Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

Engineering Studies Data Book

2010

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SI base units

Base quantity	SI base unit	
	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K

Selected SI derived units

Derived quantity	SI derived unit	
	Name	Symbol
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	$kg\ m^{-3}$
current density	ampere per square metre	$A\ m^{-2}$
magnetic field strength	ampere per metre	$A\ m^{-1}$

Selected SI derived units with special names

Derived quantity	SI derived unit			
	Name	**Symbol**	**Expression in terms of other SI units**	**Expression in terms of SI base units**
plane angle	radian	rad	-	$m\ m^{-1} = 1$
solid angle	steradian	sr	-	$m^2\ m^{-2} = 1$
frequency	hertz	Hz	-	s^{-1}
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	$J\ s^{-1}$	$m^2\ kg\ s^{-3}$
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	$V\ A^{-1}$	$m^2\ kg\ s^{-3}\ A^{-2}$
Celsius temperature	degree Celsius	°C	-	K

SI unit 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

Some common constants

Item	Symbol	Value
Acceleration due to gravity	g	9.80 m s^{-2}
Ratio of the circumference of a circle to its diameter (Pi)	π	3.14159
Natural base of logarithms	e	2.71828
Radians in a circle	2 π	6.28318 rad

General formulae 1

Area of a circle [A]	$A = \pi \cdot r^2$	r is the radius
Perimeter of a circle [P]	$P = \pi \cdot d$	d is the diameter
Volume of a cylinder [V]	$V = \pi \cdot r^2 \cdot h$	r is the radius h is the height
Volume of a sphere [V]	$V = \frac{4}{3}\pi \cdot r^3$	r is the radius
Surface area of a sphere [A]	$A = 4\pi \cdot r^2$	r is the radius

General formulae 2

Parameter	Formula	Terms
Mechanical advantage [MA]	$MA = \frac{F_{out}}{F_{in}}$	F_{out} is the output force F_{in} is the input force
Work [W]	$W = F \cdot s$	F is the force s is the distance moved
Power [P]	$P = \frac{F \cdot s}{t} = F \cdot v$	F is the force s is the distance t is the time taken v is the velocity
Heat energy [E_h]	$E_h = c \cdot m \cdot \Delta T$	c is the specific heat capacity M is the mass ΔT is the change in temperature
Force [F]	$F = m \cdot a$	m is the mass a is the acceleration
Equilibrium conditions	$\sum M = 0$ $\sum V = 0$ $\sum H = 0$	M are the moments V are the vertical force components H are the horizontal force components
Pressure in a liquid	$p = \rho \cdot g \cdot h$	ρ is the density of the liquid g is the acceleration due to gravity h is the depth below the surface of the liquid.

MECHANICAL SYSTEMS

Selected material properties

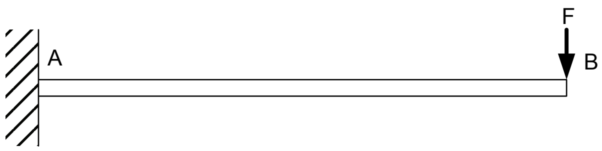
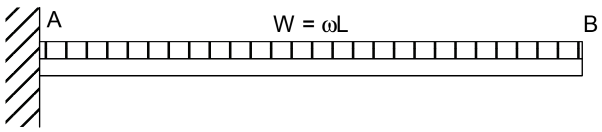
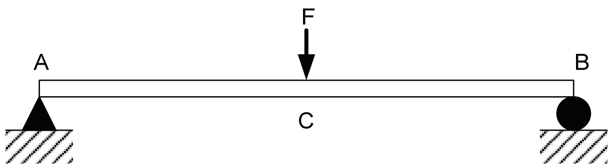
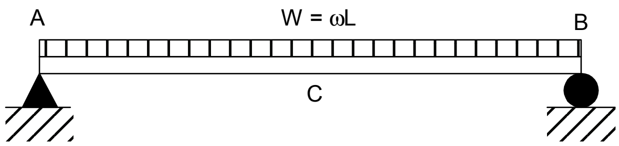
Material	Density kg m^{-3}	Elastic (Young's) modulus kN mm^{-2}	Ultimate tensile * strength N mm^{-2}	Yield stress N mm^{-2}	Specific heat kJ kg^{-1} K^{-1}	Electrical conductivity $\Omega^{-1}m^{-1} \times 10^6$	Thermal conductivity W $m^{-1}K^{-1}$
Structural steel	7850	200	400	250	0.503	13.0	46
Stainless steel	7600	200	860	502			16
Cast iron	7000	120	160		0.46	10.3	55
Wrought iron	7750	200			0.50	10.3	59
Aluminium	2710	69	110	95	0.897	37.7	237
Brass	8740	110	250	50	0.38		109
Copper	8930		220	70	0.39	59.5	401
Concrete	2400	30	40 (compressive)		0.88		0.8
Concrete (steel reinforced)					0.88		0.8
Plastic polypropylene	1240	7.6	19.7 - 80	50	2		0.13
Timber (parallel to grain)		11			1.7		0.16
Polycarbonate	1200	2.3	70		1.2		0.19
ABS plastics		2.3	40	48.3	1.423		2.34
Glass		69		3600	0.84		1.05
Diamond		1000		50 000			2320
Gold	19 320	82	220	40	0.13	44.6	318
Ice		9.17.5@-5°C		85	2.27@-5°C		2.25@-5°C
Water pure	1000				4.19		
Sea water	1022				3.93		
Petrol	740				2.13		0.15
Crude oil	800						0.15
Alcohol	790				2.72		0.15
Nylon	1160	2 - 4	75	45			

* Unless noted as compressive strength.

Basic formulae

Parameter	Formula	Terms
Torque [τ]	$\tau = F \cdot r$	F is the force r is the radius
Rotational power [P_r]	$P_r = 2 \cdot \pi \cdot n \cdot \tau$	n is the number of revolutions per second τ is the torque
Pressure [p] or Stress[σ]	$(p)\,\sigma = \frac{F}{A}$	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
Elastic (Young's) modulus [E]	$E = \frac{\sigma}{\varepsilon}$	σ is the stress ε is the strain
Potential energy (E_p]	$E_p = m \cdot g \cdot h$	m is the mass g is the acceleration due to gravity h is the height
Kinetic energy [E_k]	$E_k = \frac{1}{2} m \cdot v^2$	m is the mass v is the velocity
Acceleration [a]	$a = \frac{v - u}{t}$	v is the final velocity u is the initial velocity t is the time
Velocity [v]	$v = \sqrt{(u^2 + 2 \cdot a \cdot s)}$	u is the initial velocity a is the acceleration s is the distance
Distance [s]	$s = u \cdot t + \frac{1}{2} a \cdot t^2$	u is the initial velocity t is the time a is the acceleration

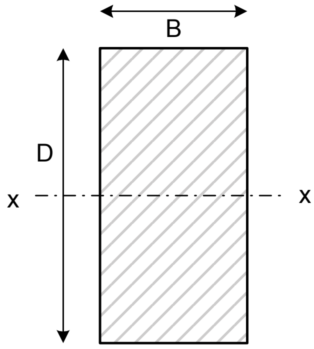
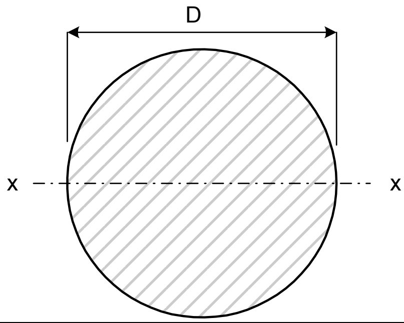
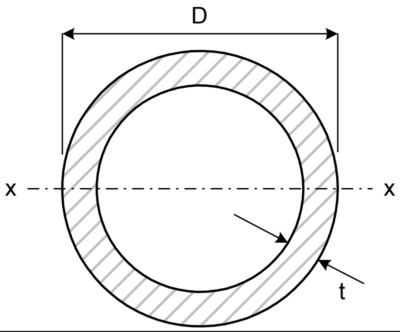
Simple beams

Beam configuration	Maximum bending moment	Maximum deflection
	$= F.L \quad \text{at}\,A$	$= \dfrac{F.L^3}{3.E.I} \quad \text{at}\,B$
	$= \dfrac{\omega.L^3}{2} \quad \text{at}\,A$	$= \dfrac{\omega.L^4}{8.E.I} \quad \text{at}\,B$
	$= \dfrac{F.L}{4} \quad \text{at}\,C$	$= \dfrac{F.L^3}{48.E.I} \quad \text{at}\,C$
	$= \dfrac{\omega.L^2}{8} \quad \text{at}\,C$	$= \dfrac{5.\omega.L^4}{384.E.I} \quad \text{at}\,C$

Terms:

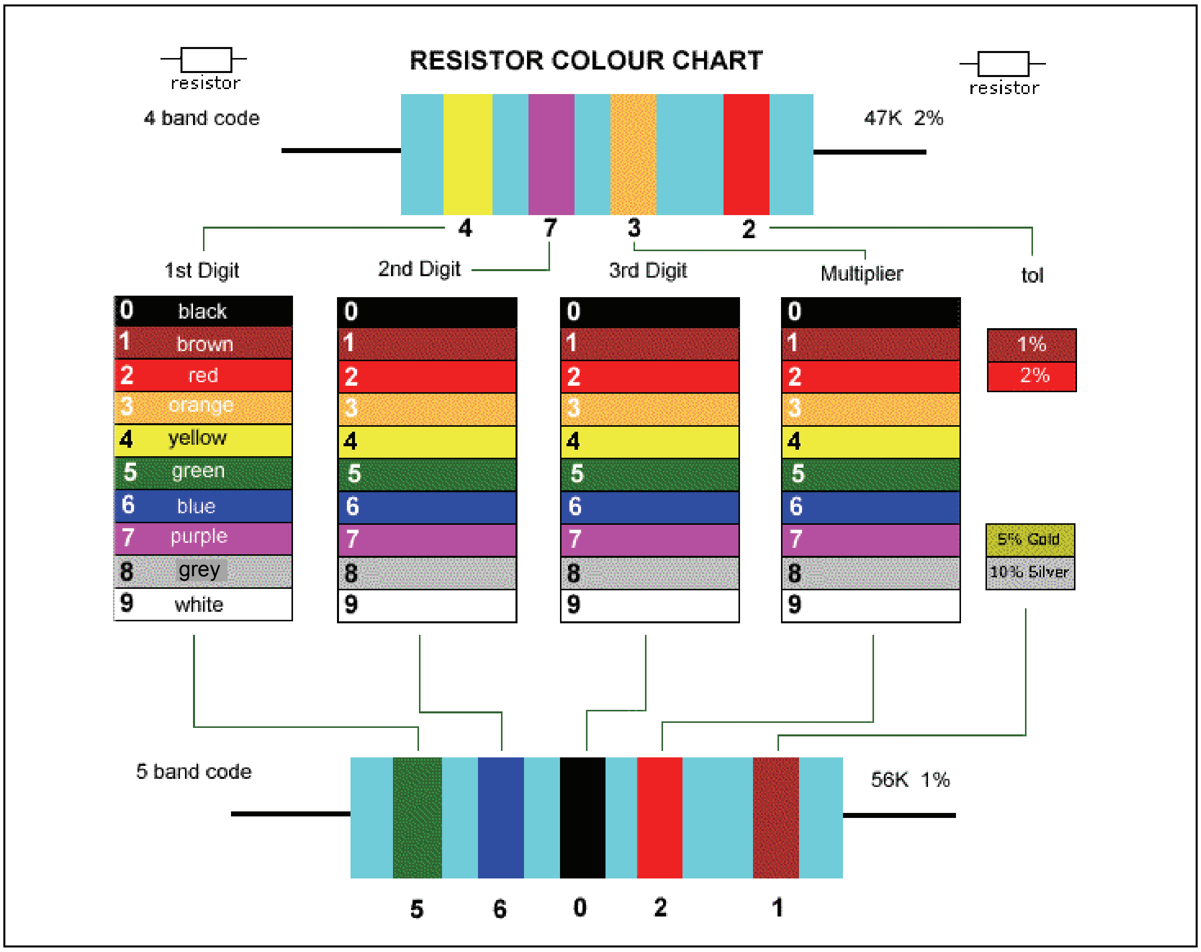
- L Length of beam between supports
- ω A uniformly distributed load per unit length
- W The total applied distributed load
- F An applied point load
- E The elastic (Young's) modulus of the material of the beam.
- I The second moment of area of the beam section.
- A The left hand end of the beam
- B The right hand end of the beam
- C The mid point of the beam

Second moments of area

Shape	Dimensions	Second moment of area about centroidal axis
Rectangle section		$I_{xx} = \frac{B \cdot D^3}{12}$
Circular solid section		$I_{xx} = \frac{\pi . D^4}{64}$
Circular tube section		$I_{xx} = \frac{\pi}{8} . D^3 . t$

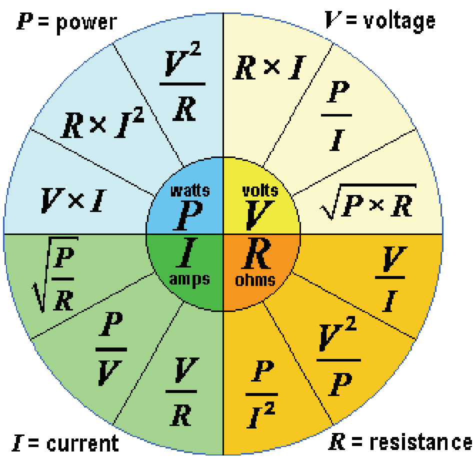
ELECTRONIC/ELECTRICAL

Resistor colour codes



Preferred values: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82
And decades (e.g. 100, 1000, 10000, …..10000000) thereafter

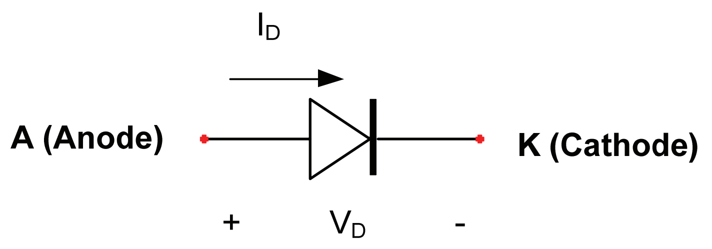
Electrical formula wheel



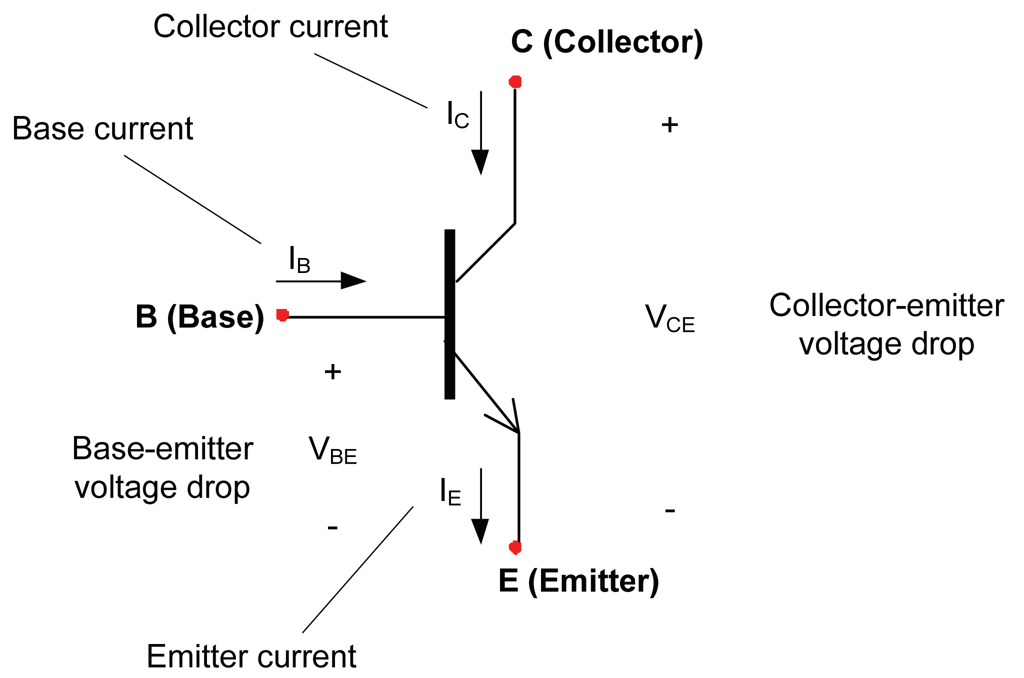
Basic formulae

Parameter	Formula	Terms
Ohm's law	$V = I \cdot R$	V is the voltage I is the current R is the resistance
Power law	$P = I \cdot V = I^2 \cdot R$	P is the power I is the current V is the voltage R is the resistance
Electrical energy [E_e]	$E_e = V \cdot I \cdot t$	V is the voltage I is the current t is the time
Resistors in series	$R = R_1 + R_2 + \ldots$	R is the total resistance R_1, R_2, … are the individual resistances
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$	R 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	$Q = C \cdot V$	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	$\frac{V_S}{V_P} = \frac{N_S}{N_P}$ $V_P \cdot I_P = V_S \cdot I_S$	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	$V_D = V_{D,on} \quad (\text{or } V_D = V_F)$ **Check:** $I_D > 0$
Off	$I_D = 0\text{ A}$ **Check:** $V_D < V_{D,on}\ (\text{or } V_F)$
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:** $I_B > 0$ $\frac{I_C}{I_B} < \beta\ (\text{or } h_{FE})$
Forward-active	$V_{BE} = 0.7\text{ V}$ $I_C = \beta \times I_B \quad (\text{or } I_C = h_{FE} \times I_B)$ **Check:** $I_B > 0$ $V_{CE} > 0$

Standard symbols

- Wire or track
- Wires or tracks not connected
- Wires or tracks connected
- Cell
- Battery
- AC sources (AC, AC +)
- V_{cc} or + : Positive power supply connection
- 0V or− : Negative or 0V power supply connection
- Earth or ground or 0V
- Fuse

- SPST switch (single pole single throw)
- SPDT switch (single pole double throw)
- DPDT switch (double pole double throw)
- Push to make or N/O momentary switch
- Push to break or N/C momentary switch
- Reed switch

- Non-polarised capacitor
- Polarised capacitor
- Signal lamp
- Bulb or lamp
- Crystal (also used to represent a piezo sounder)
- Heater
- Speaker

Transistors and ICs

- NPN
- PNP
- Phototransistor
- Darlington pair
- IC: It is usual to use a box to represent an integrated circuit

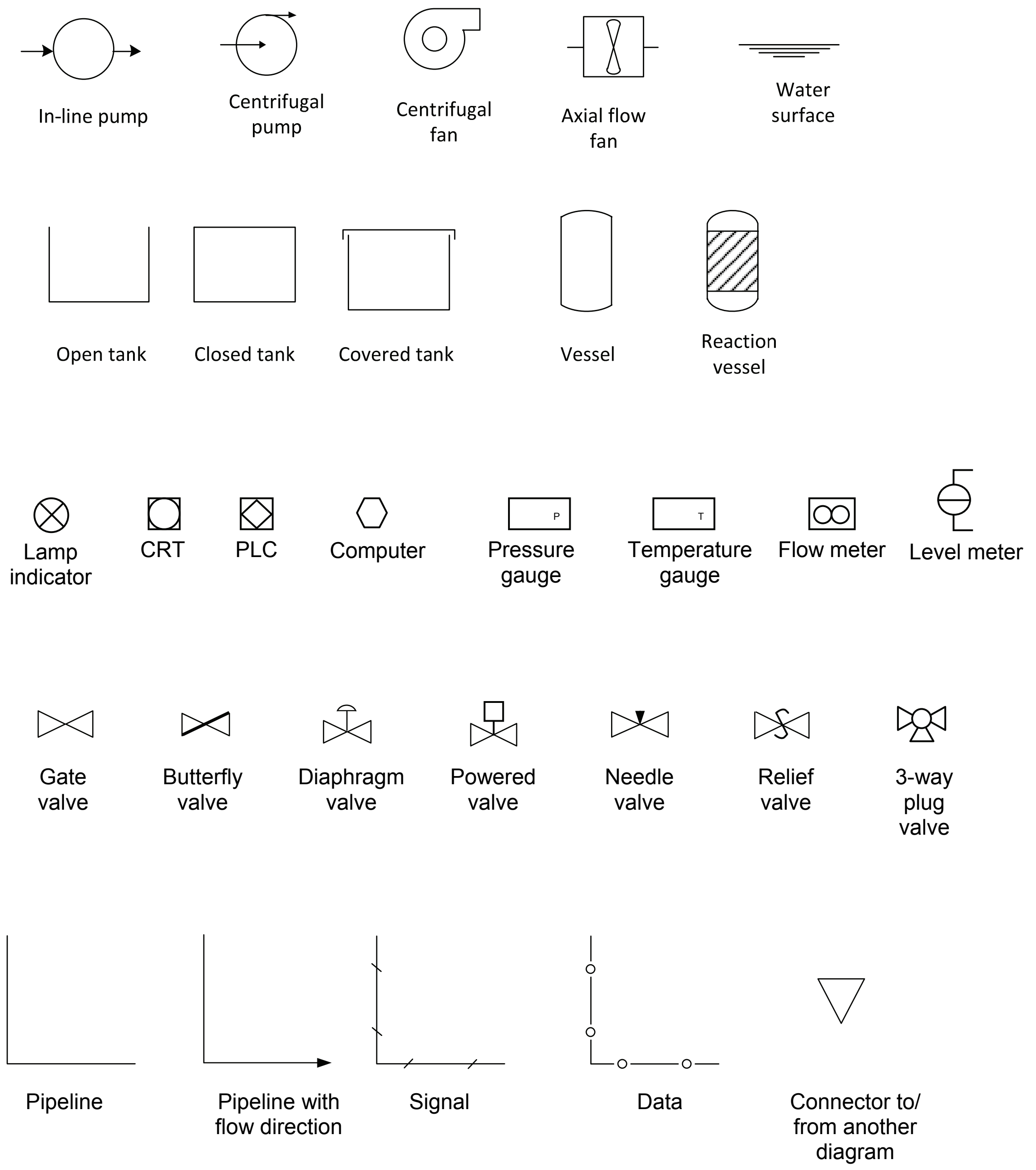
- Fixed value resistor
- Variable resistor
- Potentiometer
- NTC thermistor (negative thermal coefficient) (-t°)
- LDR (light dependent resistor)
- Diode
- LED (light emitting diode)
- Photo diode
- Coil
- Transformer

- Relay with SPDT changeover switch
- Relay with DPDT changeover switch

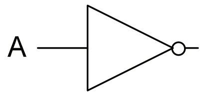
- V: Voltmeter
- A: Ammeter
- Ω: Ohmmeter
- M: Motor

SYSTEMS AND CONTROL

System components



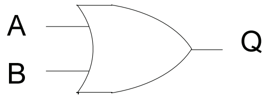
Logic symbols and their truth tables



A	Q
0	1
1	0

NOT Gate

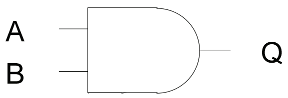
Output = $\overline{A}$



OR Gate

Output = $A + B$

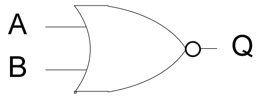
A	B	Q
0	0	0
1	0	1
0	1	1
1	1	1



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

AND Gate

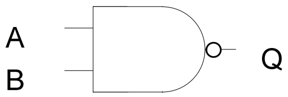
Output = $A . B$



NOR Gate

Output = $\overline{A . B}$

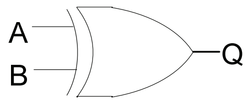
A	B	Q
0	0	1
1	0	0
0	1	0
1	1	0



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

NAND Gate

Output = $\overline{A + B}$

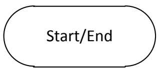


XOR Gate

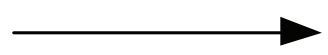
Output = A (+) B

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

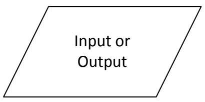
Flow chart symbols



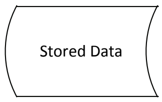
Start or end of a program or subroutine



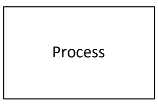
Flow of computation



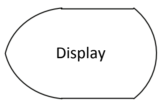
Input from a device, switch or keyboard, or output to a device.



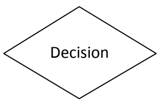
Data stored permanently on disk or non-volatile memory



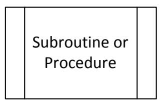
A step in the computational process.



A display device, CRT/LCD panel.



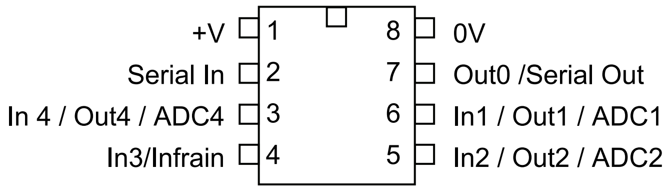
A decision point with a Yes/No result



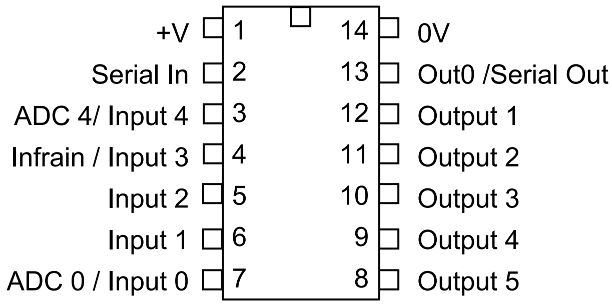
A predefined process

Selected PICAXE microprocessor pin allocations

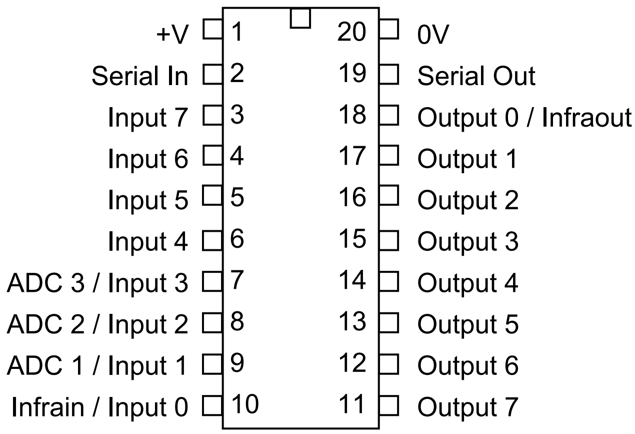
PICAXE-08M



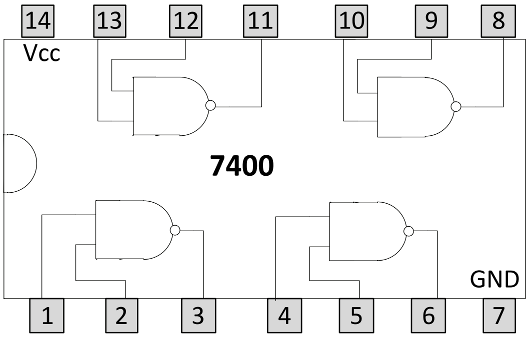
PICAXE-14M

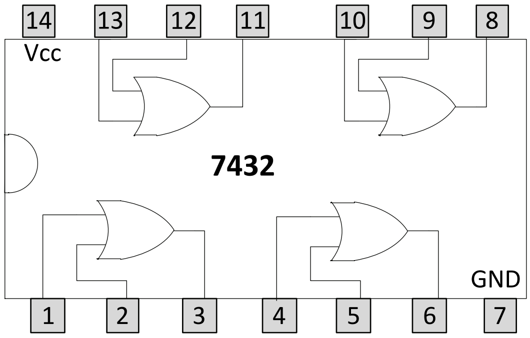


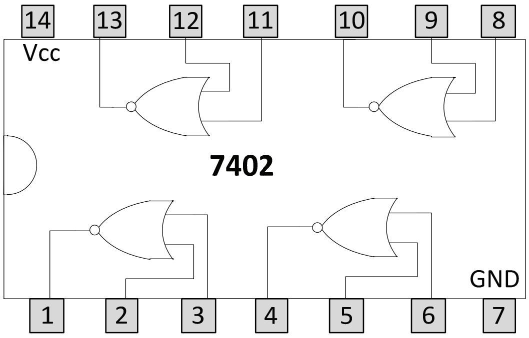
PICAXE-20M

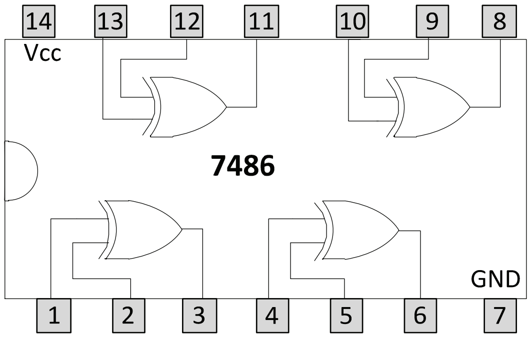


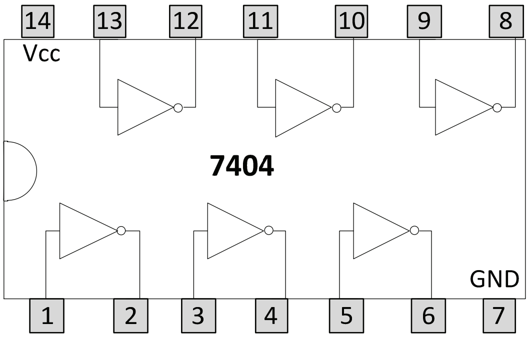
7400 logic chip layouts

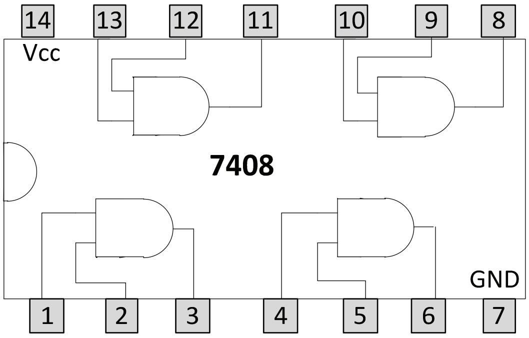












End of Data Booklet

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ACKNOWLEDGEMENTS

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