# Engineering Formula Sheet

## Statistics

### *Mean*

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

$\mu$ = mean value
$\Sigma x_i$ = sum of all data values ($x_1$, $x_2$, $x_3$, …)
n = number of data values

### *Standard Deviation*

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

$\sigma$ = standard deviation
$x_i$ = individual data value ( $x_1$, $x_2$, $x_3$, …)
$\mu$ = 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
$\Sigma x_i$ = sum of all data values ($x_1$, $x_2$, $x_3$, …)
n = number of data values

### *Conditional Probability*

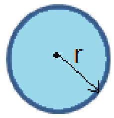
$$P(A|D) = \frac{P(A) \cdot P(D|A)}{P(A) \cdot P(D|A) + P(\sim A) \cdot P(D|\sim A)}$$

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

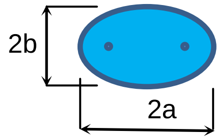
### Circle

Circumference $= 2 \pi r$
Area $= \pi r^2$



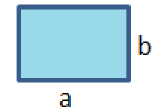

### Ellipse

Area $= \pi a b$



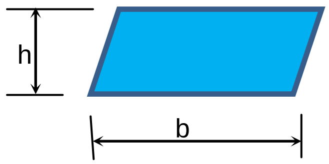

### Rectangle

Perimeter $= 2a + 2b$
Area $= ab$




### Parallelogram

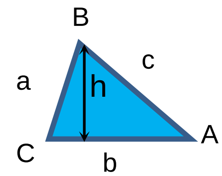
Area $= bh$




### Triangle

Area $= \frac{1}{2} bh$

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



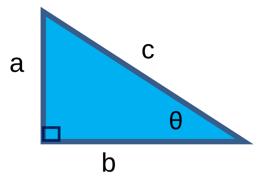

### Right Triangle

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

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

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

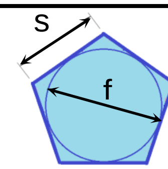
$\tan\theta = \frac{a}{b}$




### Regular Polygons

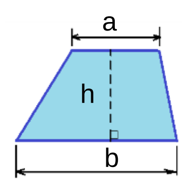
Area $= n \frac{s(\frac{1}{2} f)}{2}$

n = number of sides




### Trapezoid

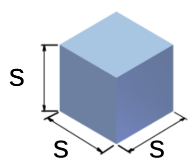
Area $= \frac{1}{2}(a + b)h$




## Solid Geometry

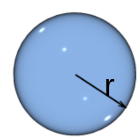
### Cube

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



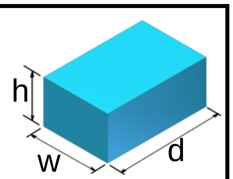

### Sphere

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



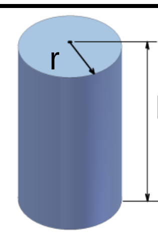

### Rectangular Prism

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




### Cylinder

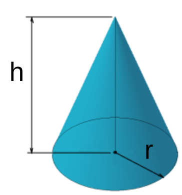
Volume $= \pi r^2 h$
Surface Area $= 2 \pi r h + 2 \pi r^2$




### Right Circular Cone

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

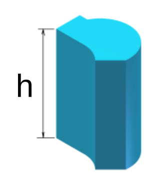
Surface Area $= \pi r \sqrt{r^2+h^2}$




### Irregular Prism

Volume = Ah

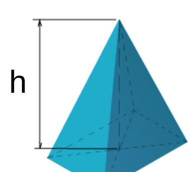
A = area of base




### Pyramid

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

A = area of base




## Constants

**$g = 9.8\ m/s^2 = 32.27\ ft/s^2$**
**$G = 6.67 \times 10^{-11}\ m^3/kg \cdot s^2$**
**$\pi = 3.14159$**

## Conversions

### *Mass*

| | |
|---|---|
| 1 kg | = 2.205 $lb_m$ |
| 1 slug | = 32.2 $lb_m$ |
| 1 ton | = 2000 $lb_m$ |

### *Area*

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

### *Force*

| | |
|---|---|
| 1 N | = 0.225 $lb_f$ |
| 1 kip | = 1,000 $lb_f$ |

### *Energy*

| | |
|---|---|
| 1 J | = 0.239 cal |
| | = 9.48 x $10^{-4}$ Btu |
| | = 0.7376 ft·$lb_f$ |
| 1kW h | = 3,6000,000 J |

### *Length*

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

### *Volume*

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

### *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 $H_2O$ |

### *Temperature Change*

| | |
|---|---|
| 1 K | = 1 ºC |
| | = 1.8 ºF |
| | = 1.8 ºR |

### *Time*

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

### *Power*

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

## 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 Ω | = 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*

$T_K = T_C + 273$

$T_R = T_F + 460$

$$\frac{T_F - 32}{180} = \frac{T_C}{100}$$

$T_K$ = 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*

$W = F \cdot d$

W = work
F = force
d = distance

### *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)

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$ (Guy-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*

$s = \frac{d}{t}$ *(where acceleration = 0)*

$\mathbf{v} = \frac{\mathbf{d}}{t}$ *(where acceleration = 0)*

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

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

$v = v_0 + at$

$d = d_0 + v_0t + ½at^2$

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

$\tau = dF\sin\theta$

s = speed
v = velocity
a = acceleration
X = range
t = time
d = distance
g = acceleration due to gravity
d = distance
θ = angle
**τ** = torque
F = force

### *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*

$P = Q' = AU\Delta T$

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

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

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

$A_1v_1 = A_2v_2$

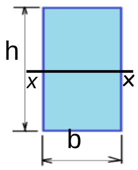
$P_{net} = \sigma Ae(T_2^4 - T_1^4)$

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

# Section Properties

### *Moment of Inertia*

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




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

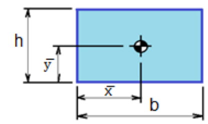
### *Complex Shapes Centroid*

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

$\bar{x}$ = 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

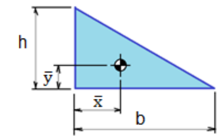
### *Rectangle Centroid*

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



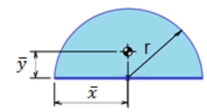

### *Right Triangle Centroid*

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




### *Semi-circle Centroid*

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




$\bar{x}$ = 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*

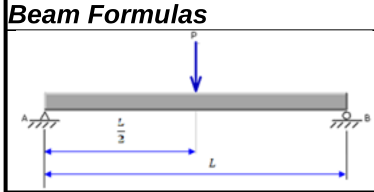
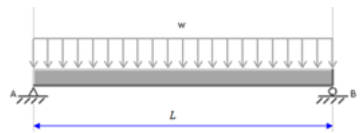
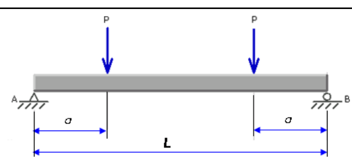
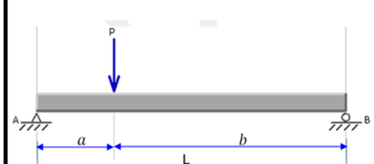
$$E = \frac{\sigma}{\varepsilon}$$

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

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

# Structural Analysis

### *Beam Formulas*

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

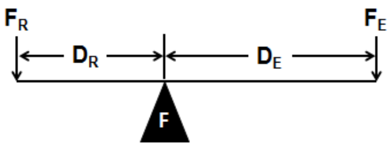
$$IMA = \frac{D_E}{D_R} \qquad AMA = \frac{F_R}{F_E}$$

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

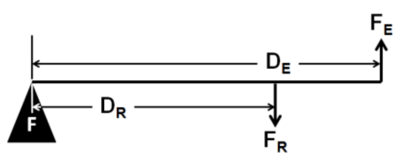
IMA = Ideal Mechanical Advantage
AMA = Actual Mechanical Advantage
$D_E$ = Effort Distance   $D_R$ = Resistance Distance
$F_E$ = Effort Force   $F_R$ = Resistance Force

### Lever

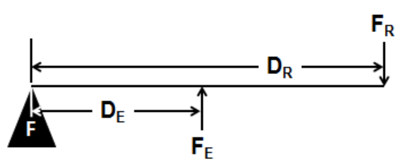
1st Class




2nd Class

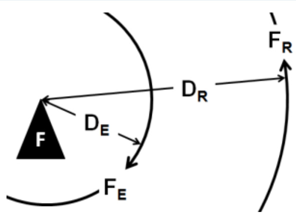



3rd Class

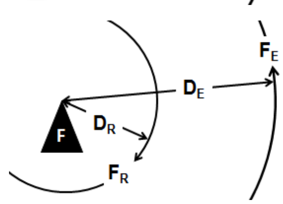



### Wheel and Axle

Effort at Axle




Effort at Wheel



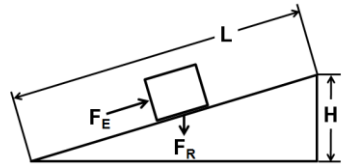

### Pulley Systems

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

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

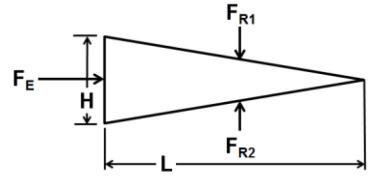
### Inclined Plane

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




### Wedge

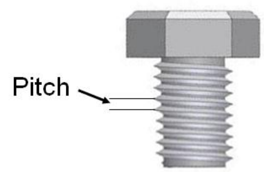
$$IMA = \frac{L \text{ (}\perp\text{ to height)}}{H}$$

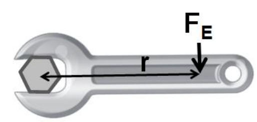



### Screw

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

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




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

### Compound Machines

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

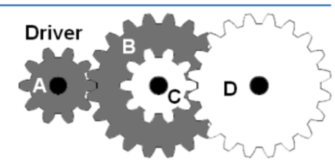
### Gears; Sprockets with Chains; and Pulleys with Belts Ratios

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

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

### Compound Gears

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




GR = Gear Ratio
$\omega_{in}$ = Angular Velocity - driver
$\omega_{out}$ = Angular Velocity - driven
$N_{in}$ = Number of Teeth - driver
$N_{out}$ = Number of Teeth - driven
$d_{in}$ = Diameter - driver
$d_{out}$ = Diameter - driven
$\tau_{in}$ = Torque - driver
$\tau_{out}$ = Torque - driven

# Structural Design

### Steel Beam Design: Shear

$$V_a = \frac{V_n}{\Omega_v}$$

$$V_n = 0.6F_yA_w$$

$V_a$ = allowable shear strength
$V_n$ = nominal shear strength
$\Omega_v$ = 1.5 = factor of safety for shear
$F_y$ = yield stress
$A_w$ = area of web

### Steel Beam Design: Moment

$$M_a = \frac{M_n}{\Omega_b}$$

$$M_n = F_yZ_x$$

$M_a$ = allowable bending moment
$M_n$ = nominal moment strength
$\Omega_b$ = 1.67 = factor of safety for bending moment
$F_y$ = yield stress
$Z_x$ = plastic section modulus about neutral axis

### Spread Footing Design

$$q_{net} = q_{allowable} - p_{footing}$$

$$p_{footing} = t_{footing} \cdot 150\frac{lb}{ft^2}$$

$$q = \frac{P}{A}$$

$q_{net}$ = net allowable soil bearing pressure
$q_{allowable}$ = total allowable soil bearing pressure
$p_{footing}$ = soil bearing pressure due to footing weight
$t_{footing}$ = thickness of footing
q = soil bearing pressure
P = column load applied
A = area of footing

# Storm Water Runoff

### Storm Water Drainage

$$Q = C_fCiA$$

$$C_c = \frac{C_1A_1 + C_2A_2 + \cdots}{A_1 + A_2 + \cdots}$$

Q = peak storm water runoff rate ($ft^3/s$)
$C_f$ = runoff coefficient adjustment factor
C = runoff coefficient
i = rainfall intensity (in./h)
A = drainage area (acres)

| ***Runoff Coefficient Adjustment Factor*** | |
|---|---|
| ***Return Period*** | ***Cf*** |
| ***1, 2, 5, 10*** | ***1.0*** |
| ***25*** | ***1.1*** |
| ***50*** | ***1.2*** |
| ***100*** | ***1.25*** |

| Rational Method Runoff Coefficients | |
|---|---|
| Categorized by Surface | |
| Forested | 0.059—0.2 |
| Asphalt | 0.7—0.95 |
| Brick | 0.7—0.85 |
| Concrete | 0.8—0.95 |
| Shingle roof | 0.75—0.95 |
| Lawns, well drained (sandy soil) | |
| Up to 2% slope | 0.05—0.1 |
| 2% to 7% slope | 0.10—0.15 |
| Over 7% slope | 0.15—0.2 |
| Lawns, poor drainage (clay soil) | |
| Up to 2% slope | 0.13—0.17 |
| 2% to 7% slope | 0.18—0.22 |
| Over 7% slope | 0.25—0.35 |
| Driveways, | 0.75—0.85 |
| Categorized by Use | |
| Farmland | 0.05—0.3 |
| Pasture | 0.05—0.3 |
| Unimproved | 0.1—0.3 |
| Parks | 0.1—0.25 |
| Cemeteries | 0.1—0.25 |
| Railroad yard | 0.2—0.40 |
| Playgrounds | 0.2—0.35 |
| Business Districts | |
| Neighborhood | 0.5—0.7 |
| City (downtown) | 0.7—0.95 |
| Residential | |
| Single-family | 0.3—0.5 |
| Multi-plexes, | 0.4—0.6 |
| Multi-plexes, | 0.6—0.75 |
| Suburban | 0.25—0.4 |
| Apartments, | 0.5—0.7 |
| Industrial | |
| Light | 0.5—0.8 |
| Heavy | 0.6—0.9 |

# Water Supply

### Hazen-Williams Formula

$$h_f = \frac{10.44LQ^{1.85}}{C^{1.85}d^{4.8655}}$$

$h_f$ = head loss due to friction (ft of $H_2O$)
L = length of pipe (ft)
Q = water flow rate (gpm)
C = Hazen-Williams constant
d = diameter of pipe (in.)

### Dynamic Head

dynamic head = static head – head loss

## Hazen-Williams Constants

| Pipe Material | Typical Range | Clean, New Pipe | Typical Design Value |
|---|---|---|---|
| Cast Iron and Wrought Iron | 80 - 150 | 130 | 100 |
| Copper, Glass or Brass | 120 - 150 | 140 | 130 |
| Cement lined Steel or Iron | | 150 | 140 |
| Plastic PVC or ABS | 120 - 150 | 140 | 130 |
| Steel, welded and seamless or interior riveted | 80-150 | 140 | 100 |

## Equivalent Length of (Generic) Fittings

| Screwed Fittings | | Pipe Size | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1/4 | 3/8 | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 | 4 |
| Elbows | Regular 90 degree | 2.3 | 3.1 | 3.6 | 4.4 | 5.2 | 6.6 | 7.4 | 8.5 | 9.3 | 11.0 | 13.0 |
| | Long radius 90 degree | 1.5 | 2.0 | 2.2 | 2.3 | 2.7 | 3.2 | 3.4 | 3.6 | 3.6 | 4.0 | 4.6 |
| | Regular 45 degree | 0.3 | 0.5 | 0.7 | 0.9 | 1.3 | 1.7 | 2.1 | 2.7 | 3.2 | 4.0 | 5.5 |
| Tees | Line Flow | 0.8 | 1.2 | 1.7 | 2.4 | 3.2 | 4.6 | 5.6 | 7.7 | 9.3 | 12.0 | 17.0 |
| | Branch Flow | 2.4 | 3.5 | 4.2 | 5.3 | 6.6 | 8.7 | 9.9 | 12.0 | 13.0 | 17.0 | 21.0 |
| Return Bends | Regular 180 degree | 2.3 | 3.1 | 3.6 | 4.4 | 5.2 | 6.6 | 7.4 | 8.5 | 9.3 | 11.0 | 13.0 |
| Valves | Globe | 21.0 | 22.0 | 22.0 | 24.0 | 29.0 | 37.0 | 42.0 | 54.0 | 62.0 | 79.0 | 110.0 |
| | Gate | 0.3 | 0.5 | 0.6 | 0.7 | 0.8 | 1.1 | 1.2 | 1.5 | 1.7 | 1.9 | 2.5 |
| | Angle | 12.8 | 15.0 | 15.0 | 15.0 | 17.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 |
| | Swing Check | 7.2 | 7.3 | 8.0 | 8.8 | 11.0 | 13.0 | 15.0 | 19.0 | 22.0 | 27.0 | 38.0 |
| Strainer | | | 4.6 | 5.0 | 6.6 | 7.7 | 18.0 | 20.0 | 27.0 | 29.0 | 34.0 | 42.0 |

| Flanged Fittings | | Pipe Size | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
| Elbows | Regular 90 degree | 0.9 | 1.2 | 1.6 | 2.1 | 2.4 | 3.1 | 3.6 | 4.4 | 5.9 | 7.3 | 8.9 | 12.0 | 14.0 | 17.0 | 18.0 | 21.0 | 23.0 |
| | Long radius 90 degree | 1.1 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 2.7 | 3.4 | 4.2 | 5.0 | 5.7 | 7.0 | 8.0 | 9.0 | 9.4 | 10.0 | 11.0 |
| | Regular 45 degree | 0.5 | 0.6 | 0.8 | 1.1 | 1.3 | 1.7 | 2.0 | 2.6 | 3.5 | 4.5 | 5.6 | 7.7 | 9.0 | 11.0 | 13.0 | 15.0 | 16.0 |
| Tees | Line Flow | 0.7 | 0.8 | 1.0 | 1.3 | 1.5 | 1.8 | 1.9 | 2.2 | 2.8 | 3.3 | 3.8 | 4.7 | 5.2 | 6.0 | 6.4 | 7.2 | 7.6 |
| | Branch Flow | 2.0 | 2.6 | 3.3 | 4.4 | 5.2 | 6.6 | 7.5 | 9.4 | 12.0 | 15.0 | 18.0 | 24.0 | 30.0 | 34.0 | 37.0 | 43.0 | 47.0 |
| Return Bends | Regular 180 degree | 0.9 | 1.2 | 1.6 | 2.1 | 2.4 | 3.1 | 3.6 | 4.4 | 5.9 | 7.3 | 8.9 | 12.0 | 14.0 | 17.0 | 18.0 | 21.0 | 23.0 |
| | Long radius 180 degree | 1.1 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 2.9 | 3.4 | 4.2 | 5.0 | 5.7 | 7.0 | 8.0 | 9.0 | 9.4 | 10.0 | 11.0 |
| Valves | Globe | 38.0 | 40.0 | 45.0 | 54.0 | 59.0 | 70.0 | 77.0 | 94.0 | 120.0 | 150.0 | 190.0 | 260.0 | 310.0 | 390.0 | | | |
| | Gate | | | | | | 2.6 | 2.7 | 2.8 | 2.9 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| | Angle | 15.0 | 15.0 | 17.0 | 18.0 | 18.0 | 21.0 | 22.0 | 28.0 | 38.0 | 50.0 | 63.0 | 90.0 | 120.0 | 140.0 | 160.0 | 190.0 | 210.0 |
| | Swing Check | 3.8 | 5.3 | 7.2 | 10.0 | 12.0 | 17.0 | 21.0 | 27.0 | 38.0 | 50.0 | 63.0 | 90.0 | 120.0 | 140.0 | | | |

## 555 Timer Design Equations

$T = 0.693\,(R_A + 2R_B)C$

$f = \dfrac{1}{T}$

$\text{duty-cycle} = \dfrac{(R_A + R_B)}{(R_A + 2R_B)} \cdot 100\%$

T = period
*f* = frequency
$R_A$ = resistance A
$R_B$ = resistance B
C = capacitance

## Boolean Algebra

***Boolean Theorems***

$X \bullet 0 = 0$

$X \bullet 1 = X$

$X \bullet X = X$

$X \bullet \overline{X} = 0$

$X + 0 = X$

$X + 1 = 1$

$X + X = X$

$X + \overline{X} = 1$

$\overline{\overline{X}} = X$

***Commutative Law***

$X \bullet Y = Y \bullet X$

$X + Y = Y + X$

***Associative Law***

$X(YZ) = (XY)Z$

$X + (Y + Z) = (X + Y) + Z$

***Distributive Law***

$X(Y+Z) = XY + XZ$

$(X+Y)(W+Z) = XW+XZ+YW+YZ$

***Consensus Theorems***

$X + \overline{X}Y = X + Y$

$X + \overline{X}\,\overline{Y} = X + \overline{Y}$

$\overline{X} + XY = \overline{X} + Y$

$\overline{X} + X\overline{Y} = \overline{X} + \overline{Y}$

***DeMorgan's Theorems***

$\overline{XY} = \overline{X} + \overline{Y}$

$\overline{X+Y} = \overline{X} \bullet \overline{Y}$

## Speeds and Feeds

$N = \dfrac{CS\left(12\frac{in.}{ft}\right)}{\pi d}$

$f_m = f_t \cdot n_t \cdot N$

Plunge Rate = $\frac{1}{2} \cdot f_m$

N = spindle speed (rpm)
CS = cutting speed (in./min)
d = diameter (in.)
$f_m$ = feed rate (in./min)
$f_t$ = feed (in./tooth)
$n_t$ = number of teeth

# Aerospace Equations

## Forces of Flight

$C_D = \frac{2D}{A\rho v^2}$

$R_e = \frac{\rho v l}{\mu}$

$C_L = \frac{2L}{A\rho v^2}$

$M = Fd$

$C_L$ = coefficient of lift
$C_D$ = coefficient of drag
L = lift
D = drag
A = wing area
ρ = density
$R_e$ = Reynolds number
v = velocity
l = length of fluid travel
μ = fluid viscosity
F = force
m = mass
g = acceleration due to gravity
M = moment
d = moment arm (distance from datum perpendicular to F)

## Propulsion

$F_N = W(v_j - v_o)$

$I = F_{ave}\Delta t$

$F_{net} = F_{avg} - F_g$

$a = v_f \Delta t$

$F_N$ = net thrust
W = air mass flow
$v_o$ = flight velocity
$v_j$ = jet velocity
I = total impulse
$F_{ave}$ = average thrust force
Δt = change in time (thrust duration)
$F_{net}$ = net force
$F_{avg}$ = average force
$F_g$ = force of gravity
$v_f$ = final velocity
a = acceleration
Δt = change in time (thrust duration)

NOTE: $F_{ave}$ and $F_{avg}$ are easily confused.

## Energy

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

$U = \frac{-GMm}{R}$

$E = U + K = -\frac{GMm}{2R}$

K = kinetic energy
m =mass
v = velocity
U = gravitational potential energy
G = universal gravitation constant
M =mass of central body
m = mass of orbiting object
R = Distance center main body to center of orbiting object
E = Total Energy of an orbit

## Orbital Mechanics

$e = \sqrt{1 - \frac{b^2}{a^2}}$

$T = 2\pi \frac{a^{\frac{3}{2}}}{\sqrt{\mu}} = 2\pi \frac{a^{\frac{3}{2}}}{\sqrt{GM}}$

$F = \frac{GMm}{r^2}$

$e$ = eccentricity
b = semi-minor axis
a =semi-major axis
T = orbital period
a = semi-major axis
μ = gravitational parameter
F = force of gravity between two bodies
G = universal gravitation constant
M =mass of central body
m = mass of orbiting object
r = distance between center of two objects

## Bernoulli's Law

$\left(P_s + \frac{\rho v^2}{2}\right)_1 = \left(P_s + \frac{\rho v^2}{2}\right)_2$

$P_S$ = static pressure
v = velocity
ρ = density

## Atmosphere Parameters

$T = 15.04 - 0.00649h$

$p = 101.29 \left[\frac{(T + 273.1)}{288.08}\right]^{5.256}$

$\rho = \frac{p}{0.2869(T + 273.1)}$

T = temperature
h = height
p = pressure
ρ = density