1.0 Statistics

Mean

\[ \mu = \frac{\sum x_i}{N} \quad (1.1a) \]
\[ \bar{x} = \frac{\sum x_i}{n} \quad (1.1b) \]

\( \mu \) = population mean
\( \bar{x} \) = sample mean
\( \sum x_i \) = sum of all data values \( (x_1, x_2, x_3, \ldots) \)
\( N \) = size of population
\( n \) = size of sample

Median

Place data in ascending order.
If \( N \) is odd, median = central value
If \( N \) is even, median = mean of two central values
\( N \) = size of population

Mode

Place data in ascending order.
Mode = most frequently occurring value
(1.4)
If two values occur with maximum frequency the data set is **bimodal**.
If three or more values occur with maximum frequency the data set is **multi-modal**.

Standard Deviation

\[ \sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}} \quad (Population) \quad (1.5a) \]
\[ s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \quad (Sample) \quad (1.5b) \]

\( \sigma \) = population standard deviation
\( s \) = sample standard deviation
\( x_i \) = individual data value \( (x_1, x_2, x_3, \ldots) \)
\( \mu \) = population mean
\( \bar{x} \) = sample mean
\( N \) = size of population
\( n \) = size of sample

Range

\[ \text{Range} = x_{\text{max}} - x_{\text{min}} \quad (1.3) \]

\( x_{\text{max}} \) = maximum data value
\( x_{\text{min}} \) = minimum data value

2.0 Probability

Frequency

\[ f_x = \frac{n_x}{n} \quad (2.1) \]

\( f_x \) = relative frequency of outcome \( x \)
\( n_x \) = number of events with outcome \( x \)
\( n \) = total number of events

Binomial Probability

(order doesn’t matter)

\[ P_k = \frac{n!p^k(q^{n-k})}{k!(n-k)!} \quad (2.2) \]

\( P_k \) = 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

\[ P (A \text{ and } B \text{ and } C) = P_A P_B P_C \quad (2.3) \]

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

Mutually Exclusive Events

\[ P (A \text{ or } B) = P_A + P_B \quad (2.4) \]

\( P (A \text{ or } B) \) = probability of either mutually exclusive event \( A \) or \( B \) occurring in a trial
\( P_A \) = probability of event \( A \)

Conditional Probability

\[ P(A|D) = \frac{P(A)P(D|A)}{P(A)P(D|A) + P(\sim A)P(D|\sim A)} \quad (2.5) \]

\( P(A|D) \) = probability of event \( A \) given event \( D \)
\( P(A) \) = probability of event \( A \) occurring
\( P(\sim A) \) = probability of event \( A \) not occurring
\( P(D|\sim A) \) = probability of event \( D \) given event \( A \) did not occur
3.0 Plane Geometry

**Circle**
- Circumference = $2\pi r$ (3.1)
- Area = $\pi r^2$ (3.2)

**Parallelogram**
- Area = $bh$ (3.3)

**Triangle** (3.6)
- Area = $\frac{1}{2} bh$ (3.11)
- $a^2 = b^2 + c^2 - 2bc \cos \angle A$ (3.12)
- $b^2 = a^2 + c^2 - 2ac \cos \angle B$ (3.13)
- $c^2 = a^2 + b^2 - 2ab \cos \angle C$ (3.14)

**Regular Polygons**
- Area = $n \frac{s^2 f}{2} = \frac{ns^2}{4 \tan \left( \frac{180}{n} \right)}$ (3.15)
  - $n$ = number of sides

**Trapezoid** (3.16)
- Area = $\frac{1}{2}(a + b)h$

4.0 Solid Geometry

**Cube**
- Volume = $s^3$ (4.1)
- Surface Area = $6s^2$ (4.2)

**Rectangular Prism**
- Volume = $wdh$ (4.3)
- Surface Area = $2(wd + wh + dh)$ (4.4)

**Right Circular Cone**
- Volume = $\frac{\pi r^2 h}{3}$ (4.5)
- Total Surface Area = $\pi r^2 + \pi r \sqrt{r^2 + h^2}$ (4.6)

**Pyramid**
- Volume = $\frac{Ah}{3}$ (4.7)
  - $A$ = area of base

**Ellipse**
- Area = $\pi ab$ (3.8)

**Rectangle**
- Perimeter = $2a + 2b$ (3.9)
- Area = $ab$ (3.10)

**Ellipse**
- Area = $\pi ab$ (3.8)

**Regular Polygons**
- Area = $n \frac{s^2 f}{2} = \frac{ns^2}{4 \tan \left( \frac{180}{n} \right)}$ (3.15)
  - $n$ = number of sides

5.0 Constants

- $g = 9.8 \text{ m/s}^2 = 32.17 \text{ ft/s}^2$
- $G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg} \cdot \text{s}^2$
- $\pi = 3.14159$
### 6.0 Conversions

#### Mass/Weight (6.1)
- 1 kg = 2.205 lb
- 1 slug = 32.2 lb
- 1 ton = 2000 lb
- 1 lb = 16 oz

#### Length (6.2)
- 1 m = 3.28 ft
- 1 km = 0.621 mi
- 1 in. = 2.54 cm
- 1 mi = 5280 ft
- 1 yd = 3 ft

#### Time (6.3)
- 1 d = 24 h
- 1 h = 60 min
- 1 min = 60 s
- 1 yr = 365 d

#### Area (6.4)
- 1 acre = 4047 m²
- 1 m² = 16.13 sq ft

#### Volume (6.5)
- 1L = 0.264 gal
- 1 mL = 1 cm³ = 1 cc

#### Temperature Unit Equivalents (6.6)
- Δ K = Δ 1 °C
- Δ 1.8 °F
- Δ 1.8 °R

#### Power (6.9)
- 1 W = 3.412 Btu/h
- 1 hp = 0.7376 ft·lb/sec
- 1 kW·h = 3,600,000 J

#### Pressure (6.8)
- 1 atm = 1.01325 bar
- 1 psi = 2.31 ft of H₂O

#### Rotational Speed (6.11)
- 1 Hz = 2π rad/sec = 60 rpm

#### 7.0 Defined Units

#### Numbers Less Than One

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<th>Prefix</th>
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### 8.0 SI Prefixes

### 9.0 Equations

#### Mass and Weight
- m = VDₘ (9.1)
- W = mg (9.2)
- W = VDₘ (9.3)

#### Force (6.7)
- 1 N = 0.225 lb
- 1 kip = 1,000 lb

#### Temperature
- Tₖ = Tₙ + 273 (9.4)
- Tᵣ = Tᵣ + 460 (9.5)
- Tₜ = Tₜ + 32 (9.6a)
- Tₚ = Tₚ + 32 (9.6b)

#### Rotational Speed
- 1 Hz = 2π rad/sec = 60 rpm

#### Equations of Static Equilibrium

#### Temperature
- Tₖ = temperature in Kelvin
- Tₙ = temperature in Celsius
- Tᵣ = temperature in Rankin
- Tₚ = temperature in Fahrenheit

#### Force and Moment
- F = ma (9.7a)
- M = Fd (9.7b)
- F = force
- m = mass
- a = acceleration
- M = moment
- dₘ = perpendicular distance

#### Equations of Static Equilibrium

- 2Fₓ = 0
- 2Fᵧ = 0
- 2Mₚ = 0 (9.8)
# 9.0 Equations (Continued)

## Energy: Work

\[ W = F \cdot d \quad (9.9) \]

- \( W \) = work
- \( F \) = force parallel to direction of displacement
- \( d \) = displacement

## Power

\[ P = \frac{E}{t} = \frac{W}{t} \quad (9.10) \]

- \( P \) = power
- \( E \) = energy
- \( W \) = work
- \( t \) = time
- \( \tau \) = torque
- \( \omega \) = angular velocity

## Efficiency

\[ \text{Efficiency} \% = \frac{P_{\text{out}}}{P_{\text{in}}} \cdot 100\% \quad (9.12) \]

- \( P_{\text{out}} \) = useful power output
- \( P_{\text{in}} \) = total power input

## Energy: Potential

\[ U = mgh \quad (9.13) \]

- \( U \) = potential energy
- \( m \) = mass
- \( g \) = acceleration due to gravity
- \( h \) = height

## Energy: Kinetic

\[ K = \frac{1}{2} mv^2 \quad (9.14) \]

- \( K \) = kinetic energy
- \( m \) = mass
- \( v \) = velocity

## Energy: Thermal

\[ \Delta Q = mc\Delta T \quad (9.15) \]

- \( \Delta Q \) = change in thermal energy
- \( m \) = mass
- \( c \) = specific heat
- \( \Delta T \) = change in temperature

## Fluid Mechanics

\[ p = \frac{F}{A} \quad (9.16) \]

- \( p \) = absolute pressure
- \( F \) = force
- \( A \) = area

\[ V_1 = \frac{V_2}{T_1} \quad (9.17) \]

- \( V_1 \) = initial volume
- \( V_2 \) = final volume
- \( T_1 \) = initial temperature
- \( T_2 \) = final temperature

\[ \rho \cdot V_1 = \rho \cdot V_2 \quad (9.18) \]

- \( \rho \) = density

\[ Q = Av \quad (9.20) \]

- \( Q \) = rate of heat transfer
- \( A \) = area
- \( v \) = flow velocity

\[ P = Qp \quad (9.22) \]

- \( P \) = power
- \( Q \) = rate of heat transfer

\[ 1 \quad (9.23) \]

- \( v \) = flow velocity
- \( P \) = power

\[ \frac{\rho_1 \cdot V_1 + \rho_2 \cdot V_2}{\rho_1} \quad (9.21) \]

- \( \rho_1 \) = density of fluid 1
- \( V_1 \) = volume of fluid 1
- \( \rho_2 \) = density of fluid 2
- \( V_2 \) = volume of fluid 2

## Thermodynamics

\[ P = Q' = A\rho\Delta T \quad (9.38) \]

- \( P \) = power
- \( Q' \) = rate of heat transfer
- \( A \) = area
- \( \rho \) = thermal conductivity
- \( \Delta T \) = change in temperature

\[ U = \frac{\rho}{R} \quad (9.40) \]

- \( U \) = coefficient of heat conductivity
- \( R \) = resistance

\[ P = \frac{kA\Delta T}{L} \quad (9.41) \]

- \( P \) = power
- \( k \) = thermal conductivity
- \( A \) = area
- \( \Delta T \) = change in temperature
- \( L \) = thickness

\[ P_{\text{net}} = \sigma\varepsilon(\varepsilon_2T_2^4 - \varepsilon_1T_1^4) \quad (9.43) \]

- \( \sigma \) = Stefan-Boltzmann constant
- \( \varepsilon \) = emissivity
- \( \varepsilon_1, \varepsilon_2 \) = emissivities
- \( T_1, T_2 \) = temperature at time 1, time 2

## Electricity

### Ohm’s Law

\[ V = IR \quad (9.32) \]

- \( V \) = voltage
- \( I \) = current
- \( R \) = resistance

\[ P = IV \quad (9.33) \]

- \( P \) = power

\[ R_1 (\text{series}) = R_1 + R_2 + \cdots + R_n \quad (9.34) \]

\[ R_{\text{f}} (\text{parallel}) = \frac{1}{R_1 + \frac{1}{R_2} + \cdots + \frac{1}{R_n}} \quad (9.35) \]

### Kirchhoff’s Current Law

\[ I_1 = I_2 + I_3 + \cdots + I_n \quad (9.36) \]

### Kirchhoff’s Voltage Law

\[ V_T = V_1 + V_2 + \cdots + V_n \quad (9.37) \]

- \( V_T \) = total voltage
- \( I_1, I_2, \ldots, I_n \) = currents
- \( V_1, V_2, \ldots, V_n \) = voltages

\[ \tau = \omega \quad (9.42) \]

- \( \tau \) = torque
- \( \omega \) = angular velocity

\[ \text{efficiency} \% = \frac{1}{100\%} \quad (9.44) \]

- \( \text{efficiency} \% \) = useful power output
- \( \text{in} \) = total power input

\[ v = \text{flow velocity} \]

- \( v \) = flow velocity

\[ T = \text{absolute temperature} \]

- \( T \) = absolute temperature
10.0 Section Properties

**Moment of Inertia**

\[ I_{xx} = \frac{bh^3}{12} \]  \hspace{1cm} (10.1)

\( I_{xx} \) = moment of inertia of a rectangular section about x axis

**Complex Shapes Centroid**

\[ \bar{x} = \frac{\sum x_i A_i}{\sum A_i} \quad \text{and} \quad \bar{y} = \frac{\sum y_i A_i}{\sum A_i} \]  \hspace{1cm} (10.2)

\( \bar{x} \) = 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**

\( \bar{x} = \frac{b}{2} \quad \text{and} \quad \bar{y} = \frac{h}{2} \)  \hspace{1cm} (10.3)

**Right Triangle Centroid**

\( \bar{x} = \frac{b}{3} \quad \text{and} \quad \bar{y} = \frac{h}{3} \)  \hspace{1cm} (10.4)

**Semi-circle Centroid**

\( \bar{x} = r \quad \text{and} \quad \bar{y} = \frac{4r}{3\pi} \)  \hspace{1cm} (10.5)

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

11.0 Material

**Stress (axial)**

\[ \sigma = \frac{F}{A} \]  \hspace{1cm} (11.1)

\( \sigma \) = stress
\( F \) = axial force
\( A \) = cross-sectional area

**Strain (axial)**

\[ \varepsilon = \frac{\delta}{L_0} \]  \hspace{1cm} (11.2)

\( \varepsilon \) = strain
\( L_0 \) = original length
\( \delta \) = change in length

**Modulus of Elasticity**

\[ E = \frac{\sigma}{\varepsilon} \]  \hspace{1cm} (11.3)

\[ E = \frac{(F_2-F_1)L_0}{(\delta_2-\delta_1)A} \]  \hspace{1cm} (11.4)

\( E \) = modulus of elasticity
\( \sigma \) = stress
\( \varepsilon \) = strain
\( A \) = cross-sectional area
\( F \) = axial force
\( \delta \) = deformation

12.0 Structural Analysis

**Beam Formulas**

**Reaction**

\[ R_A = R_B = \frac{P}{2} \]  \hspace{1cm} (12.1)

**Moment**

\[ M_{max} = \frac{PL}{4} \]  \hspace{1cm} (at point of load) (12.2)

**Deflection**

\[ \Delta_{max} = \frac{PL^3}{384EI} \]  \hspace{1cm} (at point of load) (12.3)

**Reaction**

\[ R_A = R_B = \frac{0.5L}{2} \]  \hspace{1cm} (12.4)

**Moment**

\[ M_{max} = \frac{0.5L^2}{8} \]  \hspace{1cm} (at center) (12.5)

**Deflection**

\[ \Delta_{max} = \frac{0.5L^4}{384EI} \]  \hspace{1cm} (at center) (12.6)

**Reaction**

\[ R_A = R_B = P \]  \hspace{1cm} (12.7)

**Moment**

\[ M_{max} = Pa \]  \hspace{1cm} (12.8)

**Deflection**

\[ \Delta_{max} = \frac{Pa^2}{24EI} \left( 3L^2-4a^2 \right) \]  \hspace{1cm} (at center) (12.9)

**Reaction**

\[ R_A = \frac{Pb}{L} \quad \text{and} \quad R_B = \frac{Pb}{L} \]  \hspace{1cm} (12.10)

**Moment**

\[ M_{max} = \frac{Pab(L^2+2a^2)}{2L} \]  \hspace{1cm} (at Point of Load) (12.11)

**Deflection**

\[ \Delta_{max} = \frac{Pab(L^2+2a^2)}{27EI} \]  \hspace{1cm} (12.12)

\( x = \frac{a^2+b^2}{a+b} \) when \( a > b \)

\( E \) = modulus of elasticity
\( I \) = moment of inertia

**Deformation: Axial**

\[ \delta = \frac{FL_0}{AE} \]  \hspace{1cm} (12.13)

\( \delta \) = deformation
\( F \) = axial force
\( L_0 \) = original length
\( A \) = cross-sectional area
\( E \) = modulus of elasticity

**Truss Analysis**

\[ 2J = M + R \]  \hspace{1cm} (12.14)

\( J \) = number of joints
\( M \) = number of members
\( R \) = number of reaction forces
# 13.0 Simple Machines

## Mechanical Advantage (MA)

\[
IMA = \frac{D_E}{D_R} \quad (13.1) \quad AMA = \frac{F_R}{F_E} \quad (13.2)
\]

% Efficiency = \( \left( \frac{AMA}{IMA} \right) \times 100 \) \( (13.3) \)

IMA = ideal mechanical advantage
AMA = actual mechanical advantage
\( D_E \) = effort distance \( D_R \) = resistance distance
\( F_E \) = effort force \( F_R \) = resistance force

## Inclined Plane

\[
IMA = \frac{L}{H} \quad (13.6)
\]

## Wedge

\[
IMA = \frac{L}{H} \quad (13.7)
\]

## Screw

\[
IMA = \frac{C}{Pitch} \quad (13.8)
\]

Pitch = \( \frac{1}{TPI} \) \( (13.9) \)

\( C \) = circumference \( r \) = radius
Pitch = distance between threads
TPI = threads per inch

## Compound Machines

\[
MA_{\text{TOTAL}} = (MA_1)(MA_2)(MA_3) \ldots \quad (13.10)
\]

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

\[
GR = \frac{N_{\text{out}}}{N_{\text{in}}} = \frac{d_{\text{out}}}{d_{\text{in}}} = \frac{\omega_{\text{in}}}{\omega_{\text{out}}} = \frac{\tau_{\text{out}}}{\tau_{\text{in}}} \quad (13.11)
\]

\[
\frac{d_{\text{out}}}{d_{\text{in}}} = \frac{\omega_{\text{in}}}{\omega_{\text{out}}} = \frac{\tau_{\text{out}}}{\tau_{\text{in}}} \quad (\text{pulleys}) \quad (13.12)
\]

## Compound Gears

\[
GR_{\text{TOTAL}} = \left( \frac{B}{A} \right) \left( \frac{D}{C} \right) \quad (13.13)
\]

GR = gear ratio
\( \omega_{\text{in}} \) = angular velocity - driver
\( \omega_{\text{out}} \) = angular velocity - driven
\( N_{\text{in}} \) = number of teeth - driver
\( N_{\text{out}} \) = number of teeth - driven
\( d_{\text{in}} \) = diameter - driver
\( d_{\text{out}} \) = diameter - driven
\( \tau_{\text{in}} \) = torque - driver
\( \tau_{\text{out}} \) = torque - driven
### 14.0 Structural Design

#### Steel Beam Design: Shear

\[ V_a \leq \frac{V_n}{\Omega_v} \]  
(14.1)

\[ V_n = 0.6F_yA_w \]  
(14.2)

- \( V_a \): internal shear force
- \( V_n \): nominal shear strength
- \( \Omega_v \): 1.5 = factor of safety for shear
- \( F_y \): yield stress
- \( A_w \): area of web
- \( \frac{V_n}{\Omega_v} \): allowable shear strength

#### Steel Beam Design: Moment

\[ M_a \leq \frac{M_n}{\Omega_b} \]  
(14.3)

\[ M_n = F_Y Z_c \]  
(14.4)

- \( M_a \): internal bending moment
- \( M_n \): nominal moment strength
- \( \Omega_b \): 1.67 = factor of safety for bending moment
- \( F_Y \): yield stress
- \( Z_c \): plastic section modulus about neutral axis
- \( \frac{M_n}{\Omega_b} \): allowable bending strength

### 15.0 Storm Water Runoff

#### Storm Water Drainage

\[ Q = C_c C_i A \]  
(15.1)

\[ C_c = \frac{C_i A_1 + C_2 A_2 + \ldots}{A_1 + A_2 + \ldots} \]  
(15.2)

- \( Q \): peak storm water runoff rate (ft³/s)
- \( C_c \): runoff coefficient adjustment factor
- \( C_i \): runoff coefficient
- \( i \): rainfall intensity (in./h)
- \( A \): drainage area (acres)

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#### 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): 0.05—0.1
- Up to 2% slope: 0.10—0.15
- Over 7% slope: 0.15—0.2
- Lawns, poor drainage (clay soil): 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:
  - Light: 0.5—0.8
  - Heavy: 0.6—0.9

### 16.0 Water Supply

#### Hazen-Williams Formula

\[ h_r = \frac{10.44 L Q^{1.85}}{C_i^{1.85} q^{0.865}} \]  
(16.1)

- \( h_r \): head loss due to friction (ft of H₂O)
- \( L \): length of pipe (ft)
- \( Q \): water flow rate (gpm)
- \( C_i \): Hazen-Williams constant

#### Dynamic Head

\( h_r = \frac{V^2}{2g} \)  
(16.2)

- \( V \): velocity (ft/s)
- \( g \): gravitational acceleration (ft/s²)

### 17.0 Heat Loss/Gain

#### Heat Loss/Gain

\[ Q' = AU\Delta T \]  
(17.1)

\[ U = \frac{1}{R} \]  
(17.2)

- \( Q' \): thermal energy
- \( A \): area of thermal conductivity
- \( U \): coefficient of heat conductivity (U-factor)
- \( \Delta T \): change in temperature
- \( R \): resistance to heat flow (R-value)
### 18.0 Hazen-Williams Constants

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Typical Range</th>
<th>Clean, New Pipe</th>
<th>Typical Design Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron and Wrought Iron</td>
<td>80 - 150</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>Copper, Glass or Brass</td>
<td>120 - 150</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>Cement lined Steel or Iron</td>
<td>150</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Plastic PVC or ABS</td>
<td>120 - 150</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>Steel, welded and seamless or interior riveted</td>
<td>80-150</td>
<td>140</td>
<td>100</td>
</tr>
</tbody>
</table>

### 19.0 Equivalent Length of (Generic) Fittings

#### Screwed Fittings

<table>
<thead>
<tr>
<th>Elbows</th>
<th>1/4</th>
<th>3/8</th>
<th>1/2</th>
<th>3/4</th>
<th>1</th>
<th>1 ¼</th>
<th>1 ½</th>
<th>2</th>
<th>2 ½</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular 90 degree</td>
<td>2.3</td>
<td>3.1</td>
<td>3.6</td>
<td>4.4</td>
<td>5.2</td>
<td>6.6</td>
<td>7.4</td>
<td>8.5</td>
<td>9.3</td>
<td>11.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Long radius 90 degree</td>
<td>1.5</td>
<td>2.0</td>
<td>2.2</td>
<td>2.3</td>
<td>2.7</td>
<td>3.2</td>
<td>3.4</td>
<td>3.6</td>
<td>3.6</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Regular 45 degree</td>
<td>0.3</td>
<td>0.5</td>
<td>0.7</td>
<td>0.9</td>
<td>1.3</td>
<td>1.7</td>
<td>2.1</td>
<td>2.7</td>
<td>3.2</td>
<td>4.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>

| 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                        |     |     |     |     |     |     |     |     |     |     |     |
| 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

<table>
<thead>
<tr>
<th>Elbows</th>
<th>1/2</th>
<th>3/4</th>
<th>1</th>
<th>1 ¼</th>
<th>1 ½</th>
<th>2</th>
<th>2 ½</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular 90 degree</td>
<td>0.9</td>
<td>1.2</td>
<td>1.6</td>
<td>2.1</td>
<td>2.4</td>
<td>3.1</td>
<td>3.6</td>
<td>4.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Long radius 90</td>
<td>1.1</td>
<td>1.3</td>
<td>1.6</td>
<td>2.0</td>
<td>2.3</td>
<td>2.7</td>
<td>2.7</td>
<td>3.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Regular 45 degree</td>
<td>0.5</td>
<td>0.6</td>
<td>0.8</td>
<td>1.1</td>
<td>1.3</td>
<td>1.7</td>
<td>2.0</td>
<td>2.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

| 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 |
| Branch Flow                  | 2.0 | 2.6 | 3.3 | 4.4 | 5.2 | 6.6 | 7.5 | 9.4 | 12.0| 15.0| 18.0|

| Return                        |     |     |     |     |     |     |     |     |     |     |     |
| 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 |

| Return Bends                 |     |     |     |     |     |     |     |     |     |     |     |
| Long radius 180              | 1.1 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 2.9 | 3.4 | 4.2 | 5.7 | 7.0 |

| Valves                        |     |     |     |     |     |     |     |     |     |     |     |
| Globe                        | 38.0| 40.0| 45.0| 54.0| 59.0| 70.0| 77.0| 94.0| 120.0|150.0|190.0|
| Gate                         | 2.6 | 2.7 | 2.8 | 2.9 | 3.1 | 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| 285.0|38.0 |50.0 |63.0 |
| Swing Check                  | 3.8 | 5.3 | 7.2 | 10.0| 12.0| 17.0| 21.0| 27.0| 38.0| 50.0 |63.0 |

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21.A Boolean Algebra

**Boolean Theorems**

- $X \cdot 0 = 0$ (21.1)
- $X \cdot 1 = X$ (21.2)
- $X \cdot X = X$ (21.3)
- $X \cdot \bar{X} = 0$ (21.4)
- $X + 0 = X$ (21.5)
- $X + 1 = 1$ (21.6)
- $X + X = X$ (21.7)
- $X + \bar{X} = 1$ (21.8)

**Consensus Theorems**

- $X + XY = X + Y$ (21.16)
- $X + \bar{Y} = X + \bar{Y}$ (21.17)
- $X + XY = X + Y$ (21.18)
- $X + XY = X + \bar{Y}$ (21.19)

**DeMorgan's Theorems**

- $XY = \bar{X} \cdot \bar{Y}$ (21.20)
- $X + Y = \bar{X} \cdot \bar{Y}$ (21.21)

**Commutative Law**

- $X \cdot Y = Y \cdot X$ (21.10)
- $X + Y = Y + X$ (21.11)

**Associative Law**

- $X(YZ) = (XY)Z$ (21.12)
- $X + (Y + Z) = (X + Y) + Z$ (21.13)

**Distributive Law**

- $X(Y+Z) = XY + XZ$ (21.14)
- $(X+Y)(W+Z) = XW+XZ+YW+YZ$ (21.15)


<table>
<thead>
<tr>
<th>1st Band</th>
<th>2nd Band</th>
<th>Multiplier</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>.01</td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>Silver</td>
<td>.001</td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Gold</td>
<td>00.1</td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Black</td>
<td>0</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Gray</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>1000M</td>
<td>1000M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

22.0 Speeds and Feeds

- $N = \frac{CS(12n_{in})}{\pi d}$ (22.1)
- $f_m = f_r \cdot n_t \cdot N$ (22.2)

- Plunge Rate = $\frac{1}{2} \cdot f_m$
- $N$ = spindle speed (rpm)
- $CS$ = cutting speed (ft/min)
- $d$ = diameter (in.)
- $f_m$ = feed rate (in./min)
- $f_r$ = feed (in./tooth/rev)
- $n_t$ = number of teeth

23.A G&M Codes

- G00 = Rapid Traverse
- G01 = Straight Line Interpolation
- G02 = Circular Interpolation (clockwise)
- G03 = Circular Interpolation (c-clockwise)
- G04 = Dwell (wait)
- G05 = Pause for user intervention
- G06 = Tool change
- G20 = Inch programming units
- G21 = Millimeter programming units
- G80 = Canned cycle cancel
- G81 = Drilling cycle
- G82 = Drilling cycle with dwell
- G90 = Absolute Coordinates
- G91 = Relative Coordinates
- M00 = Pause
- M01 = Optional stop
- M02 = End of program
- M03 = Spindle on
- M04 = Spindle off
- M05 = Tool change
- M08 = Accessory # 1 on
- M09 = Accessory # 1 off
- M10 = Accessory # 2 on
- M11 = Accessory # 2 off
- M30 = Program end and reset
- M47 = Rewind
### 24.0 Aerospace

#### Forces of Flight

- **C_D** = \( \frac{2D}{Apv^2} \) \hspace{1cm} (24.1)
- **R_e** = \( \frac{pvl}{\mu} \) \hspace{1cm} (24.2)
- **C_L** = \( \frac{2L}{Apv^2} \) \hspace{1cm} (24.3)
- **M** = \( Fd \) \hspace{1cm} (24.4)

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

#### Bernoulli’s Law

\[
\left( P_s + \frac{\rho v^2}{2} \right)_1 = \left( P_s + \frac{\rho v^2}{2} \right)_2 \hspace{1cm} (24.16)
\]

- \( P_s \) = static pressure
- \( v \) = velocity
- \( \rho \) = density

#### Propulsion

- \( F_N = W(v_f - v_o) \) \hspace{1cm} (24.5)
- \( I = F_{ave} \Delta t \) \hspace{1cm} (24.6)
- \( F_{net} = F_{avg} - F_g \) \hspace{1cm} (24.7)
- \( a = \frac{\nu_f}{\Delta t} \) \hspace{1cm} (24.8)

- \( F_N \) = net thrust
- \( W \) = air mass flow
- \( v_o \) = flight velocity
- \( v_f \) = jet velocity
- \( I \) = total impulse
- \( \Delta t \) = change in time
- \( F_{ave} \) = average thrust force
- \( F_{net} \) = net force
- \( F_{avg} \) = average force
- \( F_g \) = force of gravity
- \( \nu_f \) = final velocity
- \( a \) = acceleration
- \( \Delta t \) = change in time

**NOTE:** \( F_{ave} \) and \( F_{avg} \) are easily confused.

#### Energy

- \( K = \frac{1}{2}mv^2 \) \hspace{1cm} (24.9)
- \( U = -\frac{GMM}{R} \) \hspace{1cm} (24.10)
- \( E = U + K = -\frac{GMM}{2R} \) \hspace{1cm} (24.11)
- \( G = 6.67 \times 10^{-11} \frac{m^3}{kg \times s^2} \) \hspace{1cm} (24.12)

- \( K \) = 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
- \( M_{Earth} = 5.97 \times 10^{24} \) kg
- \( r_{Earth} = 6.378 \times 10^3 \) km

#### Orbital Mechanics

- \( e = \sqrt{1 - \frac{b^2}{a^2}} \) \hspace{1cm} (24.13)
- \( T = 2\pi \frac{a^3}{\sqrt{\mu}} = 2\pi \frac{a^3}{\sqrt{GM}} \) \hspace{1cm} (24.14)
- \( F = \frac{GMM}{r^2} \) \hspace{1cm} (24.15)

- \( e \) = eccentricity
- \( b \) = semi-minor axis
- \( a \) = semi-major axis
- \( T \) = orbital period
- \( \mu \) = 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

### 25.0 Environmental Sustainability

#### Transformation Efficiency

\[
\text{# of moles of } CO_2 \times \frac{\text{# of transformants/}\mu g \text{ of DNA}}{\text{# of moles of glucose produced in formula}} = \frac{\text{# of moles consumed in experiment}}{\text{# of moles of glucose produced in experiment}} \hspace{1cm} (25.3)
\]

#### Economic Growth

\[
\text{R}_I = \frac{\text{distance the substance travels}}{\text{distance the solvent travels}} \hspace{1cm} (25.5)
\]

- \( \text{GDP}_2 \) = GDP at recovery
- \( \text{GDP}_1 \) = GDP
- \( \text{volume plated} \) = (mL)
- \( \text{final volume at recovery} \)

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26.0 **USCS Soil Classification Chart**

**Visual Examination.** Is soil highly organic, coarse grained, or fine grained?

50% or more retained on the No. 200 sieve

<table>
<thead>
<tr>
<th>%G &gt; %S</th>
<th>%S &gt; %G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Grained</td>
<td>Run sieve analysis</td>
</tr>
</tbody>
</table>

More than 50% passes the No. 200 sieve

**Coarse Grained** Run sieve analysis

- **Gravel (G)**
  - Less than 5% pass No. 200 sieve
  - Between 5% and 12% pass No. 200 sieve
  - More than 12% pass No. 200 sieve
- **Sand (S)**
  - Less than 5% pass No. 200 sieve
  - Between 5% and 12% pass No. 200 sieve
  - More than 12% pass No. 200 sieve

**Fine grained** Run LL and PL on minus No. 40 sieve material

- **LL < 50**
  - Below line on Plasticity Chart or PI < 4
- **LL ≥ 50**
  - Limits plot in shaded area of Plasticity Chart
  - Above line on Plasticity Chart and PI > 7

**Highly Organic Soils (Pt)** Color, odor, very high moisture content, particles of plant life, fibrous.

- **ML** Inorganic
- **ML-CL** Organic
- **CL** Inorganic
- **CH** Organic

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