Spirometer

Technician and teacher sheet

Apparatus

Spirometer.

Pressure filter fitted

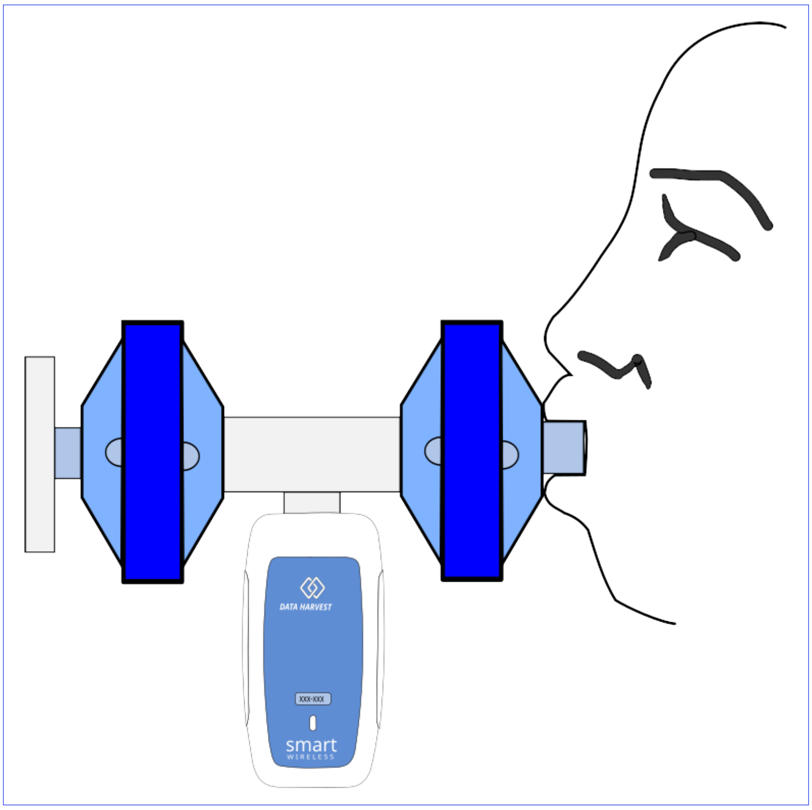
1 x filter per person to be tested

Data recording setup.

You need to go fast to get the best results, 50ms intersample or shorter.

A trigger of something like rises above 0.2 l/s

See practical notes for more detail.



A spirometer is a device that measures breathing patterns, lung capacities and function. The Spirometer measures accurately the flow of air through the device. This investigation will allow you to calculate the various lung capacities that can be measured.

The spirometer flowhead contains a sheet of resistance material that restricts the flow of air; the resistance to the air flow creates an increase in pressure across it. The increase in air pressure is measured via two air lines, one inside the flowhead and one inside the instrument body. An air pressure sensor is used to measure the changes in air pressure.

A second flowhead is used by the test subject to breath into the Spirometer. A plastic guard is supplied to make it obvious that one of the flowheads is not for use by a subject. The flowheads contain a filter that is effective in trapping and blocking transmission of Viral and bacterial particles into the Spirometer.

The air flow data can be converted to Volume using the Spirometer displacement function in the software.

The volume of air that is breathed into and out of the lungs while at rest is called the Tidal Volume (Tv), this is normally around 0.5 of a litre and supplies the oxygen needed for the normal respiration of the individual at rest.

Once exercise starts the need for oxygen increases, to increase the turnover of oxygen in the lungs the rate of ventilation of the gas exchange surface must increase. Using yourself as a model, you can identify the change in a breathing pattern with exercise – usually the breathing becomes deeper and quicker. This tells us that the lung has reserves of volume that can be used for the increase in oxygen exchange required in exercise.

The maximum you can inspire (breathe in) over the normal tidal inspiration is the Inspiratory Reserve Volume (Irv).

The maximum you can expire (breath out) over the normal tidal expiration is the Expiratory Reserve Volume (Erv). The Erv has been found to be approximately 1/6th of the Total Lung Capacity (Tlc)

The sum of the Tidal Volume, Inspiratory Reserve Volume and Expiratory Reserve Volume give the Vital Capacity (Vc) of the lung.

The lungs can never be fully emptied of air, this remainder air volume that is in the lung after the maximal forced expiration is the Residual Volume (Rv). It is created by the volume inside the alveoli, trachea and other tubes of the lungs. The residual volume can be approximated by converting the subjects mass into a volume. The conversion is 0.45 kg = 1 cm^3 of volume.

Practical advice

All airflow spirometers are prone to drift when the when the volume is calculated from the air flow data. The integration of the area under the flow curve can accumulate a slight numerical error. As long as drift is no more than 0.3 litres over the time of the recording it is not significant. With technique the user can reduce the effect of the drift.

The test subject should use a nose clip; this can upset breathing and create a non-normal breathing pattern at first so give time to adapt to breathing with the clip in place.

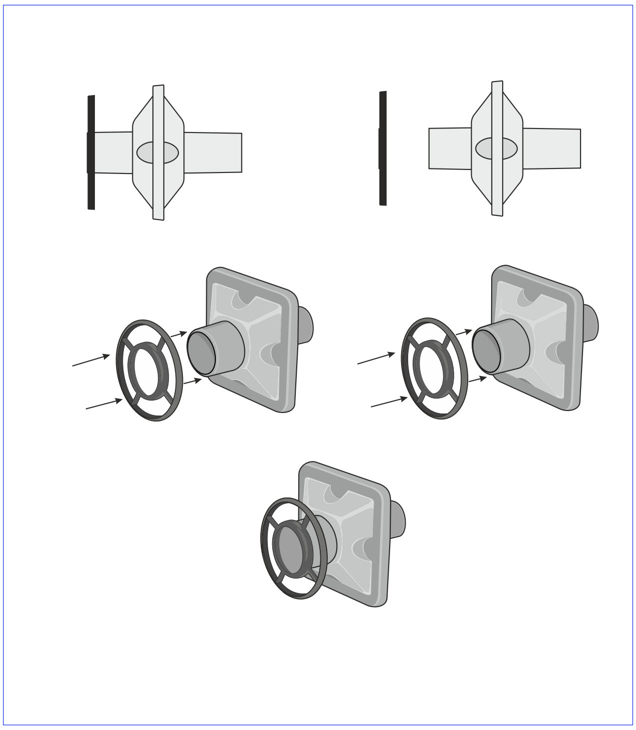
For this investigation the user should try to breathe smoothly and create a rapid exhalation / inspiration. As long as they can reach the point where they feel they cannot expire or inspire any more they will get the results needed.

Try to keep the Spirometer level during the logging. The Spirometer uses a high resolution differential pressure transducer which is sensitive to orientation.

The blue flowheads contain a bacterial and viral filter to prevent cross contamination. It is recommended that each user has their own flowhead and they should be marked to identify them. They are not washable; the filter material will felt and clog if immersed in water. One of the flowheads is “semi-permanent” it is to be used many times and it provides the resistance that creates the pressure change in the device. The fixed flow head should have the large ring clipped onto it to make a strong visual reminder that this one is not used for breathing.

Assembly of the protective ring to the reference flowhead is shown

.



Measurement procedure

The procedure to record lung volumes is not instinctive and may require practice by the test subjects.

It is recommended that you carefully read the instructions and try a few sample logs before attempting to collect "real" data. Breathing through the apparatus is unnatural and takes adjustment. Encourage the test subject not to rush to complete the breathing cycles, it is better to discard a few incomplete cycles and learn how to use the Spirometer correctly.

Logging time should be 30 seconds. This should be enough time for about 6 tidal cycles and one expire and one inspire. It also gives enough data points to reduce inaccuracies when the volume is calculated.

If the intersample period is reduced the data will have a higher resolution, but may start to introduce pressure artifacts if set too short. 20 - 10 ms of intersample time should be good enough.

The software can be set with a trigger to activate recording and the setup allows you to set a recording duration.

The user should be allowed to breathe in and out of the apparatus for a short period to get used to the apparatus, it is not a natural piece of apparatus and can induce discomfort.

The routine for data collection should be,

1. A few moments of getting used to the apparatus and breathing through it - during this period no data is being collected.

2. Select start and watch the trace being developed, after "3" tidal inhalations / exhalations breathe full in (as far as can be)

3. Then immediately after reaching maximum inhalation exhale to maximum exhalation.

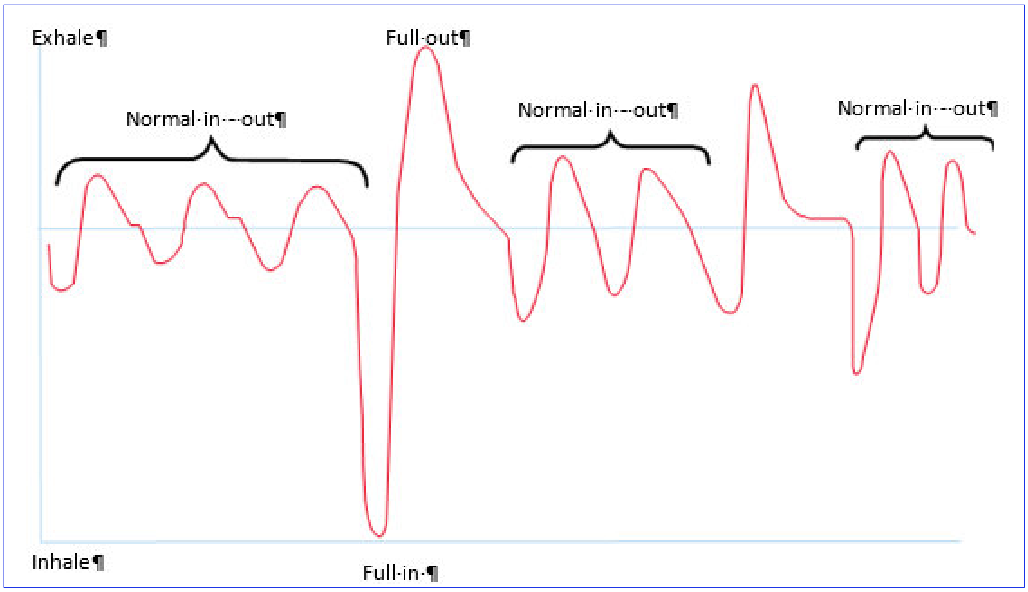
4. Collect at least "3" more tidal exhalations / inhalations.

5. If time allows, make an attempt for one more maximum inhalation / exhalation cycle.

If data is not good, wait for a short period and repeat.

It is not recommended to ask any one subject to go through many cycles, it is s surprisingly "distressing" process.

Students will produce better data after a short rest from the procedure as they get used to the very unnatural breathing exercise.



An example of a good clean set of inhalations / exhalations.

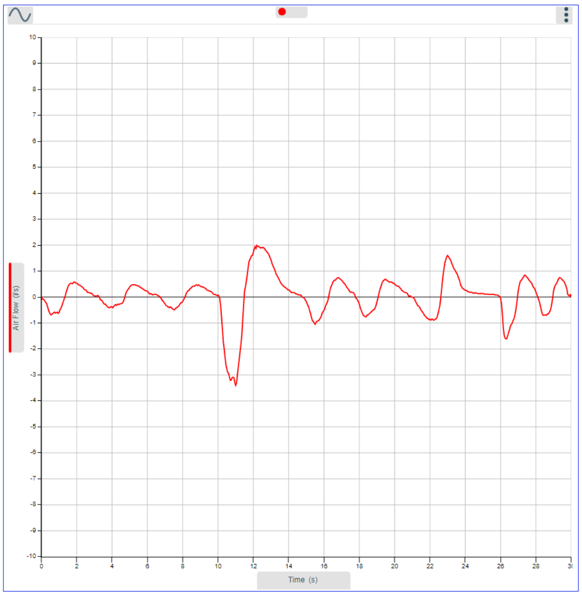
Constants

Residual Volume (Rv)= Mass of subject in kg x 0.45 = volume in cm^3

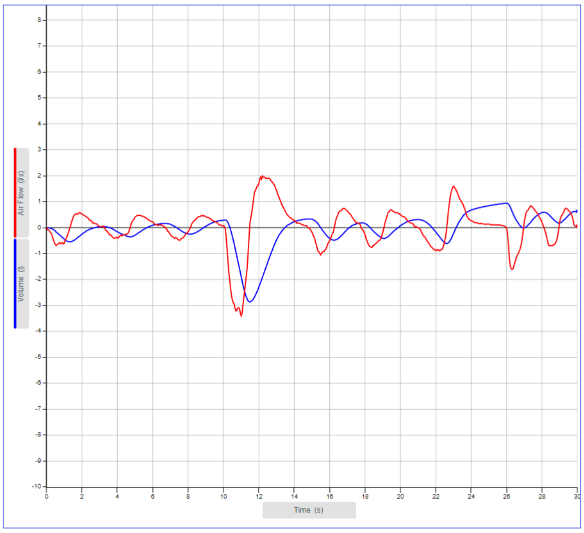
Estimate of Total lung capacity (Tlc) from Erv = Erv x 6 = Tlc in litres

Ventilation rate = Breaths per minute x Tidal volume = litres per minute

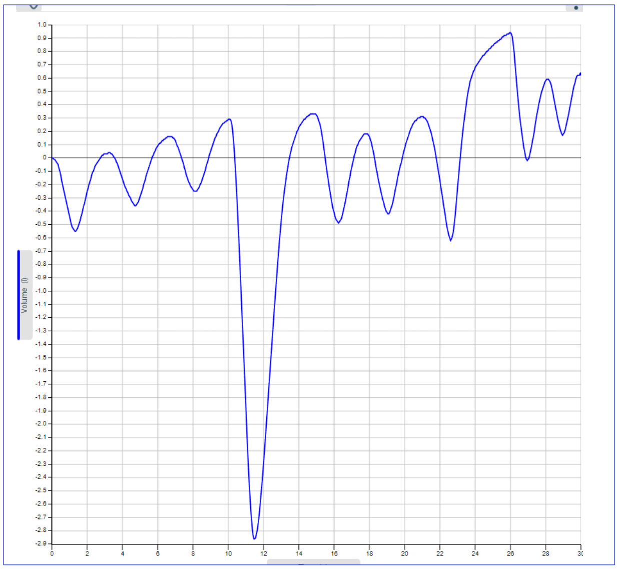
Example data - flow data collected



Example data as collected from the described protocol



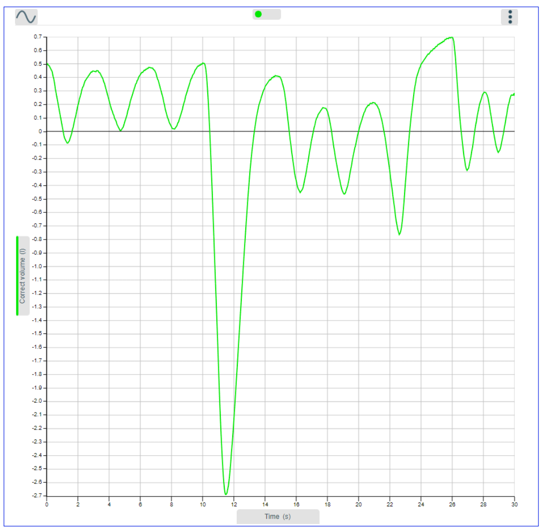
Example data with volume conversion overlaid



Volume data only, re scaled. Note the "slope" over the first part of the data, this is drift created by the integration of the data and small non zero start value that increments through the data.

After application of the drift correction the data is much more aligned to the base line.

The data can be further enhanced by centering the data around the baseline using the ax + b calculation with b being the correction factor.



Notes about basic lung volumes and calculations.

The total lung capacity can be determined by multiplying the expiratory reserve volume by 6. This has been found to give a a reasonably accurate value.

The dead space of the lung (lung tissue, for example bronchi, bronchioles etc) can be calculated. For a normal individual the subjects mass is linked by a simple ratio to the lung volume. Roughly 0.45 kg is equal to 1 cm^3 of lung volume.

For example an individual of 63.5 kg will have a lung volume of 63.5/0.45 = 141 cm^3.

Software knowledge required.

- Connect spirometer to the software.
- Use a triggered setup to get comparable data (optional)
- Use tare to zero the flow before data collection.
- Use flow to volume tool
- Use Drift correction tool
- Use values to extract required data