# Unit 5: Applications of Vehicle Science and Mathematics

**NQF Level 3:** **BTEC National**

**Guided learning hours: 60**

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## Unit abstract

Mathematical and scientific principles are an inherent part of many areas of motor vehicle technology. This unit will develop learners' knowledge of these principles and their application in the automotive engineering environment. These can be in a variety of vocational areas, such as the fine detail needed in the calculations in motorsport or the crucial calculations required when working with large commercial vehicles.

Learners will carry out data collection and manipulation in vehicle-related areas such as speed, acceleration and power. They will also complete a variety of practical activities including carrying out an engine performance test and comparing the outcomes to scientific calculations.

## Learning outcomes

**On completion of this unit a learner should:**

1 Be able to apply mathematical and statistical methods to vehicle-related tasks

2 Be able to apply fundamental algebraic laws and trigonometric ratios to solve vehicle-related tasks

3 Be able to apply scientific principles related to heat, force and machines to solve vehicle-related tasks

4 Be able to carry out engine testing and apply scientific principles related to vehicle and engine performance.

## Unit content

1 **Be able to apply mathematical and statistical methods to vehicle-related tasks**

*Data for vehicle-related tasks*: data eg engine speed, stopping distance, miles per gallon, brake pad life, vehicle speed, acceleration, wheel bearing life; sources eg manufacturers, workshop experiments, publicly available figures, (such as media, internet); considerations eg types of error, accuracy, representation

*Mathematical*: methods eg addition, subtraction, multiplication, division, use of brackets, order, estimation techniques, use of calculators, expressing numbers using standard form and scientific notation eg 5.6 x 105, 12 x 103W, 12kW; features eg ratio and proportion, percentage, real and integer numbers, binary systems, vulgar and decimal fractions, ratios, direct and inverse proportion, roots and powers (such as v = √2gh, $I = \sqrt{\frac{P}{R}}$, s = ut + ½at2, v2 = u2 + 2as, ½mv2 = mgh find v, ½QV = ½CV2 find V)

*Data manipulation and graphical representation*: data represented in graphical format eg bar charts, pie charts, frequency distributions, class boundaries and class width, frequency table, variables (discrete and continuous); histogram (continuous and discrete variants); cumulative frequency curves

*Statistical information*: arithmetic mean; median; mode; discrete and grouped data

2 **Be able to apply fundamental algebraic laws and trigonometric ratios to solve vehicle-related tasks**

*Linear equations and straight line graphs*: linear equations eg y = mx + c; straight line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line)

*Factorisation and quadratics*: multiply expressions in brackets by a number, symbol or by another expression in a bracket; by extraction of a common factor eg $ax + ay, a(x + 2) + b(x + 2)$ ; by grouping eg $ax - ay + bx - by$ ; quadratic expressions eg $a^2 + 2ab + b^2$ ; roots of an equation eg quadratic equations with real roots by factorisation, and by the use of formula

*Trigonometric ratios*: basic ratios eg sine, cosine, tangent; Sinθ/Cosθ = Tanθ

*Vehicle-related tasks*: algebraic application eg Ohm's law, pair of simultaneous linear equations in two unknowns, acceleration 30 to 50 mph, time taken to cover a given distance when subjected to constant acceleration, volume and area of combined shapes eg swept, clearance volume, loading capacity, workshop areas; trigonometric application eg steering and suspension angles, valve timing, wiper motion angles

3 **Be able to apply scientific principles related to force, heat and machines to solve vehicle-related tasks**

*Force*: laws of friction; friction in a clutch; stress and strain; Young's modulus; forces in tension/compression; vehicle component subjected to tension/compression eg tie rod, cylinder head bolt, push rod, valve stem, piston, connecting rod, braking components

*Heat*: gas laws eg Boyle's law, Charles' law, general gas equation $pV/T = C$, ideal gas equation $pV = mRT$; change of dimension eg linear, superficial, cubical, heat dissipation; pressure eg fluid, gas, air; gauge pressure, atmospheric pressure

*Machines*: ratios eg steering box, gear ratio, final drive ratio, compression ratio; vehicle mechanism eg alternator and power steering, pulleys, winches, levers eg handbrake lever, brake operation, cylinder, gearbox

4 **Be able to carry out engine testing and apply scientific principles related to vehicle and engine performance**

*Vehicle performance*: equations of motion; Newton's laws; performance eg work, power, velocity, acceleration, retardation

*Engine testing*: safe use of equipment eg rolling road, dynamometer rig, engine analyser; collection of data eg torque, power (indicated and brake), fuel consumption

*Engine performance*: performance to report on eg torque, power (indicated and brake), mechanical efficiency, thermal efficiency, volumetric efficiency, specific fuel consumption, brake mean effective pressure, indicated mean effective pressure; presentation within report eg engine indicator diagrams, calculations using data (such as efficiency, frictional loss, temperature variations)

## Grading grid

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all of the learning outcomes for the unit. The criteria for a pass grade describes the level of achievement required to pass this unit.

| Grading criteria | | |
|---|---|---|
| **To achieve a pass grade the evidence must show that the learner is able to:** | **To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:** | **To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:** |
| P1 gather different data from two different sources and explain the considerations to make before using this data<br>P2 use mathematical methods for different features to manipulate collected data to present statistical information in a graphical format<br>P3 solve a linear equation by plotting a straight line graph, using given experimental data, and use it to deduce the gradient, intercept and equation of the line for a vehicle-related task<br>P4 factorise by extraction and grouping of a common factor from expressions with two, three and four terms respectively<br>P5 use trigonometric ratios to solve two vehicle-related tasks | M1 solve a pair of simultaneous linear equations in two unknowns<br>M2 solve a quadratic equation by factorisation and one by the formula method<br>M3 explain, with examples, the importance of the accuracy of data that is used to solve a range of problems related to engine and vehicle performance. | D1 compare and analyse actual data and calculated data for engine or vehicle performance. |

| Grading criteria | | |
|---|---|---|
| **To achieve a pass grade the evidence must show that the learner is able to:** | **To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:** | **To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:** |
| P6 use the laws of friction to find the friction in a clutch and determine Young's modulus for a given tension/compression on a given vehicle component<br>P7 use a gas law to determine the change in dimensions of the gas<br>P8 describe how ratios help a given vehicle mechanism function properly<br>P9 calculate vehicle performance using Newton's laws and the equations of motion<br>P10 carry out engine testing to obtain data and report on engine performance. | | |

## Essential guidance for tutors

### Delivery

This unit would be best delivered at an early stage in the qualification. It should be linked with other technical units to demonstrate the practical application of science and mathematics within vehicle technology.

Before starting the unit, learners should be able to demonstrate proficiency in basic mathematical concepts and in the use of an electronic scientific calculator to carry out a variety of functions. As a guide to the level required, tutors should consult *Unit 10: Vehicle Science and Mathematics* from the Edexcel Level 2 BTEC First in Vehicle Technology.

It is essential that the unit content is delivered in a vehicle context. Ideally this will be achieved through integration with other units which will also help reduce the assessment burden on learners. There are natural links with other units in the qualification. For example, electrical units that use algebraic application of Ohm's law, units involving calculation of engine ratios and volumes or trigonometric applications to do with steering and suspension. For example when studying *Unit 14: Light Vehicle Suspension, Steering and Braking Systems*, learners could investigate specific components, tyres, wheels or ride height. They could then use the data collected during their investigation for the mathematical content of this unit.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

### Assessment

For P1, the collation of data should be made vocationally relevant by using vehicle-related subject areas such as engine power to stroke or fuel consumption to capacity. A variety of sources should be used, for example manufacturers or internet sites, and an explanation of the considerations to be taken into account before using the data should be included.

For P2, the methods (eg add, subtract etc) and features (eg ratio or percentages etc) need to be completed prior to graphical presentation. This can be in a variety of formats (eg bar and pie charts, frequency distribution tables). This could be achieved by using computer-based software packages, although care must be taken to ensure authenticity of the evidence provided. Learners need to calculate mean, median and mode for discrete and grouped data. The graphical format used must include at least one from bar charts, pie charts, frequency distributions, and frequency table. It should also include a histogram (continuous and discrete variants) and a cumulative frequency curve.

The evidence for P3 could be generated using vehicle speed and timing and the task set should ensure that gradient, intercept and the equation of the line can be presented in the evidence. P4 should also use vehicle-related formulae where possible.

Assessment of M1 and M2 can be linked to that for P3 and P4. If a vehicle context is difficult to apply, then P4, M1 and M2 could be achieved through a purely mathematical context. However, P4 will require a range of tasks that allows expressions with two, three and four terms. Each task is therefore likely to have a different vehicle-related algebraic application or mathematical scenario.

For P5, the use of steering geometry or piston displacement could give vocational relevance when using one basic ratio and $\text{Sin}\theta/\text{Cos}\theta = \text{Tan}\theta$ to calculate angles and length of steering components. This could be integrated with other units that cover vehicle componentry applications.

The evidence for P6 would naturally link to clutch or brake linings and the use of components for applying loads, such as handbrake cables, to determine Young's modulus.

Assessment of P7 could be integrated with that of other units. The task used should focus on vocational gas applications, such as within engine technology, suspension or brake systems. The task should enable learners to use one of the gas laws outlined in the unit content and must include data on pressure.

Using a system application such as the handbrake, complete with its lever mechanism, would enable learners to generate evidence for P8. There needs to be clear direction to ensure that responses include a description of how mechanical ratios help the system function.

For P9, learners will need to produce evidence of calculating vehicle performance using Newton's laws and the equations of motion. This should be contextualised to their intended vocational area (eg light vehicle, heavy vehicle, motorsport).

For P10, learners will need to complete engine testing to obtain a range of performance data, as set out in the unit content. Assessment of P10 could be linked to that for M3 and D1 and would need to be completed after achievement of P1.

**Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications**

This unit provides underpinning knowledge for, and can be integrated with, most of the other units within this qualification.

The unit covers some of the knowledge and understanding associated with some of the units in the Automotive Skills Level 3 National Occupational Standards in Vehicle Maintenance and Repair and the Level 3 SEMTA National Occupational Standards in Automotive Engineering.

**Essential resources**

It is anticipated that this unit will be integrated with other units in the qualification and therefore centres should consider the resource requirements of these other units.

As a minimum centres will need to provide learners with access to workshop facilities to enable practical investigation and assessment of friction, Young's modulus, ratios, measuring bores and complete calculations linked to gas laws etc.

**Indicative reading for learners**

Greer A, Fuller A and Taylor G W — *BTEC National Mathematics for Technicians* (Nelson Thornes, 2004) ISBN 0748779493

Twigg P — *Science for Motor Vehicle Engineers* (Butterworth-Heinemann, 1995) ISBN 034064527X

## Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

| **Application of number Level 3** | |
|---|---|
| **When learners are:** | **They should be able to develop the following key skills evidence:** |
| • gathering data from two different sources and explaining the considerations to make before using this data<br>• using mathematical methods for different features to manipulate collected data to present statistical information in a graphical format<br>• solving a linear equation by plotting a straight line graph using given experimental data and using it to deduce the gradient, intercept and equation of the line for a vehicle-related task. | N3.1 Plan an activity and get relevant information from relevant sources.<br>N3.2 Use this information to carry out multi-stage calculations to do with:<br>a amounts or sizes<br>b scales or proportion<br>c handling statistics<br>d using formulae.<br>N3.3 Interpret the results of your calculations, present your findings and justify your methods. |