Dissecting Geometry

Creative Learning
Teacher Resource

Resource Overview

This learning resource has been developed for Primary and Secondary students and supports multidisciplinary learning across Mathematics, Design and Technology, Visual Arts and Geography.

This resource includes discussion questions and activities designed for the classroom but can be adapted to suit the needs of your students and teaching context.

Workshop Overview

General capabilities and cross-curriculum priorities

Creative and Critical Thinking

Students observe and analyse the geometry of the Sydney Opera House. They make intentional decisions about form, perspective and construction to develop their artworks.

Numeracy

Students explore the mathematical principles embedded in the architecture of the Opera House. They use geometry, scale and perspective, to inform their drawing and model-making.

Personal and Social Capability

Students collaborate with their classmates to share ideas, problem-solve and create artworks together.

Sustainability

Students investigate the design principles that shaped the Sydney Opera House and consider how architecture can respond thoughtfully to its natural context.

Workshop Overview

What students can expect – sensory elements

Touch

- Direct handling of paper and recycled materials
- Sketching with pencils, pens, and other writing tools
- Cutting with blades and using hot glue guns to create models

Sight

- Archival objects and photographs of the building's design and history
- Bright, well-lit workshop space
- Paper and materials displayed on tables
- Visual demonstrations by facilitator before making begins

Sound

- Facilitated group discussions
- Presentations of models at the end of workshop
- No amplified music or loud sound events during the workshop
- Enclosed indoor space at the Centre for Creativity

Movement

- Mix of seated and standing activities
- Moving between workstations during the making phase
- 90-minute session – no break built in

A (very) brief history of the Sydney Opera House

Tubowgule
Now known as Bennelong Point

The Gadigal people in Warrang/Warrane (Sydney Cove) call the place around the Opera House 'Tubowgule' – meaning the knowledge water.

Tubowgule was a point located at the end of a long, wide ridge and surrounded by rocky shoals that mostly covered at high tide.

The Gadigal believe that the coming together of the saltwater (from the Pacific Ocean) and freshwater (from the Parramatta River) creates a surge of energy and nutrients – making the Sydney Harbour an ideal spot for fishing, eating, meeting and sharing stories.

Tubowgule
Now known as Bennelong Point

Being close to the harbour, cove, freshwater creek and mud flats, the area was rich in resources. This included oysters, mussels, fish, possums, wallabies, kangaroos and many edible plants.

Aboriginal people gathered and ate these foods over thousands of years, leaving behind shells and animal bones that formed 'middens' around Sydney Harbour

Whispers, 2023, Megan Cope, Sydney Opera House.
This was an art installation of a midden made of 85,000 repurposed oyster shell waste and other natural and recycled materials.

The Sydney Opera House
A building nobody thought was possible

In 1956, the NSW government held an international competition for a new performing arts centre on Tubowgule, now known as Bennelong Point.

Over 220 entries arrived from 32 countries, and the winner was a Danish architect named Jørn Utzon.

Today, the Opera House is a World Heritage-listed building and the country's number one tourist destination.

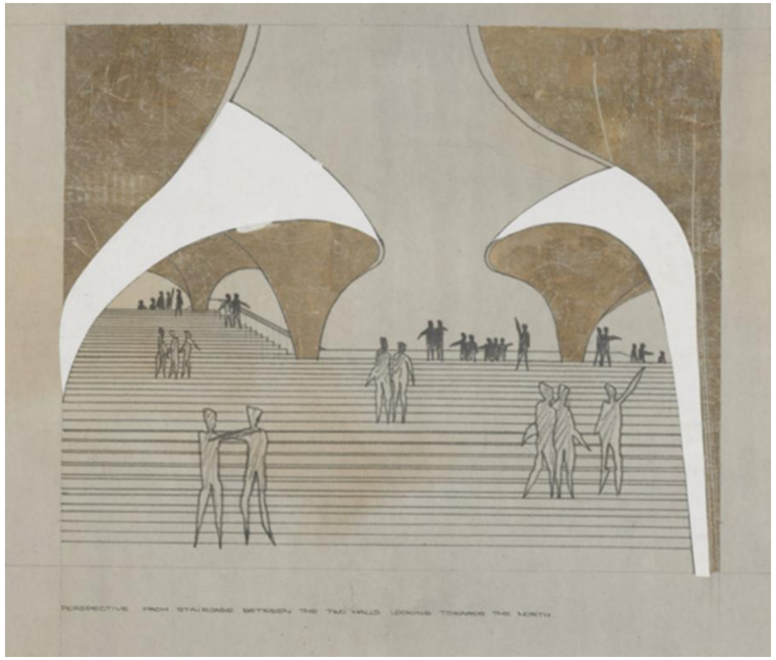
It welcomes more than 10.9 million visitors a year and hosts more than 1,800 performances attended by more than 1.4 million people.

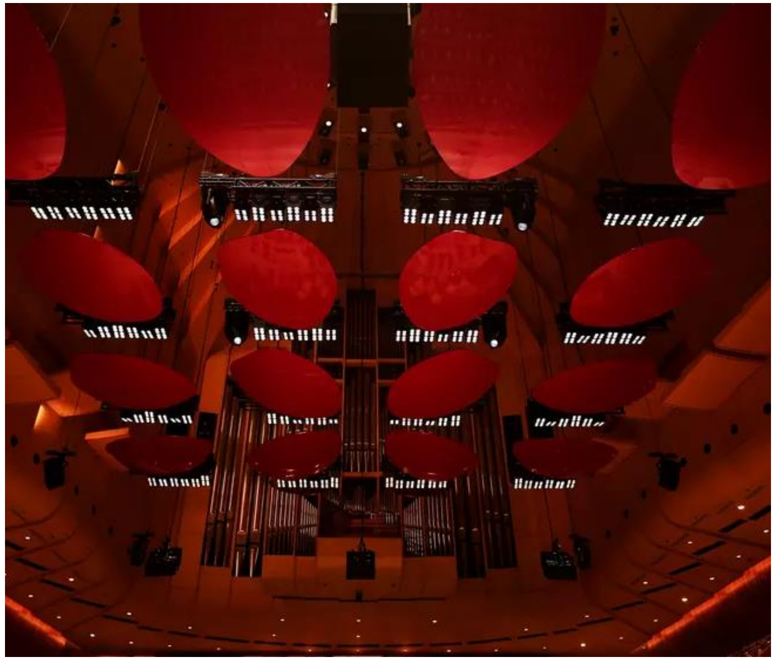
Jørn Utzon
The vision: shells, sails and nature

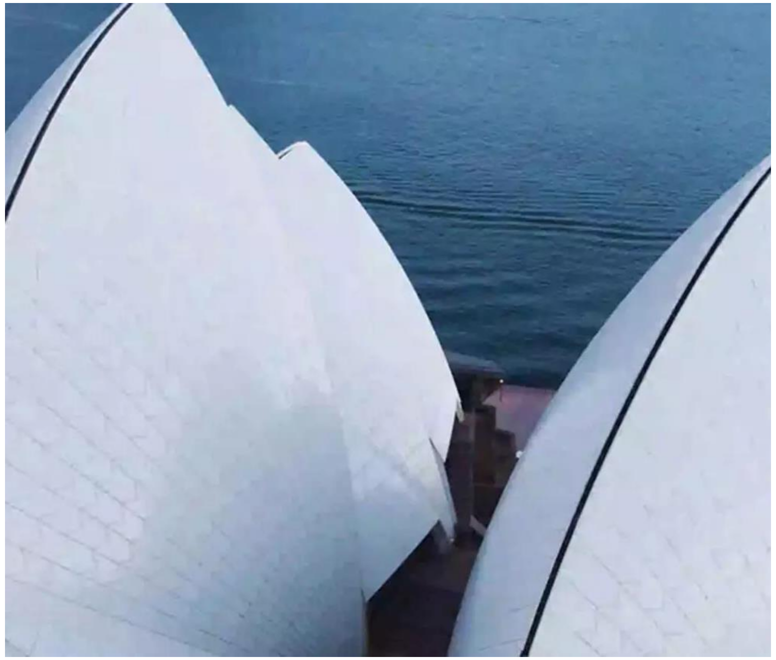
When designing the Opera House, Jørn Utzon was inspired by nature. The way an orange peels apart, the curve of a nautilus shell, the wings of a bird, the colours of the sunrise, and the sunset.

Utzon was also interested in how designs inspired by nature can shape the visitor experience.

He wanted the building to bring joy, transport people to another world, offer a sense of detachment from the city, and create moments of rest.







Jørn Utzon
The engineering problem

Utzon's iconic 'shell' roof forms grew from a single geometric principle – a striking idea on paper, but nobody knew how to actually build them.

To work out how to build the shells, the engineers at Arup & Partners needed to express the shapes mathematically.

In 1958, when they asked Utzon to define the curves of the roof, he took a plastic ruler, bent it against a table, and simply traced the curves

This drawing by Jørn Utzon shows the thinking behind the design's development, and how the natural world and organic forms can inspire a building.

Jørn Utzon
The Spherical Solution

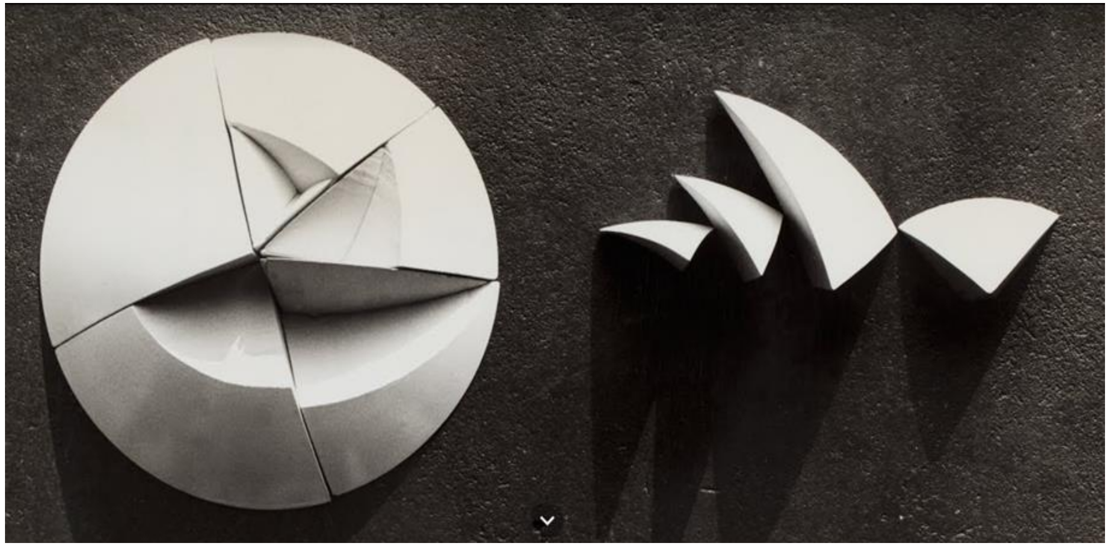
In 1961, Utzon had a breakthrough idea: what if every shell roof was cut from the same sphere?

No matter where you slice a sphere, the curve is the same shape.

That meant Utzon didn't need to design a different curve for each shell. He could cut them all from one sphere, like cutting different-sized wedges from one orange.

The shells could be different sizes, but they'd all share the same curve, which made them possible to build and made the whole roof feel like one connected family of shapes.

With help from designers, engineers and computer experts, Utzon and the team finally worked out how to turn this idea into a real building.



Jørn Utzon
Prototypes and prefabrication

Building the Opera House was incredibly difficult. Through a long process of trial and error, Utzon and his team worked through the design with sketches, models and prototypes.

Construction actually began before the working drawings were finished. Once builders and engineers were happy with a prototype, they could make a mould, or blueprint, of the final sections.

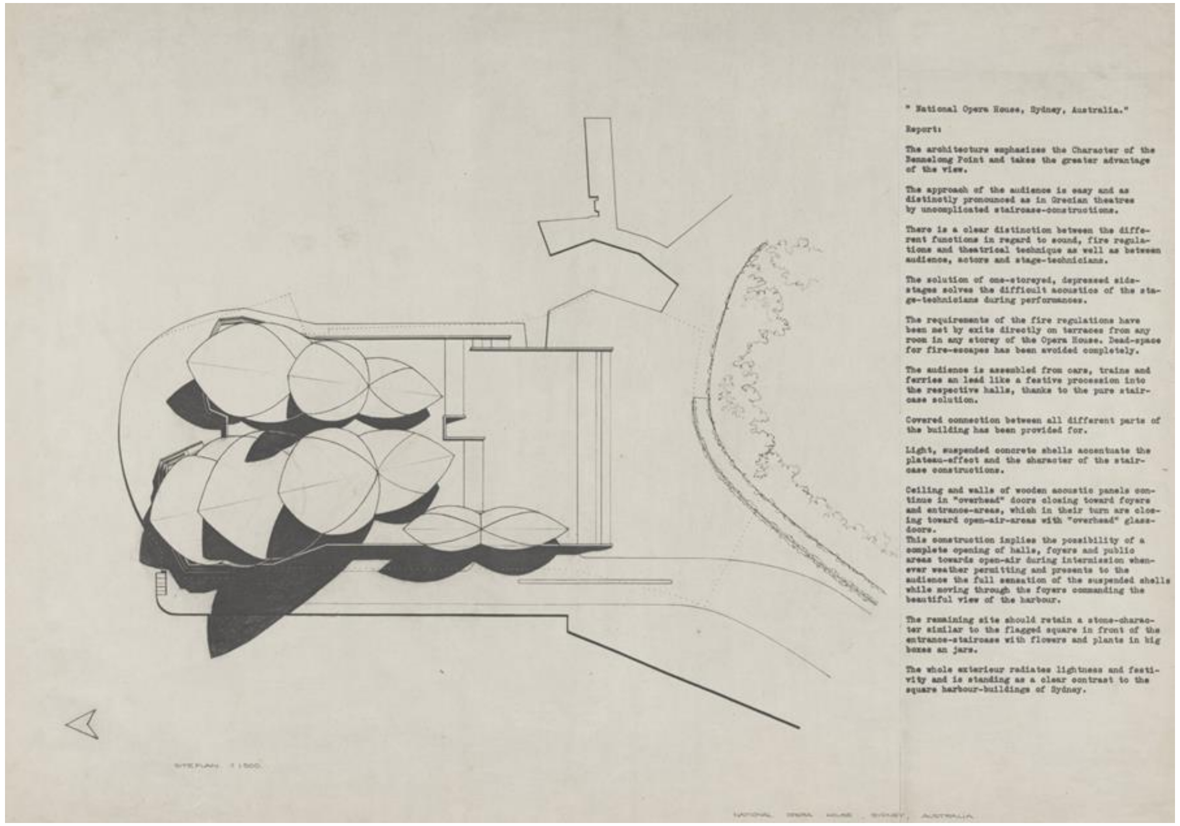
From there, all the pieces needed could be produced quickly and easily – a process called prefabrication.

Jørn Utzon

The Utzon Design Principles

The Utzon Design Principles are a document prepared by architects Jørn Utzon and Richard Johnson.

They outline Utzon's vision for the Sydney Opera House, its setting, and his thoughts on its future.



Jørn Utzon

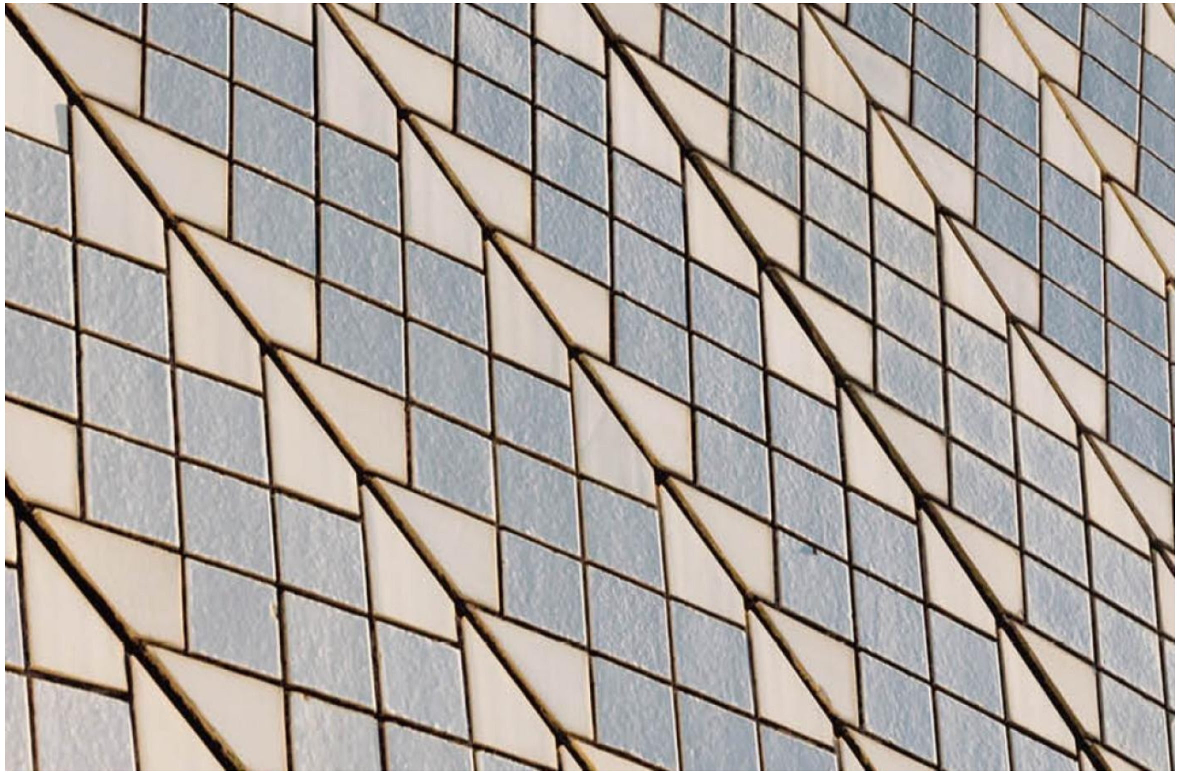
The tiles

Utzon wanted the shells to contrast with the deep blue of Sydney Harbour and the clear blue of the Australian sky.

The tiles needed to be glossy but not cause glare. Utzon was inspired by Japanese ceramic bowls, which were slightly coarse and had a granular texture in the clay.

Three years of work by Höganäs of Sweden produced the effect Utzon wanted: 120mm square tiles, made from clay and crushed stone.

Tiles were placed face down in one of 26 chevron-shaped beds, each with a base shaped to match the curve of the roof. In total, there are 1,056,006 tiles on the roof.



Activities

Discussion Questions

Where have you seen geometry in the world around you? In buildings, nature, or everyday objects? What shapes appear the most often and why do you think that is?

What do you think mathematics and art have in common?

Jørn Utzon described the Sydney Opera House as a sculpture. What do you think the difference between a building and a sculpture is?

If you were going to design a building using only one geographic shape repeated over and over, what shape would you choose and why?

If you were to redesign a part of the Opera House using what you know now about geometry and engineering, what would you change and why?

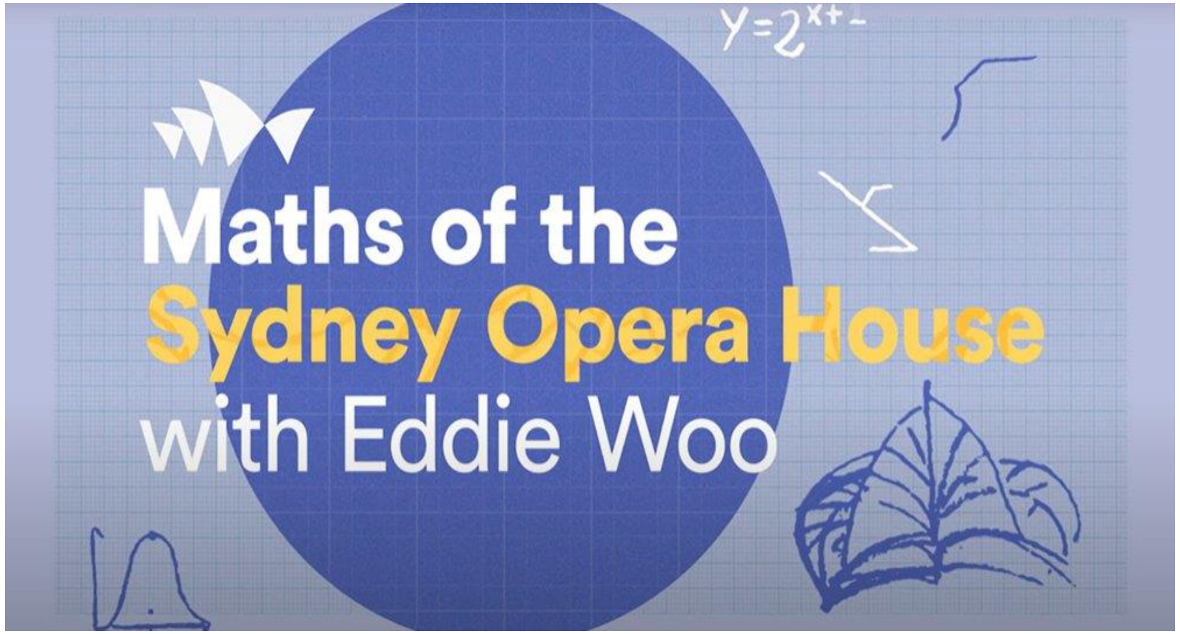
Activity 1

The purity of geometry

Watch this video to find out how geometry and Utzon's 'Spherical Solution' resolved the construction dilemma that the unique design of the arched sails caused.

Ask students to take notes on the following questions:

- What was the actual problem?
- What was Utzon's solution?
- How did geometry make construction possible?



Eddie Woo and Peter Mould, former NSW Government Architect.

Activity 1
Mathematicians

Students watch the Eddie Woo video and create their own short video explanation of the Spherical Solution. Their explanation must include:

- The problem: what made the Opera House shells so difficult to build?

- The geometry: a labelled diagram showing how a sphere can produce different shell shapes from the same surface. This doesn't need to be technically precise, but it needs to show understanding.

- Why it matters: one sentence explaining what would have happened to the Opera House if the solution hadn't been found.

- A question: something the video or the workshop made them curious about that they haven't found the answer to yet.

Activity 2

The purity of geometry

In groups, imagine you're designing ten shell shaped roofs for a building. Making custom parts for each one would cost too much.

The challenge: every shell must be built from the same set of parts, repeated and arranged in different ways.

Think about LEGO: one set of bricks can build many different things, because the pieces are designed to fit together in lots of ways.

Your task: design one repeatable part (a single shape or panel) that could be arranged, rotated, or combined to create ten different roof forms. Sketch or describe your solution, and be ready to explain:

- What shape you chose as your base unit, and why
- How arranging copies of it differently produces different roof shapes

Reflection

Exit Questions

What did you learn?

What is one thing about the Opera House that surprised you today?

I used to think geometry was about… but now, I think…

If you had to explain the Spherical Solution to someone who didn't know what it was, how would you describe it in two sentences?

Would you like to be someone who designs a building, or someone who builds it?

Key Learning Areas Curriculum Map – NSW Syllabus Outcomes

Dissecting Geometry – Stage 3 – 5

Visual Arts
Stage 3 – 5 (Yr 5 – 10)

CA3-VIS-01
Makes artworks in intentional ways to represent ideas about their world, and explains ways artists are influenced by contexts and how artworks are interpreted by audiences

VA4-AMV-01
Makes artworks to represent ideas that explore Artworld concepts and their relationships

VA5-AMC-01
Makes and refines artworks to represent different ideas informed by an understanding of Artworld concepts and their relationships

VA5-CHV-01
Interprets meaning and significance of artworks and the artworld using Viewpoints

Mathematics
Stage 3 (Yr 5 - 6)

MA3-GM-02
Selects and uses the appropriate unit and device to measure lengths and distances including perimeters

MA3-GM-03
Measures and constructs angles, and identifies the relationships between angles on a straight line and angles at a point

MA3-2DS-01
Investigates and classifies two-dimensional shapes, including triangles and quadrilaterals based on their properties

MA3-2DS-03
Combines, splits and rearranges shapes to determine the area of parallelograms and triangles

MA3-3DS-01
Visualises, sketches and constructs three-dimensional objects, including prisms and pyramids, making connections to two-dimensional representations

Mathematics
Stage 4 (Yr 7 - 8)

MA4-GEO-C-01
Identifies and applies the properties of triangles and quadrilaterals to solve problems

MA4-ANG-C-01
Applies angle relationships to solve problems, including those related to transversals on sets of parallel lines

MA4-LEN-C-01
Applies knowledge of the perimeter of plane shapes and the circumference of circles to solve problems

MA4-ARE-C-01
Applies knowledge of area and composite area involving triangles, quadrilaterals and circles to solve problems

MA4-VOL-C-01
Applies knowledge of volume and capacity to solve problems involving right prisms and cylinders

Mathematics
Stage 5 (Yr 9 - 10)

MA5-GEO-01
Applies analytical and computational thinking to recognise congruent and similar shapes, and applies the properties of similar figures to solve problems

MA5-GEO-02
Applies deductive reasoning to evaluate, prove and apply results related to triangles and trapeziums

Design and Technology
Stage 4 - 5 (Yr 7 - 10)

DITLS-IVT-01
Recognises designed products used in everyday life

DITLS-WOR-01
Identifies ways that designers work

DITLS-DES-01
Participates in developing design ideas

DITLS-MAT-01
Recognises the properties of a range of materials

DITLS-USE-01
Uses materials, tools or equipment for design or production

DITLS-COM-01
Communicates ideas and information in design and production contexts

Design and Technology
Stage 5 (Yr 9 – 10)

DIT5-COM-01
Communicates ideas, concepts, processes and solutions for design and production

DIT5-DEP-01
Applies technical and practical skills for design and production

DIT5-MAT-01
Selects and justifies the use of materials based on their properties and suitability for purpose

DIT5-USE-01
Selects and justifies the use of materials, tools, equipment and processes to make products

DIT5-EVL-01
Develops and evaluates innovative design solutions using quality principles and design processes

Geography
Stage 4 – 5 (Yr 7 – 10)

GE4-DFC-01
Locates the diverse features and describes the characteristics of a range of places and environments

GE5-DFC-01
Locates the diverse features and describes the characteristics of a range of places and environments