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AS and A LEVEL

Delivery Guide

PHYSICS A

H156/H556
For first teaching in 2015

Foundations of physics

Version 2

AS and A LEVEL
PHYSICS A

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- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

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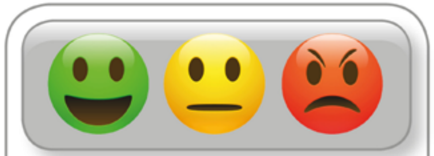

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Module 2: Foundations of physics
The aim of this module is to introduce important conventions and ideas that permeate the fabric of physics. Understanding of physical quantities, SI units, scalars and vectors helps physicists to effectively communicate their ideas within the scientific community (HSW8,11).

2.1 Physical quantities and units
This section provides knowledge and understanding of physical quantities and units.

2.1.1 Physical quantities
Students should be able to demonstrate and apply their knowledge and understanding of:

(a) physical quantities have a numerical value and a unit

(b) making estimates of physical quantities listed in this specification.

2.1.2 SI units
Students should be able to demonstrate and apply their knowledge and understanding of:

(a) Système Internationale (SI) base quantities and their units - mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol)

(b) derived units of SI base units

(c) units listed in this specification

(d) checking the homogeneity of physical equations using SI base units

(e) prefixes and their symbols to indicate decimal submultiples or multiples of units – pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)

(f) the conventions used for labelling graph axes and table columns.

2.2 Making measurements and analysing data
This section provides knowledge and understanding of physical measurements and treatment of errors and uncertainties.

2.2.1 Measurements and uncertainties
Students should be able to demonstrate and apply their knowledge and understanding of:

(a) systematic errors (including zero errors) and random errors in measurements

(b) precision and accuracy

(c) absolute and percentage uncertainties when data are combined by addition, subtraction, multiplication, division and raising to powers

(d) graphical treatment of errors and uncertainties; line of best fit; worst line; absolute and percentage uncertainties; percentage difference.

2.3 Nature of quantities
This section provides knowledge and understanding of scalar and vector quantities. Vector quantities add and subtract very differently to scalar quantities; hence it is important to know whether a quantity is a vector or a scalar.

2.3.1 Scalars and vectors
Students should be able to demonstrate and apply their knowledge and understanding of:

(a) scalar and vector quantities

(b) vector addition and subtraction

(c) vector triangle to determine the resultant of any two coplanar vectors

(d) resolving a vector into two perpendicular components; $F_x = F\cos\theta$; $F_y = F\sin\theta$

Approaches to teaching the content

This module introduces students to the essential language of quantities, units, measurements, data and data analysis, and the terminology that describes the significance of final answers. It forms the basis of all aspects of practical physics.

Students should be given opportunities to gain confidence in the use of technical terms, making careful measurements, handling very large and very small numbers and using graphs to present data and recognize trends. The goal for the experimental aspect of this theme can be seen as making a valid determination of the spring constant of a spring to the degree of precision permissible with the measuring devices used, together with a statement of the uncertainty of the final result. It is important to encourage the discussion of experimental results and sources of uncertainty in all measurements made throughout the course.

Common misconceptions or difficulties students may have

Students commence their A level studies in physics having achieved, with varying degrees of success, basic mathematical skills. Earlier work will have covered the use of prefixes and standard notation. However, many students find conversions or calculations involving prefixes difficult. Two examples that frequently cause confusion are:

- the conversion of an area in mm^2 to an area in m^2
- the calculation of the area of a circle in m^2, when given the diameter of the circle in mm.

A helpful exercise in this respect might be for students to determine the cross-sectional area of a wire (in m^2), from measurements made of the diameter (in mm) along the length of the wire using a micrometer screwgauge. Practice of such calculations will build confidence and develop useful practical skills.

An appreciation that measurements are made to the degree of precision permitted by a given measuring instrument leads to an understanding that all readings should be recorded to the same number of *decimal places*. Historically, a significant number of students have confused the term *decimal places* with the term *significant figures*. Students are expected to understand the meaning of each term and when to use it.

There has also been confusion between the terms *absolute* and *percentage* uncertainties and with the adding together of uncertainties when processing measurements. The absolute uncertainty and percentage uncertainty in measurements made should be practiced regularly in practical work carried out throughout the course.

Activities

Students frequently fail to identify base SI units. Exercises such as the following are useful to employ throughout the course.

Convert the units of the following quantities into base units and then draw a line to link the quantity with its corresponding base units (you may use a base SI unit box more than once).

Pressure in Pa
Force in N
Kinetic Energy in J
Moment in N m
Power in W
Acceleration g in N kg^{-1}
Charge in C

A s
m s^{-2}
kg m^2 s^{-2}
kg m^2 s^{-3}
kg m s^{-2}
kg m^{-1} s^{-2}

When students study the topic of scalars and vectors for the first time, it is common for confusion to develop in the terminology used to describe the direction of a force. Where a sign convention is used, such as the addition of forces with the same line of action but with opposing directions, a positive value may represent a force acting to the right while a negative value may represent a force acting to the left. The addition of these forces necessarily involves the adding together of both positive and negative numbers. Many students will ignore the sign and simply subtract the two forces. While the magnitude of the resultant vector is correct, the sign (and hence the direction) is ignored. This has subsequent consequences when discussing a triangle of forces F_1, F_2 and F_3 in equilibrium and it is common to find that students will conclude that $F_1 + F_2 = F_3$.

Students need to develop confidence in the use of vectors and scalars. Directing them towards support resources such as Khan Academy's short lecture on the 'introduction to vectors and scalars' is an excellent place to start the process.

Activities

The module contains the basic language essential for the further study of topics which will be applied in different contexts throughout the course. The skills of observing, measuring, recording, tabulating, concluding and evaluating are deployed in a very similar fashion to the practical investigations in all topic areas.

Opportunities exist to consider percentage uncertainties in every practical measurement made throughout the course. Identifying and comparing the percentage uncertainty in each type of measurement is the first step to evaluating the weakness in the method.

A few opportunities to develop the skills identified above to the required standard are listed below. These span mostly GCSE physics content, but also include topics that will be studied in more depth later on in the course.

Activities

Learner Activity 1
Measurement of lengths

Measure the length of:

(a) the classroom using a metre rule with 10 cm divisions

(b) the table top using a 30 cm ruler with mm divisions

(c) the long side of an A4 piece of paper using a 30 cm rule

(d) the thickness of an exercise book using vernier calipers.

For each measurement, write down:

(i) the absolute uncertainty

(ii) the percentage uncertainty

(e) Rank the measurements in order of the smallest % uncertainty to the greatest % uncertainty

(f) Rank the measuring devices in order of the degree of precision with which a reading may be made

Learner Activity 2
Determination of the spring constant of a helical spring

Learner Resource 1.

1) Measure the original length of the spring in cm.
2) Hang a 100 g mass hanger on the spring and record the new length of the spring.
3) Calculate the extension x of the spring.
4) Calculate the force F applied to the spring.
5) Put all of your measurements into a table. Include columns for extension and force.
6) Take a further five sets of readings to enable you to measure the extension x for masses in the range 100 g ≤ x ≤ 600 g and include these in your table.
7) Plot a graph of Force/N (y-axis) against extension x/cm (x-axis) and draw a best fit line.
8) Find the gradient of this line and hence a value for k, the spring constant.
9) Add error bars to each plot and draw a worst-*acceptable fit* line (with a maximum gradient).
10) Find the gradient of this line and hence a maximum acceptable value for k.
11) Calculate the uncertainty in the value of k.

https://spark.iop.org/episode-227-hookes-law

Learner Activity 3
Determining the tensile stress in a wire.
Learner Resource 2.

A load may be applied to a clamped wire, putting the wire under tensile stress. If the term *stress* is defined, students can be asked to determine the tensile stress by following the instructions below.

1) Measure the mass attached to the lower end of the wire.
2) Record the mass to an appropriate number of decimal places.
3) Calculate the load in newtons.
4) Calculate the percentage uncertainty in the mass and hence the weight.
5) Measure the diameter of the wire in several places along its length.
6) Calculate the cross-sectional area of the wire in m^2.
7) Calculate the percentage uncertainty in the area.
8) Calculate the tensile stress giving a percentage uncertainty in the value.

Learner Activity 4
Use of the triangle of forces to determine the weight of an object of unknown mass.
Learner Resource 3.

Apparatus: two 0-10 N newtonmeters, unknown mass (about 45 g), pulley wheel, string, two clamp stands, two G-clamps.

1) Tie loops at each end and in the middle of a piece of string which is approximately 75 cm in length. Attach a second piece of string, 50 cm in length, to the loop in the middle of the first string.
2) Attach a newtonmeter to the loop at each end of the 75 cm string. Attach the other end of each newtonmeter to a clamp stand that is firmly secured to the table with a G-clamp.
3) Attach the unknown mass to the end of the 50 cm length of string.
4) Adjust the newtonmeters so that the angle between the lines of action of the unknown weight and newtonmeter 1 is 90°.
5) With the system in equilibrium, measure the angle between the line of action of newtonmeter 2 and the line of action of the unknown weight.
6) Measure the values shown on the two newtonmeters.
7) Draw a scale diagram of the triangle of forces and determine a value for the weight of the mass.

https://spark.iop.org/episode-202-forces-equilibrium

Learner Activity 5

Determination of the density of steel

Six steel ball bearings of different diameter are required for this experiment. The uncertainty of each measurement made should be considered.

1) Determine the diameter of each of the steel ball bearings and put your answers into a table. Note the percentage uncertainty in each measurement.
2) Measure the mass of each ball bearing and record this in the table. Note the percentage uncertainty in each measurement of the mass.
3) Calculate the volume of each ball bearing. Record your answers in the table. Note the percentage uncertainty in the calculation of the volume of each of the ball bearings.
4) Plot a graph of mass (*y*-axis) against volume (*x*-axis).
5) Draw the best fit line and calculate the gradient.
6) By adding error bars to your graph, draw a worst acceptable fit line and determine a maximum value for the density of steel.
7) State the density of steel and the tolerance within which it lies.

Learner Activity 6

Determination of the resistance of an ohmic conductor

Learner Resource 4.

It should be possible to carry out this experiment with little revision. A 15 Ω ceramic resistor may be used as an ohmic conductor if the current used is small.

1) Connect a rheostat, an ammeter and an ohmic conductor in series with a single cell. Connect a voltmeter in parallel with the ohmic conductor.
2) Using the full range of currents available by varying the rheostat, take six readings of p.d. and current.
3) Note the uncertainty in each reading.
4) Put the raw data into a table, making sure that the appropriate number of decimal places is recorded for each type of reading.
5) Plot a graph of p.d./V (*y*-axis) against current/A (*x*-axis).
6) Draw a best fit line and find the gradient.
7) Add error bars to your plots and determine the gradient of the worst acceptable fit line.
8) Give a value for the resistance of the ohmic conductor together with the uncertainty expressed as a percentage.

Learner Activity 7
Determination of the mass (and hence density) of a wooden ruler using the principle of moments

Once again it should be possible to carry out this experiment with little revision.

Learner Resource 5.

1) Determine the width, depth and length of the wooden ruler and calculate its volume.
2) Set up a stand and clamp to hold a large nail horizontally and insert this nail through the hole in the bulldog clip.
3) Attach the ruler to the bulldog clip as shown and adjust the position of the 200g mass labelled M so it is approximately 1cm from one end of the ruler. Move the bulldog clip until the ruler balances horizontally.
4) Record distances ***a*** and ***b*** when the ruler is balanced horizontally.
5) Collect five more sets of data for ***a*** and ***b*** by moving the mass and then the bulldog clip until the ruler is once again balanced. Do this for values of *a* in the range 10 cm $\leq a \leq$ 35cm and record all your readings in a table.
6) Plot a graph of ***b*** (*y*-axis) against ***a*** (*x*-axis) and draw a best fit line.
7) Determine the gradient.
8) Determine the y-intercept. Theory suggests that:

$$\boldsymbol{b} = \frac{mL}{2M} - \frac{m\boldsymbol{a}}{M}$$

where m = mass of the ruler

9) Use *both* your gradient and intercept values to calculate *two* values for the mass of the ruler.
10) Use the mean value of the two values for mass to determined in step 9 to calculate the density of the wooden ruler.

Learner Activity 8
Hooke's law (Institute of Physics)

https://spark.iop.org/episode-227-hookes-law

Suggested lesson plan for 'Hooke's law'.

Learner Activity 9
Forces in equilibrium (Institute of Physics)

https://spark.iop.org/episode-202-forces-equilibrium

Suggested lesson plan for 'forces in equilibrium'.

Learner Activity 10
Resistance (Institute of Physics)

https://spark.iop.org/episode-108-resistance

Suggested lesson plan for 'resistance'.

Learner Activity 11
Scalars and Vectors (Khan Academy)

https://www.khanacademy.org/science/physics/one-dimensional-motion/displacement-velocity-time/v/introduction-to-vectors-and-scalars

Suggested as an alternative teaching sequence for the introduction to vectors and scalars

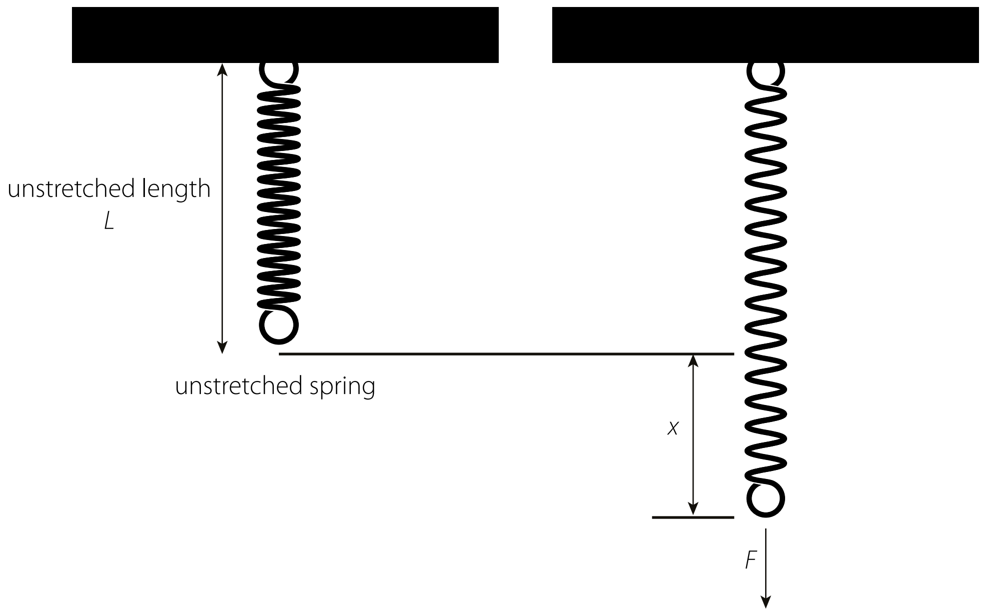
General reference:

Practical Skills Handbook (OCR)
https://pdf.ocr.org.uk/Images/295483-practical-skills-handbook.pdf

The handbook provides guidance on the required standard for measurement, recording, graph plotting, drawing of best fit lines, calculation of gradients, quoting of uncertainties and the significance of the final answer.

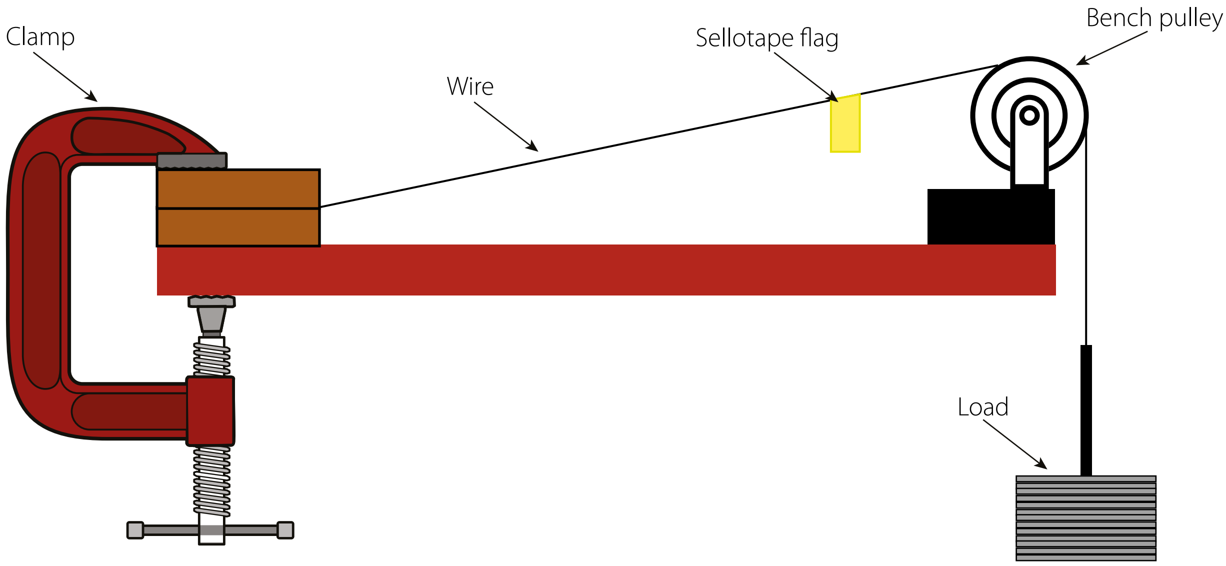
Learner Resource 1

Determination of the spring constant of a helical spring



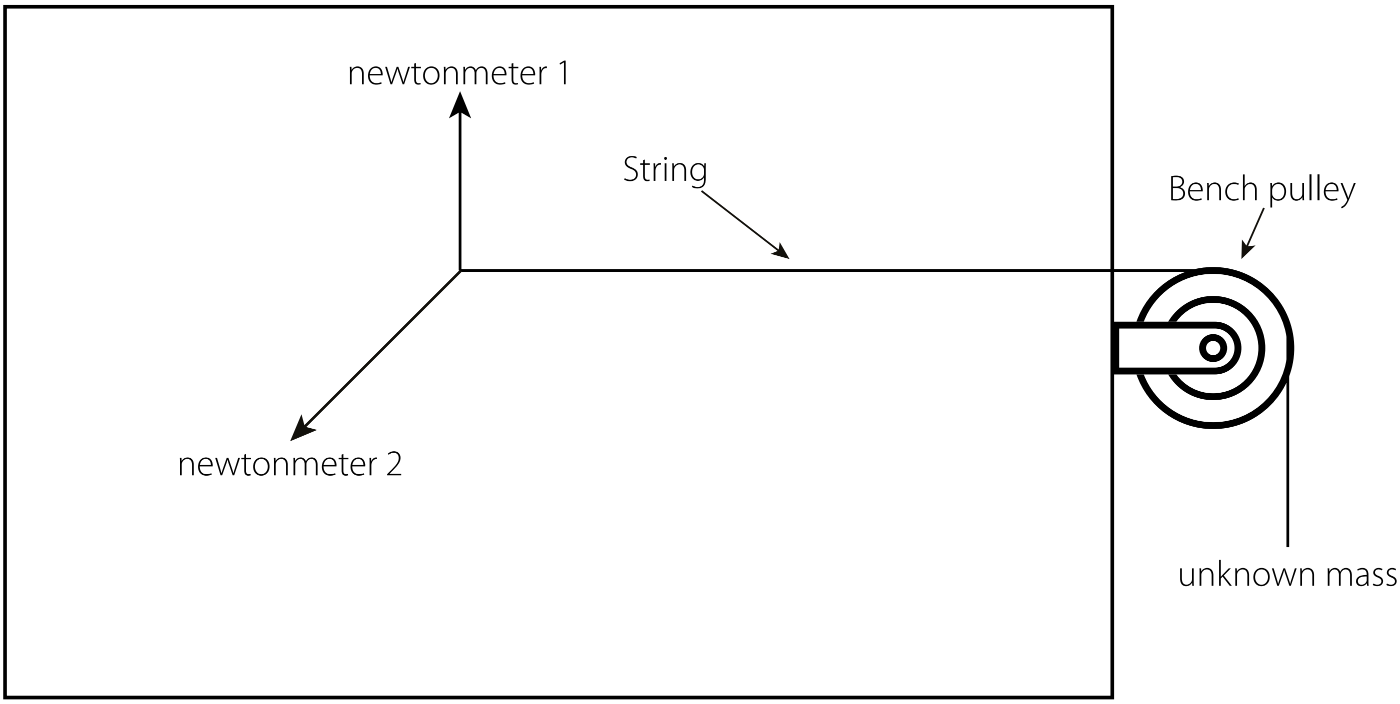
Learner Resource 2

Determining the tensile stress in a wire

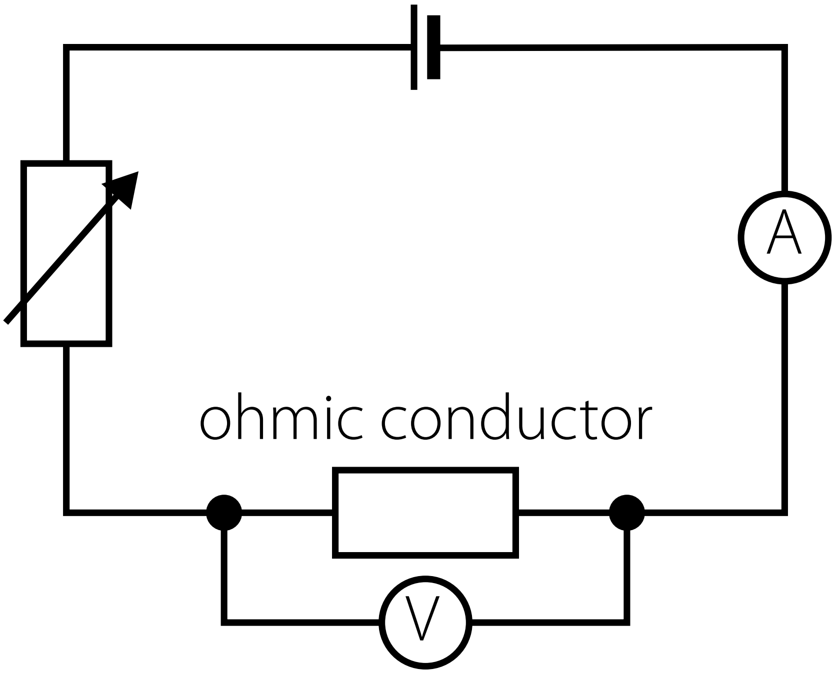


Learner Resource 3

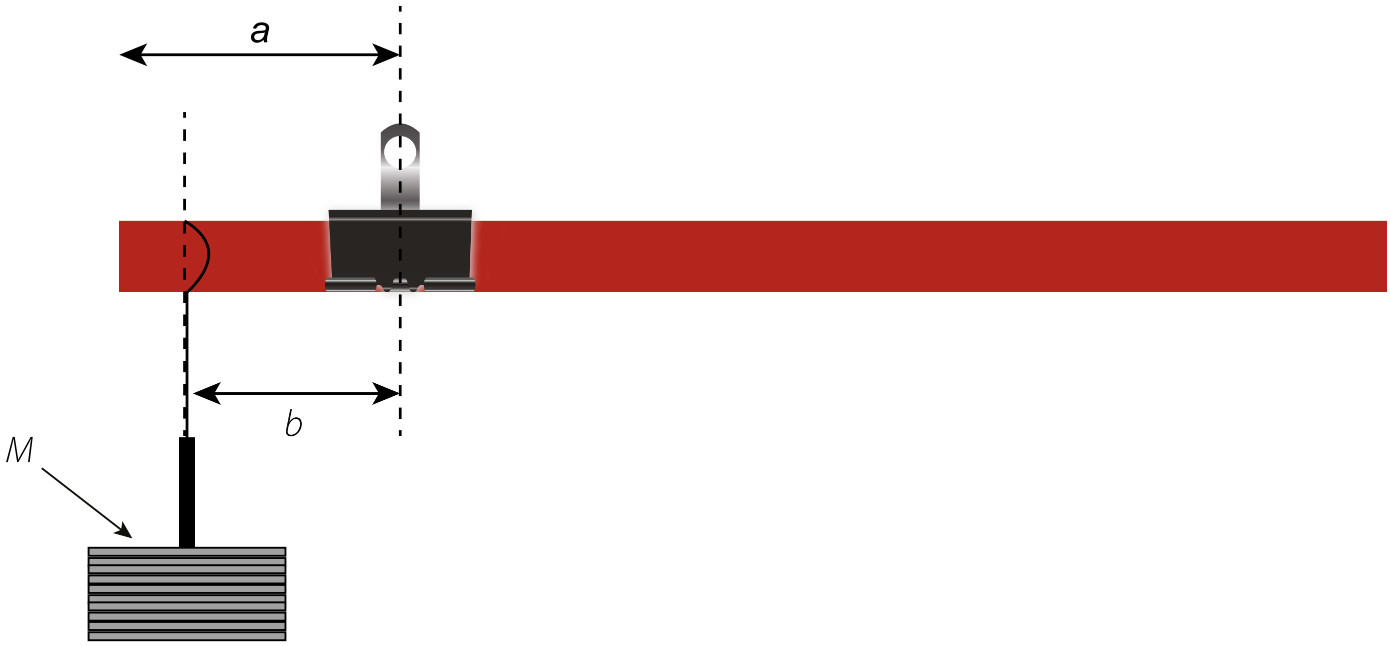
Use of the triangle of forces to determine the weight of an object of unknown mass



Determination of the resistance of an ohmic conductor



Determination of the mass (and hence density) of a wooden ruler using the principle of moments



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