Important Flow and Lift Distribution Formulas PDF

Formulas
Examples
with Units

List of 24
Important Flow and Lift Distribution Formulas

1) Flow over Cylinder Formulas

1.1) Lifting Flow over Cylinder Formulas

1.1.1) 2-D Lift Coefficient for Cylinder Formula

Evaluate Formula

Formula

$$C_L = \frac{\Gamma}{R \cdot V_\infty}$$

Example with Units

$$1.2681 = \frac{0.7\,\mathrm{m^2/s}}{0.08\,\mathrm{m} \cdot 6.9\,\mathrm{m/s}}$$

1.1.2) Angular Position given Radial Velocity for Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\theta = \arccos\left(\frac{V_r}{\left(1 - \left(\frac{R}{r}\right)^2\right) \cdot V_\infty}\right)$$

Example with Units

$$0.9025\,\mathrm{rad} = \arccos\left(\frac{3.9\,\mathrm{m/s}}{\left(1 - \left(\frac{0.08\,\mathrm{m}}{0.27\,\mathrm{m}}\right)^2\right) \cdot 6.9\,\mathrm{m/s}}\right)$$

1.1.3) Angular Position of Stagnation Point for Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\theta_0 = \arcsin\left(-\frac{\Gamma_0}{4 \cdot \pi \cdot V_{s,\infty} \cdot R}\right)$$

Example with Units

$$-1.056\,\mathrm{rad} = \arcsin\left(-\frac{7\,\mathrm{m^2/s}}{4 \cdot 3.1416 \cdot 8\,\mathrm{m/s} \cdot 0.08\,\mathrm{m}}\right)$$

1.1.4) Freestream Velocity given 2-D Lift Coefficient for Lifting Flow Formula

Evaluate Formula

Formula

$$V_\infty = \frac{\Gamma}{R \cdot C_L}$$

Example with Units

$$7.2917\,\mathrm{m/s} = \frac{0.7\,\mathrm{m^2/s}}{0.08\,\mathrm{m} \cdot 1.2}$$

1.1.5) Location of Stagnation Point Outside Cylinder for Lifting Flow Formula

Evaluate Formula

Formula

$$r_0 = \frac{\Gamma_0}{4 \cdot \pi \cdot V_\infty} + \sqrt{\left(\frac{\Gamma_0}{4 \cdot \pi \cdot V_\infty}\right)^2 - R^2}$$

Example with Units

$$0.0916\,\mathrm{m} = \frac{7\,\mathrm{m^2/s}}{4 \cdot 3.1416 \cdot 6.9\,\mathrm{m/s}} + \sqrt{\left(\frac{7\,\mathrm{m^2/s}}{4 \cdot 3.1416 \cdot 6.9\,\mathrm{m/s}}\right)^2 - 0.08\,\mathrm{m}^2}$$

1.1.6) Radial Velocity for Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$V_r = \left(1 - \left(\frac{R}{r}\right)^2\right) \cdot V_\infty \cdot \cos(\theta)$$

Example with Units

$$3.9126\,\mathrm{m/s} = \left(1 - \left(\frac{0.08\,\mathrm{m}}{0.27\,\mathrm{m}}\right)^2\right) \cdot 6.9\,\mathrm{m/s} \cdot \cos(0.9\,\mathrm{rad})$$

1.1.7) Radius of Cylinder for Lifting Flow Formula

Evaluate Formula

Formula

$$R = \frac{\Gamma}{C_L \cdot V_\infty}$$

Example with Units

$$0.0845\,\mathrm{m} = \frac{0.7\,\mathrm{m^2/s}}{1.2 \cdot 6.9\,\mathrm{m/s}}$$

1.1.8) Stream Function for Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\psi = V_\infty \cdot r \cdot \sin(\theta) \cdot \left(1 - \left(\frac{R}{r}\right)^2\right) + \frac{\Gamma}{2 \cdot \pi} \cdot \ln\left(\frac{r}{R}\right)$$

Example with Units

$$1.4667\,\mathrm{m^2/s} = 6.9\,\mathrm{m/s} \cdot 0.27\,\mathrm{m} \cdot \sin(0.9\,\mathrm{rad}) \cdot \left(1 - \left(\frac{0.08\,\mathrm{m}}{0.27\,\mathrm{m}}\right)^2\right) + \frac{0.7\,\mathrm{m^2/s}}{2 \cdot 3.1416} \cdot \ln\left(\frac{0.27\,\mathrm{m}}{0.08\,\mathrm{m}}\right)$$

1.1.9) Surface Pressure Coefficient for Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$C_p = 1 - \left(\left(2 \cdot \sin(\theta) \right)^2 + \frac{2 \cdot \Gamma \cdot \sin(\theta)}{\pi \cdot R \cdot V_\infty} + \left(\frac{\Gamma}{2 \cdot \pi \cdot R \cdot V_\infty} \right)^2 \right)$$

Example with Units

$$-2.1275 = 1 - \left(\left(2 \cdot \sin(0.9\,\text{rad}) \right)^2 + \frac{2 \cdot 0.7\,\text{m}^2/\text{s} \cdot \sin(0.9\,\text{rad})}{3.1416 \cdot 0.08\,\text{m} \cdot 6.9\,\text{m/s}} + \left(\frac{0.7\,\text{m}^2/\text{s}}{2 \cdot 3.1416 \cdot 0.08\,\text{m} \cdot 6.9\,\text{m/s}} \right)^2 \right)$$

1.1.10) Tangential Velocity for Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$V_\theta = -\left(1 + \left(\frac{R}{r} \right)^2 \right) \cdot V_\infty \cdot \sin(\theta) - \frac{\Gamma}{2 \cdot \pi \cdot r}$$

Example with Units

$$-6.2921\,\text{m/s} = -\left(1 + \left(\frac{0.08\,\text{m}}{0.27\,\text{m}} \right)^2 \right) \cdot 6.9\,\text{m/s} \cdot \sin(0.9\,\text{rad}) - \frac{0.7\,\text{m}^2/\text{s}}{2 \cdot 3.1416 \cdot 0.27\,\text{m}}$$

1.2) Nonlifting Flow over Cylinder Formulas

1.2.1) Angular Position given Pressure Coefficient for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\theta = arsin\left(\frac{\sqrt{1 - (C_p)}}{2} \right)$$

Example with Units

$$1.0835\,\text{rad} = arsin\left(\frac{\sqrt{1 - (-2.123)}}{2} \right)$$

1.2.2) Angular Position given Radial Velocity for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\theta = \arccos\left(\frac{V_r}{\left(1 - \left(\frac{R}{r} \right)^2 \right) \cdot V_\infty} \right)$$

Example with Units

$$0.9025\,\text{rad} = \arccos\left(\frac{3.9\,\text{m/s}}{\left(1 - \left(\frac{0.08\,\text{m}}{0.27\,\text{m}} \right)^2 \right) \cdot 6.9\,\text{m/s}} \right)$$

1.2.3) Angular Position given Tangential Velocity for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\theta = -\arcsin\left(\frac{V_\theta}{\left(1+\frac{R^2}{r^2}\right)\cdot V_\infty}\right)$$

Example with Units

$$0.9936\,\text{rad} = -\arcsin\left(\frac{-6.29\,\text{m/s}}{\left(1+\frac{0.08\,\text{m}^2}{0.27\,\text{m}^2}\right)\cdot 6.9\,\text{m/s}}\right)$$

1.2.4) Doublet Strength given Radius of Cylinder for Non-Lifting Flow Formula

Evaluate Formula

Formula

$$\kappa = R^2 \cdot 2 \cdot \pi \cdot V_\infty$$

Example with Units

$$0.2775\,\text{m}^3/\text{s} = 0.08\,\text{m}^2 \cdot 2 \cdot 3.1416 \cdot 6.9\,\text{m/s}$$

1.2.5) Freestream Velocity given Doublet Strength for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$V_\infty = \frac{\kappa}{R^2 \cdot 2 \cdot \pi}$$

Example with Units

$$5.471\,\text{m/s} = \frac{0.22\,\text{m}^3/\text{s}}{0.08\,\text{m}^2 \cdot 2 \cdot 3.1416}$$

1.2.6) Radial Velocity for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$V_r = \left(1-\left(\frac{R}{r}\right)^2\right)\cdot V_\infty \cdot \cos(\theta)$$

Example with Units

$$3.9126\,\text{m/s} = \left(1-\left(\frac{0.08\,\text{m}}{0.27\,\text{m}}\right)^2\right)\cdot 6.9\,\text{m/s} \cdot \cos(0.9\,\text{rad})$$

1.2.7) Radius of Cylinder for Non-Lifting Flow Formula

Evaluate Formula

Formula

$$R = \sqrt{\frac{\kappa}{2 \cdot \pi \cdot V_\infty}}$$

Example with Units

$$0.0712\,\text{m} = \sqrt{\frac{0.22\,\text{m}^3/\text{s}}{2 \cdot 3.1416 \cdot 6.9\,\text{m/s}}}$$

1.2.8) Stream Function for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$\psi = V_\infty \cdot r \cdot \sin(\theta) \cdot \left(1 - \left(\frac{R}{r}\right)^2\right)$$

Example with Units

$$1.3312\,\mathrm{m^2/s} = 6.9\,\mathrm{m/s} \cdot 0.27\,\mathrm{m} \cdot \sin(0.9\,\mathrm{rad}) \cdot \left(1 - \left(\frac{0.08\,\mathrm{m}}{0.27\,\mathrm{m}}\right)^2\right)$$

1.2.9) Surface Pressure Coefficient for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$C_p = 1 - 4 \cdot (\sin(\theta))^2$$

Example with Units

$$-1.4544 = 1 - 4 \cdot (\sin(0.9\,\mathrm{rad}))^2$$

1.2.10) Tangential Velocity for Non-Lifting Flow over Circular Cylinder Formula

Evaluate Formula

Formula

$$V_\theta = -\left(1 + \left(\frac{R}{r}\right)^2\right) \cdot V_\infty \cdot \sin(\theta)$$

Example with Units

$$-5.8795\,\mathrm{m/s} = -\left(1 + \left(\frac{0.08\,\mathrm{m}}{0.27\,\mathrm{m}}\right)^2\right) \cdot 6.9\,\mathrm{m/s} \cdot \sin(0.9\,\mathrm{rad})$$

2) Kutta-Joukowski Lift Theorem Formulas

2.1) Circulation by Kutta-Joukowski Theorem Formula

Evaluate Formula

Formula

$$\Gamma = \frac{L'}{\rho_\infty \cdot V_\infty}$$

Example with Units

$$0.698\,\mathrm{m^2/s} = \frac{5.9\,\mathrm{N/m}}{1.225\,\mathrm{kg/m^3} \cdot 6.9\,\mathrm{m/s}}$$

2.2) Freestream Density by Kutta-Joukowski Theorem Formula

Evaluate Formula

Formula

$$\rho_\infty = \frac{L'}{V_\infty \cdot \Gamma}$$

Example with Units

$$1.2215\,\mathrm{kg/m^3} = \frac{5.9\,\mathrm{N/m}}{6.9\,\mathrm{m/s} \cdot 0.7\,\mathrm{m^2/s}}$$

2.3) Freestream Velocity by Kutta-Joukowski Theorem Formula

Evaluate Formula

Formula

$$V_\infty = \frac{L'}{\rho_\infty \cdot \Gamma}$$

Example with Units

$$6.8805\,\mathrm{m/s} = \frac{5.9\,\mathrm{N/m}}{1.225\,\mathrm{kg/m^3} \cdot 0.7\,\mathrm{m^2/s}}$$

2.4) Lift Per Unit Span by Kutta-Joukowski Theorem Formula

Evaluate Formula

Formula

$$L' = \rho_{\infty} \cdot V_{\infty} \cdot \Gamma$$

Example with Units

$$5.9168\,\mathrm{N/m} = 1.225\,\mathrm{kg/m^3} \cdot 6.9\,\mathrm{m/s} \cdot 0.7\,\mathrm{m^2/s}$$

Variables used in list of Flow and Lift Distribution Formulas above

- C_L Lift Coefficient
- C_p Surface Pressure Coefficient
- **L'** Lift per Unit Span *(Newton per Meter)*
- **r** Radial Coordinate *(Meter)*
- **R** Cylinder Radius *(Meter)*
- r_0 Radial Coordinate of Stagnation Point *(Meter)*
- V_∞ Freestream Velocity *(Meter per Second)*
- V_r Radial Velocity *(Meter per Second)*
- $V_{s,\infty}$ Stagnation Freestream Velocity *(Meter per Second)*
- V_θ Tangential Velocity *(Meter per Second)*
- **Γ** Vortex Strength *(Square Meter per Second)*
- Γ_0 Stagnation Vortex Strength *(Square Meter per Second)*
- **θ** Polar Angle *(Radian)*
- θ_0 Polar Angle of Stagnation Point *(Radian)*
- **κ** Doublet Strength *(Cubic Meter per Second)*
- ρ_∞ Freestream Density *(Kilogram per Cubic Meter)*
- **ψ** Stream Function *(Square Meter per Second)*

Constants, Functions, Measurements used in list of Flow and Lift Distribution Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288 *Archimedes' constant*
- Functions: **arccos**, arccos(Number) *Arccosine function, is the inverse function of the cosine function.It is the function that takes a ratio as an input and returns the angle whose cosine is equal to that ratio.*
- Functions: **arsin**, arsin(Number) *Arcsine function, is a trigonometric function that takes a ratio of two sides of a right triangle and outputs the angle opposite the side with the given ratio.*
- Functions: **cos**, cos(Angle) *Cosine of an angle is the ratio of the side adjacent to the angle to the hypotenuse of the triangle.*
- Functions: **ln**, ln(Number) *The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.*
- Functions: **sin**, sin(Angle) *Sine is a trigonometric function that describes the ratio of the length of the opposite side of a right triangle to the length of the hypotenuse.*
- Functions: **sqrt**, sqrt(Number) *A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.*
- Measurement: **Length** in Meter (m) *Length Unit Conversion*
- Measurement: **Speed** in Meter per Second (m/s) *Speed Unit Conversion*
- Measurement: **Angle** in Radian (rad) *Angle Unit Conversion*
- Measurement: **Volumetric Flow Rate** in Cubic Meter per Second (m³/s) *Volumetric Flow Rate Unit Conversion*
- Measurement: **Surface Tension** in Newton per Meter (N/m) *Surface Tension Unit Conversion*

- Measurement: **Density** in Kilogram per Cubic Meter (kg/m³)
  Density Unit Conversion
- Measurement: **Velocity Potential** in Square Meter per Second (m²/s)
  Velocity Potential Unit Conversion

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