## Engineering Formula Sheet

### Probability

#### Binomial Probability (order doesn’t matter)

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

- \( P_k \) is 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

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

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

### Mutually Exclusive Events

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

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

### Conditional Probability

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

- \( P(A)\) = 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

### Statistics

#### Mean

\[ \mu = \frac{\sum x_i}{n} \]

- \( \mu \) = mean value
- \( \sum x_i \) = sum of all data values (\( x_1, x_2, x_3, \ldots \))
- \( n \) = number of data values

#### Standard Deviation

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

- \( \sigma \) = standard deviation
- \( x_i \) = individual data value (\( x_1, x_2, x_3, \ldots \))
- \( \mu \) = mean value
- \( n \) = number of data values

#### Frequency

\[ f_x = \frac{n_x}{n} \]

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

\[ P_x = \frac{f_x}{f_a} \]

- \( P_x \) = probability of outcome \( x \)
- \( f_a \) = frequency of all events

### 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

\[ \text{Range} = x_{\text{max}} - x_{\text{min}} \]

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

### Range

\[ \text{Range} = \text{xmax} - \text{xmin} \]

- \( \text{xmax} \) = maximum data value
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### Condition

\[ \mu = \frac{\sum x_i}{n} \]

- \( \mu \) = mean value
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- \( \sigma \) = standard deviation
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### Independent Events

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

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- \( P(D|A)\) = probability of event \( D \) given event \( A \) occurred
Plane Geometry

**Circle**
- Circumference = $2\pi r$
- Area = $\pi r^2$

**Parallelogram**
- Area = $bh$

**Triangle**
- Area = $\frac{1}{2} \cdot bh$
- $a^2 = b^2 + c^2 - 2bc \cdot \cos\angle A$
- $b^2 = a^2 + c^2 - 2ac \cdot \cos\angle B$
- $c^2 = a^2 + b^2 - 2ab \cdot \cos\angle C$

**Ellipse**
- Area = $\pi a b$

**Rectangle**
- Perimeter = $2a + 2b$
- Area = $ab$

**Regular Polygons**
- Area = $n \cdot s \left(\frac{1}{2}f\right)$

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

**Solid Geometry**

**Cube**
- Volume = $s^3$
- Surface Area = $6s^2$

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

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

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

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

**Cylinder**
- Volume = $\pi r^2 h$
- Surface Area = $2 \pi rh + 2 \pi r^2$

**Irregular Prism**
- Volume = $Ah$
- $A = \text{area of base}$

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

**Mass**
- 1 kg = 2.205 lbm
- 1 slug = 32.2 lbm
- 1 ton = 2000 lbm

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

**Area**
- 1 acre = 4047 m²
- = 43,560 ft²
- = 0.00156 mi²

**Force**
- 1 N = 0.225 lbf
- 1 kip = 1000 lbf

**Pressure**
- 1 atm = 1.01325 bar
- = 33.9 ft H₂O
- = 29.92 in. Hg
- = 760 mm Hg
- = 101,325 Pa
- = 14.7 psi
- 1 psi = 2.31 ft of H₂O

**Temperature**
- TK = TC + 273
- TR = TF + 460
- TF = \(\frac{5}{9}T_C + 32\)

**Volume**
- 1 L = 0.264 gal
- = 0.0353 ft³
- = 33.8 fl oz
- 1 mL = 1 cm³ = 1 cc

**Power**
- 1 W = 3.412 Btu/h
- = 0.00134 hp
- = 14.34 cal/min
- = 0.7376 ft·lb/s

**Energy**
- 1 J = 0.239 cal
- = 9.48 x 10⁻⁴ Btu
- = 0.7376 ft·lb
- 1 kW h = 3,600,000 J

**Time**
- 1 d = 24 h
- 1 h = 60 min
- 1 min = 60 s
- 1 yr = 365 d

**Units Equivalents**
- 1 K = 1 °C
- = 1.8 °F
- = 1.8 °R

**Angles**
- π = 180°
- 1° = \(\frac{\pi}{180}\)

**Defined Units**
- 1 J = 1 N·m
- 1 N = 1 kg·m/s²
- 1 Pa = 1 N/m²
- 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**

<table>
<thead>
<tr>
<th>Power of 10</th>
<th>Prefix</th>
<th>Abbreviation</th>
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</thead>
<tbody>
<tr>
<td>10⁻¹</td>
<td>deci-</td>
<td>d</td>
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<tr>
<td>10⁻²</td>
<td>centi-</td>
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<tr>
<td>10⁻³</td>
<td>milli-</td>
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<td>10⁻⁶</td>
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<td>10²</td>
<td>hecto-</td>
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<td>10⁶</td>
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**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

**Force**
- F = ma
- F = force
- m = mass
- a = acceleration

**Temperature**
- T_K = T_C + 273
- T_R = T_F + 460
- T_F = \(\frac{5}{9}T_C + 32\)

**Pressure**
- 1 atm = 1.01325 bar
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**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
Section Properties

**Moment of Inertia**

\[ I_{xx} = \frac{bh^3}{12} \]

\[ I_{xx} = \text{moment of inertia of a rectangular section about x-x axis} \]

**Complex Shapes Centroid**

\[ \bar{x} = \frac{\sum x_i A_i}{\sum A_i} \quad \text{and} \quad \bar{y} = \frac{\sum y_i A_i}{\sum A_i} \]

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

\[ \sigma = \frac{F}{A} \]

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

**Strain (axial)**

\[ \epsilon = \frac{\delta}{L_0} \]

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

**Modulus of Elasticity**

\[ E = \frac{\sigma}{\epsilon} \]

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

Structural Analysis

**Beam Formulas**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>( R_A = R_B = \frac{P}{2} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment</td>
<td>( M_{max} = \frac{PL}{4} ) (at point of load)</td>
</tr>
<tr>
<td>Deflection</td>
<td>( \Delta_{max} = \frac{PL^2}{48EI} ) (at point of load)</td>
</tr>
<tr>
<td>Reaction</td>
<td>( R_A = R_B = \frac{\omega L}{2} )</td>
</tr>
<tr>
<td>Moment</td>
<td>( M_{max} = \frac{\omega L^2}{8} ) (at center)</td>
</tr>
<tr>
<td>Deflection</td>
<td>( \Delta_{max} = \frac{\omega L^4}{16EI} ) (at center)</td>
</tr>
<tr>
<td>Reaction</td>
<td>( R_A = R_B = \frac{Pb}{L} ) and ( R_B = \frac{Pa}{L} )</td>
</tr>
<tr>
<td>Moment</td>
<td>( M_{max} = \frac{PbL}{2} ) (between loads)</td>
</tr>
<tr>
<td>Deflection</td>
<td>( \Delta_{max} = \frac{Pb(\epsilon+2b)}{24E} \left( \frac{3(\epsilon+2b)}{a} \right) ) (at center)</td>
</tr>
</tbody>
</table>

| Reaction | \( R_A = \frac{Pb}{L} \) (at Point of Load) |
| Moment   | \( M_{max} = \frac{Pb(\epsilon+2b)}{2} \) (at Point of Load) |
| Deflection | \( \Delta_{max} = \frac{Pb(\epsilon+2b)}{3} \) (when \( a > b \)) |

**Deformation: Axial**

\[ \delta = \frac{FL_0}{AE} \]

\( \delta \) = 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
Aerospace Equations

**Forces of Flight**

\[ F_D = \frac{2D}{Apv^2} \]
\[ R_e = \frac{pvL}{\mu} \]
\[ C_L = \frac{2L}{Apv^2} \]
\[ M = \frac{Fd}{m} \]

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

**Propulsion**

\[ F_N = W(v_j - v_o) \]
\[ I = F_{ave}\Delta t \]
\[ F_{net} = F_{avg} - F_g \]
\[ a = v_i\Delta t \]

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

**Energy**

\[ K = \frac{1}{2}mv^2 \]
\[ U = -\frac{GMm}{R} \]
\[ E = U + K = -\frac{GMm}{2R} \]

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

**Orbital Mechanics**

\[ e = \sqrt{1 - \frac{b^2}{a^2}} \]
\[ T = 2\pi\sqrt{\frac{a^3}{\mu}} = 2\pi\sqrt{\frac{a^3}{GM}} \]
\[ F = \frac{GMm}{r^2} \]

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

**Bernoulli’s Law**

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

\( P_s = \text{static pressure} \)
\( v = \text{velocity} \)
\( \rho = \text{density} \)

**Atmosphere Parameters**

\[ T = 15.04 - 0.00649h \]
\[ p = 101.29 \frac{(T + 273.1)}{288.08}^{6.256} \]
\[ \rho = \frac{p}{0.2869(T + 273.1)} \]

\( T = \text{temperature} \)
\( h = \text{height} \)
\( p = \text{pressure} \)
\( \rho = \text{density} \)