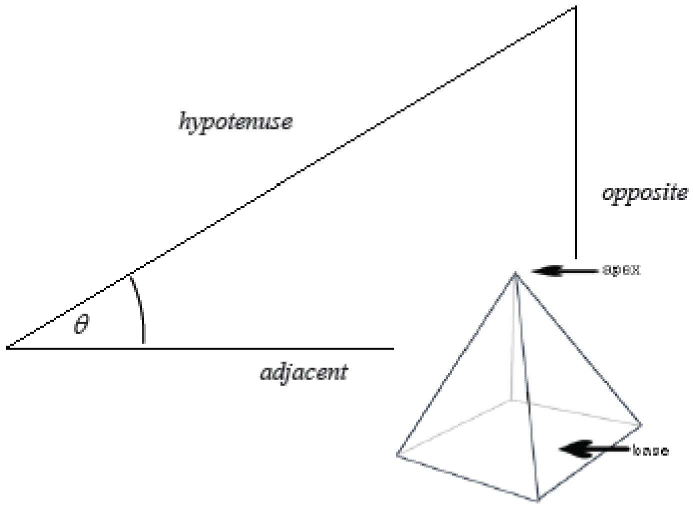

The Engineers Pocket Guide

Formulas and Conversions

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Chapter 1

Definition and Abbreviations for Physical Quantities

Symbol	Unit	Quantity
m	meter	Length
kg	kilogram	Mass
s	second	Time
A	ampere	Electric current
K	kelvin	Thermodynamic temp
cd	candela	Luminous intensity

Quantity	Unit	Symbol	Equivalent
Plane angle	radian	rad	-
Force	newton	N	$kg \cdot m/s^2$
Work, energy	heat	joule	J·N·m
Power	watt	W	J/s
Frequency	hertz	Hz	s^{-1}
Viscosity: kinematic	-	m^2/s	10 c St (Centistoke)
Viscosity: Dynamic	-	Ns/m^2	10^3 cP (Centipoise)
Pressure	-	Pa or N/m^2	pascal, Pa

Symbol	Prefix	Factor by which unit is multiplied
T	Tera	10^{12}
G	Giga	10^9
M	Mega	10^6

Symbol	**Prefix**	**Factor by which unit is multiplied**
k	Kilo	10^{3}
h	Hecto	10^{2}
da	Deca	10
d	Deci	10^{-1}
c	Centi	10^{-2}
m	Milli	10^{-3}
µ	Micro	10^{-6}
n	Nano	10^{-9}
p	Pico	10^{-12}

Quantity	**Electrical unit**	**Symbol**	**Derived unit**
Potential	Volt	V	W/A
Resistance	Ohm	'Ω	V/A
Charge	Coulomb	C	A·s
Capacitance	Farad	F	A·s/V
Electric field strength	-	V/m	-
Electric flux density	-	C/m^2	-

Quantity	**Magnetic unit**	**Symbol**	**Derived unit**
Magnetic flux	Weber	Wb	V·s = N·m/A
Inductance	Henry	H	$V·s/A = N·m/A^2$
Magnetic field strength	-	A/m	-
Magnetic flux density	Tesla	T	Wb/m^2 = (N)/(Am)

Chapter 2

Units of Physical Quantities

Conversion Factors (general):
1 acre = 43,560 square feet
1 cubic foot = 7.5 gallons
1 foot = 0.305 meters
1 gallon = 3.79 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)
Degrees Fahrenheit = (Degrees Celsius) (9/5) + 32
1% = 10,000 mg/L

Name	**To convert from**	**To**	**Multiply by**	**Divide by**
Acceleration	ft/sec^2	m/s^2	0.3048	3.2810
Area	acre	m^2	4047	2.471E-04
Area	ft^2	m^2	9.294E-02	10.7600
Area	hectare	m^2	1.000E+04	1.000E-04
Area	in^2	m^2	6.452E-04	1550
Density	g/cm^3	kg/m^3	1000	1.000E-03
Density	lbm/ft^3	kg/m^3	16.02	6.243E-02
Density	lbm/in^3	kg/m^3	2.767E+04	3.614E-05

Name	To convert from	To	Multiply by	Divide by
Density	$lb\cdot s^2/in^4$	kg/m^3	1.069E+07	9.357E-08
Density	$slug/ft^3$	kg/m^3	515.40	1.940E-03
Energy	BTU	J	1055	9.478E-04
Energy	cal	J	4.1859	0.2389
Energy	erg	J	1.000E-07	1.000E+07
Energy	eV	J	1.602E-19	6.242E+18
Energy	Ft·lbf	J	1.3557	0.7376
Energy	kiloton TNT	J	4.187E+12	2.388E-13
Energy	KW·hr	J	3.600E+06	2.778E-07
Energy	Megaton TNT	J	4.187E+15	2.388E-16
Force	Dyne	N	1.000E-05	1.000E+05
Force	Lbf	N	4.4484	0.2248
Force	Ozf	N	0.2780	3.5968
Heat capacity	BTU/lbm · °F	J/kg·°C	4188	2.388E-04
Heat transfer coefficient	$BTU/hr\cdot ft^2\cdot °F$	$W/m^2\cdot °C$	5.6786	0.1761
Length	AU	m	1.496E+11	6.685E-12
Length	ft	m	0.3048	3.2810
Length	in	m	2.540E-02	39.3700
Length	mile	m	1609	6.214E-04
Length	Nautical mile	m	1853	5.397E-04
Length	parsec	m	3.085E+16	3.241E-17
Mass	amu	kg	1.661E-27	6.022E+26
Mass	lbm	kg	0.4535	2.2050
Mass	$lb\cdot s^2/in$	kg	1200.00	5.711E-03
Mass	slug	kg	14.59	6.853E-02
Mass flow rate	lbm/hr	kg/s	1.260E-04	7937

Name	To convert from	To	Multiply by	Divide by
Mass flow rate	lbm/sec	kg/s	0.4535	2.2050
Moment of inertia	ft·lb·s^2	kg·m^2	1.3557	0.7376
Moment of inertia	in·lb·s^2	kg·m^2	0.1130	8.8510
Moment of inertia	oz·in·s^2	kg·m^2	7.062E-03	141.60
Power	BTU/hr	W	0.2931	3.4120
Power	hp	W	745.71	1.341E-03
Power	tons of refrigeration	W	3516	2.844E-04
Pressure	bar	Pa	1.000E+05	1.000E-05
Pressure	dyne/cm^2	Pa	0.1000	10.0000
Pressure	in. mercury	Pa	3377	2.961E-04
Pressure	in. water	Pa	248.82	4.019E-03
Pressure	kgf/cm^2	Pa	9.807E+04	1.020E-05
Pressure	lbf/ft^2	Pa	47.89	2.088E-02
Pressure	lbf/in^2	Pa	6897	1.450E-04
Pressure	mbar	Pa	100.00	1.000E-02
Pressure	microns mercury	Pa	0.1333	7.501
Pressure	mm mercury	Pa	133.3	7.501E-03
Pressure	std atm	Pa	1.013E+05	9.869E-06
Specific heat	BTU/lbm·°F	J/kg·°C	4186	2.389E-04
Specific heat	cal/g·°C	J/kg·°C	4186	2.389E-04
Temperature	°F	°C	0.5556	1.8000
Thermal conductivity	BTU/hr·ft·°F	W/m·°C	1.7307	0.5778
Thermal conductivity	BTU·in/hr·ft^2·°F	W/m·°C	0.1442	6.9340
Thermal conductivity	cal/cm·s·°C	W/m·°C	418.60	2.389E-03
Thermal conductivity	cal/ft·hr·°F	W/m·°C	6.867E-03	145.62
Time	day	S	8.640E+04	1.157E-05

Name	To convert from	To	Multiply by	Divide by
Time	sidereal year	S	3.156E+07	3.169E-08
Torque	ft·lbf	N·m	1.3557	0.7376
Torque	in·lbf	N·m	0.1130	8.8504
Torque	In·ozf	N·m	7.062E-03	141.61
Velocity	ft/min	m/s	5.079E-03	196.90
Velocity	ft/s	m/s	0.3048	3.2810
Velocity	Km/hr	m/s	0.2778	3.6000
Velocity	miles/hr	m/s	0.4470	2.2370
Viscosity – absolute	centipose	N·s/m^2	1.000E-03	1000
Viscosity – absolute	g/cm·s	N·s/m^2	0.1000	10
Viscosity – absolute	lbf/ft^2·s	N·s/m^2	47.87	2.089E-02
Viscosity – absolute	lbm/ft·s	N·s/m^2	1.4881	0.6720
Viscosity – kinematic	centistoke	m^2/s	1.000E-06	1.000E+06
Viscosity – kinematic	ft^2/sec	m^2/s	9.294E-02	10.7600
Volume	ft^3	m^3	2.831E-02	35.3200
Volume	in^3	m^3	1.639E-05	6.102E+04
Volume	Liters	m^3	1.000E-03	1000
Volume	U.S. gallons	m^3	3.785E-03	264.20
Volume flow rate	ft^3/min	m^3/s	4.719E-04	2119
Volume flow rate	U.S. gallons/min	m^3/s	6.309E-05	1.585E+04

A. DISTANCE (Length)

Conversions

Multiply	By	To obtain
LENGTH		
Centimeter	0.03280840	foot
Centimeter	0.3937008	inch

Multiply	By	To obtain
Fathom	1.8288*	meter(m)
Foot	0.3048*	meter(m)
Foot	30.48*	centimeter(cm)
Foot	304.8*	millimeter(mm)
Inch	0.0254*	meter(m)
Inch	2.54*	centimeter(cm)
Inch	25.4*	millimeter(mm)
Kilometer	0.6213712	mile(USstatute)
Meter	39.37008	Inch
Meter	0.54680066	Fathom
Meter	3.280840	Foot
Meter	0.1988388	Rod
Meter	1.093613	Yard
Meter	0.0006213712	mile(USstatute)
Microinch	0.0254*	micrometer(micron)(μm)
micrometer(micron)	39.37008	Microinch
mile(USstatute)	1,609.344*	meter(m)
mile(USstatute)	1.609344*	kilometer(km)
millimeter	0.003280840	Foot
millimeter	0.0397008	Inch
Rod	5.0292*	meter(m)
Yard	0.9144*	meter(m)

To Convert	To	Multiply By
Cables	Fathoms	120
Cables	Meters	219.456
Cables	Yards	240

To Convert	To	Multiply By
Centimeters	Meters	0.01
Centimeters	Yards	0.01093613
Centimeters	Feet	0.0328084
Centimeters	Inches	0.3937008
Chains, (Surveyor's)	Rods	4
Chains, (Surveyor's)	Meters	20.1168
Chains, (Surveyor's)	Feet	66
Fathoms	Meters	1.8288
Fathoms	Feet	6
Feet	Statute Miles	0.00018939
Feet	Kilometers	0.0003048
Feet	Meters	0.3048
Feet	Yards	0.3333333
Feet	Inches	12
Feet	Centimeters	30.48
Furlongs	Statute Miles	0.125
Furlongs	Meters	201.168
Furlongs	Yards	220
Furlongs	Feet	660
Furlongs	Inches	7920
Hands (Height Of Horse)	Inches	4
Hands (Height Of Horse)	Centimeters	10.16
Inches	Meters	0.0254
Inches	Yards	0.02777778
Inches	Feet	0.08333333
Inches	Centimeters	2.54
Inches	Millimeters	25.4

To Convert	To	Multiply By
Kilometers	Statute Miles	0.621371192
Kilometers	Meters	1000
Leagues, Nautical	Nautical Miles	3
Leagues, Nautical	Kilometers	5.556
Leagues, Statute	Statute Miles	3
Leagues, Statute	Kilometers	4.828032
Links, (Surveyor's)	Chains	0.01
Links, (Surveyor's)	Inches	7.92
Links, (Surveyor's)	Centimeters	20.1168
Meters	Statute Miles	0.000621371
Meters	Kilometers	0.001
Meters	Yards	1.093613298
Meters	Feet	3.280839895
Meters	Inches	39.370079
Meters	Centimeters	100
Meters	Millimeters	1000
Microns	Meters	0.000001
Microns	Inches	0.0000394
Miles, Nautical	Statute Miles	1.1507794
Miles, Nautical	Kilometers	1.852
Miles, Statute	Kilometers	1.609344
Miles, Statute	Furlongs	8
Miles, Statute	Rods	320
Miles, Statute	Meters	1609.344
Miles, Statute	Yards	1760
Miles, Statute	Feet	5280
Miles, Statute	Inches	63360

To Convert	To	Multiply By
Miles, Statute	Centimeters	160934.4
Millimeters	Inches	0.039370079
Mils	Inches	0.001
Mils	Millimeters	0.0254
Paces (US)	Inches	30
Paces (US)	Centimeters	76.2
Points (Typographical)	Inches	0.013837
Points (Typographical)	Millimeters	0.3514598
Rods	Meters	5.0292
Rods	Yards	5.5
Rods	Feet	16.5
Spans	Inches	9
Spans	Centimeters	22.86
Yards	Miles	0.00056818
Yards	Meters	0.9144
Yards	Feet	3
Yards	Inches	36
Yards	Centimeters	91.44

Conversion	
Length	
1 ft = 12 in	1 yd = 3 ft
1 cm = 0.3937 in	1 in = 2.5400 cm
1 m = 3.281 ft	1 ft = 0.3048 m
1 m = 1.0936 yd	1 yd = 0.9144 m
1 km = 0.6214 mile	1 mile = 1.6093 km
1 furlong = 40 rods	1 fathom = 6 ft

Conversion	
1 statute mile = 8 furlongs	1 rod = 5.5 yd
1 statute mile = 5280 ft	1 in = 100 mils
1 nautical mile = 6076 ft	1 light year = 9.461 x 10^{15} m
1 league = 3 miles	1 mil = 2.540 x 10^{-5} m
Area	
1 ft^2 = 144 in^2	1 acre = 160 rod^2
1 yd^2 = 9 ft^2	1 acre = 43,560 ft^2
1 rod^2 = 30.25 yd^2	1 $mile^2$ = 640 acres
1 cm^2 = 0.1550 in^2	1 in^2 = 6.4516 cm^2
1 m^2 = 10.764 ft^2	1 ft^2 = 0.0929 m^2
1 km^2 = 0.3861 $mile^2$	1 $mile^2$ = 2.590 km^2
Volume	
1 cm^3 = 0.06102 in^3	1 in^3 = 16.387 cm^3
1 m^3 = 35.31 ft^3	1 ft^3 = 0.02832 m^3
1 Litre = 61.024 in^3	1 in^3 = 0.0164 litre
1 Litre = 0.0353 ft^3	1 ft^3 = 28.32 litres
1 Litre = 0.2642 gal. (U.S.)	1 yd^3 = 0.7646 m^3
1 Litre = 0.0284 bu (U.S.)	1 gallon (US) = 3.785 litres
1 Litre = 1000.000 cm^3	1 gallon (US) = 3.785 x 10^{-3} m^3
1 Litre = 1.0567 qt. (liquid) or 0.9081 qt. (dry)	1 bushel (US) = 35.24 litres
1 oz (US fluid) = 2.957 x 10^{-5} m^3	1 stere = 1 m^3
Liquid Volume	
1 gill = 4 fluid ounces	1 barrel = 31.5 gallons
1 pint = 4 gills	1 hogshead = 2 bbl (63 gal)
1 quart = 2 pints	1 tun = 252 gallons
1 gallon = 4 quarts	1 barrel (petrolum) = 42 gallons

Conversion	
Dry Volume	
1 quart = 2 pints	1 quart = 67.2 in^3
1 peck = 8 quarts	1 peck = 537.6 in^3
1 bushel = 4 pecks	1 bushel = 2150.5 in^3

B. Area

Conversions

Multiply	By	To obtain
	AREA	
acre	4,046.856	$meter^2$ (m^2)
acre	0.4046856	hectare
$centimeter^2$	0.1550003	$inch^2$
$centimeter^2$	0.001076391	$foot^2$
$foot^2$	0.09290304*	$meter^2$ (m^2)
$foot^2$	929.0304^2	$centimeter^2$ (cm^2)
$foot^2$	92,903.04	$millimeter^2$ (mm^2)
hectare	2.471054	acre
$inch^2$	645.16*	$millimeter^2$ (mm^2)
$inch^2$	6.4516	$centimeter^2$ (cm^2)
$inch^2$	0.00064516	$meter^2$ (m^2)
$meter^2$	1,550.003	$inch^2$
$meter^2$	10.763910	$foot^2$
$meter^2$	1.195990	$yard^2$
$meter^2$	0.0002471054	acre
$millimeter^2$	0.00001076391	$foot^2$
$millimeter^2$	0.001550003	$inch^2$
$yard^2$	0.8361274	$meter^2$ (m^2)

C. Volume

Conversions

Metric Conversion Factors: Volume (including Capacity)

Multiply	By	To obtain
VOLUME (including CAPACITY)		
centimeter^3	0.06102376	inch^3
foot^3	0.028311685	meter^3 (m^3)
foot^3	28.31685	liter
gallon (UK liquid)	0.004546092	meter^3 (m^3)
gallon (UK liquid)	4.546092	litre
gallon (US liquid)	0.003785412	meter^3 (m^3)
gallon (US liquid)	3.785412	liter
inch^3	16,387.06	millimeter^3 (mm^3)
inch^3	16.38706	centimeter^3 (cm^3)
inch^3	0.00001638706	meter^3 (m^3)
Liter	0.001*	meter^3 (m^3)
Liter	0.2199692	gallon (UK liquid)
Liter	0.2641720	gallon (US liquid)
Liter	0.03531466	foot^3
meter^3	219.9692	gallon (UK liquid)
meter^3	264.1720	gallon (US liquid)
meter^3	35.31466	foot^3
meter^3	1.307951	yard^3
meter^3	1000.*	liter
meter^3	61,023.76	inch^3
millimeter^3	0.00006102376	inch^3
Yard^3	0.7645549	meter^3 (m^3)

D. Mass and Weight

Conversions

To Convert	To	Multiply By
Carat	Milligrams	200
Drams, Avoirdupois	Avoirdupois Ounces	0.06255
Drams, Avoirdupois	Grams	1.7718452
Drams, Avoirdupois	Grains	27.344
Drams, Troy	Troy Ounces	0.125
Drams, Troy	Scruples	3
Drams, Troy	Grams	3.8879346
Drams, Troy	Grains	60
Grains	Kilograms	6.47989E-05
Grains	Avoirdupois Pounds	0.00014286
Grains	Troy Pounds	0.00017361
Grains	Troy Ounces	0.00208333
Grains	Avoirdupois Ounces	0.00228571
Grains	Troy Drams	0.0166
Grains	Avoirdupois Drams	0.03657143
Grains	Pennyweights	0.042
Grains	Scruples	0.05
Grains	Grams	0.06479891
Grains	Milligrams	64.79891
Grams	Kilograms	0.001
Grams	Avoirdupois Pounds	0.002204623
Grams	Troy Pounds	0.00267923
Grams	Troy Ounces	0.032150747
Grams	Avoirdupois Ounces	0.035273961
Grams	Avoirdupois Drams	0.56438339
Grams	Grains	15.432361

To Convert	To	Multiply By
Grams	Milligrams	1000
Hundredweights, Long	Long Tons	0.05
Hundredweights, Long	Metric Tons	0.050802345
Hundredweights, Long	Short Tons	0.056
Hundredweights, Long	Kilograms	50.802345
Hundredweights, Long	Avoirdupois Pounds	112
Hundredweights, Short	Long Tons	0.04464286
Hundredweights, Short	Metric Tons	0.045359237
Hundredweights, Short	Short Tons	0.05
Hundredweights, Short	Kilograms	45.359237
Hundredweights, Short	Avoirdupois Pounds	100
Kilograms	Long Tons	0.0009842
Kilograms	Metric Tons	0.001
Kilograms	Short Tons	0.00110231
Kilograms	Short Hundredweights	0.02204623
Kilograms	Avoirdupois Pounds	2.204622622
Kilograms	Troy Pounds	2.679229
Kilograms	Troy Ounces	32.15075
Kilograms	Avoirdupois Ounces	35.273962
Kilograms	Avoirdupois Drams	564.3834
Kilograms	Grams	1000
Kilograms	Grains	15432.36
Milligrams	Grains	0.015432358
Ounces, Avoirdupois	Kilograms	0.028349523
Ounces, Avoirdupois	Avoirdupois Pounds	0.0625
Ounces, Avoirdupois	Troy Pounds	0.07595486
Ounces, Avoirdupois	Troy Ounces	0.9114583

To Convert	To	Multiply By
Ounces, Avoirdupois	Avoirdupois Drams	16
Ounces, Avoirdupois	Grams	28.34952313
Ounces, Avoirdupois	Grains	437.5
Ounces, Troy	Avoirdupois Pounds	0.06857143
Ounces, Troy	Troy Pounds	0.0833333
Ounces, Troy	Avoirdupois Ounces	1.097143
Ounces, Troy	Troy Drams	8
Ounces, Troy	Avoirdupois Drams	17.55429
Ounces, Troy	Pennyweights	20
Ounces, Troy	Grams	31.1034768
Ounces, Troy	Grains	480
Pennyweights	Troy Ounces	0.05
Pennyweights	Grams	1.55517384
Pennyweights	Grains	24
Pounds, Avoirdupois	Long Tons	0.000446429
Pounds, Avoirdupois	Metric Tons	0.000453592
Pounds, Avoirdupois	Short Tons	0.0005
Pounds, Avoirdupois	Quintals	0.00453592
Pounds, Avoirdupois	Kilograms	0.45359237
Pounds, Avoirdupois	Troy Pounds	1.215278
Pounds, Avoirdupois	Troy Ounces	14.58333
Pounds, Avoirdupois	Avoirdupois Ounces	16
Pounds, Avoirdupois	Avoirdupois Drams	256
Pounds, Avoirdupois	Grams	453.59237
Pounds, Avoirdupois	Grains	7000
Pounds, Troy	Kilograms	0.373241722
Pounds, Troy	Avoirdupois Pounds	0.8228571

To Convert	To	Multiply By
Pounds, Troy	Troy Ounces	12
Pounds, Troy	Avoirdupois Ounces	13.16571
Pounds, Troy	Avoirdupois Drams	210.6514
Pounds, Troy	Pennyweights	240
Pounds, Troy	Grams	373.2417216
Pounds, Troy	Grains	5760
Quintals	Metric Tons	0.1
Quintals	Kilograms	100
Quintals	Avoirdupois Pounds	220.46226
Scruples	Troy Drams	0.333
Scruples	Grams	1.2959782
Scruples	Grains	20
Tons, Long (Deadweight)	Metric Tons	1.016046909
Tons, Long (Deadweight)	Short Tons	1.12
Tons, Long (Deadweight)	Long Hundredweights	20
Tons, Long (Deadweight)	Short Hundredweights	22.4
Tons, Long (Deadweight)	Kilograms	1016.04691
Tons, Long (Deadweight)	Avoirdupois Pounds	2240
Tons, Long (Deadweight)	Avoirdupois Ounces	35840
Tons, Metric	Long Tons	0.9842065
Tons, Metric	Short Tons	1.1023113
Tons, Metric	Quintals	10
Tons, Metric	Long Hundredweights	19.68413072
Tons, Metric	Short Hundredweights	22.04623
Tons, Metric	Kilograms	1000
Tons, Metric	Avoirdupois Pounds	2204.623
Tons, Metric	Troy Ounces	32150.75

To Convert	To	Multiply By
Tons, Short	Long Tons	0.8928571
Tons, Short	Metric Tons	0.90718474
Tons, Short	Long Hundredweights	17.85714
Tons, Short	Short Hundredweights	20
Tons, Short	Kilograms	907.18474
Tons, Short	Avoirdupois Pounds	2000

E. Density

Conversions

To Convert	To	Multiply By
Grains/imp. Gallon	Parts/million	14.286
Grains/US gallon	Parts/million	17.118
Grains/US gallon	Pounds/million gal	142.86
Grams/cu. Cm	Pounds/mil-foot	3.405E-07
Grams/cu. Cm	Pounds/cu. in	0.03613
Grams/cu. Cm	Pounds/cu. ft	62.43
Grams/liter	Pounds/cu. ft	0.062427
Grams/liter	Pounds/1000 gal	8.345
Grams/liter	Grains/gal	58.417
Grams/liter	Parts/million	1000
Kilograms/cu meter	Pounds/mil-foot	3.405E-10
Kilograms/cu meter	Pounds/cu in	0.00003613
Kilograms/cu meter	Grams/cu cm	0.001
Kilograms/cu meter	Pound/cu ft	0.06243
Milligrams/liter	Parts/million	1
Pounds/cu ft	Pounds/mil-foot	5.456E-09
Pounds/cu ft	Pounds/cu in	0.0005787

To Convert	To	Multiply By
Pounds/cu ft	Grams/cu cm	0.01602
Pounds/cu ft	Kgs/cu meter	16.02
Pounds/cu in	Pounds/mil-foot	0.000009425
Pounds/cu in	Gms/cu cm	27.68
Pounds/cu in	Pounds/cu ft	1728
Pounds/cu in	Kgs/cu meter	27680

F. Relative Density (Specific Gravity) Of Various Substances

Substance	Relative Density
Water (fresh)	1.00
Mica	2.9
Water (sea average)	1.03
Nickel	8.6
Aluminum	2.56
Oil (linseed)	0.94
Antimony	6.70
Oil (olive)	0.92
Bismuth	9.80
Oil (petroleum)	0.76-0.86
Brass	8.40
Oil (turpentine)	0.87
Brick	2.1
Paraffin	0.86
Calcium	1.58
Platinum	21.5
Carbon (diamond)	3.4

Substance	**Relative Density**
Sand (dry)	1.42
Carbon (graphite)	2.3
Silicon	2.6
Carbon (charcoal)	1.8
Silver	10.57
Chromium	6.5
Slate	2.1-2.8
Clay	1.9
Sodium	0.97
Coal	1.36-1.4
Steel (mild)	7.87
Cobalt	8.6
Sulphur	2.07
Copper	8.77
Tin	7.3
Cork	0.24
Tungsten	19.1
Glass (crown)	2.5
Wood (ash)	0.75
Glass (flint)	3.5
Wood (beech)	0.7-0.8
Gold	19.3
Wood (ebony)	1.1-1.2
Iron (cast)	7.21
Wood (elm)	0.66
Iron (wrought)	7.78

Substance	Relative Density
Wood (lignum-vitae)	1.3
Lead	11.4
Magnesium	1.74
Manganese	8.0
Mercury	13.6
Lead	11.4
Magnesium	1.74
Manganese	8.0
Wood (oak)	0.7-1.0
Wood (pine)	0.56
Wood (teak)	0.8
Zinc	7.0
Wood (oak)	0.7-1.0
Wood (pine)	0.56
Wood (teak)	0.8
Zinc	7.0
Mercury	13.6

G. Greek Alphabet

Name	Lower Case	Upper Case
Alpha	α	A
Beta	β	B
Gamma	γ	Γ
Delta	δ	Δ
Epsilon	ε	E
Zeta	ζ	Z

Name	Lower Case	Upper Case
Eta	η	Η
Theta	θ	Θ
Iota	ι	Ι
Kappa	κ	Κ
Lambda	λ	Λ
Mu	μ	Μ
Nu	ν	Ν
Xi	ξ	Ξ
Omicron	ο	Ο
Pi	π	Π
Rho	ρ	Ρ
Sigma	σ and ς	Σ
Tau	τ	Τ
Upsilon	υ	Υ
Phi	φ	Φ
Chi	χ	Χ
Psi	ψ	Ψ
Omega	ω	Ω

Chapter 3

System of Units

The two most commonly used systems of units are as follows:

- SI
- Imperial

SI: The International System of Units (abbreviated "SI") is a scientific method of expressing the magnitudes of physical quantities. This system was formerly called the meter-kilogram-second (MKS) system.

Imperial: A unit of measure for capacity officially adopted in the British Imperial System; British units are both dry and wet

Metric System

	Exponent value	Numerical equivalent	Representation	Example
Tera	10^{12}	1000000000000	T	Thz (Tera hertz)
Giga	10^{9}	1000000000	G	Ghz (Giga hertz)
Mega	10^{6}	1000000	M	Mhz (Mega hertz)
Unit quantity	1	1		hz (hertz) F (Farads)
Micro	10^{-6}	0.001	μ	μF (Micro farads)
Nano	10^{-9}	0.000001	n	nF (Nano farads)
Pico	10^{-12}	0.000000000001	p	pF (Pico farads)

Conversion Chart

Multiply by	**Into Milli**	**Into Centi**	**Into Deci**	**Into MGL***	**Into Deca**	**Into Hecto**	**Into Kilo**
To convert Kilo	10^{6}	10^{5}	10^{4}	10^{3}	10^{2}	10^{1}	1

Multiply by	**Into Milli**	**Into Centi**	**Into Deci**	**Into MGL***	**Into Deca**	**Into Hecto**	**Into Kilo**
To convert Hecto	10^5	10^4	10^3	10^2	10^1	1	10^{-1}
To convert Deca	10^4	10^3	10^2	10^1	1	10^{-1}	10^{-2}
To convert MGL*	10^3	10^2	10^1	1	10^{-1}	10^{-2}	10^{-3}
To convert Deci	10^2	10^1	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}
To convert Centi	10^1	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
To convert Milli	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}

MGL = meter, gram, liter

Example:

To convert Kilogram Into Milligram → (1 Kilo X 10^6) Milligrams

Physical constants

Name	Symbolic Representation	Numerical Equivalent
Avogadro's number	N	6.023×10^{26} /(kg mol)
Bohr magneton	B	9.27×10^{-24} Am 25^2
Boltzmann's constant	k	1.380×10^{-23} J/k
Stefan-Boltzmann constant	d	5.67×10^{-8} $W/(m^2K^4)$
Characteristic impedance of free space	Zo	$(\mu_o/E_o)^{1/2}=120\Pi\Omega$
Electron volt	eV	1.602×10^{-19} J
Electron charge	e	1.602×10^{-19} C

Name	Symbolic Representation	Numerical Equivalent
Electronic rest mass	m_e	9.109×10^{-31} kg
Electronic charge to mass ratio	e/m_e	1.759×10^{11} C/kg
Faraday constant	F	9.65×10^{7} C/(kg mol)
Permeability of free space	μ_0	$4\Pi \times 10^{-7}$ H/m
Permittivity of free space	E_o	8.85×10^{-12} F/m
Planck's constant	h	6.626×10^{-34} J s
Proton mass	m_p	1.672×10^{-27} kg
Proton to electron mass ratio	m_p/m_e	1835.6
Standard gravitational acceleration	g	9.80665 m/s^2, 9.80665 N/kg
Universal constant of gravitation	G	6.67 x 10-11 N m^2/kg^2
Universal gas constant	R_o	8.314 kJ/(kg mol K)
Velocity of light in vacuum	C	2.9979×10^{8} m/s
Temperature	^0C	$5/9(^0F - 32)$
Temperature	K	$5/9(^0F + 459.67)$, $5/9^0R$, $^0C + 273.15$
Speed of light in air	c	3.00×10^{8} m s^{-1}
Electron charge	e	-1.60×10^{-19} C
Mass of electron	m_e	9.11×10^{-31} kg
Planck's constant	h	6.63×10^{-34} J s
Universal gravitational constant	G	6.67×10^{-11} N m^2 kg^{-2}
Electron volt	1 eV	1.60×10^{-19} J
Mass of proton	m_p	1.67×10^{-27} kg

Name	Symbolic Representation	Numerical Equivalent
Acceleration due to gravity on Earth	g	9.80 m s^{-2}
Acceleration due to gravity on the Moon	g_M	1.62 m s^{-2}
Radius of the Earth	R_E	6.37×10^{6} m
Mass of the Earth	M_E	5.98×10^{24} kg
Radius of the Sun	R_S	6.96×10^{8} m
Mass of the Sun	M_S	1.99×10^{30} kg
Radius of the Moon	R_M	1.74×10^{6} m
Mass of the Moon	M_M	7.35×10^{22} kg
Earth-Moon distance	-	3.84×10^{8} m
Earth-Sun distance	-	1.50×10^{11} m
Speed of light in air	c	$3.00 \times 10^{8} \text{ m s}^{-1}$
Electron charge	e	-1.60×10^{-19} C
Mass of electron	m_e	9.11×10^{-31} kg
Planck's constant	h	6.63×10^{-34} J s
Universal gravitational constant	G	$6.67 \times 10^{-11} \text{ N m}^{2} \text{ kg}^{-2}$
Electron volt	1 eV	1.60×10^{-19} J
Mass of proton	m_p	1.67×10^{-27} kg
Acceleration due to gravity on Earth	g	9.80 m s^{-2}
Acceleration due to gravity on the Moon	g_M	1.62 m s^{-2}
Ton	1 ton	1.00×10^{3} kg

Chapter 4

General Mathematical Formulae

4.1 Algebra

A. Expansion Formulae

Square of summation

- $(x + y)^2 = x^2 + 2xy + y^2$

Square of difference

- $(x - y)^2 = x^2 - 2xy + y^2$

Difference of squares

- $x^2 - y^2 = (x + y)(x - y)$

Cube of summation

- $(x + y)^3 = x^3 + 3x^2y + 3xy^2 + y^3$

Summation of two cubes

- $x^3 + y^3 = (x + y)(x^2 - xy + y^2)$

Cube of difference

- $(x - y)^3 = x^3 - 3x^2y + 3xy^2 - y^3$

Difference of two cubes

- $x^3 - y^3 = (x - y)(x^2 + xy + y^2)$

B. Quadratic Equation

- If $ax^2 + bx + c = 0$,

Then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

The basic algebraic properties of real numbers a, b and c are:

Property	**Description**
Closure	a + b and ab are real numbers
Commutative	a + b = b + a, ab = ba
Associative	(a+b) + c = a + (b+c), (ab)c = a(bc)
Distributive	(a+b)c = ac+bc

Identity	a+0 = 0+a = a
Inverse	a + (-a) = 0, a(1/a) = 1
Cancellation	If a+x=a+y, then x=y
Zero-factor	a0 = 0a = 0
Negation	-(-a) = a, (-a)b= a(-b) = -(ab), (-a)(-b) = ab

Algebraic Combinations

Factors with a common denominator can be expanded:

$$\frac{a+b}{c} = \frac{a}{c} + \frac{b}{c}$$

Fractions can be added by finding a common denominator:

$$\frac{a}{c} + \frac{b}{d} = \frac{ad+bc}{cd}$$

Products of fractions can be carried out directly:

$$\frac{a}{c} \times \frac{b}{d} = \frac{ab}{cd}$$

Quotients of fractions can be evaluated by inverting and multiplying:

$$\frac{a/b}{c/d} = \frac{a}{b} \times \frac{d}{c} = \frac{ad}{bc}$$

Radical Combinations

$$\sqrt[n]{ab} = \sqrt[n]{a}\sqrt[n]{b}$$

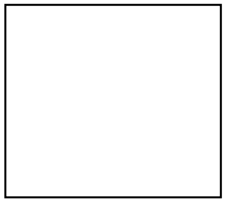
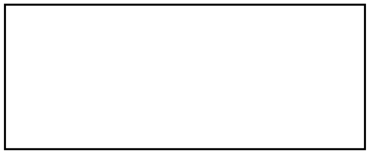
$$\sqrt[n]{a} = a^{1/n}$$

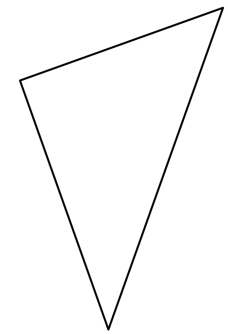
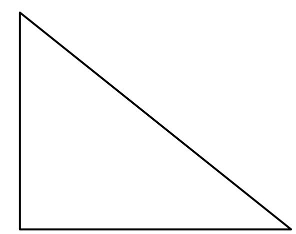
$$\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$$

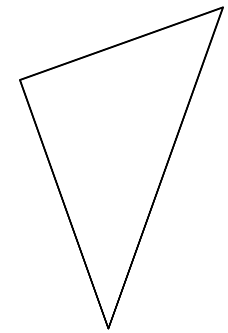
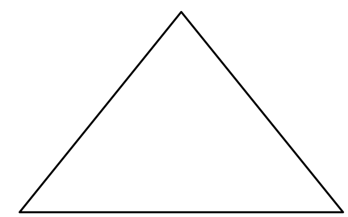
$$\sqrt[n]{a^m} = a^{\frac{m}{n}}$$

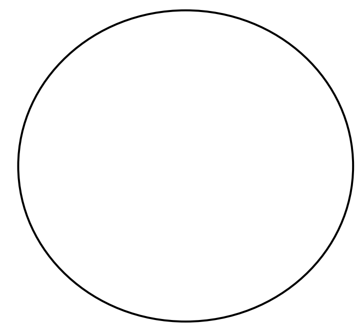
$$\sqrt[n]{\sqrt[m]{a}} = \sqrt[mn]{a}$$

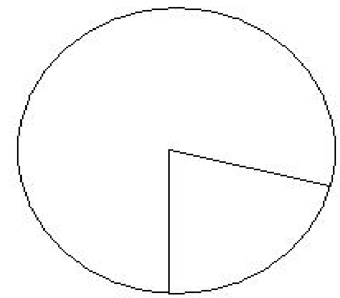
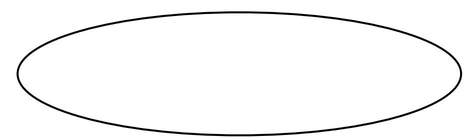
4.2 Geometry

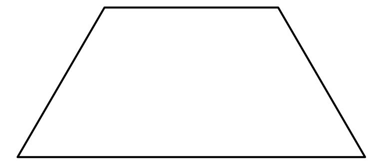
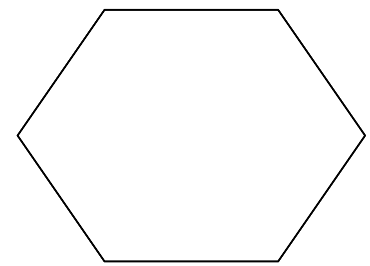
Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Square	4s	s^2	NA	NA	
Rectangle	2 (L + B)	(Length)(Breadth) = L·B	NA	NA	

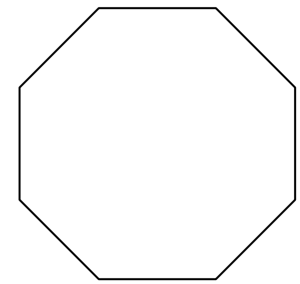
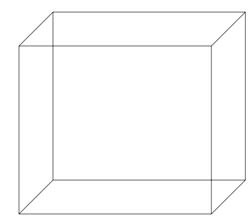
Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Triangle	$s_1 + s_2 + s_3$ where s_1, s_2, s_3 are the 3 sides of the triangle	$\frac{1}{2} \times B \times H$	NA	NA	
Right triangle	$s_1 + s_2 + s_3$	$\frac{1}{2} \times B \times H$	NA	NA	

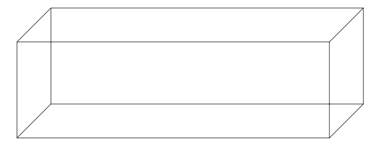
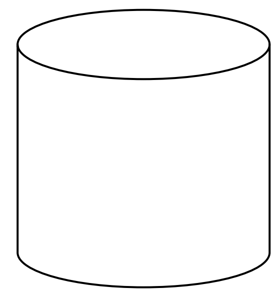
Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Generic triangle	$s_1 + s_2 + s_3$	$\sqrt{s(s-a)(s-b)(s-c)}$ where $s = \frac{a+b+c}{2}$	NA	NA	
Equilateral triangle	3s where s is the length of each side	$A = \frac{1}{2}bh$	NA	NA	

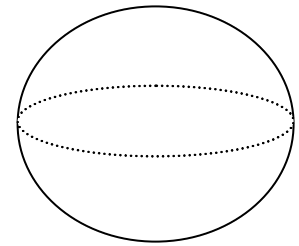
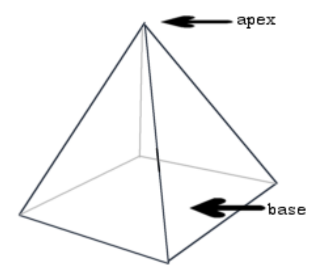
Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Trapezoid	$a+b+h\left(\frac{1}{\sin\theta}+\frac{1}{\sin\phi}\right)$ where Θ and Φ are the 2 base angles	$A=\left(\frac{a+b}{2}\right)h$	NA	NA	
Circle	C = 2πr C = πd	A = πr^2	NA	NA	

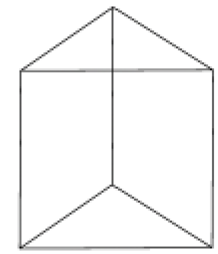
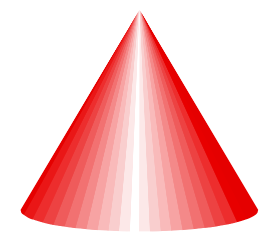
Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Circle Sector	2r + (arc length)	$A = \frac{arc \times r}{2}$ $A = \frac{\theta°}{360} \times \pi r^2$ $A = \frac{\theta° r^2}{2}$	NA	NA	
Ellipse	(1/4)·D·d·∏ where D and d are the two axis	$A = \frac{\pi}{4} Dd$ D is the larger radius and d is the smaller radius	NA	NA	

Item	**Circumference / Perimeter**	**Area**	**Surface Area**	**Volume**	**Figure**
Trapezoid	Sum of all sides	$A = \frac{1}{2}(b_1 + b_2)h$	NA	NA	
Hexagon	6s	A = 2.6s^2 Where s is the length of 1 side	NA	NA	

Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Octagon	8s	$A = 4.83\ s^2$ Where s is the length of 1 side	NA	NA	
Cube	NA	NA	$6s^2$	s^3	

Item	**Circumference / Perimeter**	**Area**	**Surface Area**	**Volume**	**Figure**
Rectangular solid	NA	NA	$2l\,h + 2wh + 2$	$l \times w \times h$	
Right cylinder	NA	NA	$S = 2\pi rh + 2\pi r^2$	$V = \pi r^2 h$	

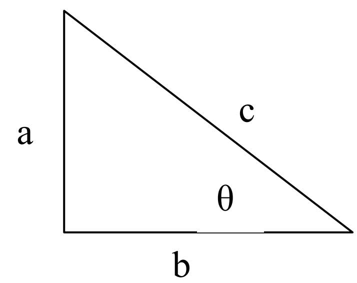
Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Sphere	NA	NA	$S = 4\pi r^2$	$\frac{4}{3}\pi r^3$	
Pyramid	NA	NA	½.perimeter· slant height + B	$\frac{1}{3}$ base area· perpendicular height	

Item	Circumference / Perimeter	Area	Surface Area	Volume	Figure
Rectangular prism	NA	NA	2lh+2lw+2wh	V = lwh	
Cone	NA	NA	pi·r(r+sh)	$\frac{1}{3}\pi r^2 h$	

4.3 Trigonometry

A. Pythagoras' Law

$$c^2 = a^2 + b^2$$

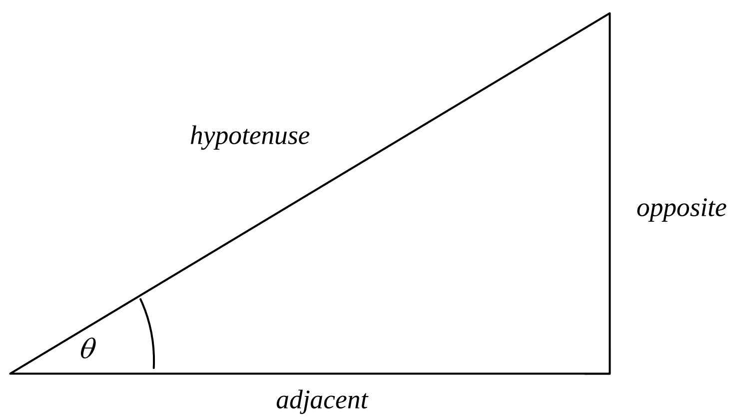


B. Basic Ratios

- Sin $\theta = a/c$
- Cos $\theta = b/c$
- Tan $\theta = a/b$
- Cosec $\theta = c/a$
- Sec $\theta = c/b$
- Cot $\theta = b/a$

Degrees versus Radians

- A circle in degree contains 360 degrees
- A circle in radians contains 2π radians



Sine, Cosine and Tangent

$$\sin\theta = \frac{opposite}{hypotenus} \qquad \cos\theta = \frac{adjacent}{hypotenus} \qquad \tan\theta = \frac{opposite}{adjacent}$$

Sine, Cosine and the Pythagorean Triangle

$$[\sin\theta]^2 + [\cos\theta]^2 = \sin^2\theta + \cos^2\theta = 1$$

Tangent, Secant and Co-Secant

$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$
$$\sec\theta = \frac{1}{\cos\theta}$$
$$\csc\theta = \frac{1}{\sin\theta}$$

C. Trigonometric Function Values

Euler's Representation

$$e^{j\theta} = \cos(\theta) + j\sin(\theta)$$

$$e^{-j\theta} = \cos(\theta) - j\sin(\theta)$$

$$e^{jn\theta} = \cos(n\theta) + j\sin(n\theta)$$

$$\cos\theta = \frac{e^{j\theta} + e^{-j\theta}}{2}$$

$$\sin\theta = \frac{e^{j\theta} - e^{-j\theta}}{2j}$$

4.4 Logarithm

Definition

The **logarithm** of a number to a particular base is the **power (or index)** to which that **base** must be raised to obtain the number.

The number 8 written in **index form** as $\mathbf{8 = 2^3}$

The equation can be rewritten in **logarithm form** as $\mathbf{\log_2 8 = 3}$

Logarithm laws

The logarithm laws are obtained from the index laws and are:

- $\log_a x + \log_a y = \log_a xy$

- $\log_a x - \log_a y = \log_a (x/y)$
- $\log_a xy = y \log_a x$
- $\log_a (1/x) = -\log_a x$
- $\log_a 1 = 0$
- $\log_a a = 1$
- $a^{(\log_a x)} = x$

Note: It is not possible to have the logarithm of a negative number. All logarithms must have the same base.

Euler Relationship

The trigonometric functions are related to a complex exponential by the Euler relationship:

$$e^{jx} = \cos x + j \sin x$$

$$e^{-jx} = \cos x - j \sin x$$

From these relationships the trig functions can be expressed in terms of the complex exponential:

$$\cos x = \frac{e^{jx} + e^{-jx}}{2}$$

$$\sin x = \frac{e^{jx} - e^{-jx}}{2}$$

Hyperbolic Functions

The hyperbolic functions can be defined in terms of exponentials.

Hyperbolic sine = sinh x = $\frac{e^x - e^{-x}}{2}$

Hyperbolic cosine = cosh x = $\frac{e^x + e^{-x}}{2}$

Hyperbolic tangent = tanh x = $\frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^x}$

4.5 Exponents

Summary of the Laws of Exponents

Let *c*, *d*, *r*, and *s* be any real numbers.

$c^r \cdot c^s = c^{r+s}$	$(c \cdot d)^r = c^r \cdot d^r$
$\frac{c^r}{c^s} = c^{r-s}, \; c \neq 0$	$\left(\frac{c}{d}\right)^r = \frac{c^r}{d^r}, \; d \neq 0$
$(c^r)^s = c^{r \cdot s}$	$c^{-r} = \frac{1}{c^r}$

Basic Combinations

Since the raising of a number n to a power p may be defined as multiplying n times itself p times, it follows that

$$n^{p_1 + p_2} = n^{p_1} n^{p_2}$$

The rule for raising a power to a power can also be deduced

$(n^a)^b = n^{ab}$

$(ab)^n = a^n b^n$

$a^m / a^n = a^{m-n}$
where a not equal to zero

4.6 Complex Numbers

A complex number is a number with a real and an imaginary part, usually expressed in Cartesian form
$a + jb$ where $j = \sqrt{-1}$ and $j \cdot j = -1$

Complex numbers can also be expressed in polar form

$Ae^{j\theta}$ where $A = \sqrt{a^2 + b^2}$ and $\theta = \tan^{-1}(b/a)$

The polar form can also be expressed in terms of trigonometric functions using the Euler relationship
$e^{j\theta} = \cos\theta + j \sin\theta$

Euler Relationship

The trigonometric functions are related to a complex exponential by the Euler relationship

$e^{jx} = \cos x + j \sin x$

$e^{-j\theta}$ **= cos x - j sin x**

From these relationships the trigonometric functions can be expressed in terms of the complex exponential:

$$\cos x = \frac{e^{jx} + e^{-jx}}{2}$$
$$\sin x = \frac{e^{jx} - e^{-jx}}{2}$$

This relationship is useful for expressing complex numbers in polar form, as well as many other applications.

Polar Form, Complex Numbers

The standard form of a complex number is

a + jb where j = √-1

But this can be shown to be equivalent to the form

$Ae^{j\theta}$ **where** $A = \sqrt{a^2 + b^2}$ **and** $\theta = \tan^{-1}(b/a)$

which is called the polar form of a complex number. The equivalence can be shown by using the Euler relationship for complex exponentials.

$$Ae^{j\theta} = \sqrt{a^2 + b^2}\left(\cos\left[\tan^{-1}\frac{b}{a}\right] + j\sin\left[\tan^{-1}\frac{b}{a}\right]\right)$$

$$Ae^{j\theta} = \sqrt{a^2 + b^2}\left(\frac{a}{\sqrt{a^2 + b^2}} + j\frac{b}{\sqrt{a^2 + b^2}}\right) = a + jb$$

Chapter 5

Engineering Concepts and Formulae

5.1 Electricity

Ohm's Law

$$I = \frac{V}{R}$$

Or

$V = IR$

Where
I = current (amperes)
E = electromotive force (volts)
R = resistance (ohms)

Temperature correction

$R_t = Ro\ (1 + \alpha t)$

Where
Ro = resistance at 0ºC (.)
R_t = resistance at tºC (.)
α = temperature coefficient which has an average value for copper of 0.004 28 (Ω/Ω ºC)

$$R_2 = R_1 \frac{(1+\alpha t_2)}{(1+\alpha t_1)}$$

Where R_1 = resistance at t_1
R_2 = resistance at t_2

Values of alpha	**Ω/Ω ºC**
Copper	0.00428
Platinum	0.00358
Nickel	0.00672
Tungsten	0.00450

Aluminum	0.0040

Current, $I = \frac{nqvtA}{t} = nqvA$

Conductor Resistivity

$R = \frac{\rho L}{a}$

Where
ρ = specific resistance (or resistivity) (ohm meters, Ωm)
L = length (meters)
a = area of cross-section (square meters)

Quantity	**Equation**
Resistance R of a uniform conductor	$R = \rho \frac{L}{A}$
Resistors in series, R_s	$R_s = R_1 + R_2 + R_3$
Resistors in parallel, R_p	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
Power dissipated in resistor:	$P = VI = I^2 R = \frac{V^2}{R}$
Potential drop across R	V = I R

Dynamo Formulae

Average e.m.f. generated in each conductor = $\frac{2\varphi NpZ}{60c}$

Where
Z = total number of armature conductors
c = number of parallel paths through winding between positive and negative brushes
Where c = 2 (wave winding), c = 2p (lap winding)
Φ = useful flux per pole (webers), entering or leaving the armature
p = number of pairs of poles
N = speed (revolutions per minute)

Generator Terminal volts = EG – IaRa
Motor Terminal volts = EB + IaRa

Where EG = generated e.m.f.
EB = generated back e.m.f.
Ia = armature current
Ra = armature resistance

Alternating Current

RMS value of sine curve = 0.707 of maximum value
Mean Value of Sine wave = 0.637 of maximum value
Form factor = RMS value / Mean Value = 1.11
Frequency of Alternator = $\frac{pN}{60}$ cycles per second
Where p is number of pairs of poles
N is the rotational speed in r/min

Slip of Induction Motor

[(Slip speed of the field – Speed of the rotor) / Speed of the Field] × 100

Inductors and Inductive Reactance

Physical Quantity	**Equation**
Inductors and Inductance	$V_L = L \frac{di}{dt}$
Inductors in Series:	$L_T = L_1 + L_2 + L_3 + \ldots$
Inductor in Parallel:	$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots..$
Current build up (switch initially closed after having been opened)	At $v_L(t) = E\,e^{-\frac{t}{\tau}}$ $v_R(t) = E(1 - e^{-\frac{t}{\tau}})$ $i(t) = \frac{E}{R}(1 - e^{-\frac{t}{\tau}})$ $\tau = \frac{L}{R}$
Current decay (switch moved to a new position)	$i(t) = I_o\,e^{-\frac{t}{\tau'}}$ $v_R(t) = R\,i(t)$ $v_L(t) = -R_T\,i(t)$

Physical Quantity	Equation
	$\tau' = \frac{L}{R_T}$
Alternating Current	f = 1/T $\varpi = 2 \pi f$
Complex Numbers:	C = a + j b $C = M \cos \theta + j M \sin \theta$ $M = \sqrt{a^2 + b^2}$ $\theta = \tan^{-1}\left(\frac{b}{a}\right)$
Polar form:	$C = M \angle \theta$
Inductive Reactance	$\lvert X_L \rvert = \omega L$
Capacitive Reactance	$\lvert X_C \rvert = 1 / (\omega C)$
Resistance	R
Impedance	Resistance: $Z_R = R \angle 0°$ Inductance: $Z_L = X_L \angle 90° = \omega L \angle 90°$ Capacitance: $Z_C = X_C \angle -90° = 1 / (\omega C) \angle -90°$

Quantity	Equation
Ohm's Law for AC	V = I Z
Time Domain	$v(t) = V_m \sin (\omega t \pm \phi)$ $i(t) = I_m \sin (\omega t \pm \phi)$
Phasor Notation	$V = V_{rms} \angle \phi$ $V = V_m \angle \phi$
Components in Series	$Z_T = Z_1 + Z_2 + Z_3 + . .$
Voltage Divider Rule	$V_x = V_T \frac{Z_x}{Z_T}$
Components in Parallel	$\frac{1}{Z_T} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \ldots$

Quantity	**Equation**
Current Divider Rule	$I_x = I_T \frac{Z_T}{Z_x}$
Two impedance values in parallel	$Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2}$

Capacitance

Capacitors	$C = \frac{Q}{V}$ [F] (Farads)
Capacitor in Series	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$
Capacitors in Parallel	$C_T = C_1 + C_2 + C_3 + ...$
Charging a Capacitor	$i(t) = \frac{E}{R} e^{-\frac{t}{RC}}$ $v_R(t) = E\, e^{-\frac{t}{RC}}$ $v_C(t) = E(1 - e^{-\frac{t}{RC}})$ $\tau = RC$
Discharging a Capacitor	$i(t) = -\frac{V_o}{R} e^{-\frac{t}{\tau'}}$ $v_R(t) = -V_o\, e^{-\frac{t}{\tau'}}$ $v_C(t) = V_o\, e^{-\frac{t}{\tau'}}$ $\tau' = R_T C$

Quantity	**Equation**
Capacitance	$C = \frac{Q}{V}$

Quantity	**Equation**
Capacitance of a Parallel-plate Capacitor	$C = \frac{\varepsilon A}{d}$ $E = \frac{V}{d}$
Isolated Sphere	$C = 4\pi\varepsilon r$
Capacitors in parallel	$C = C_1 + C_2 + C_3$
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
Energy stored in a charged capacitor	$W = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$
If the capacitor is isolated	$W = \frac{Q^2}{2C}$
If the capacitor is connected to a battery	$W = \frac{1}{2}CV^2$
For R C circuits Charging a capacitor	$Q = Q_o\,(1 - e^{-t/RC})$; $V = V_o$ $(1 - e^{-t/RC})$
Discharging a capacitor	$Q = Q_o\, e^{-\,t/RC}$ $V = V_o\, e^{-t/RC}$

- If the capacitor is isolated, the presence of the dielectric decreases the potential difference between the plates
- If the capacitor is connected to a battery, the presence of the dielectric increases the charge stored in the capacitor.
- The introduction of the dielectric increases the capacitance of the capacitor

Current in AC Circuit

RMS Current

In Cartesian form	$I = \dfrac{V}{\left[R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2\right]} \cdot \left[R - j\left(\omega L - \dfrac{1}{\omega C}\right)\right]$ Amperes
In polar form	$I = \dfrac{V}{\sqrt{[R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2]}} \angle - \phi_s$ Amperes where $\phi_s = \tan^{-1}\left[\dfrac{\omega L - \dfrac{1}{\omega C}}{R}\right]$
Modulus	$\lvert I \rvert = \dfrac{V}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}$ Amperes

Complex Impedance

In Cartesian form	$Z = R + j\left(\omega L - \dfrac{1}{\omega C}\right)$ Ohms
In polar form	$Z = \sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2} \angle \phi_s$ Ohms Where $\phi_s = \tan^{-1}\left[\dfrac{\omega L - \dfrac{1}{\omega C}}{R}\right]$
Modulus	$\lvert Z \rvert = \sqrt{[R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2]}$ Ohms

Power dissipation

Average power,	$P = VI\cos\phi$ Watts
Power dissipation in a resistor	$P = \lvert I\rvert^2 R$ Watts

Rectification

Controlled half wave rectifier	Average DC voltage $= \frac{V_m}{2\pi}(1+\cos\alpha)$ Volts
Controlled full wave rectifier	Average DC voltage $= \frac{V_m}{\pi}(1+\cos\alpha)$ Volts

Power Factor

DC Power	$P_{dc} = VI = I^2R = \frac{V^2}{R}$
AC Power	$Pac = \mathrm{Re}(V.I) = VI\cos\phi$

Power in ac circuits

Quantity	**Equation**
Resistance	The mean power = $\overline{P}$ = I_{rms} V_{rms} = I_{rms}^2 R
Inductance	The instantaneous power = (Io sin wt) (Vo sin (wt + π)
The mean power	$\overline{P}$ = 0
Capacitance	The instantaneous power = (Io sin (wt + π/2)) (V_o sin wt)
The mean power	$\overline{P}$ = 0
Formula for a.c. power	The mean power = $\overline{P}$ = I_{rms} V_{rms} cos ϕ

Three Phase Alternators

Star connected

Line voltage = $\sqrt{3} \bullet$ Phase Voltage

Line current = phase current

Delta connected

Line voltage = phase voltage

Line current = $\sqrt{3} \bullet$ Phase Current

Three phase power

$P = \sqrt{3} \bullet E_L \bullet I_L \bullet \cos\phi$

Where:

P is the active power in Watts

E_L is the Line Voltage in Volts

I_L is the line current in Amperes

Cos ϕ is the power factor

Electrostatics

Quantity	Equation
Instantaneous current,	$I = \frac{dq}{dt} = C\frac{dv}{dt}$ Amperes
Permittivity of free space	$\varepsilon_0 = \frac{10^{-9}}{36\pi} = 8.85 \times 10^{-12}$ Farads (meters)$^{-1}$
Energy stored in a capacitor	$= \frac{1}{2}CV^2$ Joules

Quantity	Equation
Coulomb's law	$F = k\frac{Q_1Q_2}{r^2}$
Electric fields	$E = \frac{F}{q}$
Due to a point charge	$E = \frac{Q}{4\pi\varepsilon_o r^2}$

Quantity	**Equation**
Due to a conducting sphere carrying charge Q Inside the sphere	E = 0
Outside the sphere	$E = \frac{Q}{4\pi\varepsilon_o r^2}$
Just outside a uniformly charged conducting sphere or plate	$E = \frac{\sigma}{\varepsilon_o}$

- An electric field E is a vector
- The electric field strength is directly proportional to the number of electric field lines per unit cross-sectional area,
- The electric field at the surface of a conductor is perpendicular to the surface.
- The electric field is zero inside a conductor.

Quantity	**Equation**
Suppose a point charge Q is at A. The work done in bringing a charge q from infinity to some point a distance r from A is	$W = \frac{Qq}{4\pi\varepsilon_o r}$
Electric potential	$V = \frac{W}{q}$
Due to a point charge	$V = \frac{Q}{4\pi\varepsilon_o r}$
Due to a conducting sphere, of radius a, carrying charge Q: Inside the sphere	$V = \frac{Q}{4\pi\varepsilon_o a}$
Outside the sphere	$V = \frac{Q}{4\pi\varepsilon_o r}$
If the potential at a point is V, then the potential energy of a charge q at that point is	U = qV

Quantity	**Equation**
Work done in bringing charge q from A of potential V_A to point B of potential V_B	$W = q (V_B - V_A)$
Relation between E and V	$E = -\frac{dV}{dx}$
For uniform electric field	$E = \frac{V}{d}$

Magnetostatics

Physical Quantity	**Equation**
Magnetic flux density (also called the B-field) is defined as the force acting per unit current length.	$B = \frac{F}{I\lambda}$
Force on a current-carrying conductor in a magnetic field	$F = I \lambda B \vec{F} = I \vec{\lambda} \cdot \vec{B}$ And Magnitude of $\vec{F} = F = I \lambda B \sin \theta$
Force on a moving charged particle in a magnetic field	$F = q \vec{v} \cdot \vec{B}$
Circulating Charges	$qvB = \frac{mv^2}{r}$

Calculation of magnetic flux density

Physical Quantity	**Equation**
Magnetic fields around a long straight wire carrying current I	$B = \frac{\mu_o I}{2\pi a}$ where a = perp. distance from a very long straight wire.
Magnetic fields inside a long solenoid, carrying current	I: $B = \mu_o n I$, where n = number of turns per unit length.
Hall effect At equilibrium	$Q\frac{V_H}{d} = QvB$ and $V_H = B v d$

Physical Quantity	Equation
The current in a material is given by	I = nQAv
The forces between two current-carrying conductors	$F_{21} = \frac{\mu_o I_1 I_2 \lambda}{2\pi a}$

Physical Quantity	Equation
The torque on a rectangular coil in a magnetic field	T = F b sin θ = N I λ B b sinθ = N I A B sinθ
If the coil is in a radial field and the plane of the coil is always parallel to the field, then	T = N I A B sin θ = N I A B sin 90^o = N I A B
Magnetic flux ϕ	ϕ = B A cos θ and Flux-linkage = $N\phi$
Current Sensitivity	$S_I = \frac{\theta}{I} = \frac{NAB}{c}$

Lenz's law The direction of the induced e.m.f. is such that it tends to oppose the flux-change causing it, and does oppose it if induced current flows.	$\varepsilon = -N \frac{d}{dt} \phi$

EMF Equations

E.m.f. induced in a straight conductor	ε = B L v
E.m.f. induced between the center and the rim of a spinning disc	ε = B $\pi r^2 f$
E.m.f. induced in a rotating coil	E = N A B w sin wt

Quantity	Equation
Self-induction	$L = -\frac{\varepsilon}{dI/dt}$

Quantity	Equation
	N ϕ = L I
Energy stored in an inductor:	$U = \frac{1}{2} L I^2$
Transformers:	$\frac{V_S}{V_P} = \frac{N_S}{N_P}$
The L R (d.c.) circuit:	$I = \frac{E}{R}(1 - e^{-Rt/L})$
When a great load (or smaller resistance) is connected to the secondary coil, the flux in the core decreases. The e.m.f., ε_p, in the primary coil falls.	$V_p - \varepsilon_p = IR$; $I = \frac{V_P - \varepsilon_p}{R}$

Kirchoff's laws

Kirchoff's first law (Junction Theorem)

At a junction, the total current entering the junction is equal to the total current leaving the junction.

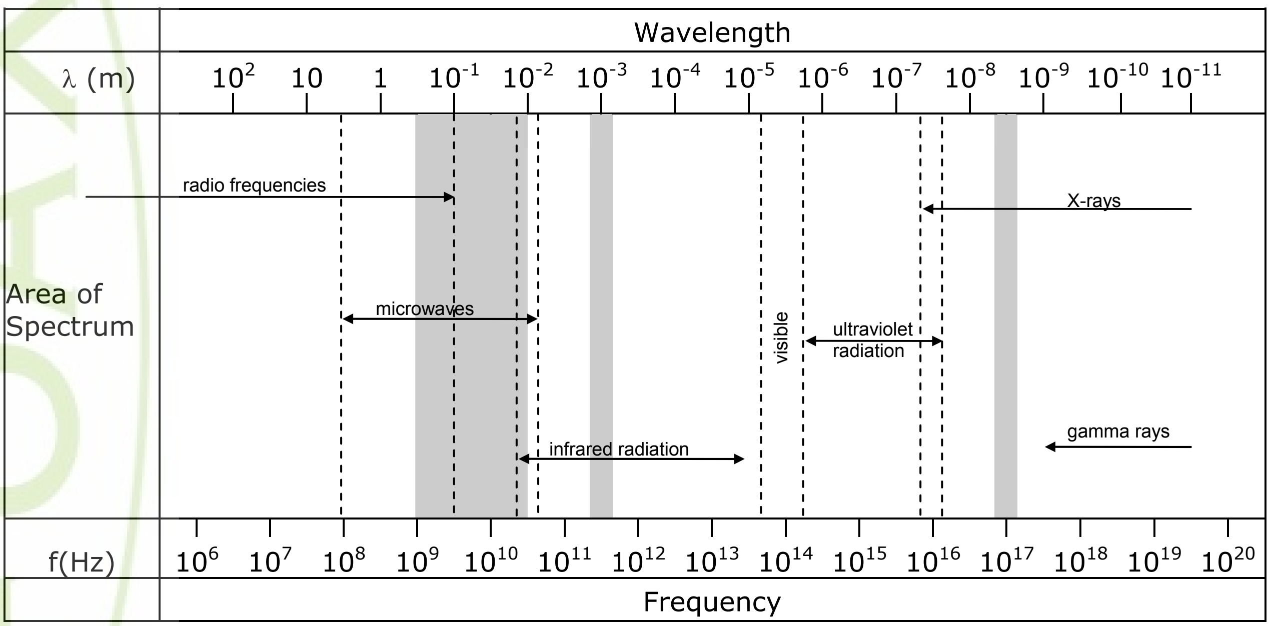
Kirchoff's second law (Loop Theorem)

The net e.m.f. round a circuit is equal to the sum of the p.d.s round the loop.

Physical Quantity	Equation
Power	$P = \frac{W}{t} = VI$
Electric current	$I = \frac{q}{t}$
Work	$W = qV$
Ohm's Law	$V = IR$
Resistances in Series	$R_T = R_1 + R_2 K$
Resistances in Parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} K$

Magnetic flux	$\Phi = BA$
Electromagnetic induction	$Emf = -N \frac{(\Phi_2 - \Phi_1)}{t}$ $emf = l v B$
Magnetic force	$F = I l B$
Transformer turns ratio	$\frac{Vs}{Vp} = \frac{Ns}{Np}$

Electromagnetic spectrum



Note: 1. Shaded areas represent regions of overlap.
2. Gamma rays and X-rays occupy a common region.

5.2 Applied Mechanics

5.2.1 Newton's laws of motion

Newton' first law of motion

The inertia of a body is the reluctance of the body to change its state of rest or motion. Mass is a measure of inertia.

Newton's second law of motion

$$F = \frac{m\,v - m\,u}{\Delta\,t}\ ;$$

$F = m\,a$

Impulse = force · time = change of momentum

$F\,t = m\,v - m\,u$

Newton's third law of motion

When two objects interact, they exert equal and opposite forces on one another.

"Third-law pair" of forces act on two different bodies.

Universal Law

$F = Gm_s m_p/d^2$

m_s is the mass of the sun.

m_p is the mass of the planet.

The Universal law and the second law must be consistent

Newton’s Laws of Motion and Their Applications

Physical Quantity	Equations
Average velocity	$v_{av} = \frac{s}{t} = \frac{v+u}{2}$
Acceleration	$a = \frac{v - u}{t}$
Momentum	$p = mv$
Force	$F = ma$
Weight	weight = mg
Work done	$W = Fs$
Kinetic energy	$E_k = \frac{1}{2}mv^2$
Gravitational potential energy	$E_p = mgh$
Equations of motion	$a = \frac{v-u}{t}$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$
Centripetal acceleration	$a = \frac{v^2}{r}$
Centripetal force	$F = ma = \frac{mv^2}{r}$

Physical Quantity	Equations
Newton's Law of Universal Gravitation	$F = G\frac{m_1 m_2}{r^2}$
Gravitational field strength	$g = G\frac{M}{r^2}$

Physical Quantity	Equations
Moment of a force	$M = rF$
Principle of moments	$\sum M = 0$
Stress	$\text{Stress} = \frac{F}{A}$
Strain	$\text{Strain} = \frac{\Delta l}{l}$
Young's Modulus	$Y = \frac{F / A}{\Delta l / l}$

Scalar: a property described by a magnitude only

Vector: a property described by a magnitude and a direction

Velocity: vector property equal to displacement / time

The magnitude of velocity may be referred to as **speed**
In SI the basic unit is m/s, in Imperial ft/s
Other common units are km/h, mi/h
Conversions:
1m/s = 3.28 ft/s
1km/h = 0.621 mi/h

Speed of sound in dry air is 331 m/s at 0°C and increases by about 0.61 m/s for each °C rise.

Speed of light in vacuum equals 3 x 10^8m/s

Acceleration: vector property equal to change in velocity time.

In SI the basic unit is m/s^2

In Imperial ft/s^2

Conversion:

$$1\frac{m}{s^2} = 3.28\frac{ft}{s^2}$$

Acceleration due to gravity, g is 9.81 m/s^2

5.2.2 Linear Velocity and Acceleration

Quantity	**Equations**
If u initial velocity and v final velocity, then displacement s,	$s = \left(\frac{v+u}{2}\right)$
If t is the elapsed time	$s = ut + \frac{1}{2}at^2$
If a is the acceleration	$v^2 = u^2 + 2as$

Angular Velocity and Acceleration

Quantity	**Equations**
θ angular displacement (radians) • ω angular velocity (radians/s); ω_1 = initial, ω_2 = final	$\theta = \frac{\omega_1 + \omega_2}{2} \times t$
	$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$
α angular acceleration (radians/s^2)	$\omega_2{}^2 = \omega_1{}^2 + 2\alpha\theta$
Linear displacement	s = r θ
Linear velocity	v = r ω
Linear, or tangential acceleration	aT = r α

Tangential, Centripetal and Total Acceleration

Quantity	**Equations**

Tangential acceleration aT is due to angular acceleration ɑ	aT = rɑ
Centripetal (Centrifugal) acceleration ac is due to change in direction only	$ac = v^2/r = r\,\omega^2$
Total acceleration, a, of a rotating point experiencing angular acceleration is the vector sum of aT and ac	a = aT + ac

5.2.3 Force

Vector quantity, a push or pull which changes the shape and/or motion of an object
In SI the unit of force is the newton, N, defined as a kg m
In Imperial the unit of force is the pound lb
Conversion: 9.81 N = 2.2 lb

Weight

The gravitational force of attraction between a mass, m, and the mass of the Earth
In SI weight can be calculated from Weight = F = mg, where $g = 9.81\ m/s^2$
In Imperial, the mass of an object (rarely used), in slugs, can be calculated from the known weight in pounds

$$m = \frac{weight}{g}$$

$$g = 32.2\frac{ft}{s^2}$$

Torque Equation

T = I α where T is the acceleration torque in Nm, I is the moment of inertia in $kg\ m^2$ and α is the angular acceleration in $radians/s^2$

Momentum

Vector quantity, symbol p,
p = mv [Imperial p = (w/g)v, where w is weight]
in SI unit is kgm / s

Work

Scalar quantity, equal to the (vector) product of a force and the displacement of an object. In simple systems, where W is work, F force and s distance
W = F s
In SI the unit of work is the joule, J, or kilojoule, kJ
1 J = 1 Nm
In Imperial the unit of work is the ft-lb

Energy

Energy is the ability to do work, the units are the same as for work; J, kJ, and ft-lb

Kinetic Energy

$$E_R = \frac{1}{2} mk^2 \omega^2$$

Where k is radius of gyration, ω is angular velocity in rad/s

Kinetic Energy of Rotation

$$Er = \frac{1}{2} I\omega^2$$

Where I = mk^2 is the moment of inertia

5.2.4 Centripetal (Centrifugal) Force

$$F_c = \frac{mv^2}{r}$$

Where r is the radius
Where ω is angular velocity in rad/s

Potential Energy

Quantity	Equation
Energy due to position in a force field, such as gravity	Ep = m g h
In Imperial this is usually expressed	Ep = w h Where w is weight, and h is height above some specified datum

Thermal Energy

In SI the common units of thermal energy are J, and kJ, (and kJ/kg for specific quantities)
In Imperial, the units of thermal energy are British Thermal Units (Btu)

Conversions

1 Btu = 1055 J
1 Btu = 778 ft-lb

Electrical Energy

In SI the units of electrical energy are J, kJ and kilowatt hours kWh. In Imperial, the unit of electrical energy is the kWh

Conversions

1 kWh = 3600 kJ
1 kWh = 3412 Btu = 2.66×10^6 ft-lb

Power

A scalar quantity, equal to the rate of doing work
In SI the unit is the Watt W (or kW)

$$1W = 1\frac{J}{s}$$

In Imperial, the units are:
Mechanical Power – (ft – lb) / s, horsepower h.p.
Thermal Power – Btu / s
Electrical Power - W, kW, or h.p.

Conversions

$$746W = 1h.p.$$

$$1h.p. = 550\frac{ft - lb}{s}$$

$$1kW = 0.948\frac{Btu}{s}$$

Pressure

A vector quantity, force per unit area
In SI the basic units of pressure are pascals Pa and kPa

$$1Pa = 1\frac{N}{m^2}$$

In Imperial, the basic unit is the pound per square inch, psi

Atmospheric Pressure

At sea level atmospheric pressure equals 101.3 kPa or 14.7 psi

Pressure Conversions

1 psi = 6.895 kPa
Pressure may be expressed in standard units, or in units of static fluid head, in both SI and Imperial systems
Common equivalencies are:

- 1 kPa = 0.294 in. mercury = 7.5 mm mercury
- 1 kPa = 4.02 in. water = 102 mm water
- 1 psi = 2.03 in. mercury = 51.7 mm mercury
- 1 psi = 27.7 in. water = 703 mm water
- 1 m H_2O = 9.81 kPa

Other pressure unit conversions:

- 1 bar = 14.5 psi = 100 kPa
- 1 kg/cm^2 = 98.1 kPa = 14.2 psi = 0.981 bar
- 1 atmosphere (atm) = 101.3 kPa = 14.7 psi

Simple Harmonic Motion

Velocity of P = $\omega\sqrt{R^2 - x^2}\ \frac{m}{s}$

5.2.5 Stress, Strain And Modulus Of Elasticity

Young's modulus and the breaking stress for selected materials

Material	Young modulus x 10^{11} Pa	Breaking stress x 10^8 Pa
Aluminium	0.70	2.4
Copper	1.16	4.9
Brass	0.90	4.7
Iron (wrought)	1.93	3.0
Mild steel	2.10	11.0
Glass	0.55	10
Tungsten	4.10	20
Bone	0.17	1.8

5.3 Thermodynamics

5.3.1 Laws of Thermodynamics

- $W = P\Delta V$
- $\Delta U = Q - W$
- $W = nRT \ln V_f/V_i$
- $Q = Cn\Delta T$
- $C_v = 3/2R$
- $C_p = 5/2R$
- $C_p/C_v = \gamma = 5/3$
- $e = 1 - Qc/Q_h = W/Q_h$
- $e_c = 1 - T_c/T_h$
- $COP = Q_c/W$ (refrigerators)
- $COP = Q_h/W$ (heat pumps)
- $W_{max} = (1 - T_c/T_h)Q_h$
- $\Delta S = Q/T$

5.3.2 Momentum

- $p = mv$
- $\sum F = \Delta p/\Delta t$

5.3.3 Impulse

$I = F_{av}\Delta t = mv_f - mv_i$

5.3.4 Elastic and Inelastic collision

- $m_i v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$
- $(½)\, m_i v_{1i}^2 + (½)\, m_2 v_{2i}^2 = ½\, m_1 v_{1f}^2 + ½\, m_2 v_{2f}^2$
- $m_i v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$

5.3.5 Center of Mass

- $x_{cm} = \sum mx/M$
- $V_{cm} = \sum mv/M$
- $A_{cm} = \sum ma/M$
- $MA_{cm} = F_{net}$

5.3.6 Angular Motion

- $s = r\theta$
- $v_t = r\omega$
- $a_t = r\alpha$
- $a_c = v_t^2/r = r\omega^2$
- $\omega = 2\pi/T$
- $1\ rev = 2\pi\ rad = 360^o$

For constant α

- $\omega = \omega_o + \alpha t$
- $\omega^2 = \omega_o^2 + 2\alpha\theta$
- $\theta = \omega_o t + ½\alpha t^2$
- $\theta = (\omega_o + \omega)\cdot t/2$
- $I = \sum mr^2$
- $KE_R = ½I\omega^2$
- $\tau = rF$
- $\sum\tau = I\alpha$
- $W_R = \tau\theta$
- $L = I\omega$
- $\sum\tau = I\alpha$
- $W_R = \tau\theta$
- $L = I\omega$
- $L_i = L_f$

5.3.7 Conditions of Equilibrium

- $\sum F_x = 0$
- $\sum F_y = 0$
- $\sum \tau = 0$ (any axis)

5.3.8 Gravity

- $F = Gm_1m_2/r^2$
- $T = 2\pi / \sqrt{r^3} /GM_s$
- $G = 6.67 \times 10^{-11} N\text{-}m^2/kg^2$
- $g = GM_E / R^2_E$
- $PE = - Gm_1m_2 / r$
- $v_e = \sqrt{2}GM_E / R_E$
- $v_s = \sqrt{GM_E} / r$
- $M_E = 5.97 \times 10^{24}$ kg
- $R_E = 6.37 \times 10^6$ m

5.3.9 Vibrations & Waves

- $F = -kx$
- $PE_s = ½kx^2$
- $x = A\cos\theta = A\cos(\omega t)$
- $v = -A\omega \sin(\omega t)$
- $a = -A\omega^2 \cos(\omega t)$
- $\omega = \sqrt{k} / m$
- $f = 1 / T$
- $T = 2\pi\sqrt{m} / k$
- $E = ½kA^2$
- $T = 2\pi\sqrt{L} / g$
- $v_{max} = A\omega$
- $a_{max} = A\omega^2$
- $v = \lambda f$ $v = \sqrt{F_T}/\mu$
- $\mu = m/L$
- $I = P/A$
- $\beta = 10\log(I/I_o)$
- $I_o = 1 \times 10^{-12}$ W/m^2
- $f' = f[(1 \pm v_0/v)/(1\ \mu\ v_s/v)]$
- Surface area of the sphere = $4\pi r^2$
- Speed of sound waves = 343 m/s

5.3.10 Standing Waves

- $f_n = nf_1$
- $f_n = nv/2L$ (air column, string fixed both ends) n = 1,2,3,4…….
- $f_n = nv/4L$ (open at one end) n = 1,3,5,7………

5.3.11 Beats

- $f_{beats} = | f_1 - f_2 |$
- Fluids
- $\rho = m/V$
- $P = F/A$
- $P_2 = P_1 + \rho gh$
- $P_{atm} = 1.01 \times 10^5 Pa = 14.7\ lb/in^2$
- $F_B = \rho_f Vg = W_f$ (weight of the displaced fluid)
- $\rho_o/\rho_f = V_f/V_o$ (floating object)
- $\rho_{water} = 1000\ kg/m^3$
- $W_a = W - F_B$

Equation of Continuity: Av = constant
Bernoulli's equation: $P + ½ \rho v^2 + \rho gy = 0$

5.3.12 Temperature and Heat

- $T_F = (9/5)\ T_C + 32$
- $T_C = 5/9(T_F - 32)$
- $\Delta T_F = (9/5)\ \Delta T_C$
- $T = T_C + 273.15$
- $\rho = m/v$
- $\Delta L = \alpha L_o \Delta T$
- $\Delta A = \gamma A_o \Delta T$
- $\Delta V = \beta V_o \Delta T\ \beta = 3\alpha$
- $Q = mc\Delta T$
- $Q = mL$
- 1 kcal = 4186 J
- Heat Loss = Heat Gain
- $Q = (kA\Delta T)t/L$,
- $H = Q/t = (kA\Delta T)/L$
- $Q = e\sigma T^4 At$
- $P = Q/t$
- $P = \sigma AeT^4$
- $P_{net} = \sigma Ae(T^4 - T_S^4)$
- $\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$

5.3.13 Ideal Gases

- $PV = nRT$
- $R = 8.31$ J/mol K
- $PV = NkT$
- $N_A = 6.02 \times 10^{23}$ molecules/mol
- $k = 1.38 \times 10^{-23}$ J/K
- $M = N_A m$
- $(KE)_{av} = (1/2mv^2)_{av} = 3/2kT$
- $U = 3/2NkT = 3/2nRT$

5.3.14 Elastic Deformation

- $P = F/A$
- $Y = FL_o/A\Delta L$
- $S = Fh/A\Delta x$
- $B = -V_o\Delta F / A\Delta V$
- Volume of the sphere = $4\pi r^3/3$
- 1 atm = 1.01×10^5 Pa

5.3.15 Temperature Scales

- °C = 5/9 (°F – 32)
- °F = (9/5) °C + 32
- °R = °F + 460 (R Rankine)
- K = °C + 273 (K Kelvin)

5.3.16 Sensible Heat Equation

- $Q=mc\Delta T$
- M=mass
- C=specific heat
- ΔT=temperature chance

5.3.17 Latent Heat

- Latent heat of fusion of ice = 335 kJ/kg
- Latent heat of steam from and at 100°C = 2257 kJ/kg
- 1 tonne of refrigeration = 335 000 kJ/day = 233 kJ/min

5.3.18 Gas Laws

Boyle's Law

When gas temperature is constant

PV = constant or

$P_1V_1 = P_2V_2$

Where P is absolute pressure and V is volume

Charles' Law

When gas pressure is constant,

$$\frac{V}{T} = const.$$

or

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where V is volume and T is absolute temperature

Gay-Lussac's Law

When gas volume is constant,

$$\frac{P}{T} = const.$$

or

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

where P is absolute pressure and T is absolute temperature

General Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = const.$$

P V = m R T where P = absolute pressure (kPa)
V = volume (m^3)
T = absolute temp (K)
m = mass (kg)
R = characteristic constant (kJ/kgK)

Also
PV = nRoT where P = absolute pressure (kPa)
V = volume (m^3)
T = absolute temperature K
N = the number of kmoles of gas
Ro = the universal gas constant 8.314 kJ/kmol/K

5.3.19 Specific Heats Of Gases

GAS	Specific Heat at Constant Pressure kJ/kgK or kJ/kg °C	Specific Heat at Constant Volume kJ/kgK or kJ/kg °C	Ratio of Specific γ= cp / cv
Air	1.005	0.718	1.40
Ammonia	2.060	1.561	1.32
Carbon Dioxide	0.825	0.630	1.31
Carbon	1.051	0.751	1.40

GAS	Specific Heat at Constant Pressure kJ/kgK or kJ/kg °C	Specific Heat at Constant Volume kJ/kgK or kJ/kg °C	Ratio of Specific γ= cp / cv
Monoxide			
Helium	5.234	3.153	1.66
Hydrogen	14.235	10.096	1.41
Hydrogen Sulphide	1.105	0.85	1.30
Methane	2.177	1.675	1.30
Nitrogen	1.043	0.745	1.40
Oxygen	0.913	0.652	1.40
Sulphur Dioxide	0.632	0.451	1.40

5.3.20 Efficiency of Heat Engines

Carnot Cycle

$$\eta = \frac{T_1 - T_2}{T_1}$$

where T_1 and T_2 are absolute temperatures of heat source and sink

Air Standard Efficiencies

Spark Ignition Gas and Oil Engines (Constant Volume Cycle)

$$\eta = 1 - \frac{1}{r_v^{(\gamma-1)}}$$

r_v= compression ratio

γ = specific heat (constant pressure) / Specific heat (constant volume)

Diesel Cycle

$$\eta = 1 - \frac{R\gamma - 1)}{r_v^{\gamma-1}\gamma(R-1)}$$

Where r = ratio of compression

R = ratio of cut-off volume to clearance volume

High Speed Diesel (Dual-Combustion) Cycle

$$\eta = 1\frac{k\beta^{\gamma} - 1}{r_v^{\gamma-1}\left[(k-1) + \gamma k(\beta - 1)\right]}$$

Where r_v= cylinder volume / clearance volume
k = absolute pressure at the end of constant V heating (combustion) / absolute pressure at the beginning of constant V combustion
β = volume at the end of constant P heating (combustion) / clearance volume

Gas Turbines (Constant Pressure or Brayton Cycle)

$$\eta = 1 - \frac{1}{r_p^{\left(\frac{\gamma-1}{\gamma}\right)}}$$

where r_p = pressure ratio = compressor discharge pressure / compressor intake pressure

5.3.21 Heat Transfer by Conduction

Material	**Coefficient of Thermal Conductivity W/m °C**
Air	0.025
Brass	104
Concrete	0.85
Cork	0.043
Glass	1.0
Iron, cast	70
Steel	60
Wallboard, paper	0.076
Aluminum	206
Brick	0.6
Copper	380
Felt	0.038
Glass, fibre	0.04
Plastic, cellular	0.04
Wood	0.15

5.3.22 Thermal Expansion of Solids

Increase in length = L α ($T_2 - T_1$)
Where L = original length
α = coefficient of linear expansion
($T_2 - T_1$) = rise in temperature
Increase in volume = V β ($T_2 - T_1$)
Where V = original volume
β = coefficient of volumetric expansion
($T_2 - T_1$) = rise in temperature
Coefficient of volumetric expansion = Coefficient of linear expansion × 3
β = 3α

5.3.23 Chemical Heating Value of a Fuel

Chemical Heating Value MJ per kg of fuel = $33.7C + 144(H_2 - \frac{O_2}{8}) + 9.3S$

C is the mass of carbon per kg of fuel
H_2 is the mass of hydrogen per kg of fuel
O_2 is the mass of oxygen per kg of fuel
S is the mass of sulphur per kg of fuel

Theoretical Air Required to Burn Fuel

Air (kg per kg of fuel) = $\left[\frac{8}{3}C + 8(H_2 - O_2) + S\right]\frac{100}{23}$

Air Supplied from Analysis of Flue Gases

Air in kg per kg of fuel = $\frac{N_2}{33(CO_2 + CO)} \times C$

Boiler Formulae

Equivalent evaporation $= \frac{m_s(h_1 - h_2)}{2257kj/kg}$

Factor of evaporation $= \frac{(h_1 - h_2)}{2257kj/kg}$

Boiler Efficiency

$$\frac{m_s(h_1 - h_2)}{mf \times (calorificvalue)}$$

Where
m_s = mass flow rate of steam
h_1 = enthalpy of steam produced in boiler
h_2 = enthalpy of feedwater to boiler

m_f = mass flow rate of fuel

Name of process	Value of n	P-V-T Relationships			Heat added	Work done	Change in Internal Energy	Change in Enthalpy	Change in Entropy
		P-V	T-P	T-V					
Constant Volume V=Constant	∞	--	$\frac{T_1}{T_2}=\frac{P_1}{P_2}$	--	$mc_v(T_2-T_1)$	0	$mc_v(T_2-T_1)$	$mc_p(T_2-T_1)$	$mc_v\log_e\left(\frac{T_2}{T_1}\right)$
Constant pressure P=Pressure	0	--	--	$\frac{T_1}{T_2}=\frac{V_1}{V_2}$	$mc_p(T_2-T_1)$	$P(V_2-V_1)$	$mc_v(T_2-T_1)$	$mc_p(T_2-T_1)$	$mc_n\log_e\left(\frac{T_2}{T_1}\right)$
Isothermal T=Constant	1	$\frac{P_1}{P_2}=\frac{V_2}{V_1}$	--	--	$mRT\log_e\left(\frac{P_1}{P_2}\right)$	$mRT\log_e\left(\frac{P_1}{P_2}\right)$	0	0	$mR\log_e\left(\frac{P_1}{P_2}\right)$
Isentropic S=Constant	γ	$\frac{P_1}{P_2}=\left[\frac{V_2}{V_1}\right]^{\gamma}$	$\frac{T_1}{T_2}=\left[\frac{P_1}{P_2}\right]^{\frac{\gamma-1}{\gamma}}$	$\frac{T_1}{T_2}=\left[\frac{V_2}{V_1}\right]^{\gamma-1}$	0	$mc_v(T_1-T_2)$	$mc_v(T_2-T_1)$	$mc_p(T_2-T_1)$	0
Polytropic PV^n = Constant	n	$\frac{P_1}{P_2}=\left[\frac{V_2}{V_1}\right]^{n}$	$\frac{T_1}{T_2}=\left[\frac{P_1}{P_2}\right]^{\frac{n-1}{n}}$	$\frac{T_1}{T_2}=\left[\frac{V_2}{V_1}\right]^{n-1}$	$mc_n(T_2-T_1)$	$\frac{mR}{n-1}(T_1-T_2)$	$mc_v(T_2-T_1)$	$mc_p(T_2-T_1)$	$mc_n\log_e\left(\frac{T_2}{T_1}\right)$

Thermodynamic Equations for perfect gases

*Can be used for reversible adiabatic processes

c_v = Specific heat at constant volume, kJ/kgK

c_p = Specific heat at constant pressure, kJ/kgK

c_m = Specific heat for polytropic process = $c_v\left(\frac{\gamma - n}{1 - n}\right) kJ / kgK$

H = Enthalpy, kJ
γ = Isentropic Exponent, c_p/c_v
n = polytropic exponent
P = Pressure, kPa
R = Gas content, kJ/kgK
S = Entropy, kJ/K
T = Absolute Temperature, K = 273+˚C
U = Internal Energy, kJ
V = Volume, m^3
m = Mass of gas, kg

Specific Heat and Linear Expansion of Solids	**Mean Specific Heat between 0°C and 100°C kJ/kgK or kJ/kg°C**	**Coefficient of Linear Expansion between 0°C and 100°C (multiply by 10^{-6})**
Aluminum	0.909	23.8
Antimony	0.209	17.5
Bismuth	0.125	12.4
Brass	0.383	18.4
Carbon	0.795	7.9
Cobalt	0.402	12.3
Copper	0.388	16.5
Glass	0.896	9.0
Gold	0.130	14.2
Ice (between -20°C & 0°C)	2.135	50.4
Iron (cast)	0.544	10.4
Iron (wrought)	0.465	12.0
Lead	0.131	29.0
Nickel	0.452	13.0
Platinum	0.134	8.6
Silicon	0.741	7.8
Silver	0.235	19.5
Steel (mild)	0.494	12.0
Tin	0.230	26.7
Zinc	0.389	16.5

Specific Heat and Volume Expansion for Liquids

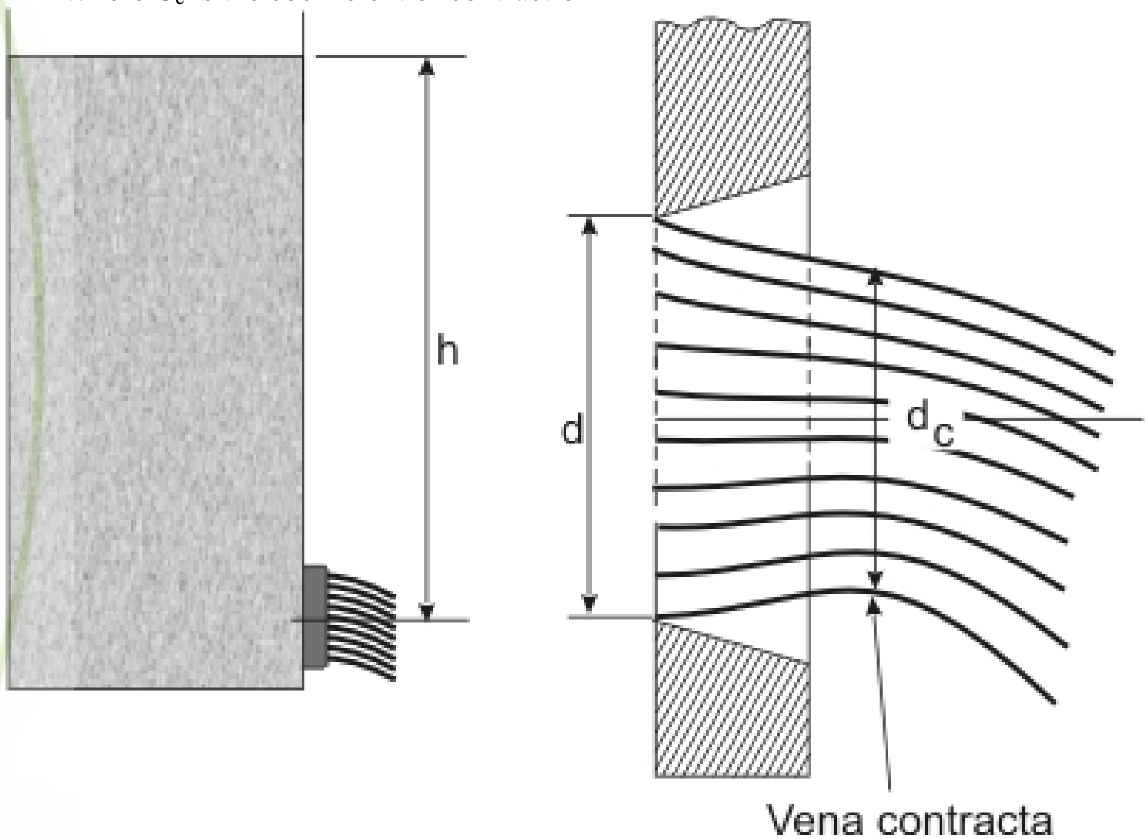
Liquid	**Specific Heat (at 20°C) KJ/kgK or kJ/kg°C**	**Coefficient of Volume Expansion (Multiply by 10^{-4})**
Alcohal	2.470	11.0
Ammonia	0.473	
Benzine	1.138	12.4
Carbon Dioxide	3.643	1.82
Mercury	0.139	1.80
Olive oil	1.633	
Petroleum	2.135	
Gasoline	2.093	12.0
Turpentine	1.800	9.4
Water	4.183	3.7

5.4 Fluid Mechanics

5.4.1 Discharge from an Orifice

Let A = cross-sectional area of the orifice =	$\frac{\pi}{4} d^2$
And Ac = cross-sectional area of the jet at the vena conrtacta	$\frac{\pi}{4} d_c^2$
Then Ac = CcA	Or $C_c = \frac{A_c}{A} = \left(\frac{d_c}{d}\right)^2$

Where C_c is the coefficient of contraction



At the vena contracta, the volumetric flow rate Q of the fluid is given by

- Q = area of the jet at the vena contracta · actual velocity = A_cV
- Or $Q = C_c A C_v \sqrt{2gh}$
- Typically, values for Cd vary between 0.6 and 0.65
- Circular orifice: Q = 0.62 A √2gh
- Where Q = flow (m^3/s) A = area (m^2) h = head (m)
- Rectangular notch: Q = 0.62 (B · H) 2/3 √2gh

Where B = breadth (m)
H = head (m above sill)
Triangular Right Angled Notch: $Q = 2.635\ H^{5/2}$
Where H = head (m above sill)

5.4.2 Bernoulli's Theory

$$H = h + \frac{P}{w} + \frac{v^2}{2g}$$

H = total head (meters)
w = force of gravity on 1 m^3 of fluid (N)
h = height above datum level (meters)
v = velocity of water (meters per second)
P = pressure (N/m^2 or Pa)
Loss of Head in Pipes Due to Friction

Loss of head in meters = $f \frac{L}{d} \frac{v^2}{2g}$

L = length in meters
v = velocity of flow in meters per second
d = diameter in meters
f = constant value of 0.01 in large pipes to 0.02 in small pipes

5.4.3 Actual pipe dimensions

Nominal pipe size (in)	**Outside diameter (mm)**	**Inside diameter (mm)**	**Wall thickness (mm)**	**Flow area (m^2)**
1/8	10.3	6.8	1.73	3.660×10^{-5}
1/4	13.7	9.2	2.24	6717×10^{-5}
3/8	17.1	12.5	2.31	1.236×10^{-4}
1/2	21.3	15.8	2.77	1.960×10^{-4}
3/4	26.7	20.9	2.87	3.437×10^{-4}
1	33.4	26.6	3.38	5.574×10^{-4}
1¼	42.2	35.1	3.56	9.653×10^{-4}
1½	48.3	40.9	3.68	1.314×10^{-3}
2	60.3	52.5	3.91	2.168×10^{-3}

Nominal pipe size (in)	Outside diameter (mm)	Inside diameter (mm)	Wall thickness (mm)	Flow area (m^2)
2½	73.0	62.7	5.16	3.090×10^{-3}
3	88.9	77.9	5.49	4.768×10^{-3}
3½	101.6	90.1	5.74	6.381×10^{-3}
4	114.3	102.3	6.02	8.213×10^{-3}
5	141.3	128.2	6.55	1.291×10^{-2}
6	168.3	154.1	7.11	1.864×10^{-2}
8	219.1	202.7	8.18	3.226×10^{-2}
10	273.1	254.5	9.27	5.090×10^{-2}
12	323.9	303.2	10.31	7.219×10^{-2}
14	355.6	333.4	11.10	8.729×10^{-2}
16	406.4	381.0	12.70	0.1140
18	457.2	428.7	14.27	0.1443
20	508.0	477.9	15.06	0.1794
24	609.6	574.7	17.45	0.2594

Chapter 6

References

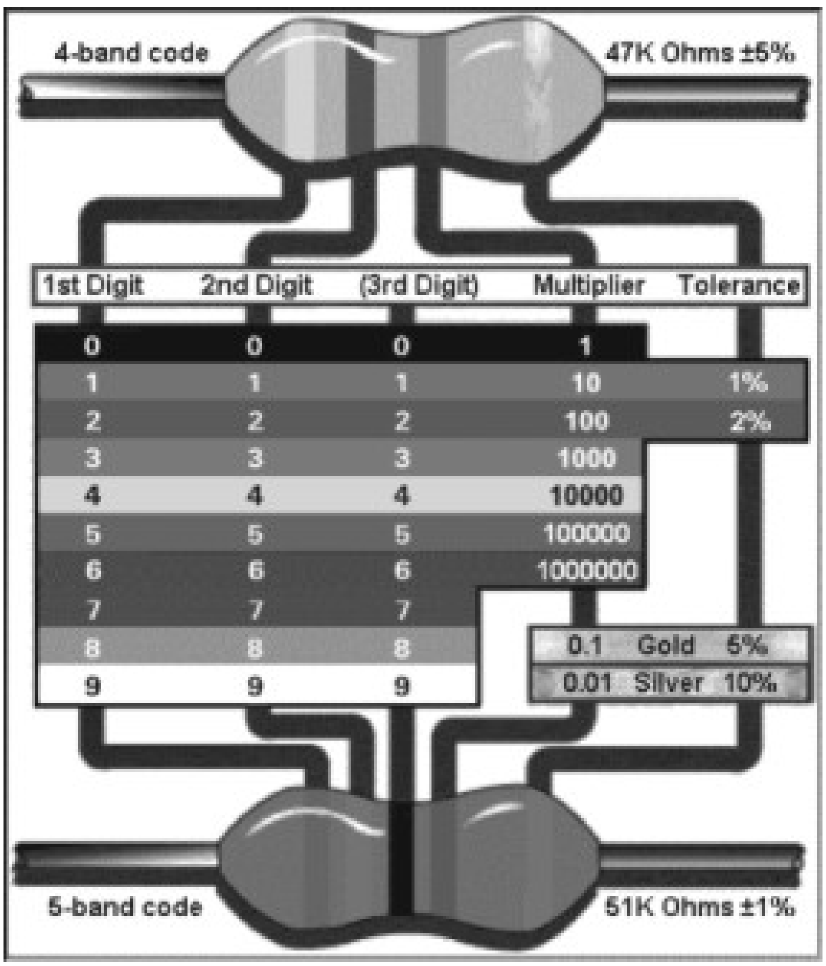
6.1 Periodic Table of Elements

A 1																	8A 18
1 H 1.008	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 97.9	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (265)	109 Mt (268)									

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

6.2 Resistor Color Coding

Color	Value
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet / Purple	7
Grey	8
White	9



Courtesy: Dick Smith Electronics, Australia