Government of Western Australia
School Curriculum and Standards Authority

Engineering Studies

ATAR course

Year 12 syllabus

IMPORTANT INFORMATION

This syllabus is effective from 1 January 2017.

Users of this syllabus are responsible for checking its currency.

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

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Content

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: impacts on the environment, sustainable energy, health and safety, and consultation processes to understand social attitudes and opinion.

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 is essentially a practical course focusing on real-life contexts. 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.

Course outcomes

The Engineering Studies ATAR course is designed to facilitate achievement of the following outcomes.

Outcome 1 – Engineering process

Students apply and communicate a process to design, make, and evaluate engineered products.

In achieving this outcome, students:

- investigate needs and opportunities
- generate engineering production proposals to provide solutions
- manage engineering production processes to produce solutions
- evaluate intentions, plans and actions.

Outcome 2 – Engineering understandings

Students demonstrate understanding of materials, components, and scientific and mathematical concepts used in the engineering context.

In achieving this outcome, students:

- understand and explain properties and behaviours of materials and components
- understand and apply scientific and mathematical concepts used in the engineering context.

Outcome 3 – Engineering technology skills

Students use materials, skills and technologies when undertaking an engineering challenge.

In achieving this outcome, students:

- apply initiative and organisational skills
- apply materials, techniques and technologies to achieve solutions to engineering challenges
- operate equipment and resources safely
- apply skills of calculation and computation.

Outcome 4 – Engineering in society

Students investigate, analyse and understand the interrelationships between engineering projects and society.

In achieving this outcome, students:

- identify forms, sources and uses of energy
- analyse the life cycle of engineered products.

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 12 syllabus is divided into two units which are delivered as a pair. The notional time for the pair of units is 110 class contact hours.

Unit 3

In this unit, students develop their understanding of core and specialist area theory. They also study the impacts of obtaining and using the different forms of renewable and non-renewable energy on society, business and the environment.

Students use the engineering design process beginning with the development of a comprehensive design brief that has a focus on a problem, need or opportunity. They synthesise responses to the brief by engaging in a range of activities that include: detailed research of similar existing engineered products; construction materials and components; sketching, drawing and notating concepts; analysing and justifying the choice of the most promising of these for production as a prototype or working model. Students refine their understanding and skills of the engineering design process, undertaking tasks to produce, test and evaluate the product.

Unit 4

In this unit, students consider and analyse the stages within the life cycle of engineering products. Students develop and demonstrate an understanding of the impacts on society, business and the environment that occur during the life cycle of engineered products.

Students continue to refine their understanding and skills of the engineering design process, undertaking tasks to produce, test and evaluate the product. Core and specialist area theory continues to be studied to forge greater understanding of the scientific, mathematical and technical concepts that explain how engineered products function.

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 utilises 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 for students to develop a greater specific practical understanding of major engineering and industrial technologies.

Core content

- Engineering design process
- Materials
- Fundamental engineering calculations
- Engineering in society

Specialist engineering fields

- Mechanical

  OR

- Mechatronics

Core content

Engineering design process

Investigating

Creating, interpreting and responding to a design brief is the starting point for the engineering design process. 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 that is developed and/or maintained by the student.

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 in making functional models and prototypes.

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.

Engineering in society

The impact of engineering on society is a vital consideration. Two major concepts are studied. These are: forms, sources and uses of energy; and product life cycle analysis.

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
  - deflection of beams
  - method of sections
- Dynamics (Unit 4 only)

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. Plastics, wood and, most importantly, metals (ferrous, non-ferrous, pure and alloy) 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 three content areas:

- Electrical/electronics
  - components (Unit 3 only)
  - laws and principles
  - production
  - quantities and unit prefixes
- Systems and control
  - nature of control systems
  - programming (Unit 3 only)
  - interfacing with a microcontroller
- Mechanics (Unit 4 only)
  - types of motion
  - mechanical drive systems
  - calculations
  - quantities

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

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 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. Core and specialist area theory continues to be studied 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 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, 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 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/place. Students understand that many engineering activities occur on land that is part of traditional 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 may 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 3

Unit description

In this unit, students develop their understanding of core and specialist area theory. They also study the impacts of obtaining and using the different forms of renewable and non-renewable energy on society, business and the environment.

Students use the engineering design process beginning with the development of a comprehensive design brief that has a focus on a problem, need or opportunity. They synthesise responses to the brief by engaging in a range of activities that include: detailed research of similar existing engineered products; construction materials and components; sketching, drawing and notating concepts; analysing and justifying the choice of the most promising of these for production as a prototype or working model. Students refine their understanding and skills of the engineering design process, undertaking tasks to produce, test and evaluate the product.

Unit content

An understanding of the Year 11 content is assumed knowledge for students in Year 12. It is recommended that students studying Unit 3 and Unit 4 have completed Unit 1 and Unit 2.

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

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 comprehensive design brief
- identify and assess existing solutions or similar products that are identified using a variety of research skills
- research and critique materials and components relevant to the design brief
- consider different and appropriate sources of energy

Devising

- produce annotated pictorial drawings of design ideas
- produce annotated orthographic drawings of design ideas
- analyse and justify the choice of option to be used as the solution

Producing

- present specifications for the selected solution
  - dimensioned pictorial and orthographic drawings
  - orthographic drawings and sketches as 3rd angle projections and include the following
    - lines – outlines, hidden detail and centrelines
    - dimensioning – linear, radii, circles, holes through or partial depth with flat base
  - materials selection
  - parts lists
  - costing of prototype or working model
- develop and use timeline for construction and testing of solution
- construct solutions by selecting and using appropriate tools and machines and by following safe work practices
- test the solution for correct function and document using checklists and test data

Evaluating

- evaluate the final solution in terms of:
  - meeting the requirements of the design brief
  - safety, function and finish of the product
  - modifications and changes to the design and processes during production
  - refinements and changes for future development

Materials

- define types of materials
  - metals (pure)
  - alloys (ferrous and non-ferrous)
  - polymer
  - composite
- classify listed materials into types
  - aluminium
  - copper
  - zinc
  - iron
  - cast iron
  - brass
  - solder (lead/tin)
  - steel
  - stainless steel
  - concrete, including reinforced concrete
  - polypropylene
  - polycarbonate
  - acrylic
  - ABS
  - nylon

Fundamental engineering calculations

Dimensional

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

Perimeter

- square and rectangular plane figures
- right triangular plane figures
  - $\text{hypotenuse}^2 = \text{opposite}^2 + \text{adjacent}^2$
  - $\cos\theta = a/h$, $\sin\theta = o/h$ and $\tan\theta = o/a$
- circle
  - $p = \Xi d$

Surface area

- square and rectangular plane figures
- cubes and rectangular right prisms
- right triangular plane figures
- triangular right prisms
- circles
  - $A = \Xi r^2$
- open ended cylinders
  - $A = \Xi dh$
- spheres
  - $A = 4\Xi r^2$

Quantity estimates

- determine lengths and surface areas of geometric shapes and forms
  - individual
  - simple combinations

Engineering in society

Energy

- relationships between:
  - energy
  - power
  - work
- different forms of energy
  - kinetic
  - potential
  - thermal

  - chemical
  - electrical
  - electro-chemical
  - electromagnetic (light)
  - nuclear
- non-renewable sources
  - fossil fuels: coal, gas and oil
  - nuclear
- renewable sources of energy
  - solar: thermal, biomass, photovoltaic and wind, including waves
  - gravity: tidal and hydroelectric
  - geothermal
- analyse the impacts on society and the environment of obtaining and using non-renewable and renewable sources of energy

Specialist engineering fields

Mechanical

Materials

- apply the following processes in relation to steel alloys
  - bright drawn
  - cold drawn
  - casting
  - forging
  - pressing
- analyse stress versus strain graphs for the common materials
  - polypropylene
  - copper
  - mild steel
  - stainless steel
- stress and use of the formula to determine one unknown variable

  $$\sigma = \frac{F}{A}$$

  Stress = Force/Area
- strain and use of the formula to determine one unknown variable

  $$\varepsilon = \frac{\Delta L}{L}$$

  Strain = change in length/original length. Strain is a ratio and therefore is without units
- Young's Modulus (elastic modulus) and use of the formula to determine one unknown value
  - $E = \frac{\sigma}{\varepsilon}$ and its extension $E = \frac{FL}{A\Delta L}$

- convert between the stress units
  - N m^{-2}
  - N mm^{-2}
  - kN mm^{-2}
  - Pa
  - kPa
  - Mpa
  - GPa
- derive values from graphical and tabled data
  - Young's Modulus: gradient of stress/strain curve
  - elastic limit
  - yield stress
  - yield strain
  - ultimate tensile stress (UTS)
- properties of materials
  - toughness as the energy absorbed by a material without fracturing and measured by the area under the stress-strain graph up to the point of failure – no calculations are required
  - resilience as the energy absorbed by a material within its linearly elastic range and measured by the area under the stress-strain graph up to the yield point – no calculations are required

Statics

- apply moments formula to determine one unknown where the applied force may need to be resolved into its component forces, to contain no more than two vector resolutions
  - $M = Fd$
- apply the three conditions for equilibrium and use the formulae to determine one unknown variable
  - $\sum M = 0$ or $\Sigma CWM = \Sigma ACWM$
  - $\sum F_x = 0$ or $\Sigma F(left) = \Sigma F(right)$
  - $\sum F_y = 0$ or $\Sigma F(up) = \Sigma F(down)$
- calculate applied forces as vertical and horizontal with no more than one angular force requiring trigonometry to resolve for its horizontal and vertical components
- use 'conditions of equilibrium' formulae to determine the reaction forces at a structure's supports (two supports only)
- use 'conditions of equilibrium' formulae to solve for one unknown external force or distance variable
- use moments formula to determine the reaction forces at a beam's supports
  - $\sum \text{CWM} = \sum \text{ACWM}$
- construct shear force and bending moment diagrams for simple supported beams (horizontal and supported at both ends) or simple cantilevers (horizontal and supported at one end). Forces applied can be:
  - vertical point loads
  - partial uniformly distributed loads (UDLs)
  - or a combination of the two

- calculate shear force (SF) values finding the SF to the left and right of specified points
- calculate bending moment (BM) values at specified points, including the magnitude and position of the maximum bending moment

Mechatronics

Electrical/electronics

- recognise the circuit symbols for:
  - cells and batteries
  - power supply (DC)
  - fuse
  - voltage regulator – 3 pin fixed voltage positive
  - switches
    - SPST, SPDT and DPDT
    - push to make and push to break
  - fixed value resistors
  - potentiometer, including its use as a variable resistor
  - light dependent resistor (LDR)
  - thermistor (NTC)
  - capacitor – polarised and non-polarised
  - diodes – rectifier and LED
  - bulbs/lamps
  - DC motor
  - Servo
  - Stepper motor (unipolar)
  - SPDT and DPDT relays
  - transistor (NPN)
  - integrated circuit (generic)
  - measuring instruments – voltmeter, ohmmeter and ammeter
- describe general characteristics of components
- read and sketch simple circuit diagrams that contain the components that relate to microcontroller and interfacing circuits
- apply markings
  - fixed value resistors – 4 band E12 series
  - capacitors: pF, nF and µF
  - serial numbers – data sheets
    - pin outs: voltage regulator, transistor and integrated circuits

Laws and principles

- Ohm's Law
  - $V = IR$
- Kirchhoff's Laws
  - $\sum I = 0$ Kirchhoff's Current Law
  - $\sum \Delta V = 0$ Kirchhoff's Voltage Law

- calculate power
  - $P = VI = I^2 R = \frac{V^2}{R}$
  - $R = \frac{P}{I^2} = \frac{V^2}{P}$
  - $V = \frac{P}{I} = \sqrt{P R}$
  - $I = \frac{P}{V} = \sqrt{\frac{P}{R}}$
- cells and batteries
  - series
    - $V_T = V_{B1} + V_{B2} + \ldots\ldots$
    - $I_T = I_{B1} = I_{B2} = \ldots\ldots$
  - parallel
    - $V_T = V_{B1} = V_{B2} = \ldots\ldots$
    - $I_T = I_{B1} + I_{B2} + \ldots\ldots$
- resistor networks
  - series
    - $R_T = R_1 + R_2 + R_3 + \ldots\ldots$
  - parallel (maximum of 3 resistors)
    - $R_T = \frac{R_1 R_2}{R_1 + R_2}$ for a pair
    - $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
  - combinational networks of up to 5 resistors
    - Ohm’s Law
    - Kirchhoff’s Laws
    - power
- capacitor networks
  - series (maximum of 3)
    - $C_T = \frac{C_1 C_2}{C_1 + C_2}$ for a pair
    - $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
  - parallel
    - $C_T = C_1 + C_2 + C_3 + \ldots\ldots$

- digital input
  - switch with resistor
    - 'pull up' (normally high signal)
    - 'tie down' (normally low signal)
    - Ohm's Law
    - Kirchhoff's Laws

Production

- safety
  - electrical
  - drilling
  - soldering
- design printed circuit boards
  - single sided through hole
- populate a through hole printed circuit board
- soldering technique using correct equipment
  - identify and correct soldering faults
- measure resistance, voltage and current using a digital multimeter

Quantities

Quantity	Unit name	Symbol
electric potential difference/e.m.f.	volt	V
current (I)	ampere	A
resistance	ohm	Ω
power	watt	W
capacitance (C)	farad	F

Unit prefixes

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

Systems and control

Nature of control systems

- systems/control diagrams
  - simple open loop (universal block diagram)
    - input
    - process
    - output
  - complex open loop
    - inputs
    - processes
      - subsystems inside process block
      - subsystems outside process block
    - outputs
  - simple closed loop
    - input
    - process
    - control
      - feedback loop
      - error detection (negative only)
    - output
  - complex closed loop
    - inputs
    - processes
      - subsystems inside process block
      - subsystems outside process block
    - control
      - feedback loop
      - error detection (negative only)
    - outputs

Programming

- flowcharts
  - standard symbols
    - start/end
    - input/output
    - decision
    - process, including time delays
    - subroutine/procedure
    - flow of computation
- interpret flowcharts and explain functions
  - up to 10 standard symbols
- draw flowchart given specifications
- identify and correct fault(s) in a flowchart

- systems/control diagrams
- pulse width modulation (PWM)
  - speed control of DC motor
  - dimming a light output

Interfacing with microcontroller

- nature of microcontroller
  - internal subsystems
    - ALU, ROM, RAM, ADC, I/O and bus
- power supply
  - batteries
    - voltage to be specified or found on data sheet
  - voltage regulator
    - fixed positive voltage to be specified or found on data sheet
- digital input
  - 'high' and 'low' signals (also 0 and 1, 'on' and 'off')
  - sensors
    - switch with resistor (pull up and tie down)
    - other sensors that only produce 'high' and 'low' signals – this requires additional data to be supplied or sourced
- analogue input
  - signal values that can vary on a defined scale
  - sensors
    - voltage dividers
    - other sensors that produce analogue signals – this requires additional data to be supplied or sourced
- analogue to digital conversion (ADC)
  - binary counting as it pertains to ADC range and number of combinations
  - range
    - $2^n - 1$
    - 8 bit 0 – 255
    - 10 bit 0 – 1023
  - number of combinations
    - 2^n
  - relationship to input voltage

Unit 4

Unit description

In this unit, students consider and analyse the stages within the life cycle of engineering products. Students develop and demonstrate an understanding of the impacts on society, business and the environment that occur during the life cycle of engineered products.

Students continue to refine their understanding and skills of the engineering design process, undertaking tasks to produce, test and evaluate the product. Core and specialist area theory continues to be studied to forge greater understanding of the scientific, mathematical and technical concepts that explain how engineered products function.

Unit content

This unit builds on the content covered in Unit 3.

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

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 comprehensive design brief
- identify and assess existing solutions or similar products that are identified using a variety of research skills
- research and critique materials and components relevant to the design brief
- consider different and appropriate sources of energy

Devising

- produce annotated pictorial drawings of design ideas
- produce annotated orthographic drawings of design ideas
- analyse and justify the choice of option to be used as the solution

Producing

- present specifications for the selected solution
  - dimensioned pictorial and orthographic drawings
  - orthographic drawings and sketches are 3rd angle projections and include
    - lines – outlines, hidden detail and centerlines
    - dimensioning – linear, radii, circles, holes through or partial depth with flat base
  - list and/or descriptions of selected materials with justification of choices
  - parts lists
  - costing of prototype or working model

- develop and use a timeline for construction and testing of solution
- construct solutions by selecting and using appropriate tools and machines and by following safe work practices
- test the solution for correct function and document using checklists and test data

Evaluating

- evaluate the final solution in terms of:
  - meeting the requirements of the design brief
  - safety, function and finish of product
  - modifications and changes to the design and processes during production
  - refinements and changes for future development

Materials

- define physical properties of materials
  - density
  - elasticity
  - plasticity
  - strength – tensile and compressive
  - stiffness
  - toughness
  - ductility
  - malleability
  - conductivity – electrical and thermal
  - corrosion resistance
- fitness for purpose
  - identify and justify the required properties of a material for a specified application

Fundamental engineering calculations

Volume

- cubes, rectangular right prisms and triangular right prisms
- cylinders
  - $V = \Xi r^2 h$
- spheres
  - $V = {}^{4}/_{3}\, \Xi r^3$

Density

- $\text{density} = \dfrac{\text{mass}}{\text{volume}}$ (measured in kg m^{-3})

Quantity estimates

- determine volume, mass and density of geometric forms
  - individual or simple combinations
  - hollow or solid

Energy

- E = Pt
- 1 joule = 1 watt x 1 second
- 1 kW h = 1000 watts x 1 hour

Efficiency

- calculate efficiency as a percentage = $\frac{\text{output}}{\text{input}} \times 100$

Unfamiliar formula

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

Engineering in society

Life cycle analysis of engineered products

- the stages of the life cycle
  - materials acquisition
  - processing materials
  - manufacture
  - packaging
  - transport
  - maintenance/operation
  - reuse/recycle/disposal
- impacts for society, business and the environment that occur during the life cycle of engineered products

Specialist engineering fields

Mechanical

Materials

- define Factor of Safety (FS) as the ratio of ultimate failure stress to safe working stress
- use the formula to determine one unknown variable
  - Factor of Safety (FS) = $\frac{\sigma_{UTS}}{\sigma_{safeworking}}$

Statics

- calculate second moment of area for material cross-sections
  - vertical rectangular solid section

    $$I_{xx} = \frac{bh^3}{12}$$

  - round solid section

    $$I_{xx} = \frac{\pi D^4}{64}$$

- circular tube section

$$I_{xx} = \frac{\pi(D_o^4 - D_i^4)}{64}$$

Deflection of beams

- calculate one unknown variable using one of the four beam deflection formulae
- deflection scenarios, when solving for 'y', are to be calculated in isolation and a maximum of two load scenarios in total may be combined to give the final deflection sum

  Note 1 – Second moment of area (I_{xx}) values for differing beam cross-sections beyond the three specified under the 'Second moment of area' heading can be directly provided for use in deflection calculations.

  Note 2 – Maximum bending moment calculations are only to be dealt with in the context of bending moment diagram problems – not in deflection questions.

  - cantilevered beam with a single load at its unsupported end

  $$y = \frac{FL^3}{3EI_{xx}}$$

  - cantilevered beam with a universally distributed load along the whole length of the beam (can be self-weight of beam)

  $$y = \frac{F_{UDL}L^3}{8EI_{xx}}$$

  - centrally loaded beam simply supported at both ends

  $$y = \frac{FL^3}{48EI_{xx}}$$

  - universally loaded beam, simply supported at both ends. The UDL is spread along the whole length of the beam (can be self-weight of beam)

  $$y = \frac{5F_{UDL}L^3}{384EI_{xx}}$$

Method of sections for simply supported pin-jointed trusses

- use the $\Sigma CWM = \Sigma ACWM$ formula to determine the reaction forces at the supports of horizontal, simply supported pin-jointed trusses, where all external forces are vertical
- calculate the forces in no more than three members in a simple pin-jointed truss by using the method of sections. Sectioning lines shall remain straight whilst crossing the maximum three members. The moment arm, not the force, shall be the variable requiring trigonometry in determining any particular moment required. All external forces are to be vertical only

Dynamics

- apply the formulae to find one unknown variable in constant acceleration, straight line motion
  - $F = ma$
  - $a = \frac{v - u}{t}$
  - $v^2 = u^2 + 2as$
  - $s = ut + \frac{1}{2}at^2$ (not quadratic equation)
- define potential energy as energy of position or state
- define kinetic energy as energy of motion
- solve problems involving energy and energy conversion using:
  - $E_p = mgh$
  - $E_k = \frac{1}{2}mv^2$
  - $\Delta E_p = \Delta E_k$
- apply the formula for Work to find one unknown variable
  - $W = Fs$
- define efficiency (η%) and apply the formula to find one unknown variable

  $$\text{Efficiency}(\eta)\ \% = \frac{\text{Work done in moving load}}{\text{Work done by the effort}} \times 100$$

- apply Power formula to find one unknown variable

  $$P = \frac{Fs}{t}$$

Mechatronics

Electrical/electronics

Laws and principles

- analogue inputs
  - voltage dividers
    - LDR with resistor or variable resistor
    - NTC thermistor with resistor or variable resistor
    - potentiometer
  - $V_1 = V_{cc} \frac{R_1}{(R_1 + R_2)}$
  - $V_2 = V_{cc} \frac{R_2}{(R_1 + R_2)}$
  - $V_{CC} = V_1 + V_2$
  - Ohm's Law
  - Kirchhoff's Laws

- NPN transistor
  - transistor model
  - cut-off
  - saturation
    - $< \beta \quad \frac{I_C}{I_B}$
  - forward-active
    - $\beta = \frac{I_C}{I_B}$
  - buffer/driver for a microcontroller
    - driving relays, DC motor (unidirectional), bulb/lamp, high current LED
      - transistor model
      - Ohm's Law
      - Kirchhoff's Laws
      - power
- diodes
  - power/rectifier diode (silicon)
    - forward bias voltage 0.6 V
    - back e.m.f. protection
  - light emitting diode (LED)
    - $R = \frac{(V_{CC} - V_{LED})}{I_{LED}}$
- voltage regulator
  - positive voltage 3 pin fixed value, including 78XX series
  - smoothing capacitors
- unfamiliar formula
  - determine unknown factor in unfamiliar formula given sufficient data, with descriptions, to complete the calculation
- data extraction
  - extract and use data from charts, graphs, tables and diagrams

Systems and control

Interfacing with microcontroller

- outputs
  - LED – low power
  - piezo sounder
  - servo – separate supply voltage
  - NPN transistor driver/buffer
    - relays, DC motor (unidirectional), bulb/lamp, high current LED
  - DC motor (bi-directional)
    - H-bridge concept – mechanical switch models using:
      - four (4) SPST switches

    - single DPDT switch
    - DPDT relay
  - H-bridge integrated circuit – motor controlled by two (2) outputs from microcontroller
    - includes L293D motor controller
  - Pulse width modulation speed control
- stepper motor (unipolar)
  - controlled by four (4) outputs from microcontroller via Darlington driver integrated circuit (given sufficient data/information)

Mechanics

Types of motion

- linear, rotary, oscillating and reciprocating
- transformation
  - identify and describe examples
    - rotary to linear
    - rotary to reciprocating
    - rotary to oscillating

Mechanical drive systems

- recognise and describe general characteristics and applications for:
  - pulley belt
  - chain and sprocket
  - spur gear drive
  - compound gear drive
  - worm and worm wheel
  - rack and pinion

Calculations

- velocity ratio = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$
- mechanical advantage = $\frac{\text{load}}{\text{effort}}$
- pulley belt ratio = $\frac{\text{Ø follower pulley}}{\text{Ø driver pulley}}$ = input revolutions:1 output revolution
- chain and sprocket ratio = $\frac{\text{n}^{\text{o}}\text{ teeth follower gear}}{\text{n}^{\text{o}}\text{ teeth driver gear}}$ = input revolutions:1 output revolution
- gear ratio = $\frac{\text{n}^{\text{o}}\text{ teeth follower gear}}{\text{n}^{\text{o}}\text{ teeth driver gear}}$ = input revolutions:1 output revolution
  - pinion gear
  - idler gear
  - pitch

- compound gear drive ratio = $VR_T = VR_1 \times VR_2 \times VR_3 \times ...$ = input revolutions: 1 output revolution
- worm and worm wheel ratio = $\frac{\text{n}^{\text{o}}\text{ teeth follower gear}}{1}$ = input revolutions: 1 output revolution
- rack and pinion
  - distance moved = $\frac{\text{n}^{\text{o}}\text{ teeth pinion} \times \text{n}^{\text{o}}\text{ revolutions}}{\text{n}^{\text{o}}\text{ teeth per metre of rack}}$
- speed/velocity
  - velocity (v) = $\frac{\text{distance}}{\text{time}} = \frac{(\text{rpm})(2\pi r)}{60}$
  - output speed (rpm) = $\frac{\text{input speed (rpm)}}{\text{gear or pulley ratio}}$

Quantities

Quantity	Unit name	Symbol
speed/velocity (v)	metre per second	$m\ s^{-1}$
distance	metre	m
time (t)	second	s

School-based assessment

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

Teachers design school-based assessment tasks to meet the needs of students. The table below provides details of the assessment types for the Engineering Studies ATAR Year 12 syllabus and the weighting for each assessment type.

Assessment table – Year 12

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, service conditions, materials, components and parts. Teachers assess how well students conduct the investigation and the devising of a solution in response to the design brief by referring to the student's 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, confidence 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.	30%
Examination Typically conducted at the end of each semester and/or unit and reflecting the examination design brief for this syllabus.	40%

Teachers are required to use the assessment table to develop an assessment outline for the pair of units.

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 twice.

The set of assessment tasks must provide a representative sampling of the content for Unit 3 and Unit 4.

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

Grading

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. 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 12 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.

ATAR course examination

All students enrolled in the Engineering Studies ATAR Year 12 course are required to sit the ATAR course examination. The examination is based on a representative sampling of the content for Unit 3 and Unit 4. Details of the ATAR course examination are prescribed in the examination design brief on the following page.

Refer to the WACE Manual for further information.

Examination design brief – Year 12

Time allowed

Reading time before commencing work: ten minutes
Working time for paper: three hours

Permissible items

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

Provided by the supervisor

A Data Book

Additional information

If or when required, prior to the examination, a document booklet will be provided.

Section	Supporting information
Section One **Core content** 40% of the total examination **Part A** 10% of the examination 10 multiple-choice questions **Part B** 30% of the examination 3–4 questions with parts Suggested working time: 70 minutes	In Part B, questions can relate to scenarios or engineering design problems. The questions can have parts that increase in complexity. The Part B questions can require answers in the form of short paragraphs, calculations and/or diagrams. Wherever appropriate, the candidate should use examples and labelled sketches and/or diagrams to illustrate and support their answers. The Part B questions can require the candidate to refer to stimulus materials, including: descriptive texts, diagrams, short excerpts from journal articles, screen captures, photographs and/or tabular information. These stimulus materials can be presented in a document booklet.
Section Two **Specialist engineering fields** 60% of the total examination Candidates choose from **one** of the following specialist engineering fields: • Mechanical • Mechatronics Each field contains: **Part A** 10% of the examination 10 multiple-choice questions **Part B** 50% of the examination 6–8 questions, each with parts Suggested working time: 110 minutes	The candidate is required to answer all Part A and Part B questions in this section from their chosen specialist engineering field. In Part B questions can relate to scenarios or engineering design problems. The questions can have parts that increase in complexity. The Part B questions can require answers comprising short paragraphs, calculations or diagrams. Wherever appropriate, the candidate should use examples and fully labelled sketches and/or diagrams to illustrate and support their responses. The Part B questions can refer to stimulus materials, such as descriptive texts, diagrams, short excerpts from journal articles, screen captures, photographs or tabular information. These stimulus materials can be presented in a document booklet.

Appendix 1 – Grade descriptions Year 12

A	**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. Thoroughly tests and evaluates the final design against criteria that are defined in the design brief. Develops a variety of annotated drawings, diagrams, tables, charts and text, as required; these are complete, accurate and clearly communicate information that is central to understanding the development and evaluation of the design proposal. Presents the final design proposal, clearly evaluated against the design brief criteria.
	Production Clearly explains and documents the final specifications for the solution using accurate, complete and neatly presented drawings, diagrams, tables, charts and text, as required. Presents appropriate, complete, sophisticated final specifications as a response to the design brief. Prepares, maintains and modifies, as required, a timeline for producing and testing the resulting model or prototype, meeting all deadlines. Uses tools and techniques in a safe and appropriate manner to manufacture and/or assemble the engineered product to a very high standard. Delivers a product that functions correctly, reliably and safely.
	Examination Interprets data correctly to develop comprehensive and realistic solutions to given problems. Applies correct formulas and units, and completes all calculations accurately. Presents accurate, comprehensive and fully annotated diagrams to communicate solutions to given problems. Explains key concepts comprehensively, using appropriate justifications where required.

Grade	Description
B	**Design** Investigates needs, opportunities and problems that are well documented and defined in a design brief. Investigates and evaluates alternative solutions, such as existing products, systems, components and parts, including student ideas against the design brief criteria. Develops annotated project drawings, diagrams, tables, charts and text, as required. Presents, with few errors or omissions, accurate and clear information that is central to understanding the development and evaluation of the design proposal. Provides the final design proposal, evaluated against the design brief criteria.
	Production Clearly explains and documents the final specifications for the solution using complete and neatly presented drawings, diagrams, tables, charts and text, as required, with some minor omissions and/or errors. Presents the final specifications as an appropriate response to the design brief. Refers to and uses a timeline for producing and testing the resulting model or prototype to meet all or most deadlines. Uses tools and techniques in a safe and appropriate manner to manufacture and/or assemble the engineered product to a high standard. Delivers a product that functions correctly, reliably and safely.
	Examination Interprets data correctly to develop realistic solutions to given problems. Applies correct formulas and units, and completes most calculations accurately. Presents accurate, annotated diagrams to communicate solutions to given problems. Explains key concepts accurately, and uses appropriate justifications where required.

Grade	Description
C	**Design** With assistance, investigates and documents needs, opportunities and problems that are defined in a design brief. Investigates and evaluates alternative solutions, such as existing products, systems, components and parts, including student ideas against the main points of the design brief. Provides drawings with some annotations, diagrams, tables and/or charts, as required. Presents information with occasional errors and/or omissions, showing the development and evaluation of the design. Presents the final design proposal evaluated against most of the design brief criteria.
	Production Clearly explains and documents the final specifications for the solution using neat drawings, diagrams, tables, charts and text, as required, but with some noticeable omissions and/or errors. Presents the final specifications as an appropriate response to the design brief. Refers to and uses a timeline for producing and testing the resulting model or prototype to meet most deadlines. Uses tools and techniques in a safe and appropriate manner to manufacture and/or assemble the engineered product to a satisfactory standard. Delivers a product that functions correctly, reliably and safely most of the time.
	Examination Uses data to develop partial or simple solutions to given problems. Applies correct formulas and units, and completes simple calculations. Attempts complex calculations but with errors. Produces simple, partially annotated diagrams to communicate solutions to given problems. Explains key concepts with simple or superficial justifications.

D	**Design** Presents a design brief showing limited consideration and documentation of needs, opportunities or problems. Develops project ideas with limited investigation or evaluation of alternative solutions. Presents few annotated drawings, diagrams, tables or charts. Provides little evidence of understanding the development or evaluation of the design proposal. Presents the final design proposal with minimal evaluation or reference to the design brief criteria.
	Production Provides specifications that are suitable, yet brief or simplistic, responses to the design brief. Presents the final specifications for the solution with obvious omissions and errors. Infrequently refers to a timeline for producing and testing the resulting model or prototype, and does not meet most deadlines. Uses tools and techniques in a safe manner to manufacture and/or assemble the engineered product. Delivers a product that does not function as designed.
	Examination Often interprets data incorrectly, resulting in vague and/or unfeasible solutions to given problems. Achieves limited accuracy with simple calculations. Produces vague or confusing diagrams when attempting to communicate solutions to given problems. Explains key concepts simplistically, or only partially.

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