# Teacher Delivery Guide Mechanics: Dimensional Analysis

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| **Specification** | **Ref.** | **Learning outcomes** | **Notes** | **Notation** | **Exclusions** |
| **Y421 MECHANICS MAJOR: DIMENSIONAL ANALYSIS (a)****Y431 MECHANICS MINOR: DIMENSIONAL ANALYSIS (a)****Y411 MECHANICS a: DIMENSIONAL ANALYSIS** |
| Dimensional consistency | Mq1 | Be able to find the dimensions of a quantity in terms of M, L, T. | Know the dimensions of angle and frequency. Work out without further guidance the dimensions of density (mass per unit volume), pressure (force per unit area) and other quantities in this specification.Other kinds of density will be referred to as e.g. mass per unit area.Deduce the dimensions of an unfamiliar quantity from a given relationship. | M, L, T, [ ] |  |
| q2 | Understand that some quantities are dimensionless. |  |  |  |
| q3 | Be able to determine the units of a quantity by reference to its dimensions. | And vice versa. |  |  |
|  | q4 | Be able to change the units in which a quantity is given. | E.g. density from kg m–3 to g cm–3. |  |  |
| q5 | Be able to use dimensional analysis to check the consistency of a relationship. |  |  |  |

***DISCLAIMER***

This resource was designed using the most up to date information from the specification at the time it was published. Specifications are updated over time, which means there may be contradictions between the resource and the specification, therefore please use the information on the latest specification at all times.If you do notice a discrepancy please contact us on the following email address: resources.feedback@ocr.org.uk

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| Formulating and using models by means of dimensional arguments | q6  | Use dimensional analysis to determine unknown indices in a proposed formula. | E.g. for the period of a pendulum. |  |  |
| q7  | Use a model based on dimensional analysis. | E.g. to find the value of a dimensionless constant.E.g. to investigate the effect of a percentage change in some of the variables. |  |  |

# Thinking Conceptually

### General approaches

The first step in delivery the content of this topic is to familiarise learners with how to write the dimensions of common quantities. Emphasise to learners that knowing the S.I units for a quantity means that they can find the dimensions in terms of mass [M], length [L] and time [T]. Quantities like velocity, acceleration and force can be easily written using their dimensions by looking at the formulae that define them or, in simple cases, by looking at their units. For example, Newton’s 2nd Law states that ***F***=*m****a***, and because we know that the units of acceleration are ms–2 which, in terms of dimensions, is LT-2 , then the dimensions of force, [***F***]=MLT–2.

There are number of examples that learners can practise, including formulae for momentum, energy, work, power etc. The famous example of *E=mc*2 can also be analysed in this way! Once learners are comfortable with finding the dimensions of a quantity then harder examples involving finding unknown indices in formulae can be tackled.

### Common difficulties learners may have

Learners must be aware that some quantities are dimensionless. For example, the coefficient of friction, *μ*, is defined as *μ=F/R* where *F* and *R* are both forces. Therefore [*μ*]=(MLT–2)/(MLT–2 ) =1 and therefore *μ* is dimensionless. Learners must be confident in applying the laws of indices as applying these laws incorrectly can lead to mistakes. For example, let’s see how the temporal period *t* for a vibrating string depends on its tension *T*, length *l* and linear density *ρ*. If the formula is of the form *t=kTa lb ρc*, where *k* is a dimensionless constant, then the learners task is to find out what *a*,*b* and *c* are. Using the fact that [*T*]=MLT–2 and [*ρ*]=ML–1 then dimensions of [*t*]=1.M*a* L*a* T–2*a* L*b* M*c* L–*c*, which can be written as M*a*+*c* L*a*+*b*–*c* T-2*a* once simplified. Now the dimensions of time are T and hence we have an equation to solve T= Ma+c La+b–c T–2a. By equating the exponents of M, L and T we find that *a*= – ½ , *b*=1 and *c*= ½ .

Learners should understand that dimensional analysis can only be used to derive formulas which are a product of powers of other quantities.

### Common misconceptions learners may have

A very easy mistake to make is confusing the ‘M’ dimension as a length because metres is a unit of length! Make sure learners are aware of this very common error.

### Conceptual links to other areas of the specification

A good understanding of dimensional analysis will help learners whenever they encounter a formula with physical quantities. For example, if a learner is unsure of the formula for a certain quantity but have a rough idea, then they can use dimensional analysis to check whether their formula is correct. For example, a learner may know that the formula for kinetic energy *K*=*mv*something. Using dimensional analysis leaners can easily verify that the ‘something’ is 2 if they know the dimensions of energy (ML2 T–2).

Checking using dimensional analysis can be used for formulas which consist of several terms; each term should have the same dimensions.

# Thinking Contextually

As mentioned above, whenever a formula is encountered in the course, it is good practice to perform dimensional analysis to check the validity of the equation. This can be done throughout the delivery of the entire Mechanics syllabus.

# Resources

| **Title** | **Organisation** | **Description** | **Ref** |
| --- | --- | --- | --- |
| [The power of Dimensional Analysis](https://nrich.maths.org/6636) | Nrich | This is an NRICH article that explains the basic concepts of dimensional analysis This could be used as a `flipped lesson’ resource. Ask learners to read this as a pre-lesson homework task for the first lesson on the topic so they are prepared for the new material. A short quiz could at the beginning of the class to ensure learners | q1, q2, q3, q4, q5, q6 and q7 |
| [New Units for Old](https://nrich.maths.org/6153) | Nrich | An excellent revision activity where learners have to match units together from their current standard name to their `old’ standard name | q3 |
| [Dimensionless quantity](https://ipfs.io/ipfs/QmXoypizjW3WknFiJnKLwHCnL72vedxjQkDDP1mXWo6uco/wiki/Dimensionless_quantity.html) | Wikipedia | Background reading on dimensionless quantities in maths and science. | q2 |
| [Dimensions, Quantities and Units](http://www.springer.com/cda/content/document/cda_downloaddocument/9781441976611-c1.pdf?SGWID=0-0-45-1074240-p174073261) | Springer | Review notes on units and dimensions. Interesting to highlight to students that this article is produced for food process engineers, dimensional analysis is not only of interest to mechanical engineers and physicists.  | q1,q2 and q3 |
| [Dimensional analysis](https://www.physics.uoguelph.ca/tutorials/dimanaly/) | University of Guelph | Notes with test questions on using dimensional analysis to check formulae. | q5 |
| [Dam Busters 2](https://nrich.maths.org/5838) | Nrich | This activity is an extension task on dimensional analysis and projectiles on the context of bouncing bombs | q5 and q6 |

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