Guide to Maths

AS and A Level Design and Technology

Pearson Edexcel Level 3 Advanced Subsidiary GCE in Design and Technology (Product Design) (8DT0)

Pearson Edexcel Level 3 Advanced GCE in Design and Technology (Product Design) (9DT0)

Contents

Introduction

Mathematical skills are an essential part of AS and A Level Design and Technology.

In order to be able to develop their skills, knowledge and understanding in design and technology, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to design and technology, as indicated in the tables that follow.

The assessment of mathematical skills will include at least 15% level 2 or above for design and technology, in the context of the examinations.

The following tables illustrate where these mathematical skills may be developed and could be assessed.

Reference	Mathematical skills requirement	Potential applications
a	Confident use of number, percentages and percentiles	• Calculation of quantities of materials, costs and sizes
b	Use of ratios	• Scaling drawings
c	Calculation of surface areas and/or volumes	• Determining quantities of materials
d	Use of trigonometry	• Calculation of sides and angles as part of product design
e	Construction, use and/or analysis of graphs and charts	• Representation of data used to inform decisions and evaluation of outcomes • Presentation of market data, user preferences, outcomes and market research
f	Use of coordinates and geometry	• Use of datum points and geometry when setting out design drawings
g	Use of statistics and probability as a measure of likelihood	• Interpretation of statistical analyses to determine user needs and preferences • Use of data related to human scale and proportion to determine product scale and dimensions

Reference	Mathematical skills requirement	Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)
a	Confident use of number, percentages and percentiles	
	Recognise and make use of appropriate units in calculations	Candidates may be tested on their ability to: • convert between units, e.g. mm^3 to cm^3 as part of volumetric

		calculations.
	Recognise and use expressions in decimal and standard form	Candidates may be tested on their ability to: • use an appropriate number of decimal places in calculations • carry out calculations using numbers in standard and ordinary form.
	Change the subject of an equation	Candidates may be tested on their ability to: • use and manipulate equations, e.g. density = mass / volume.
	Calculate percentage changes	Candidates may be tested on their ability to: • carry out calculations to work out profits or losses during manufacture • work out the percentage of a quantity • work out reverse percentages and compound interest.
	Recognise and make use of percentiles	Candidates may be tested on their ability to: • identify the percentile ranges on a graph, such as anthropometric data.

Reference	Mathematical skills requirement	Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)
b	Use of ratios	
	Use ratios	Candidates may be tested on their ability to: • calculate quantities of materials when mixing resin and a catalyst for GRPs • produce scaled production drawings.

Reference	Mathematical skills requirement	Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)
c	Calculation of surface areas and/or volumes	
	Calculate the surface areas and volumes of regular shapes	Candidates may be tested on their ability to: • calculate the circumference and area

		of a circle • calculate the surface area and volume of rectangular prisms, cylindrical prisms and spheres • calculate the volume of paint required when applying a surface finish.

Reference	**Mathematical skills requirement**	**Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)**
d	Use of trigonometry	
	Recognise and use Pythagoras' theorem to find the length of sides in a right-angled triangle	Candidates may be tested on their ability to: • find the length of the sides in a right-angled triangle or the length of a shorter side in a right-angled triangle.
	Identify when to use sine and cosine rules	Candidates may be tested on their ability to: • calculate the length of a side in a right-angled triangle • calculate angles when constructing products • calculate the surface area and volume of rectangular prisms, cylindrical prisms and spheres.

Reference	**Mathematical skills requirement**	**Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)**
e	Construction, use and/or analysis of graphs and charts	
	Construct and interpret frequency tables and diagrams, bar charts and histograms	Candidates may be tested on their ability to: • represent a range of data in a table with clear headings and units • interpret data from a variety of tables, e.g. power or energy consumption • plot a range of data in an appropriate format, e.g. anthropometric data • interpret data for a variety of graphs.

	Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: • understand that data may be presented in different formats and be able to use this data, e.g. user preferences.

Reference	**Mathematical skills requirement**	**Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)**
f	Use of coordinates and geometry	
	Use datum points when marking out materials	Candidates may be tested on their ability to: • construct triangles, squares and simple regular geometric shapes • represent a design drawing from a set of sketches.

Reference	**Mathematical skills requirement**	**Exemplification of mathematical skill in the context of A Level Design and Technology (assessment is not limited to the examples given below)**
g	Use of statistics and probability as a measure of likelihood	
	Understand simple probability	Candidates may be tested on their ability to: • use the terms probability and chance appropriately • understand the probability associated with random quality control checks.

It is expected that the development of mathematical skills would be integrated, where appropriate, within teaching of the theoretical and practical specification content.

Maths skills for AS and A Level Design and Technology

Confident use of number, percentages and percentiles

Number

To convert from one metric unit to another, it is necessary to know the following:

Length	Weight	Volume
10 mm = 1 cm 100 cm = 1 m 1000 mm = 1 m 1000 m = 1 km	1000 mg = 1 g 1000 g = 1 kg	100 c*l* = 1 litre 1000 m*l* = 1 litre 1000 cm^3 = 1 litre 1000 *l* = 1 m^3

You only need to be able to multiply or divide by 10, 100 or 1000 in order to be able to convert between metric units.

- When converting from a **smaller number to a larger number** you must remember to **divide**.
- When converting from a **bigger number to a smaller number** you must remember to **multiply**.

When carrying out some complex calculations, you may get an answer on your calculator with lots of numbers, such as 125.3867

If the answer was being used to measure out a length, it would not be possible to mark out the length to that level of accuracy.

Certainly when measuring components with a micrometer or Vernier callipers, it is possible to measure to 2 decimal places, e.g. 26.67 mm.

We therefore **round** numbers to a given number of decimal places.

12.48 = 12.5 correct to 1 decimal place	Round up because 12.48 is closer to 12.5 than 12.4
0.0648 = 0.06 correct to 2 decimal places	Round down because 0.0648 is closer to 0.06 than to 0.07
6.2475 = 6.248 correct to 3 decimal places	If the figure in the fourth decimal place is 5 or more then round up

Standard form is used to represent very large (or very small) numbers.

A number in standard form looks like this.

$$5.7 \times 10^4$$

This part is written as a number between 1 and 10

This part is written as a power of 10

1 mm = 1×10^{-3} m or 1/1000 m
1 m^2 = 1×10^6 mm^2
1 m^2 = 1×10^4 cm^2

It is important to be able to manipulate equations.

To solve density-related questions, we can use the following equation:

$$\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}}$$

When mass is measured in kilograms and the volume is in cubic metres or m^3, the density is measured in kg per m^3 or kg/m^3. Density can also be measured in g/cm^3.

Worked example:

A ring has a mass of 15 g.

Gold has a density of 19.3 g/cm^3.

Calculate the volume of gold required to make the ring.

Using $\textbf{density} = \frac{\textbf{mass}}{\textbf{volume}}$

this formula can be rearranged to give $\textbf{volume} = \frac{\textbf{mass}}{\textbf{density}}$

$$\frac{15}{19.3} = 0.777 \text{ g/cm}^3$$

Percentages and percentiles

Percentage change is, perhaps, one of the most common calculations.

The percentage change could be an increase, where the answer would be positive, or a decrease, where the answer would be negative.

To calculate percentage change, the following equation can be used:

$$\left(\frac{\text{final data set} - \text{initial data set}}{\text{initial data set}}\right) \times 100$$

So, if the initial data set is 22 and the final data set is 40, then the percentage change is:

$$\left(\frac{40-22}{22}\right) \times 100 = \left(\frac{18}{22}\right) \times 100 = 81.8\% \text{ (or 82\%)}$$

Worked example:

A manufacturing company has moved to a new factory.
The old factory was 8000 m^2 and the new factory is 11500 m^2.

Calculate the percentage increase in floor space.

$$\frac{11500 - 8000}{8000} \times 100 = 43.75\% \text{ (or } 44\%\text{)}$$

Worked example:

The mass of a casting is reduced by 8% due to machining.
The original casting weighs 3.65 kg.

Calculate the final weight of the casting once it has been machined.

Method 1

8% of 3.65 $= \frac{8}{100} \times 3.65$

$= 0.292$ g [the 8% reduction is 0.292 g]

$3.65 - 0.292 = 3.358$ kg [subtract it to work out the final weight]

Method 2

$100\% - 8\% = 92\%$ [the final value is 92% of the original weight]

$92\% = \frac{92}{100} = 0.92$ [0.92 is the multiplier]

$0.92 \times 3.65 = 3.358$ kg [multiply the original weight by 0.92]

Compound percentage increases are often used by companies to project future costs such as staff salaries or materials costs.

If materials costs are estimated to rise at 3% a year for the next three years, companies can calculate their materials costs using **compound interest** calculations.

Year	**Amount at the start of the year**	**Amount plus interest**	**Total amount at the end of the year**
1	£100,000	$100{,}000 \times 1.03$	£103,000
2	£103,000	$103{,}000 \times 1.03 = 100{,}000 \times 1.03^2$	£106,090
3	£106,090	$106{,}090 \times 1.03 = 100{,}000 \times 1.03^3$	£109,272.70

Use of ratios

Ratios are used to compare quantities. The simplest form of a ratio has a whole number with no common factors, e.g. 1:3

Ratios are often given in the form 1:*n* where *n* is a number.

This form of ratio, the **unitary** ratio, is most often used for scale drawings of things like buildings or for maps.

To write a ratio in the form of 1:*n* divide each number in the ratio by the first number in that ratio.

For example, 5:16 $= \frac{5}{5}:\frac{16}{5}$

$= 1:3.2$

Calculation of surface areas and/or volumes

Many wooden toys such as trains and building blocks are made up of combinations of regular solid geometric shapes such as cuboids, cylinders and prisms.

So that manufacturers can work out how much timber to buy and, indeed, consider the most economical form of timber to buy, it is important that they are able to calculate volumes. The calculation of surface area is also important so that manufacturers can calculate the volume of surface finishes, for example.

It is also important for companies to be able to consider volumes when packaging items. If a manufacturing company is shipping laptops, they need to be able to convert between units of volumes when they package smaller boxes into larger boxes for transportation. Sometimes even shipping container volumes have to be considered to ensure maximum use is made of the available volume when moving goods from one country to another.

Insert a diagram of volume and surface area formula for: cube, cylinder, hemisphere and sphere. Make sure to cover circumference and area of a circle.

Use of trigonometry

Trigonometry is used extensively in the world of technology and engineering. It is used to calculate the paths and movements of robots and automated guided vehicles (AGVs) within factories. Pythagoras' theorem is also used to calculate the length of sides of a right-angled triangle, or for checking that a right-angled triangle has been marked out correctly with a 90^0 angle.

The longest side of a right-angled triangle is known as the **hypotenuse** (hyp) and is always opposite the right angle. The remaining two sides are known as the **opposite** (opp) and **adjacent** (adj), as shown in **Figure 1**.

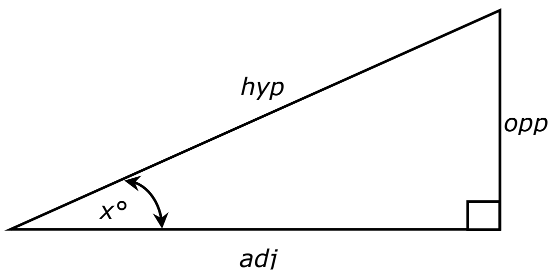

Figure 1

Trigonometry can also be used to calculate the angles of joints when manufacturing products. In these cases, we need to be able to apply and use the **sine** and **cosine** of angles.

In **Figure 2**, we can use the sine and cosine of the angle to calculate the unknown lengths of the triangle.

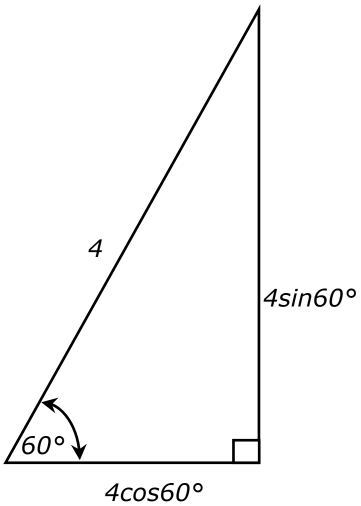

Figure 2

The length of the opposite can be calculated by $4 \times \sin 60^0$ or $4\sin 60^0$

The length of the adjacent can be calculated by $4 \times \cos 60^0$ or $4\cos 60^0$

In the event that the length of the hypotenuse is unknown, the opposite and adjacent can be calculated using the following formulae:

$$\sin 60^0 = \frac{opp}{hyp} \qquad \text{and } \cos 60^0 = \frac{adj}{hyp}$$

However, these rules are only true for right-angled triangles.

When the opposite side and the adjacent side are involved:

$$\tan 60^0 = \frac{opp}{adj}$$

The acronym **SOHCAHTOA** might help you to remember these formulae:

Sin Opp Hyp Cos Adj Hyp Tan Opp Adj

Construction, use and/or analysis of graphs and charts

Graphs and charts are a very popular and efficient method of representing a great deal of information and data. Various charts and graphs are used, such as bar charts, pie charts and histograms.

User's needs, preferences and views are often canvassed as part of the research process, with the results being represented in a graphical form.

Bar charts

Bar charts are used to represent grouped data, using rectangular bars with varying lengths, proportional to the values that they represent. Bars can be plotted vertically or horizontally, in 2D or 3D. With a vertically plotted bar chart, the vertical axis will be used to represent a numerical value and the bars used to identify a specific category.

Figure 3 shows a bar chart indicating the height of a number of trees that were planted on the same day in a managed forest. This type of graph might be used to analyse growth rates or to identify the number of trees below a certain height that might need to be felled, thereby allowing the remaining trees greater access to light, and water and nutrients in the soil.

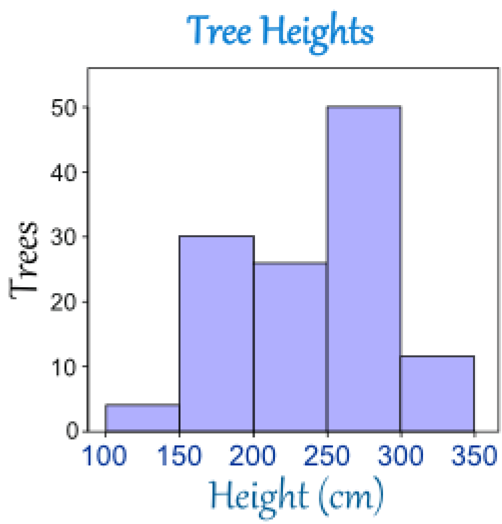

Figure 3

Pie charts

Pie charts are another popular method to represent data. They can easily be generated in programs such as Microsoft® excel.

The whole circle represents the total number of items or responses. The size of a sector will be a proportion of the total frequency. The angles at the centre of the pie chart must add up to 360^0.

The angle for each sector can be found using the following formula:

$$\text{sector angle} = \frac{\text{frequency} \times 360^0}{\text{total frequency}}$$

Table 1 shows the number of owners of mobile phones and **Figure 4** shows the same data in the form of a pie chart.

Phone	iPhone 6	iPhone 7	Samsung S8	Samsung Galaxy edge	Nokia X1
Number	38	26	15	13	8

Table 1

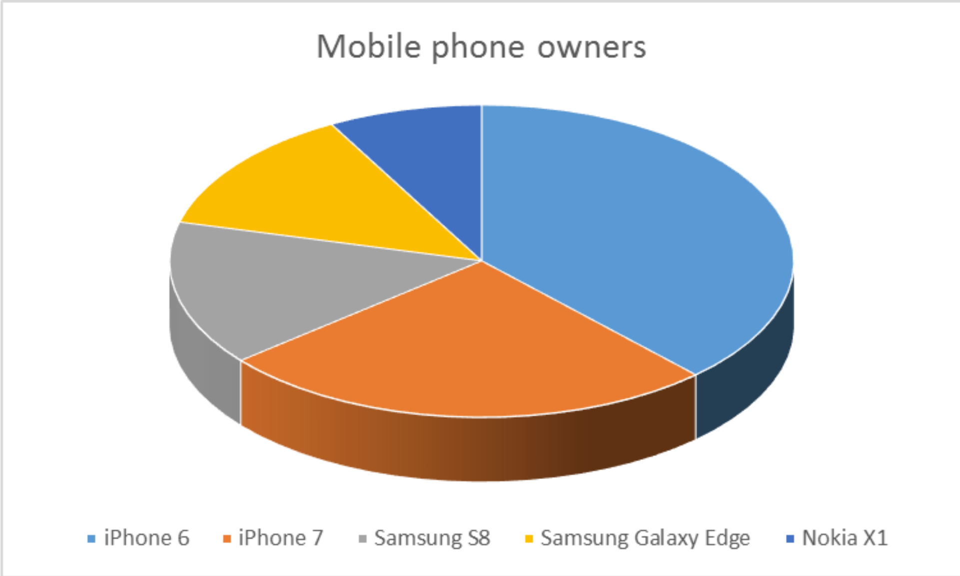

Figure 4

Total frequency $= 38 + 26 + 15 + 13 + 8 = 100$

iPhone 6 $= \frac{38}{100} \times 360^0 = 136.8^0$

Once all of the frequencies have been calculated, you should check that all the angles add up to 360^0.

Histograms

A histogram is used to represent continuous data such as anthropometric data, e.g. the heights of students in your class. Continuous data means there are no gaps between the bars.

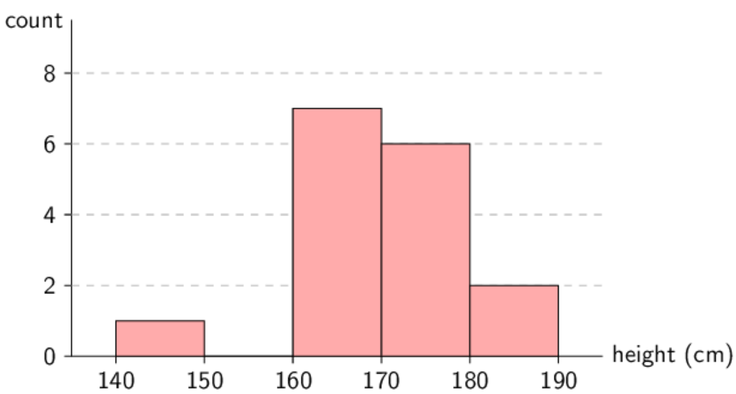

Figure 5

Source: https://www.siyavula.com/maths/grade-11/11-statistics/tikzpictures/ba9a8476461bd31254adb0c5bd764539.png

Use of coordinates and geometry

A **datum reference** point is used when marking out during manufacturing processes. It is a single point from which all measurements are taken or points marked out. Measurements would be given in mm, cm or m depending on the scale and size of the object being marked out.

On some occasions, it is necessary to mark out geometric shapes such as squares and triangles. There are three different types of triangles, but they can all be constructed with a compass, given the side lengths. The compass is set to the length required and then used to draw an arc. The sides of the triangle can be drawn where the arcs intersect.

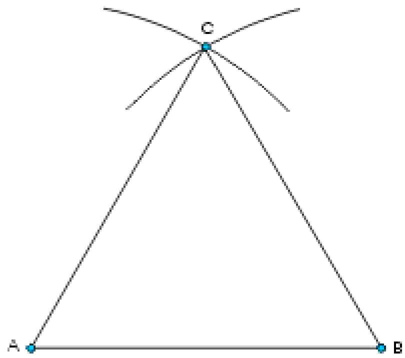

Figure 6

In **Figure 6**, the triangle is an **isosceles** triangle: this means that all three sides are equal in length. It also means that the three internal angles are equal at 60^0, there being a total of 180^0 in any triangle.

A square of the known side length can also be constructed using a compass, since it is possible to create a 90^0 right-angle by bisecting a straight line (which is essentially an 180^0 angle). This is shown in **Figure 7**.

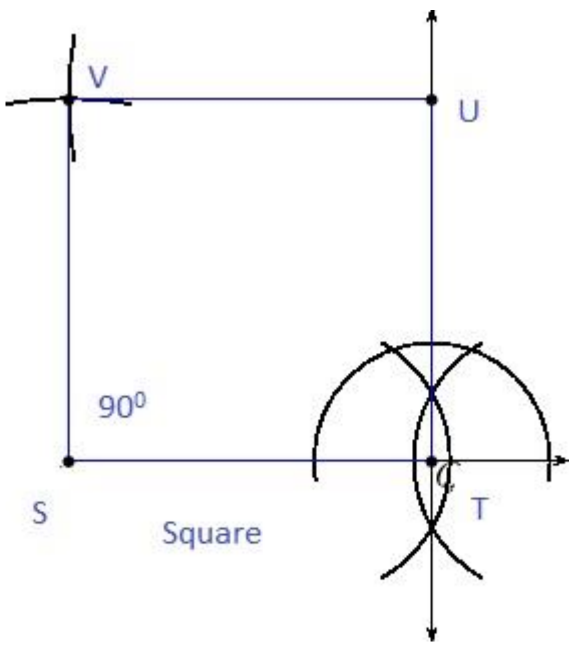

Figure 7

Use of statistics and probability as a measure of likelihood

As part of any commercial manufacturing process, some form of quality control check will take place. Depending on the scale of production and what is being manufactured, there will be a set number of samples that are extracted for some form of checking, such as dimensional accuracy for example.

The sample for testing may well be taken at random if the product is, for example, a plastic injection-moulded pencil sharpener, where one in every thousand components might be tested. If it is an airplane, every part will be subjected to some form of testing.

Probability is the measure that an event will occur, such as a product not being made to a specific size or weight. The higher the probability, the more likely it is that the event will occur.

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