# Dimensional Analysis - Algebra With Units 48.3

Year 9 P P P

A Level C C C

## Step Up to GCSE Physics

Given the units of specific heat capacity $[c] = \mathrm{J/kg^\circ C}$, and density $[\rho] = \mathrm{kg/m^3}$, what quantity could $c\rho AL$ represent if $L$ is a length and $A$ an area?

- Specific heat capacity ($\mathrm{J/kg^\circ C}$ or $\mathrm{m^2/s^2{}^\circ C}$)
- Temperature change ($^\circ\mathrm{C}$)
- Heat capacity ($\mathrm{J/^\circ C}$ or $\mathrm{kg\ m^2/s^2{}^\circ C}$)
- Energy ($\mathrm{J}$ or $\mathrm{kg\ m^2/s^2}$)

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# Dimensional Analysis - Algebra With Units 48.4

Year 9 P P P  A Level C C C

**Step Up to GCSE Physics**

Complete the table below, giving each named unit in terms of kilograms ($\mathrm{kg}$), metres ($\mathrm{m}$), seconds ($\mathrm{s}$) and amps ($\mathrm{A}$). Use the equations given as hints, and use previous answers as stepping-stones. The page reference for each formula is given in brackets next to it.

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Energy $E$ | joule ($\mathrm{J}$) | $\Delta E = F\Delta s$ | (a) |
| Power $P$ | watt ($\mathrm{W}$) | $\Delta E = P\Delta t$ | (b) |
| Pressure $P$ | pascal ($\mathrm{Pa}$) | $F = PA$ | (c) |
| Charge $Q$ | coulomb ($\mathrm{C}$) | $\Delta Q = I\Delta t$ | (d) |
| Voltage $V$ | volt ($\mathrm{V}$) | $E = VQ$ | (e) |
| Resistance $R$ | ohm ($\Omega$) | $V = IR$ | (f) |

## Part A Energy $E$

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Energy $E$ | joule (J) | $\Delta E = F\Delta s$ | (a) |

- $\mathrm{kg\ m^2/s}$
- $\mathrm{kg\ m^2/s^2}$
- $\mathrm{kg\ m/s}$
- $\mathrm{kg\ m/s^2}$

## Part B Power $P$

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Power $P$ | watt (W) | $\Delta E = P\Delta t$ | (b) |

- $\mathrm{kg\ m^2/s^3}$
- $\mathrm{kg\ m^2/s^2}$
- $\mathrm{kg\ m/s^2}$
- $\mathrm{kg\ m^2/s^4}$

## Part C Pressure $P$

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Pressure $P$ | pascal ($\mathrm{Pa}$) | $F = PA$ | (c) |

- $\mathrm{kg/m^2\,s^2}$
- $\mathrm{kg\,m/s^2}$
- $\mathrm{kg/s^2}$
- $\mathrm{kg/m\,s^2}$

## Part D Charge $Q$

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Charge $Q$ | coulomb ($\mathrm{C}$) | $\Delta Q = I\Delta t$ | (d) |

- $\mathrm{A}$
- $\mathrm{A\,s^2}$
- $\mathrm{A\,s}$
- $\mathrm{A/s}$

## Part E Voltage $V$

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Voltage $V$ | volt ($\mathrm{V}$) | $E = VQ$ | (e) |

- $\mathrm{kg\,m^2/A\,s^2}$
- $\mathrm{kg\,m^2/A\,s^3}$
- $\mathrm{kg\,m/A\,s^3}$
- $\mathrm{kg\,m/A\,s}$

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## Part F Resistance $R$

| Quantity | Unit | Useful formula | Unit in $\mathrm{kg}$, $\mathrm{m}$, $\mathrm{s}$, $\mathrm{A}$ |
|---|---|---|---|
| Resistance $R$ | ohm ($\Omega$) | $V = IR$ | (f) |

- $\mathrm{kg\,m^2/A^2\,s^3}$
- $\mathrm{kg\,m^2/A^2\,s}$
- $\mathrm{kg\,m^2/A\,s^3}$
- $\mathrm{kg\,m/A\,s^2}$

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# Dimensional Analysis - Algebra With Units 48.7

Year 9 P P P

A Level C C C

## Step Up to GCSE Physics

Aerodynamicists often calculate $\frac{1}{2}\rho v^2$ where $\rho$ is the density of air and $v$ is the speed of an aircraft. Which of the quantities given in question 4 could it give?

- Voltage
- Resistance
- Energy
- Power
- Pressure
- Charge

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# Derived and Base SI Units 7

GCSE C C C

A Level C C C

## Essential Pre-Uni Physics A2.7

Express the following derived unit in terms of the SI base units.

As an example, the first row ($\mathrm{m\,s^{-2}}$) has been done for you:

| Derived Unit | in Base Units | Power of each base unit | | | |
|---|---|---|---|---|---|
| | | $\mathrm{m}$ | $\mathrm{s}$ | $\mathrm{kg}$ | $\mathrm{A}$ |
| $\mathrm{m\,s^{-2}}$ | $\mathrm{m\,s^{-2}}$ | $1$ | $-2$ | $0$ | $0$ |
| $\mathrm{N\,C^{-1}}$ | | | | | |

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# Derived and Base SI Units 9

GCSE C C C

A Level C C C

## Essential Pre-Uni Physics A2.9

Express the following derived units in terms of the unit specified and base units. The first one has been done for you.

### Part A The ohm

Express the ohm in terms of the volt and base units.

### Part B The joule

Express the joule in terms of the newton and base unit(s).

$$\mathrm{J} = \mathrm{N}\ \square$$

Items:

$\mathrm{m}$ $\mathrm{m}^{-1}$ $\mathrm{s}^{-2}$ $\mathrm{s}^{-1}$ $\mathrm{A}^{-1}$ $\mathrm{m}^{-4}$ $\mathrm{s}^{2}$ $\mathrm{m}^{3}$ $\mathrm{m}^{2}$

## Part C The pascal

Express the pascal in terms of the joule and base unit(s).

$$\mathrm{Pa} = \mathrm{J}\ \square$$

Items:

$\mathrm{m}^{-3}$ $\mathrm{m}$ $\mathrm{s}^{-1}$ $\mathrm{s}^{-2}$ $\mathrm{s}^{2}$ $\mathrm{m}^{3}$ $\mathrm{m}^{-1}$ $\mathrm{A}^{-1}$ $\mathrm{m}^{2}$

## Part D Pressure

The answer to Part C means that pressure in effect measures an amount of energy per unit $\square$.

Items:

**length** **mass** **area** **volume**

## Part E Volts per metre

Express the $\mathrm{V\,m^{-1}}$ in terms of the joule and base unit(s).

$$\mathrm{V\,m^{-1}} = \mathrm{J}\ \square\ \square\ \square$$

Items:

$\mathrm{m}$ $\mathrm{s}^{-1}$ $\mathrm{s}^{-2}$ $\mathrm{m}^{3}$ $\mathrm{m}^{-1}$ $\mathrm{s}^{2}$ $\mathrm{m}^{-4}$ $\mathrm{m}^{2}$ $\mathrm{A}^{-1}$

## Part F Density

Express the unit of density in newtons and base unit(s).

$$\text{unit of density} = \mathrm{N}\ \square\ \square$$

Items:

$\mathrm{s}^2$ $\mathrm{m}^3$ $\mathrm{m}$ $\mathrm{A}^{-1}$ $\mathrm{m}^{-1}$ $\mathrm{m}^2$ $\mathrm{m}^{-4}$ $\mathrm{s}^{-2}$ $\mathrm{s}^{-1}$

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# Waving Along

A Level

Ripples on the surface of deep water have a speed of propagation $v$ given by $v = \sqrt{\frac{2\pi\gamma}{\lambda\rho}}$.

where $\gamma$ = the coefficient of surface tension, $\lambda$ = the wavelength of the ripples and $\rho$ = the density of water.

## Part A Wave speed

If the speed of the waves of wavelength $10\,\mathrm{mm}$ is $0.22\,\mathrm{m\,s^{-1}}$, calculate the speed of waves of wavelength $2.5\,\mathrm{mm}$.

## Part B Wave frequency

What is the frequency of these $2.5\,\mathrm{mm}$ waves?

## Part C Units

What are the units of $\gamma$?

- $\mathrm{W}$
- $\mathrm{W\,m^{-2}}$
- $\mathrm{kg}$
- $\mathrm{J\,m^{-2}}$
- $\mathrm{N\,m^{2}}$

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Adapted with permission from UCLES, A Level Physics, June 1981, Paper 1, Question 8

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# Aerodynamic Lift Introduction

A Level

*This question introduces equations and quantities that are not typically covered in Physics A Level, but they are explained so that the question can be attempted by A Level students.*

The lift force from a wing (or other aerofoil) is given by the formula

$$L = \tfrac{1}{2} C_\mathrm{L} \rho S v^n$$

where

- $C_\mathrm{L}$ is the co-efficient of lift
- $\rho$ is the density of air
- $S$ is the area of the wing
- $v$ is the speed of the wing through the air, and
- $n$ is an integer.

The co-efficient of lift $C_\mathrm{L}$ depends on the design of the wing itself, and also on the angle made by the wing to the oncoming air. In this question, you may always assume that the lift force points vertically upwards.

*This is a shortened form of a question which explores lift in more detail. Here is a link to the full question.*

## Part A The power $n$

The force $L$ is measured in newtons where $1\,\mathrm{N} = 1\,\mathrm{kg\,m\,s^{-2}}$. Given that the co-efficient of lift has no units (it is a pure number), that the density will be measured in $\mathrm{kg\,m^{-3}}$, the area in $\mathrm{m^2}$ and the speed in $\mathrm{m\,s^{-1}}$, work out the missing power $n$ in order for the units in $L = \tfrac{1}{2} C_\mathrm{L} \rho S v^n$ to agree.

## Part B Co-efficient of lift at cruise speed

A loaded aircraft with a mass of $758\,\mathrm{kg}$ and a wing area of $13.9\,\mathrm{m}^2$ is flying in air of density $1.21\,\mathrm{kg\,m^{-3}}$. If the aircraft is flying horizontally at a steady speed of $45.0\,\mathrm{m\,s^{-1}}$, calculate the co-efficient of lift to three significant figures. Take $g = 9.81\,\mathrm{N\,kg^{-1}}$.

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# Alternate Dimensions

A Level

On a distant planet, some aliens have developed their own version of physics. It is mostly similar to ours, with one difference being in dimensional analysis. Whereas we use Length, Time, Mass and Current as base units, they have chosen four different quantities:

| Quantity | Dimension symbol |
|---|---|
| Speed | $[\mathrm{V}]$ |
| Acceleration | $[\mathrm{A}]$ |
| Force | $[\mathrm{F}]$ |
| Charge | $[\mathrm{Q}]$ |

Use relevant equations from your physics course to express some other quantities in terms of the aliens' base units. Drag the numbers to raise the base units to appropriate powers, and use a power of $0$ for any base unit that the quantity does not depend on.

## Part A Time

$$\text{Time} = [\mathrm{V}]^{\square}[\mathrm{A}]^{\square}[\mathrm{F}]^{\square}[\mathrm{Q}]^{\square}$$

Items:

$-5$ $-4$ $-3$ $-2$ $-1$ $0$ $1$ $2$ $3$ $4$ $5$

## Part B Length

$$\text{Length} = [\text{V}]^{\square}[\text{A}]^{\square}[\text{F}]^{\square}[\text{Q}]^{\square}$$

Items:

$-5$ $-4$ $-3$ $-2$ $-1$ $0$ $1$ $2$ $3$ $4$ $5$

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## Part C Pressure

$$\text{Pressure} = [\text{V}]^{\square}[\text{A}]^{\square}[\text{F}]^{\square}[\text{Q}]^{\square}$$

Items:

$-5$ $-4$ $-3$ $-2$ $-1$ $0$ $1$ $2$ $3$ $4$ $5$

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## Part D Voltage

$$\text{Voltage} = [\text{V}]^{\square}[\text{A}]^{\square}[\text{F}]^{\square}[\text{Q}]^{\square}$$

Items:

$-5$ $-4$ $-3$ $-2$ $-1$ $0$ $1$ $2$ $3$ $4$ $5$

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## Part E Resistivity

$$\text{Resistivity} = [\text{V}]^{\square}[\text{A}]^{\square}[\text{F}]^{\square}[\text{Q}]^{\square}$$

Items:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $-5$ | $-4$ | $-3$ | $-2$ | $-1$ | $0$ | $1$ | $2$ | $3$ | $4$ | $5$ |

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