Government of **Western Australia**
School Curriculum and Standards Authority

ENGINEERING STUDIES

ATAR course

Year 11 syllabus

Acknowledgement of Country

Kaya. The School Curriculum and Standards Authority (the Authority) acknowledges that our offices are on Whadjuk Noongar boodjar and that we deliver our services on the country of many traditional custodians and language groups throughout Western Australia. The Authority acknowledges the traditional custodians throughout Western Australia and their continuing connection to land, waters and community. We offer our respect to Elders past and present.

Important information

This syllabus is effective from 1 January 2025.

Users of this syllabus are responsible for checking its currency.

Syllabuses are formally reviewed by the School Curriculum and Standards Authority (the Authority) on a cyclical basis, typically every five years.

2013/33814[v5]

Contents

Rationale

Engineers are involved in the design, manufacture and maintenance of a diverse range of products and infrastructure integral to the functioning of society, business and industry. They rely strongly on their creativity and problem solving to turn ideas into reality, by applying lateral thinking and mathematical and scientific principles to develop solutions to problems, needs and opportunities. An engineer also needs to be socially aware and involved in broader community issues such as impacts on the environment, sustainable energy, health and safety, and consultation processes to understand social attitudes and opinions.

The Engineering Studies ATAR course provides opportunities for students to investigate, research and present information, design and make products and undertake project development. These opportunities allow students to apply engineering processes, understand underpinning scientific and mathematical principles, develop engineering technology skills and explore the interrelationships between engineering and society.

The Engineering Studies ATAR course focuses on real-life contexts through a blend of theoretical and practical applied learning. It aims to prepare students for a future in an increasingly technological world by providing the foundation for life-long learning about engineering. It is particularly suited to those students who are interested in engineering and technical industries as future careers.

Aims

The Engineering Studies ATAR course is designed to enable students to:

- identify and compare forms, sources and uses of energy
- apply and communicate a process to design, make, and evaluate engineered products through
  - investigating needs and opportunities
  - generating engineering production proposals to provide solutions
  - managing engineering production processes to produce solutions
  - evaluating intentions, plans and actions
- understand and explain properties and behaviours of materials and components
- understand and apply scientific and mathematical concepts used in the engineering context
- use materials, skills and technologies when undertaking an engineering challenge by
  - applying initiative and organisational skills
  - applying skills of calculation and computation
  - utilising materials, techniques and technologies to achieve solutions to engineering challenges
  - operating equipment and resources safely
- investigate, analyse and understand the interrelationships between engineering projects and society, the environment and industry.

Organisation

This course is organised into a Year 11 syllabus and a Year 12 syllabus. The cognitive complexity of the syllabus content increases from Year 11 to Year 12.

Structure of the syllabus

The Year 11 syllabus is divided into two units, each of one semester duration, which are typically delivered as a pair. The notional time for each unit is 55 class contact hours.

Unit 1

Given guidelines and a context, students use an engineering design process to develop and respond to a design brief that has a problem, need or opportunity as its focus. Design ideas are developed through research of similar products and associated components and materials leading to annotated sketches and concept drawings. Students then select and analyse the most suitable concept for production as a prototype or working model. They finalise their chosen design by documenting its specifications in the form of orthographic drawings, specialist diagrams, and lists of materials and components, including the costing of these items. By following a given timeline, students begin to undertake the production of their product, including formative testing and evaluation.

Through the study of core and specialist area theory, students develop their understanding of the scientific, mathematical and technical concepts that explain how engineered products function.

They also study the effects on society, the environment and industry of obtaining and using different forms of renewable and non-renewable energy.

Unit 2

Students apply the engineering design process to improve their knowledge, understandings and skills necessary to complete the production of their major project and to test and evaluate the resulting product.

They continue to study core and specialist area theory to further develop their understanding of the scientific, mathematical and technical concepts necessary to predict and explain the behaviour of engineered products.

Students also consider and analyse different forms of obsolescence in the context of engineered products. Furthermore, they develop and demonstrate an understanding of the effects on society, the environment and industry that occur due to obsolescence.

Each unit includes:

- a unit description – a short description of the purpose of the unit
- unit content – the content to be taught and learned.

Organisation of content

The course content is sequential and hierarchical in nature, and increases in complexity as further units are studied.

Course content contains core content material and two specialist fields. The core content uses an engineering design process to enable students to learn about engineering in a practical project-focused approach. The study of core content develops student knowledge, understandings and skills of general engineering concepts and processes. The content of the two specialist fields allows students to develop a more specific practical understanding of major engineering and industrial technologies.

Core content

- Engineering design process
- Materials
- Fundamental engineering calculations
- Mechanisms
- Effects on society, the environment and industry

Specialist engineering fields

- Mechanical

OR

- Mechatronics

Core content

Engineering design process

Investigating

The starting point for the engineering design process is creating, interpreting and responding to a design brief. Existing engineered products, materials, components and sources of energy are researched to develop greater understanding of what a solution might include.

Devising

Annotated sketches and drawings of design ideas are used to generate concepts that are analysed and compared to the requirements of the design brief. The preferred concept is identified and used for the production phase.

Producing

The production phase commences with the specifications of the chosen design being confirmed and documented. Pictorial and orthographic drawings are produced that contain sufficient information for manufacture of the product to be undertaken. Depending on the specialist area being studied, there may also be other forms of drawing or graphics necessary to explain the final solution. Materials and parts lists are derived from the drawings and production techniques identified. The construction and testing of the product – a prototype or working model – is undertaken by following safe and appropriate work practices and by following a timeline.

Evaluating

Evaluation occurs throughout the engineering design process to assess the viability, appropriateness and performance of existing solutions, materials, components, energy systems, design ideas, construction methods and the final prototype or working model.

Materials

Identifying and understanding the characteristics of common materials used in engineering is a necessary requirement for the selection and use of materials that contribute to the safe and reliable operation of engineered products.

Fundamental engineering calculations

Applying mathematical concepts is a fundamental requirement for the Engineering Studies ATAR course. This entails extracting data from drawings, charts, diagrams and tables; determining perimeters, surface area, volume, density and mass of engineered products; simple energy and efficiency calculations; and using unfamiliar formulae to solve problems.

Mechanisms

Identifying and understanding the characteristics of common simple machines and mechanisms, including the mechanics of motion, drive systems, formulas and calculations, and quantities used to measure variables associated with inputs and outputs of mechanical systems.

Effects on society, the environment and industry

The effects of engineering on society, the environment and industry are vital considerations in engineering. Two major concepts are studied. These are: forms, sources and uses of energy; and the nature of obsolescence and its different forms.

Specialist engineering fields

Mechanical

The content in this section is specialised knowledge that applies to mechanical engineering. It is divided into three content areas:

- Materials
- Statics
- Dynamics.

An understanding of the scientific and mathematical nature and properties of materials underpins fundamental decisions concerning their selection and use in the design of engineering projects.

Materials used in engineering and solid-state structures are classified, on the basis of their structure and properties. Metals, polymers, composites and timber products are materials commonly used in engineering because of their structure and properties, both static and dynamic.

Young's modulus and stress/strain graphs are fundamental to all materials, structures and mechanical principles used throughout engineering.

There are testing regimes for stress, strain, tension, compression and torsion. The analysis of results from such regimes, together with information on existing data and specifications tables, forms the basis for selecting materials for engineering technologies.

Structures are defined as a body of materials selected and used because they can resist applied forces. Equilibrium, forces, structures, bending moments, shear force, torsion and Newton's three laws of motion are important when analysing static loads and the application of forces to structures.

Newton's three laws of motion in conjunction with equilibrium principles are the basis for analysing engineering mechanisms and motion conversion systems.

Mechatronics

The content in this section is specialised knowledge that applies to students who are undertaking the study of mechatronics. It is divided into two content areas:

- Electrical and electronics
- Systems and control.

Mechatronics is a multidisciplinary field that refers to the skill sets needed in contemporary advanced automated technology industries. At the intersection of mechanics, electronics and computing, mechatronics specialists create simpler, smarter systems. Mechatronics is an essential foundation for the growing trends in robotics and automation in many fields such as manufacturing, minerals processing, mining, pollution control, renewable power generation and waste processing.

The subject content is based around the characteristics and use of microcontrollers and how they are interfaced into real-world applications

An understanding of scientific, mathematical and technical concepts contained in the two content areas coupled with the engineering core content and design process provides students with the opportunity to design, make, analyse, test and evaluate mechatronic devices.

Progression from the Years 7–10 curriculum

This syllabus builds on the design and technology explored in the Years 7–10 Technologies curriculum with learning experiences which allow students to develop systems, design and computational thinking, create digital solutions, and create product-, service- and environment-designed solutions.

This syllabus continues to develop students' understandings of engineering principles and systems and skills in the design of engineering solutions.

Representation of the general capabilities

The general capabilities encompass the knowledge, skills, behaviours and dispositions that will assist students to live and work successfully in the twenty-first century. Teachers may find opportunities to incorporate the capabilities into the teaching and learning program for the Engineering Studies ATAR course. The general capabilities are not assessed unless they are identified within the specified unit content.

Literacy

Literacy is of fundamental importance in the study of the Engineering Studies ATAR course. Students access engineering and technological content through a variety of print, oral, visual, spatial and electronic forms, including data books, texts, computer software, images and written technical materials. They learn to investigate, interpret and apply engineering principles from a variety of sources to design solutions for engineering tasks. They analyse and evaluate information for authority, reliability, relevance and accuracy. They learn to monitor their own language use for accuracy in the use of design principles and technological terms, for clarity of ideas, processes and explanations of engineering activities, and for development and evaluation of functioning prototypes.

Numeracy

Numeracy is fundamental in calculating and evaluating engineering processes. Students develop their understanding and skills of numeracy while undertaking tasks to produce, test and evaluate engineered products. They continue to study core and specialist area theory to forge greater understanding of the scientific, mathematical and technical concepts that explain how engineered products function.

Information and communication technology capability

Information and communication technology (ICT) capability is important in all stages of the design process. Students use digital tools and strategies to locate, access, process and analyse information. They use ICT skills and understandings to investigate and devise design ideas. Students access information from websites and software programs to develop design solutions. Students use computer-aided drawing software and computer control software to produce engineered products.

Critical and creative thinking

Critical and creative thinking is integral to the design process. Design thinking methodologies are fundamental to the Engineering Studies ATAR course. Students develop understandings and skills in critical and creative thinking during periods of evaluation at various stages of the design process. They devise plausible solutions to problems and then, through interrogation, critically assess the performance of the most efficient solution. Students identify possible weaknesses in their design solutions, and analyse, evaluate and modify the developing solution to construct a functioning prototype.

Personal and social capability

Personal and social capability skills are developed and practiced in the Engineering Studies ATAR course by students enhancing their communication skills and participating in teamwork. Students have opportunities to work collaboratively during stages of investigation and when producing engineering products. Students develop increasing social awareness through the study of the impact of engineering in society and on the environment.

Ethical understanding

Students have opportunities to explore and understand the diverse perspectives and circumstances that shaped engineering technology, and the actions and possible motivations of people in the past compared with those of today. Students have opportunities, both independently and collaboratively, to explore the values, beliefs and principles that have influenced past engineering achievements and global engineering activities of today.

Intercultural understanding

Students have opportunities to explore the different beliefs and values of a range of cultural groups and develop an appreciation of cultural diversity. Students have opportunities to develop an understanding of different contemporary perspectives with regard to building materials, styles of structures, energy supply and use, and engineering and technological influences on different groups within society, and how they contribute to individual and group actions in the contemporary world.

Representation of the cross-curriculum priorities

The cross-curriculum priorities address the contemporary issues which students face in a globalised world. Teachers may find opportunities to incorporate the priorities into the teaching and learning program for the Engineering Studies ATAR course. The cross-curriculum priorities are not assessed unless they are identified within the specified unit content.

Aboriginal and Torres Strait Islander histories and cultures

Students have opportunities to explore Aboriginal and Torres Strait Islander development and use of engineering and technology, and the interconnectedness between technologies and identity, people, culture and Country. Students understand that many engineering activities occur on Country.

Asia and Australia's engagement with Asia

Students have opportunities to explore traditional, contemporary and emerging technological achievements in the countries of the Asia region. Students explore Australia's rich and ongoing engagement with the peoples and countries of Asia to create appropriate products and services to meet personal, community, national, regional and global needs.

Sustainability

Students take action to create more sustainable patterns of living. Students develop knowledge, understanding and skills necessary to design for effective sustainability.

Students focus on the knowledge, understanding and skills necessary to choose technologies and systems with regard to costs and benefits. They evaluate the extent to which the process and designed solutions embrace sustainability. Students reflect on past and current practices, and assess new and emerging technologies from a sustainability perspective.

Unit 1

Unit description

Given guidelines and a context, students use an engineering design process to develop and respond to a design brief that has a problem, need or opportunity as its focus. Design ideas are developed through research of similar products and associated components and materials leading to annotated sketches and concept drawings. Students then select and analyse the most suitable concept for production as a prototype or working model. They finalise their chosen design by documenting its specifications in the form of orthographic drawings, specialist diagrams, and lists of materials and components, including the costing of these items. By following a given timeline, students begin to undertake the production of their product including formative testing and evaluation.

Through the study of core and specialist area theory, students develop their understanding of the scientific, mathematical and technical concepts that explain how engineered products function.

They also study the effects on society, the environment and industry of obtaining and using different forms of renewable and non-renewable energy.

Unit content

This unit includes the knowledge, understandings and skills described below. It is divided into core content and specialist engineering fields. Students must study **all** of the core content material and **one** of the specialist engineering fields.

Core content

Engineering design process

Investigating

- develop a design brief in response to a problem, need or opportunity, given guidelines and a context
- conduct research to identify and assess existing solutions/products
- research and critique materials and components relevant to the design brief
- consider different ways to supply energy for efficient and effective functioning of the design

Devising

- produce annotated pictorial sketches and/or drawings of design ideas
- produce annotated third-angle orthographic sketches and/or drawings of design ideas
- compare and analyse alternative designs and justify the choice of option to be used as the solution

Producing

- present specifications for the selected solution
- produce dimensioned pictorial and orthographic drawings
- produce third-angle orthographic projections that comply with the accepted standards for
  - lines – outlines, hidden detail and centrelines
  - dimensioning – linear, radii, circles, through holes or partial depth with flat base

- select materials with justification of choices
- present a parts lists
- present costing of project, i.e. the prototype or working model
- display project management skills for timely development and testing of the project
- construct a prototype or working model by selecting and using appropriate tools and machines, and by following safe work practices
- test those aspects of the prototype or working model that have been completed for correct function and document using checklists and test data

Evaluating

- evaluate the development of the project
  - meeting the requirements of the design
  - safety, function fit and finish
  - modifications and changes to the design during production

Materials

Types and classification

- define
  - metals (pure)
  - alloys
    - ferrous
    - non-ferrous
  - polymers
    - thermoplastic
    - thermoset
    - elastomer
  - composite
- classify
  - metals (pure)
    - aluminium
    - copper
    - zinc
    - iron
  - alloys
    - ferrous (includes major constituents)
      - steel (iron and carbon)
      - stainless steel (iron, carbon, nickel and chromium)
      - cast iron (iron and carbon)
    - non-ferrous (includes major constituents)
      - brass (copper and zinc)
      - bronze (copper and tin)
  - polymers
    - thermoplastic (abbreviations only where applicable)
      - acrylic

    - polycarbonate
    - ABS (acrylonitrile butadiene styrene)
    - PLA (polylactic acid)
    - PVC (polyvinyl chloride)
  - thermoset
    - epoxy and polyester resin
  - elastomer
    - natural and synthetic rubber
- composite
  - concrete
    - normal and reinforced
  - fibre-reinforced plastic (FRP)

Fundamental engineering calculations

Dimensional

- examine dimensioned drawings to determine
  - overall length, height and width
  - direct and indirect dimensions: linear measurements, radii and diameters

Perimeter

- determine perimeter of
  - square and rectangular plane figures
  - right-triangular plane figures
    - Pythagoras' theorem
      - $a^2 + b^2 = c^2$ where c is the hypotenuse and a and b are the other two sides
  - circles
    - $C = \pi d$

Surface area

- determine surface area of
  - square and rectangular plane figures
  - cubes and rectangular right-prisms
  - right-triangular plane figures
  - triangular right-prisms
  - circles
    - $A = \pi r^2$
  - open-ended cylinders
    - $A = \pi dh$

Volume

- determine volume of
  - cubes, rectangular right-prisms and triangular right-prisms
  - cylinders
    - $V = \pi r^2 h$
  - spheres
    - $V = \frac{4}{3}\pi r^3$

Units

Quantity	Unit name	Unit
length (L)	metre	m
area (A)	square metre	m^2
volume (V)	cubic metre	m^3

Prefixes

Prefix	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Mechanisms

Simple machines and mechanisms

- mechanical advantage (MA)
  - definition and examples
    - inclined plane (including screw threads)
    - three classes of levers
- velocity ratio (VR)
  - definition and examples
- explain and give examples of the following types of motion
  - linear
  - reciprocating
  - rotary
  - oscillating
  - transformation of motion
    - rotary into linear
    - rotary into reciprocating
    - rotary into oscillating
- recognise and describe general characteristics and applications for
  - pulley belt
  - chain and sprocket
  - simple gear drive
    - idler gear
  - compound gear drive
  - worm and worm wheel (single start)
  - rack and pinion
  - lead screw (single start)

Effects on society, the environment and industry

Energy

- energy, work, and power
  - definitions
  - examples
- conservation of energy
  - definition
  - examples
- forms of energy
  - kinetic
    - definition
    - examples
  - potential
    - definition
    - examples
- non-renewable sources of energy
  - fossil fuels: coal, gas and oil
  - nuclear
- renewable sources of energy
  - solar
    - thermal and photovoltaic
  - wind
  - hydroelectric
  - geothermal
  - ocean
    - tidal and waves
  - hydrogen
    - assuming production uses renewable sources
- advantages and disadvantages for society, the environment and industry of obtaining and using non-renewable and renewable sources of energy

Specialist engineering field

Mechanical

Materials

Processes

- define each of the following engineering processes with respect to carbon steel and describe in point form the main steps of each process
  - hardening
  - tempering
  - normalising
  - case hardening
  - annealing
- describe the effect of carbon content (C%) in steel
- describe steel's ability to be work-hardened and changes that occur to its properties

Stress and strain

- define stress and use the formula to determine one unknown value
  $\sigma = \frac{F}{A}$
- define pressure and use the formula to solve for one unknown value using
  $P = \frac{F}{A}$
- define strain and use the formula to determine one unknown value
  $\varepsilon = \frac{\Delta L}{L}$
  (strain can be expressed as a percentage)
- define Young's modulus (elastic modulus) and use the formulae to determine one unknown value
  $E = \frac{\sigma}{\varepsilon}$ and its extension $E = \frac{FL}{A\Delta L}$

Units

Quantity	Unit name	Unit
stress (σ) or pressure (P)	newton per square metre or pascal	N m^{-2} Pa
	kilonewton per square metre or kilopascal	kN m^{-2} kPa
	newton per square millimetre or megapascal	N mm^{-2} MPa
	kilonewton per square millimetre or gigapascal	kN mm^{-2} GPa
force (F)	newton	N
area (A)	square metre	m^2
strain (ε)	no unit (ratio of length over length)	
length (L)	metre	m
Young's modulus (E)	kilonewton per square millimetre or gigapascal	kN mm^{-2} GPa

Statics

- resolve force triangles and parallelograms to find unknown angles or forces
- resolve for unknown force or distance in both simply supported and cantilevered beams
- use the moments formula to determine one unknown variable, where the unknown variable does not require vector resolution
  - $M = Fd$
- state the three conditions for equilibrium as per
  - $\Sigma M = 0$ or $\Sigma CWM = \Sigma ACWM$
  - $\Sigma F_x = 0$ or $\Sigma F_{left} = \Sigma F_{right}$
  - $\Sigma F_y = 0$ or $\Sigma F_{up} = \Sigma F_{down}$

  Note: for this course the conventions are that CWM is positive, F_{right} is positive and F_{up} is positive
- Use $\Sigma CWM = \Sigma ACWM$ and $\Sigma F_y = 0$ to determine the reaction forces at a horizontal structure's supports (only two supports and only vertical forces applied)
- Use $\Sigma CWM = \Sigma ACWM$ to solve for one unknown force or distance variable

Units

Quantity	Unit name	Unit
moment (M)	newton metre	N m
force (F)	newton	N
distance (d)	metre	m

Specialist engineering field

Mechatronics

Electrical and electronics

Components and equipment

- circuit symbols, appearance and characteristics of
  - cells and batteries
  - power supply (DC)
  - fuse
  - voltage regulator
    - 3-pin fixed voltage positive (7805 or similar)
  - switches
    - SPST, SPDT and DPDT
    - push to make (N/O) and push to break (N/C)
    - N/O magnetic reed
  - fixed value resistors
  - potentiometer
    - including its use as a variable resistor
  - light dependent resistor (LDR)
  - thermistor (NTC)
  - capacitor
    - polarised (electrolytic and tantalum)
    - non-polarised (assume not electrolytic or tantalum)
  - diodes
    - silicon rectifier
    - LED
  - piezo sounder
  - electromagnet including solenoid
  - DC motor
  - SPDT and DPDT relays
  - transistor
    - NPN
  - integrated circuits
    - voltage regulator (7805 or similar)
    - microcontroller
    - L293D or similar H-bridge IC
    - UNL2803 Darlington driver or similar

- read and understand markings
  - fixed value resistors – 4 band E12 values
  - capacitors: E12 values, µF (polarised) and 3-digit labelling (non-polarised)
  - serial numbers
    - refer to data sheets or diagrams to identify component and determine pinouts for:
      - voltage regulator
      - NPN transistors
      - integrated circuits (including microcontroller)
- read and sketch circuit diagrams that contain listed components
- multimeter
  - correct setup and use to measure
    - voltage
    - resistance
    - current

Laws and principles

- charge
  - $q = It$
- Ohm's law
  - $V = IR$
- power
  - $P = VI = I^2R = \frac{V^2}{R}$
- voltage
  - $V = \frac{P}{I} = \sqrt{PR}$
- current
  - $I = \frac{V}{R} = \frac{P}{V} = \sqrt{\frac{P}{R}}$
- resistance
  - $R = \frac{V}{I} = \frac{P}{I^2} = \frac{V^2}{P}$
- Kirchhoff's laws
  - Kirchhoff's voltage law (KVL)
    - $\Sigma \Delta V = 0$
  - Kirchhoff's current law (KCL)
    - $\Sigma I = 0$
- cells and batteries
  - series
    - $V_T = V_1 + V_2 + \cdots$
    - $I_T = I_1 = I_2 = \cdots$
  - parallel
    - $V_T = V_1 = V_2 = \cdots$
- resistor networks
  - series
    - $R_T = R_1 + R_2 + \cdots$
  - parallel
    - $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

- combinational
  - apply following formulae
    - series resistances
    - parallel resistances
    - Ohm's law
    - power
    - KVL
    - KCL
- capacitor networks
  - series
    - $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$
  - parallel
    - $C_T = C_1 + C_2 + \cdots$
- voltage dividers
  - $V_1 = V_{CC} \times \frac{R_1}{R_1 + R_2}$
  - $V_2 = V_O = V_{CC} \times \frac{R_2}{R_1 + R_2}$
  - $V_{CC} = V_1 + V_2$
- diodes
  - silicon rectifier diode
    - forward and reverse bias
    - 0.6 V forward voltage
    - back emf protection
    - reverse voltage protection
    - AC/DC rectification (full wave bridge rectifier with smoothing)
- light emitting diode (LED)
    - forward and reverse bias
    - forward voltage from data sheet
    - current limiting resistor
      - $R = \frac{V_{CC} - V_{LED}}{I_{LED}}$
      - KVL
      - KCL

Units

Quantity	Unit name	Symbol
charge (q)	coulomb	C
electric potential difference/emf (V)	volt	V
current (I)	ampere	A
resistance (R)	ohm	Ω
power (P)	watt	W
capacitance (C)	farad	F

Systems and control

Systems and control diagrams

- universal block diagram
  - input
  - process
  - output
- subsystem diagram
  - systems boundary
  - external input/s
  - external output/s
  - subsystems within boundary
    - microcontroller
    - programming
    - interfacing circuits
      - sensors
      - driver circuits
    - actuators
      - electromagnet including solenoid
      - DC motor
    - mechanisms
- open-loop
  - input
  - processes
  - output
  - no feedback from output to input
- closed-loop
  - input
    - set point
  - controller
  - system (plant)
  - output
  - output sensor
  - feedback loop

Unit 2

Unit description

Students apply the engineering design process to improve their knowledge, understandings and skills necessary to complete the production of their major project and to test and evaluate the resulting product.

They continue to study core and specialist area theory to further develop their understanding of the scientific, mathematical and technical concepts necessary to predict and explain the behaviour of engineered products.

Students also consider and analyse different forms of obsolescence in the context of engineered products. Furthermore, they develop and demonstrate an understanding of the effects on society, the environment and industry that occur due to obsolescence.

Unit content

This unit builds on the content covered in Unit 1.

This unit includes the knowledge, understandings and skills described below.

Core content

Engineering design process

Producing

- present specifications for the selected solution
- produce annotated pictorial drawings
- produce third-angle projections that comply with accepted standards for
  - lines – outlines, hidden detail and centrelines
  - dimensioning – linear, radii, circles, through holes and partial depth holes with flat base
- select materials with justification of choices
- present a parts lists
- present costing of project, i.e. the prototype or working model
- display project management skills for timely completion and testing of the project
- construct the prototype or working model by selecting and using appropriate tools and machines, and by following safe work practices
- test the prototype or working model for correct function and document using checklists and test data

Evaluating

- evaluate the prototype or working model
  - meeting the requirements of the design
  - safety, function, fit and finish
  - modifications and changes to the design during production

Materials

Properties

- define
  - density
  - elasticity
  - plasticity
  - ductility
  - malleability
  - strength
    - tensile
    - compressive
    - torsional
    - shear
  - stiffness
  - toughness
  - conductivity
    - thermal
    - electrical
  - corrosion resistance
  - hardness
- fitness for purpose
  - identify and describe the properties of a material required for a specified application

Fundamental engineering calculations

Density

- $density = \rho = \frac{m}{V}$

Quantity estimates

- determine the following for individual and simple combinations of previously specified Unit 1 geometric forms (may be solid and/or hollow)
  - surface area
  - volume
  - mass
  - density

Efficiency

- calculate efficiency as a percentage
  - $\eta = \frac{output}{input}$ x 100%

Unfamiliar formula

- determine unknown factor in unfamiliar formula given sufficient data to complete the calculation

Units

Quantity	Unit name	Unit
length (L)	metre	m
area (A)	square metre	m^2
volume (V)	cubic metre	m^3
mass (m)	kilogram	kg
density (ρ)	kilogram per cubic metre	kg m^{-3}

Prefixes

Prefix	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Mechanisms

- mechanical advantage (MA)
  - $MA = \frac{F_{load}}{F_{effort}}$
- velocity ratio (VR)
  - $VR = \frac{d_{effort}}{d_{load}}$
  - pulley belt
    - $VR = \frac{\emptyset_{follower}}{\emptyset_{driver}}$
  - chain and sprocket
    - $VR = \frac{n^o\ teeth_{(follower)}}{n^o\ teeth_{(driver)}}$
  - gear drive
    - $VR = \frac{n^o\ teeth_{(follower)}}{n^o\ teeth_{(driver)}}$
    - idler gear
  - worm and worm wheel (single start)
    - $VR = \frac{n^o\ teeth_{(worm\ wheel)}}{1}$
  - compound gear drive
    - compound gear
    - $VR = \frac{F_1 F_2 F_3}{D_1 D_2 D_3} \ldots$
      - F = n° teeth follower
      - D = n° teeth driver

- rack and pinion
  - $distance\ moved = \frac{n^o\ teeth\ pinion \times n^o\ revolutions}{n^o\ teeth\ per\ metre\ rack}$
- lead screw
  - single start
    - $distance\ moved = pitch\ \times revolutions$
- ideal machine (100% efficiency)
  - $MA = VR$
- speed
  - $speed\ (linear\ translation) = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$
  - $speed\ (rotational\ to\ linear\ translation) = \frac{(rpm)(2\pi r)}{60}$
  - $output\ speed\ (rpm) = \frac{input\ speed\ (rpm)}{VR}$
- torque
  - $\tau = rF$
    - no vector resolution required for calculations of torque

Units

Quantity	Unit name	Unit
average speed/velocity (v_{av})	metre per second	$m\ s^{-1}$
distance (d)	metre	m
displacement (s)		
time (t)	second	s
torque (τ)	newton metre	N m
force (F)	newton	N

Energy, work and power

Calculations

- energy
  - $E = Pt$
  - $E_P = mg\Delta h$
  - $E_K = \frac{1}{2}mv^2$
- work done
  - $W = \Delta E$
- work (linear)
  - $W = Fs = F\Delta x = F(x_f - x_i)$
- power
  - $P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t}$
- power (linear)
  - $P = \frac{Fs}{\Delta t} = \frac{F\Delta x}{\Delta t} = \frac{F(x_f - x_i)}{\Delta t} = Fv$
- power (electrical)
  - $P = VI$

Units

Quantity	Unit name	Unit
energy (E)	joule	J
	kilowatt hour	kW h
	megawatt hour	MW h
power (P)	watt	W
time (t)	second	s
mass (m)	kilogram	kg
gravity (g)	metre per second squared	m s^{-2}
height (h)	metre	m
velocity (v)	metre per second	m s^{-1}
work (W)	joule	J
force (F)	newton	N
distance (d)	metre	m
displacement (s)		
voltage (V)	volt	V
current (I)	ampere	A

Effects on society, the environment and industry

Obsolescence

- define and compare forms of obsolescence
  - technical
  - functional
  - planned
- describe advantages and disadvantages for society, industry and the environment that result from the different forms of obsolescence

Specialist engineering field

Mechanical

Materials

Stress and strain

- draw, label and interpret stress and strain graphs for common steel alloys
- define the following terms with reference to common steel alloys and their stress/strain graphs
  - yield stress
  - yield strain
  - ultimate tensile stress (UTS)
  - elastic limit

  Note: for this course of study elastic limit = proportional limit = yield point

Hardness test

- describe hardness tests
  - Vickers, Rockwell and Brinell

Toughness (impact) test

- describe toughness (impact test)
  - Charpy impact test
    - energy absorbed
  - discuss effect of temperature on results of test

Shear strength

- use ultimate shear strength (USS) to calculate force required to punch or shear various materials
  - $F = USS \times A$

Shear Stress

- determine shear stress in single shear and double shear couplings

Units

Quantity	Unit name	Unit
force (F)	newton	N
ultimate tensile stress (UTS) and ultimate shear stress (USS)	newton per square millimetre	N mm^{-2} or MPa
area (A)	square millimetre	mm^2

Dynamics

- Constant acceleration in straight-line motion
  - $F = ma$
  - $a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$
  - $v_f = v_i + a\Delta t$
  - ${v_f}^2 = {v_i}^2 + 2as$
  - $s = v_i\Delta t + \frac{1}{2}a\Delta t^2$
    - not quadratic equation

Units

Quantity	Unit name	Unit
force (F)	newton	N
mass (m)	kilogram	kg
acceleration (a)	metre per second squared	m s^{-2}
initial velocity (v_i)	metre per second	m s^{-1}
final velocity (v_f)		
displacement (s)	metre	m
time (t)	second	s

Specialist engineering field

Mechatronics

Electrical and electronics

Laws and principles

- NPN transistor model
  - cut-off
    - $I_B = I_C = 0$ A
  - forward-active
    - $\beta = \frac{I_C}{I_B}$
    - $I_B > 0$ A
    - $V_{BE} = 0.7$ V
    - $V_{CE} > 0$ V
  - saturation
    - $\frac{I_C}{I_B} < \beta$
    - $I_B > 0$ A
    - $V_{BE} = 0.7$ V
    - $V_{CE} = 0$ V
  - determine circuit values and variables
    - voltage
    - resistance
    - current
    - power
    - gain (β)
- data extraction
  - extract and use data from charts, graphs, tables and diagrams

Systems and control

Interfacing with microcontroller

- microcontroller
  - advantages and disadvantages
  - internal architecture – meaning and purpose of
    - CPU, ALU, clock (crystal/resonator/oscillator), ROM, RAM, EEPROM, I/O, ADC and bus
  - external connections
    - power
      - 5 V voltage regulator
      - 7805 or similar
      - input voltage as per data sheet
      - 5 V output
      - smoothing capacitors
    - digital pins (I/O)
      - two (2) states

        - high low
        - on off
        - 5 V 0 V
        - 1 0
      - input
        - virtually no current draw
      - output
        - current draw per pin and total as per data sheet
    - analogue pins
      - detects voltage on a scale 0–5 V
      - analogue to digital conversion (ADC)
      - virtually no current draw
    - serial
      - serial input (RX)
      - serial output (TX)
      - no need to code the above serial connections
- digital inputs
  - switch with pull-up resistor
  - switch with tie-down resistor
  - calculate digital states as voltages
- analogue inputs
  - voltage dividers
    - potentiometer
    - LDR in series with fixed value resistor or variable resistor
    - NTC in series with fixed value resistor or variable resistor
  - calculate values for voltage and resistance
  - analogue to digital conversion (ADC):
    - convert voltage into 8-bit and 10-bit values and vice versa
      - 8-bit
        - range 0 – 255
        - values $2^8 = 256$
        - 8-bit value = $\frac{V_O}{5V} \times 255$
      - 10-bit
        - range 0 – 1023
        - values $2^{10} = 1024$
        - 10-bit value = $\frac{V_O}{5V} \times 1023$
- digital outputs
  - light-emitting diode (LED)
    - sink configuration
    - source configuration
    - forward bias (correct polarity)
    - forward voltage
    - current limiting resistor

    - calculate values for voltage, current, resistance and power
- piezo sounder
    - source configuration
    - controlled by potential difference
- NPN transistor
    - common emitter configuration
    - base resistor
    - back emf diode (inductive loads)
    - calculate values for voltage, current, resistance, power and gain (β)
    - output transducers
        - high-power LED
        - SPST and DPDT relay
        - DC motor
        - electromagnet (including solenoid)
- H-bridge
    - DPDT switch
    - DPDT relay
    - L293D or similar
        - pinout sourced from data sheet
        - single DC motor
        - independent pair DC motors
        - PWM speed control
            - $f = \frac{1}{t}$
            - duty cycle, i.e. % t is high

Flow charts

- standard symbols
  - start/subroutine/stop
    - symbol: rectangle with semicircular ends
  - decision
    - symbol: diamond
    - yes no
      - switch condition
      - analogue value
      - variable value
  - process
    - symbol: rectangle
    - delay
    - mathematical operations (variables)
      - set variable/s
      - add
      - subtract
      - multiply
      - divide
      - comparison
        - $= \neq < \leq > \geq$
  - output
    - symbol: parallelogram
  - subroutine – call up
    - symbol: rectangle with vertical stripes inset at each end
  - flow of computation
    - symbol: arrowed line
- interpret flow charts
  - explain functions
- draw flow charts
  - these relate to listed interfacing circuits and mechatronic applications

Assessment

Assessment is an integral part of teaching and learning that at the senior secondary years:

- provides evidence of student achievement
- identifies opportunities for further learning
- connects to the standards described for the course
- contributes to the recognition of student achievement.

Assessment for learning (formative) and assessment of learning (summative) enable teachers to gather evidence to support students and make judgements about student achievement. These are not necessarily discrete approaches and may be used individually or together, and formally or informally.

Formative assessment involves a range of informal and formal assessment procedures used by teachers during the learning process to improve student achievement and to guide teaching and learning activities. It often involves qualitative feedback (rather than scores) for both students and teachers, which focuses on the details of specific knowledge and skills that are being learnt.

Summative assessment involves assessment procedures that aim to determine students' learning at a particular time; for example, when reporting against the standards or after completion of a unit or units. These assessments should be limited in number and made clear to students through the assessment outline.

Appropriate assessment of student work in this course is underpinned by reference to the set of pre-determined course standards. These standards describe the level of achievement required to achieve each grade from A to E. Teachers use these standards to determine how well a student has demonstrated their learning.

Where relevant, higher order cognitive skills (e.g. application, analysis, evaluation and synthesis) and the general capabilities should be included in the assessment of student achievement in this course. All assessment should be consistent with the requirements identified in the course assessment table.

Assessment should not generate workload and/or stress that, under fair and reasonable circumstances, would unduly diminish the performance of students.

School-based assessment

The *Western Australian Certificate of Education (WACE) Manual* contains essential information on principles, policies and procedures for school-based assessment that must be read in conjunction with this syllabus.

School-based assessment involves teachers gathering, describing and quantifying information about student achievement.

Teachers design school-based assessment tasks to meet the needs of students. As outlined in the *WACE Manual*, school-based assessment of student achievement in this course must be based on the Principles of Assessment:

- Assessment is an integral part of teaching and learning
- Assessment should be educative
- Assessment should be fair
- Assessment should be designed to meet its specific purpose/s
- Assessment should lead to informative reporting
- Assessment should lead to school-wide evaluation processes
- Assessment should provide significant data for improvement of teaching practices.

The table below provides details of the assessment types and their weighting for the Engineering Studies ATAR Year 11 syllabus.

Summative assessments in this course must:

- be limited in number to no more than eight tasks
- allow for the assessment of each assessment type at least once over the year/pair of units
- have a minimum value of five per cent of the total school assessment mark
- provide a representative sampling of the syllabus content.

Assessment tasks not administered under test or controlled conditions require appropriate authentication processes.

Assessment table – Year 11

Type of assessment	Weighting
Design Students investigate needs, opportunities and problems that are defined in a design brief. They devise a solution that considers factors such as function, environment, materials, components and parts. Teachers assess how well students conduct the investigation and devise a solution in response to the design brief by referring to the students' documentation of the process. Types of evidence must include a project folio (hard copy or electronic or combination) and can also include a research assignment. Students apply their knowledge and skills in responding to a series of stimuli or prompts. Types of evidence can include tests, worksheets, a journal or observation checklists.	30%
Production Students finalise and document the specifications for their solution. They plan the making process by identifying and using appropriate tools and techniques. They manufacture and/or assemble their engineered product which they test for safe and correct function. Planning also includes working to deadlines. The product and process are evaluated by the student. Teachers assess the students' understanding and competence when undertaking the making and evaluation of their engineered product. Types of evidence required include the engineered product and project folio (hard copy or electronic or combination). Other evidence can include a journal and observation checklists.	40%
Examination Typically conducted at the end of each semester and/or unit. In preparation for Unit 3 and Unit 4, the examination should reflect the examination design brief included in the ATAR Year 12 syllabus for this course.	30%

Teachers must use the assessment table to develop an assessment outline for the pair of units (or for a single unit where only one is being studied).

The assessment outline must:

- include a set of assessment tasks
- include a general description of each task
- indicate the unit content to be assessed
- indicate a weighting for each task and each assessment type
- include the approximate timing of each task (for example, the week the task is conducted or the issue and submission dates for an extended task).

In the assessment outline for the pair of units, each assessment type must be included at least once over the year/pair of units. In the assessment outline where a single unit is being studied, each assessment type must be included at least once.

The set of assessment tasks must provide a representative sampling of the content for Unit 1 and Unit 2.

Reporting

Schools report student achievement in terms of the following grades:

Grade	Interpretation
A	Excellent achievement
B	High achievement
C	Satisfactory achievement
D	Limited achievement
E	Very low achievement

The teacher prepares a ranked list and assigns the student a grade for the pair of units (or for a unit where only one unit is being studied). The grade is based on the student's overall performance as judged by reference to a set of pre-determined standards. These standards are defined by grade descriptions and annotated work samples. The grade descriptions for the Engineering Studies ATAR Year 11 syllabus are provided in Appendix 1. They can also be accessed, together with annotated work samples, through the Guide to Grades link on the course page of the Authority website at www.scsa.wa.edu.au.

To be assigned a grade, a student must have had the opportunity to complete the education program, including the assessment program (unless the school accepts that there are exceptional and justifiable circumstances).

Refer to the *WACE Manual* for further information about the use of a ranked list in the process of assigning grades.

The grade is determined by reference to the standard, not allocated on the basis of a pre-determined range of marks (cut-offs).

Appendix 1 – Grade descriptions Year 11

<table>
<tr><td rowspan="3">A</td><td>Design
Independently investigates needs, opportunities and problems that are comprehensively documented and defined in a design brief.
Investigates, evaluates and documents, with attention to detail, alternative solutions that demonstrate insightful analytical skills. These may include existing products, systems, components and parts as well as the student's ideas.
Presents a final design, thoroughly tested and evaluated against criteria that are defined in the design brief.
Includes a variety of drawings, diagrams, tables, charts and text in the design folio, as required, and these are complete, accurate and clearly communicate information that is central to understanding the development, testing and evaluation of the design.
Where other types of design-related tasks are undertaken (for example, tests, worksheets, a journal or observation checklists), completes these with very few errors and with careful attention to detail.</td></tr>
<tr><td>Production
Presents in the design folio clearly explained and documented final specifications for the solution and includes relevant detailed drawings, diagrams, tables, charts and text as required. These are accurate, complete and neatly presented.
Provides final specifications that are an appropriate and sophisticated response to the design brief.
Uses a timeline for producing and testing the resulting model or prototype; this is referred to, maintained and modified as required. Meets all deadlines on time.
Uses tools and techniques in a safe and appropriate manner to manufacture and/or assemble the engineered product which is crafted to a very high standard with great care and attention to detail.
Delivers a product that functions correctly, reliably and safely.</td></tr>
<tr><td>Examination
Attempts all calculations, which are accurately completed and with correct units applied.
Produces accurate, comprehensive and fully annotated diagrams to communicate solutions to given problems.
Comprehensively explains key concepts using appropriate justifications where required.
Correctly interprets data to develop comprehensive and realistic solutions to given problems.</td></tr>
</table>

B	**Design** Investigates, given some direction, the needs, opportunities and problems that are well-documented and defined in a design brief. Investigates, evaluates and documents several alternative solutions with attention to coverage of all significant and obvious criteria identified in the design brief. Alternative solutions may include existing products, systems, components and parts as well as the student's ideas. Presents a final design that is thoroughly tested and evaluated against the criteria defined in the design brief. Includes drawings, diagrams, tables, charts and text in the design folio, as required. There are some obvious omissions but most of what is presented accurately and clearly communicates information that is central to understanding the development, testing and evaluation of the design. Where other types of design related tasks are undertaken (for example, tests, worksheets, a journal or observation checklists), completes these with very few errors and with attention to detail.
	Production Clearly explains and documents in the design folio final specifications for the solution, and includes drawings, diagrams, tables, charts and text as required. There are some minor omissions and/or errors but most of the specifications are accurate, complete and neatly presented. Presents final specifications as an appropriate response to the design brief with some degree of innovation and/or clever insight. Uses a timeline for producing and testing the resulting model or prototype, and refers to and uses it to meet all or most deadlines on time. Uses tools and techniques in a safe and appropriate manner to manufacture and/or assemble the engineered product, which is crafted to a high standard with care and attention to detail. Delivers a product that functions correctly, reliably and safely.
	Examination Completes most calculations accurately and applies correct units. Communicates solutions to given problems with accurate, annotated diagrams. Explains key concepts accurately and uses appropriate justifications where required. Correctly interprets data to develop realistic solutions to given problems.

C	**Design** Investigates, given direction and prompting, the needs, opportunities and problems that are documented and defined in a design brief. Investigates, evaluates and documents several alternative solutions with reference to most of the significant and obvious criteria identified in the design brief. Alternative solutions may include existing products, systems, components and parts as well as the student's ideas. Provides the final design that has been thoroughly tested and evaluated against most of the criteria that are defined in the design brief. Includes in the design folio relevant drawings, diagrams, tables, charts and text as required. There are some obvious omissions but most of what is presented accurately and clearly communicates information that is central to understanding most key elements of the development, testing and evaluation of the design. Where other types of design-related tasks are undertaken (for example, tests, worksheets, a journal or observation checklists), completes these to a satisfactory standard and with some attention to detail.
	Production Clearly explains and documents in the design folio the final specifications for the solution and includes drawings, diagrams, tables, charts and text as required. There are some noticeable omissions and/or errors but most of the specifications are accurate, complete and neatly presented. Provides final specifications that are an appropriate response to the design brief. Follows a timeline for producing and testing the resulting model or prototype, and meets most deadlines on time. Uses tools and techniques in a safe and appropriate manner to manufacture and/or assemble the engineered product, which is crafted to a good standard with care and attention to most details. Delivers a resulting product that functions correctly, reliably and safely most of the time.
	Examination Correctly completes simple calculations. Attempts complex calculations but is prone to making errors. Produces simple, partially annotated diagrams to communicate solutions to given problems. Explanations of key concepts are mostly correct with simple or superficial justifications where required. Selects correct data to develop partial or simple solutions to given problems.

D	**Design** Given considerable direction and prompting, interprets a teacher-directed design brief that shows a simplistic understanding of the need, opportunity or problem. Investigates, evaluates and documents one or two alternative solutions. These are referenced to some of the criteria identified in the design brief. Tests and evaluates the final design in a superficial manner against some of the criteria that are defined in the design brief. Provides few drawings, diagrams, tables, charts and text in the design folio. These are mostly incomplete, and only provide the reader with a little understanding of the development, testing and evaluation of the design. If other types of design-related tasks are undertaken (for example, tests, worksheets, a journal or observation checklists), completes these with a significant number of careless errors and/or omissions.
	Production Presents simplistic documentation of final specifications in the design folio. A significant number of required drawings, diagrams, tables, charts and text are incomplete and/or missing. The final specifications are an appropriate, albeit simplistic, response to the design brief. Generally does not adhere to a timeline for producing and testing the resulting model or prototype, and most deadlines are not met on time. Uses tools and techniques on most occasions in a safe and appropriate manner to manufacture and/or assemble the engineered product, which is crafted to a limited standard with some obvious inaccuracies and/or incomplete sections. Delivers a resulting product that occasionally functions reasonably well but is unreliable.
	Examination Achieves limited accuracy with simple calculations. Produces vague or confusing diagrams when attempting to communicate solutions to given problems. Explains key concepts in a simplistic or only partially completed manner. Often interprets data incorrectly, resulting in vague and/or unfeasible solutions to given problems.

E	Does not meet the requirements of a D grade and/or has completed insufficient assessment tasks to be assigned a higher grade.