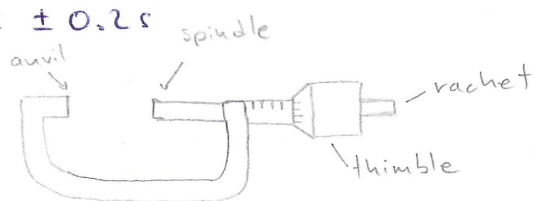


- true value - value obtained in an ideal experiment
 - error - difference between obtained and true value
 - ↳ systematic - same if repeated - check for 0 error (offset)
 - ↳ random - different if repeated - repeat and average out
 - accuracy - agreement between obtained and true value
 - precision - agreement between repeated measurements
 - uncertainty - limits of measuring equipment + procedure
- Δx = absolute uncertainty $\frac{\Delta x}{x}$ - fractional uncertainty
 $\frac{\Delta x}{x} \times 100$ - percentage uncertainty $\Delta x = \frac{1}{2} \text{range} = \frac{1}{2}(x_{\max} - x_{\min})$

- Ruler: $\pm 0.1 \text{cm}$ Protractor: $\pm 2^\circ$ Stopwatch: $\pm 0.2 \text{s}$
- micrometer screw gauge $\pm 0.01 \text{mm}$
 - ↳ add values of rotating + main scale
 - vernier calipers $\pm 0.1 \text{mm}$
 - ↳ add value of main scale + value on vernier scale where it lines up
 - repeat at least 3 times then average out
 - double uncertainty if there was difficulty in experiment
 - calculated results given to same or +1 no of sf as the measured quantity (the least one)
 - calculate %sk and if %sk $< 10\%$ then results agree with hypothesis as they are within expected uncertainty. if difficulty increase 10% or use expected uncertainty
 - error - 2 readings are not sufficient to draw a valid conclusion
 - improvement - repeat experiment to obtain multiple values of t in outside range as possible and observe diff or plot on graph analyze
 - in table include all measurements used for final result



- water
 - ↳ tables get wet - use waterproof markers
 - ↳ difficult to see water surface - use coloured liquid
- ball
 - ↳ difficult to locate centre - measure to centre and mark with marker
 - ↳ inconsistent bounce of the ball - use a large flat surface
- fast moving object
 - ↳ difficult to judge max displacement - use motion sensor to plot graph
- record with camera - play frame by frame
 - ↳ difficult to see when object strikes surface - use pressure sensor
 - ↳ difficult to judge the toppling point - move through newtonmeter and tilt until $F=0$ (incrementally)
- releasing objects from rest
 - ↳ difficult to release without force - use remote controlled clamp or electromagnet
 - ↳ rod falls sideways - keep it vertical by using a guide
- oscillation
 - ↳ time T too short so large uncertainty - use motion sensor or video playback frame by frame, time more oscillations.
 - ↳ friction between pivot and object - make hole bigger or bearing/bushing
 - ↳ non-constant oscillations - turn off fan or use heavier object
 - ↳ difficult to judge end/start point or complete swing - use fiducial marker
 - ↳ retort stand wobbles - use g -clamp or add mass to base
- electricity
 - ↳ resistance or current fluctuating - clean contacts
 - ↳ voltmeter not sensitive enough - use a digital voltmeter
 - ↳ wires not straight - tape to ruler or hang a weight on it + clamp
- Force
 - ↳ max force reached suddenly - force sensor with data logger
- Pulley
 - ↳ masses collide - use a larger pulley
 - ↳ friction at the pulley - lubricate pulley
 - ↳ uncertain starting position - release with electromagnet or clamp remotely controlled
- Movement
 - ↳ ruler hits bench - stack something underneath to elevate apparatus
 - ↳ ruler slips on support - glue support to block / use a hinge (doesn't shift centre of mass)
- Magnetism
 - ↳ effects of surrounding materials - use non-magnetic materials and test setup with different materials

- ⑤
- Bench / Ramp surface
 - ↳ uneven resistance from surface - ensure same part of surface used allways
 - ↳ board slips / supporting blocks topple - clamp to bench / use blue tack
 - ↳ difficult pulling in line with board - use long piece of string but connect newtonmeter to block (or pulley)
 - Heat loss
 - ↳ heat lost through sides / bottom / top - insulate / use polystyrene container
 - ↳ thermometer bulb not immersed completely - use larger vol of liquid - use a thermocouple
 - ↳ resistor gives off heat after switched off - wait untill max temp before reading
 - Terminal velocity
 - ↳ may not have reached terminal velocity - time over 3 constantly separated markers
 - Light dependant
 - ↳ external light affects LDR - do experiment in total darkness
 - ↳ cylinders not alligned - allign on desk using rule
 - ↳ difficult to hold together - tape / use clamps
 - Metre rule
 - ↳ difficult to hold still - mount rule in stand
 - ↳ difficult to measure vertical - clamp in stand use set square or spirit level to ensure vertical
 - Newtonmeter
 - ↳ difficult to pull newtonmeter parallel - use long string or pulleys
 - ↳ difficult to read newtonmeter while applying force - use newtonmeter with hold max feature or plot F
 - Circular objects
 - ↳ difficult to measure diameter - object flexible or uneven
 - use vernier calipers / micrometer skate
 - multiple readings then average out
 - ↳ difficult to create perfectly spherical / circular - use moulds
 - protractor
 - ↳ protractor wobbles - fix in clamp use spirit level to ensure horizontal / vertical
 - ↳ protractor in way / doesn't fit - film on video then superimpose protractor in playback
 - parallax error
 - ↳ in θ or m - use mirror scale