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

ENGINEERING STUDIES
ATAR COURSE

DATA BOOK

2025

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CONTENT **PAGES**

Core

Base International System (SI) units	4
Derived SI units	4
SI prefixes	4
Common constant	4
Right triangular plane figures	5
Circles, cylinder and sphere figures	5
Density	5
Energy, work and power	5
Mechanisms	6
Efficiency	6
Selected materials properties (at 25 °C)	7

Specialist field: Mechanical

Base International System (SI) units	8
Derived SI units	8
Common constant	8
Materials formulae	8
Statics formulae	9
Dynamics formulae	9
Second moment of area for materials cross sections (I_{xx})	10
Deflection of beams	11

Specialist field: Mechatronics

Base International System (SI) units	12
Derived SI units	12
Laws and principles formulae	12
Diode and transistor models	14
Resistor colour codes	15
Sample microcontroller chip	15
Standard circuit symbols	16
Flow chart symbols	18

Base International System (SI) units

Physical quantity		SI units	
Name	Symbol	Name	Symbol
Length	L	metre	m
Mass	m	kilogram	kg
Time	t	second	s

Derived SI units

Derived physical quantities		SI units	
Name	Symbol	Name	Symbol
Area	A	square metre	m^2
Volume	V	cubic metre	m^3
Density	ρ	kilogram per cubic metre	$kg\ m^{-3}$
Energy	E	joule	J
Work	W		
Displacement	s	metre	m
Distance	d		
Power	P	watt	W
Speed	no symbol	metre per second	$m\ s^{-1}$
Velocity (linear)	v		
Angular displacement	θ	radian	rad
Velocity (angular)	ω	radian per second	$rad\ s^{-1}$
Force	F	newton	N
Torque	τ	newton metre	N m

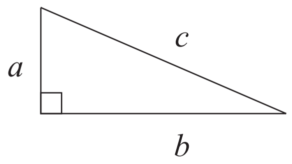
SI prefixes

Prefixes	Abbreviations	Multipliers
Tera	T	10^{12} = 1 000 000 000 000
Giga	G	10^{9} = 1 000 000 000
Mega	M	10^{6} = 1 000 000
Kilo	k	10^{3} = 1000
		10^{0} = 1
Milli	m	10^{-3} = 0.001
Micro	µ	10^{-6} = 0.000 001
Nano	n	10^{-9} = 0.000 000 001
Pico	p	10^{-12} = 0.000 000 000 001

Common constant

Item	Symbol	Value
Gravity	g	$9.80\ m\ s^{-2}$

Right triangular plane figures

Parameter	Formulae
Pythagoras' theorem 	$a^2 + b^2 = c^2$
Angular relationships	$\cos\theta = \frac{a}{h}$ $\sin\theta = \frac{o}{h}$ $\tan\theta = \frac{o}{a}$

Circles, cylinder and sphere figures

Parameter	Formulae
Circumference (C) of a circle	$C = \pi d$
Area (A) of a circle	$A = \pi r^2$
Surface area (A) of open-ended cylinder	$A = \pi dh$
Surface area (A) of a sphere	$A = 4\pi r^2$
Volume (V) of a cylinder	$V = \pi r^2 h$
Volume (V) of a sphere	$V = \frac{4}{3}\pi r^3$

Density

Parameter	Formula
Density (ρ)	$\rho = \frac{m}{V}$

Energy, work and power

Parameter	Formulae
Energy (E)	$E = Pt$
Gravitational potential energy (E_p)	$E_P = mg\Delta h$
Kinetic energy (E_k)	$E_K = \frac{1}{2}mv^2$
Work done (W)	$W = \Delta E$
Work (W) linear	$W = Fs = F\Delta x = F\left(x_f - x_i\right)$
Work (W) rotational	$W = \tau\theta$
Power (P)	$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t}$
Power (P) linear	$P = \frac{Fs}{\Delta t} = \frac{F\Delta x}{\Delta t} = \frac{F\left(x_f - x_i\right)}{\Delta t} = Fv$
Power (P) rotational	$P = \frac{\tau\theta}{t} = \tau\omega = \tau\frac{(rpm)(2\pi)}{60}$

Mechanisms

Parameter	Formulae
Mechanical advantage (MA)	$MA = \frac{F_{load}}{F_{effort}}$
Velocity ratio (VR)	$VR = \frac{d_{effort}}{d_{load}}$
Ideal machine (100% efficient)	$MA = VR$
Pulley belt ratio (VR)	$VR = \frac{\varnothing_{follower}}{\varnothing_{driver}}$
Chain and sprocket ratio (VR) Gear ratio (VR)	$VR = \frac{n^\circ\, teeth_{(follower)}}{n^\circ\, teeth_{(driver)}}$
Compound gear or pulley ratio (VR) comprised of 3 or more gears or pulleys	$VR = \frac{F_1 F_2 F_3}{D_1 D_2 D_3} \ldots$
Worm and worm wheel (VR)	$VR = \frac{n^\circ\, teeth_{(worm\ wheel)}}{1}$
Rack and pinion (VR)	$distance\ moved = \frac{n^\circ\, teeth\ pinion \times n^\circ\, revolutions}{n^\circ\, teeth\ per\ metre\ rack}$
Lead screw (VR) single start multiple start	 $distance\ moved = pitch \times revolutions$ $distance\ moved = n^\circ\, starts \times pitch \times revolutions$
Speed (linear translation)	$speed = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$
Speed (rotational to linear translation)	$speed = \frac{(rpm)(2\pi \mathrm{r})}{60}$
Speed of rotation (rpm)	$output\ speed\,(rpm) = \frac{input\ speed\,(rpm)}{VR}$
Torque (force perpendicular to lever arm)	$\tau = rF$

Efficiency

Parameter	Formula
Efficiency (η) %	$\eta = \frac{output}{input} \times 100\%$

Selected materials properties (at 25 °C)

Material	Density kg m^{-3}	Elastic (Young's) modulus kN mm^{-2}	Ultimate tensile strength N mm^{-2}	Yield stress N mm^{-2}	Ultimate shear stress N mm^{-2}	Electrical conductivity Ω^{-1} m^{-1} × 10^{6}	Thermal conductivity W m^{-1} K^{-1}
Aluminium	2710	70	150	95	Assume ultimate shear stress (USS) is 70% of ultimate tensile strength (UTS)	37.70	237
Copper	8930	112	210	70		59.50	401
Zinc	7130	108	200	13.80		16.80	116
Wrought iron	7750	200				10.30	80
Structural steel	7850	200	470	250		13.00	46
Stainless steel	7600	200	860	502		1.35	16
Cast iron	7200	120	180			10.30	80
Brass	8740	90	190	50		16.70	109
Bronze	8800	105	467	282		7.25	60
Acrylic	1190	3.20	70.00	73.70			0.19
Polycarbonate	1200	2.39	64.20	62.50			0.22
ABS	1070	2.35	40.90	44.80			0.16
PLA	1250	2.37	58.80	30.00			0.04
PVC	1380	2.16	16.60	43.20			0.16
Polypropylene	930	1.67	29.20	31.70			0.16
Epoxy resin	1100	2.17	56				0.35
Polyester resin	1100	25.00	250				0.40
Concrete	2400	30	40 (compressive)				0.80
Pine (along grain)	550	9	40				
Pure water	1000						
Sea water	1022						

Note: The values shown in the above chart are indicative of typical values for these materials and are to be only used for the purposes of this course.

Base International System (SI) units

Physical quantity		SI units	
Name	**Symbol**	**Name**	**Symbol**
Length	L	metre	m
Mass	m	kilogram	kg
Time	t	second	s

Derived SI units

Derived physical quantities		SI units	
Name	**Symbol**	**Name**	**Symbol**
Stress	σ	pascal	Pa
Pressure	P		
Force	F	newton	N
Area	A	square metre	m^2
Strain	ε	dimensionless number	
Young's modulus	E	kilonewton per square millimetre	$kN\ mm^{-2}$
		gigapascal	GPa
Moment	M	newton metre	N m
Acceleration	a	metre per second squared	$m\ s^{-2}$
Velocity	v	metre per second	$m\ s^{-1}$
Displacement	s	metre	m
Distance	d		
Maximum deflection	y	millimetre	mm
Second moment of area	I_{xx}	millimetre to the power of four	mm^4

Common constant

Item	Symbol	Value
Gravity	g	$9.80\ m\ s^{-2}$

Materials formulae

Parameter	Formulae
Stress (σ)	$\sigma = \frac{F}{A}$
Pressure (P)	$P = \frac{F}{A}$
Strain (ε)	$\varepsilon = \frac{\Delta L}{L}$
Young's Modulus (E)	$E = \frac{\sigma}{\varepsilon}$ $E = \frac{FL}{A\Delta L}$
Factor of Safety (FS)	$FS = \frac{\sigma_{UTS}}{\sigma_{safeworking}}$

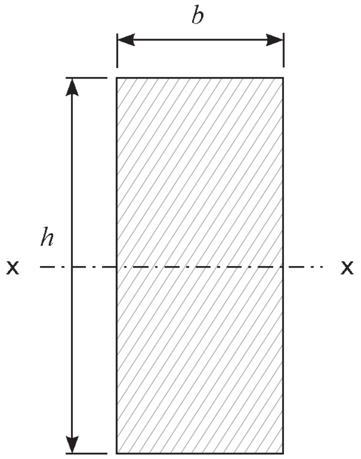
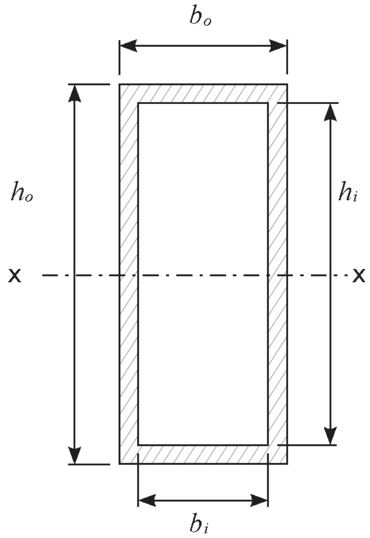
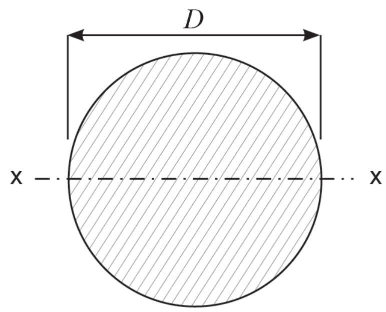
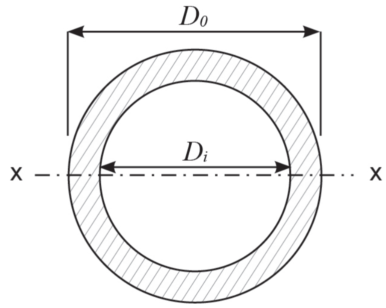
Statics formulae

Parameter	Formulae
Moment (M) of a force	$M = Fd$
Equilibrium conditions – moments (M) Note: CWM are positive	$\Sigma M = 0$ $\Sigma CWM = \Sigma ACWM$
Equilibrium conditions – horizontal forces (F_x) Note: F_{right} are positive	$\Sigma F_x = 0$ $\Sigma F_{left} = \Sigma F_{right}$
Equilibrium conditions – vertical forces (F_y) Note: F_{up} are positive	$\Sigma F_y = 0$ $\Sigma F_{up} = \Sigma F_{down}$
Where position of maximum bending moment (x) occurs along a UDL as measured from start of UDL	$x = \frac{y}{m}$

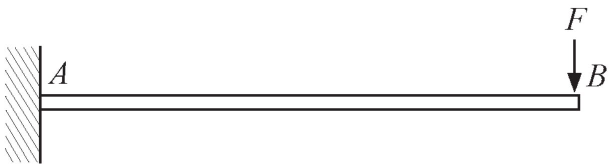
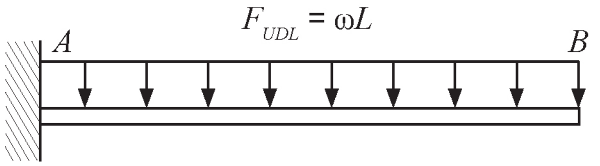
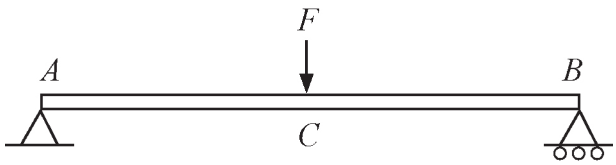
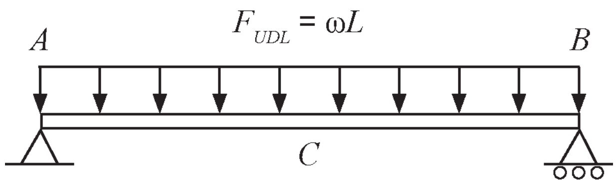
Dynamics formulae

Parameter	Formulae
Force (F)	$F = ma$
Acceleration (a)	$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$
Velocity (v)	$v_f = v_i + a\Delta t$ $v_f^2 = v_i^2 + 2as$
Displacement (s)	$s = v_i\Delta t + \frac{1}{2}a\Delta t^2$

Second moment of area for materials cross sections (I_{xx})

Shapes	Dimensions	Second moment of area about centroid axis
Vertical rectangle solid section		$$I_{xx} = \frac{bh^3}{12}$$ b = base h = height
Vertical rectangle hollow section		$$I_{xx} = \frac{b_o h_o^3}{12} - \frac{b_i h_i^3}{12}$$ b_o = base (outside) h_o = height (outside) b_i = base (inside) h_i = height (inside)
Round solid section		$$I_{xx} = \frac{\pi D^4}{64}$$ D = diameter
Circular tube section		$$I_{xx} = \frac{\pi \left(D_o^4 - D_i^4\right)}{64}$$ D_o = diameter (outside) D_i = diameter (inside)

Deflection of beams

Beam configurations	Maximum deflection (y)
Cantilevered beam – single load at unsupported end 	$y = \dfrac{FL^3}{3EI_{xx}}$ at B
Cantilevered beam – universally distributed load 	$y = \dfrac{F_{UDL}L^3}{8EI_{xx}}$ at B
Centrally loaded beam – simply supported at both ends 	$y = \dfrac{FL^3}{48EI_{xx}}$ at C
Universally loaded beam – simply supported at both ends 	$y = \dfrac{5F_{UDL}L^3}{384EI_{xx}}$ at C

Terms
E = elastic (Young's) modulus of the material of the beam
F = single vertical point load
F_{UDL} = product of ω and the length of the beam
I_{xx} = second moment of area of the beam section
L = length of beam
ω = uniformly distributed load per unit length

Base International System (SI) units

Physical quantity		SI units	
Name	**Symbol**	**Name**	**Symbol**
Current	I	ampere	A

Derived SI units

Derived physical quantities		SI units	
Name	**Symbol**	**Name**	**Symbol**
Charge	q	coulomb	C
Capacitance	C	farad	F
Voltage	V	volt	V
Resistance	R	ohm	Ω
Power	P	watt	W
Frequency	f	hertz	Hz

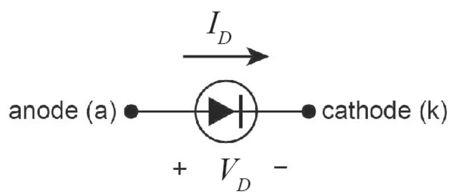
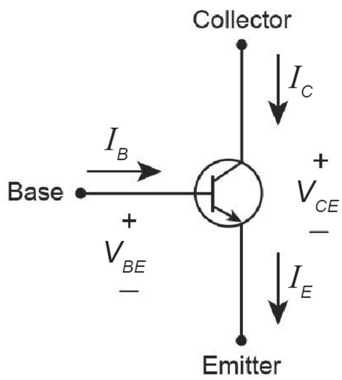
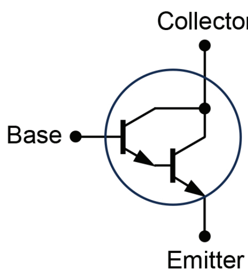
Laws and principles formulae

Parameter	Formulae
Charge (q)	$q = It$
Relationships between Ohm's law and power formula	
Voltage (V)	$V = \mathrm{IR} = \frac{P}{I} = \sqrt{PR}$
Current (I)	$I = \frac{V}{R} = \frac{P}{V} = \sqrt{\frac{P}{R}}$
Resistance (R)	$R = \frac{V}{I} = \frac{P}{I^2} = \frac{V^2}{P}$
Power (P)	$P = VI = I^2R = \frac{V^2}{R}$
Kirchhoff's voltage law	$\Sigma\Delta V = 0$
Kirchhoff's current law	$\Sigma I = 0$
Resistances (R) in series	$R_T = R_1 + R_2 + \ldots$
Resistances (R) in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
Charge (q) capacitor	$q = CV$
Charge (q) capacitances in series	$q_T = q_1 = q_2 = \ldots$
Charge (q) capacitances in parallel	$q_T = q_1 + q_2 + \ldots$
Capacitances (C) in series	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
Capacitances (C) in parallel	$C_T = C_1 + C_2 + \ldots$

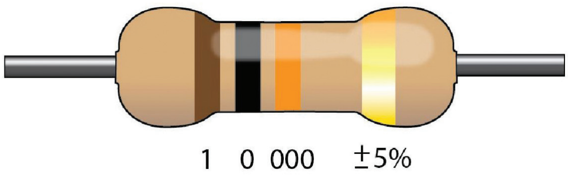
Laws and principles formulae (continued)

Parameter	Formulae
Current capacity ($A\ h$) cells and batteries	$Ah = \frac{Wh}{V}$
Cells and batteries in series	$V_T = V_1 + V_2 + \ldots$ $I_T = I_1 = I_2 = \ldots$
Cells and batteries in parallel	$I_T = I_1 + I_2 + \ldots$ $V_T = V_1 = V_2 = \ldots$
Voltage dividers	$V_{CC} = V_1 + V_2$ $V_1 = V_{CC} \times \frac{R_1}{R_1 + R_2}$ $V_2 = V_O = V_{CC} \times \frac{R_2}{R_1 + R_2}$
Resistor (R) in series with an LED	$R = \frac{V_{cc} - V_{LED}}{I_{LED}}$
Frequency (f)	$f = \frac{1}{t}$

Diode and transistor models

Diode model	Formulae	Diagram
On	$V_D = V_{D,ON}$ (or V_F) **Check:** $I_D > 0$ A	
Off	$I_D = 0$ A **Check:** $V_D < V_{D,ON}$ (or V_F)	
Transistor model (NPN)	**Formulae**	**Diagram**
Cut-off	$I_B = I_C = 0$ A **Check:** $V_{BE} < 0.7$ V	
Saturation	$V_{BE} = 0.7$ V $V_{CE} = 0$ V **Check:** $I_B > 0$ A $\frac{I_C}{I_B} < \beta$ (or h_{FE})	
Forward-active	$V_{BE} = 0.7$ V $\beta = \frac{I_C}{I_B}$ **Check:** $I_B > 0$ A $V_{CE} > 0$ V	
Darlington pair	**Formulae**	**Diagram**
Gain (β or h_{FE})	$\beta_{total} = \beta_1 \times \beta_2$	
Base-emitter voltage	$V_{BE,\ total} = V_{BE1} + V_{BE2}$ $= 0.7 + 0.7$ $= 1.4$ V	

Resistor colour codes

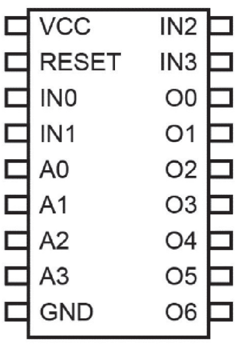


Example: 4-band E12 resistor colour code

Band colours	Band 1	Band 2	Band 3 (multiplier)	Band 4 (tolerance)
Black	0	0	1	
Brown	1	1	10	± 1%
Red	2	2	100	± 2%
Orange	3	3	1000	
Yellow	4	4	10 000	
Green	5	5	100 000	
Blue	6	6	1 000 000	
Violet	7	7		
Grey	8	8		
White	9	9		
Gold			0.1	± 5%

E12 Preferred values: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68 and 82

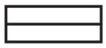
Sample microcontroller



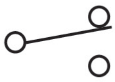
Standard circuit symbols

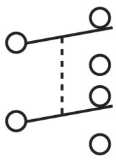

Cell

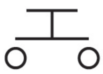

Battery

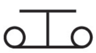

Fuse


SPST switch

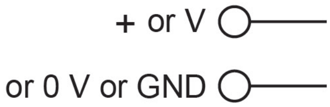

SPDT switch


DPTP switch


Push-to-make switch


Push-to-break switch

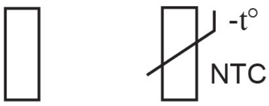

Magnetic reed switch



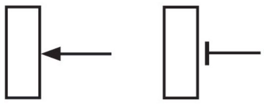
Terminals for power supply unit (PSU)

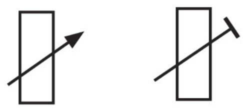
Voltage regulator

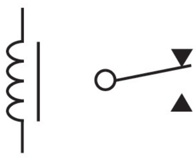

Polarised and non-polarised capacitor

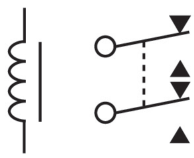


Resistor Thermistor


Potentiometer


Variable resistor


SPST relay


DPDT relay

Standard circuit symbols (continued)

Voltmeter

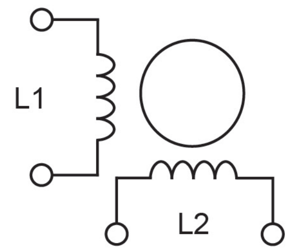
Ammeter

Ohmmeter

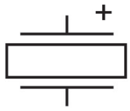

NPN transistor


Diode

Motor

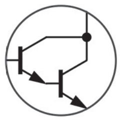


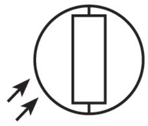
Bipolar stepper motor

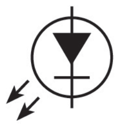


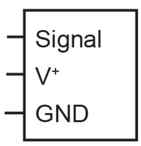
Piezo sounder


Electromagnet
(solenoid)


Darlington pair

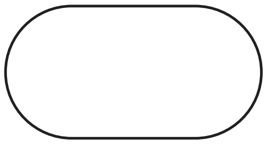

Light dependent
resistor


Light emitting
diode



Servo

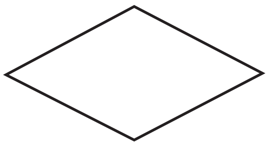
Flow chart symbols



Terminator – start or end of a program or subroutine

Output to a device

Delay or computational process



Decision with Yes/No result

Subroutine – a predefined process

Flow of computation

End of Data Book

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