Engineering Formula Sheet

Statistics

Mean

$$\mu = \frac{\sum x_i}{n}$$

μ = mean value
Σx_i = sum of all data values (x_1, x_2, x_3, …)
n = number of data values

Standard Deviation

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{n}}$$

σ = standard deviation
x_i = individual data value (x_1, x_2, x_3, …)
μ = mean value
n = number of data values

Mode

Place data in ascending order.
Mode = most frequently occurring value

If two values occur at the maximum frequency the data set is *bimodal.*
If three or more values occur at the maximum frequency the data set is *multi-modal.*

Median

Place data in ascending order.
If n is odd, median = central value
If n is even, median = mean of two central values

n = number of data values

Range

Range = x_{max} - x_{min}

x_{max} = maximum data value
x_{min} = minimum data value

Probability

Frequency

$$f_x = \frac{n_x}{n}$$

$$P_x = \frac{f_x}{f_a}$$

f_x = relative frequency of outcome x
n_x = number of events with outcome x
n = total number of events
P_x = probability of outcome x
f_a = frequency of all events

Binomial Probability (order doesn't matter)

$$P_k = \frac{n!(p^k)(q^{n-k})}{k!(n-k)!}$$

P_k = binomial probability of k successes in n trials
p = probability of a success
q = 1 – p = probability of failure
k = number of successes
n = number of trials

Independent Events

P (A and B and C) = $P_A P_B P_C$

P (A and B and C) = probability of independent events A and B and C occurring in sequence
P_A = probability of event A

Mutually Exclusive Events

P (A or B) = $P_A + P_B$

P (A or B) = probability of either mutually exclusive event A or B occurring in a trial
P_A = probability of event A
Σx_i = sum of all data values (x_1, x_2, x_3, …)
n = number of data values

Conditional Probability

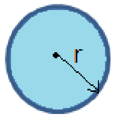
$$P(A|D) = \frac{P(A) \cdot P(D|A)}{P(A) \cdot P(D|A) + P(\sim A) \cdot P(D|\sim A)}$$

P (A|D) = probability of event A given event D
P(A) = probability of event A occurring
P(~A) = probability of event A not occurring
P(D|~A) = probability of event D given event A did not occur

Plane Geometry

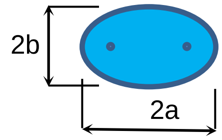
Circle

Circumference = $2\pi r$
Area = πr^2



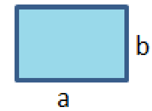
Ellipse

Area = $\pi a b$



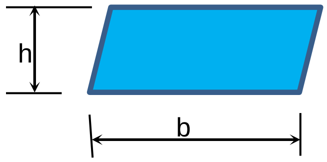
Rectangle

Perimeter = 2a + 2b
Area = ab



Parallelogram

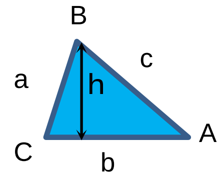
Area = bh



Triangle

Area = ½ bh

$a^2 = b^2 + c^2 - 2bc \cdot cos\angle A$
$b^2 = a^2 + c^2 - 2ac \cdot cos\angle B$
$c^2 = a^2 + b^2 - 2ab \cdot cos\angle C$



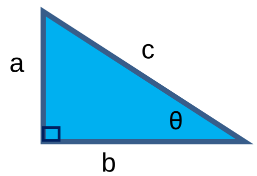
Right Triangle

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

$sin\,\theta = \frac{a}{c}$

$cos\,\theta = \frac{b}{c}$

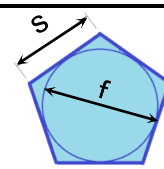
$tan\,\theta = \frac{a}{b}$



Regular Polygons

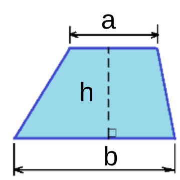
Area = $n\frac{s(\frac{1}{2}f)}{2}$

n = number of sides



Trapezoid

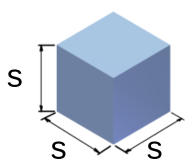
Area = ½(a + b)h



Solid Geometry

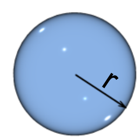
Cube

Volume = s^3
Surface Area = $6s^2$



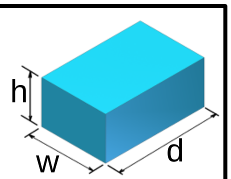
Sphere

Volume $\frac{4}{3}\pi r^3$
Surface Area = $4\pi r^2$



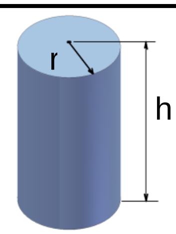
Rectangular Prism

Volume = wdh
Surface Area = 2(wd + wh + dh)



Cylinder

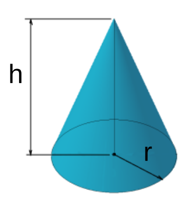
Volume = $\pi r^2 h$
Surface Area = $2\pi r h + 2\pi r^2$



Right Circular Cone

Volume = $\frac{\pi r^2 h}{3}$

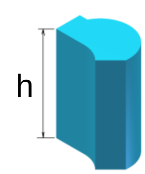
Surface Area = $\pi r \sqrt{r^2+h^2}$



Irregular Prism

Volume = Ah

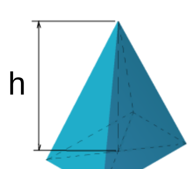
A = area of base



Pyramid

Volume = $\frac{Ah}{3}$

A = area of base



Constants

g = 9.8 m/s² = 32.27 ft/s² ($g = 9.8\ m/s^2 = 32.27\ ft/s^2$)
G = 6.67 x 10⁻¹¹ m³/kg·s² ($G = 6.67 \times 10^{-11}\ m^3/kg \cdot s^2$)
π = 3.14159

Conversions

Mass

1 kg = 2.205 lb_m
1 slug = 32.2 lb_m
1 ton = 2000 lb_m

Length

1 m = 3.28 ft
1 km = 0.621 mi
1 in. = 2.54 cm
1 mi = 5280 ft
1 yd = 3 ft

Time

1 d = 24 h
1 h = 60 min
1 min = 60 s
1 yr = 365 d

Area

1 acre = 4047 m^2
= 43,560 ft^2
= 0.00156 mi^2

Volume

1L = 0.264 gal
= 0.0353 ft^3
= 33.8 fl oz
1mL = 1 cm^3 = 1 cc

Temperature <u>Unit</u> Equivalents

1 K = 1 ºC
= 1.8 ºF
= 1.8 ºR

See below for temperature calculation

Force

1 N = 0.225 lb_f
1 kip = 1,000 lb_f

Pressure

1 atm = 1.01325 bar
= 33.9 ft H_2O
= 29.92 in. Hg
= 760 mm Hg
= 101,325 Pa
= 14.7 psi
1psi = 2.31 ft of H_2O

Power

1 W = 3.412 Btu/h
= 0.00134 hp
= 14.34 cal/min
= 0.7376 ft·lb_f/s

Energy

1 J = 0.239 cal
= 9.48 x 10^{-4} Btu
= 0.7376 ft·lb_f
1kW h = 3,600,000 J

Defined Units

1 J = 1 N·m
1 N = 1 kg·m / s^2
1 Pa = 1 N / m^2
1 V = 1 W / A
1 W = 1 J / s
1 W = 1 V / A
1 Hz = 1 s^{-1}
1 F = 1 A·s / V
1 H = 1 V·s / V

SI Prefixes

Numbers Less Than One

Power of 10	Prefix	Abbreviation
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	µ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f
10^{-18}	atto-	a
10^{-21}	zepto-	z
10^{-24}	yocto-	y

Numbers Greater Than One

Power of 10	Prefix	Abbreviation
10^{1}	deca-	da
10^{2}	hecto-	h
10^{3}	kilo-	k
10^{6}	Mega-	M
10^{9}	Giga-	G
10^{12}	Tera-	T
10^{15}	Peta-	P
10^{18}	Exa-	E
10^{21}	Zetta-	Z
10^{24}	Yotta-	Y

Equations

Mass and Weight

$M = VD_m$

$W = mg$

$W = VD_w$

V = volume
D_m = mass density
m = mass
D_w = weight density
g = acceleration due to gravity

Temperature

$T_K = T_C + 273$

$T_R = T_F + 460$

$T_F = \frac{5}{9} T_c + 32$

T_K = temperature in Kelvin
T_C = temperature in Celsius
T_R = temperature in Rankin
T_F = temperature in Fahrenheit

Force

$F = ma$

F = force
m = mass
a = acceleration

Equations of Static Equilibrium

$\Sigma F_x = 0$ $\Sigma F_y = 0$ $\Sigma M_P = 0$

F_x = force in the x-direction
F_y = force in the y-direction
M_P = moment about point P

Equations (Continued)

Energy: Work

$W = F_{\parallel} \cdot \mathbf{d}$

W = work
$F_{\parallel}$ = force parallel to direction of displacement
d = displacement

Power

$P = \frac{E}{t} = \frac{W}{t}$

$P = \frac{\tau \cdot rpm}{5252}$

P = power
E = energy
W = work
t = time
τ = torque
rpm = revolutions per minute

Efficiency

$\text{Efficiency (\%)} = \frac{P_{out}}{P_{in}} \cdot 100\%$

P_{out} = useful power output
P_{in} = total power input

Energy: Potential

$U = mgh$

U = potential energy
m =mass
g = acceleration due to gravity
h = height

Energy: Kinetic

$K = \frac{1}{2} mv^2$

K = kinetic energy
m = mass
v = velocity

Energy: Thermal

$Q = mc\Delta T$

Q = thermal energy
m = mass
c = specific heat
ΔT = change in temperature

Fluid Mechanics

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

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (Charles' Law)

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$ (Gay-Lussanc's Law)

$p_1V_1 = p_2V_2$ (Boyle's Law)

$Q = Av$

$A_1v_1 = A_2v_2$

$\text{Horsepower} = \frac{Qp}{1714}$

absolute pressure = gauge pressure + atmospheric pressure

p = absolute pressure
F = Force
A = Area
V = volume
T = absolute temperature
Q = flow rate
v = flow velocity

Mechanics

$\bar{s} = \frac{d}{t}$

$\bar{\mathbf{v}} = \frac{\Delta \mathbf{d}}{\Delta t}$

$a = \frac{v_f - v_i}{t}$

$X = \frac{v_i^2 \sin(2\theta)}{-g}$

$v = v_0 + at$

$d = d_0 + v_0t + ½at^2$

$v^2 = v_0^2 + 2a(d - d_0)$

$\tau = dF\sin\theta$

$\bar{s}$ = average speed
$\bar{\mathbf{v}}$ = average velocity
v = velocity
a = acceleration
X = range
t = time
Δ**d** = change in displacement
d = distance
g = acceleration due to gravity
θ = angle
τ = torque

Electricity

Ohm's Law
$V = IR$

$P = IV$

$R_T \text{ (series)} = R_1 + R_2 + \cdots + R_n$

$R_T \text{ (parallel)} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}}$

Kirchhoff's Current Law
$I_T = I_1 + I_2 + \cdots + I_n$
or $I_T = \sum_{k=1}^{n} I_k$

Kirchhoff's Voltage Law
$V_T = V_1 + V_2 + \cdots + V_n$
or $V_T = \sum_{k=1}^{n} V_k$

V = voltage
V_T = total voltage
I = current
I_T = total current
R = resistance
R_T = total resistance
P = power

Thermodynamics

$P = Q' = AU\Delta T$

$P = \frac{Q}{\Delta t}$

$U = \frac{1}{R} = \frac{k}{L}$

$P = \frac{kA\Delta T}{L}$

$A_1v_1 = A_2v_2$

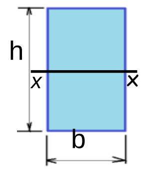
$P_{net} = \sigma Ae(T_2^4 - T_1^4)$

P = rate of heat transfer
Q = thermal energy
A = Area of thermal conductivity
U = coefficient of heat conductivity (U-factor)
ΔT = change in temperature
Δt = change in time
R = resistance to heat flow (R-value)
k = thermal conductivity
v = velocity
P_{net} = net power radiated
$\sigma = 5.6696 \times 10^{-8} \frac{W}{m^2 \cdot K^4}$
e = emissivity constant
L = thickness

Section Properties

Moment of Inertia

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



I_{xx} = moment of inertia of a rectangular section about x-x axis

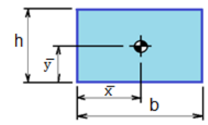
Complex Shapes Centroid

$$\bar{x} = \frac{\Sigma x_i A_i}{\Sigma A_i} \quad \textbf{and} \quad \bar{y} = \frac{\Sigma y_i A_i}{\Sigma A_i}$$

$\bar{x}$ = x-distance to the centroid
$\bar{y}$ = y-distance to the centroid
x_i = x distance to centroid of shape i
y_i = y distance to centroid of shape i
A_i = Area of shape i

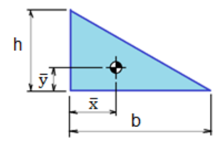
Rectangle Centroid

$$\bar{x} = \frac{b}{2} \quad \textbf{and} \quad \bar{y} = \frac{h}{2}$$



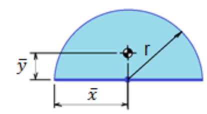
Right Triangle Centroid

$$\bar{x} = \frac{b}{3} \quad \textbf{and} \quad \bar{y} = \frac{h}{3}$$



Semi-circle Centroid

$$\bar{x} = r \quad \textbf{and} \quad \bar{y} = \frac{4r}{3\pi}$$



$\bar{x}$ = x-distance to the centroid
$\bar{y}$ = y-distance to the centroid

Material Properties

Stress (axial)

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

σ = stress
F = axial force
A = cross-sectional area

Strain (axial)

$$\epsilon = \frac{\delta}{L_0}$$

ϵ = strain
L_0 = original length
δ = change in length

Modulus of Elasticity

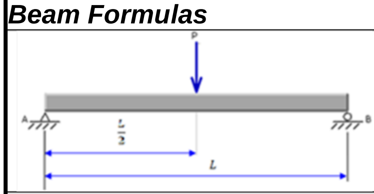
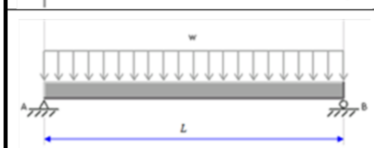
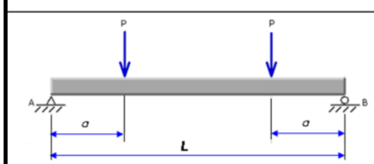
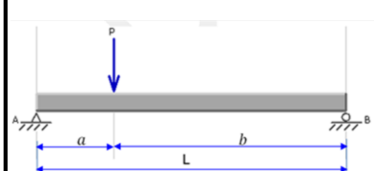
$$E = \frac{\sigma}{\varepsilon}$$

$$E = \frac{(F_2 - F_1)L_0}{(\delta_2 - \delta_1)A}$$

E = modulus of elasticity
σ = stress
ε = strain
A = cross-sectional area
F = axial force
δ = deformation

Structural Analysis

Beam Formulas

	**Reaction** **Moment** **Deflection**	$R_A = R_B = \frac{P}{2}$ $M_{max} = \frac{PL}{4}$ (at point of load) $\Delta_{max} = \frac{PL^3}{48EI}$ (at point of load)
	**Reaction** **Moment** **Deflection**	$R_A = R_B = \frac{\omega L}{2}$ $M_{max} = \frac{\omega L^2}{8}$ (at center) $\Delta_{max} = \frac{5\omega L^4}{384EI}$ (at center)
	**Reaction** **Moment** **Deflection**	$R_A = R_B = P$ $M_{max} = Pa$ (between loads) $\Delta_{max} = \frac{Pa}{24EI}(3L^2 - 4a^2)$ (at center)
	**Reaction** **Moment** **Deflection**	$R_A = \frac{Pb}{L}$ **and** $R_B = \frac{Pa}{L}$ $M_{max} = \frac{Pab}{L}$ (at Point of Load) $\Delta_{max} = \frac{Pab(a+2b)\sqrt{3a(a+2b)}}{27EI}$ (at $x = \sqrt{\frac{a(a+2b)}{3}}$ when $a > b$)

Deformation: Axial

$$\delta = \frac{FL_0}{AE}$$

δ = deformation
F = axial force
L_0 = original length
A = cross-sectional area
E = modulus of elasticity

Truss Analysis

2J = M + R

J = number of joints
M =number of members
R = number of reaction forces

Simple Machines

Mechanical Advantage (MA)

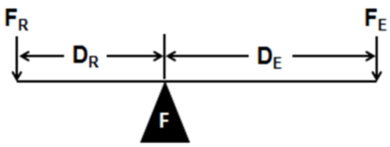
$$IMA = \frac{D_E}{D_R} \qquad AMA = \frac{F_R}{F_E}$$

$$\%\ Efficiency = \left(\frac{AMA}{IMA}\right) 100$$

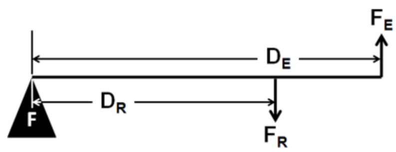
IMA = Ideal Mechanical Advantage
AMA = Actual Mechanical Advantage
D_E = Effort Distance D_R = Resistance Distance
F_E = Effort Force F_R = Resistance Force

Lever

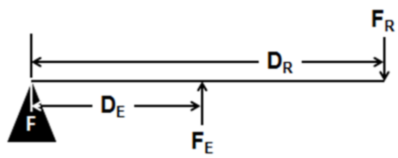
1st Class



2nd Class

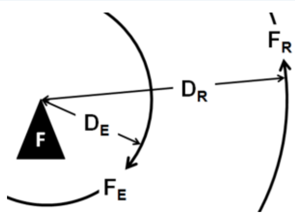


3rd Class

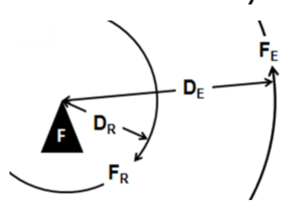


Wheel and Axle

Effort at Axle



Effort at Wheel



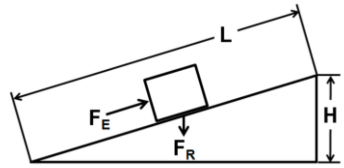
Pulley Systems

IMA = Total number of strands of a single string supporting the resistance

$$IMA = \frac{D_E \text{ (string pulled)}}{D_R \text{ (resistance lifted)}}$$

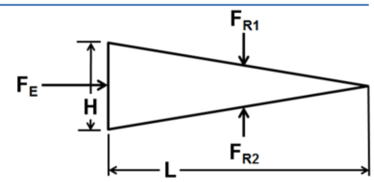
Inclined Plane

$$IMA = \frac{L \text{ (slope)}}{H}$$



Wedge

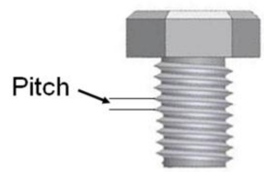
$$IMA = \frac{L\ (\perp \text{ to height})}{H}$$

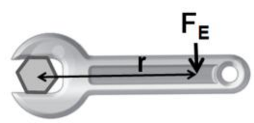


Screw

$$IMA = \frac{C}{Pitch}$$

$$Pitch = \frac{1}{TPI}$$





C = Circumference
r = radius
Pitch = distance between threads
TPI = Threads Per Inch

Compound Machines

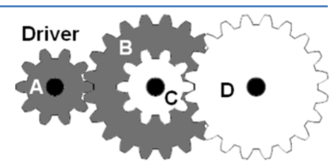
$$MA_{TOTAL} = (MA_1)(MA_2)(MA_3)\ .\ .\ .$$

Gears; Sprockets with Chains; and Pulleys with Belts Ratios

$$GR = \frac{N_{out}}{N_{in}} = \frac{d_{out}}{d_{in}} = \frac{\omega_{in}}{\omega_{out}} = \frac{\tau_{out}}{\tau_{in}}$$

$$\frac{d_{out}}{d_{in}} = \frac{\omega_{in}}{\omega_{out}} = \frac{\tau_{out}}{\tau_{in}} \text{ (pulleys)}$$

Compound Gears



$$GR_{TOTAL} = \left(\frac{B}{A}\right)\left(\frac{D}{C}\right)$$

GR = Gear Ratio
ω_{in} = Angular Velocity - driver
ω_{out} = Angular Velocity - driven
N_{in} = Number of Teeth - driver
N_{out} = Number of Teeth - driven
d_{in} = Diameter - driver
d_{out} = Diameter - driven
τ_{in} = Torque - driver
τ_{out} = Torque - driven