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| ­­­­STEM Stage 5 | Science, Industrial Technology Engineering, Mathematics | *Water Rockets* |

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| Summary |  | Duration |
| This unit of work challenges students to create a water-bottle rocket in order to engage in Science, Technology, Engineering and Mathematics (STEM) learning experiences. Students, through a range of design, experimentation and testing procedures, aim to create a rocket then compete against others to see which rocket flies the highest and farthest, and are aesthetically appealing. Throughout the design, development and production phases of the project, students expand their knowledge of STEM and collaboratively develop an engineered solution. Students document their evidence of scientific testing, mathematical problem-solving and design development through the use of digital technologies. |  | 8 weeks2–3 hours a week |

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| Teacher background information |  | Resources overview  |
| Water-bottle rockets are constructed using water-filled recycled PET (polyethylene terephthalate) bottles with individualised nose cones and fins. Air is pumped into the bottles, pressurised, and the rockets are launched from a mechanical device. Students learn about and apply the aeronautical concepts of thrust and propulsion, drag and pitch. They research and experiment with nose cone and fin designs using mathematical concepts and calculations.Students form teams of up to 4 to produce their water-bottle rocket, with each student accepting the lead role for one of the following positions – lead designer, lead engineer, lead scientist and data/media manager. While all students are encouraged to make holistic and collaborative contributions to the unit, one student needs to accept responsibility for each of the key roles. The lead designer is responsible for the graphical design work and aesthetic finishes; the lead engineer is responsible for the practical production of the rocket; the lead scientist for the research, experimentation and testing; and the data/media manager for the collation and presentation of the team’s work and data. |  | * Example(s) of water-bottle rocket designs
* Balls or throwing football/rocket toys
* Computers with various software including spreadsheet, CAD and video editing
* NASA water-bottle rocket simulator
* Camera to take photos and videos
* Graph paper and geometric tools, eg ruler, compass, protractor
* 1.25L PET bottles and other materials for fins and nose cone
* Cloth tape and/or hot glue for joining
* Bottle rocket launching device
* Markers and measuring tools, eg trundle wheel, measuring tape
* Optional: profile (and other gauges), tracker software, 3D printer, vinyl cutter
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| Key inquiry questions |  | Vocabulary |
| * How can scientific principles be applied to solve design and engineering problems in aerodynamics?
* How can mathematical calculations aid in analysis and design development in engineering?
* How do changing variables (for example different amounts of water, air pressure or launch angle) affect the aerodynamics of water-bottle rockets?
 |  | aerodynamics, aeronautical, aesthetic, aesthetics, air pressure, angle, angle of elevation, bivariate data, centre of mass, circumference, collaborate, compressive, computer aided design, dependent variable, distance, elevation, experiment, fair test, force, frames per second, fuselage, height, hypothesis, independent variable, launch, mass, orthogonal drawings, pitch, quadratic equation, reliable, simulation, surface area, symmetrical, tensile, thrust, torsional, trajectory, valid, velocity, weight, WHS, yaw |

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| Outcomes |
| Science K–10* ST5‑1VA appreciates the importance of science in their lives and the role of scientific enquiry in increasing the understanding of the world around them
* ST5-4WS develops questions or hypotheses to be investigated scientifically
* ST5-5WS produces a plan to investigate identified questions, hypotheses or problems, individually and collaboratively
* ST5-6WS undertakes first-hand investigations to collect valid and reliable data and information, individually and collaboratively
* ST5-7WS processes, analyses and evaluates data from first-hand investigations and secondary sources to develop evidence-based arguments and conclusions
* ST5-8WS applies scientific understanding and critical thinking skills to suggest possible solutions to identified problems
* ST5-9WS presents science ideas and evidence for a particular purpose and to a specific audience, using appropriate scientific language, conventions and representations
* ST5-10PW applies models, theories and laws to explain situations involving energy, force and motion

Industrial Technology – Engineering* 5.1.2 applies WHS practices to hand tools, machine tools, equipment and processes
* 5.2.2 identifies, selects and competently uses a range of hand and machine tools, equipment and processes to produce quality practical projects
* 5.3.2 selects and uses appropriate materials for specific applications
* 5.4.1 selects, applies and interprets a range of suitable communication techniques in the development, planning, production and presentation of ideas and projects
* 5.4.2 works cooperatively with others in the achievement of common goals
* 5.5.1 applies and transfers acquired knowledge and skills to subsequent learning experiences in a variety of contexts and projects
* 5.6.1 evaluates products in terms of functional, economic, aesthetic and environmental qualities and quality of construction

Mathematics K–10 * MA5.2‑2WM interprets mathematical or real-life situations, systematically applying appropriate strategies to solve problems
* MA5.2-5NA recognises direct and indirect proportion, and solves problems involving direct proportion
* MA5.2-8NA solves linear and simple quadratic equations, linear inequalities and linear simultaneous equations, using analytical and graphical techniques
* MA5.2-10NA connects algebraic and graphical representations of simple non-linear relationships
* MA5.2-11MG calculates the surface areas of right prisms, cylinders and related composite solids
* MA5.2-12MG applies formulae to calculate the volumes of composite solids composed of right prisms and cylinders
* MA5.2-13MG applies trigonometry to solve problems, including problems involving bearings
* MA5.2-16SP investigates relationships between two statistical variables, including their relationship over time
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| Syllabus content |  | Teaching, learning and assessment  |  | Student diversity |
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| **Science** Working ScientificallyWS6 Students conduct investigations by:1. individually and collaboratively using appropriate investigation methods, including fieldwork and laboratory experimentation, to collect reliable data (ACSIS165, ACSIS199)
2. safely constructing, assembling and manipulating identified equipment
3. selecting and using appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166, ACSIS200)
4. using appropriate units for measuring physical quantities
5. reporting data and information, evidence and findings, with accuracy and honesty

Physical WorldPW2 The motion of objects can be described and predicted using the laws of physicsStudents:1. describe qualitatively the relationship between force, mass and acceleration
2. explain qualitatively the relationship between distance, speed and time
3. relate acceleration qualitatively to a change in speed and/or direction as a result of a net force
4. analyse qualitatively everyday situations involving motion in terms of Newton’s laws

**Industrial Technology – Engineering**Students learn about:Engineering Principles and Processesthe nature and purpose of structures elements that make up structures fundamental quantities, derived quantities and their units: force, mass, acceleration forces that act on structures: wind loads, live loads, weight etc the effects of forces on structures: reactions, induced stress, deflection and motion  |  | Week 1: Design brief**Summary***In this lesson the teacher presents the design brief to design and produce a water-bottle rocket. Students form teams for the project and investigate the features of water-bottle rockets and basic aerodynamics. Students will record the project stages using a digital folio.***Resources*** Water-bottle rocket design brief (this may need to be aligned with the school’s task format)
* Examples of water-bottle rockets:
	+ <http://www.science-sparks.com/2012/03/12/making-a-bottle-rocket/>
	+ <https://spaceflightsystems.grc.nasa.gov/education/rocket/BottleRocket/about.htm>
* Balls and/or throwing football/rocket toys (eg Vortex Aero Howler)
* Forces on a rocket – <https://spaceflightsystems.grc.nasa.gov/education/rocket/rktfor.html>
* Newton’s laws applied to water-bottle rockets – <https://www.grc.nasa.gov/WWW/K-12/rocket/BottleRocket/historyofrocketrypostconfact.htm>

**Design brief**‘Design and produce a water-bottle rocket to travel as far as possible. You will use approved resource materials and the finished design will be launched from a bottle-rocket launcher. You will need to conduct research, test designs and make calculations to develop a *water-bottle rocket* that balances the key features of aerodynamics, performance and aesthetics to win this challenge.While the water-bottle rocket that flies the farthest will satisfy one assessment criteria, the overall assessment will include your team’s ability to present an aesthetically appealing design and produce a presentation detailing your scientific experiments, research and mathematical data as supportive evidence of your team’s work.’**Rocket teams*** Teacher explanation:
	+ Each team of four has a Lead Designer (graphical design and aesthetics), Lead Engineer (production), Lead Scientist (research, experimentation and testing) and Data/Media Manager (collation and presentation of the team’s work and data, and video presentation)
	+ Each team member will need to contribute collaboratively to each of the project’s activities
	+ Outline the roles of a team and the factors contributing to team success.
* As a class, discuss the roles of scientific researchers, designers and engineers in society.
* Teams are formed and roles assigned.

**Digital folio*** Students will be documenting their research, experimentation, design development and evaluation using a range of software to record processes and present their final design concept.
* As a class discuss:
	+ image file creation, methods of saving, storing and transferring image and video files
	+ the school’s digital technology policies and the responsible use of digital technology
	+ the most appropriate computer equipment and devices to be used
	+ the use of collaborative documents, eg Google docs.

**Initial research**Students:* Research the characteristics of water-bottle rockets. Optional: students present/collate ideas via Pinterest.
* Perform initial experiments by ‘throwing/launching’ a ball or throwing football/rocket and measuring/estimating the average distance travelled.
* Measure and calculate the average distances travelled, by comparing trajectory angles (pitch) and launch directions (wind assistance/resistance).
* Document and record information and results in the desired format.

Teacher:* Outlines the basic principles of aerodynamics – forces of a rocket: lift, weight, thrust and drag (see Resources - Forces on a rocket).
* Outlines the application of Newton’s Three Laws of Motion in aerodynamics (see Resources - Newton’s laws).
 |  | **Extension*** Schools could choose to enter teams in interschool competitions
* Schools could explore opportunities to involve Engineers Without Borders – <https://ewb.app.box.com/s/nnb2f1gyxa8m9lunc2kxteh2hami0479>

**Extension*** Remove the fins from the foam rocket to test how they improve the rocket’s motion.
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| **Science**Working ScientificallyWS6 Students conduct investigations by:1. individually and collaboratively using appropriate investigation methods, including fieldwork and laboratory experimentation, to collect reliable data (ACSIS165, ACSIS199)
2. selecting and using appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166, ACSIS200)

WS7.1 Students process data and information by:1. selecting and using a variety of methods to organise data and information including diagrams, tables, models, spreadsheets and databases
2. applying numerical procedures and mathematical concepts and using digital technologies, where appropriate
3. identifying data which supports or discounts a question or hypothesis being investigated or a proposed solution to a problem

WS7.2 Students analyse data and information by: 1. analysing patterns and trends, including identifying inconsistencies in data and information (ACSIS169, ACSIS203) NCCT
2. describing relationships between variables (ACSIS169, ACSIS203) CCT
3. synthesising data and information to develop evidence-based arguments

**Industrial Technology – Engineering**Students learn about:Materialsthe properties, structure and applications of materials including: hardnessductility tensile and compressive strength the elastic and plastic behaviour of materials the basic structure and advantages of composite materials used in engineered structuresDesigndesign principles and processesAustralian Standards for engineering designWorkplace Communication Skillsfreehand drawing and sketchingpictorial and orthogonal drawings a range of computer software applicationsindustry terminologyStudents learn to:Workplace Communication Skillssketch ideas for simple structures**Mathematics**5.2 Ratios and RatesStudents:Solve problems involving direct proportion; explore the relationship between graphs and equations corresponding to simple rate problems (ACMNA208) convert between units for rates, eg kilometres per hour to metres per second identify and describe everyday examples of inverse (indirect) proportion, eg as speed increases, the time taken to travel a particular distance decreases L |  | Week 2: Design factors investigation**Summary***Students investigate the factors that affect the design of their water rocket through a simulation. Students investigate the properties of materials that may be used in their design. Using this knowledge of design factors, students develop their idea using drawings and CAD modelling.***Resources*** NASA water-bottle rocket simulator – <https://spaceflightsystems.grc.nasa.gov/education/rocket/BottleRocket/sim.htm>
* Tips for improving the performance of a water rocket – <http://www.aircommandrockets.com/flying_higher.htm>
* Properties of materials – <http://www.technologystudent.com/joints/matprop1.htm> and <http://www.technologystudent.com/joints/matprop2.htm>
* A range of materials for testing, eg PET bottle, cardboard, corrugated plastic
* Computer with spreadsheet software and CAD software
* Graph paper
* Examples of orthogonal drawings
* CAD modelled bottle rocket – [https://grabcad.com/library/bottle-rocket-1#](https://grabcad.com/library/bottle-rocket-1)

**Simulation investigation*** Teacher explains to students that they will be investigating design factors through the analysis of a water-bottle rocket simulation (see Resources).
* Teacher demonstrates the launching device, launching process, specifications and limitations in the simulation.
* Students investigate the factors that affect aeronautical design success (eg surface area, drag, wing/fin shape and size, number of fins).
* Students conduct test launches at different angles, with different air pressure (in Pascals (Pa)) and various water quantities (in millilitres (mL)) to answer questions such as, what is the optimum ratio of water volume to fuselage volume?
* Record and analyse the collected data in a spreadsheet.

**Properties of materials and testing*** Teacher discusses recycling of clean PET bottles and other appropriate materials to use for fins. *Students could bring materials from home.*
* As a class, discuss the importance of recycling for sustainability, resource costs and the benefits to the local and global community.
* Students investigate the properties of various materials to be used in construction (eg compressive and tensile strength, stiffness, torsional strength, durability).
* Students conduct simple tests (eg bending, twisting, impact, hardness), record results for a range of materials, analyse and compare results.
* Students select appropriate materials to use in their design based on the findings from their investigation.

**Conceptual design*** Students conduct research to help develop their idea.
* Each student or team member sketches a rocket proposal with at least four design elements outlined on the sketch.
* All students collaborate to select a preferred design.
* The team present the final design concept using high-quality 3D drawing (texture/colour, outline, shadow, annotations), dimensioned orthogonal drawings, product name and team name.

**Engineering drawings*** Teacher demonstrates the production of high-quality rendered concept drawings.
* During the demonstration, the teacher outlines the basic CAD modelling techniques including creating and saving files, x/y/z planes, sketching, extrusion, cut-outs, rounds, chamfers and applying colours to surfaces.
* Teacher introduces students to basic orthogonal projection and AS1100 drawing standards.
* To communicate their idea, students produce a:
	+ basic computer aided design (CAD) file for one or more parts of their concept, eg fuselage, cone
	+ basic third angle projection drawing
	+ dimensioned orthogonal drawing (top view, front view, right-hand end view).

**Assessment overview*** Informal assessment of student/team designs with feedback provided for possible improvements.
* Tests and drawings produced and filed for later presentation in the team’s design folio/presentation.
 |  | **Extension*** Orthogonal drawings could be produced using a CAD software package.
* Students could utilise 3D printing or CNC (computer numerically controlled) equipment to produce parts modelled in CAD software.
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| **Industrial Technology – Engineering**Students learn about:WHS and Risk Management* the safe use and handling of hand, power and machine tools
* the use of personal protective equipment in the workshop

Students learn to:Materialsuse materials in the design and production of structures based on an understanding of their properties conduct experiments and tests to understand the properties of materials Equipment, Tools and Machinesuse a range of equipment to carry out experiments and construct projects in relation to engineered structuresEngineering Principles and Processesdesign and construct simple structures for specific purposes**Mathematics**5.2 VolumeStudents:Solve problems involving volume for a range of prisms, [cylinders](https://syllabus.bostes.nsw.edu.au/glossary/mat/cylinder/?ajax) and composite solids (ACMMG242) find the volumes of solids that have uniform cross-sections that are sectors, including semicircles and quadrants  |  | Week 3: Fuselage construction**Summary***The WHS policies and processes are introduced and/or reinforced to students, with specific explanation and demonstration of the tools and techniques to be used in the production of the water rocket. Students begin construction of the rocket fuselage.***Resources*** School/Faculty’s safety policies and other documentation
* Water rocket safety – <https://spaceflightsystems.grc.nasa.gov/education/rocket/BottleRocket/safety.htm>
* 1.25L PET bottles (larger is ok) and other resources as required
* Cloth tape, hot glue for joining
* Computer/tablet to record construction

**Work Health and Safety** * Teacher identifies the range of tools, equipment and processes to be used throughout project.
* Teacher explains mandatory safety instruction and testing (following WHS guidelines, including the school’s and faculty’s safety policies and processes). These will include the use of the battery (DC) drill, drill press, hot glue gun, disc sander and woodworking and metalworking hand tools.
* Class discussion of the safety related to the launching and testing of water-bottle rockets (see Resources - Water rocket safety).

**Production of water-bottle rocket fuselage/body*** Teacher demonstrates the safe use of a range of tools and techniques (ensuring this is appropriately recorded using the school’s WHS system) including woodworking and metalworking hand tools, model-making tools, light machinery, power tools and general workshop safety.
* Students investigate methods of creating bottle rockets.
* Select the range of resource materials to be used to produce their design.
* Students perform appropriate techniques when constructing the fuselage, including:
	+ measuring the circumference of each bottle, when joining two bottles together, to determine the location of the ‘press fit’, before cutting each bottle
	+ ensuring the rocket body is symmetrical by conducting a ‘roll’ test prior to joining the nose cone bottle to the base bottle
	+ using cloth tape or hot glue to join the two components to form the fuselage.
* Students estimate the volume of the fuselage using the formula for the volume of a cylinder.
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| **Science**Physical WorldPW2 The motion of objects can be described and predicted using the laws of physicsStudents:1. describe qualitatively the relationship between force, mass and acceleration
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**Industrial Technology – Engineering**Students learn about:Engineering Principles and Processeselements that make up structures fundamental quantities, derived quantities and their units: force, mass, acceleration forces that act on structures: wind loads, live loads, weight etc the effects of forces on structures: reactions, induced stress, deflection and motion **Mathematics**5.2 EquationsStudentsSubstitute values into formulae to determine an unknown (ACMNA234)solve equations arising from substitution into formulae, eg given P=2l+2b and P=20, l=6, solve for b * substitute into formulae from other strands of the syllabus or from other subjects to solve problems and interpret solutions, eg A=12xy, v=u+at, C=59(F−32), V=πr2h (Problem Solving) CCT
 |  | Week 4: Forces and fins**Summary***Students learn about centre of mass and the forces acting on the rocket. They represent these in a free body diagram. Students design the shape and position of the fins, then construct and fix them to the rocket using suitable materials and tools. Students should be reminded to take photos/videos regularly during rocket construction.***Resources*** Centre of mass – <http://www.technologystudent.com/forcmom/cengrav1.html>
* Drawing tools, including rulers, protractors, compasses
* Materials for fins, eg thin cardboard, foam sheet
* Joining materials, eg hot glue, cloth tape
* Optional: profile gauge

**Centre of mass (C of M)*** Teacher explains the concept of centre of mass (C of M) and its importance to the successful functioning of their water-bottle rocket (see Resources - Centre of mass).
* Teacher demonstrates how the position of the C of M can be found by balancing the rocket on a straight edge.
* Class discussion of how the position of the C of M and mass distribution can be altered. For example weighting the nose, altering the number and shape of fins and so on.
* Students find the position of the C of M on their rocket body.

**Calculations involving forces*** Teacher introduces the concepts of tensile and compressive forces.
* As a class, discuss the importance of minimising the total weight force of the rocket by limiting the use of tape, glue and so on.
* Students draw a free body diagram to indicate the forces acting on their rocket when launched, ensuring the force arrows extend from the C of M.
* Students use a digital scale to ‘weigh’ the mass of their rockets and calculate the weight force (Force = mass x acceleration or F = ma) and record the calculation for their presentations.

**Fin geometry and design*** Students determine the positions of the fins on the rocket fuselage using mathematical reasoning and document their working for their presentations.
* Students create a template of their fin design that fits to the profile of the fuselage exactly. (This can be assisted using a profile gauge if available).
* The surface area of the fins will need to be calculated for the comparison test launch results later in the unit.
* Students apply templates to the chosen material, then trace and accurately cut and shape using appropriate tools and equipment.

**Assessment overview*** No formal assessment during this week. However, evidence of testing design solutions and free body diagrams must be documented and collated for presentation in the team’s submission.
 |  | **Extension*** Students explore other types of forces – <http://www.technologystudent.com/forcmom/force1.htm>

**Support*** Provide students with sample fin templates.
* Guide students in placement of the fins using geometric constructions and tools (ruler, compass, protractor) to evenly divide the bottle circumference.

**Extension*** Rocket components could be produced using laser cutting, vinyl cutters, 3D printing or CNC equipment as available.
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| **Industrial Technology – Engineering**Students learn to:Materialsuse materials in the design and production of structures based on an understanding of their properties conduct experiments and tests to understand the properties of materials Equipment, Tools and Machinesuse a range of equipment to carry out experiments and construct projects in relation to engineered structuresEngineering Principles and Processesdesign and construct simple structures for specific purposesDesignidentify the functional and aesthetic aspects of the design of some structures use elementary design principles and processes in the design and production of structures **Mathematics**5.2 Area and Surface AreaStudents:Solve problems involving the surface areas of right pyramids, right cones, spheres and related composite solids (ACMMG271) identify the 'perpendicular heights' and 'slant heights' of right pyramids and right cones Lapply Pythagoras' theorem to find the slant heights, base lengths and perpendicular heights of right pyramids and right cones devise and use methods to find the surface areas of right pyramids develop and use the formula to find the surface areas of right cones: Curved surface area of cone=πrl where r is the length of the radius and l is the slant height CCT |  | Week 5: Construction continues**Summary***Students learn about the importance of tolerances and accurate measurement when constructing the rocket. Students complete the rocket by designing the nose cone and fixing it and the fins to the fuselage. Students design a logo and attach it to the rocket, along with other aesthetic features. Students finalise the documentation of the rocket construction for presentation.***Resources*** Instructions to create a (net of a) cone – <http://hubpages.com/education/How-to-Develop-a-Cone>
* Logo design tips – <http://mashable.com/2014/04/30/logo-design-tips/>
* Assorted resources for applying aesthetic finishes
* Example software to present rocket construction:
	+ Video: iMovie, Windows Movie Maker, Animoto <https://animoto.com/>
	+ Interactive presentations: Adobe Spark <https://spark.adobe.com/>, Microsoft Sway <https://sway.com/>

**Tolerances*** As a class, discuss the importance of measuring the geometry accurately.
* Teacher explains the concept of tolerances
* Using examples, teacher leads further discussion on the importance and application of measurement, angles and mathematics in design and engineering.
* Teacher demonstrates the use of a range of measurement tools (eg calipers, dividers, gauges) for the marking out of holes, templates and determining correct angles for successful functioning of the rocket.

**Completing the rocket*** Students design and construct the nose cone component of their rocket (see Resources – creating a cone). This includes the exploration of the amount of cardboard/plastic required to form the cone and its relationship to the formula for the surface area of a cone:
	+ Determine the intended perpendicular height (h) and radius of the nose-cone base (b)
	+ Calculate the slant height (l) length using Pythagoras’ theorem (l2 = h2 + b2)
	+ Draw a circle with radius (l)on a piece of paper
	+ Calculate the angle portion of the circle needed to create the cone using the formula for arc length (arc length = angle x π ÷ 180 x *L*), where arc length is the diameter of the cone base = 2π*B*. Therefore the angle = *B* ÷ *L* x 360.
* Teacher leads discussion on the advantages and disadvantages of each joining method (eg hot glue, cloth tape).
* Students join the fins and nose cone to rocket fuselage using a joining method/material of their choice. *Note: students will need to pay attention to symmetry, mass distribution and the correct alignment of the fins*.

**Aesthetics and documentation*** As a class, discuss the importance of aesthetics to successful design.
* Using a range of well-known logos, teacher leads discussion on what makes a good logo design.
* Students use available graphic software to produce their logo design, using the ideas formed during the discussion.
* Students use appropriate methods to fix the completed logo to their rocket along with any other aesthetic finishes.
* Students organise the photos and videos of their rocket construction and begin making a presentation, eg slide-show, video, website or interactive presentation (see Resources).

**Assessment overview*** Ongoing assessment of the teams’ and individuals’ application of mathematical principles in practical production, ensuring high tolerance levels and quality projects are produced.
* Feedback and assistance provided, as per student need, catering for the pursuit of innovative and creative design solutions.
 |  | **Support*** Students can be given an example net from which to base their own.

**Extension*** Test the nose-cone design using a wind tunnel or wind tunnel simulator – <http://www.grc.nasa.gov/WWW/K-12/freesoftware_page.htm>

**Extension*** Laser/vinyl cutting and design equipment could be used to produce graphic elements to fix to the rockets.
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| **Science**Working ScientificallyWS4 Students question and predict by:1. formulating questions or hypotheses that can be investigated scientifically (ACSIS164, ACSIS198)

WS5.2 Students plan first-hand investigations by:1. planning and selecting appropriate investigation methods, including fieldwork and laboratory experimentation, to collect reliable data (ACSIS165, ACSIS199)
2. describing a logical procedure for undertaking a range of investigation types
3. designing controlled experiments to collect valid first-hand data
4. specifying the dependent and independent variables for controlled experiments

WS6 Students conduct investigations by:1. individually and collaboratively using appropriate investigation methods, including fieldwork and laboratory experimentation, to collect reliable data (ACSIS165, ACSIS199)
2. selecting and using appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166, ACSIS200)
3. using appropriate units for measuring physical quantities
4. reporting data and information, evidence and findings, with accuracy and honesty

WS7.1 Students process data and information by:1. selecting and using a variety of methods to organise data and information including diagrams, tables, models, spreadsheets and databases
2. applying numerical procedures and mathematical concepts and using digital technologies, where appropriate
3. identifying data which supports or discounts a question or hypothesis being investigated or a proposed solution to a problem

WS8 Students solve problems by:1. describing strategies to develop a range of possible solutions to an identified problem
2. assessing strategies that have been identified as possible solutions to an identified problem
3. applying the processes of Working Scientifically in developing creative solutions to problems

**Industrial Technology – Engineering**Students learn to:Equipment, Tools and Machinesuse a range of equipment to carry out experiments and construct projects in relation to engineered structuresEngineering Principles and Processesdetermine the effects of forces on engineered structures**Mathematics**5.2 VolumeStudents:Solve problems involving volume for a range of prisms, cylinders and composite solids (ACMMG242) find the volumes of solids that have uniform cross-sections that are sectors, including semicircles and quadrants 5.2 Non-linear RelationshipsGraph simple non-linear relationships, with and without the use of digital technologies, and solve simple related equations (ACMNA296) graph parabolic relationships of the form y=ax2,y=ax2+c, with and without the use of digital technologies * identify parabolic shapes in the environment (Reasoning)
* determine the equation of a parabola, given a graph of the parabola with the main features clearly indicated (Reasoning) CCT L

5.2 Right-angled Triangles (Trigonometry)Solve right-angled triangle problems, including those involving direction and angles of elevation and depression (ACMMG245) solve a variety of practical problems involving angles of elevation and depression, including problems for which a diagram is not provided * draw diagrams to assist in solving practical problems involving angles of elevation and depression (Communicating, Problem Solving) CCT

5.2 Bivariate Data AnalysisUse scatter plots to investigate and comment on relationships between two numerical variables (ACMSP251) investigate a matter of interest involving two numerical variables and construct a scatter plot, with or without the use of digital technologies, to determine and comment on the relationship between them, eg height versus arm span, reaction time versus hours of sleep CCTICT |  | Weeks 6 & 7: Testing the rockets**Summary***Students design and conduct tests to assess the performance of their rocket under different conditions.**Students film the rocket’s motion and map its path using video software, calculating the equation of the quadratic graph formed using problem-solving.***Resources*** Bottle-rocket launching device
* Markers and measuring tool, eg trundle wheel, measuring tape
* Camera/video camera
* Computer and software to view footage
* Graph paper
* The quadratic function – <http://amsi.org.au/teacher_modules/Quadratic_Function.html>
* Optional: Tracker software – <http://physlets.org/tracker/>

**Designing a test*** Teacher reviews the concepts of aerodynamics and airflow.
* Teacher outlines the characteristics of a fair test (changing only one variable), validity (suitability of tools used to measure) and reliability (repeating the test).
* Class discussion of a suitable method for gathering the result data to meet the above needs:
	+ fair: which variables should be changed and the others remain the same – bivariate data, independent and dependent variables
	+ valid: what measuring tools will be used – what would be best for time, distance, height
	+ reliable: how many tests can we do given the restrictions of time?
* Students develop hypotheses and identify the variables they will be changing in their tests, such as the amounts of water (mass of fuel), angles of launch (trajectory/pitch), air pressures pumped into the water-bottle and changing launch directions (wind effects).

**Motion tracking**Teacher presents ‘tracking’ of video footage as a method of collecting and analysing data:1. Set up a camera on a tripod to film the water rocket’s motion, perpendicular to the direction of motion
2. Ensure there is an object of known length/height (such as a person) in view of the camera, at the same initial distance as the rocket from the camera (used for calibration)
3. View video footage in software where you can step from one frame to the next
4. Use graph paper held over the screen to track and plot the rocket’s motion
5. Calibrate the graph axes using the known heights and distances.

**Rocket launch and data analysis*** Students test-launch their initial design solutions, experimenting and recording the distances travelled as the variables are changed in a table.
* If time allows, students make modifications to their rockets based on the test-launches and re-test.
* Students perform mathematical calculations on and create scatter plots of the tabulated data to allow analysis of the variable effect, including finding the average of the repeat results and differences between averages.
* Using the test results, student redesign and modify aspects of their rocket to improve the distance travelled, eg fin shape or surface area and nose-cone design as well as mass distribution.
* Students plot the rocket’s motion using the video footage, then use trial and error to determine the quadratic equation for the curve assuming the axis of symmetry is at x = 0 (start with a simple quadratic, then translate up and down, and change the width by adjusting the parameters).
* Students document the test method, data, analysis, photos and evaluations in their folios.

**Evaluation*** Discuss and evaluate the test launches.
* Analyse ‘fails’ and the causes/design flaws.
* If time, apply possible solutions.

**Assessment overview*** Ongoing assessment of the teams’ and individual’s application of mathematical principles in practical production to support appreciation of STEM discipline integration and the production of quality projects.
* Feedback and assistance provided, as per student need, catering for the pursuit of innovative and creative design solutions.
* Assessment of graphing skills following the Working Scientifically outcome criteria: <https://syllabus.bostes.nsw.edu.au/assets/global/files/sci_ws.doc> (page 5)
 |  | **Extension*** Discuss the use of trigonometry to estimate the height the rocket reaches when directed straight up into the air (ie using an observer measuring the angle of elevation with an inclinometer and the observer is standing on the launch spot).

**Support*** Students focus on one variable to test.
* Teacher provides a table to which students can add their data.

**Extension*** Use an online simulation eg <http://cjh.polyplex.org/rockets/simulation/> to determine the optimal amount of water and air pressure to put into the rocket. This can be used to inform the hypothesis.

**Extension*** Use tracking software to conduct the video analysis and determine the quadratic equation - <http://www.sciencebuddies.org/science-fair-projects/project_ideas/Sports_p036.shtml>
* Use a more systematic method to find the quadratic equation – <http://amsi.org.au/teacher_modules/Quadratic_Function.html>

**Extension*** An accelerometer could be inserted into the nose cone to record additional data.

**Support*** Teacher provides a scaffold for testing discussion and evaluation.
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| **Science**Working ScientificallyWS9 Students communicate by:1. selecting and using in presentations, for different purposes and contexts, appropriate text types including discussions, explanations, expositions, procedures, recounts or reports
2. presenting scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations for specific audiences (ACSIS174, ACSIS208)

**Industrial Technology – Engineering**Students learn to:Workplace Communication Skillsprepare reports to document experiments and processes undertaken in the development and production of practical projects  |  | Week 8: Presentation and folio**Summary***Students complete their presentation and present it to the class. Students finalise their digital folio, which includes the presentation.***Resources*** Digital hardware and software applications for image and video editing, and presentation.

**Presentation and folio** * Students use their photos and video footage to create their presentation.
* Students use appropriate hardware and software to format and edit image and video files, and collate into their presentation.
* Students finalise their digital folio, embedding the video.
* Students present and/or share their folio and video.
 |  | **Extension*** Animation of the rocket made by tracking the rocket’s motion captured in the video footage (rotoscoping). This could then be used to show a comparison of the motion for the different tests in one scene.
* To sell their rocket students develop an advertisement that includes statistics about the rocket’s features and performance.
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| Assessment overview  |
| * Ongoing, informal assessment of students’ designs, documentation, processes, techniques and problem-solving, and of them working in a team. Feedback for improvement should be provided regularly throughout the unit.
* Formal assessment and weightings for this unit should follow the NESA and school’s policies and procedures. Final submission can include:
	+ finished team water-bottle rocket
	+ documentation folio
	+ video presentation.
* Refer to the unit overview document for assessment for learning ideas for each outcome.
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| Evaluation  |
| Questions to guide reflection:* To what level did students achieve the learning outcomes?
* How effective were the activities in helping students to understand key concepts and achieve the learning outcomes?
* How did the teaching strategies and activities facilitate student engagement?
* How could the unit be improved to enhance student engagement and learning?
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