

Measuring breathing – spirometry

Specification reference

- 3.1.1 (e)

Learning outcomes

After completing the worksheet you should be able to:

- identify steps in the method for using a spirometer, and know the reasons for each step
- interpret the trace produced from a spirometer
- perform calculations based in a spirometer trace.

Introduction

Measuring lung volumes and breathing rates is an important technique, used by clinicians and sports physiologists amongst others. The principle piece of equipment used for measuring breathing is called a spirometer. Although there are many different designs for this piece of equipment, the basic functioning is the same.

Spirometry is technique which can present a number of issues. There are a number of points in the methods for spirometry that students tend to forget in any answer or description of the process. Secondly interpreting the trace produced from spirometry can cause problems.

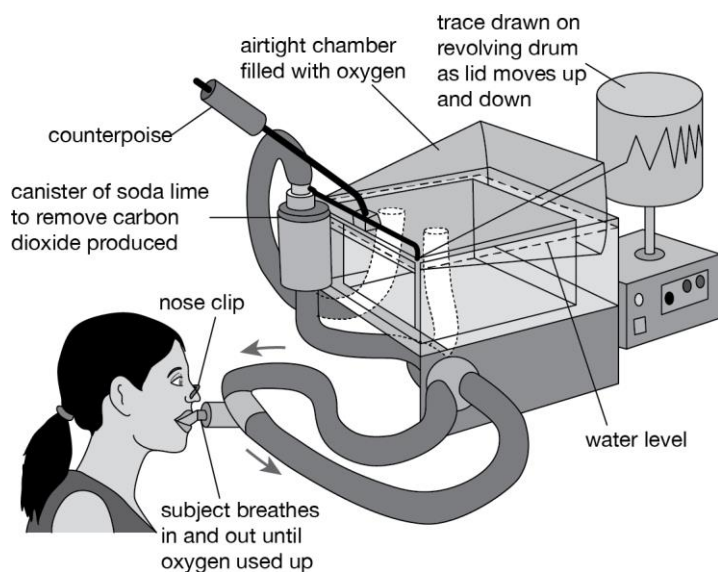
The aim of this sheet is to reinforce the basic steps in the method for the use of a spirometer. In addition the sheet will offer support in analysing a trace.

Background

The structure and function of the human respiratory system has been covered in Topic 7.2 'The Mammalian Gaseous Exchange System.' This topic describes the various organs in the system and how they are adapted for their function, it also explains how humans ventilate their lungs.

The volumes of air breathed in or out of the lungs can vary depending on the activity or health of a person. Measuring these volumes has considerable use to doctors, when concerned by respiratory problems, or sports physiologists, when analysing fitness levels. The spirometer is the piece of equipment used by scientists to measure lung volumes. The most common type of spirometer in school laboratories is shown in Figure 1.

It is important to know the major steps in the method for using a spirometer. Examiners like to ask experimental questions. It could be the whole method or more commonly just one or two steps. An aid for remembering the steps is to number the steps, and also to know the reason for each step. Look at the table below showing the main steps in the method.



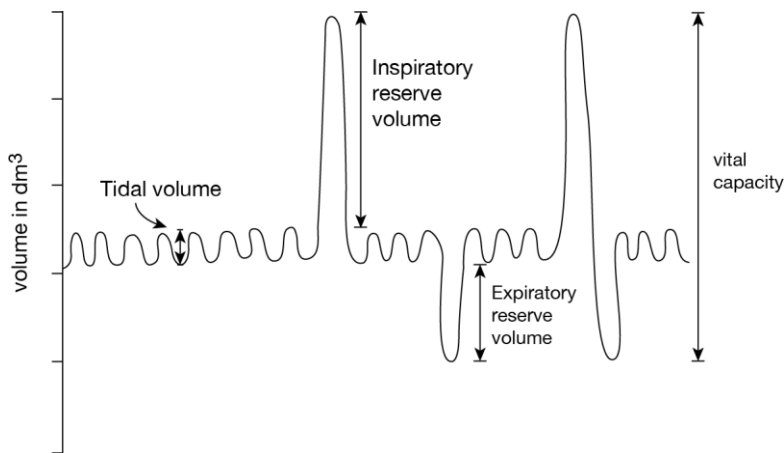
Step	Reason
Calibrate the spirometer. The details vary from machine to machine, but you need to know how to measure a litre and a minute on the trace.	This allows us to calculate the actual volumes breathed.
Fill the drum with fresh air.	To ensure normal levels of oxygen in the air to be breathed by the subject.
Subject should be in good health.	To avoid any medical problems during the experiment.
Subject wears a noseclip.	To stop air moving through nose. This allows valid measurements.
Subject breathes normally into the machine through the mouthpiece.	To record the volume of air being breathed.
Use a sterile mouthpiece.	To avoid infection.
The subjects exhaled air passes through a canister of soda lime.	To absorb carbon dioxide.
Turn on the kymograph.	To start the recording of the trace.
Subject breathes normally for at least three full breaths.	To record resting breathing rate.
The drum will move up and down.	Up as the subject breathes out, down as they breath in.

There are a number of important lung volumes.

- *Tidal volume* – the volume of air that we breathe in and out during a normal breath. This is usually about 500 cm³.
- *Inspiratory reserve volume* – the maximum volume (in excess of the tidal volume) we can breathe in during one forced breath.

- *Expiratory reserve volume* – the maximum volume (in excess of the tidal volume) we can breathe out in one forced breath.
- *Vital capacity* – the maximum volume of air that can be breathed during a forced breath in and then out.

Residual volume is the amount of air left in the lungs after a forced breath out. You cannot measure this using a spirometer.



You may be asked to analyse a trace produced by a spirometer.

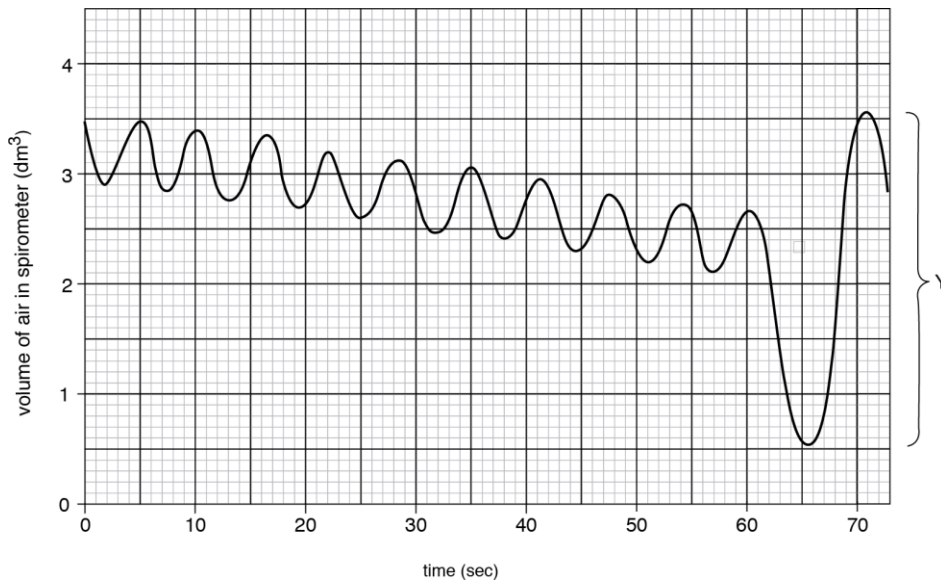
First you need to be able to identify the four different volumes. Look at the trace in the diagram above, and memorise the different traces. This is not usually too difficult to remember. There are a number different calculations that could be taken from the trace. The most common values that examiners expect you to be able to calculate are:

- breathing rate
- tidal volume
- vital capacity
- oxygen uptake.

Task

- 1 Spirometers are used to measure lung volumes.
 - a Give one reason why scientists might record lung volumes.
 - b State two precautions taken when using a spirometer.
 - c State the purpose of soda lime in the canister attached to the breathing tubes.
 - d In which direction does the drum move during inspiration?

2 Here are some examples of how to calculate lung volumes. Look at the trace below, and then look at how it is used in the following calculations.



a Breathing rate

Step 1: Count the number of breaths taken per minute on the time trace.

Tip – you need to count full breaths, so count the number of peaks (or troughs) in 1 minute.

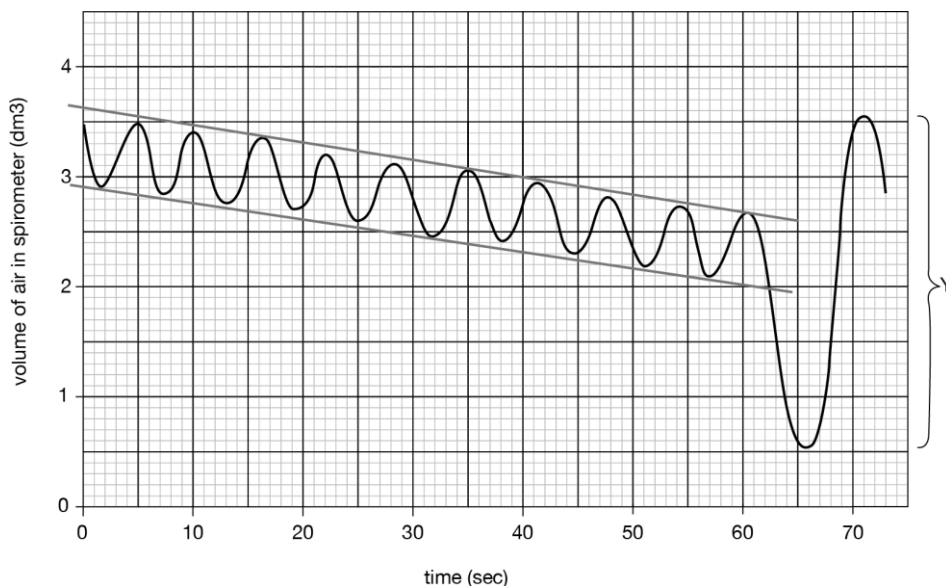
Answer: In this trace there are 10 peaks during the 60 seconds, so the breathing rate is 10 breaths per minute.

b Tidal volume

Step 1: Draw two lines on the trace, one above, and one below the trace of tidal volume.

Step 2: Measure about 3 or 4 volumes (between the top and bottom line).

Step 3: Take the mean.



Answer: In this trace the distance between the lines can be measured for three peaks:

- at the first peak the volume is = 0.65 dm^3
- at the fourth peak the volume is = 0.65 dm^3
- at the eighth peak the volume is = 0.60 dm^3

The mean volume is 0.63 dm^3

c Vital capacity

Step 1: Measure the height of the vital capacity indicated by the letter 'Y' on the trace.

Step 2: Convert this to a volume using the axis.

Answer: The height is 41 mm. This is equivalent to 3 dm^3 .

d Oxygen uptake.

Step 1: The reason why the trace slopes downward is that the oxygen is being used up by the subject. (Although the subject is breathing out carbon dioxide in replacement, it is being absorbed by the soda lime and does not play any part in the trace.)

Step 2: If we measure the drop of the slope in a period of time we get a value of the oxygen uptake.

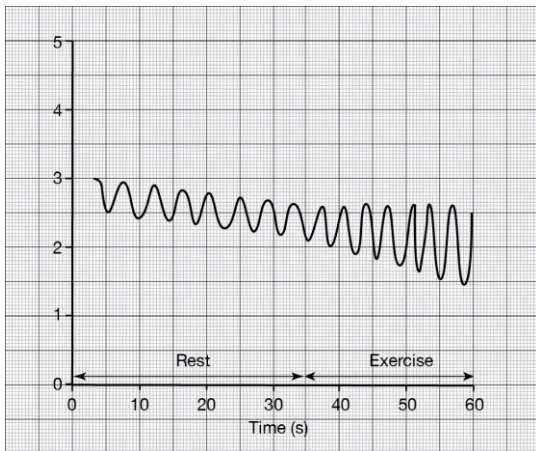
Step 3: Draw a line across the top of the trace (use the drawing above).

Step 4: In one minute this line has fallen 8.5 squares on the axis. This is 0.85 dm^3 . This is the volume of oxygen used in one minute.

Questions

- 1 The spirometer is a piece of apparatus used to investigate lung function.
- a** Name the gas absorbed by the soda lime in the canister in the spirometer. (1 mark)
 - b** Explain why the subject using a spirometer to measure their tidal volume wears a nose clip. (2 marks)
 - c** Explain how you would use the spirometer to measure a subject's tidal volume. (3 marks)

2 The following trace from a spirometer was recorded from a male athlete.



- a State the name of the lung volume being measured by the athlete during the period of rest. (1 mark)
- b Label on the trace, using the letter 'E' a point where the athlete is exhaling. (1 mark)
- c Describe the changes which occur to the athlete's breathing shown on the trace during exercise. (2 marks)
- d Calculate the breathing rate per minute of the athlete during rest. (1 mark)
- e Calculate the oxygen uptake in dm^3 per minute for the athlete during the rest period. Show your working. (2 marks)