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

WACE
Western Australian Certificate of Education

Engineering Studies Data Book

2015

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SI units

Quantity	SI unit	
	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
thermodynamic temperature	kelvin	K
energy, work, quantity of heat	joule	J
power, radiant flux	watt	W
Celsius temperature	degree Celsius	°C
area	square metre	m^2
volume	cubic metre	m^3
speed, velocity	metre per second	$m\ s^{-1}$
acceleration	metre per second squared	$m\ s^{-2}$
mass density	kilogram per cubic metre	$kg\ m^{-3}$

Standard prefixes

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

Common constants

Item	Symbol	Value
Ratio of the circumference of a circle to its diameter (Pi)	π	3.14159

CORE CONTENT

General formulae

Side lengths of a right triangular plane figure	$h^2 = o^2 + a^2$	h is the hypotenuse o is the opposite side a is the adjacent side
Angular relationships of a right triangular figure	$\cos\theta = \frac{a}{h}$ $\sin\theta = \frac{o}{h}$ $\tan\theta = \frac{o}{a}$	θ is the angle h is the hypotenuse o is the opposite side a is the adjacent side
Perimeter of a circle [p]	$p = \pi d$	d is the diameter
Area of a circle [A]	$A = \pi r^2$	r is the radius
Surface area of open ended cylinder [A]	$A = \pi dh$	d is the diameter h is the height
Volume of a cylinder [V]	$V = \pi r^2 h$	r is the radius h is the height
Surface area of a sphere [A]	$A = 4\pi r^2$	r is the radius
Volume of a sphere [V]	$V = \frac{4}{3}\pi r^3$	r is the radius
Density [ρ] of a material	$\rho = \frac{m}{V}$	m is mass V is volume
Energy [E]	$E = Pt$	t is the time taken P is the power
Efficiency [η] %	$\eta\% = \frac{Output}{Input} \times 100$	

Common constants

Item	Symbol	Value
Acceleration due to gravity	g	9.80 m s^{-2}

Selected material properties

Material	Density kg m^{-3}	Elastic (Young's) modulus kN mm^{-2}	Ultimate tensile * strength N mm^{-2}	Yield stress N mm^{-2}	Electrical conductivity $\Omega^{-1}m^{-1} \times 10^{6}$	Thermal conductivity W $m^{-1}K^{-1}$
Structural steel	7850	200	470	250	13.0	46
Stainless steel	7600	200	860	502	1.35	16
Cast iron	7200	120	180		10.3	80
Wrought iron	7750	200			10.3	80
Aluminium	2710	70	150	95	37.7	237
Brass	8740	90	190	50	16.7	109
Copper	8930	112	210	70	59.5	401
Zinc	7130	108	200	13.8	16.8	116
Solder (60% lead, 40% tin)	9280	23.7	37	-	7.28	43.6
Concrete	2400	30	40 (compressive)			0.8
Concrete (steel reinforced)						0.8
Timber (parallel to grain)		12	105			0.16
Polypropylene	1240	4	19.7 – 80	50		0.13
Polycarbonate	1200	2.3	70			0.19
ABS plastics		2.3	40	48.3		2.34
Nylon	1160	2 – 4	75	45		
Acrylic	1190	3.2	70	73.7		0.19
Glass	2500	69		3600		1.05
Diamond	3520	1000		50 000		2320
Gold	19 320	82	220	40	44.6	318
Ice	931	9.17.5@-5°C		85		2.25@-5°C
Water pure	1000					
Sea water	1022					
Petrol	740					0.15
Crude oil	800					0.15

* Unless noted as compressive strength.

Basic formulae (Mechanical) 1

Parameter	Formula	Terms
Mechanical Advantage [MA]	$MA = \frac{F_{load}}{F_{effort}}$	F_{load} is the output force F_{effort} is the input force
Velocity Ratio [VR]	$VR = \frac{d_{effort}}{d_{load}}$	d_{effort} is the distance moved by the effort d_{load} is the distance moved by the load
Velocity ratios in drive trains (for gear or pulley train) [VR]	$VR = \frac{F_1}{D_1}\frac{F_2}{D_2}\frac{F_3}{D_3}$	$F_{1,2 \text{ and } 3}$ are the followers $D_{1,2 \text{ and } 3}$ are the drivers (measured via number of teeth on gears or by pulley diameters)
Torque [τ]	$\tau = Fr$	F is the force r is the radius
Moment of a force [M]	$M = Fd$	F is the force d is the perpendicular distance
Stress[σ] or Pressure [p]	$\sigma\ (p) = \frac{F}{A}$	F is the force A is the area
Strain [ε]	$\varepsilon = \frac{\Delta L}{L}$	ΔL is the change in length L is the original length
Young's (Elastic) modulus [E]	$E = \frac{\sigma}{\varepsilon}$	σ is the stress ε is the strain
Young's (Elastic) modulus [E] expanded formula	$E = \frac{FL}{A\Delta L}$	F is the force A is the area ΔL is the change in length L is the original length
Factor of Safety [FS]	$FS = \frac{\sigma_{UTS}}{\sigma_{safeworking}}$	σ_{UTS} is the ultimate tensile stress $\sigma_{safeworking}$ is the safe working stress
Acceleration [a]	$a = \frac{v-u}{t}$	v is the final velocity u is the initial velocity t is the time
Velocity [v]	$v^2 = u^2 + 2as$	u is the initial velocity a is the acceleration s is the distance
Distance [s]	$s = ut + \frac{1}{2}at^2$	u is the initial velocity t is the time a is the acceleration
Force [F]	$F = ma$	m is the mass a is the acceleration
Equilibrium conditions	$\sum M = 0$ $\sum F_y = 0$ $\sum F_x = 0$	Σ is the 'sum of' M are the moments F_y are the vertical force components F_x are the horizontal force components
Equilibrium conditions (expanded)	$\Sigma CWM = \Sigma ACWM$ $\Sigma F(up) = \Sigma F(down)$ $\Sigma F(left) = \Sigma F(right)$	Σ is the 'sum of' CWM are clockwise moments $ACWM$ are anticlockwise moments

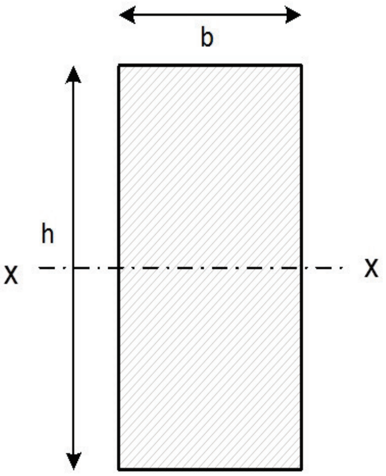
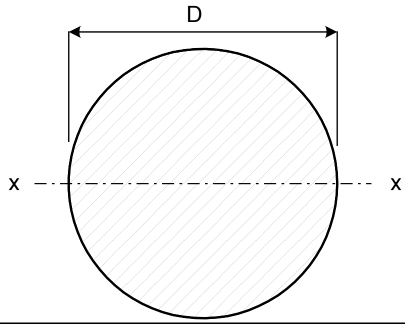
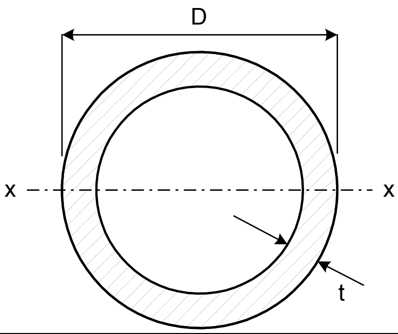
Basic formulae (Mechanical) 2

Parameter	Formula	Terms
Work [W]	$W = Fs$	F is the force s is the distance moved
Power [P]	$P = \frac{Fs}{t} = Fv$	F is the force s is the distance t is the time taken v is the average velocity
Energy [E]	$E = Pt$	t is the time taken P is the power
Potential energy [E_p]	$E_p = mgh$	m is the mass g is the acceleration due to gravity h is the height
Kinetic energy [E_k]	$E_k = \frac{1}{2} mv^2$	m is the mass v is the velocity
Potential and kinetic energy conversion	$\Delta E_p = \Delta E_k$	Δ is the 'change in'
Efficiency [η] %	$\eta\% = \frac{Work\ done\ in\ moving\ load}{Work\ done\ by\ the\ effort} \times 100$	Work done in moving load is the output Work done by the effort is the input
Compound gear or pulley system [RPM]	$output\ RPM = \frac{input\ RPM}{VR}$	VR is the velocity ratio RPM is the revolutions per minute
Linear velocity of a gear or pulley system [v]	$v = \frac{(RPM)(2\pi r)}{60} = \frac{s}{t}$	r is the radius of the gear or pulley s is the distance travelled t is the time taken
Distance around a winch drum [s]	$s = 2\pi r$	r is the radius of the drum

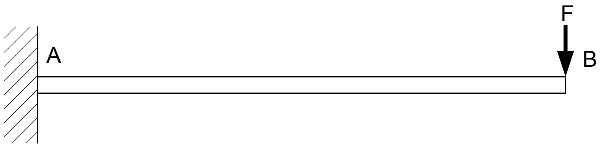
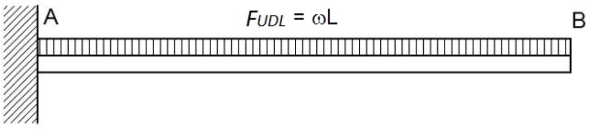
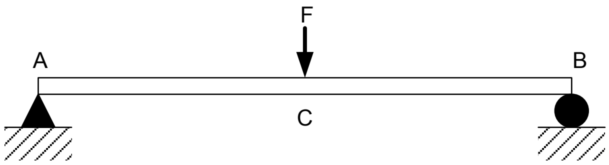
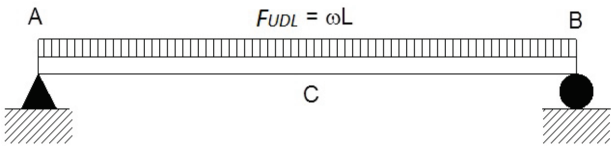
Selected SI units

Derived quantity	SI unit			
	Name	Symbol	Expression in terms of other SI units	Expression in terms of SI base units
force	newton	N	–	m kg s^{-2}
pressure, stress	pascal	Pa	N m^{-2}	m^{-1} kg s^{-2}
energy, work, quantity of heat	joule	J	N m	m^2 kg s^{-2}
power, radiant flux	watt	W	–	m^2 kg s^{-3}

Second moments of area

Shape	Dimensions	Second moment of area about centroidal axis
Rectangle solid section (vertical)		$I_{xx} = \dfrac{bh^3}{12}$
Circular solid section		$I_{xx} = \dfrac{\pi D^4}{64}$
Circular tube section		$I_{xx} = \dfrac{\pi(D_o^4 - D_i^4)}{64}$ D_o = cylinder outside diameter D_i = cylinder inside diameter

Simple beams

Beam configuration	Maximum bending moment	Maximum deflection (y)
	$BM_{\max} = FL \quad at\, A$ Here F is the single vertical point load.	$y = \frac{FL^3}{3EI_{xx}} \quad at\, B$ Here F is the single vertical point load.
	$BM_{\max} = \frac{F_{UDL}\, L}{2} \quad at\, A$ Here F_{UDL}= ωL which is the load per unit length (ω) times the length of the beam (L)	$y = \frac{F_{UDL}\, L^3}{8EI_{xx}} \quad at\, B$ Here F_{UDL}= ωL which is the load per unit length (ω) times the length of the beam (L)
	$BM_{\max} = \frac{FL}{4} \quad at\, C$ Here F is the single vertical point load.	$y = \frac{FL^3}{48EI_{xx}} \quad at\, C$ Here F is the single vertical point load.
	$BM_{\max} = \frac{F_{UDL}L}{8} \quad at\, C$ Here F_{UDL}= ωL which is the load per unit length (ω) times the length of the beam (L)	$Y = \frac{5F_{UDL}L^3}{384EI_{xx}} \quad at\, C$ Here F_{UDL}= ωL which is the load per unit length (ω) times the length of the beam (L)

Terms:

L	Length of beam between supports
ω	A uniformly distributed load per unit length
F_{UDL}	The product of the UDL's applied load/unit length (ω) and the length of the beam (L)
F	An applied vertical point load
E	The elastic (Young's) modulus of the material of the beam.
I_{xx}	The second moment of area of the beam section.
A	The left hand end of the beam
B	The right hand end of the beam
C	The mid-point of the beam

Resistor colour codes

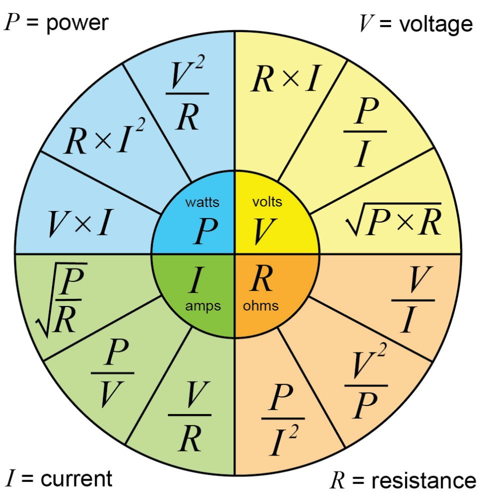
band colour	1st band	2nd band	multiplier
Black		0	1
Brown	1	1	10
Red	2	2	100
Orange	3	3	1000
Yellow	4	4	10 000
Green	5	5	100 000
Blue	6	6	1 000 000
Violet	7	7	
Grey	8	8	
White	9	9	

tolerance band	
Brown	± 1%
Red	± 2%
Gold	± 5%
Silver	± 10%

E12 Preferred values: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82
And decades (e.g. 100, 1000, 10 000, …..10 000 000) thereafter

Example: 4 band colour code

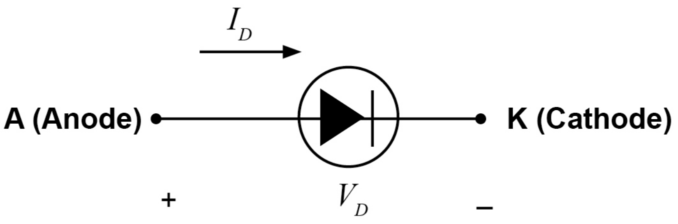
Electrical formula wheel



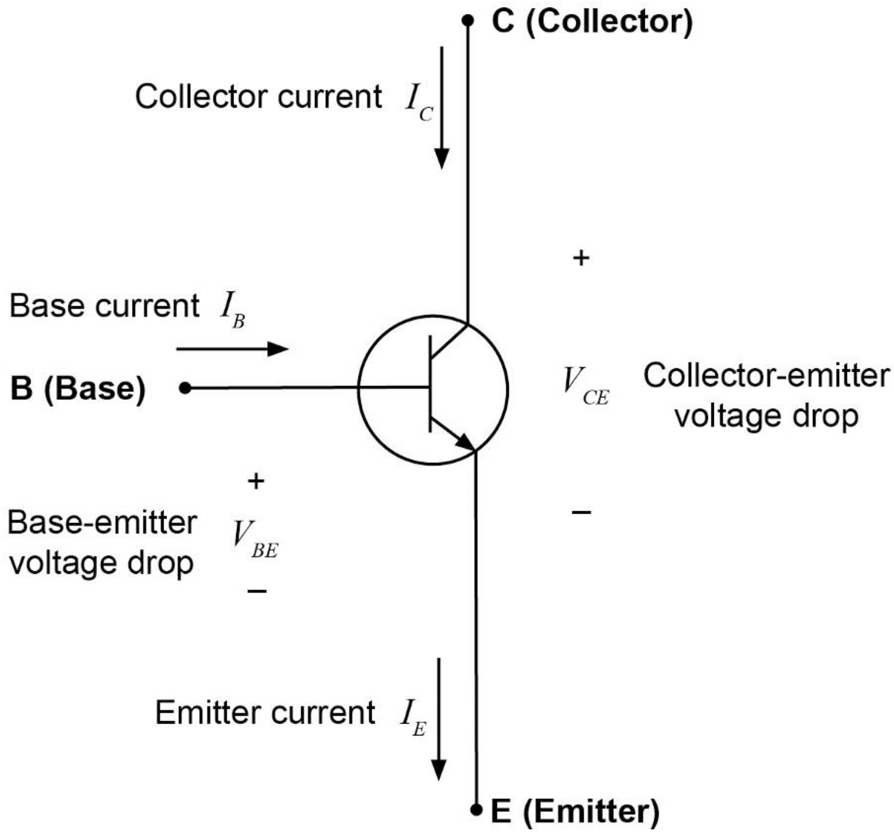
Basic formulae (Electrical/Electronic)

Parameter	Formula	Terms
Ohm's law	$V = IR$	V is the voltage I is the current R is the resistance
Power law	$P = VI = I^2R = \frac{V^2}{R}$	P is the power I is the current V is the voltage R is the resistance
Electrical energy [E_e]	$E_e = VIt$	V is the voltage I is the current t is the time
Resistors in series	$R_t = R_1 + R_2 + \ldots$	R_t is the total resistance R_1, R_2, … are the individual resistances
Resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$	R_t is the total resistance R_1, R_2, … are the individual resistances
Capacitors in parallel	$C = C_1 + C_2 + \cdots$	C is the total capacitance C_1, C_2, … are the individual capacitances
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$	C is the total capacitance C_1, C_2, … are the individual capacitances
Charge of capacitor	$Q = CV$	Q is the charge C is the capacitance V is the voltage
Potential dividers	$V_{cc} = V_1 + V_2$ $V_1 = V_{cc}\frac{R_1}{R_1 + R_2}$ $V_2 = V_{cc}\frac{R_2}{R_1 + R_2}$	V_{cc} is the total voltage across the resistor pair V_1 is the voltage across resistor R_1 V_2 is the voltage across resistor R_2
Transistor current gain	$h_{FE} = \frac{I_C}{I_B}$	I_C is the collector current I_B is the base current
LED in series with a resistor	$R = \frac{(V_{cc} - V_{LED})}{I_{LED}}$	V_{cc} is the total applied voltage V_{LED} is the voltage across the LED I_{LED} is the current through the LED R is the series resistor
Transformers	$\frac{V_S}{V_P} = \frac{N_S}{N_P}$ $V_P I_P = V_S I_S$	V_s is the secondary voltage V_p is the primary voltage N_s is the number of turns in the secondary coil N_p is the number of turns in the primary coil I_p is the primary current I_s is the secondary current
Kirchoff's first law	$\sum I = 0$	The sum of currents flowing toward that point is equal to the sum of currents flowing away from that point
Kirchoff's second law	$\sum \Delta V = 0$	The directed sum of the electrical potential differences around a closed loop in a circuit must be zero

Diode symbol



Transistor symbol (bipolar NPN transistor)

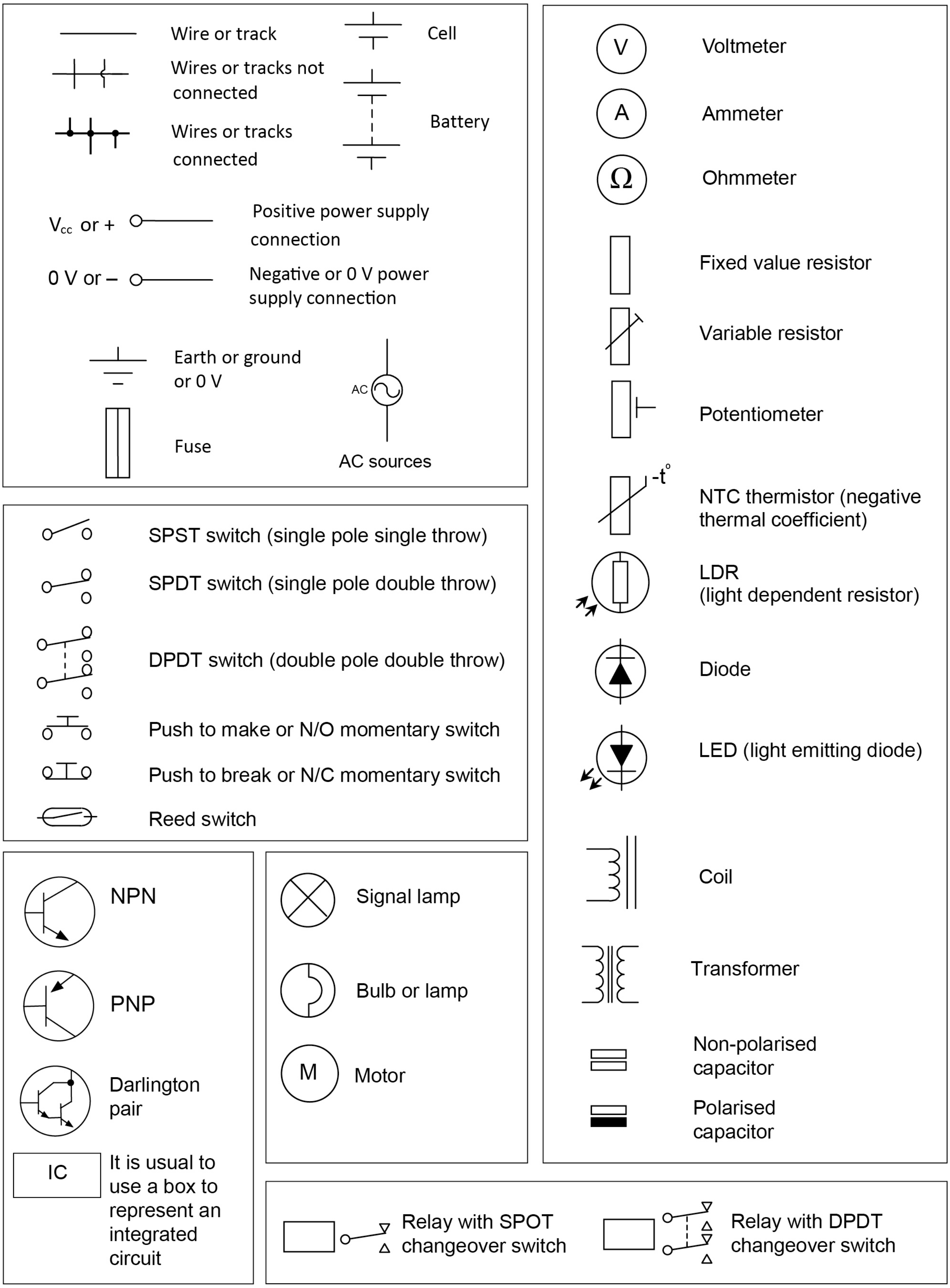


Diode models	
On	$V_D = V_{D,on} \quad (or\, V_D = V_F)$ **Check:** $I_D > 0$
Off	$I_D = 0\,\text{A}$ **Check:** $V_D < V_{D,on}\,(or\, V_F)$
Transistor models (NPN BJT)	
Cut-off	$I_B = I_C = 0$ **Check:** $V_{BE} < 0.7\,\text{V}$
Saturation	$V_{BE} = 0.7\,\text{V}$ $V_{CE} = 0\,\text{V}$ **Check:** $I_B > 0$ $\frac{I_C}{I_B} < \beta\,(or\, h_{FE})$
Forward-active	$V_{BE} = 0.7\,\text{V}$ $I_C = \beta \times I_B \quad (or\, I_C = h_{FE} \times I_B)$ **Check:** $I_B > 0$ $V_{CE} > 0$

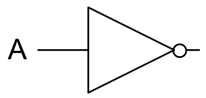
Selected SI units

Derived quantity	SI unit			
	Name	Symbol	Expression in terms of other SI units	Expression in terms of SI base units
frequency	hertz	Hz	–	s^{-1}
power, radiant flux	watt	W	–	$m^2\,kg\,s^{-3}$
electric charge, quantity of electricity	coulomb	C	–	s A
electric potential difference, electromotive force	volt	V	$W\,A^{-1}$	$m^2\,kg\,s^{-3}\,A^{-1}$
capacitance	farad	F	$C\,V^{-1}$	$m^{-2}\,kg^{-1}\,s^4\,A^2$
electric resistance	ohm	Ω	$V\,A^{-1}$	$m^2\,kg\,s^{-3}\,A^{-2}$

Standard symbols



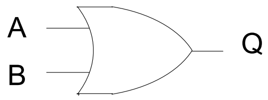
Logic symbols and their truth tables



NOT Gate

Output = $\overline{A}$

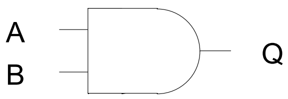
A	Q
0	1
1	0



OR Gate

Output = $A+B$

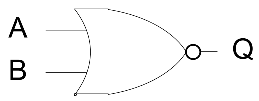
A	B	Q
0	0	0
1	0	1
0	1	1
1	1	1



AND Gate

Output = $A.B$

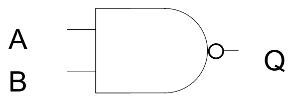
A	B	Q
0	0	0
1	0	0
0	1	0
1	1	1



NOR Gate

Output = $\overline{A+B}$

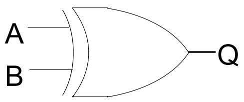
A	B	Q
0	0	1
1	0	0
0	1	0
1	1	0



NAND Gate

Output = $\overline{A.B}$

A	B	Q
0	0	1
1	0	1
0	1	1
1	1	0

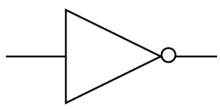
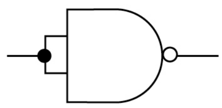
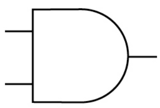
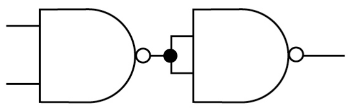
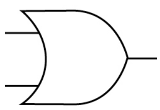
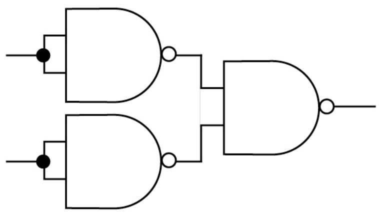
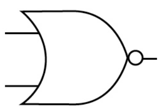
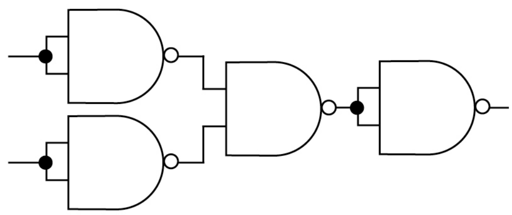


XOR Gate

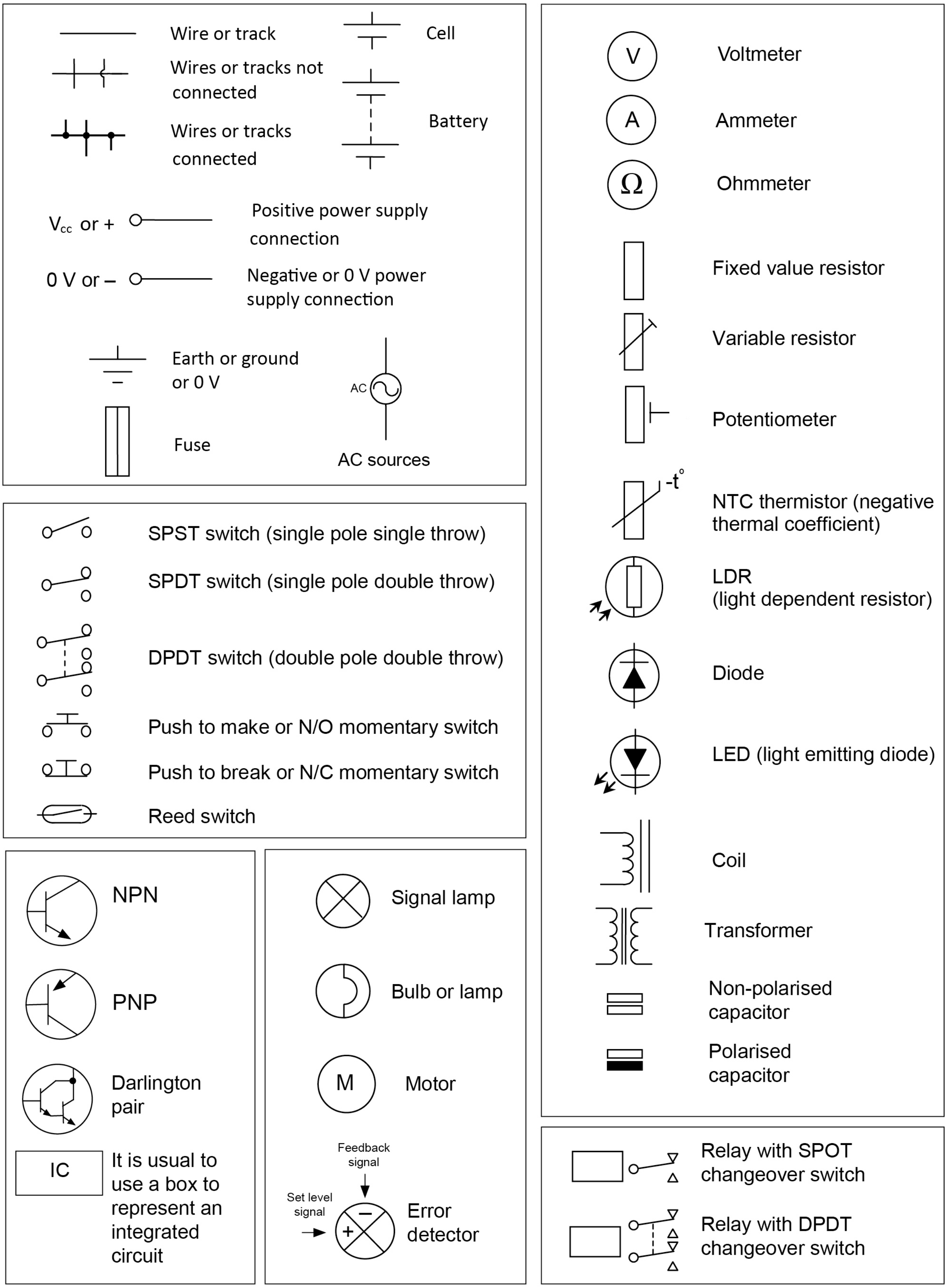
Output = $A \oplus B$

A	B	Q
0	0	0
1	0	1
0	1	1
1	1	0

NAND Gate Equivalents

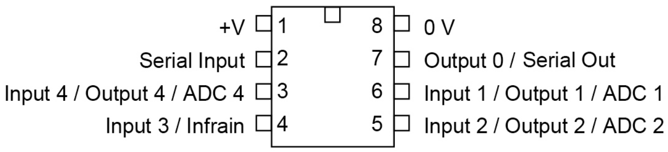
Gate		Equivalent in NAND gates
NOT		
AND		
OR		
NOR		

Standard symbols

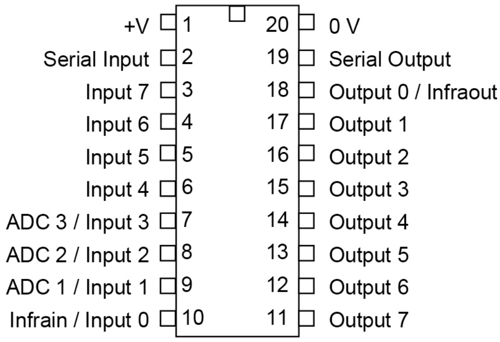


Selected PICAXE microprocessor pin allocations

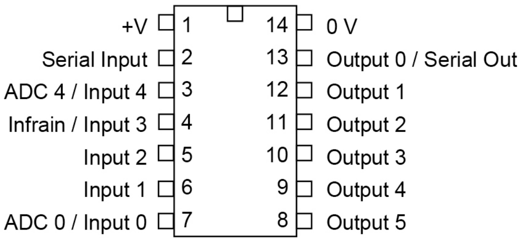
PICAXE-08M



PICAXE-20M

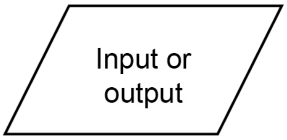


PICAXE-14M

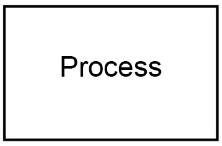


Flow chart symbols

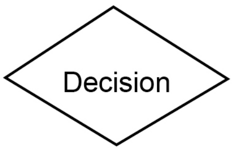
Start or end of a program or subroutine



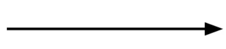
Input from a device, switch or keyboard, or output to a device



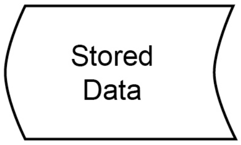
A step in the computational process



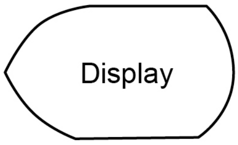
A decision point with a Yes/No result



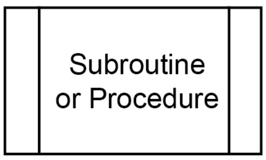
Flow of computation



Data stored permanently on disk or non-volatile memory

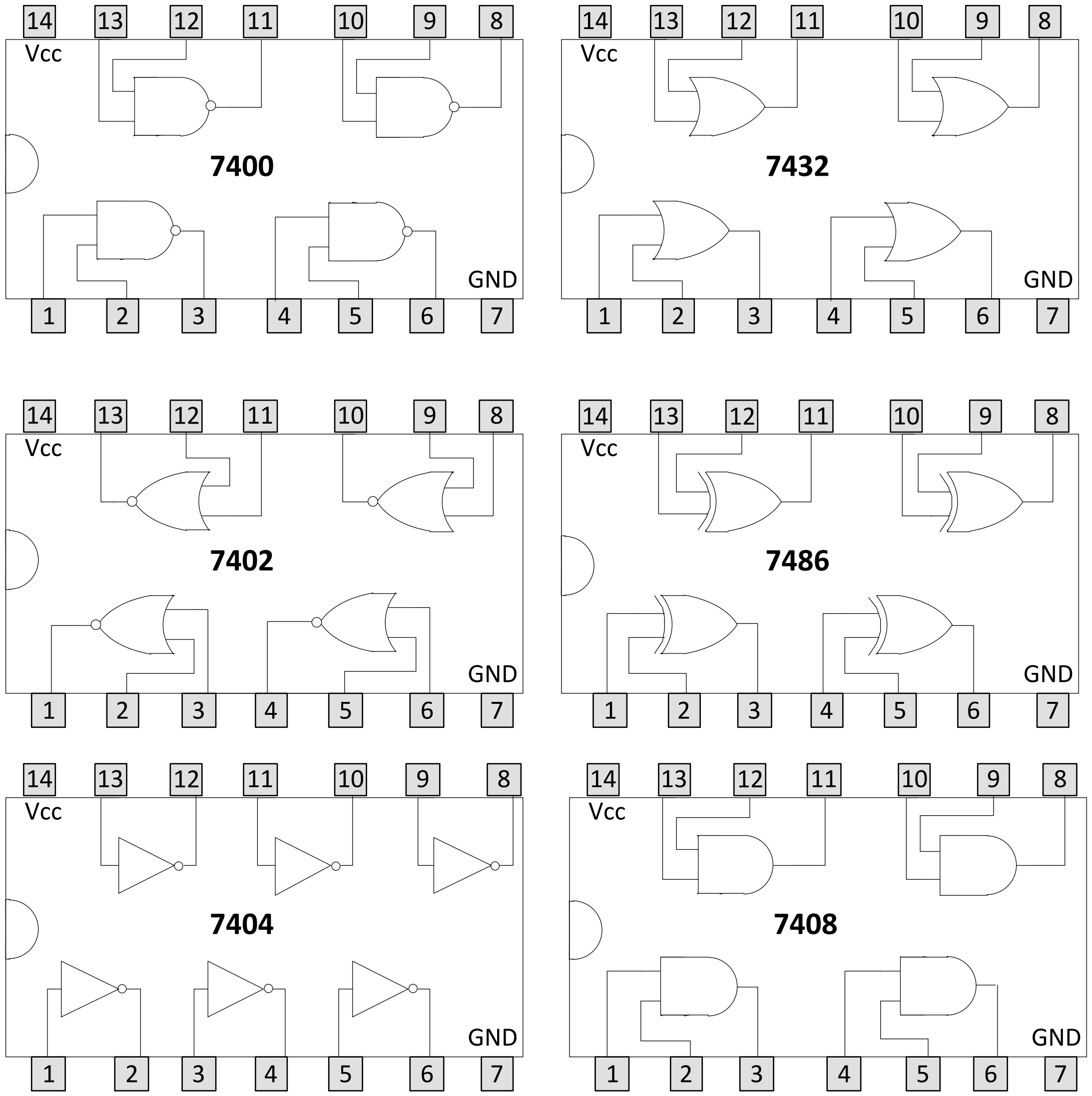


A display device, CRT/LCD panel

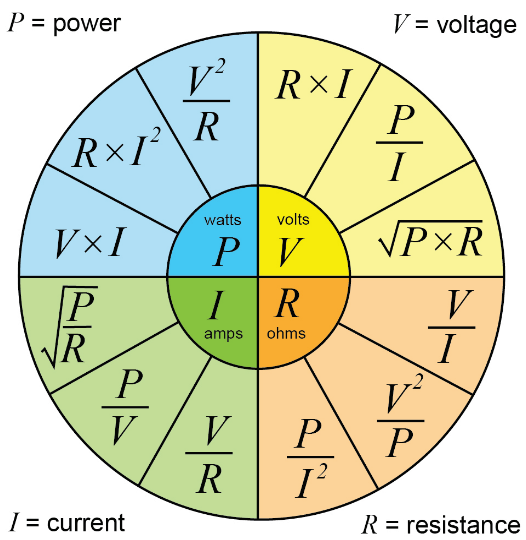


A predefined process

7400 logic chip layouts



Electrical formula wheel



Basic formulae (Systems and control)

Parameter	Formula	Terms
Ohm's law	$V = IR$	V is the voltage I is the current R is the resistance
Power law	$P = IV = I^2R = \frac{V^2}{R}$	P is the power I is the current V is the voltage R is the resistance
Resistors in series	$R_t = R_1 + R_2 + \ldots$	R_t is the total resistance R_1, R_2, … are the individual resistances
Resistors in parallel	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots.$	R_t is the total resistance R_1, R_2, … are the individual resistances
Potential dividers	$V_{cc} = V_1 + V_2$ $V_1 = V_{cc}\frac{R_1}{R_1 + R_2}$ $V_2 = V_{cc}\frac{R_2}{R_1 + R_2}$	V_{cc} is the total voltage across the resistor pair V_1 is the voltage across resistor R_1 V_2 is the voltage across resistor R_2
Mechanical advantage [MA]	$MA = \frac{F_{output}}{F_{input}} = \frac{F_{load}}{F_{effort}}$ $F_{in} \times d_{in} = F_{out} \times d_{out}$	F_{output}, F_{load} is the output force F_{input}, F_{effort} is the input force
Distance moved [d_r]	$distance\ moved\ (d_r) = \frac{n^o\ of\ teeth\ on\ pinion \times n^o\ of\ revolutions}{n^o\ of\ teeth\ per\ metre\ of\ rack}$	
Velocity ratio of a gear or pulley [VR]	$VR = \frac{v_{input}}{v_{output}} = \frac{\tau_{output}}{\tau_{input}} = \frac{d_{input}}{d_{output}}$ $VR = \frac{N_{in}}{N_{out}}$	v is the input or output velocity τ is the input or output torque d is the distance moved of the input or output N is the speed of rotation of the input or output
Torque [τ]	$\tau = Fr$	F is the force r is the radius
Moment of a force [M]	$M = Fd$	F is the force d is the perpendicular distance
Efficiency [η]	$\eta = \frac{MA}{VR}$	MA is the mechanical advantage VR is the velocity ratio

End of Data Booklet

ACKNOWLEDGEMENTS

Electrical relationships: *Electrical formula wheel*. Retrieved January, 2010, from www.sengpielaudio.com/calculatorohm.htm#top

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