

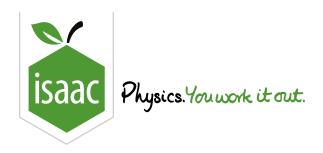
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# Dimensional Analysis - Algebra With Units 48.3



Step Up to GCSE Physics

e units of specific heat capacity $[c]={ m J/kg^\circ C}$ , and density $[ ho]={ m kg/m^3}$ , what quantity could $c ho AL$ nt if $L$ is a length and $A$ an area?
Specific heat capacity ( $ m J/kg^{\circ}C$ or $ m m^2/s^2^{\circ}C$ )
Temperature change (°C)
Heat capacity ( $ m J/{^{\circ}C}$ or $ m kg~m^2/s^2{^{\circ}C}$ )
Energy ( $ m J~or~kg~m^2/s^2$ )



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# Dimensional Analysis - Algebra With Units 48.4



Step Up to GCSE Physics

Complete the table below, giving each named unit in terms of kilograms (kg), metres (m), seconds (s) and amps (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 kg, m, s, A
Energy $E$	joule (J)	$\Delta E = F \Delta s$	(a)
Power $P$	watt (W)	$\Delta E = P \Delta t$	(b)
Pressure $P$	pascal (Pa)	F=PA	(c)
Charge $Q$	coulomb (C)	$\Delta Q = I \Delta t$	(d)
Voltage $V$	volt (V)	E=VQ	(e)
Resistance $R$	ohm $(\Omega)$	V=IR	(f)

## $\mathbf{Part}\,\mathbf{A} \quad \mathbf{Energy}\,E$

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

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

$$\bigcirc \quad kg \; m^2/s^2$$

$$ho$$
 kg m/s<sup>2</sup>

## $\mathbf{Part}\,\mathbf{B} \quad \mathbf{Power}\,P$

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

- $\bigcirc \quad kg \; m^2/s^3$
- $\bigcirc \quad kg \; m^2/s^2$
- $\bigcirc \quad kg \; m^2/s^4$

## ${\bf Part \ C} \qquad {\bf Pressure} \ P$

Quantity	Unit	Useful formula	Unit in kg, m, s, A
Pressure $P$	pascal (Pa)	F=PA	(c)

1 / 2	•
$kg/m^2$	$\mathbf{S}^2$

$$\bigcirc \quad kg\,m/s^2$$

$$ightharpoonup \, \mathrm{kg/s^2}$$

$$\bigcirc \quad kg/m\,s^2$$

## ${\bf Part\ D} \qquad {\bf Charge}\ Q$

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

( A

 $\bigcirc \quad A\,s^2$ 

As

 $\bigcirc$  A/s

### $\mathbf{Part} \; \mathbf{E} \quad \; \mathbf{Voltage} \; V$

Quantity	Unit	Useful formula	Unit in kg, m, s, A
Voltage $V$	volt (V)	E=VQ	(e)

${ m kg}{ m m}^2/A$	$\mathbf{s}^2$
Kg III / I	rs

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

$$m kg\,m/A\,s^3$$

$$\log m/As$$

### ${\bf Part} \ {\bf F} \qquad {\bf Resistance} \ R$

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

	$kg m^2/A^2$	$s^3$
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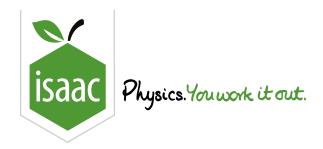
$$\bigcirc \quad kg\,m^2/A^2\,s$$

$$\bigcirc \quad kg\,m^2/A\,s^3$$

$$\bigcirc \quad kg\,m/A\,s^2$$

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**STEM SMART Physics 21 - Dimensional Analysis** 



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# Dimensional Analysis - Algebra With Units 48.7

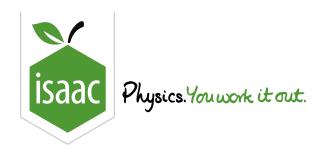


Step Up to GCSE Physics

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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<u>Home</u> <u>Gameboard</u>

Physics

Skills Units Essential Pre-Uni Physics A2.7

# Essential Pre-Uni Physics A2.7



Express the following derived unit in terms of the SI base units. As an example, the first row  $(m\,s^{-2})$  has been done for you:

Derived Unit	in Base Units	Power of each base unit			
		m	S	kg	A
${ m ms^{-2}}$	$ m ms^{-2}$	1	-2	0	0
$ m NC^{-1}$		(a)	(b)	(c)	(d)

#### Power of $\mathbf{m}$ Part A

What is the power of m?

#### Power of $\mathbf s$ Part B

What is the power of s?

#### Part C Power of $\ensuremath{\mathrm{kg}}$

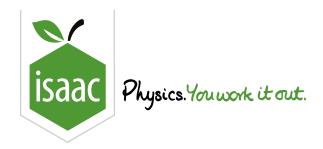
What is the power of kg?

### Part D Power of A

What is the power of A?

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Physics

Skills Units

Essential Pre-Uni Physics A2.9

# 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
a) Express the ohm in terms of the volt and base units.
Part B The joule
b) Express the joule in terms of the newton and base unit(s).
$igcup_{mN^{-1}}$
○ N m

## Part C The pascal

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

 $\int J m^3$ 

 $\int \mathrm{J}\,\mathrm{m}^{-3}$ 

 $\int \mathrm{J}\,\mathrm{m}^{-2}$ 

### Part D Pressure

d) The answer to part (c) means that pressure in effect measures an amount of energy per unit ...?

Volume

Length

Area

Mass

## Part E $Vm^{-1}$

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

 $\int \, {
m J} \, {
m m}^{-1} \, {
m s}^{-1} \, {
m A}$ 

 $\bigcirc \quad J \, m^{-1} \, s^{-1} \, A^{-1} \\$ 

### Part F The unit of density

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

 $\bigcirc \quad N\,m^{-3}\,s^2$ 

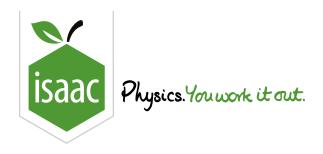
 $ightharpoonup N\,\mathrm{m}^{-4}\,\mathrm{s}$ 

 $ightarrow N^{-1} \, m^{-4} \, s^2$ 

 $\bigcirc \quad N\,m^{-4}\,s^2$ 

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## <u>STEM SMART Physics 21 - Dimensional Analysis</u>



Home Gameboard Maths Algebra Manipulation Introducing Dimensional Analysis

## Introducing Dimensional Analysis

Pre-Uni Maths for Sciences 2.1.9



The dimensions of physical properties do not depend on specific units; here we use length L, time T and mass M as our fundamental dimensions. In any equation relating physical properties the dimensions must be the same on both sides.

For example force = mass  $\times$  acceleration.

Obviously mass has dimensions M. To deduce the dimensions of acceleration recall that acceleration = change in velocity over time; velocity (= change in displacement over time) has dimensions of  $LT^{-1}$  so acceleration has dimensions  $(LT^{-1})(T^{-1}) = LT^{-2}$ .

Thus force has dimensions  $MLT^{-2}$ .

#### Part A Dimensions of kinetic energy

The kinetic energy of a body of mass m moving with speed v is equal to  $\frac{1}{2}mv^2$ .

Find the dimensions of (kinetic) energy. Recall that the factor of  $\frac{1}{2}$  in the expression is dimensionless.

The following symbols may be useful:  $\mbox{\tiny L}$  ,  $\mbox{\tiny M}$  ,  $\mbox{\tiny T}$ 

#### Part B Planck unit

One type of "Planck unit" is defined as:

$$h^{rac{1}{2}}G^{rac{1}{2}}c^{-rac{5}{2}}$$

where h is Planck's constant (dimensions  $ML^2T^{-1}$ ), G is the universal constant of gravitation (dimensions  $M^{-1}L^3T^{-2}$ ) and c is the speed of light (dimensions  $LT^{-1}$ ).

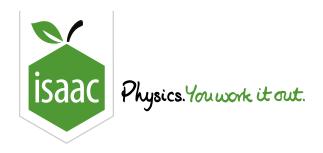
Find the dimensions of this "Planck unit".

The following symbols may be useful: L, M, T

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**STEM SMART Physics 21 - Dimensional Analysis** 



Home Gameboard Physics Waves & Particles Wave Motion Waving Along

# **Waving Along**



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

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

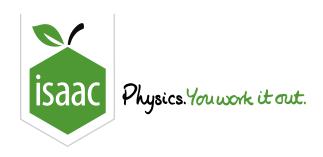
What is the frequency of these  $2.5\,\mathrm{mm}$  waves?

Part C Units			
What are the unit	ts of $\gamma$ ?		
$\bigcirc$ w			
$\bigcirc  W \ m^{-2}$			
○ kg			
$\int  \mathrm{J}  \mathrm{m}^{-2}$			
$\bigcirc$ N m <sup>2</sup>			

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

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Home Gameboard Physics Waves & Particles Wave Motion Rayleigh Scattering

## Rayleigh Scattering



#### Part A Intensity decay

Intensity decays as you move further away from the source, due to the diverging of rays. Indeed, if I is the intensity and r is the distance from the source, then  $I \propto r^n$  for what value of n (to 1 significant figure)?

#### Part B Exponent of wavelength

Rayleigh scattering is an effect that causes many optical phenomena around us. It is caused by the scattering of light by small particles, such as the molecules that make up air in the atmosphere.

If a beam of intensity  $I_0$  and wavelength  $\lambda$  interacts with one of these particles then the intensity of the light scattered at an angle  $\theta$  is proportional to  $I_0\lambda^m r^n\alpha^6[1+\cos^2\theta]$ , where r is the distance from the scattering particle and  $\alpha$  is the diameter of the scattering particle. The relationship of the intensity of the scattered light (for a given wavelength) with distance from the scattering particle is the same as for a point source.

By considering the dimensions of the quantities involved, what is m to 1 significant figure?

What colour would you expect to see most of in the sky, if the colour is caused by the scattering of light from
the sun, which you assumed was to be of uniform intensity for all wavelengths?
red
blue
green
yellow
violet
orange
indigo

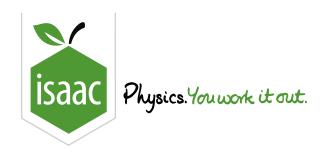
Adapted with permission from UCLES, Scholarship Paper, June 1954, Paper 3, Question 5

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Colour of sky

Part C



Home Gameboard Physics Mechanics Dynamics Aerodynamic Lift Introduction

## **Aerodynamic Lift Introduction**





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

$$L=rac{1}{2}C_{\mathsf{L}}
ho Sv^n$$

#### where

- ullet  $C_{\mathsf{L}}$  is the co-efficient of lift
- $m{\cdot}$  ho 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  $C_L$  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 <u>full question</u>.

#### Part A The power n

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

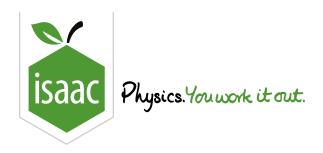
### Part B Co-efficient of lift at cruise speed

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  $1.21\,\mathrm{kg}\,\mathrm{m}^{-3}$ . If the aircraft is flying horizontally at a steady speed of  $45.0\,\mathrm{m}\,\mathrm{s}^{-1}$ , calculate the co-efficient of lift to three significant figures. Take  $g=9.81\,\mathrm{N}\,\mathrm{kg}^{-1}$ .

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<u>Home</u> <u>Gameboard</u> Physics Skills Units Alternate Dimensions

## **Alternate Dimensions**



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	[V]
Acceleration	[A]
Force	$[\mathbf{F}]$
Charge	[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

$$Time = [V]$$
  $[A]$   $[F]$   $[Q]$ 

Items:



### Part B Length

#### Items:



#### Part C Pressure

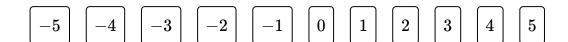
#### Items:



### Part D Voltage

$$ext{Voltage} = [ ext{V}] extstyle [A] extstyle [F] extstyle [Q] extstyle [A] ext{Voltage}$$

#### Items:



### Part E Resistivity

Items:

 $\begin{bmatrix} -5 \end{bmatrix} \begin{bmatrix} -4 \end{bmatrix} \begin{bmatrix} -3 \end{bmatrix} \begin{bmatrix} -2 \end{bmatrix} \begin{bmatrix} -1 \end{bmatrix} \begin{bmatrix} 0 \end{bmatrix} \begin{bmatrix} 1 \end{bmatrix} \begin{bmatrix} 2 \end{bmatrix} \begin{bmatrix} 3 \end{bmatrix} \begin{bmatrix} 4 \end{bmatrix} \begin{bmatrix} 5 \end{bmatrix}$ 

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