Higher Physics

Uncertainties

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. 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} ± 0.02 ms^{-1}

Systematic Errors

Systematic errors are due to:

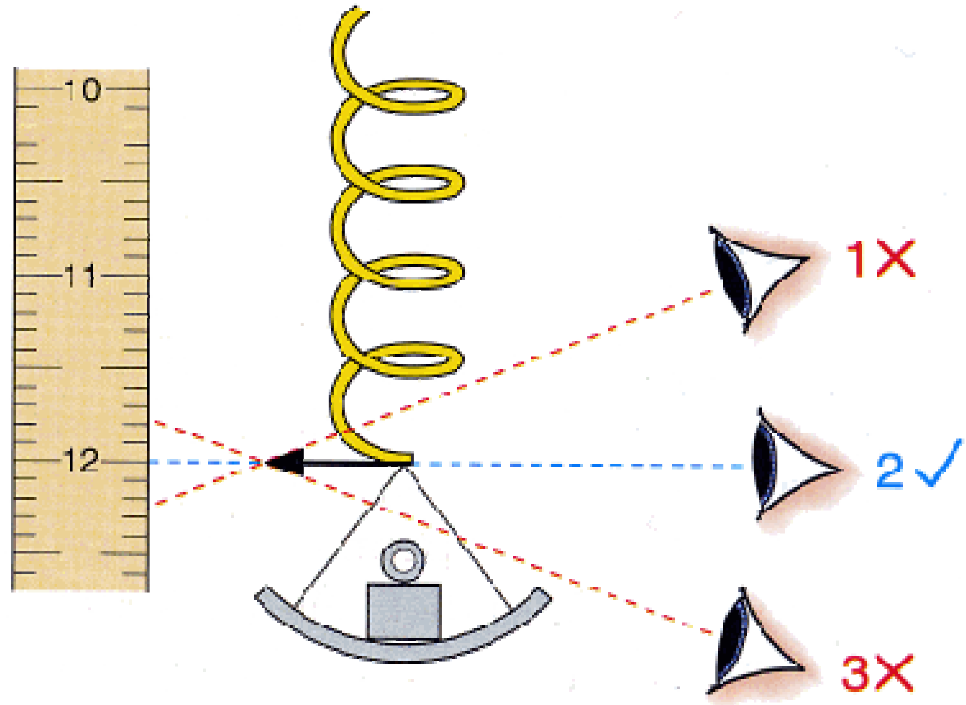
- faults in the apparatus
- wrong experimental technique.

These errors, cause readings to be consistently higher or lower than the true value really is.

Your results are systematically wrong.

Experimental Technique

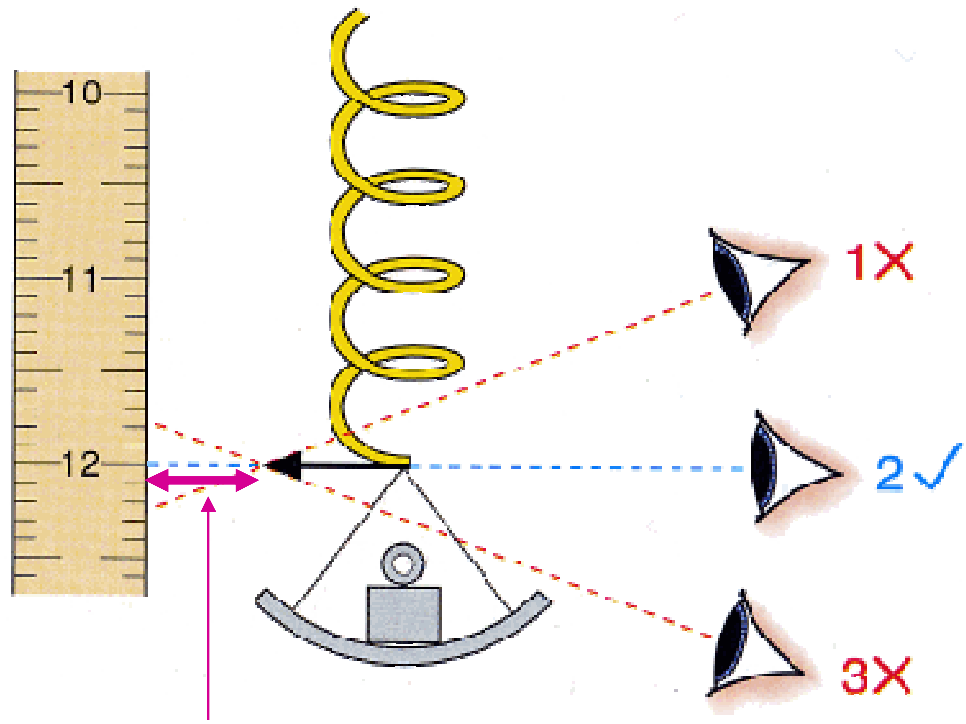
Consider the error you may make in a reading a scale as shown.



Measurement 2 is best.

1 and 3 give the wrong readings.

This is called a **parallax** error.

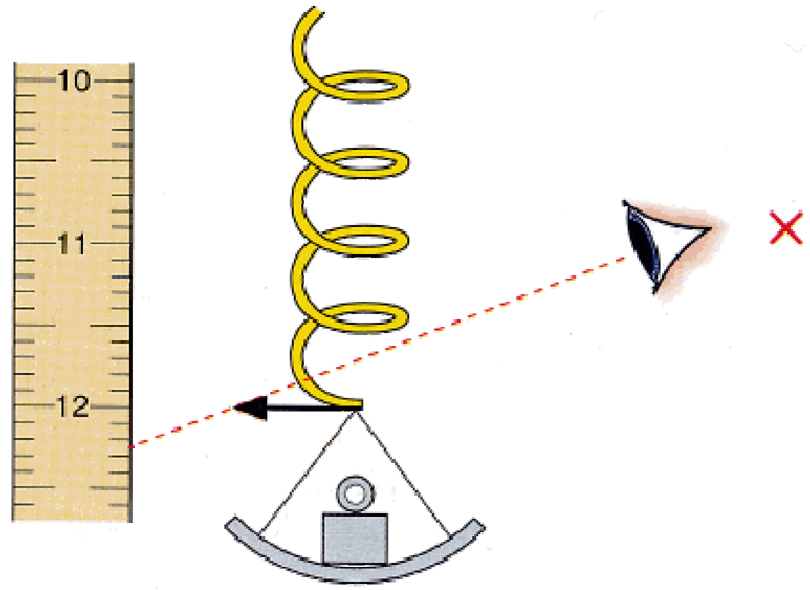


It is due to the gap here, between the pointer and the scale.

Should the gap be wide or narrow for best results?

Systematic Errors

Consider if you make an error consistently on reading on a scale.



Your results will always be higher than they should be.

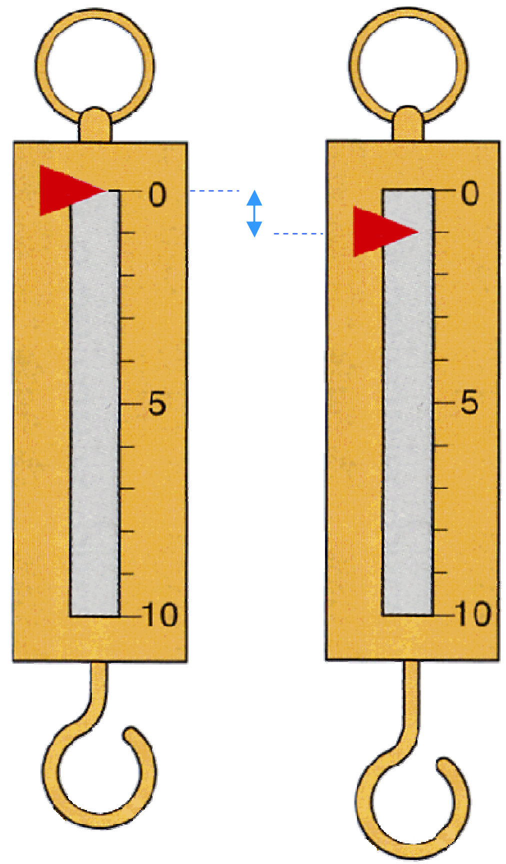
Zero Errors

A particular type of systematic error is the zero error.

Apparatus that does not read zero even when it should.

Over a period of time, the spring may weaken, and so the pointer does not point to zero.

What affect does this have on ALL the readings?




0
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2
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4
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A
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+


NET
ZERO
0.02 g
ON/OFF
SAMPLE
PRINT
MODE
RE-ZERO

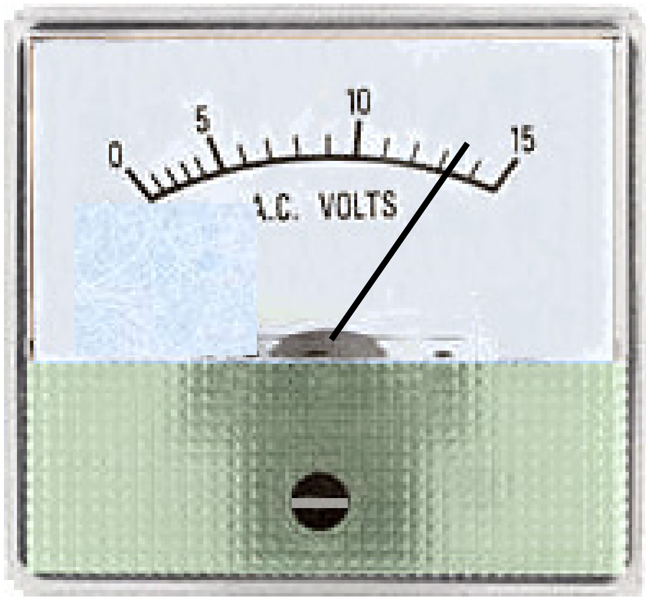
Reading Uncertainties

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

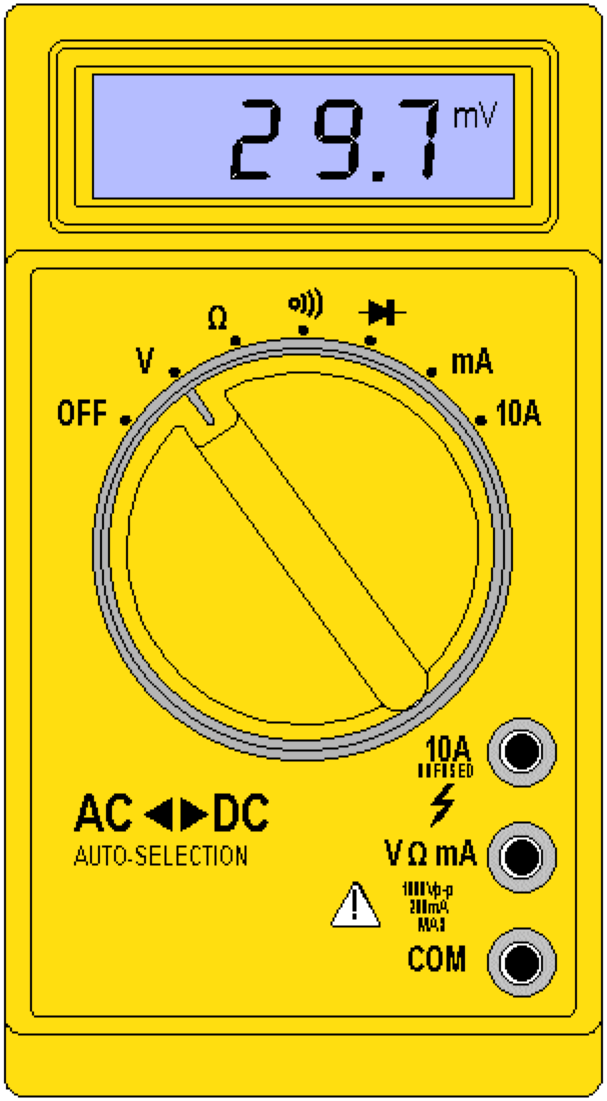
Digital Scale

For a digital scale, the uncertainty is taken as:

the smallest scale reading

e.g. voltage = 29.7 mV ± 0.1 mV

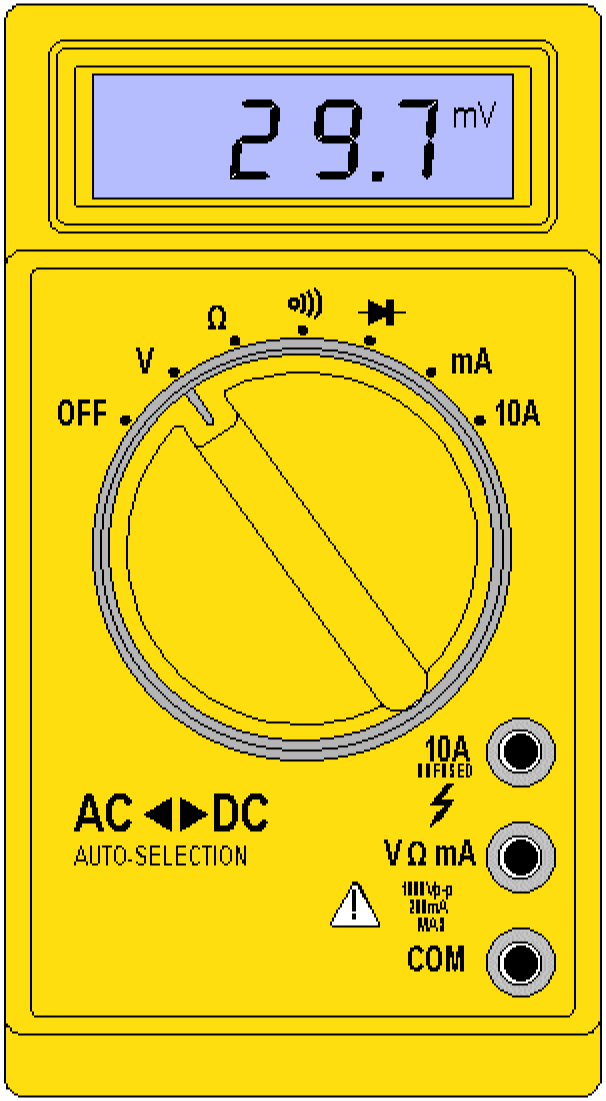
This means the actual reading could be anywhere from



For a digital meter the uncertainty is taken as the smallest scale reading.

e.g. Voltage = 29.7 mV ± 1 mV

(actual reading could be from 29.65 to 29.74)???



Percentage Uncertainty

The percentage uncertainty is calculated as follows:

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

Example 1

Calculate the percentage uncertainty of the measurement:

$$d = 8cm \pm 0.5cm$$

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

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

$$= 0.0625 \times 100$$

$$= 6.25\,\%$$

$$(d = 8cm \pm 6.25\%)$$

Question 1

Calculate the % uncertainty of the following:

a) $I = 5A \pm 0.5A$ 10 %

b) $t = 20s \pm 1s$ 5 %

c) $m = 1000g \pm 1g$ 0.1 %

d) $E = 500J \pm 25J$ 5 %

e) $F = 6N \pm 0.5N$ 8.3 %

Combining Uncertainties

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

Calculation of Speed

$$d = 16\text{ cm} \pm 0.5\text{ cm}$$

$$t = 2\text{ s} \pm 0.5\text{ s}$$

$$v = ?$$

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

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

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

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: $v = 8\ \text{cm s}^{-1} \pm 25\%$

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

$$= 0.25\% \times 8$$

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

Answer

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