Introduction

The LEGO® Education team is pleased to present the LEGO MINDSTORMS® Education EV3 Science Activity Pack for use in Secondary education (Years 7 - 13). These innovative teaching and learning materials will help you to carry out science projects with your students as mapped out in the curriculum.

Target Group

These science experiments will help teachers inspire students to think about the key phenomena, principles, and concepts involved in physics and physical science. Students will also gain and acquire the knowledge called for in the curriculum as part of a creative process. Teachers will also be able to draw upon the digital Content Editor integrated into the EV3 Software.

The science experiments will help simplify lesson planning and aid the actual teaching process by providing practical applications for typical science class course content and practicals aimed at students from Years 7 - 13. Teacher support is provided in the form of notes to aid lesson preparation, learning objective descriptions, pedagogical notes, Building Instructions, predefined programs, and learning success review questionnaires. You do NOT need to possess extensive experience with LEGO MINDSTORMS EV3 to be able to use this material in your class. Teachers who are unfamiliar with LEGO MINDSTORMS can easily acquaint themselves with its features using the Robot Educator tutorials.

Objective

The students should behave like physicists while working on the science experiments. Every student is assigned to a small team that is given an experiment to conduct. Initially, the whole class goes over preliminary considerations together; students are encouraged to make qualified conjectures about the sequence and results of the experiment. After that, the students will conduct the experiment following the instructions. If several teams are working in parallel, they can explain their methods to each other and compare results. This type of experimental learning requires teamwork, communication skills, and an ability on the part of each student to express themselves; it aids in the acquisition and application of engineering procedures while imparting knowledge of the physical sciences.

Content of the Pack

Science projects

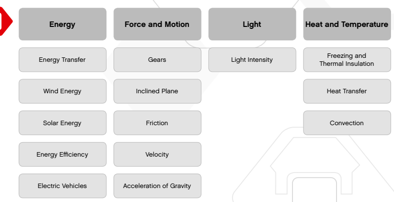
The pack includes fourteen science projects in the following categories:
- Energy
- Force and Motion
- Light
- Heat and Temperature

The multimedia environment contains material for teachers and students. Prior preparations (e.g., preparation of additional material such as lamps, fans, or ice) are identified explicitly in the teacher notes. The experiment to be carried out is at the core of each individual project. The accompanying materials include step-by-step Building Instructions, notes, and background materials about the topic or the category to which the science project belongs and with questionnaires (including sample solutions). In addition to the LEGO MINDSTORMS Education EV3 Core Set, some projects require the LEGO MINDSTORMS Temperature Sensor (9749) or the LEGO Education Renewable Energy Add-on Set (9688).

Science Projects

Each project revolves around an experiment-based assignment. The assignment is organized through the Content Editor integrated into the EV3 Software, whose features enable multimedia presentation, interaction, and documentation. It includes the following features, among others:

- Images of the structure of the experiment, both in the form of general overviews and at the detailed level
- Notes on how to build or use the models
- Tables to facilitate the structuring and organization of test data and observations
- Data logging tools for sensor data analysis (measured values)
- Software buttons that make it easy to add video clips, photos, and other images as well as text, audio recordings, and webcam recordings.



Every project for students contains the following pages related to the experimentation process:

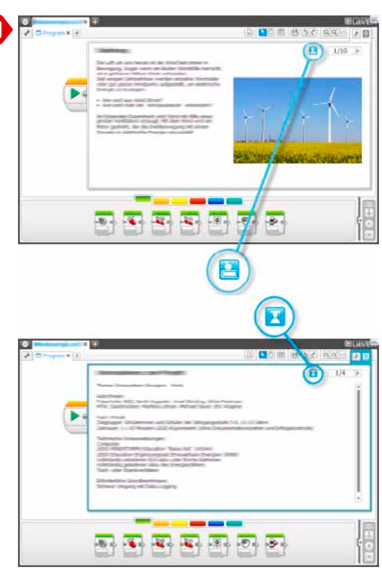
- Introduction
- Preliminary Considerations
- Building Instructions
- Download Program
- Notes on Using the Model
- Experiment – Measure
- Analyse
- What Did We Measure and What Did We Find Out?
- This Is What We Learned
- On to New Discoveries

The Learning Success Review can be performed using questionnaires handed out by the teacher.

While working on the science projects, pages with teacher notes will be displayed in Teacher Mode. These will include:

- Information About the Project
- Learning Objectives
- Teacher Notes
- Lesson Preparation
- Notes on Preliminary Considerations
- Experiment – Measure
- Analyse
- Review
- Report
- Learning Success Review

In addition, the teacher notes include comments, warnings, suggestions for further experiments, and other helpful material.



Click the button to toggle between the student pages and the teachers' notes.

Lesson Sequence

Select the Science option in the EV3 Software menu.

1. Choose between the categories Energy, Force and Motion, Light, or Heat and Temperature and select one of the projects offered.
2. Read the page with Information About the Project to learn what grade level(s) the project is suitable for, how much time to allow for the experiment, and what technical prerequisites are required. The next two pages contain information about the learning objectives and pedagogical methods. The Lesson Preparation page has additional information that you should consider before having the class conduct the experiment.
3. The next page provides Building Instructions for the model required in the experiment you selected. The next step is to build the model or to have the students build it. Most experiments will now require you to download the program as well.

4. Next, carry out the experiment according to the instructions. The instructions may vary from experiment to experiment. Some experiments involve producing measurement series whose values are shown on the EV3 Brick display, and some of the values measured will need to be entered in data tables.
5. Observations made while conducting the experiment should then be analyzed; encourage the students to enter comments in the field provided for this purpose.
6. Now the students document the experiment by summarizing their results, entering information in the appropriate field.
7. The students describe what they have learned (physical phenomena), entering their information in the appropriate field.

Lesson Organization Tips

Time required

The time required by the individual projects depends on a range of factors, including the students' age, their prior experience with LEGO® MINDSTORMS®, the complexity of the experiment, and the scope of the topic addressed by the project in question.

There are four categories containing different numbers of projects. These categories correspond to the curriculum established for science in Years 7 - 13. Every experiment includes possible variations and options for further investigation. There are no standard solutions that would suggest an exact time allowance. The forty-five-minute time allotment is an approximate indication of how much time an average student will need to build the model according to the Building Instruction and then carry out the experiment. The time allotment does not include the time required for documentation or the Learning Success Review, since these may vary considerably depending on the students' capabilities and the demands placed on them by the teacher.

There is additional teaching material available in accompanying PDF files for the topics explored through the fourteen science projects. This material consists of background knowledge, definitions, relevant equations, historical facts, ties to modern developments, and inspiration for student research topics. Also included in this material are questions you can use as pre- or post-assessments for the broad range of topics linked with the fourteen science projects. Explore this material before using it with your students to ensure it meets your teaching objectives.

The projects are distributed over the four categories as follows:

Energy
- Energy Transfer
- Wind Energy
- Solar Energy
- Energy Efficiency
- Electric Vehicles

Force and Motion
- Gears
- Inclined Plane
- Friction
- Velocity
- Acceleration of Gravity

Light
- Light Intensity

Heat and Temperature
- Freezing and Thermal Insulation
- Heat Transfer
- Convection

If you do not have a double period available for the project, the digital tools will help students save the current status of their work so that they can resume work on their projects in the next lesson. Students are encouraged to present their work to classmates by having to document the work process and their results. For example, you can ask each team of students to present its own project or discuss the projects in a larger group or as an entire class. This will allow students to compare their experiences and discuss the reasons behind differing results. One of the main lessons the students will learn in the physics projects is that no solution is perfect. Every experiment is subject to disruptive factors or unplanned side effects that may skew the results.

Tying the Tutorials Provided in the Robot Educator into the Science Projects

The EV3 Software Lobby contains a Robot Educator with a total of forty-eight tutorials. If the students have no prior experience with the EV3 Software, we recommend working through at least a few relevant learning units in the Robot Educator before moving on to the physics experiments. The Data Logging involved in numerous experiments is particularly important.

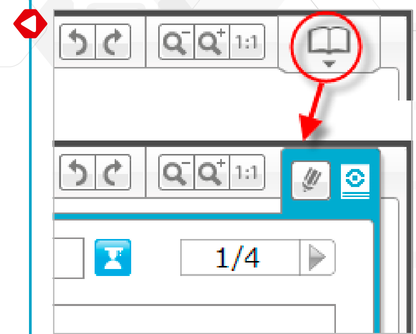
Some teachers ask their students to work through a few of the tutorials before they are allowed to start building the models. Other teachers inform the class about what hardware and software is available while the students are building their models. Both methods will lead to the desired outcome.

It is a good idea to go over the menus in the Robot Educator in detail so that the students are familiar with the overall structure and content of the tutorials, so that they will know how to locate information there.

If you prefer to begin by having the students work through the Robot Educator tutorials before starting the physics projects, you can find more detailed information in the PDF document Robot Educator – Introduction that is located under the Teacher's Guide section of Robot Educator.

Content Editor

Customized instructions



The Content Editor gives you the power to customize the project files included in the science projects, allowing you to create lessons tailored to your class's particular needs. Here are some of the things that you can do:

- Adapt the text to better match your students' reading comprehension skills
- Add pictures that are more relevant to your students
- Modify the assignments to make them easier or more difficult
- Change the project objectives to either expand or narrow the range of potential experiments
- Formulate your own project objectives or assignments
- Add your own evaluation categories or evaluation tools

To ensure that you do not overwrite the files included in the science projects, any changes made are saved as a new project. All of the files included in the original project will also be transferred into the new project file so that you can then make them available to the students ((e.g., on a shared network drive).

The Content Editor can be used to document progress, findings, and results while working through the respective project. It allows students to

- compose descriptions of their group discussions, methods employed, observations, results, and reflections;
- enter their data in tables;
- post audio recordings of their ongoing work on the experiment and recordings related to their discussions and experimental methods;
- add their own pages;
- add images and videos showing their own models in action;
- publish their unique projects and share them with fellow students.

More information about the Content Editor is available in the Quick Start videos (open the video called **Content Editor)** and in the User Guide located under Quick Start in the EV3 Software Lobby.

Science Projects (overview)

Energy	Force and Motion	Light	Heat and Temperature
Energy Transfer	Gears	Light Intensity	Freezing and Thermal Insulation
Wind Energy	Inclined Plane		Heat Transfer
Solar Energy	Friction		Convection
Energy Efficiency	Velocity		
Electric Vehicles	Acceleration of Gravity		

Curriculum Grid

National Curriculum Science
Key Stage 3

● = addresses standard
◐ = partially addresses standard

National Curriculum Science Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Working scientifically Through the content across all three disciplines, pupils should be taught to:																		
Scientific attitudes																		
pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility		●	●	●	●	●		●	●	●	●	●		●		●	●	●
understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review		●	●	●	●	●		●	●	●	●	●		●		●	●	●
evaluate risks.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Experimental skills and investigations																		
ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience		●	●	●	●	●		●	●	●	●	●		●		●	●	●
make predictions using scientific knowledge and understanding		●	●	●	●	●		●	●	●	●	●		●		●	●	●
select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety		●	●	●	●	●		●	●	●	●	●		●		●	●	●
make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements		●	●	●	●	●		●	●	●	●	●		●		●	●	●
apply sampling techniques.		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Analysis and evaluation																		
apply mathematical concepts and calculate results		●	●	●	●	●		●	●	●	●	●		●		●	●	●
present observations and data using appropriate methods, including tables and graphs		●	●	●	●	●		●	●	●	●	●		●		●	●	●
interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
present reasoned explanations, including explaining data in relation to predictions and hypotheses		●	●	●	●	●		●	●	●	●	●		●		●	●	●
evaluate data, showing awareness of potential sources of random and systematic error		●	●	●	●	●		●	●	●	●	●		●		●	●	●
identify further questions arising from their results		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use and derive simple equations and carry out appropriate calculations		●	●	●	●	●		●	●	●	●	●		●		●	●	●
undertake basic data analysis including simple statistical techniques		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Subject content – Physics Pupils should be taught about:																		
Energy: **Calculation of fuel uses and costs in the domestic context**																		
comparing power ratings of appliances in watts (W, kW)		◐	◐	◐	◐	◐								◐				
comparing amounts of energy transferred (J, kJ, kW hour)		●	●	●	●	●								◐				
domestic fuel bills, fuel use and costs														◐		◐	◐	◐

National Curriculum Science Key Stage 3

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National Curriculum Science Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Energy changes and transfers																		
simple machines give bigger force but at the expense of smaller movement (and vice versa): product of force and displacement unchanged								●	●	●	●	●						
heating and thermal equilibrium: temperature difference between two objects leading to energy transfer from the hotter to the cooler one, through contact (conduction) or radiation; such transfers tending to reduce the temperature difference: use of insulators																●	●	●
other processes that involve energy transfer: changing motion, dropping an object, completing an electrical circuit, stretching a spring, metabolism of food, burning fuels		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Changes in systems																		
energy as a quantity that can be quantified and calculated; the total energy has the same value before and after a change		●	●	●	●	●		●	●	●	●	●		●		●	●	●
comparing the starting with the final conditions of a system and describing increases and decreases in the amounts of energy associated with movements, temperatures, changes in positions in a field, in elastic distortions and in chemical compositions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
using physical processes and mechanisms, rather than energy, to explain the intermediate steps that bring about such changes		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Motion and forces: Describing motion																		
speed and the quantitative relationship between average speed, distance and time (speed = distance ÷ time)								●	●	●	●	●						
the representation of a journey on a distance-time graph								●	●	●	●	●						
relative motion: trains and cars passing one another								●	●	●	●	●						
Forces																		
forces as pushes or pulls, arising from the interaction between two objects								●	●	●	●	●						
using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces								●										
moment as the turning effect of a force								●	●	●	●	●						
forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water								●	●	●	●	●						
Forces and motion																		
forces being needed to cause objects to stop or start moving, or to change their speed or direction of motion (qualitative only)								●	●	●	●	●						
change depending on direction of force and its size								●	●	●	●	●						
Light waves																		
the similarities and differences between light waves and waves in matter														●				
light waves travelling through a vacuum; speed of light														●				
the transmission of light through materials: absorption, diffuse scattering and specular reflection at a surface														●				
light transferring energy from source to absorber leading to chemical and electrical effects; photo-sensitive material in the retina and in cameras														●				
colours and the different frequencies of light, white light and prisms (qualitative only); differential colour effects in absorption and diffuse reflection														●				

National Curriculum Science Key Stage 3

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National Curriculum Science Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Matter: **Physical changes**																		
conservation of material and of mass, and reversibility, in melting, freezing, evaporation, sublimation, condensation, dissolving																●		
similarities and differences, including density differences, between solids, liquids and gases																●		
the difference between chemical and physical changes																●		
Particle model																		
the differences in arrangements, in motion and in closeness of particles explaining changes of state, shape and density, the anomaly of ice-water transition																●	◐	
Energy in matter																		
changes with temperature in motion and spacing of particles																●	●	●
internal energy stored in materials		●	●	●	●	●												
Space physics:																		
gravity force, weight = mass x gravitational field strength (g), on Earth g=10 N/kg, different on other planets and stars; gravity forces between Earth and Moon, and between Earth and Sun (qualitative only)												●						
the seasons and the Earth's tilt, day length at different times of year, in different hemispheres														●				

National Curriculum Science Key Stage 4

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◐ = partially addresses standard

	National Curriculum Science Key Stage 4	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
1. Data evidence, theories and explanations																			
Pupils should be taught:																			
a	how scientific data can be collected and analysed		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	how interpretation of data, using creative thought, provides evidence to test ideas and develop theories		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	how explanations of many phenomena can be developed using scientific theories, models and ideas		●	●	●	●	●		●	●	●	●	●		●		●	●	●
2. Practical and enquiry skills																			
Pupils should be taught to:																			
a	plan to test a scientific idea, answer a scientific question, or solve a scientific problem		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	collect data from primary or secondary sources, including using ICT sources and tools		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	work accurately and safely, individually and with others, when collecting first-hand data		●	●	●	●	●		●	●	●	●	●		●		●	●	●
d	evaluate methods of collection of data and consider their validity and reliability as evidence.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
3. Communication skills																			
Pupils should be taught to:																			
a	recall, analyse, interpret, apply and question scientific information or ideas		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	use both qualitative and quantitative approaches		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
c	present information, develop an argument and draw a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
4. Applications and implications of science																			
Pupils should be taught to:																			
a	about the use of contemporary scientific and technological developments and their benefits, drawbacks and risks		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	to consider how and why decisions about science and technology are made, including those that raise ethical issues, and about the social, economic and environmental effects of such decisions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
7. Energy, electricity and radiations																			
In their study of science, the following should be covered:																			
a	energy transfers can be measured and their efficiency calculated, which is important in considering the economic costs and environmental effects of energy use		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	evaluate scientific evidence and working methods.		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Mathematics Key Stage 3 ● = addresses standard ◐ = partially addresses standard	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Working mathematically Through the mathematics content, pupils should be taught to:																		
Develop fluency																		
consolidate their numerical and mathematical capability from key stage 2 and extend their understanding of the number system and place value to include decimals, fractions, powers and roots		●	●	●	●	●		●	●	●	●	●		●		●	●	●
select and use appropriate calculation strategies to solve increasingly complex problems		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use algebra to generalise the structure of arithmetic, including to formulate mathematical relationships		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
substitute values in expressions, rearrange and simplify expressions, and solve equations		●	●	●	●	●		●	●	●	●	●		●		●	●	●
move freely between different numerical, algebraic, graphical and diagrammatic representations [for example, equivalent fractions, fractions and decimals, and equations and graphs]		●	●	●	●	●		●	●	●	●	●		●		●	●	●
develop algebraic and graphical fluency, including understanding linear and simple quadratic functions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use language and properties precisely to analyse numbers, algebraic expressions, 2-D and 3-D shapes, probability and statistics.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Reason mathematically																		
extend their understanding of the number system; make connections between number relationships, and their algebraic and graphical representations		●	●	●	●	●		●	●	●	●	●		●		●	●	●
extend and formalise their knowledge of ratio and proportion in working with measures and geometry, and in formulating proportional relations algebraically		●	●	●	●	●		●	●	●	●	●		●		●	●	●
identify variables and express relations between variables algebraically and graphically		◐	◐	◐	◐	◐		◐	◐	◐	●	●		◐		◐	◐	◐
make and test conjectures about patterns and relationships; look for proofs or counter-examples		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
begin to reason deductively in geometry, number and algebra, including using geometrical constructions		◐	◐	◐	◐	◐		◐	◐	◐	●	●		◐		◐	◐	◐
Solve problems																		
develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems		●	●	●	●	●		●	●	●	●	●		●		●	●	●
develop their use of formal mathematical knowledge to interpret and solve problems, including in financial mathematics																		
begin to model situations mathematically and express the results using a range of formal mathematical representations		●	●	●	●	●		●	●	●	●	●		●		●	●	●
select appropriate concepts, methods and techniques to apply to unfamiliar and non- routine problems		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Mathematics Key Stage 3

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National Curriculum Mathematics Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Subject content																		
Number Pupils should be taught to:																		
understand and use place value for decimals, measures and integers of any size		●	●	●	●	●		●	●	●	●	●		●		●	●	●
order positive and negative integers, decimals and fractions; use the number line as a model for ordering of the real numbers; use the symbols =, ≠, <, >, ≤, ≥		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
use the concepts and vocabulary of prime numbers, factors (or divisors), multiples, common factors, common multiples, highest common factor, lowest common multiple, prime factorisation, including using product notation and the unique factorisation property		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use the four operations, including formal written methods, applied to integers, decimals, proper and improper fractions, and mixed numbers, all both positive and negative		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
use conventional notation for the priority of operations, including brackets, powers, roots and reciprocals		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
recognise and use relationships between operations including inverse operations		◐	◐	◐	◐	◐		●	◐	◐	◐	◐		◐		◐	◐	◐
use integer powers and associated real roots (square, cube and higher), recognise powers of 2, 3, 4, 5 and distinguish between exact representations of roots and their decimal approximations								◐	◐	◐	◐	◐						
interpret and compare numbers in standard form A x 10n 1≤A<10, where n is a positive or negative integer or zero		◐	◐	◐	◐	◐		◐	◐	◐	●	●		●		◐	◐	◐
work interchangeably with terminating decimals and their corresponding fractions (such as 3.5 and $^7/_2$ or 0.375 and $^3/_8$)		◐	◐	◐	◐	◐		●	●	●	●	●		●		●	●	●
define percentage as 'number of parts per hundred', interpret percentages and percentage changes as a fraction or a decimal, interpret these multiplicatively, express one quantity as a percentage of another, compare two quantities using percentages, and work with percentages greater than 100%		●	●	●	●	●		●	●	●	●	●		●		●	●	●
interpret fractions and percentages as operators		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
use standard units of mass, length, time, money and other measures, including with decimal quantities		●	●	●	●	●		●	●	●	●	●		●		●	●	●
round numbers and measures to an appropriate degree of accuracy [for example, to a number of decimal places or significant figures]		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use approximation through rounding to estimate answers and calculate possible resulting errors expressed using inequality notation a<x≤b		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use a calculator and other technologies to calculate results accurately and then interpret them appropriately		●	●	●	●	●		●	●	●	●	●		●		●	●	●
appreciate the infinite nature of the sets of integers, real and rational numbers		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Mathematics
Key Stage 3

● = addresses standard
◐ = partially addresses standard

National Curriculum Mathematics Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Algebra Pupils should be taught to:																		
use and interpret algebraic notation, including: - ab in place of a×b - 3y in place of y+y +y and 3×y - a^2 in place of a×a ,a^3 in place of a×a×a; a^2b in place of a×a×b - $^a/_b$ in place of a÷b - coefficients written as fractions rather than as decimal - brackets											●	●						
substitute numerical values into formulae and expressions, including scientific formulae											●	●						
understand and use the concepts and vocabulary of expressions, equations, inequalities, terms and factors		●	●	●	●	●		●	●	●	●	●		●		●	●	●
understand and use standard mathematical formulae; rearrange formulae to change the subject								◐	◐	◐	●	●						
model situations or procedures by translating them into algebraic expressions or formulae and by using graphs								◐	◐	◐	●	●						
use algebraic methods to solve linear equations in one variable (including all forms that require rearrangement)								◐	◐	◐	●	●						
work with coordinates in all four quadrants											●	●						
recognise, sketch and produce graphs of linear and quadratic functions of one variable with appropriate scaling, using equations in x and y and the Cartesian plane								◐	◐	◐	●	●						
interpret mathematical relationships both algebraically and graphically								◐	◐	◐	●	●						
reduce a given linear equation in two variables to the standard form y = mx + c; calculate and interpret gradients and intercepts of graphs of such linear equations numerically, graphically and algebraically								◐	◐	◐	◐	◐						
use linear and quadratic graphs to estimate values of y for given values of x and vice versa and to find approximate solutions of simultaneous linear equations								◐	◐	◐	◐	◐						
find approximate solutions to contextual problems from given graphs of a variety of functions, including piece-wise linear, exponential and reciprocal graphs								◐	◐	◐	◐	◐						
generate terms of a sequence from either a term-to-term or a position-to-term rule		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
recognise arithmetic sequences and find the nth term		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
recognise geometric sequences and appreciate other sequences that arise																		

National Curriculum Mathematics Key Stage 3

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National Curriculum Mathematics Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Ratio, proportion and rates of change Pupils should be taught to:																		
change freely between related standard units [for example time, length, area, volume/capacity, mass]		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use scale factors, scale diagrams and maps		●	●	●	●	●		●	●	●	●	●		●		●	●	●
express one quantity as a fraction of another, where the fraction is less than 1 and greater than 1		●	●	●	●	●		●	●	●	●	●		●		●	●	●
use ratio notation, including reduction to simplest form		●	●	●	●	●		●	●	●	●	●		●		●	●	●
divide a given quantity into two parts in a given part:part or part:whole ratio; express the division of a quantity into two parts as a ratio		●	●	●	●	●		●	●	●	●	●		●		●	●	●
understand that a multiplicative relationship between two quantities can be expressed as a ratio or a fraction		●	●	●	●	●		●	●	●	●	●		●		●	●	●
relate the language of ratios and the associated calculations to the arithmetic of fractions and to linear functions		◐	◐	◐	◐	◐		●	●	●	●	●		●		◐	◐	◐
solve problems involving percentage change, including: percentage increase, decrease and original value problems and simple interest in financial mathematics		●	●	●	●	●		●	●	●	●	●		●		●	●	●
solve problems involving direct and inverse proportion, including graphical and algebraic representations		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
use compound units such as speed, unit pricing and density to solve problems		◐	◐	◐	◐	◐		◐	◐	◐	●	●		●		●	◐	◐
Geometry and measures Pupils should be taught to:																		
derive and apply formulae to calculate and solve problems involving: perimeter and area of triangles, parallelograms, trapezia, volume of cuboids (including cubes) and other prisms (including cylinders)								●	●	●	●	●						
calculate and solve problems involving: perimeters of 2-D shapes (including circles), areas of circles and composite shapes								●	●	●	●	●						
identify properties of, and describe the results of, translations, rotations and reflections applied to given figures								●	●	●	●	●						
understand and use the relationship between parallel lines and alternate and corresponding angles									●									
apply angle facts, triangle congruence, similarity and properties of quadrilaterals to derive results about angles and sides, including Pythagoras' Theorem, and use known results to obtain simple proofs									●									
use Pythagoras' Theorem and trigonometric ratios in similar triangles to solve problems involving right-angled triangles									●									
use the properties of faces, surfaces, edges and vertices of cubes, cuboids, prisms, cylinders, pyramids, cones and spheres to solve problems in 3-D									●									

National Curriculum Mathematics Key Stage 3 ● = addresses standard ◐ = partially addresses standard	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Probability Pupils should be taught to:																		
record, describe and analyse the frequency of outcomes of simple probability experiments involving randomness, fairness, equally and unequally likely outcomes, using appropriate language and the 0-1 probability scale		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
generate theoretical sample spaces for single and combined events with equally likely, mutually exclusive outcomes and use these to calculate theoretical probabilities		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Statistics Pupils should be taught to:																		
describe, interpret and compare observed distributions of a single variable through: appropriate graphical representation involving discrete, continuous and grouped data; and appropriate measures of central tendency (mean, mode, median) and spread (range, consideration of outliers)		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
construct and interpret appropriate tables, charts, and diagrams, including frequency tables, bar charts, pie charts, and pictograms for categorical data, and vertical line (or bar) charts for ungrouped and grouped numerical data		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
describe simple mathematical relationships between two variables (bivariate data) in observational and experimental contexts and illustrate using scatter graphs		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐

National Curriculum Mathematics Key Stage 4

● = addresses standard
◐ = partially addresses standard

		ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
1 Key Concepts																			
1.1 Competence																			
a	Applying suitable mathematics accurately within the classroom and beyond.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	Communicating mathematics effectively.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	Selecting appropriate mathematical tools and methods, including ICT.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
1.2 Creativity																			
a	Combining understanding, experiences, imagination and reasoning to construct new knowledge.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	Using existing mathematical knowledge to create solutions to unfamiliar problems.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	Posing questions and developing convincing arguments.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
1.3 Application and implications of mathematics																			
a	Knowing that mathematics is a rigorous, coherent discipline.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	Understanding that mathematics is used as a tool in a wide range of contexts.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	Engaging in mathematics as an interesting and worthwhile activity.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
1.4 Critical understanding																			
a	Knowing that mathematics is essentially abstract and can be used to model, interpret or represent situations.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	Recognising the limitations and scope of a model or representation.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
2 Key Processes																			
2.1 Representing Pupils should be able to:																			
a	identify the mathematical aspects of a situation or problem		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	compare and evaluate representations of a situation before making a choice		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	simplify the situation or problem in order to represent it mathematically, using appropriate variables, symbols, diagrams and models		●	●	●	●	●		●	●	●	●	●		●		●	●	●
d	select mathematical information, methods and tools to use.		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Mathematics
Key Stage 4

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		ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
2.2 Analysing																			
Use mathematical reasoning Pupils should be able to:																			
a	make connections within mathematics		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	use knowledge of related problems		●	●	●	●	●		●	●	●	●	●		●		●	●	●
e	make and begin to justify conjectures and generalisations, considering special cases and counter-examples		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
f	explore the effects of varying values and look for invariance and covariance		●	●	●	●	●		●	●	●	●	●		●		●	●	●
g	take account of feedback and learn from mistakes		●	●	●	●	●		●	●	●	●	●		●		●	●	●
h	work logically towards results and solutions, recognising the impact of constraints and assumptions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
i	identify a range of techniques that could be used to tackle a problem, appreciating that more than one approach may be necessary		●	●	●	●	●		●	●	●	●	●		●		●	●	●
j	reason inductively, deduce and prove.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Use appropriate mathematical procedures Pupils should be able to:																			
k	make accurate mathematical diagrams, graphs and constructions on paper and on screen		●	●	●	●	●		●	●	●	●	●		●		●	●	●
l	calculate accurately, using mental methods or calculating devices as appropriate		●	●	●	●	●		●	●	●	●	●		●		●	●	●
m	manipulate numbers, algebraic expressions and equations and apply routine algorithms		●	●	●	●	●		●	●	●	●	●		●		●	●	●
n	use accurate notation, including correct syntax when using ICT		●	●	●	●	●		●	●	●	●	●		●		●	●	●
o	record methods, solutions and conclusions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
p	estimate, approximate and check working.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
2.3 Interpreting and evaluating Pupils should be able to:																			
a	form convincing arguments based on findings and make general statements		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	consider the assumptions made and the appropriateness and accuracy of results and conclusions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	appreciate the strength of empirical evidence and distinguish between evidence and proof		●	●	●	●	●		●	●	●	●	●		●		●	●	●
d	look at data to find patterns and exceptions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
e	relate their findings to the original question or conjecture, and indicate reliability		●	●	●	●	●		●	●	●	●	●		●		●	●	●
f	make sense of someone else's findings and judge their value in the light of the evidence they present		●	●	●	●	●		●	●	●	●	●		●		●	●	●
g	critically examine strategies adopted.		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Mathematics Key Stage 4

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	National Curriculum Mathematics Key Stage 4	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
2.4 Communicating Pupils should be able to:																			
a	use a range of forms to communicate findings to different audiences		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	engage in mathematical discussion of results		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	consider the elegance and efficiency of alternative solutions		●	●	●	●	●		●	●	●	●	●		●		●	●	●
d	look for equivalence in relation to both the different approaches to the problem and different problems with similar structures		●	●	●	●	●		●	●	●	●	●		●		●	●	●
e	give examples of similar contexts they have previously encountered and identify how these contexts differed from or were similar to the current situation and how and why the same, or different, strategies were used.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
3 Range and content																			
3.1 Number and algebra																			
a	real numbers, their properties and their different representations		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	rules of arithmetic applied to calculations and manipulations with real numbers, including standard index form and surds		●	●	●	●	●		●	●	●	●	●		●		●	●	●
3.2 Geometry and measures																			
a	properties of 2D and 3D shapes		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	circle theorems		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
c	trigonometrical relationships									●									
d	properties and combinations of transformations		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
e	3D coordinate systems		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
f	vectors in two dimensions		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
g	conversions between measures and compound measures		●	●	●	●	●		●	●	●	●	●		●		●	●	●
3.3 Statistics																			
a	the handling data cycle		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
b	presentation and analysis of large sets of grouped and ungrouped data, including box plots and histograms, lines of best fit and their interpretation		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
c	measures of central tendency and spread						●		●	●	●	●	●						
d	experimental and theoretical probabilities of single and combined events.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
4. Curriculum opportunities																			
a	develop confidence in an increasing range of methods and techniques		●	●	●	●	●		●	●	●	●	●		●		●	●	●
b	work on sequences of tasks that involve using the same mathematics in increasingly difficult or unfamiliar contexts, or increasingly demanding mathematics in similar contexts		●	●	●	●	●		●	●	●	●	●		●		●	●	●
c	work on open and closed tasks in a variety of real and abstract contexts that allow them to select the mathematics to use		●	●	●	●	●		●	●	●	●	●		●		●	●	●
d	work on problems that arise in other subjects and in contexts beyond the school		●	●	●	●	●		●	●	●	●	●		●		●	●	●
e	work on tasks that bring together different aspects of concepts, processes and mathematical content		●	●	●	●	●		●	●	●	●	●		●		●	●	●
f	work collaboratively as well as independently in a range of contexts		●	●	●	●	●		●	●	●	●	●		●		●	●	●
g	become familiar with a range of resources, including ICT, so that they can select appropriately.		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Computing ● = addresses standard ◐ = partially addresses standard	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Key Stage 3																		
Design, use and evaluate computational abstractions that model the state and behaviour of real-world problems and physical systems		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Understand several key algorithms that reflect computational thinking (for example, ones for sorting and searching); use logical reasoning to compare the utility of alternative algorithms for the same problem.		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Use two or more programming languages, at least one of which is textual, to solve a variety of comutational problems; make appropriate use of data structures (for example, lists, tables or arrays);design and develop modular programs that use procedures or functions.		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Understand the hardware and software components that make up computer systems and how they communicate with one another and with other systems.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Understand how instructions are stored and executed within a computer system; understand how data of various types (including text, sounds and pictures) can be represented and manipulated digitally in the form of binary digits.		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Undertake creative projects that involve selecting, using and combining multiple applications, preferably across a range of devices to achieve challenging goals, including collecting and analysing data and meeting the needs of known users.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Develop their capability, creativity and knowledge in computer science, digital media and information technology.		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Develop and apply their analytic, problem-solving, design, and computational thinking skills.		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐

National Curriculum English Key Stage 3

● = addresses standard
◐ = partially addresses standard

National Curriculum English Key Stage 3	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
Reading Pupils should be taught to:																		
Understand increasingly challenging texts through:																		
learning new vocabulary, relating it explicitly to known vocabulary and understanding it with the help of context and dictionaries		●	●	●	●	●		●	●	●	●	●		●		●	●	●
making inferences and referring to evidence in the text		●	●	●	●	●		●	●	●	●	●		●		●	●	●
knowing the purpose, audience for and context of the writing and drawing on this knowledge to support comprehension		●	●	●	●	●		●	●	●	●	●		●		●	●	●
checking their understanding to make sure that what they have read makes sense.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Read critically through:																		
knowing how language, including figurative language, vocabulary choice, grammar, text structure and organisational features, presents meaning.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Writing Pupils should be taught to:																		
Write accurately, fluently, effectively and at length for pleasure and information through:																		
writing for a wide range of purposes and audiences		●	●	●	●	●		●	●	●	●	●		●		●	●	●
summarising and organising material, and supporting ideas and arguments with any necessary factual detail.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
applying their growing knowledge of vocabulary, grammar and text structure to their writing and selecting the appropriate form,		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Plan, draft, edit and proof-read through:																		
considering how their writing reflects the audiences and purposes for which it was intended.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
amending the vocabulary, grammar and structure of their writing to improve its coherence and overall effectiveness.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
paying attention to accurate grammar, punctuation and spelling; applying the spelling patterns and rules set out in English Appendix 1 to the key stage 1 and 2 programmes of study for English.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Grammar and vocabulary Pupils should be taught to:																		
consolidate and build on their knowledge of grammar and vocabulary through:																		
drawing on new vocabulary and grammatical constructions from their reading and listening, and using these consciously in their writing and speech to achieve particular effects.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
using Standard English confidently in their own writing and speech		●	●	●	●	●		●	●	●	●	●		●		●	●	●
Spoken English Pupils should be taught to:																		
speak confidently and effectively, including through:																		
using Standard English confidently in a range of formal and informal contexts, including classroom discussion.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
giving short speeches and presentations, expressing their own ideas and keeping to the point.		●	●	●	●	●		●	●	●	●	●		●		●	●	●
participating in formal debates and structured discussions, summarising and/or building on what has been said.		●	●	●	●	●		●	●	●	●	●		●		●	●	●

National Curriculum Design & Technology Key Stage 3

● = addresses standard
◐ = partially addresses standard

	ENERGY	Energy Transfer	Wind Energy	Solar Energy	Energy Efficiency	Electric Vehicles	FORCE AND MOTION	Gears	Inclined Plane	Friction	Velocity	Acceleration of Gravity	LIGHT	Light Intensity	HEAT AND TEMPERATURE	Freezing and Thermal Insulation	Heat Transfer	Convection
When designing and making, pupils should be taught to: **Design:**																		
develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling, oral and digital presentations and computer-based tools		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Make																		
select from and use specialist tools, techniques, processes, equipment and machinery precisely, including computer-aided manufacture		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
Evaluate																		
analyse the work of past and present professionals and others to develop and broaden their understanding		◐	◐	◐	◐	◐		◐	◐	◐	◐	◐		◐		◐	◐	◐
investigate new and emerging technologies		●	●	●	●	●		◐	◐	◐	◐	◐		◐		◐	◐	◐
understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists		●	●	●	●	●		◐	◐	◐	◐	◐		◐		◐	◐	◐
Technical knowledge																		
understand and use the properties of materials and the performance of structural elements to achieve functioning solutions		●	●	●	●	●		●	●	●	●	●		●		◐	◐	◐
understand how more advanced mechanical systems used in their products enable changes in movement and force		●	●	●	●	●		●	●	●	●	●				◐	◐	◐
understand how more advanced electrical and electronic systems can be powered and used in their products [for example, circuits with heat, light, sound and movement as inputs and outputs]		●	●	●	●	●		●	●	●	●	●		●		◐	◐	◐
apply computing and use electronics to embed intelligence in products that respond to inputs [for example, sensors], and control outputs [for example, actuators], using programmable components [for example, microcontrollers].		◐	◐	◐	◐	●		◐	◐	◐	◐	◐		◐		◐	◐	◐