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# Francis Turbine Formulas

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# List of 18 Francis Turbine Formulas

## Francis Turbine

### 1) Degree of Reaction of Turbine with Right Angled Outlet Blade

Open Calculator

fx $$R = 1 - \frac{\cot(\alpha)}{2 \cdot (\cot(\alpha) - \cot(\theta))}$$

ex $$0.450009 = 1 - \frac{\cot(11.03^\circ)}{2 \cdot (\cot(11.03^\circ) - \cot(65^\circ))}$$

### 2) Francis Turbine Flow Ratio

Open Calculator

fx $$K_f = \frac{V_{f1}}{\sqrt{2 \cdot g \cdot H_i}}$$

ex $$0.160326 = \frac{2.3\text{m/s}}{\sqrt{2 \cdot 9.8\text{m/s}^2 \cdot 10.5\text{m}}}$$

### 3) Francis Turbine Speed Ratio

Open Calculator

fx $$K_u = \frac{u_1}{\sqrt{2 \cdot g \cdot H_i}}$$

ex $$0.658733 = \frac{9.45\text{m/s}}{\sqrt{2 \cdot 9.8\text{m/s}^2 \cdot 10.5\text{m}}}$$

## 4) Guide Blade Angle given Degree of Reaction

Open Calculator

fx $$\alpha = a\cot\left(\frac{\cot(\theta)}{1-\frac{1}{2\cdot(1-R)}}\right)$$

ex $$11.03173^\circ = a\cot\left(\frac{\cot(65^\circ)}{1-\frac{1}{2\cdot(1-0.45)}}\right)$$

## 5) Pressure Head given Flow Ratio in Francis Turbine

Open Calculator

fx $$H_i = \frac{\left(\frac{V_{f1}}{K_f}\right)^2}{2\cdot g}$$

ex $$10.54289\text{m} = \frac{\left(\frac{2.3\text{m/s}}{0.16}\right)^2}{2\cdot 9.8\text{m/s}^2}$$

## 6) Pressure Head given Speed Ratio in Francis Turbine

Open Calculator

fx $$H_i = \frac{\left(\frac{u_1}{K_u}\right)^2}{2\cdot g}$$

ex $$10.52339\text{m} = \frac{\left(\frac{9.45\text{m/s}}{0.658}\right)^2}{2\cdot 9.8\text{m/s}^2}$$

### 7) Vane Angle at Inlet from Degree of Reaction

Open Calculator

$$\theta = a\cot\left(\cot(\alpha)\cdot\left(1-\frac{1}{2\cdot(1-R)}\right)\right)$$

$$64.99646^\circ = a\cot\left(\cot(11.03^\circ)\cdot\left(1-\frac{1}{2\cdot(1-0.45)}\right)\right)$$

### 8) Velocity of Flow at Inlet given Flow Ratio in Francis Turbine

Open Calculator

$$V_{f1} = K_f\cdot\sqrt{2\cdot g\cdot H_i}$$

$$2.295317\text{m/s} = 0.16\cdot\sqrt{2\cdot 9.8\text{m/s}^2\cdot 10.5\text{m}}$$

### 9) Velocity of Vane at Inlet given Speed Ratio Francis Turbine

Open Calculator

$$u_1 = K_u\cdot\sqrt{2\cdot g\cdot H_i}$$

$$9.439491\text{m/s} = 0.658\cdot\sqrt{2\cdot 9.8\text{m/s}^2\cdot 10.5\text{m}}$$

## Hydraulic Efficiency

### 10) Hydraulic Efficiency of Francis Turbine with Acute Angled Outlet Blade

Open Calculator

$$\eta_h = \frac{V_{w1}\cdot u_1 + V_{w2}\cdot u_2}{g\cdot H}$$

$$0.726813 = \frac{12.93\text{m/s}\cdot 9.45\text{m/s} + 6.5\text{m/s}\cdot 5.2\text{m/s}}{9.8\text{m/s}^2\cdot 21.9\text{m}}$$

### 11) Hydraulic Efficiency of Francis Turbine with Obtuse Angled Outlet Blade

Open Calculator

fx $$\eta_h = \frac{V_{w1} \cdot u_1 - V_{w2} \cdot u_2}{g \cdot H}$$

ex $$0.411837 = \frac{12.93\text{m/s} \cdot 9.45\text{m/s} - 6.5\text{m/s} \cdot 5.2\text{m/s}}{9.8\text{m/s}^2 \cdot 21.9\text{m}}$$

### 12) Hydraulic Efficiency of Francis Turbine with Right Angled Outlet Blade

Open Calculator

fx $$\eta_h = \frac{V_{w1} \cdot u_1}{g \cdot H}$$

ex $$0.569325 = \frac{12.93\text{m/s} \cdot 9.45\text{m/s}}{9.8\text{m/s}^2 \cdot 21.9\text{m}}$$

## Power Developed

### 13) Work Done per sec on Runner by Water for Obtuse Angled Outlet Blade

Open Calculator

fx $$W = \rho \cdot Q \cdot (V_{w1} \cdot u_1 - V_{w2} \cdot u_2)$$

ex $$132.5828\text{kW} = 1000\text{kg/m}^3 \cdot 1.5\text{m}^3\text{/s} \cdot (12.93\text{m/s} \cdot 9.45\text{m/s} - 6.5\text{m/s} \cdot 5.2\text{m/s})$$

### 14) Work Done per Second on Runner by Water for Acute Angled Outlet Blade

Open Calculator

fx $$W = \rho \cdot Q \cdot (V_{w1} \cdot u_1 + V_{w2} \cdot u_2)$$

ex $$233.9828\text{kW} = 1000\text{kg/m}^3 \cdot 1.5\text{m}^3\text{/s} \cdot (12.93\text{m/s} \cdot 9.45\text{m/s} + 6.5\text{m/s} \cdot 5.2\text{m/s})$$

### 15) Work Done per Second on Runner by Water for Right Angled Outlet Blade Angle

Open Calculator

$$W = \rho \cdot Q \cdot u_1 \cdot V_{w1}$$

$$183.2827\text{kW} = 1000\text{kg/m}^3 \cdot 1.5\text{m}^3\text{/s} \cdot 9.45\text{m/s} \cdot 12.93\text{m/s}$$

## Volume Flow Rate

### 16) Volume Flow Rate of Acute Angled Francis Turbine given Work Done Per Second on Runner

Open Calculator

$$Q = \frac{W}{\rho \cdot (V_{w1} \cdot u_1 + V_{w2} \cdot u_2)}$$

$$1.173163\text{m}^3\text{/s} = \frac{183\text{kW}}{1000\text{kg/m}^3 \cdot (12.93\text{m/s} \cdot 9.45\text{m/s} + 6.5\text{m/s} \cdot 5.2\text{m/s})}$$

### 17) Volume Flow Rate of Obtuse Angled Outlet Bladed Francis Turbine given Work Done per Second

Open Calculator

$$Q = \frac{W}{\rho \cdot (V_{w1} \cdot u_1 - V_{w2} \cdot u_2)}$$

$$2.070405\text{m}^3\text{/s} = \frac{183\text{kW}}{1000\text{kg/m}^3 \cdot (12.93\text{m/s} \cdot 9.45\text{m/s} - 6.5\text{m/s} \cdot 5.2\text{m/s})}$$

## 18) Volume Flow Rate of Right Angled Outlet Bladed Francis Turbine given Work Done per Second

Open Calculator

fx $$Q = \frac{W}{\rho \cdot u_1 \cdot V_{w1}}$$

ex $$1.497686\text{m}^3/\text{s} = \frac{183\text{kW}}{1000\text{kg}/\text{m}^3 \cdot 9.45\text{m}/\text{s} \cdot 12.93\text{m}/\text{s}}$$

## Variables Used

- **g** Acceleration due to Gravity *(Meter per Square Second)*
- **H** Net Francis Turbine Head *(Meter)*
- $H_i$ Head at Inlet of Francis Turbine *(Meter)*
- $K_f$ Flow Ratio of Francis Turbine
- $K_u$ Speed Ratio of Francis Turbine
- **Q** Volume Flow Rate for Francis Turbine *(Cubic Meter per Second)*
- **R** Degree of Reaction
- $u_1$ Velocity of Vane at Inlet for Francis Turbine *(Meter per Second)*
- $u_2$ Velocity of Vane at Outlet for Francis Turbine *(Meter per Second)*
- $V_{f1}$ Velocity of Flow at Inlet of Francis Turbine *(Meter per Second)*
- $V_{w1}$ Whirl Velocity at Inlet of Francis Turbine *(Meter per Second)*
- $V_{w2}$ Whirl Velocity at Outlet of Francis Turbine *(Meter per Second)*
- **W** Work Done per Second by Francis Turbine *(Kilowatt)*
- **α** Guide Blade Angle *(Degree)*
- $\eta_h$ Hydraulic Efficiency of Francis Turbine
- **θ** Vane Angle at Inlet *(Degree)*
- **ρ** Density of Fluid in Francis Turbine *(Kilogram per Cubic Meter)*

## Constants, Functions, Measurements used

- Function: **acot**, acot(Number)
  *Inverse trigonometric cotangent function*
- Function: **cot**, cot(Angle)
  *Trigonometric cotangent function*
- Function: **sqrt**, sqrt(Number)
  *Square root function*
- Measurement: **Length** in Meter (m)
  *Length Unit Conversion*
- Measurement: **Speed** in Meter per Second (m/s)
  *Speed Unit Conversion*
- Measurement: **Acceleration** in Meter per Square Second (m/s²)
  *Acceleration Unit Conversion*
- Measurement: **Power** in Kilowatt (kW)
  *Power Unit Conversion*
- Measurement: **Angle** in Degree (°)
  *Angle Unit Conversion*
- Measurement: **Volumetric Flow Rate** in Cubic Meter per Second (m³/s)
  *Volumetric Flow Rate Unit Conversion*
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m³)
  *Density Unit Conversion*

## Check other formula lists

- Boundary Layer Flow Formulas
- Buoyancy Formulas
- Centrifugal pumps Formulas
- Compressible Flow Formulas
- Draft Tube Formulas
- Dynamics of Fluid Flow Formulas
- Flow in Open Channels Formulas
- Forces developed by moving fluid Formulas
- Forces on Submerged Bodies Formulas
- Francis Turbine Formulas
- Hydraulic Linear Actuators Formulas
- Hydraulic Motors Formulas
- Hydraulic Pumps Formulas
- Hydraulic Turbines Formulas
- Ideal flow or Potential flow Formulas
- Kaplan Turbine Formulas
- Kinematics of Flow Formulas
- Notches and Weirs Formulas
- Orifices and Mouthpieces Formulas
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