General Physics

Measurement Techniques
AS level

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Measurement of Length

Length

- Measuring tape is used to measure relatively long lengths
- For shorter length, a metre rule or a shorter rule will be more accurate

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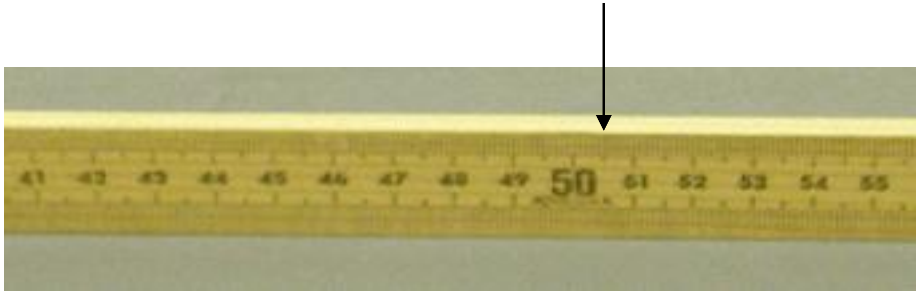
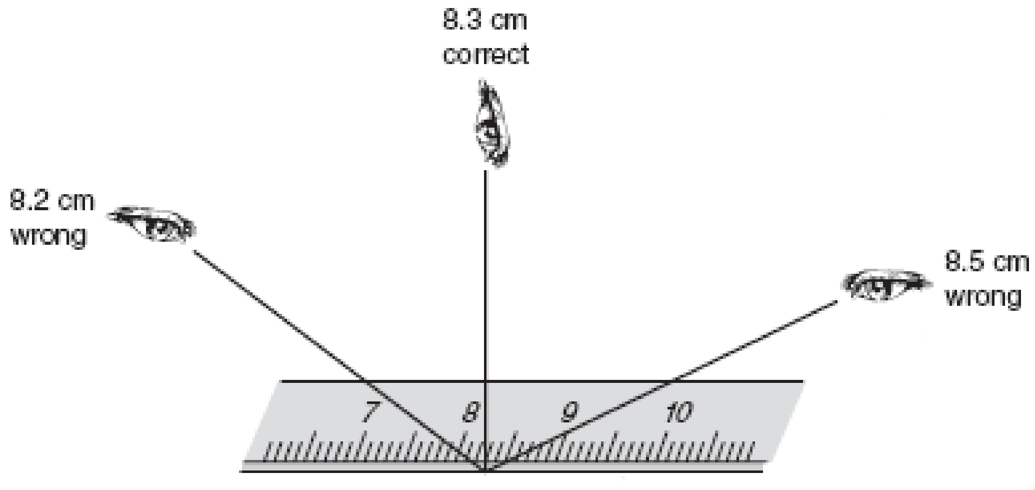
Methods of measuring length

The metre rule

- Simplest length-measuring instrument is the metre or half metre rule (i.e 100 cm or 50 cm)
- Smallest division on the metre rule is 1 mm
- Should be able to take a reading with an uncertainty of 0.5 mm
- Should be aware of 3 possible errors
  - End of the rule is worn out, giving an end error leading to something called a systematic error
  - Calibration of the metre rule i.e. markings on the ruler are not accurate
  - Parallax error



Measurement of Length



- Correct way to read the scale on a ruler
- Position eye perpendicularly at the mark on the scale to avoids parallax errors
- Another reason for error: object not align

Measurement of Length

Vernier Calipers

- The object being measured is between 2.4 cm and 2.5 cm long.
- The second decimal number is the marking on the vernier scale which coincides with a marking on the main scale.

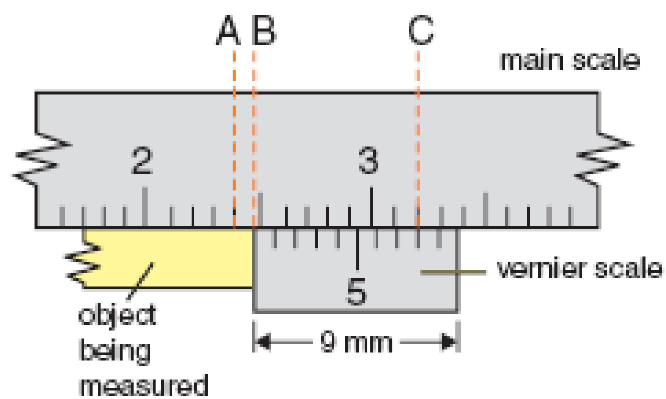


Figure 1.16 A vernier scale

Measurement of Length

- Here the eighth marking on the vernier scale coincides with the marking at C on the main scale
- Therefore the distance AB is 0.08 cm, i.e. the length of the object is 2.48 cm

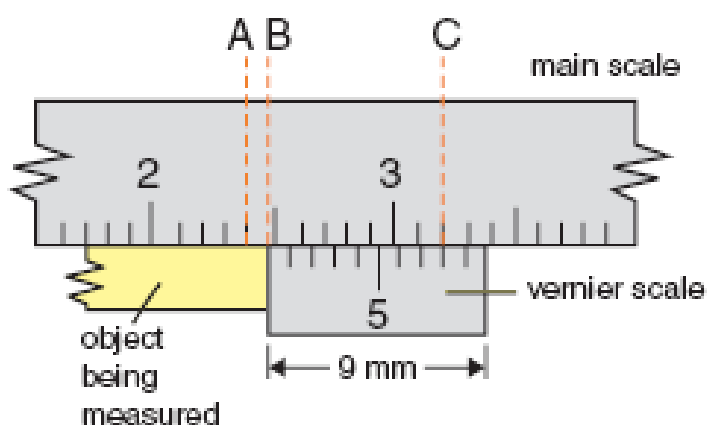


Figure 1.16 A vernier scale

Measurement of Length

Micrometer Screw Gauge

- To measure diameter of fine wires, thickness of paper and small lengths, a micrometer screw gauge is used
- The micrometer has two scales:
  - Main scale on the sleeve
  - Circular scale on the thimble
- There are 50 divisions on the thimble
- One complete turn of the thimble moves the spindle by 0.50 mm

Figure 1.18 The micrometer screw gauge is used to measure small distances to a precision of 0.01 mm.

Measurement of Length

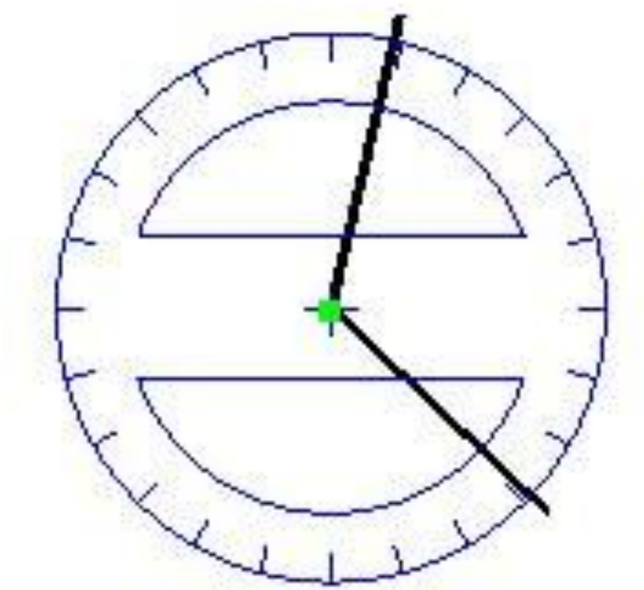
Precautions when using a micrometer

1. Never tighten thimble too much

2. Clean the ends of the anvil and spindle before making a measurement
   - Any dirt on either of surfaces could affect the reading
3. Check for zero error by closing the micrometer when there is nothing between the anvil and spindle
   - The reading should be zero, but it is common to find a small zero error
   - Correct zero error by adjusting the final measurement

Measurement an Angle

- To measure and an angle:
- Take the **Protractor**. Place protractor's center at a vertex of the angle (where two lines meet).
- Click to set the vertex of the angle you will measure.
- Move the pencil in a circle until it is touching the start of the angle (one of the lines).
- Click to set the start of the angle.
- Move the pencil in a circle until it is touching the end of the angle (other line). Notice that the protractor has marks, indicating 15 degree increments, on its edge.
- Click to measure angle.



Measurement of Mass

Top-pan balance , **The spring balance** , **Lever balance,**
Triple Beam Balance

Measurement of Mass

- Instruments used are top-pan balance, lever balances and the spring balance
- Spring balance measures directly both in force units i.e. Newton and also in kilograms

Top-pan balance

- ensure that the initial (unloaded) reading is zero
- there is a control for adjusting the zero reading, balance may have a tare facility i.e. mass of material added to the container is obtained directly
- uncertainty will be quoted by manufacturer in the manual, usually as a percentage of the reading shown on the scale

The spring balance

- based on Hooke's Law which states that extension is proportional to the load; measurement is made directly by a moving over a circular scale
- should be careful of zero error, usually has a zero error adjustment screw
- parallax error

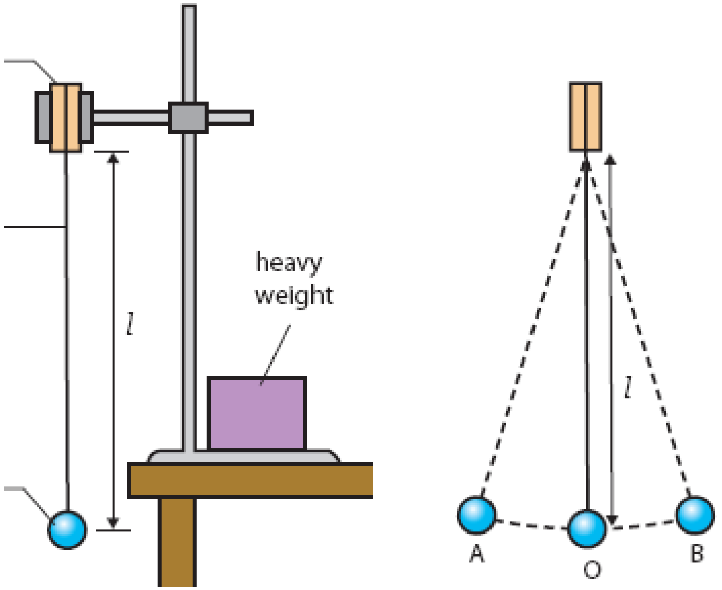
Lever/Beam balances

- based on principle of moments where unknown mass is balanced by a slider, calibrated in mass units
- should be aware of zero error, parallax error

Measurement of Time

Time

- The oscillation of a simple pendulum is an example of a regularly repeating motion.
- The time for 1 complete oscillation is referred to as the **period** of the oscillation.



Measurement of Time

Stopwatch

- Measure short intervals of time
- Two types: digital stopwatch, analogue stopwatch
- Digital stopwatch more accurate as it can measure time in intervals of 0.01 seconds.
- Analogue stopwatch measures time in intervals of 0.1 seconds.

Measurement of Time

Errors occur in measuring time

- If digital stopwatch is used to time a race, should not record time to the nearest 0.01 s.
- **reaction time** in starting and stopping the watch will be more than a few hundredths of a second

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Measurement of Time

- Many instruments do not read exactly zero when nothing is being measured.
- Happen because they are out of adjustment or some minor fault in the instrument.
- Add or subtract the zero error from the reading shown on the scale to obtain accurate readings.
- Vernier calipers or micrometer screw gauge give more accurate measurements.

Application : Measurement of Time

1) Determination of the acceleration of Free Fall

(will study this in detail in chapter : Kinematics)

Reference Notes:

International A level Physics by Chris & Mike

Methods of Measuring temperature

The Mercury in glass thermometer

A mercury-in-glass thermometer is a thermometer which provides temperature readings through the expansion and contraction of mercury inside a calibrated tube.

The thermocouple thermometer

- A thermocouple does not measure absolute temperature, but rather the difference in temperature between two points. When one end of a conductor, such as a metal strip, is hotter than the other, it creates a voltage between the two ends. The greater the temperature difference, the greater the current. Different metals react at different rates, and a thermocouple actually makes use of two metals, joined at the sensor end. At the circuitry end, they are attached to a meter that uses the difference in voltages between the metals to calculate the temperature differential.

Calibration Curves

Calibration curve of a thermometer using a mercury thermometer as a standard

- An unmarked thermometer (alcohol in this example.) can be calibrated using a mercury thermometer as a standard.
- Both thermometers are placed in melting ice (0 degrees C), the length of the alcohol "thread" is noted. A heater is switched on causing the water temperature to gradually increase.
- For at least six temperature values the corresponding length of the alcohol thread is noted. A graph of length of alcohol thread against temperature is the required calibration curve.

Calibration Curves

Calibration curve of a thermometer using a mercury thermometer as a standard

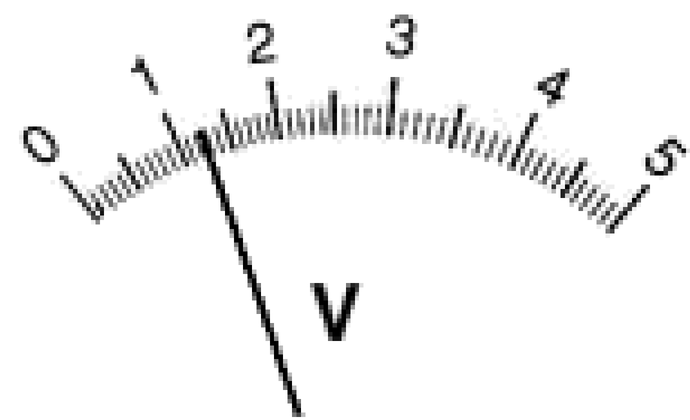
- Analysis:

Plot a graph, on graph paper, of length of alcohol thread (y-axis) against temperature. Any temperature between 0 and 100 degrees can now be measured using the unmarked thermometer. Place it in a beaker of moderately hot water, measure the length of the alcohol thread and, from the calibration curve, read the corresponding temperature.

Methods of measuring current and potential difference

- Analogue meters

An analogue meter can display any value within the range available on its scale. However, the precision of readings is limited by our ability to read them. For example the meter on the right shows 1.25V because the pointer is estimated to be half way between 1.2 and 1.3. The analogue meter can show any value between 1.2 and 1.3 but we are unable to read the scale more precisely than about half a division.



Methods of measuring current and potential difference

A Galvanometer

A **galvanometer** is a type of sensitive ammeter: an instrument for detecting electric current. It is an analog electromechanical transducer that produces a rotary deflection of some type of pointer in response to electric current flowing through its coil in a magnetic field.

Galvanometer – Null method

Any method of obtaining measurements or comparisons, in which the measurement is correct when the deflection of the galvanometer or other indicator is zero, nought or null.

Two obvious advantages attach to null methods in electric galvanometer work - one is that an uncalibrated galvanometer can be employed, the other is that a galvanometer of any high degree of sensitiveness can be employed, there being no restriction as to its fineness of winding or highness of resistance.

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Methods of measuring current and potential difference

- Digital Meters
- A digital meter is a device used by technicians to test and measure electronic circuits. Most of them are portable, battery-powered units. They show measurements as numbers and symbols on an electronic display.
- Digital multi-meters measure voltage, current, resistance and related electronic parameters. You select the quantity you want to measure, touch the meter's probe wires to a circuit, then read the results on the display.

Methods of measuring current and potential difference

- Multimeters

A multimeter measures electrical properties such as AC or DC voltage, current, and resistance. Rather than have separate meters, this device combines a voltmeter, an ammeter, and an ohmmeter. Electricians and the general public might use it on batteries, components, switches, power sources, and motors to diagnose electrical malfunctions and narrow down their cause.

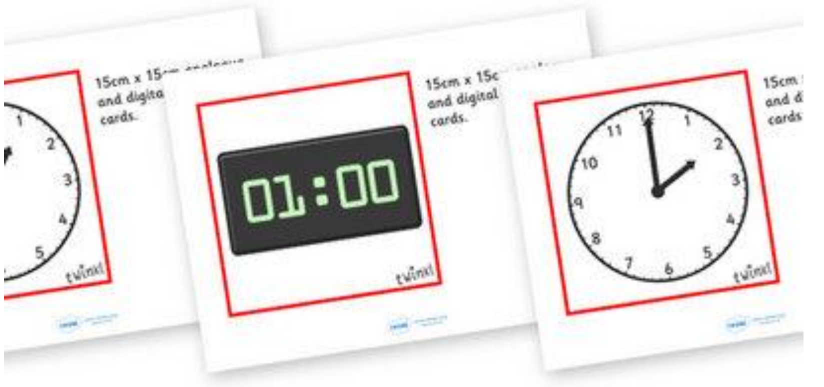
Analogue & Digital

- Analogue Scales

Analogue scales have round dials, where a pointer moves clockwise according to the weight applied. Markings are equally spaced between the numbers to indicate fractional amounts

- Digital Scales

Digital scales have LCD or LED number displays. There are no pointers on a digital scale.



Accurate Measurement

- **Random errors** occur in all measurements.
- Arise when observers estimate the last figure of an instrument reading.
- Called random errors because they are unpredictable.
- Minimize such errors by averaging a large number of readings.

Accurate Measurement

- Systematic errors are not random but constant
- Cause an experimenter to consistently underestimate or overestimate a reading
- Due to the equipment being used – e.g. a ruler with **zero error**
- May be due to environmental factors – e.g. weather conditions on a particular day
- Cannot be reduced by averaging, but they can be eliminated if the sources of the errors are known

Systematic/random

- Error can be systematic or random

Difference between	systematic	random
Direction of error	---	Both direction (plus/minus)
Eliminate/reduce	Can be eliminated Cannot reduce	Can reduce Cannot eliminate

What type of error is a) reaction time?

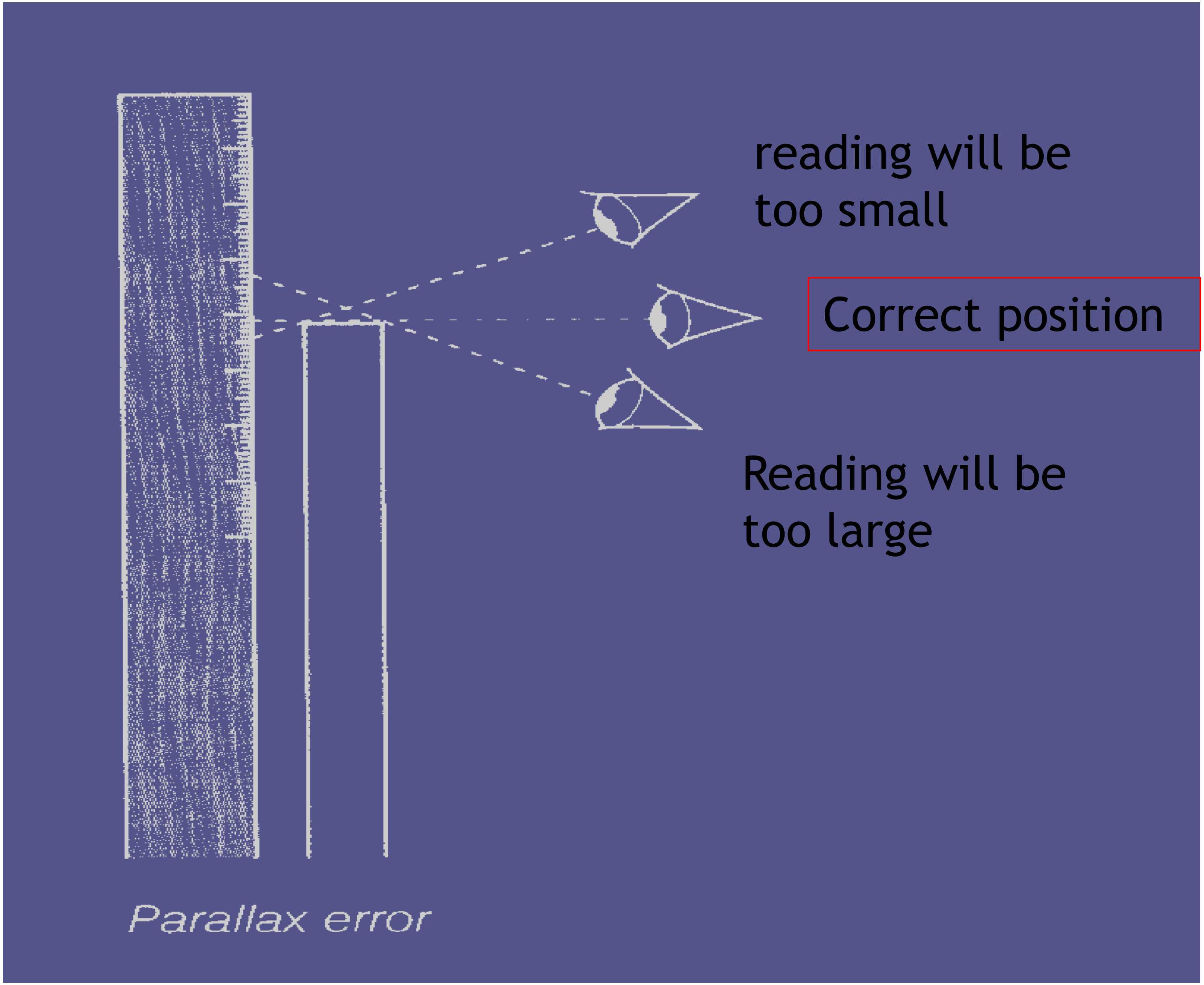
b) Parallax error?

Systematic Errors

- These are errors in the experimental method or equipment where readings are either always too big or always too small compared to the actual value.
- For example, if your newton-meter reads 0.2 N with no weights on it, then your measurements of force will always be 0.2 N too large.

Systematic Errors

- What are zero errors?
- Remember to check for any zero errors for your measuring instruments before you start.
- Another example is if you get **parallax** when reading scales with your eye in the wrong position, as shown in the diagram.


reading will be
too small
Correct position
Reading will be
too large
Parallax error

Systematic Errors

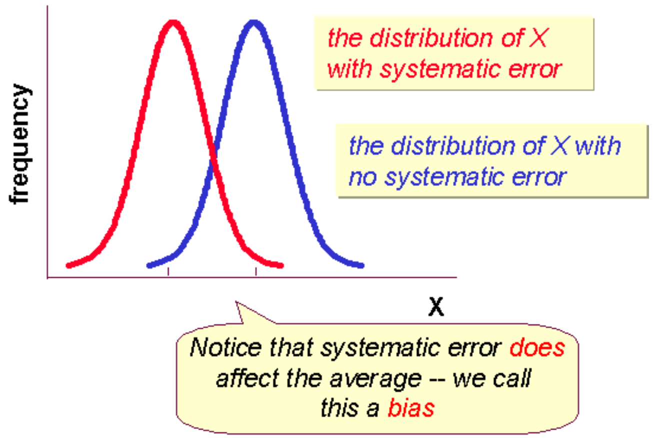
- If you heat some water to measure its specific heat capacity, there will always be thermal energy lost to the surroundings.
- So how will that affect your temperature rise reading in this process?
- Measurement of the temperature rise of the water would always be too small. This is another systematic error.

Systematic Errors

- Therefore, you will need to design your experiment carefully to correct for errors like this thermal energy loss.
- You will also need to take certain precautions for different types of experiments.

Systematic Errors

- Are **TYPICALLY** present.
- Measurements are given as:



Measurement + Systematic Error
OR
Measurement - Systematic Error

- **Sources:**
  - Instrumental, physical and human limitations.
    - Example: Device is out-of calibration.
- **How to minimize them?**
  - Careful calibration.
  - Best possible techniques.

Random Errors

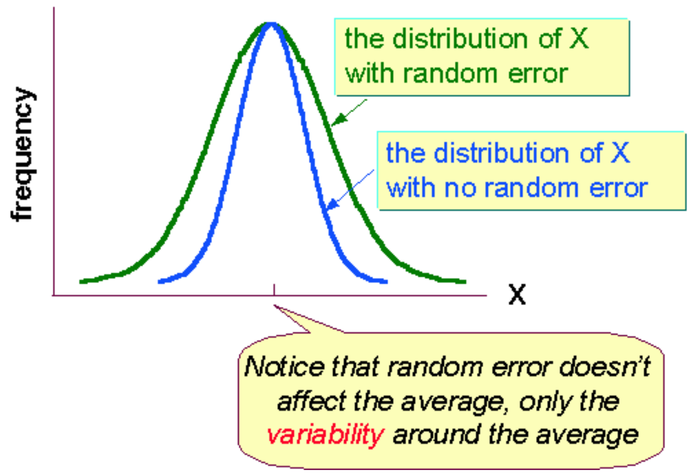
- These are errors which sometimes mean that readings are too big, and sometimes too small compared to the actual value.
- For example, when you are timing oscillations, what is the common error here?
- Error in your timing because of your reactions.

Random Errors

- There are also random errors when reading ammeters or voltmeters.
- For example, a reading of 1.0 V means that the voltage is between 0.95 V and 1.05 V, and we are not sure if the reading is too high or too low.

Random Errors

- **ALWAYS** present.
- Measurements are often shown as:



Measurement ± Random Error

- **Sources:**
  - Operator errors
  - Changes in experimental conditions
- **How to minimize them?**
  - Take repeated measurements and calculate their average.

Accuracy and Precision

Precision

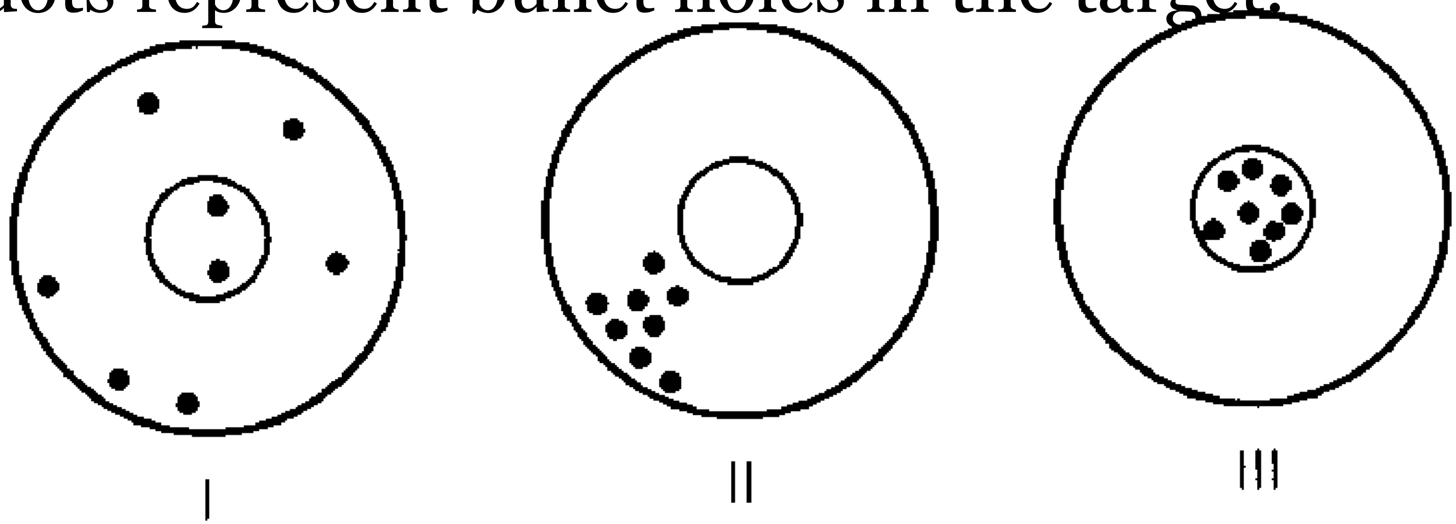
- Precision is the degree of exactness to which a measurement can be reproduced.
- The precision of an instrument is limited by the smallest division on the measurement scale.
- It also means, how close the readings are to each other.

Accuracy

- The accuracy of a measurement describes how well the result agrees with an accepted value.
- It is taken as the difference between the measured value and accepted value.

An analogy

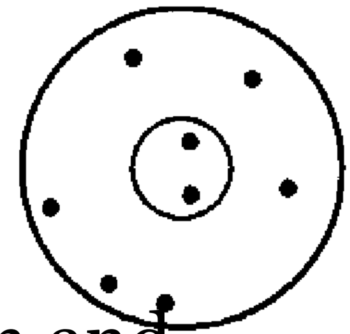
- The dots represent bullet holes in the target.



- Draw an analogy between accuracy and precision using the above 3 diagrams.

An analogy

- The first target shows moderate accuracy and poor precision;



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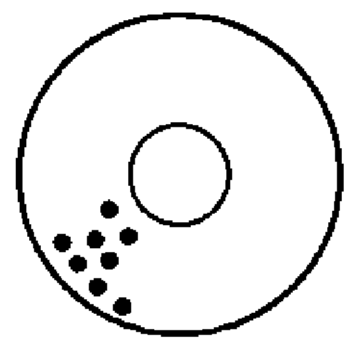
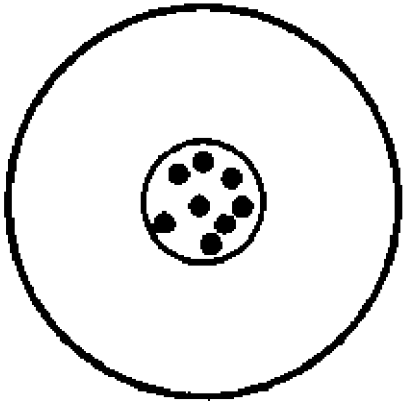
- the second shows good precision and poor accuracy.



II

An analogy

- The third represents good accuracy and good precision.



III

Precision/accuracy

	precision	**Accuracy**
meaning	Spreading about **average** values	Nearness to **actual** value
Affected by	random error	systematic error
To improve	Repeat and average/plot graph	Technique, accurate instrument,
Graph feature	Scattering about straight line	Straight line parallel to best fit

- No measurement is absolute
- Therefore measurements must be written together with uncertainty

- E.g. L = 2.5 ± 0.1 cm

Youtube reference

- http://www.youtube.com/watch?v=QruAxiYSIAY
- http://www.youtube.com/watch?v=1dTn2pt5PuA
- http://www.youtube.com/watch?v=F2pVw5FOiyA

Limit of Reading and Uncertainty

- The **Limit of Reading** of a measurement is equal to the smallest graduation of the scale of an instrument.
- The **Degree of Uncertainty** of a reading (end reading) is equal to half the smallest graduation of the scale of an instrument.
- e.g. If the limit of reading is 0.1cm then the uncertainty range is ±0.05cm
- This is the absolute uncertainty

Reducing the Effects of Random Uncertainties

- Take multiple readings
- When a series of readings are taken for a measurement, then the arithmetic mean of the reading is taken as the most probable answer
- The greatest deviation from the mean is taken as the absolute error.

Absolute/fractional errors and percentage errors

- We use ± to show an error in a measurement
- (208 ± 1) mm is a fairly precise measurement
- (2 ± 1) mm is highly inaccurate

- In order to compare uncertainties, use is made of absolute, fractional and percentage uncertainties.
- 1 mm is the absolute uncertainty
- 1/208 is the fractional uncertainty (0.0048)
- 0.48 % is the percentage uncertainty.

Uncertainties

Every measurement has an uncertainty or error.

e.g. time = 5 seconds ± 1 second

The ± 1 second is called the absolute uncertainty

There are three main types of uncertainty.

- ❑ Random Uncertainties
- ❑ Systematic Errors
- ❑ Reading Uncertainties

Random Uncertainties

Repeated measurements of the same quantity, gives a range of readings.

The random uncertainty is found using:

$$\text{random uncertainty} = \frac{\text{max reading} - \text{min reading}}{\text{number of readings}}$$

Taking more measurements will help eliminate (or reduce) random uncertainties.

The mean is the best estimate of the true value.

Example 1

Five measurements are taken to determine the length of a card.

209mm, 210mm, 209mm, 210mm, 200mm

(a) Calculate the mean length of card.

(b) Find the random uncertainty in the measurements.

(c) Express mean length including the absolute uncertainty.

(a)

$$\text{mean length} = \frac{209 + 210 + 209 + 210 + 200}{5}$$

$$= \frac{1038}{5}$$

$$\text{mean length} = 208 \text{ mm}$$

give the mean to same number of significant figures as measurements

(b)

$$\text{random uncertainty} = \frac{\text{max reading} - \text{min reading}}{\text{number of readings}}$$

$$= \frac{210 - 200}{5}$$

$$= 2\ \text{mm}$$

(c)

$$\text{length of card} = 208\ \text{mm} \pm 2\ \text{mm}$$

The "± 2mm" is the absolute uncertainty.

Question

Repeated measurements of speed give the following results:

$9.87\ ms^{-1}$, $9.80\ ms^{-1}$, $9.81\ ms^{-1}$, $9.85\ ms^{-1}$

(a) Calculate the mean speed.

(b) Find the random uncertainty.

(c) Express mean speed including the absolute uncertainty.

Answer key

Repeated measurements of speed give the following results:

9.87 ms^{-1}, 9.80 ms^{-1}, 9.81 ms^{-1}, 9.85 ms^{-1}

(a) Calculate the mean speed. 9.83 ms^{-1}

(b) Find the random uncertainty. 0.02 ms^{-1}

(c) Express mean speed including the absolute uncertainty.

9.83 ms^{-1} $\pm$ 0.02 ms^{-1}

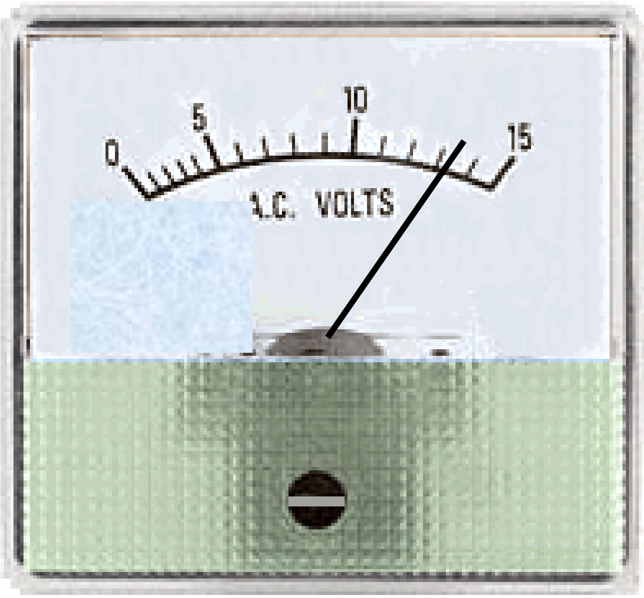
Reading Uncertainties

A reading uncertainty is how accurately an instruments scale can be read.

Analogue Scales

Where the divisions are fairly large, the uncertainty is taken as:

half the smallest scale division



Where the divisions are small,
the uncertainty is taken as:

the smallest scale division

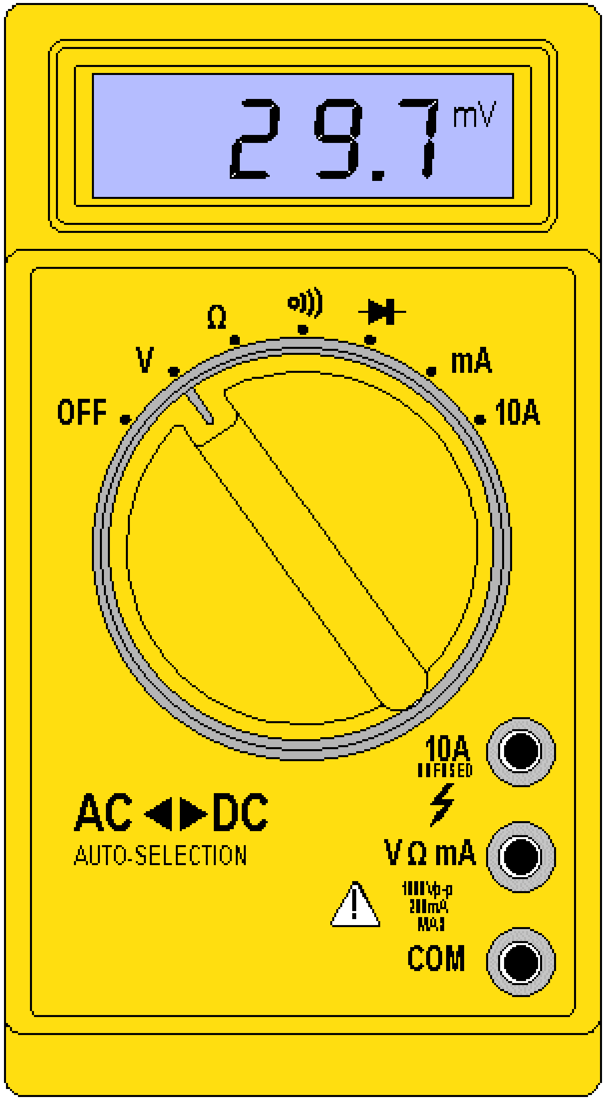
Digital Scale (example 1)

For a digital scale, the uncertainty is taken as:

the smallest scale reading

e.g. voltage = 29.7 mV ± 0.1 mV

This means the actual reading could be anywhere from .....??



Percentage Uncertainty

The percentage uncertainty is calculated as follows:

$$\%\ \text{uncertainty} = \frac{\text{absolute uncertainty}}{\text{reading}} \times 100$$

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Example 1

Calculate the percentage uncertainty of the measurement:

$$d = 8\text{cm} \pm 0.5\text{cm}$$

$$\%\ \text{uncertainty} = \frac{\text{absolute uncertainty}}{\text{reading}} \times 100$$

$$= \frac{0.5}{8} \times 100$$

$$= 0.0625 \times 100$$

$$= 6.25\ \%$$

$$(d = 8\text{cm} \pm 6.25\%)$$

Question 1

Calculate the % uncertainty of the following:

a) I = 5A ± 0.5A

b) t = 20s ± 1s

c) m = 1000g ± 1g

d) E = 500J ± 25J

e) F = 6N ± 0.5N

Answer key

Calculate the % uncertainty of the following:

a) I = 5A ± 0.5A — 10 %

b) t = 20s ± 1s — 5 %

c) m = 1000g ± 1g — 0.1 %

d) E = 500J ± 25J — 5 %

e) F = 6N ± 0.5N — 8.3 %

Combining uncertainties

- For addition, add absolute uncertainties
- $y = b+c$, then $y \pm \delta y = (b+c) \pm (\delta b + \delta c)$

Example :

Two volumes of water were added to a beaker.

The volumes measured are as follow:

Volume A = $15.0 \pm 0.1\ m^3$

Volume B = $25.0 \pm 0.1\ m^3$

Determine the final volume together with its

Uncertainty

Ans: $40.0 \pm 0.2\ m^3$

Combining uncertainties

- For subtraction, add absolute uncertainties
- $y = b - c$, then $y \pm \delta y = (b - c) \pm (\delta b + \delta c)$

Example :

- A student measured the temperature of a beaker of water before and after heating. The readings are as follow:

Initial temperature = 25.0 ± 0.5^{o} C.

Final temperature = 40.0 ± 0.5^{o} C.

- Determine the temperature rise together with its uncertainty
- Ans: $15 \pm 1\ ^{o}$C (final value rounded up to nearest 1^{o} C)

Combining uncertainties

- For multiplication and division add percentage / fractional uncertainties
- x = b x c, then $\frac{\delta x}{x} = \frac{\delta b}{b} + \frac{\delta c}{c}$

For finding percentage, we have multiply fractional error by 100.

Examples in next slide >>>>

Combining Uncertainties (Example for multiplication & Division)

- Multiplication

Determine the momentum together with uncertainty given that

mass of object = 1.50 $\pm$ 0.01 kg

Velocity of object = 2.0 $\pm$ 0.2 ms^{-1}

ans: uncertainty = 0.32

But final answer = 3.0 $\pm$ 0.3 $kgms^{-1}$

Working :

$P = mv$

$$\frac{\delta P}{P} = \frac{\delta m}{m} + \frac{\delta v}{v}$$

$$\frac{\delta P}{3} = \frac{0.01}{1.5} + \frac{0.2}{2}$$

- Division

Determine the density of water given the measurements below

Mass, m = 50 $\pm$ 1 g

Volume, V = 52 $\pm$ 5 cm^{-3}.

Ans: density = 1.0 $\pm$ 0.1 gcm^{-3}

Working :

$D = m/V$

$$\frac{\delta D}{D} = \frac{\delta m}{m} + \frac{\delta V}{V}$$

$$\frac{\delta D}{0.96} = \frac{1}{50} + \frac{5}{52}$$

Combining uncertainties

- When using powers, multiply the percentage uncertainty by the power
- $z = b^a$ then $\frac{\delta z}{z} = a \frac{\delta b}{b}$

Example :

- Determine the density of iron given the measurements below

Mass, m = 37.8 $\pm$ 0.1 g

Diameter of sphere, d = 2.10 $\pm$ 0.01 cm .

Ans: density = 7.8 $\pm$ 0.1 gcm^{-3}

Working in next slide >>>

Detailed explanation on Slide no 71 (continued)

Explanation on Slide No. 71

Determine Density

Given $m = 37.8 \pm 0.1\,g$

$d = 2.10 \pm 0.01\,cm$

Firstly find density

$$\rho = \frac{m}{V} = \frac{m}{\frac{\pi d^3}{6}} = \frac{6m}{\pi d^3}$$

$$= \frac{6 \times 37.8}{\pi (2.10)^3} = \underline{7.79} \leftarrow \text{density}$$

Combining Uncertainties

When using powers multiply the % uncertainty by the power.

ex: $Z = b^a$ then $\frac{\Delta Z}{Z} = a \cdot \frac{\Delta b}{b}$

$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{4}{3}\pi\frac{d^3}{8}$$

$$V = \frac{\pi d^3}{6}$$

Detailed explanation on Slide no 71

Next find uncertainity of density $\Delta\rho$

So, $\dfrac{\Delta\rho}{\rho} = \dfrac{0.1}{37.8} + \dfrac{3 \times 0.01}{2.10}$

$\Delta\rho = \left(\dfrac{0.1}{37.8} + \dfrac{3 \times 0.01}{2.10}\right) 7.79$

$= 0.132$

Here $\dfrac{\Delta V}{V}$ → $(2.10 \pm 0.1)^3$ → $3\,(0.01/2.10)$

$V = \dfrac{\pi d^3}{6}$

So, $\dfrac{\Delta V}{V} = 3\,\dfrac{\Delta d}{d}$

π & 6 being Constants, error is not taken (ie, no error with Constants.

This is from formulae of

$Z = b^a$

$\dfrac{\Delta z}{z} = a\,\dfrac{\Delta b}{b}$.

So $\rho = 7.79$ and $\Delta\rho = 0.1$

Final answer is $7.8 \pm 0.1\ g\,cm^{-3}$

Significant Figures and Calculations

- What is the difference between lengths of 4 m, 4.0 m and 4.00 m?
- Writing 5.00 m implies that we have measured the length more precisely than if we write 5 m.
- Writing 5.00 m tells us that the length is accurate to the nearest centimetre.

Significant Figures and Calculations
(First alternative)

- How many significant figures should you give in your answers to calculations?
- This depends on the precision of the raw numbers you use in the calculation.
- Your answer cannot be any more precise than the data you use.

Significant Figures and Calculations
(Second alternative)

- This means that you should round your answer to the same number of significant figures as those used in the calculation.
- If some of the figures are given less precisely than others, then round up to the ***lowest*** number of significant figures.

Example

- The swimmer covers a distance of 100.0 m in 68 s. Calculate her average speed.

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}} = \frac{100.0\ \text{m}}{68\ \text{s}} = 1.4705882\ \text{m s}^{-1}$$

- Our final answer should be stated as:

➢ $1.5\ \text{m s}^{-1}$ (2 s.f.)

➢ $1.47\ \text{m s}^{-1}$ (3 s.f.)

Example : Combining Uncertainties

Use the following data to calculate the speed, and the uncertainty in speed, of a moving object.

Calculation of Speed

$$d = 16\ cm\ \pm\ 0.5\ cm$$

$$t = 2\ s\ \pm\ 0.5\ s$$

$$v = ?$$

$$v = \frac{d}{t}$$

$$= \frac{16}{2}$$

$$v = 8\ cm\ s^{-1}$$

Calculation of Uncertainty

$$\%\ \text{error in } d = \frac{\text{absolute uncertainty}}{\text{reading}} \times 100$$

$$= \frac{0.5}{16} \times 100$$

$$= 3.1\ \%$$

$$\%\ \text{error in } t = \frac{\text{absolute uncertainty}}{\text{reading}} \times 100$$

$$= \frac{0.5}{2} \times 100$$

$$= 25\ \%$$

Uncertainty in Speed

The biggest uncertainty is used, so get: $v = 8\ cm\ s^{-1}\ \pm\ 25\%$

The absolute uncertainty in the speed: $v = 25\%\ of\ 8\ cm\ s^{-1}$

$= 0.25\% \times 8$

$= 2\ cm\ s^{-1}$

Answer $v = 8\ cm\ s^{-1} \pm\ 2\ cm\ s^{-1}$ **OR** $v = 8\ cm\ s^{-1} \pm\ 25\%$

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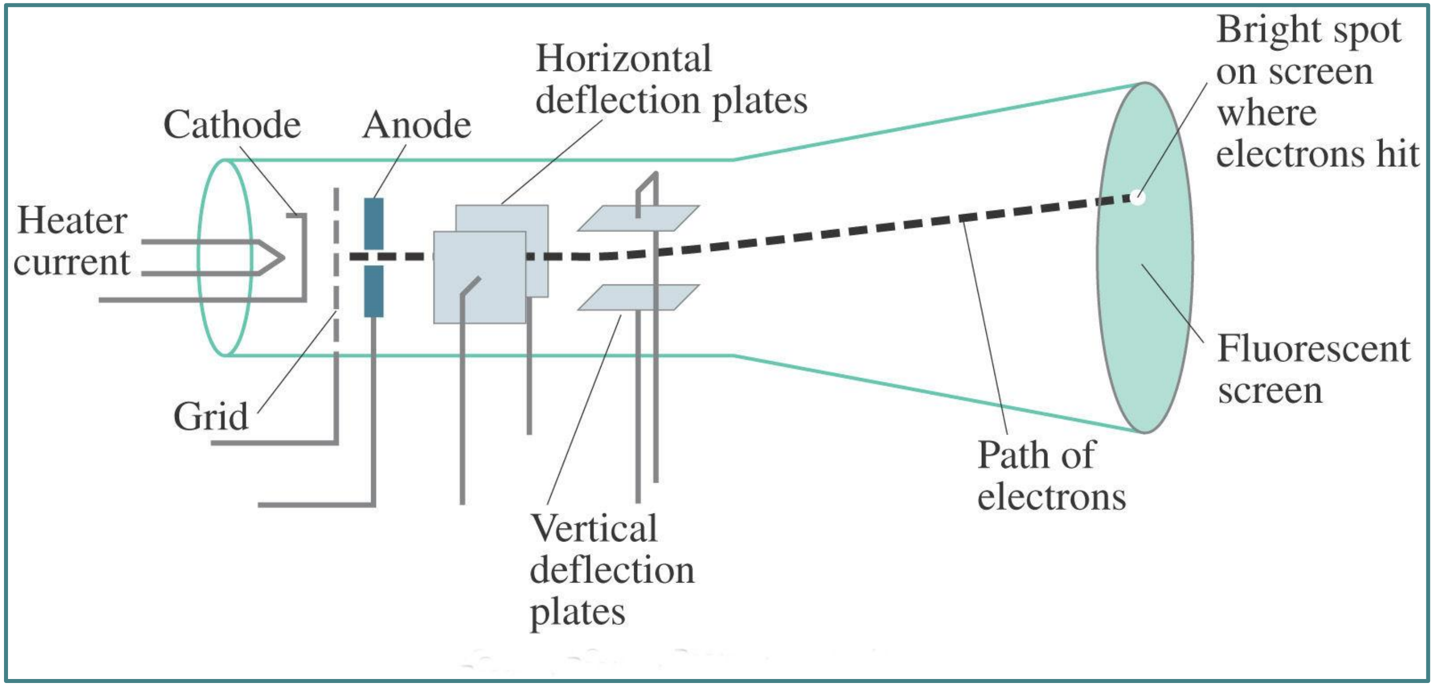
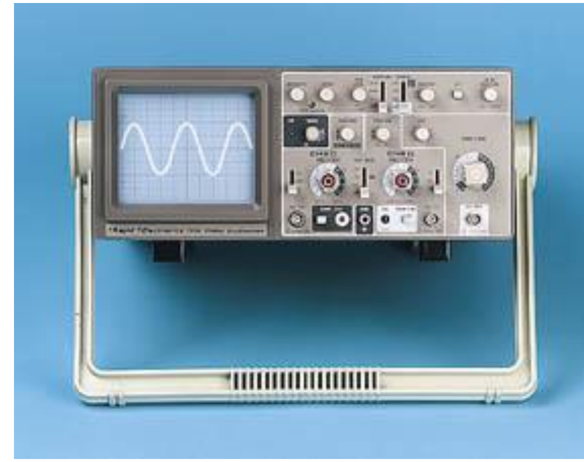
Cathode Ray Oscilloscope

- Reference Link
  http://www.kpsec.freeuk.com/cro.htm

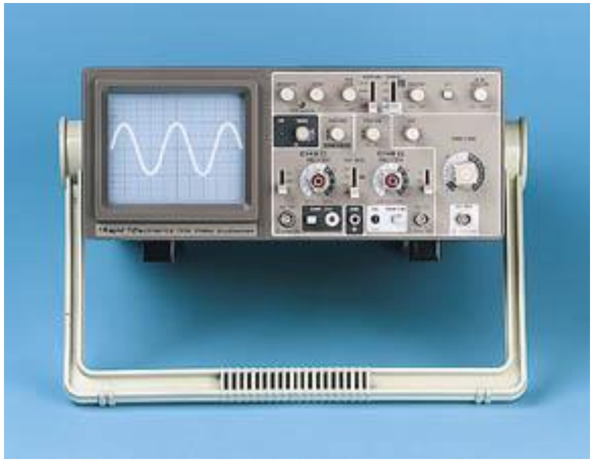


Cathode Ray Oscilloscope



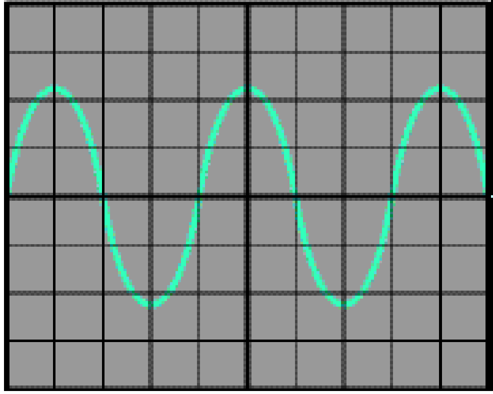
- An oscilloscope is a test instrument which allows you to look at the 'shape' of electrical signals by displaying a graph of voltage against time on its screen. It is like a voltmeter with the valuable extra function of showing how the voltage varies with time. The 1cm grid enables you to take measurements of voltage and time from the screen.
- The graph, usually called the **trace**, is drawn by a beam of electrons striking the phosphor coating of the screen making it emit light, usually green or blue. This is similar to the way a television picture is produced.

Cathode Ray Oscilloscope



- Oscilloscopes contain a vacuum tube with a **cathode** (negative electrode) at one end to emit electrons and an **anode** (positive electrode) to accelerate them so they move rapidly down the tube to the screen. This arrangement is called an electron gun. The tube also contains electrodes to deflect the electron beam up/down and left/right.
- The electrons are called cathode rays because they are emitted by the cathode and this gives the oscilloscope its full name of **cathode ray oscilloscope** or CRO.

Cathode Ray Oscilloscope

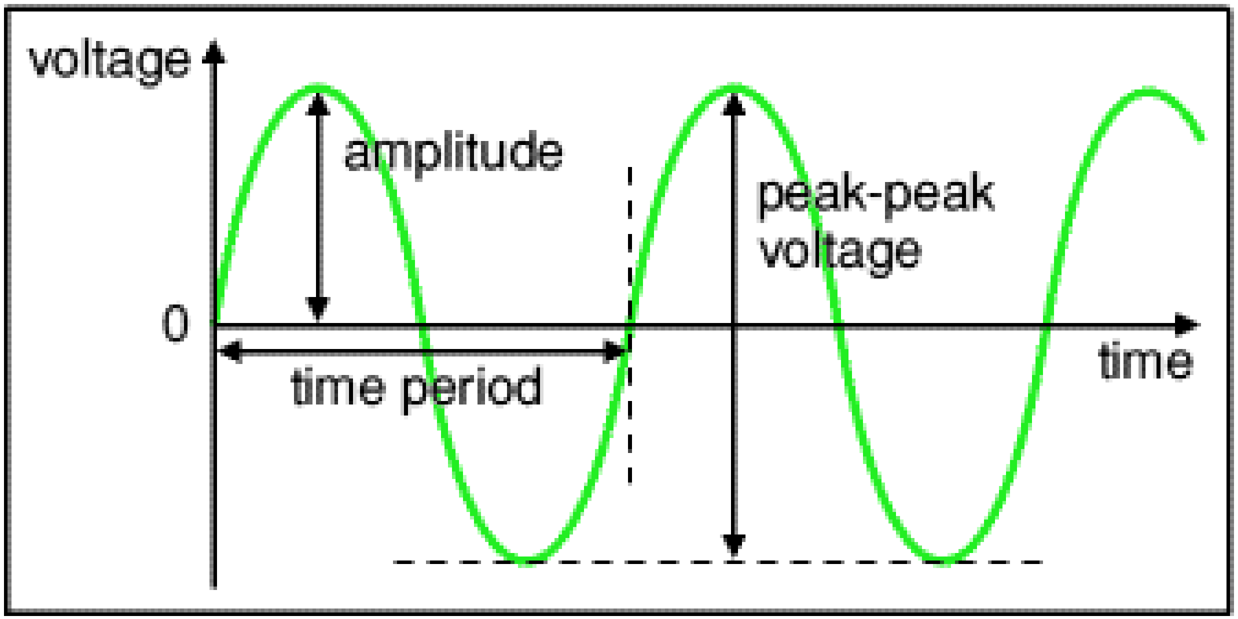


- **Obtaining a clear and stable trace**
- Once you have connected the oscilloscope to the circuit you wish to test you will need to **adjust the controls** to obtain a clear and stable trace on the screen: The **Y AMPLIFIER (VOLTS/CM)** control determines the height of the trace. Choose a setting so the trace occupies at least half the screen height, but does not disappear off the screen.
- The **TIMEBASE (TIME/CM)** control determines the rate at which the dot sweeps across the screen. Choose a setting so the trace shows at least one cycle of the signal across the screen.
- The **TRIGGER** control is usually best left set to AUTO.

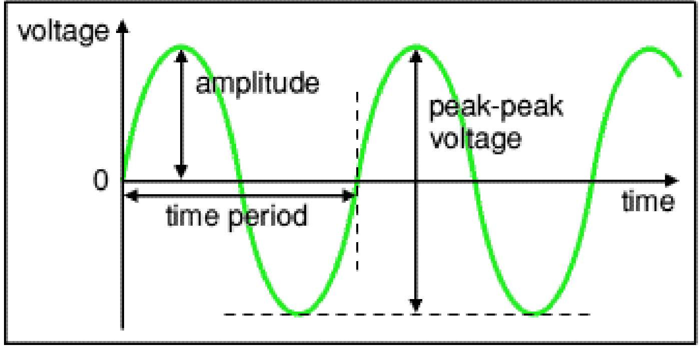
Cathode Ray Oscilloscope

Measuring voltage and time period

- The trace on an oscilloscope screen is a **graph of voltage against time**. The shape of this graph is determined by the nature of the input signal. In addition to the properties labelled on the graph, there is frequency which is the number of cycles per second.



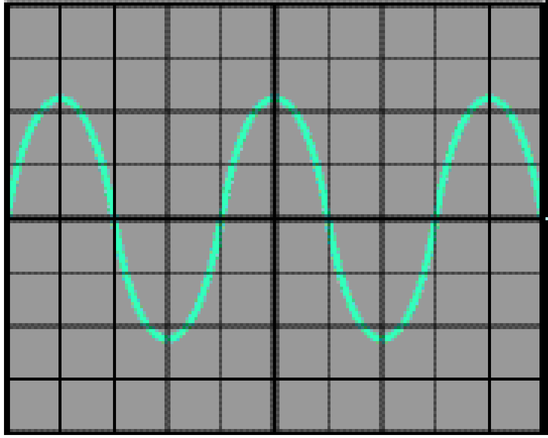
Cathode Ray Oscilloscope



- **Measuring voltage and time period**

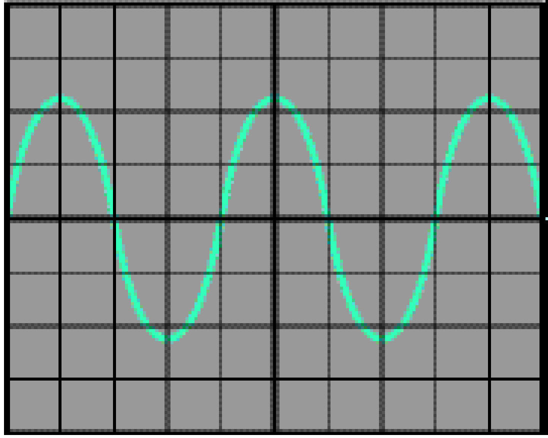
- **Amplitude** is the maximum voltage reached by the signal. It is measured in **volts**, **V**.
- **Peak voltage** is another name for amplitude.
- **Peak-peak voltage** is twice the peak voltage (amplitude). When reading an oscilloscope trace it is usual to measure peak-peak voltage.
- **Time period** is the time taken for the signal to complete one cycle. It is measured in **seconds (s)**, but time periods tend to be short so **milliseconds (ms)** and **microseconds (µs)** are often used. 1ms = 0.001s and 1µs = 0.000001s.
- **Frequency** is the number of cycles per second. It is measured in **hertz (Hz)**, but frequencies tend to be high so **kilohertz (kHz)** and **megahertz (MHz)** are often used. 1kHz = 1000Hz and 1MHz = 1000000Hz.
- Frequency = 1/time period and vice versa

Cathode Ray Oscilloscope



- **Calculating Voltage**
- Voltage is shown on the **vertical y-axis** and the scale is determined by the Y AMPLIFIER (VOLTS/CM) control. Usually **peak-peak voltage** is measured because it can be read correctly even if the position of 0V is not known. The **amplitude** is half the peak-peak voltage.
- **Voltage = distance in cm × volts/cm**
  Example: peak-peak voltage = 4.2cm × 2V/cm = 8.4V
  amplitude (peak voltage) = ½ × peak-peak voltage = 4.2V

Cathode Ray Oscilloscope



Calculating Time period

- Time is shown on the **horizontal x-axis** and the scale is determined by the TIMEBASE (TIME/CM) control. The **time period** (often just called **period**) is the time for one cycle of the signal. The **frequency** is the number of cyles per second, frequency = 1/time period.

- **Time period = distance in cm × time/cm**

Given time/cm as *5ms/cm*

Example: time period = 4.0cm × 5ms/cm = 20ms

Youtube links to explanation on :
General Physics – Measurement techniques

- http://www.youtube.com/watch?v=F2pVw5FOiyA
- http://www.youtube.com/watch?v=iIyGPV06Mf4

Any questions?