Hydraulic Radius

if a flow is turbulent or laminar. A flow is

- laminar if \( \text{Re} < 2300 \)
- transient for \( 2300 < \text{Re} < 4000 \)
- turbulent if \( \text{Re} > 4000 \)

- hydraulic diameter vs. equivalent diameter

Note that the velocity in the Reynolds equation is based on actual cross section area of duct or pipe.

The hydraulic diameter is used to calculate pressure loss in ducts or pipes.

Note! - the hydraulic diameter is not the same as the geometrical equivalent diameter of non-circular ducts or pipes.

**Hydraulic diameter can be calculated with the generic equation**

\[
d_h = 4 \frac{A}{p} \quad (1)
\]

where

- \( d_h \) = hydraulic diameter (m, ft)
- \( A \) = area section of the duct or pipe (m\(^2\), ft\(^2\))
- \( p \) = "wetted" perimeter of the duct or pipe (m, ft)

Note! - inches are commonly used in the Imperial unit system.

**Hydraulic Diameter of a Circular Tube or Duct**

\[
\begin{align*}
\text{engineeringtoolbox.com}
\end{align*}
\]

Based on equation (1) the hydraulic diameter of a circular duct can be expressed as:
\[ d_h = \frac{4 \pi r^2}{2 \pi r} \]
\[ = 2r \quad (2) \]

where

\[ r = \text{pipe or duct radius (m, ft)} \]

As we could expect the hydraulic diameter of a standard circular tube or duct is two times the radius.

**Hydraulic Diameter of a Circular Tube with an inside Circular Tube**

Based on equation (1) the hydraulic diameter of a circular duct or tube with an inside duct or tube can be expressed as

\[ d_h = \frac{4 \pi (r_o^2 - r_i^2)}{2 \pi r_o + 2 \pi r_i} \]
\[ = 2 (r_o - r_i) \quad (3) \]

where

\[ r_o = \text{inside radius of the outside tube (m, ft)} \]
\[ r_i = \text{outside radius of the inside tube (m, ft)} \]

**Hydraulic Diameter of Rectangular Tubes or Ducts**

Based on equation (1) the hydraulic diameter of a rectangular duct or pipe can be calculated as
\[ d_h = 4 \frac{a \cdot b}{(2(a + b))} \]
\[ = 2 \frac{a \cdot b}{(a + b)} \quad (4) \]

where

\[ a = \text{width/height of the duct (m, ft)} \]
\[ b = \text{height/width of the duct (m, ft)} \]

**Related Mobile Apps from The EngineeringToolBox**

- [Hydraulic Diameter App](#)
  - free apps for offline use on mobile devices.

**Rectangular to Circulate Duct/Tube Hydraulic Diameter Calculator**

The calculator below is based on formula (4) and can be used to calculate the hydraulic diameter of rectangular duct or tube. The formula is generic and any unit can be used.

**Equivalent diameter**

**Note!** The hydraulic diameter is not the same as the equivalent diameter. The equivalent diameter is the diameter of a circular duct or pipe that gives the same pressure loss as a rectangular duct or pipe area.
wetted perimeter and hydraulic diameter for geometric sections like

- rectangular channels
- trapezoidal channels
- triangular channels
- circular channels

![Rectangular Channel Diagram](image)

![Trapezoidal Channel Diagram](image)

![Triangular Channel Diagram](image)

![Circular Channel Diagram](image)
Rectangular Channel

Flow Area (partially full pipes) that usually exist in waste water

Flow area of a Rectangular channel:

\[ A = b \times h \]  
(1)

where

\[ A = \text{flow area (m}^2, \text{in}^2) \]

\[ b = \text{width of channel (m, in)} \]

\[ h = \text{height of flow (m, in)} \]

Wetted Perimeter

Wetted perimeter of a rectangular channel:

\[ P = b + 2h \]  
(1b)

where

\[ P = \text{wetted perimeter (m, in)} \]

Hydraulic Radius

Hydraulic radius of a rectangular channel:

\[ R_h = \frac{b \times h}{b + 2h} \]  
(1c)

where

\[ R_h = \text{hydraulic radius (m, in)} \]

- Hydraulic diameter
Trapezoidal Channel

Flow Area

Flow area of a trapezoidal channel:

\[ A = h \left( b + T \right) / 2 \]  \hspace{1cm} (2)

Wetted Perimeter

Wetted perimeter of a trapezoidal channel:

\[ P = b + 2 \left( \left( (T - b) / 2 \right)^2 + h^2 \right)^{1/2} \]  \hspace{1cm} (2b)

Hydraulic Radius

Hydraulic radius of a trapezoidal channel:

\[ R_h = \left( h \left( b + T \right) / 2 \right) / \left( b + 2 \left( \left( (T - b) / 2 \right)^2 + h^2 \right)^{1/2} \right) \]  \hspace{1cm} (2c)

- **Hydraulic diameter**

Triangular Channel

Flow Area

Flow area of a triangular channel:

\[ A = z h^2 \]  \hspace{1cm} (3)

where

\[ z = \text{see figure above (m, in)} \]

Wetted Perimeter

Wetted perimeter of a triangular channel:

\[ P = 2 h \left( 1 + z^2 \right)^{1/2} \]  \hspace{1cm} (3b)

Hydraulic Radius

Hydraulic radius of a triangular channel:

\[ R_h = z h / 2 \left( 1 + z^2 \right)^{1/2} \]  \hspace{1cm} (3c)

- **Hydraulic diameter**
Circular Channel

Flow Area

Flow area of a circular channel:

\[ A = \frac{D^2}{4} \left( \alpha - \sin(2\alpha)/2 \right) \]  \hspace{1cm} (4)

where

\( D = \text{diameter of channel} \)

\( \alpha = \cos^{-1}(1 - h/r) \)

Wetted Perimeter

Wetted perimeter of a circular channel:

\[ P = \alpha D \]  \hspace{1cm} (4b)

Hydraulic Radius

Hydraulic radius of a circular channel:

\[ R_h = \frac{D}{4} \left[ 1 - \sin(2\alpha) / (2\alpha) \right] \]  \hspace{1cm} (4c)

• Hydraulic diameter