# Equation Skills for GCSE Physics

**Study Guide for the Edexcel (9-1) GCSE Physics Course**

**(Paper 1)**

Part 1: Theory

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# Introduction

This booklet is the first half of a two-part revision course that covers;

- What you need to know
- Practice questions

The first part is divided into three chapters that match the three steps you should follow every time you answer a calculation question in a GCSE Physics examination.

These three steps are;

1. Recall
2. Rearrange
3. Solve

Only once you have read about and fully understand the three steps that are explained in this booklet should you start the second booklet. There is no point attempting the practice questions if you do not firmly grasp the steps you must follow to reach the correct answers!

Remember that 30 % of the marks in your GCSE Physics examination will be awarded for calculation skills so the ability to succeed in this area is absolutely essential if you want to achieve a good grade (or even to pass).

Now let’s get on with the work!

## Step 1: Recall

There are ten equations that you are expected to memorise for Paper 1 in the Edexcel GCSE (9-1) Physics course. There is also one more equation that you are expected to be able to select and use from the list of equations listed on the back page of the examination paper. (Higher Tier candidates must remember another equation and select two more equations.)

The equations for each topic in Paper 1 are listed below in symbol form – and are explained in more detail overleaf.

S indicates an equation that you do not need to memorise (you only have to recognise it to select it at the right time).

HT indicates an equation that applies only to the Higher Tier.

| **Topic** | **Equations** | **HT** | **S** |
|---|---|---|---|
| SP1 (Motion) | $s = d / t$<br>$a = (v - u) / t$<br>$v^2 - u^2 = 2 \times a \times x$ | | <br><br>✓ |
| SP2 (Motion and Forces) | $F = m \times a$<br>$w = m \times g$<br>$E = F \times d$<br>$KE = ½ \times m \times v^2$<br>$p = m \times v$<br>$F = (mv - mu) / t$ | <br><br><br><br>✓<br>✓ | <br><br><br><br><br>✓ |
| SP3 (Conservation of Energy) | $\Delta GPE = m \times g \times \Delta h$<br>$\text{Efficiency} = \dfrac{\text{useful energy}}{\text{total energy}}$ | | |
| SP4 (Waves) | $v = f \times \lambda$<br>$v = d / t$ | | |
| SP5 (Electromagnetic Spectrum) | none | | |
| SP6 (Radioactivity) | none | | |
| SP7 (Astronomy) | none | | |

**Table 1: Equations required for Paper 1.**

## What the symbols mean

To understand the equations you must first understand the symbols they use. These symbols, together with the standard SI unit for each quantity, are listed alphabetically below.

| Symbol | Meaning | SI unit | Unit symbol |
|---|---|---|---|
| a | acceleration | metres-per-second-squared | $m/s^2$ |
| d | distance | metre | m |
| E | energy (work done) | joule | J |
| F | force | newton | N |
| f | frequency | hertz | Hz |
| g | gravitational field strength | newtons-per-kilogram | N/kg |
| KE | kinetic energy | joule | J |
| m | mass | kilogram | kg |
| p | momentum | newton-metres-per-second | Nm/s |
| s | speed (average) | metres-per-second | m/s |
| t | time | second | s |
| u | velocity (initial) | metres-per-second | m/s |
| v | velocity * | metres-per-second | m/s |
| w | weight | newton | N |
| Δ | "change in" | | |
| GPE | gravitational potential energy | joule | J |
| h | height | metre | m |
| λ | wavelength | metre | m |

**Table 2: The meaning of symbols used in the equations required for Paper 1.**
***Note: v is the general term for velocity, including final velocity and wave velocity.**

You must learn and test yourself so that you are confident in recognising all these symbols and their SI units.

**Table 3a: Motion equations**

| Symbol Equation | Word Equation |
|---|---|
| s = d / t | average speed = distance / time |
| a = (v – u) / t | acceleration = change in velocity / time |
| F = m x a | force = mass x acceleration |
| w = m x g | weight = mass x gravitational field strength |
| $v^2 - u^2 = 2 \times a \times x$ | change in velocity squared = 2 x acceleration x distance travelled |
| p = m x v | momentum = mass x velocity |
| F = (mv – mu) / t | force = change in momentum / time |

**Table 3b: Energy equations**

| Symbol Equation | Word Equation |
|---|---|
| E = F x d | energy (work done) = force x distance moved |
| $KE = ½ \times m \times v^2$ | kinetic energy = ½ x mass x velocity-squared |
| ΔGPE = m x g x Δh | change in gravitational potential energy = mass x gravitational field strength x change in height |
| $Eff = \frac{\text{useful energy}}{\text{total energy}}$ | $\text{efficiency} = \frac{\text{useful energy transferred}}{\text{total energy transferred}}$ |

**Table 3c: Wave equations**

| Symbol Equation | Word Equation |
|---|---|
| v = f x λ | wave velocity = frequency x wavelength |
| v = d / t | wave velocity = distance moved by wave / time taken |

**Table 3: The required equations, grouped by topics, written in word form.**

## Three-variable equations

Seven of the equations you need to memorise contain just three variables. It is useful to learn these equations in “triangle form” as this makes rearrangement easier (see next step).

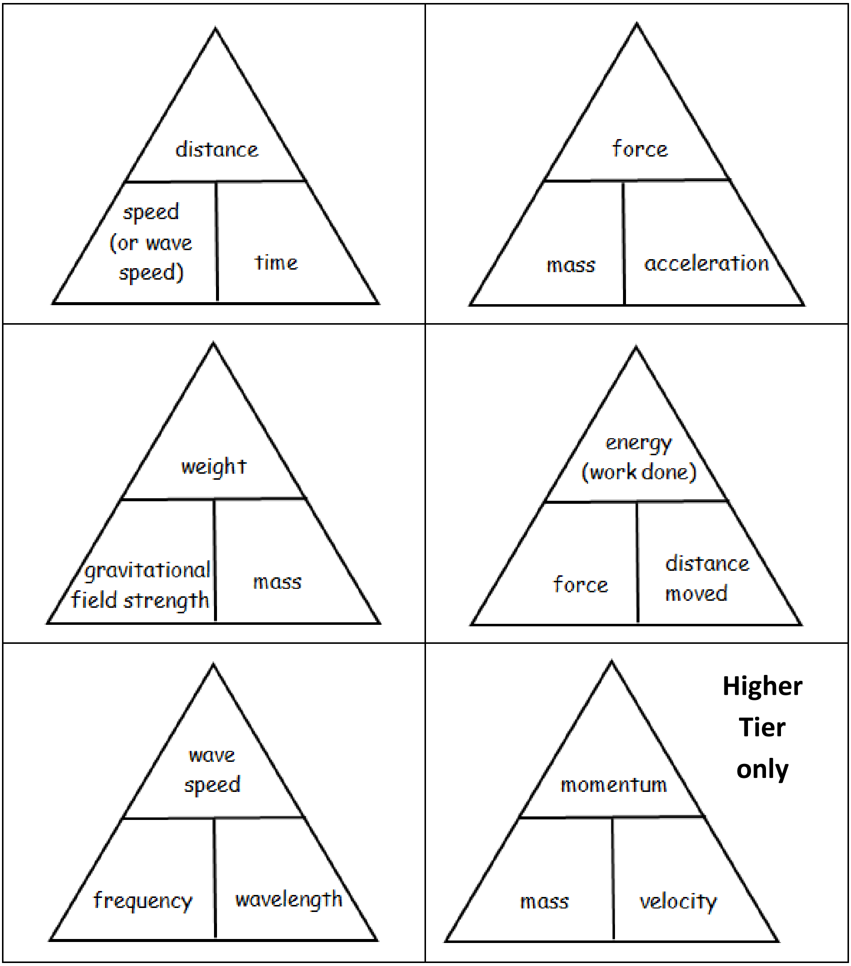



**Table 4: Equation triangles for seven of the required equations. There are only six triangles for the seven equations because the speed-distance-time equation can be used to calculate both ordinary speed and wave speed (wave velocity).**

## Step 2: Rearrange

To use any equation, the quantity that you need to calculate must be on its own on the left-hand side of the equation.

Unfortunately, some examination questions are deliberately written in a way that asks you to calculate a quantity that is not normally on the left-hand side of a remembered equation.

For example, most people remember Newton's Second Law equation as F = m x a (force = mass x acceleration) but a question might give you the force and acceleration then ask you to calculate the mass of the object.

There are three different ways to approach this situation;

i. rearrange the equation in symbol form before starting
ii. insert the numbers then rearrange to solve the equation
iii. use an equation triangle to reveal the calculation

It is up to you to choose whichever method works for you. Once you have decided on the method you will use, it's a good idea to use that same method every time so that the routine becomes automatic whenever you see a calculation question.

Let's see how the first two methods work in an example question.

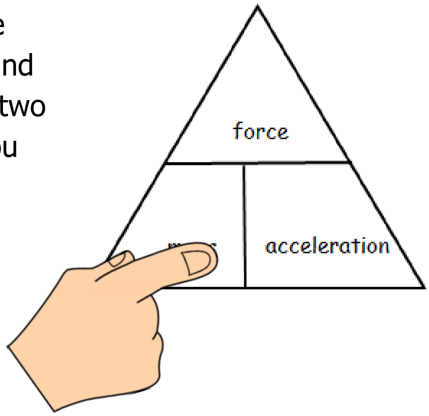
A race car engine that produces 9000 N of thrust is capable of accelerating the car at 15 m/s. Calculate the mass of the car.

i. recall F = m x a and rearrange to give m = F /a then substitute the values to calculate the answer
ii. insert the values into F = m x a to give 9000 = m x 15 then rearrange the numbers to get m = 9000 /15

If you write the correct answer (600 kg) then you will be sure to get full marks but if you made a calculation error you could still get the method mark provided that you showed your working out (including the equation that you used, written in either symbol or word form – not just the numbers).

Now let's look at how to use an equation triangle to solve this same question.

The equation triangle you need is the one that contains the three quantities mentioned in the question; force, acceleration and mass. Draw the appropriate equation triangle then cover the quantity you are trying to find and look to see the positions of the two quantities for the values that you are told in the question. In this case, you need to cover mass and you are then left with force above acceleration.




This means that to find the answer you must do the calculation; force / acceleration.

Write down; mass = $\frac{\text{force}}{\text{acceleration}}$ then put in the numbers $\frac{9000}{15}$

Finally, put this into your calculator to get the answer; 600 (kg).

As was stressed at the top of this page, you <u>**must**</u> write the word equation before you put in the numbers to get the method mark!

## Step 3: Solve

The basic method for solving calculation questions has already been covered in the previous section but there are three points that still need to be covered.

### Conversions – sig figs and realistic (inc efficiency)

As well as knowing the standard SI unit for each quantity you must also be able to recognise unit prefixes and be able to convert from those prefixes to raw units. For example, the 9000 N of thrust in the example question could have been written as 9 kN. If this had been the case, you would have got the wrong answer if you had not spotted the prefix and had instead calculated 9 / 15 (which is why it is so important to write down the equation in symbol or word form before you start the actual calculation!

The table below lists some of the common prefixes and the conversions required to get to the raw units.

| **Prefix** | **How to convert** | **Example** |
|---|---|---|
| n (nano-) | Divide by 1000 000 000 | 550 nm = 550 x $10^{-9}$ m |
| m (milli-) | Divide by 1000 | 12 mm = 0.012 m |
| c (centi-) | Divide by 100 | 20.7 cm = 0.207 m |
| k (kilo-) | Multiply by 1000 | 5.5 kN = 5500 N |
| M (mega-) | Multiply by 1000 000 | 94.8 MHz = 94.8 x $10^{6}$ Hz |
| G (giga-) | Multiply by 1000 000 000 | 2.66 GW = 2.66 x $10^{9}$ W |
| minutes | Multiply by 60 | 15 minutes = 900 s |

**Table 5: Common prefixes and their conversions.**

## Significant figures

When calculating answers to numerical questions, calculators will often display a long string of digits. For example, the answer to the calculation 270 / 13 is shown as 20.76923077 and you could write that as your answer in the space provided on an exam paper.

But at least one question in the examination paper is likely to specify that your answer must be to a certain number of significant figures. If that is the case then you must write only the number of digits specified (often, three) and round the last digit as appropriate.

The correct format for 20.76923077 would be 20.8 although it is likely that 20.7 would also be accepted as it too contains three significant figures.

Note that significant figures are **not** the same as decimal places, so writing 20.769 would not get the significant figures mark.

## Answers must be realistic

If a question is set in a specific context then the answer must be consistent with that context. For example, the mass of the race car determined in the example question earlier was 600 kg. This happens to be a typical minimum mass for race cars and is also about the same mass as a small road-going car. If the calculated answer had been 60 kg then that would have been wrong because 60 kg is the mass of a person, not a car. Similarly, if the calculation gave an answer of 9000 kg then that too would have been wrong as it is the mass of loaded lorry trailer.

You might ask how you are expected to know this. The answer is that you need to have a feel for these sorts of quantities!

There are also some facts that should set alarm bells ringing if your answer breaks these rules.

**Efficiency** is always a number **in the range 0 – 1**. If you calculate efficiency to be more than 1 then you probably put the numbers the wrong way around in the equation.

**Energies** are usually quite **large numbers** of joules (often in hundred, thousands or more). If you calculate the energy to be under 100 J – especially if your answer is less than 1 – then you probably failed to convert a prefix correctly.

By way of contrast, **velocities** are usually **small numbers** and most velocities are less than 100 m/s as this velocity equates to 360 km/h (or about 225 miles per hour).

**Accelerations** are normally **in the range 1 – 35 m/s$^2$**. The acceleration due to gravity (experienced in free fall) is roughly 10 m/s$^2$ and your head's acceleration in a violent sneeze is at the upper limit of this range (around 35 m/s$^2$). A race car might decelerate more rapidly but that's an exceptional situation.

**Negative values** are very **unlikely to be correct**. The only quantities that can have negative values are vector quantities, where the negative sign indicates the opposite direction to the direction of motion.

The wavelengths and frequencies of **visible light** are the most common examples of **extreme values**. The wavelengths range from about 400 nm (400 x $10^{-9}$ m) to 650 nm (600 x $10^{-9}$ m) with frequencies from about 4.6 x $10^{14}$ Hz to 7.5 x $10^{14}$ Hz. These are quite scary values but they are correct for visible light so have confidence in your calculations if you get these results!

**If you understand everything in this booklet then it is time to move on to the Practice Questions in Part 2.**