# Important Normal Shock Wave Formulas PDF

Formulas
Examples
with Units

## List of 35
Important Normal Shock Wave Formulas

## 1) Downstream Shock Waves Formulas

### 1.1) Characteristic Mach Number behind Shock Formula

Evaluate Formula

Formula

$$M2_{cr} = \frac{1}{M1_{cr}}$$

Example

$$0.3333 = \frac{1}{3}$$

### 1.2) Density behind Normal Shock given Upstream Density and Mach Number Formula

Evaluate Formula

Formula

$$\rho_2 = \rho_1 \cdot \left( \frac{(\gamma + 1) \cdot M^2}{2 + (\gamma - 1) \cdot M^2} \right)$$

Example with Units

$$5.6713\,\text{kg/m}^3 = 5.4\,\text{kg/m}^3 \cdot \left( \frac{(1.4 + 1) \cdot 1.03^2}{2 + (1.4 - 1) \cdot 1.03^2} \right)$$

### 1.3) Density behind Normal Shock using Normal Shock Momentum Equation Formula

Evaluate Formula

Formula

$$\rho_2 = \frac{P_1 + \rho_1 \cdot V_1^2 - P_2}{V_2^2}$$

Example with Units

$$5.5\,\text{kg/m}^3 = \frac{65.374\,\text{Pa} + 5.4\,\text{kg/m}^3 \cdot 80.134\,\text{m/s}^2 - 110\,\text{Pa}}{79.351\,\text{m/s}^2}$$

### 1.4) Density Downstream of Shock Wave using Continuity Equation Formula

Evaluate Formula

Formula

$$\rho_2 = \frac{\rho_1 \cdot V_1}{V_2}$$

Example with Units

$$5.4533\,\text{kg/m}^3 = \frac{5.4\,\text{kg/m}^3 \cdot 80.134\,\text{m/s}}{79.351\,\text{m/s}}$$

### 1.5) Enthalpy behind Normal Shock from Normal Shock Energy Equation Formula

Evaluate Formula

Formula

$$h_2 = h_1 + \frac{V_1^2 - V_2^2}{2}$$

Example with Units

$$262.6414\,\text{J/kg} = 200.203\,\text{J/kg} + \frac{80.134\,\text{m/s}^2 - 79.351\,\text{m/s}^2}{2}$$

## 1.6) Flow Velocity Downstream of Shock Wave using Continuity Equation Formula

Evaluate Formula

Formula

$$V_2 = \frac{\rho_1 \cdot V_1}{\rho_2}$$

Example with Units

$$78.677\,\text{m/s} = \frac{5.4\,\text{kg/m}^3 \cdot 80.134\,\text{m/s}}{5.5\,\text{kg/m}^3}$$

## 1.7) Mach Number behind Shock Formula

Evaluate Formula

Formula

$$M_2 = \left( \frac{2 + \gamma \cdot {M_1}^2 - {M_1}^2}{2 \cdot \gamma \cdot {M_1}^2 - \gamma + 1} \right)^{\frac{1}{2}}$$

Example

$$0.7047 = \left( \frac{2 + 1.4 \cdot 1.49^2 - 1.49^2}{2 \cdot 1.4 \cdot 1.49^2 - 1.4 + 1} \right)^{\frac{1}{2}}$$

## 1.8) Stagnation Pressure behind Normal Shock by Rayleigh Pitot Tube formula Formula

Evaluate Formula

Formula

$$p_{02} = P_1 \cdot \left( \frac{1 - \gamma + 2 \cdot \gamma \cdot {M_1}^2}{\gamma + 1} \right) \cdot \left( \frac{(\gamma + 1)^2 \cdot {M_1}^2}{4 \cdot \gamma \cdot {M_1}^2 - 2 \cdot (\gamma - 1)} \right)^{\frac{\gamma}{\gamma - 1}}$$

Example with Units

$$220.6775\,\text{Pa} = 65.374\,\text{Pa} \cdot \left( \frac{1 - 1.4 + 2 \cdot 1.4 \cdot 1.49^2}{1.4 + 1} \right) \cdot \left( \frac{(1.4 + 1)^2 \cdot 1.49^2}{4 \cdot 1.4 \cdot 1.49^2 - 2 \cdot (1.4 - 1)} \right)^{\frac{1.4}{1.4 - 1}}$$

## 1.9) Static Enthalpy behind Normal Shock for given Upstream Enthalpy and Mach Number Formula

Evaluate Formula

Formula

$$h_2 = h_1 \cdot \frac{1 + \left( \frac{2 \cdot \gamma}{\gamma + 1} \right) \cdot \left( {M_1}^2 - 1 \right)}{(\gamma + 1) \cdot \frac{{M_1}^2}{2 + (\gamma - 1) \cdot {M_1}^2}}$$

Example with Units

$$262.9808\,\text{J/kg} = 200.203\,\text{J/kg} \cdot \frac{1 + \left( \frac{2 \cdot 1.4}{1.4 + 1} \right) \cdot \left( 1.49^2 - 1 \right)}{(1.4 + 1) \cdot \frac{1.49^2}{2 + (1.4 - 1) \cdot 1.49^2}}$$

## 1.10) Static Pressure behind Normal Shock for given Upstream Pressure and Mach Number Formula

Evaluate Formula

**Formula**

$$P_2 = P_1 \cdot \left(1 + \left(\frac{2 \cdot \gamma}{\gamma + 1}\right) \cdot \left(M_1^{\,2} - 1\right)\right)$$

**Example with Units**

$$158.4306\,\text{Pa} = 65.374\,\text{Pa} \cdot \left(1 + \left(\frac{2 \cdot 1.4}{1.4 + 1}\right) \cdot \left(1.49^2 - 1\right)\right)$$

## 1.11) Static Pressure behind Normal Shock using Normal Shock Momentum Equation Formula

Evaluate Formula

**Formula**

$$P_2 = P_1 + \rho_1 \cdot V_1^{\,2} - \rho_2 \cdot V_2^{\,2}$$

**Example with Units**

$$110.0504\,\text{Pa} = 65.374\,\text{Pa} + 5.4\,\text{kg/m}^3 \cdot 80.134\,\text{m/s}^{\,2} - 5.5\,\text{kg/m}^3 \cdot 79.351\,\text{m/s}^{\,2}$$

## 1.12) Static Temperature behind Normal Shock for given Upstream Temperature and Mach Number Formula

Evaluate Formula

**Formula**

$$T_2 = T_1 \cdot \left(\frac{1 + \left(\frac{2 \cdot \gamma}{\gamma + 1}\right) \cdot \left(M_1^{\,2} - 1\right)}{\left(\gamma + 1\right) \cdot \frac{M_1^{\,2}}{2 + \left(\gamma - 1\right) \cdot M_1^{\,2}}}\right)$$

**Example with Units**

$$391.6411\,\text{K} = 298.15\,\text{K} \cdot \left(\frac{1 + \left(\frac{2 \cdot 1.4}{1.4 + 1}\right) \cdot \left(1.49^2 - 1\right)}{\left(1.4 + 1\right) \cdot \frac{1.49^2}{2 + \left(1.4 - 1\right) \cdot 1.49^2}}\right)$$

## 1.13) Velocity behind Normal Shock Formula

Evaluate Formula

**Formula**

$$V_2 = \frac{V_1}{\frac{\gamma + 1}{\left(\gamma - 1\right) + \frac{2}{M^2}}}$$

**Example with Units**

$$76.3007\,\text{m/s} = \frac{80.134\,\text{m/s}}{\frac{1.4 + 1}{\left(1.4 - 1\right) + \frac{2}{1.03^2}}}$$

## 1.14) Velocity behind Normal Shock by Normal Shock Momentum Equation Formula

Evaluate Formula

Formula

$$V_2 = \sqrt{\frac{P_1 - P_2 + \rho_1 \cdot V_1^{\,2}}{\rho_2}}$$

Example with Units

$$79.3511\,\mathrm{m/s} = \sqrt{\frac{65.374\,\mathrm{Pa} - 110\,\mathrm{Pa} + 5.4\,\mathrm{kg/m^3} \cdot 80.134\,\mathrm{m/s}^{\,2}}{5.5\,\mathrm{kg/m^3}}}$$

## 1.15) Velocity behind Normal Shock from Normal Shock Energy Equation Formula

Evaluate Formula

Formula

$$V_2 = \sqrt{2 \cdot \left( h_1 + \frac{V_1^{\,2}}{2} - h_2 \right)}$$

Example with Units

$$79.3553\,\mathrm{m/s} = \sqrt{2 \cdot \left( 200.203\,\mathrm{J/kg} + \frac{80.134\,\mathrm{m/s}^{\,2}}{2} - 262.304\,\mathrm{J/kg} \right)}$$

# 2) Normal Shock Relations Formulas

## 2.1) Characteristic Mach Number Formula

Evaluate Formula

Formula

$$M_{cr} = \frac{u_f}{a_{cr}}$$

Example with Units

$$0.1505 = \frac{12\,\mathrm{m/s}}{79.741\,\mathrm{m/s}}$$

## 2.2) Critical Speed of Sound from Prandtl Relation Formula

Evaluate Formula

Formula

$$a_{cr} = \sqrt{V_2 \cdot V_1}$$

Example with Units

$$79.7415\,\mathrm{m/s} = \sqrt{79.351\,\mathrm{m/s} \cdot 80.134\,\mathrm{m/s}}$$

## 2.3) Downstream Velocity using Prandtl Relation Formula

Evaluate Formula

Formula

$$V_2 = \frac{a_{cr}^{\,2}}{V_1}$$

Example with Units

$$79.3499\,\mathrm{m/s} = \frac{79.741\,\mathrm{m/s}^{\,2}}{80.134\,\mathrm{m/s}}$$

## 2.4) Enthalpy Difference using Hugoniot Equation Formula

Evaluate Formula

Formula

$$\Delta H = 0.5 \cdot \left( P_2 - P_1 \right) \cdot \left( \frac{\rho_1 + \rho_2}{\rho_2 \cdot \rho_1} \right)$$

Example with Units

$$8.1889\,\text{J/kg} = 0.5 \cdot \left( 110\,\text{Pa} - 65.374\,\text{Pa} \right) \cdot \left( \frac{5.4\,\text{kg/m}^3 + 5.5\,\text{kg/m}^3}{5.5\,\text{kg/m}^3 \cdot 5.4\,\text{kg/m}^3} \right)$$

## 2.5) Mach Number given Impact and Static Pressure Formula

Evaluate Formula

Formula

$$M = \left( 5 \cdot \left( \left( \frac{q_c}{p_{st}} + 1 \right)^{\frac{2}{7}} - 1 \right) \right)^{0.5}$$

Example with Units

$$1.0547 = \left( 5 \cdot \left( \left( \frac{255\,\text{Pa}}{250\,\text{Pa}} + 1 \right)^{\frac{2}{7}} - 1 \right) \right)^{0.5}$$

## 2.6) Relation between Mach Number and Characteristic Mach Number Formula

Evaluate Formula

Formula

$$M_{cr} = \left( \frac{\gamma + 1}{\gamma - 1 + \frac{2}{M^2}} \right)^{0.5}$$

Example

$$1.0248 = \left( \frac{1.4 + 1}{1.4 - 1 + \frac{2}{1.03^2}} \right)^{0.5}$$

## 2.7) Upstream Velocity using Prandtl Relation Formula

Evaluate Formula

Formula

$$V_1 = \frac{a_{cr}^{\ 2}}{V_2}$$

Example with Units

$$80.1329\,\text{m/s} = \frac{79.741\,\text{m/s}^{\ 2}}{79.351\,\text{m/s}}$$

# 3) Property Change Across Shock Waves Formulas

## 3.1) Density Ratio across Normal Shock Formula

Evaluate Formula

Formula

$$\rho_r = \left( \gamma + 1 \right) \cdot \frac{M_1^{\ 2}}{2 + \left( \gamma - 1 \right) \cdot M_1^{\ 2}}$$

Example

$$1.8449 = \left( 1.4 + 1 \right) \cdot \frac{1.49^2}{2 + \left( 1.4 - 1 \right) \cdot 1.49^2}$$

## 3.2) Entropy Change across Normal Shock Formula

Evaluate Formula

Formula

$$\Delta S = R \cdot \ln\left( \frac{p_{01}}{p_{02}} \right)$$

Example with Units

$$7.9952\,\text{J/kg*K} = 287\,\text{J/(kg*K)} \cdot \ln\left( \frac{226.911\,\text{Pa}}{220.677\,\text{Pa}} \right)$$

## 3.3) Pressure Ratio across Normal Shock Formula

Evaluate Formula

Formula

$$P_r = 1 + \frac{2 \cdot \gamma}{\gamma + 1} \cdot \left( {M_1}^2 - 1 \right)$$

Example

$$2.4234 = 1 + \frac{2 \cdot 1.4}{1.4 + 1} \cdot \left( 1.49^2 - 1 \right)$$

## 3.4) Shock Strength Formula

Evaluate Formula

Formula

$$\Delta p_{str} = \left( \frac{2 \cdot \gamma}{1 + \gamma} \right) \cdot \left( {M_1}^2 - 1 \right)$$

Example

$$1.4235 = \left( \frac{2 \cdot 1.4}{1 + 1.4} \right) \cdot \left( 1.49^2 - 1 \right)$$

## 3.5) Static Enthalpy Ratio across Normal Shock Formula

Evaluate Formula

Formula

$$H_r = \frac{1 + \left( \frac{2 \cdot \gamma}{\gamma + 1} \right) \cdot \left( {M_1}^2 - 1 \right)}{\left( \gamma + 1 \right) \cdot \frac{{M_1}^2}{2 + \left( \gamma - 1 \right) \cdot {M_1}^2}}$$

Example

$$1.3136 = \frac{1 + \left( \frac{2 \cdot 1.4}{1.4 + 1} \right) \cdot \left( 1.49^2 - 1 \right)}{\left( 1.4 + 1 \right) \cdot \frac{1.49^2}{2 + \left( 1.4 - 1 \right) \cdot 1.49^2}}$$

## 3.6) Temperature Ratio across Normal Shock Formula

Evaluate Formula

Formula

$$T_r = \frac{1 + \left( \frac{2 \cdot \gamma}{\gamma + 1} \right) \cdot \left( {M_1}^2 - 1 \right)}{\left( \gamma + 1 \right) \cdot \frac{{M_1}^2}{2 + \left( \left( \gamma - 1 \right) \cdot {M_1}^2 \right)}}$$

Example

$$1.3136 = \frac{1 + \left( \frac{2 \cdot 1.4}{1.4 + 1} \right) \cdot \left( 1.49^2 - 1 \right)}{\left( 1.4 + 1 \right) \cdot \frac{1.49^2}{2 + \left( \left( 1.4 - 1 \right) \cdot 1.49^2 \right)}}$$

# 4) Upstream Shock Waves Formulas

## 4.1) Density ahead of Normal Shock using Normal Shock Momentum Equation Formula

Evaluate Formula

Formula

$$\rho_1 = \frac{P_2 + \rho_2 \cdot {V_2}^2 - P_1}{{V_1}^2}$$

Example with Units

$$5.4\,\text{kg/m}^3 = \frac{110\,\text{Pa} + 5.5\,\text{kg/m}^3 \cdot 79.351\,\text{m/s}^2 - 65.374\,\text{Pa}}{80.134\,\text{m/s}^2}$$

## 4.2) Density Upstream of Shock Wave using Continuity Equation Formula

Evaluate Formula

Formula

$$\rho_1 = \frac{\rho_2 \cdot V_2}{V_1}$$

Example with Units

$$5.4463\,\text{kg/m}^3 = \frac{5.5\,\text{kg/m}^3 \cdot 79.351\,\text{m/s}}{80.134\,\text{m/s}}$$

## 4.3) Enthalpy ahead of Normal Shock from Normal Shock Energy Equation Formula

Evaluate Formula

Formula

$$h_1 = h_2 + \frac{V_2^2 - V_1^2}{2}$$

Example with Units

$$199.8656\,\mathrm{J/kg} = 262.304\,\mathrm{J/kg} + \frac{79.351\,\mathrm{m/s}^2 - 80.134\,\mathrm{m/s}^2}{2}$$

## 4.4) Flow Velocity Upstream of Shock Wave using Continuity Equation Formula

Evaluate Formula

Formula

$$V_1 = \frac{\rho_2 \cdot V_2}{\rho_1}$$

Example with Units

$$80.8205\,\mathrm{m/s} = \frac{5.5\,\mathrm{kg/m^3} \cdot 79.351\,\mathrm{m/s}}{5.4\,\mathrm{kg/m^3}}$$

## 4.5) Static Pressure ahead of Normal Shock using Normal Shock Momentum Equation Formula

Evaluate Formula

Formula

$$P_1 = P_2 + \rho_2 \cdot V_2^2 - \rho_1 \cdot V_1^2$$

Example with Units

$$65.3236\,\mathrm{Pa} = 110\,\mathrm{Pa} + 5.5\,\mathrm{kg/m^3} \cdot 79.351\,\mathrm{m/s}^2 - 5.4\,\mathrm{kg/m^3} \cdot 80.134\,\mathrm{m/s}^2$$

## 4.6) Velocity ahead of Normal Shock by Normal Shock Momentum Equation Formula

Evaluate Formula

Formula

$$V_1 = \sqrt{\frac{P_2 - P_1 + \rho_2 \cdot V_2^2}{\rho_1}}$$

Example with Units

$$80.1339\,\mathrm{m/s} = \sqrt{\frac{110\,\mathrm{Pa} - 65.374\,\mathrm{Pa} + 5.5\,\mathrm{kg/m^3} \cdot 79.351\,\mathrm{m/s}^2}{5.4\,\mathrm{kg/m^3}}}$$

## 4.7) Velocity ahead of Normal Shock from Normal Shock Energy Equation Formula

Evaluate Formula

Formula

$$V_1 = \sqrt{2 \cdot \left( h_2 + \frac{V_2^2}{2} - h_1 \right)}$$

Example with Units

$$80.1298\,\mathrm{m/s} = \sqrt{2 \cdot \left( 262.304\,\mathrm{J/kg} + \frac{79.351\,\mathrm{m/s}^2}{2} - 200.203\,\mathrm{J/kg} \right)}$$

## Variables used in list of Normal Shock Wave Formulas above

- $a_{cr}$ Critical Speed of Sound *(Meter per Second)*
- $h_1$ Enthalpy Ahead of Normal Shock *(Joule per Kilogram)*
- $h_2$ Enthalpy Behind Normal Shock *(Joule per Kilogram)*
- $H_r$ Static Enthalpy Ratio Across Normal Shock
- **M** Mach Number
- $M_1$ Mach Number Ahead of Normal Shock
- $M_2$ Mach Number Behind Normal Shock
- $M_{cr}$ Characteristic Mach Number
- $M1_{cr}$ Characteristic Mach Number Ahead of Shock
- $M2_{cr}$ Characteristic Mach Number Behind Shock
- $p_{01}$ Stagnation Pressure Ahead of Normal Shock *(Pascal)*
- $p_{02}$ Stagnation Pressure Behind Normal Shock *(Pascal)*
- $P_1$ Static Pressure Ahead of Normal Shock *(Pascal)*
- $P_2$ Static pressure Behind Normal shock *(Pascal)*
- $P_r$ Pressure Ratio Across Normal Shock
- $p_{st}$ Static Pressure *(Pascal)*
- $q_c$ Impact Pressure *(Pascal)*
- **R** Specific Gas Constant *(Joule per Kilogram per K)*
- $T_1$ Temperature Ahead of Normal Shock *(Kelvin)*
- $T_2$ Temperature Behind Normal Shock *(Kelvin)*
- $T_r$ Temperature Ratio Across Normal Shock
- $u_f$ Fluid Velocity *(Meter per Second)*
- $V_1$ Velocity Upstream of Shock *(Meter per Second)*
- $V_2$ Velocity Downstream of Shock *(Meter per Second)*
- $\gamma$ Specific Heat Ratio

## Constants, Functions, Measurements used in list of Normal Shock Wave Formulas above

- 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: **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: **Temperature** in Kelvin (K)
  *Temperature Unit Conversion*
- Measurement: **Pressure** in Pascal (Pa)
  *Pressure Unit Conversion*
- Measurement: **Speed** in Meter per Second (m/s)
  *Speed Unit Conversion*
- Measurement: **Heat of Combustion (per Mass)** in Joule per Kilogram (J/kg)
  *Heat of Combustion (per Mass) Unit Conversion*
- Measurement: **Specific Heat Capacity** in Joule per Kilogram per K (J/(kg*K))
  *Specific Heat Capacity Unit Conversion*
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m³)
  *Density Unit Conversion*
- Measurement: **Specific Entropy** in Joule per Kilogram K (J/kg*K)
  *Specific Entropy Unit Conversion*
- Measurement: **Specific Energy** in Joule per Kilogram (J/kg)
  *Specific Energy Unit Conversion*

- **$\Delta H$** Enthalpy Change *(Joule per Kilogram)*
- **$\Delta p_{str}$** Shock Strength
- **$\Delta S$** Entropy Change *(Joule per Kilogram K)*
- **$\rho_1$** Density Ahead of Normal Shock *(Kilogram per Cubic Meter)*
- **$\rho_2$** Density Behind Normal Shock *(Kilogram per Cubic Meter)*
- **$\rho_r$** Density Ratio Across Normal Shock

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