Lesson 13
PULMONARY FUNCTION II
Pulmonary Flow Rates

- Forced Expiratory Volume (FEV<sub>1,2,3</sub>)
- Maximal Voluntary Ventilation (MVV)

Manual Revision
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### For Forced Expiratory Volume (FEV<sub>1,2,3</sub>)

\[
FEV_{1,2,3} = \text{volume of air exhaled in 1 second} \times 100 
\]

### For Maximal Voluntary Ventilation (MVV)

\[
MVV = (\text{Average volume per cycle}) \times (\text{Number of cycles per minute}) 
\]

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

MVV = (Average volume per cycle) X (Number of cycles per minute)
Lesson 13: Pulmonary Function II

I. INTRODUCTION

The respiratory or pulmonary system performs the important functions of supplying oxygen (O\textsubscript{2}) during inhalation, removing carbon dioxide (CO\textsubscript{2}) during exhalation, and adjusting the acid-base balance (pH) of the body by removing acid-forming CO\textsubscript{2}. Because oxygen is necessary for cellular metabolism, the amount of air that the pulmonary system provides is important in setting the upper limits on work capacities or metabolism. Therefore, the measurement of lung volumes and the rate of air movement (airflow) are important tools in assessing the health and capacities of a person.

In this lesson, you will measure:

- **Forced Vital Capacity** (FVC), which is the maximal amount of air that a person can forcibly exhale after a maximal inhalation.
- **Forced Expiratory Volume** (FEV), which is the percentage of FVC that a person forcibly expels in intervals of 1, 2, and 3 seconds (FEV\textsubscript{1}, FEV\textsubscript{2}, FEV\textsubscript{3}).
- **Maximal Voluntary Ventilation** (MVV), which is a pulmonary function test that combines volume and flow rates to assess overall pulmonary ventilation.

These measurements indicate the upper limit of work that the person can do based on the capabilities of his or her respiratory system. When a person takes in maximal inhalation and then follows this with maximal exhalation the volume of expired air is that person’s **Single Stage Vital Capacity** (SSVC). The time required to achieve maximal exhalation is not a factor in determining SSVC.

Because the lungs reside in the thoracic cavity, vital capacity is ultimately restricted by the size of a person’s thoracic cavity. Therefore, size-related variables (e.g., age, gender, weight) affect the capacities of the respiratory system (Table 13.1).

<table>
<thead>
<tr>
<th>Equations for Predicted Vital Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
</tbody>
</table>

V.C. Vital Capacity in liters
H Height in centimeters
A Age in years

Using the equation in Table 13.1, you can estimate the vital capacity of a 19 year old female who is 167 centimeters tall (about 5’6”) as 3.815 liters:

\[ 0.041 \times (167) - 0.018 \times (19) - 2.69 = 3.815 \text{ liters} \]

For adults, the average pulmonary capacities decrease with age. Women tend to have smaller volumes than men of the same age and weight. As weight increases, volumes increase, with the exception that overweight people tend to have decreased volumes.

Even within one person, respiratory supply and demand differs with activity levels and health. Accordingly, the rate and depth of ventilation (the volume of gas you breathe in and out per minute) are not static but rather must constantly adjust to the changing needs of the body. As you increase your activity levels from rest, the volume and rate of air flowing in and out of your lungs also changes. The changes in volume and how fast those changes in volume (airflow) are effected can be used to assess the health of a person’s respiratory system.
Pulmonary volumes, pulmonary capacities, and pulmonary airflow rates are often measured in diagnosing and assessing the health of the respiratory system (Fig 13.1).

In general, chronic pulmonary diseases may be classified into two physiologic categories:

1. **Chronic obstructive pulmonary disease (COPD)**
2. **Chronic restrictive pulmonary disease**.

**Chronic obstructive pulmonary disease (COPD)**

In obstructive pulmonary disease, such as **asthma** or **emphysema**, airflow into and out of the lungs is reduced. In asthma, **inflammation** of the lining of the airways and heavy mucus secretion reduce airway diameters and increase airway resistance. This results in a wheezing sound (characteristic of asthmatic breathing) and a reduction in the volume of air flowing into and out of the lungs per minute. Diagnosis of obstructive pulmonary diseases usually requires measurements of pulmonary flow rates and ERV.

**Chronic restrictive pulmonary disease**

In restrictive pulmonary disease, the person’s ability to inflate and deflate the lungs is reduced, and as a result, some lung volumes and capacities are below normal. For example, in **pulmonary fibrosis** (such as occurs in coal miner’s disease), **vital capacity**, (the maximal air volume moved out of the lungs) is reduced.

Vital capacity is reduced both because of reductions in inspiratory and expiratory reserve volumes, volumes beyond normal resting tidal volume. This also occurs in silicosis or other chronic diseases of the lung in which the lungs become less distensible. Restrictive pulmonary diseases are diagnosed, in part, by determining lung volumes and capacities.

It is not uncommon for a person to have restrictive and obstructive pulmonary diseases simultaneously, even though each disease may have a different origin and may have begun at a different time. For example, a person may suffer from emphysema and fibrosis of the lung at the same time.

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

1. **Forced Expiratory Volume (FEV)**
2. **Maximal Voluntary Ventilation (MVV)**

**Test #1: Forced Expiratory Volume (FEV)**
Forced Expiratory Volume (also referred to as forced vital capacity or timed vital capacity) is a test in which a limit is placed on the length of time a Subject has to expel vital capacity air. FEV$_1$, FEV$_2$, FEV$_3$ are defined as the percentage of vital capacity that can be forcibly expelled after a maximal inhalation in the period of one second, two seconds, and three seconds, respectively (Fig. 13.2).

![Diagram of FEV$_1$ measurement](image)

**Fig 13.2 Section of a record of Forced Expiratory Volume in one second (FEV$_1$)**

The normal adult is able, with maximal effort, to expire about 66-83% of his/her vital capacity in one second (FEV$_{1.0}$), 75-94% of their vital capacity in the second second (FEV$_{2.0}$), and 78-97% of their vital capacity by the end of the third second (FEV$_{3.0}$).

A person with asthma may have a normal or near-normal vital capacity as measured in a Single Stage Vital Capacity test, which allows as long as necessary to maximally inhale and exhale. However, when an asthmatic exhales vital capacity with maximal effort, FEV measurements are all reduced because heavy mucus secretion and smooth muscle action reduces airway diameter and it takes longer to completely exhale vital capacity against increased airway resistance.
Test #2 Maximal Voluntary Ventilation (MVV)

The Maximal Voluntary Ventilation (also known as maximal breathing capacity) measures peak performance of the lungs and respiratory muscles. MVV is calculated as the volume of air moved through the pulmonary system in one minute while breathing as quickly and deeply as possible (hyperventilation). In performing this test, the Subject inspires and expires as deeply and as rapidly as possible (> 1 breath/sec) while the tidal volume and the respiratory rate are measured. Because the maximal breathing rate is difficult to maintain, the Subject hyperventilates for a maximum of 15 seconds. Then, to calculate MVV, the average volume per respiratory cycle (liters) is multiplied by the number of cycles per minute (liters/min).

MVV can also be extrapolated from the total volume of air moved in a 12-sec period (total volume in 12-sec X 5 = MVV).

\[
\text{MVV} = \text{(Average volume per cycle)} \times \text{(Number of cycles per minute)}
\]

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

Normal values vary with sex, age and body size. MVV is a measure of how much your pulmonary system limits your capacity to work or exercise.

![Diagram of respiratory cycles](image)

**Fig 13.3**

Normal values vary with sex, age and body size. MVV is a measure of how much your pulmonary system limits your capacity to work or exercise.

You can rarely exceed your MVV, even for brief periods of time. Therefore, MVV ultimately limits how much oxygen is available for exercising muscles. In general, a maximum of 50% of your MVV can be used for exercise beyond 10 minutes. Most people have trouble breathing when only using the available 30-40% MVV. MVV tends to be reduced in both restrictive and obstructive pulmonary diseases.

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 and bacteriological filter
- *Optional*: BIOPAC Autoclaveable Reusable Mouthpiece (AFT8)
- Nose clip
- BIOPAC 0.6 Liter Calibration Syringe
- Clinical Laboratory Scale

**Computer system:**
- Macintosh® - minimum 68020
  
  or

- PC running Windows® 95/98/NT 4.0/2000

Memory requirements:
- The Biopac Student Lab application needs to have at least 4MB of RAM available for its needs. This is 4MB above and beyond the operating system needs and any other programs that are running.
- Biopac Student Lab software v3.0 or greater
- BIOPAC data acquisition unit (MP30)
- BIOPAC wall transformer (AC100A)
- BIOPAC serial cable (CBLSEREA)
IV. EXPERIMENTAL METHODS

Overview

➢ As you complete the Experimental Methods (Set Up, Calibration, and Recording) and the Analysis, you may need to use the following tools and/or display options. The window display shown below is only a reference sample — it does not represent any lesson specific data. The sample screen shows 3 channels of data and four channel measurement boxes, but your screen display may vary between lessons and at different points within the same lesson.

➢ The symbols explained below are used throughout Experimental Methods and Analysis.

Key to Symbols

📖 If you encounter a problem or need further explanation of a concept, refer to the Orientation Chapter for more details.

Firestore The data collected in the step needs to be recorded in the Data Report (in the section indicated by the alpha character). You can record the data individually by hand or choose Edit > Journal > Paste measurements to paste the data to your journal for future reference.

▽ Most markers and labels are automatic. Markers appear at the top of the window as inverted triangles. This symbol is used to indicate that you need to insert a marker and key in a marker label similar to the text in quotes. You can insert and label the marker during or after acquisition. On a Mac, press “ESC” and on a PC, press “F9.”

➢ Each section is presented in a two-column format, as described below.

FAST TRACK STEPS
This side of the lesson (left, shaded column) is the “FAST TRACK” through the lesson, which contains a basic explanation of each step.

DETAILED EXPLANATION OF STEPS
This side of the lesson contains more detailed information to clarify the steps and/or concepts in the FAST TRACK, and may include reference diagrams, illustrations, and screen shots.
A. SET UP

FAST TRACK SET UP

1. Turn your computer **ON**.

2. Make sure the BIOPAC MP30 unit is turned **OFF**.

3. Plug the airflow transducer (SS11LA) into Channel 1.

4. Turn **ON** the MP30 Data Acquisition Unit.

5. Place a filter onto the end of the calibration syringe. 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.

6. **Insert** the Calibration Syringe/Filter Assembly into the airflow transducer (Fig. 13.5).

**IMPORTANT!**
Always insert on the side labeled “**Inlet**”

**Detailed Explanation of Set Up Steps**

The desktop should appear on the monitor. If it does not appear, ask the laboratory instructor for assistance.

**BIOPAC MP30 unit**

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. 13.4*

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

*Fig. 13.5*
7. **Start** the Biopac Student Lab program.
8. Choose Lesson 13 (**L13-LUNG-2**).
9. Type in your filename.
10. Click **OK**.

    **END OF SET UP**

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.

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

Use a unique identifier.  
This ends the Set Up procedure.
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).

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

3. Prepare for the second calibration stage.

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

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

**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.

![Calibration Syringe Plunger](image)

**Fig. 13.6**

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.

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.

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**.

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

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.

- If correct, go to the Recording section.
- If incorrect, **Redo Calibration**.

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

![Figure 13.7](image)

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 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.
C. RECORDING LESSON DATA

FAST TRACK Recording

1. Prepare for the recording.

Detailed Explanation of Recording Steps

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

1. Forced Expiratory Volume (FEV)
2. 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 remain in a supine position and 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.

- If using the SS11L:

  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.

  If using SS11L transducer with non-removable head, insert a new filter and mouthpiece into the larger diameter port.

  ![Fig. 13.8 SS11L](image)

- 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. 13.9 SSLA with sterilized head](image)

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

**IMPORTANT!**
Always insert on the side labeled “Inlet”

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”

after each use, insert a filter and mouthpiece into the airflow transducer on the side labeled “Inlet.”

**Airflow Transducer (SS11LA)**

Fig. 13.10 SSLA with unsterilized head

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. 13.11).

Hold Airflow Transducer upright at all times

**Segment 1 — FEV**
4. Click on **Record**.

5. Perform the following procedure:
   a) Breathe normally for 3 cycles
   b) Inhale as deeply as you can, then hold your breath for just an instant.
   c) Exhale as quickly and completely as you can.
   d) Breathe normally for 3 more cycles.

6. Click on **Stop**.

7. Review the data on the screen.
   - If correct, go to Step 8.
   - If incorrect, click on **Redo**.

   The **Director** should guide the Subject through this procedure.
   a) One complete cycle is one inhale and one exhale.
   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) Squeeze out all the air you can. You may want to bend over to physically force air out.
   d) ---

   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. 13.12.

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

   ![Fig. 13.12](image_url)  

   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).

holding the mouse button down, select an area at least 3 seconds in length (refer to Figure 13.13).

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

![Fig. 13.13](image)

9. Click on Setup FEV.

10. Review the data on the screen.

   - If correct, go to Step 11.

   - If incorrect, Redo.

![Fig. 13.14](image)

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. 13.14).

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 after comparing the data obtained to that of Fig. 13.14, you feel the area you selected in Step 7 was incorrect, you may click on the Redo button and redo Steps 8-10.

11. Click on Begin MVV.

   The current FEV data on the screen will be automatically
12. Place a noseclip on and begin breathing through the airflow transducer.

13. Click on **Record MVV**.

14. Perform the following procedure:
   a) Breathe normally into the airflow transducer for 5 cycles.
   b) Breathe quickly and deeply for 12-15 secs.
   c) Breathe normally again and continue for 5 more cycles.

15. Click on **Stop**.

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.)

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 (Fig. 13.15).

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

**Fig. 13.15**

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.

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 four saved to disk for later analysis and the screen display will change to include a **Record MVV** button.

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 noseclip.

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

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.
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.
V. DATA ANALYSIS

**FAST TRACK Data Analysis**

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

   Note channel number (CH) designations:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Displays</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 1</td>
<td>Volume</td>
</tr>
</tbody>
</table>

2. Turn Grids ON.

3. Set up the measurement boxes as follows:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 1</td>
<td>$\Delta T$</td>
</tr>
<tr>
<td>CH 1</td>
<td>$p-p$</td>
</tr>
</tbody>
</table>

Data Analysis continues…

**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. 13.16](image1)

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

![Fig. 13.17 Grids ON](image2)

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.

- $\Delta T$: The Delta Time 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

5. Use the I-beam cursor to select the first one-second interval (Fig. 13.19).

B

6. Use the I-beam cursor to select the first two-second interval (Fig. 13.20).

B

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

Fig. 13.18

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 FEV₁, which is the % of VC expired in the time interval from 0 to the end of second one.

Fig. 13.19 FEV₁

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. FEV₂ is the % of VC expired in the time interval from 0 to the end of second two.

Fig. 13.20 FEV₂

Data Analysis continues…
7. Use the I-beam cursor to select the first three-second interval (Fig. 13.21).

The selected area should be from Time 0 to the three-second reading, as displayed in the $\Delta T$ 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. 13.21 FEV$_3$](image)

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

Note channel number (CH) designations:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Displays</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 0</td>
<td>Volume</td>
</tr>
</tbody>
</table>

9. Use the zoom tool to set up your display window for optimal viewing of the deep, fast breathing segment of the recording (Fig. 13.22).

![Fig. 13.22](image)

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:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH 0</td>
<td>$\Delta T$</td>
</tr>
<tr>
<td>CH 0</td>
<td>p-p</td>
</tr>
</tbody>
</table>

Data Analysis continues…
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. 13.23).

The example shown in Fig. 13.23 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.

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 each complete individual cycle in the 12-second interval defined in Step 11. Select one cycle at a time.

You need to select each complete individual cycle 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. 13.24 shows the first cycle of the 12-second interval defined in Fig. 13.23 selected:

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.
Lesson 13

**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

<table>
<thead>
<tr>
<th>Name</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gender: Male / Female

A. **Vital Capacity (VC)**

CH 1 $p-p$ measurement: ______________

B. **Comparison of $FEV_x$% to Normal Values**

<table>
<thead>
<tr>
<th>Time Interval (sec)</th>
<th>Forced Expiratory Volume (FEV) [p-p]</th>
<th>Vital Capacity (VC) from A</th>
<th>FEV/VC calculate</th>
<th>(FEV/VC) x 100 = % calculate</th>
<th>$FEV_x$</th>
<th>Averages for reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>% $FEV_1$</td>
<td></td>
<td>83%</td>
</tr>
<tr>
<td>0-2</td>
<td></td>
<td></td>
<td></td>
<td>% $FEV_2$</td>
<td></td>
<td>94%</td>
</tr>
<tr>
<td>0-3</td>
<td></td>
<td></td>
<td></td>
<td>% $FEV_3$</td>
<td></td>
<td>97%</td>
</tr>
</tbody>
</table>
Lesson 13: Pulmonary Function II

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):

\[ RR = \text{Cycles/} \text{min} = \text{Number of cycles in 12-second interval} \times 5 \]

Number of cycles in 12-second interval (from above): ______ \times 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

<table>
<thead>
<tr>
<th>Cycle Number</th>
<th>Measurement [CH 0 p-p]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle 1</td>
<td></td>
</tr>
<tr>
<td>Cycle 2</td>
<td></td>
</tr>
<tr>
<td>Cycle 3</td>
<td></td>
</tr>
<tr>
<td>Cycle 4</td>
<td></td>
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<tr>
<td>Cycle 5</td>
<td></td>
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<tr>
<td>Cycle 6</td>
<td></td>
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<tr>
<td>Cycle 7</td>
<td></td>
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<td>Cycle 8</td>
<td></td>
</tr>
<tr>
<td>Cycle 9</td>
<td></td>
</tr>
<tr>
<td>Cycle 10</td>
<td></td>
</tr>
<tr>
<td>Cycle 11</td>
<td></td>
</tr>
<tr>
<td>Cycle 12</td>
<td></td>
</tr>
<tr>
<td>Cycle 13</td>
<td></td>
</tr>
<tr>
<td>Cycle 14</td>
<td></td>
</tr>
<tr>
<td>Cycle 15</td>
<td></td>
</tr>
</tbody>
</table>

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

Add the volumes of all counted cycles from Table 13.3.

\[ \text{Sum} = \text{________________________ liters} \]

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

\[ \text{AVPC} = \frac{\text{_______________}}{\text{# of counted cycles}} = \text{liters} \]
5) Calculate the MVV

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

\[ \text{MVV} = \frac{\text{AVPC} \times \text{RR}}{\text{AVPC}} = \frac{x}{ \text{RR}} = \text{liters/min} \]

II. Questions

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

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

<table>
<thead>
<tr>
<th>FEVx</th>
<th>less than</th>
<th>same as</th>
<th>greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEV2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEV3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F. Is it possible for a Subject to have a vital capacity (single stage) within normal range but a value for FEV1 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?

<table>
<thead>
<tr>
<th></th>
<th>less than</th>
<th>same as</th>
<th>greater than</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVV</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 FEV1 and MVV compare to an athlete?  
   Explain your answer.