only 5 complete cycles/12-sec period, then only fill in the volumes for 5 cycles. If there is an incomplete cycle, do not record it. (The Table may have more cycles than you need.)

Table 13.3

Cycle Number	Measurement [CH 2 p-p]
Cycle 1	
Cycle 2	
Cycle 3	
Cycle 4	
Cycle 5	
Cycle 6	
Cycle 7	
Cycle 8	
Cycle 9	
Cycle 10	
Cycle 11	
Cycle 12	
Cycle 13	
Cycle 14	
Cycle 15	

4) Calculate the average volume per cycle (AVPC):

Add the volumes of all counted cycles from Table 13.3.

Sum = ________________ liters

Divide the above sum by the number of counted cycles. The answer is the average volume per cycle (AVPC)

AVPC = _______ / ____________________ = ____________________liters
Sum # of counted cycles

5) Calculate the MVV_{est}

Muliply the AVPC by the number of respiratory cycles per minute (RR) as calculated earlier.

MVV = AVPC x RR = _______ x _________ = __________________liters/min
AVPC RR

II. Questions

D. Define **Forced Expiratory Volume** (FEV).

____

____

____

E. How do the Subject's FEVx values compare to the average per Table 13.2?

FEV_1	*less than*	*same as*	*greater than*
FEV_2	*less than*	*same as*	*greater than*
FEV_3	*less than*	*same as*	*greater than*

F. Is it possible for a Subject to have a vital capacity (single stage) within normal range but a value for FEV_1 below normal range? Explain your answer.

____

____

____

____

____

____

____

G. Define **Maximal Voluntary Ventilation** (MVV).

____

____

____

____

____

H. How does the Subject's MVV compare to others in the class?

less than *same as* *greater than*

I. Maximal voluntary ventilation decreases with age. Why?

____

____

____

____

____

____

____

____

J. Asthmatics tend to have their smaller airways narrowed by smooth muscle constriction, thickening of the walls, and mucous secretion. How would this affect vital capacity, FEV1, and MVV?

____

____

____

____

____

____

K. Bronchodilator drugs open up airways and clear mucous. How would this affect the FEV and MVV measurements?

___

___

___

___

L. Would a smaller person tend to have less or more vital capacity than a larger person?

__________Less _______More

M. How would an asthmatic person's measurement of FEV_1 and MVV compare to an athlete? Explain your answer.

___

___

___

End of Lesson 13 Data Report