Important Three-Dimensional Incompressible Flow Formulas PDF

Formulas
Examples
with Units

List of 29
Important Three-Dimensional Incompressible Flow Formulas

1) 3D Elementry Flows Formulas

1.1) Doublet Strength for 3D Incompressible Flow Formula

Evaluate Formula

Formula

$$\mu = -\frac{4 \cdot \pi \cdot \phi \cdot r^2}{\cos(\theta)}$$

Example with Units

$$9463.1812\,\text{m}^3/\text{s} = -\frac{4 \cdot 3.1416 \cdot -75.72\,\text{m}^2/\text{s} \cdot 2.758\,\text{m}^2}{\cos(0.7\,\text{rad})}$$

1.2) Radial Coordinate for 3D Doublet Flow given Velocity Potential Formula

Evaluate Formula

Formula

$$r = \sqrt{\frac{\text{mod}us(\mu) \cdot \cos(\theta)}{4 \cdot \pi \cdot \text{mod}us(\phi_s)}}$$

Example with Units

$$8.485\,\text{m} = \sqrt{\frac{\text{mod}us(9463\,\text{m}^3/\text{s}) \cdot \cos(0.7\,\text{rad})}{4 \cdot 3.1416 \cdot \text{mod}us(-8\,\text{m}^2/\text{s})}}$$

1.3) Radial Coordinate for 3D Source Flow given Radial Velocity Formula

Evaluate Formula

Formula

$$r = \sqrt{\frac{\Lambda}{4 \cdot \pi \cdot V_r}}$$

Example with Units

$$2.757\,\text{m} = \sqrt{\frac{277\,\text{m}^2/\text{s}}{4 \cdot 3.1416 \cdot 2.9\,\text{m/s}}}$$

1.4) Radial Coordinate for 3D Source Flow given Velocity Potential Formula

Evaluate Formula

Formula

$$r = -\frac{\Lambda}{4 \cdot \pi \cdot \phi_s}$$

Example with Units

$$2.7554\,\text{m} = -\frac{277\,\text{m}^2/\text{s}}{4 \cdot 3.1416 \cdot -8\,\text{m}^2/\text{s}}$$

1.5) Radial Velocity for 3D Incompressible Source Flow Formula

Evaluate Formula

Formula

$$V_r = \frac{\Lambda}{4 \cdot \pi \cdot r^2}$$

Example with Units

$$2.8979\,\text{m/s} = \frac{277\,\text{m}^2/\text{s}}{4 \cdot 3.1416 \cdot 2.758\,\text{m}^2}$$

1.6) Source Strength for 3D Incompressible Source Flow given Radial Velocity Formula

Evaluate Formula

Formula

$$\Lambda = 4 \cdot \pi \cdot V_r \cdot r^2$$

Example with Units

$$277.202\,\text{m}^2/\text{s} = 4 \cdot 3.1416 \cdot 2.9\,\text{m/s} \cdot 2.758\,\text{m}^2$$

1.7) Source Strength for 3D Incompressible Source Flow given Velocity Potential Formula

Evaluate Formula

Formula

$$\Lambda = -4 \cdot \pi \cdot \phi_s \cdot r$$

Example with Units

$$277.2644\,\text{m}^2/\text{s} = -4 \cdot 3.1416 \cdot -8\,\text{m}^2/\text{s} \cdot 2.758\,\text{m}$$

1.8) Velocity Potential for 3D Incompressible Doublet Flow Formula

Evaluate Formula

Formula

$$\phi = -\frac{\mu \cdot \cos(\theta)}{4 \cdot \pi \cdot r^2}$$

Example with Units

$$-75.7185\,\text{m}^2/\text{s} = -\frac{9463\,\text{m}^3/\text{s} \cdot \cos(0.7\,\text{rad})}{4 \cdot 3.1416 \cdot 2.758\,\text{m}^2}$$

1.9) Velocity Potential for 3D Incompressible Source Flow Formula

Evaluate Formula

Formula

$$\phi_s = -\frac{\Lambda}{4 \cdot \pi \cdot r}$$

Example with Units

$$-7.9924\,\text{m}^2/\text{s} = -\frac{277\,\text{m}^2/\text{s}}{4 \cdot 3.1416 \cdot 2.758\,\text{m}}$$

2) Flow over Sphere Formulas

2.1) Pressure Coefficient Formulas

2.1.1) Polar Coordinate given Surface Pressure Coefficient Formula

Evaluate Formula

Formula

$$\theta = asin\left(\sqrt{\frac{4}{9} \cdot (1 - C_p)}\right)$$

Example with Units

$$0.7001\,\text{rad} = asin\left(\sqrt{\frac{4}{9} \cdot (1 - 0.066)}\right)$$

2.1.2) Surface Pressure Coefficient for Flow over Sphere Formula

Evaluate Formula

Formula

$$C_p = 1 - \frac{9}{4} \cdot (\sin(\theta))^2$$

Example with Units

$$0.0662 = 1 - \frac{9}{4} \cdot (\sin(0.7\,\text{rad}))^2$$

2.2) Radial Velocity Formulas

2.2.1) Doublet Strength given Radial Velocity Formula

Evaluate Formula

Formula

$$\mu = 2 \cdot \pi \cdot r^3 \cdot \left(V_\infty + \frac{V_r}{\cos(\theta)} \right)$$

Example with Units

$$9463.1664 \, \mathrm{m^3/s} = 2 \cdot 3.1416 \cdot 2.758 \, \mathrm{m}^3 \cdot \left(68 \, \mathrm{m/s} + \frac{2.9 \, \mathrm{m/s}}{\cos(0.7 \, \mathrm{rad})} \right)$$

2.2.2) Freestream Velocity given Radial Velocity Formula

Evaluate Formula

Formula

$$V_\infty = \frac{\mu}{2 \cdot \pi \cdot r^3} - \frac{V_r}{\cos(\theta)}$$

Example with Units

$$67.9987 \, \mathrm{m/s} = \frac{9463 \, \mathrm{m^3/s}}{2 \cdot 3.1416 \cdot 2.758 \, \mathrm{m}^3} - \frac{2.9 \, \mathrm{m/s}}{\cos(0.7 \, \mathrm{rad})}$$

2.2.3) Polar Coordinate given Radial Velocity Formula

Evaluate Formula

Formula

$$\theta = a\cos\left(\frac{V_r}{\frac{\mu}{2 \cdot \pi \cdot r^3} - V_\infty} \right)$$

Example with Units

$$0.6996 \, \mathrm{rad} = a\cos\left(\frac{2.9 \, \mathrm{m/s}}{\frac{9463 \, \mathrm{m^3/s}}{2 \cdot 3.1416 \cdot 2.758 \, \mathrm{m}^3} - 68 \, \mathrm{m/s}} \right)$$

2.2.4) Radial Coordinate given Radial Velocity Formula

Evaluate Formula

Formula

$$r = \left(\frac{\mu}{2 \cdot \pi \cdot \left(V_\infty + \frac{V_r}{\cos(\theta)} \right)} \right)^{\frac{1}{3}}$$

Example with Units

$$2.758 \, \mathrm{m} = \left(\frac{9463 \, \mathrm{m^3/s}}{2 \cdot 3.1416 \cdot \left(68 \, \mathrm{m/s} + \frac{2.9 \, \mathrm{m/s}}{\cos(0.7 \, \mathrm{rad})} \right)} \right)^{\frac{1}{3}}$$

2.2.5) Radial Velocity for Flow over Sphere Formula

Evaluate Formula

Formula

$$V_r = -\left(V_\infty - \frac{\mu}{2 \cdot \pi \cdot r^3} \right) \cdot \cos(\theta)$$

Example with Units

$$2.899 \, \mathrm{m/s} = -\left(68 \, \mathrm{m/s} - \frac{9463 \, \mathrm{m^3/s}}{2 \cdot 3.1416 \cdot 2.758 \, \mathrm{m}^3} \right) \cdot \cos(0.7 \, \mathrm{rad})$$

2.3) Stagnation Point Formulas

2.3.1) Doublet Strength given Radial Coordinate of Stagnation Point Formula

Evaluate Formula

Formula

$$\mu = 2 \cdot \pi \cdot V_\infty \cdot R_s^{\,3}$$

Example with Units

$$9469.8696\,\text{m³/s} = 2 \cdot 3.1416 \cdot 68\,\text{m/s} \cdot 2.809\,\text{m}^{\,3}$$

2.3.2) Freestream Velocity at Stagnation Point for Flow over Sphere Formula

Evaluate Formula

Formula

$$V_\infty = \frac{\mu}{2 \cdot \pi \cdot R_s^{\,3}}$$

Example with Units

$$67.9507\,\text{m/s} = \frac{9463\,\text{m³/s}}{2 \cdot 3.1416 \cdot 2.809\,\text{m}^{\,3}}$$

2.3.3) Radial Coordinate of Stagnation Point for Flow over Sphere Formula

Evaluate Formula

Formula

$$r = \left(\frac{\mu}{2 \cdot \pi \cdot V_\infty}\right)^{\frac{1}{3}}$$

Example with Units

$$2.8083\,\text{m} = \left(\frac{9463\,\text{m³/s}}{2 \cdot 3.1416 \cdot 68\,\text{m/s}}\right)^{\frac{1}{3}}$$

2.4) Surface Velocity Formulas

2.4.1) Freestream Velocity given Maximum Surface Velocity Formula

Evaluate Formula

Formula

$$V_\infty = \frac{2}{3} \cdot V_{s,max}$$

Example with Units

$$68\,\text{m/s} = \frac{2}{3} \cdot 102\,\text{m/s}$$

2.4.2) Freestream Velocity given Surface Velocity for Flow over Sphere Formula

Evaluate Formula

Formula

$$V_\infty = \frac{2}{3} \cdot \frac{V_\theta}{\sin(\theta)}$$

Example with Units

$$68.2999\,\text{m/s} = \frac{2}{3} \cdot \frac{66\,\text{m/s}}{\sin(0.7\,\text{rad})}$$

2.4.3) Maximum Surface Velocity for Flow over Sphere Formula

Evaluate Formula

Formula

$$V_{s,max} = \frac{3}{2} \cdot V_\infty$$

Example with Units

$$102\,\text{m/s} = \frac{3}{2} \cdot 68\,\text{m/s}$$

2.4.4) Polar Coordinate given Surface Velocity for Flow over Sphere Formula

Evaluate Formula

Formula

$$\theta = asin\left(\frac{2}{3} \cdot \frac{V_\theta}{V_\infty}\right)$$

Example with Units

$$0.7037\,\text{rad} = asin\left(\frac{2}{3} \cdot \frac{66\,\text{m/s}}{68\,\text{m/s}}\right)$$

2.4.5) Surface Velocity for Incompressible Flow over Sphere Formula

Evaluate Formula

Formula

$$V_\theta = \frac{3}{2} \cdot V_\infty \cdot \sin(\theta)$$

Example with Units

$$65.7102\,\text{m/s} = \frac{3}{2} \cdot 68\,\text{m/s} \cdot \sin(0.7\,\text{rad})$$

2.5) Tangential Velocity Formulas

2.5.1) Doublet Strength given Tangential Velocity Formula

Evaluate Formula

Formula

$$\mu = 4 \cdot \pi \cdot r^3 \cdot \left(\frac{V_\theta}{\sin(\theta)} - V_\infty \right)$$

Example with Units

$$9081.9661\,\text{m}^3/\text{s} = 4 \cdot 3.1416 \cdot 2.758\,\text{m}^3 \cdot \left(\frac{66\,\text{m/s}}{\sin(0.7\,\text{rad})} - 68\,\text{m/s} \right)$$

2.5.2) Freestream Velocity given Tangential Velocity Formula

Evaluate Formula

Formula

$$V_\infty = \frac{V_\theta}{\sin(\theta)} - \frac{\mu}{4 \cdot \pi \cdot r^3}$$

Example with Units

$$66.5547\,\text{m/s} = \frac{66\,\text{m/s}}{\sin(0.7\,\text{rad})} - \frac{9463\,\text{m}^3/\text{s}}{4 \cdot 3.1416 \cdot 2.758\,\text{m}^3}$$

2.5.3) Polar Coordinate given Tangential Velocity Formula

Evaluate Formula

Formula

$$\theta = asin\left(\frac{V_\theta}{V_\infty + \frac{\mu}{4 \cdot \pi \cdot r^3}} \right)$$

Example with Units

$$0.6883\,\text{rad} = asin\left(\frac{66\,\text{m/s}}{68\,\text{m/s} + \frac{9463\,\text{m}^3/\text{s}}{4 \cdot 3.1416 \cdot 2.758\,\text{m}^3}} \right)$$

2.5.4) Radial Coordinate given Tangential Velocity Formula

Evaluate Formula

Formula

$$r = \left(\frac{\mu}{4 \cdot \pi \cdot \left(\frac{V_\theta}{\sin(\theta)} - V_\infty \right)} \right)^{\frac{1}{3}}$$

Example with Units

$$2.796\,\text{m} = \left(\frac{9463\,\text{m}^3/\text{s}}{4 \cdot 3.1416 \cdot \left(\frac{66\,\text{m/s}}{\sin(0.7\,\text{rad})} - 68\,\text{m/s} \right)} \right)^{\frac{1}{3}}$$

2.5.5) Tangential Velocity for Flow over Sphere Formula

Evaluate Formula

Formula

$$V_\theta = \left(V_\infty + \frac{\mu}{4 \cdot \pi \cdot r^3} \right) \cdot \sin(\theta)$$

Example with Units

$$66.9311\,\mathrm{m/s} = \left(68\,\mathrm{m/s} + \frac{9463\,\mathrm{m^3/s}}{4 \cdot 3.1416 \cdot 2.758\,\mathrm{m}^3} \right) \cdot \sin(0.7\,\mathrm{rad})$$

Variables used in list of Three-Dimensional Incompressible Flow Formulas above

- C_p Pressure Coefficient
- **r** Radial Coordinate *(Meter)*
- R_s Radius of Sphere *(Meter)*
- V_∞ Freestream Velocity *(Meter per Second)*
- V_r Radial Velocity *(Meter per Second)*
- $V_{s,max}$ Maximum Surface Velocity *(Meter per Second)*
- V_θ Tangential Velocity *(Meter per Second)*
- **θ** Polar Angle *(Radian)*
- **Λ** Source Strength *(Square Meter per Second)*
- **μ** Doublet Strength *(Cubic Meter per Second)*
- **ϕ** Velocity Potential *(Square Meter per Second)*
- ϕ_s Source Velocity Potential *(Square Meter per Second)*

Constants, Functions, Measurements used in list of Three-Dimensional Incompressible Flow Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288
  Archimedes' constant
- Functions: **acos**, acos(Number)
  The inverse cosine 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: **asin**, asin(Number)
  The inverse sine 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: **modulus**, modulus
  Modulus of a number is the remainder when that number is divided by another number.
- 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 (m^3/s)
  Volumetric Flow Rate Unit Conversion
- Measurement: **Velocity Potential** in Square Meter per Second (m^2/s)
  Velocity Potential Unit Conversion

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