Physics A level

Course plan

This plan shows the structure of the course and gives an outline of the contents. Sections 1–5 cover the requirements of the AS and Part 1 of the A level; Sections 6–10 cover Part 2 of the A level. You need to do Sections 1–10 to prepare for the A level.

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Sample of the A Level Physics course from Section 1

Topic 1

Calipers and micrometers

Introduction

In this topic you will learn how to use two of the most common instruments for measuring small dimensions accurately. Both can be used to measure external diameters, internal diameters and depths. They are

- vernier calipers, which have sliding jaws
- the micrometer, which has a screw action.

Electronic versions of both instruments are available, which are extremely easy to use, but there are still a large number of non-electronic instruments in use, and you may need to be able to make readings using these..

You will probably need 2 hours to complete this topic.

Objectives

When you have completed this topic you should be able to:

- understand how to 'zero' the two instruments
- know how to read the main scale and vernier of calipers
- know how to interpret the readings on the sleeve and thimble of a micrometer.

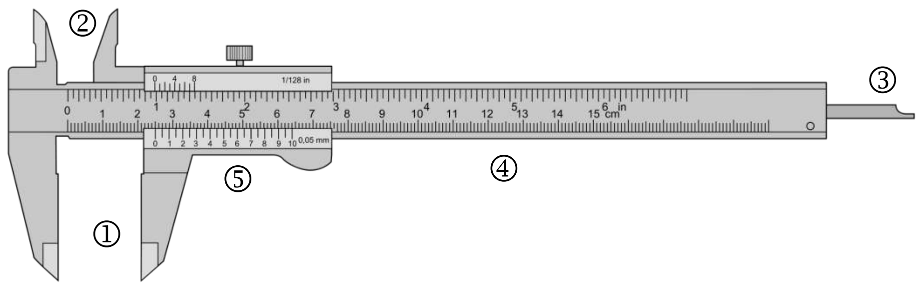
Vernier calipers

Vernier calipers are precision measuring devices. They should be handled carefully, and never dropped or have their jaws forced shut. This resource is concerned with how to use calipers with scribed markings, because reading electronic calipers is simple; the reading simply appears in the window!

The parts of the calipers

Figure 1.1 shows the main parts of a vernier caliper.

Figure 1.1



Key:

1 Jaws for measuring outer diameters and thicknesses

2 Jaws for measuring inner diameters

3 Probe for measuring depth

4 Main scale

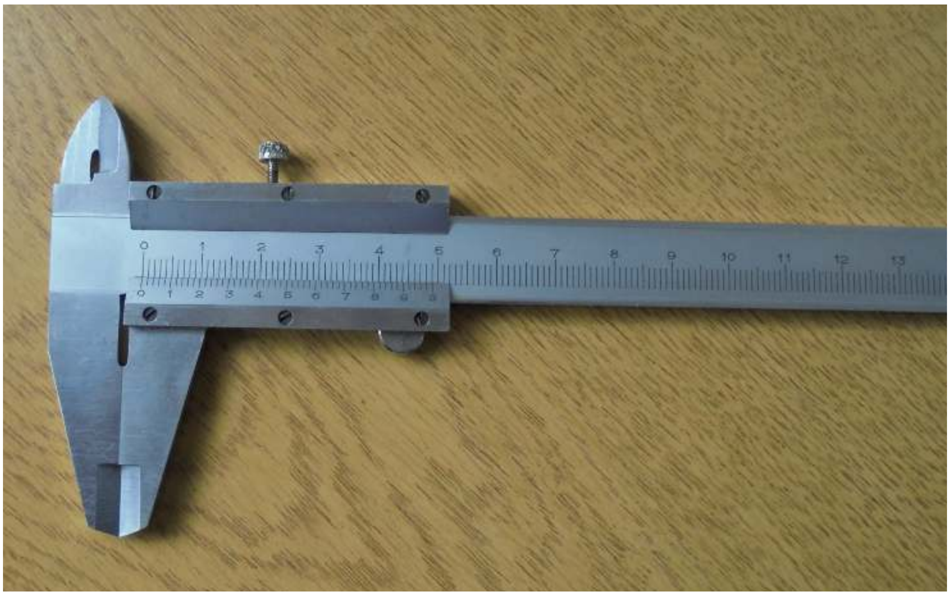
5 Vernier scale

The main scale is scribed onto the fixed jaw of the caliper, and the vernier is on the jaw that slides open and closed.

Checking the zero reading

Before using calipers, it is important to check that they read precisely zero when the jaws are brought together. The jaws should be wiped clean and they should be closed gently (not forcibly). When you do this the reading should be precisely zero, as shown in Figure 1.2.

Figure 1.2



The scale on the fixed jaw in Figure 1.2 is marked in centimetres with millimetre marks between. The caliper in Figure 1.1 also had inch measurements.

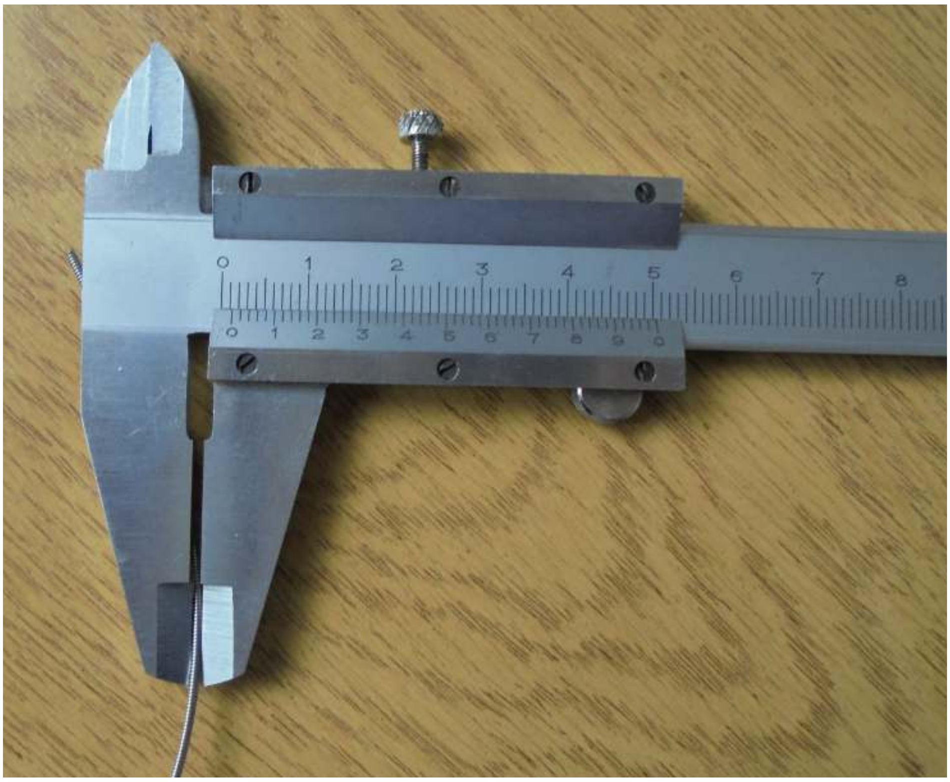
Closer examination will show that there is something a little odd about the vernier scale on the sliding jaw, as '9' on this scale seems to coincide with '4.9' on the fixed scale.

Note: designs vary, but the method of reading the vernier is the same. Among the photographs and drawings in this resource you will notice a number of different styles of vernier. Each time you pick up a new instrument you need to familiarise yourself with the scales supplied.

Making a measurement

To use the caliper to measure an object, open the jaws and close them gently on the item to be measured. A result is shown in Figure 1.3.

Figure 1.3 Measuring the diameter of a wire



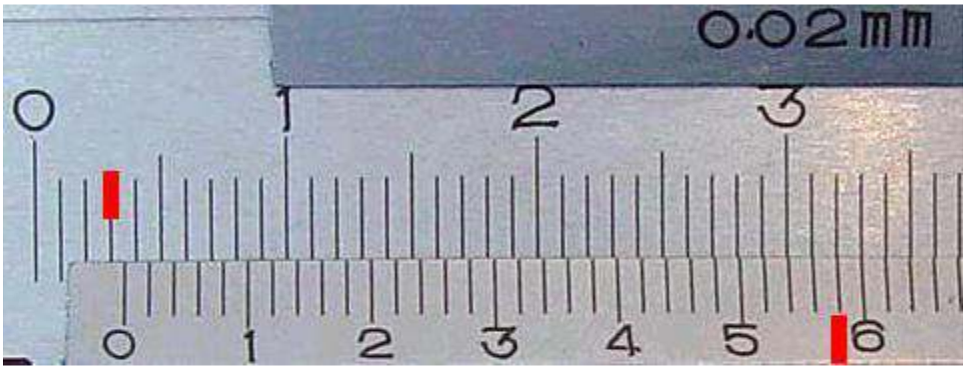
In Figure 1.3 you can see that this wire is between 1 and 2 mm in diameter, because the zero on the sliding scale is between the first and second mark on the fixed scale. This is highlighted by the left hand orange arrow on the photograph.

You can see by eye that it is nearer to 1 mm than 2 mm. To get an accurate assessment of the tenths of millimetres, you look at the vernier scale. Notice that most of the marks on this scale do not coincide with the marks on the fixed scale. You need to find a place where the marks on the scales do coincide precisely, and read off the value from the sliding scale.

In Figure 1.3 this happens somewhere between mark 2 and mark 3 on the sliding scale; the closest match is at 2.8, which is highlighted by the second orange arrow; this is equivalent to 0.28 mm. This reading is added to the reading from the fixed scale, to give a result of 1.28 mm.

Another example is shown in Figure 1.4. This scale reads 0.358 cm. The readings are highlighted with red bars.

Figure 1.4 A second example of reading the vernier scale



On the vernier scale you can see that none of the marks line up with the main scale until you get somewhere between 5.6 and 6.4. The marks at 5.6, 5.8 and 6.0 are all very nearly lined up. 5.8 is the best choice. You have to be careful to add the readings up correctly:

Main scale 0.3 + vernier 0.058 = 0.358 cm

and not

main scale 0.3 + vernier 0.58 = 0.88 cm

To avoid this kind of error, look back at the reading on the main scale, where it can be seen that the measurement is clearly about halfway between 0.3 and 0.4 cm.

Activity 1

(Allow 10 minutes)

What is the reading on the vernier caliper in Figure 1.5?

Figure 1.5 Measuring with a vernier caliper

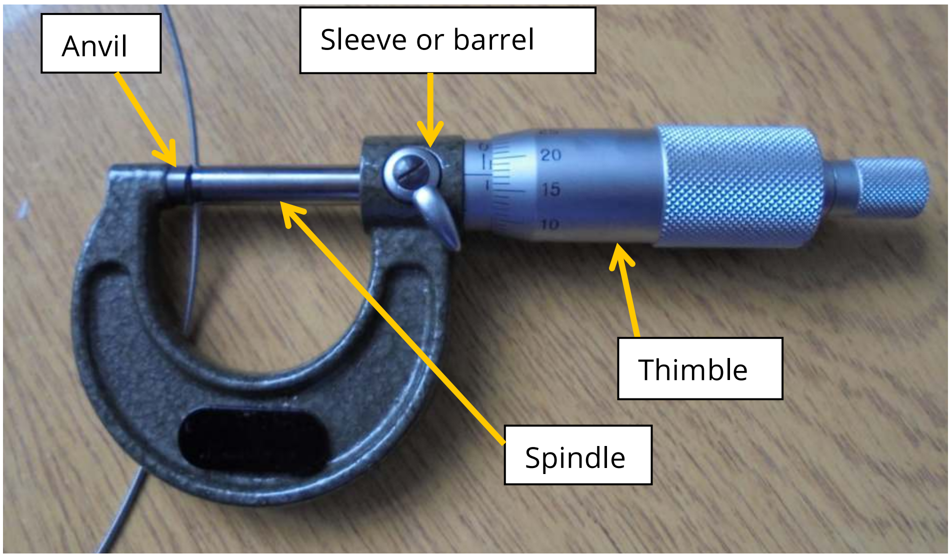
You can see that it is a little over 0.1 cm. The vernier scale lines up at approximately 1, which means that the reading is 0.11 cm.

The micrometer gauge

A micrometer has a screw mechanism for bringing its jaws together. Like the vernier caliper, it can be used for measuring internal dimensions, external dimensions and depth, but this requires dedicated variants of the micrometer.

The commonest micrometer, used for measuring external dimensions, is shown in Figure 1.6, with the major parts named.

Figure 1.6 A micrometer for measuring external dimensions



The variants for measuring internal dimensions and depth are shown in Figure 1.7.

Figure 1.7 Micrometers for measuring internal dimensions (left) and depth (right)

Checking the zero reading

The micrometer also needs to be checked to see that it reads zero when the jaws are closed. With a screw mechanism there is a danger that the user will exert large forces on the spindle and anvil when closing the device. The micrometer usually has a ratchet mechanism for ensuring that you do not force the jaws together – you close the jaws using the knurled knob in Figure 1.6 that is labeled ‘ratchet mechanism’.

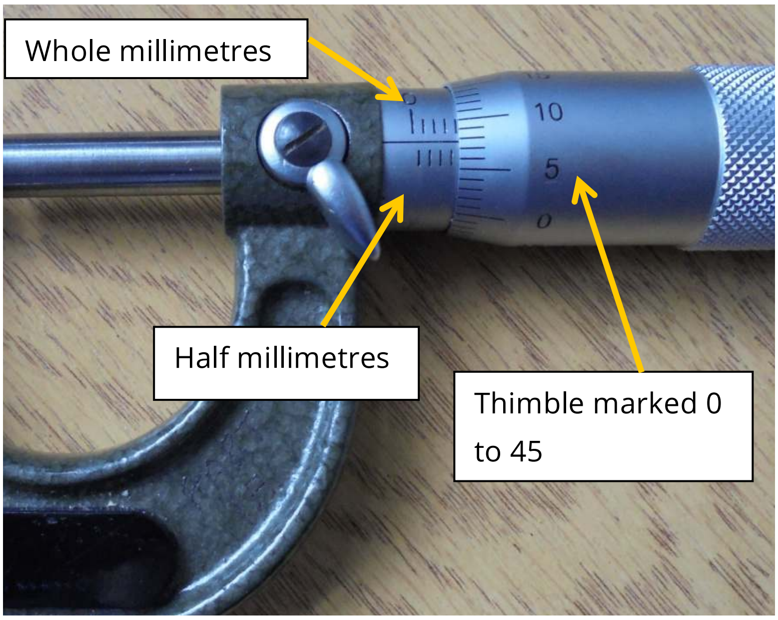
When the correct amount of force has been applied the mechanism allows the knob to rotate without driving the jaws any further, and makes a 'clicking' noise as it does so. You should always use this small knob for the final tightening of the jaws on an object to be measured.

Making a measurement with a micrometer

The scales are marked on the sleeve (which is sometimes also called the barrel) of the micrometer, in half millimetres. The whole millimetres are scribed above a line on the sleeve and the half millimetres are scribed below the line.

The rotating scale, which is called the thimble, on the example shown in Figure 1.8, is marked in tenths and hundredths of a millimetre. One complete turn of the thimble in the micrometer in the photograph opens the jaws by 0.5 mm. The scale on the thimble is marked 0, 5, 10, ... to 45.

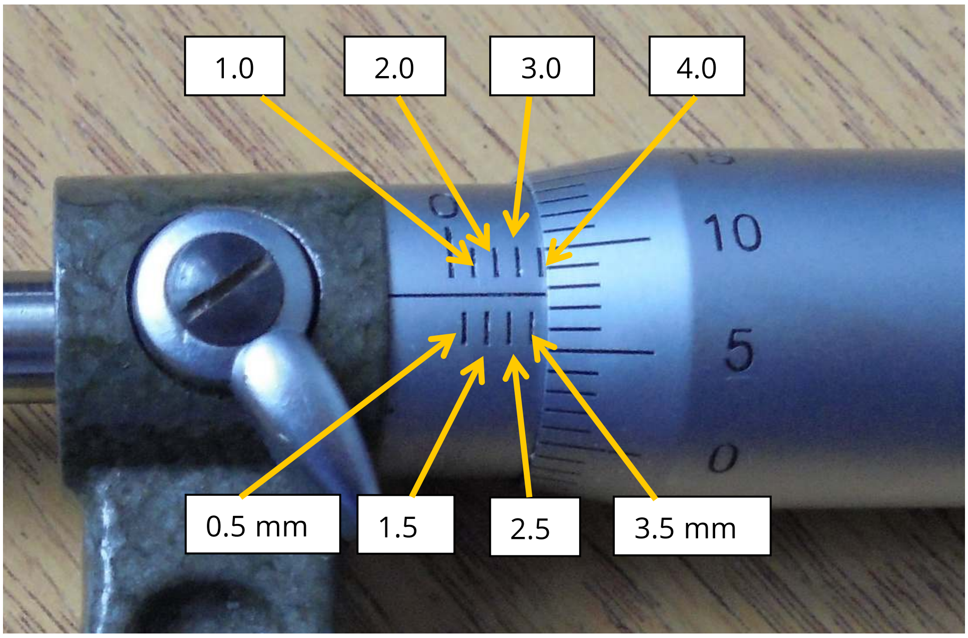
Figure 1.8 The scales on the sleeve and thimble



The markings on the thimble do vary from one model to another, so when starting to use an instrument you need to familiarise yourself with this scale.

Figure 1.9 shows in detail how the reading on the sleeve is made. On the sleeve, not counting the line which is labeled '0', we can see 8 marks exposed, which I have labeled individually.

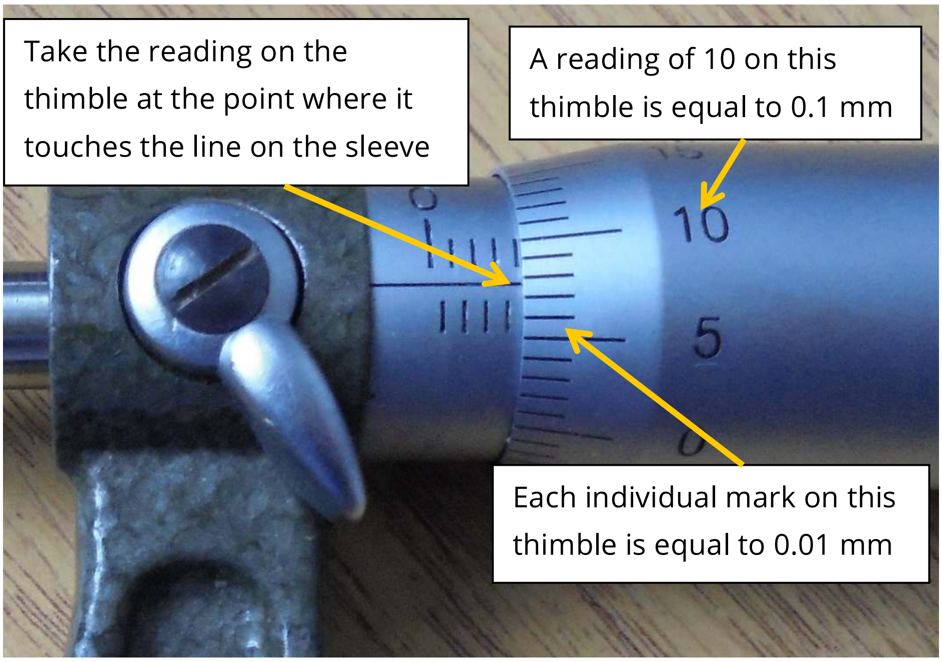
Figure 9.1 Reading the sleeve



This means that the reading on this micrometer is between 4.00 mm and 4.50 mm.

To find the fractions of a millimetre between 4.00 mm and 4.5 mm we need to read the markings on the thimble. Figure 1.10 shows how this is done.

Figure 1.10 Reading the thimble



The reading on the thimble in Figure 1.10 is very nearly 8. Remembering that one full turn of the thimble is 0.5 mm, a reading on the thimble of 10 represents 0.1 mm, so a reading of 8 represents 0.08 mm.

The gap between the anvil and spindle in Figure 1.10 is therefore 4.00 + 0.08 = 4.08 mm.

Activity 2

(Allow 10 minutes)

What is the reading on the micrometer in Figure 1.11?

Figure 1.11 Reading a micrometer

The sleeve reading is between 5.5 and 6.0 mm. The thimble marks line up with the line on the sleeve very close to 28. Therefore this measurement is 5.5 + 0.28 = 5.78 mm

Summary

In this topic you have learned how to use the vernier caliper and the micrometer. You have now seen the importance of handling them with care and checking the zero reading. You have also gone through the process of making the measurements on some real examples. When you have one of these instruments you will have to familiarise yourself with that particular model. However, looking back at this topic should help you to do that.

References

Note: Figures for which no reference is given are original work by the author.

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Figure 1.4 Wikimedia Commons. GNU Free Documentation License. https://commons.wikimedia.org/wiki/File:Noniusz_002mm_49mm_ex.jpg

Figure 1.5 Hiroshi Ishii (Flickr) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons

Figure 1.7 left: 'MicrometerInside5-30 25-50' by Photograph taken by Glenn McKechnie - Own work. Licensed under CC BY-SA 2.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:MicrometerInside5-30_25-50.jpg#/media/File:MicrometerInside5-30_25-50.jpg

Figure 1.7 right: 'MicrometerDepth916947' by Glenn McKechnie - Glenn McKechnie. Licensed under CC BY-SA 2.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:MicrometerDepth916947.jpg#/media/File:MicrometerDepth916947.jpg

Figure 1.11 '578metric-micrometer' Photograph taken by Glenn McKechnie - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:578metric-micrometer.jpg#/media/File:578metric-micrometer.jpg

Section 1

Experiments with a laser and a CD

Introduction

This practical activity includes an experiment that is fun to do. It will also give you experience of calculating sides and angles in triangles.

Do the experiment yourself if you can.

You will probably need 2 hours to complete this practical activity.

Objectives

When you have completed this activity you should be able to:

- calculate the lengths of the sides of a right angled triangle
- calculate a result using the trigonometric function sin.

Laser diffraction

This practical activity is based around the diffraction behaviour of light. You will learn more about this in Section 5 of the course, where you will also learn why CDs and DVDs show rainbow colours when seen at specific angles.

Diffraction is a phenomenon that is seen when light which is all of the same colour (and hence the same wavelength) and has waves that are all in step with one another, passes through narrow gaps. A piece of material which has alternating transparent gaps and opaque stripes is called a 'grating'.

A laser emits light that is both all of the same wavelength and the waves are all in step with one another. Laser pointers cost very little and are readily available.

When laser light passes through a grating the result is a series of spots on the far wall. This is a consequence of the light beams which emerge on the far side of the gaps interfering with each other. The equation that describes this behavior is:

$$n\lambda = d \sin \theta$$

where:

- *n* is the number of the diffraction spot; the value of this is 1 for the first spot either side of the centre,
- λ is the wavelength of the light
- *d* is the distance between the gaps through which the light is passing and
- θ is the angle at which the diffracted light emerges from the far side of the gaps.

A diagram, Figure 1, will put this into context:

Figure 1 1 A schematic of diffraction through a grating

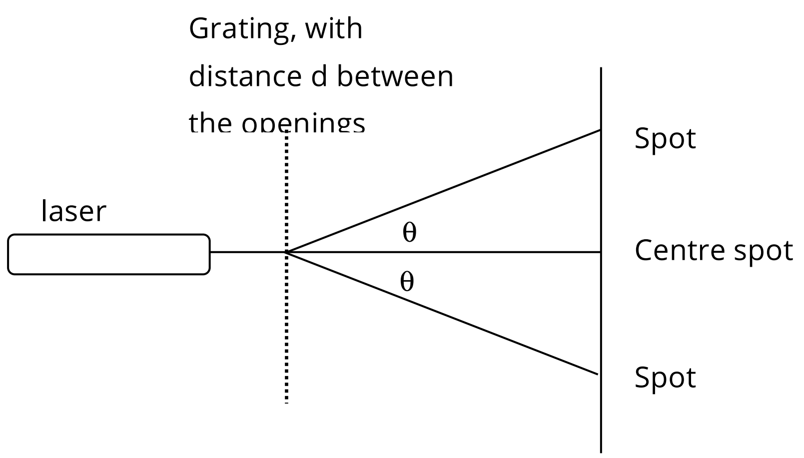
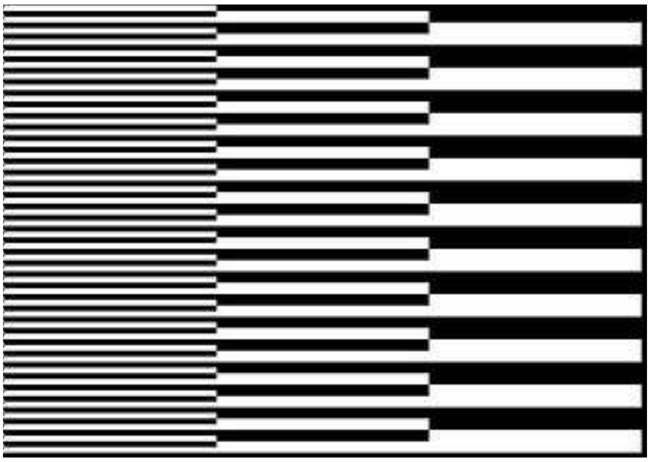


Figure 2 shows what a commercial diffraction grating looks like (magnified). This grating has three different spacings available.

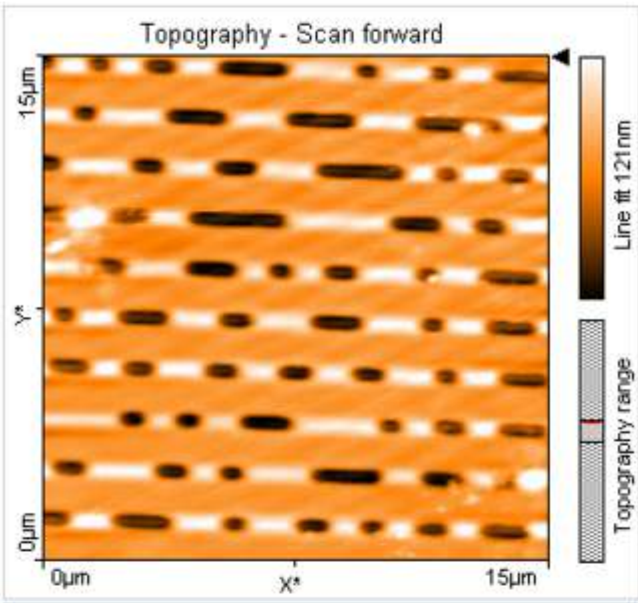
Figure 2 A commercial diffraction grating (magnified) (the original image has been cropped)



In the laboratory, it is usual to use commercial gratings, which have a defined number of gaps per unit length.

However, in the home you also probably have a number of diffraction gratings. The data on a CD is recorded in the form of pits, organised into a spiral, with a well defined spacing between the tracks. It is these tracks that are going to act as the diffraction grating. A photograph of a small section of a CD is shown in Figure 3.

Figure 3 The tracks on a CD (the original image has been cropped)



You can therefore use a CD for diffraction experiments.

Measuring the wavelength of a laser using a CD

As you have seen in the earlier sections, the spacing of the diffracted laser spots depends on three things; the wavelength of the light, the distance between adjacent gaps in the grating and the distance from the grating to the screen.

What you need

For this experiment you need:

- a laser pointer (any colour)
- an unwanted CD (or DVD) (note: it will never play again after this experiment). We did attempt to use a DVD, but was unable to remove the playing surface.
- modelling clay or other means of setting up the CD in the vertical position
- ruler or measuring tape.

Safety note:

Laser pointers should be eye safe. However, there are many devices in circulation that are not safe. Some have much higher powers than they are stated to be, and some may cause permanent eye damage if you stare at the beam. For this reason you should never look directly at the beam, and never point the beam at someone else. Never give a laser pointer to a child to play with.

Experimental method

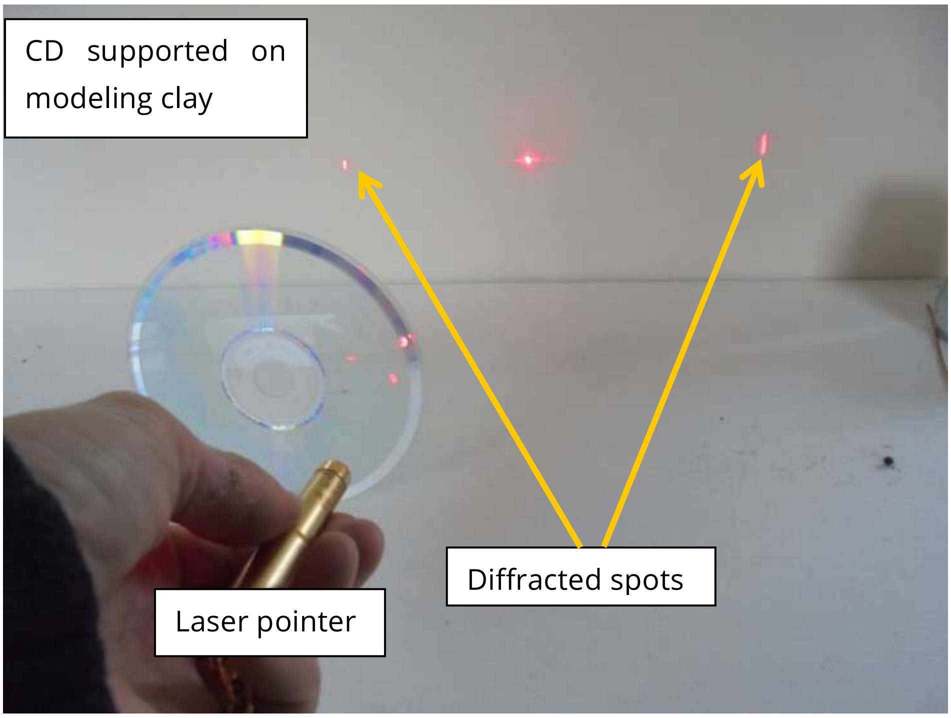
You first need to prepare the CD for the experiment, which consists of stripping off the coating. We did this by using a sharp blade to prize off a little bit of the coating near the edge, and then using sticky tape to ‘grab’ the coating and pull it off.

Figure 4 shows how we did this.

Figure 4 Stripping the CD coating

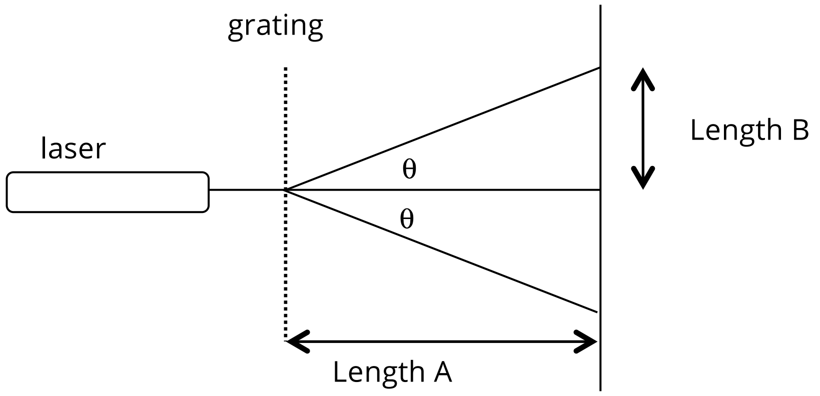
We set up our experiment as shown in Figure 5. We aimed the laser at a point about half way across the playing surface of the CD (not through the hole in the centre).

Figure 5 Obtaining the diffraction pattern



The experiment in plan view can be represented by Figure 6. The length B is the distance between the diffracted spots and the central spot. The distance A is the distance between the grating (CD) and the wall.

Figure 6 A plan view of the experiment



Our first experiment yielded the following results:

Table 1 The results of my experiment

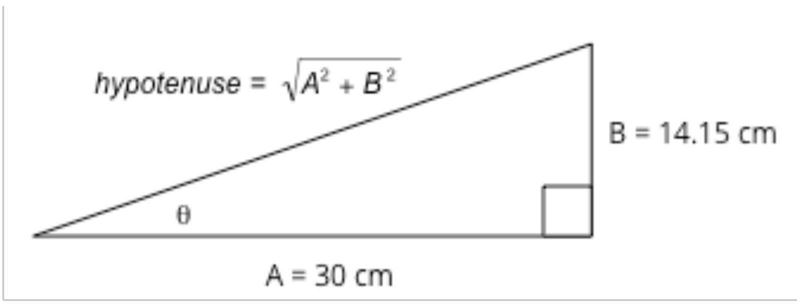
A/ cm	B/ cm			
30	14.5	13.8	14.1	14.2

The mean value of B from these experments was 14.15 cm.

To put this data into the equation we have been given we need to do some mathematics on the triangle we have above, which is bounded by A, B and containing the angle θ.

The triangle is right angled – that is, it contains an angle of 90o. The sin of angle θ is equal to the length of the opposite side divided by the length of the hypotenuse (the longest side) of the triangle in Figure 7.

Figure 7 The triangle formed from A, B and the angle θ



To obtain the length of the hypotenuse, we need to use Pythagoras' theorem which is

Length of the hypotenuse2 = the sum of the squares of the other two sides

Which gives us:

$$hypotenuse = \sqrt{A^2 + B^2}$$

Activity 1

(Allow 10 minutes)

1 Calculate the length of the hypotenuse.

2 Calculate sin θ.

1 The hypotenuse works out as 33.17 cm

2 sin θ = 14.15/33.17 = 0.427

We are now in a position to calculate the wavelength of the laser.

Activity 2

(Allow 10 minutes)

If the CD track spacing is assumed to be .16 μm, what is the wavelength of the laser?

$$n\lambda = d \sin\theta$$

where:

n = 1

d = 1.6 μm

sin θ = 0.427

hence $\lambda = 1.6 \times 10^{-6} \times 0.427 = 6.83 \times 10^{-7}$m

This is equivalent to 683 nm.

Summary

You have now used the properties of a right angled triangle to calculate the wavelength of a laser pointer.

References

The figures for which no reference is given are the author's own work.

Figure 2 Laundry (Own work) [Public domain], via Wikimedia

Figure 3 Valacosa and Blair Lebert. (Own work) [CC BY 3.0 (http://creativecommons.org/licenses/by/3.0)], via Wikimedia Commons

What next?

We hope this sample has helped you to decide whether this course is right for you.

If you have any further questions, please do not hesitate to contact us using the details below.

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