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Normal Shock Wave Formulas

Calculators! Examples! Conversions!

List of 35 Normal Shock Wave Formulas

Normal Shock Wave

Downstream Shock Waves

1) Characteristic Mach Number behind Shock

Open Calculator

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

ex $$0.333333 = \frac{1}{3}$$

2) Density behind Normal Shock given Upstream Density and Mach Number

Open Calculator

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

ex $$5.671296\text{kg/m}^3 = 5.4\text{kg/m}^3 \cdot \left(\frac{(1.4 + 1) \cdot (1.03)^2}{2 + (1.4 - 1) \cdot (1.03)^2} \right)$$

3) Density behind Normal Shock using Normal Shock Momentum Equation

Open Calculator

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

ex $$5.500008\text{kg/m}^3 = \frac{65.374\text{Pa} + 5.4\text{kg/m}^3 \cdot (80.134\text{m/s})^2 - 110\text{Pa}}{(79.351\text{m/s})^2}$$

4) Density Downstream of Shock Wave using Continuity Equation

Open Calculator

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

ex $$5.453285\text{kg/m}^3 = \frac{5.4\text{kg/m}^3 \cdot 80.134\text{m/s}}{79.351\text{m/s}}$$

5) Enthalpy behind Normal Shock from Normal Shock Energy Equation

Open Calculator

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

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

6) Flow Velocity Downstream of Shock Wave using Continuity Equation

Open Calculator

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

ex $$78.67702\text{m/s} = \frac{5.4\text{kg/m}^3 \cdot 80.134\text{m/s}}{5.5\text{kg/m}^3}$$

7) Mach Number behind Shock

Open Calculator

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

ex $$0.704659 = \left(\frac{2 + 1.4 \cdot (1.49)^2 - (1.49)^2}{2 \cdot 1.4 \cdot (1.49)^2 - 1.4 + 1}\right)^{\frac{1}{2}}$$

8) Stagnation Pressure behind Normal Shock by Rayleigh Pitot Tube formula

Open Calculator

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

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

9) Static Enthalpy behind Normal Shock for given Upstream Enthalpy and Mach Number

Open Calculator

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

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

10) Static Pressure behind Normal Shock for given Upstream Pressure and Mach Number

Open Calculator

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

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

11) Static Pressure behind Normal Shock using Normal Shock Momentum Equation

Open Calculator

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

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

12) Static Temperature behind Normal Shock for given Upstream Temperature and Mach Number

Open Calculator

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

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

13) Velocity behind Normal Shock

Open Calculator

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

$$76.30065\text{m/s} = \frac{80.134\text{m/s}}{\frac{1.4+1}{(1.4-1)+\frac{2}{(1.03)^2}}}$$

14) Velocity behind Normal Shock by Normal Shock Momentum Equation

Open Calculator

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

$$79.35106\text{m/s} = \sqrt{\frac{65.374\text{Pa} - 110\text{Pa} + 5.4\text{kg/m}^3 \cdot (80.134\text{m/s})^2}{5.5\text{kg/m}^3}}$$

15) Velocity behind Normal Shock from Normal Shock Energy Equation

Open Calculator

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

$$79.35525\text{m/s} = \sqrt{2 \cdot \left(200.203\text{J/kg} + \frac{(80.134\text{m/s})^2}{2} - 262.304\text{J/kg}\right)}$$

Normal Shock Relations

16) Characteristic Mach Number

Open Calculator

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

$$0.150487 = \frac{12\text{m/s}}{79.741\text{m/s}}$$

17) Critical Speed of Sound from Prandtl Relation

Open Calculator

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

ex $$79.74154\text{m/s} = \sqrt{79.351\text{m/s} \cdot 80.134\text{m/s}}$$

18) Downstream Velocity using Prandtl Relation

Open Calculator

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

ex $$79.34993\text{m/s} = \frac{(79.741\text{m/s})^2}{80.134\text{m/s}}$$

19) Enthalpy Difference using Hugoniot Equation

Open Calculator

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

ex $$8.188946\text{J/kg} = 0.5 \cdot (110\text{Pa} - 65.374\text{Pa}) \cdot \left(\frac{5.4\text{kg/m}^3 + 5.5\text{kg/m}^3}{5.5\text{kg/m}^3 \cdot 5.4\text{kg/m}^3}\right)$$

20) Mach Number given Impact and Static Pressure

Open Calculator

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

ex $$1.054714 = \left(5 \cdot \left(\left(\frac{255\text{Pa}}{250\text{Pa}} + 1\right)^{\frac{2}{7}} - 1\right)\right)^{0.5}$$

21) Relation between Mach Number and Characteristic Mach Number

Open Calculator

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

ex $$1.024812 = \left(\frac{1.4 + 1}{1.4 - 1 + \frac{2}{(1.03)^2}}\right)^{0.5}$$

22) Upstream Velocity using Prandtl Relation

Open Calculator

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

ex $$80.13292\text{m/s} = \frac{(79.741\text{m/s})^2}{79.351\text{m/s}}$$

Property Change Across Shock Waves

23) Density Ratio across Normal Shock

Open Calculator

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

ex $$1.844933 = (1.4 + 1) \cdot \frac{(1.49)^2}{2 + (1.4 - 1) \cdot (1.49)^2}$$

24) Entropy Change across Normal Shock

Open Calculator

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

ex $$7.995182\text{J/kg*K} = 287\text{J/(kg*K)} \cdot \ln\left(\frac{226.911\text{Pa}}{220.677\text{Pa}}\right)$$

25) Pressure Ratio across Normal Shock

Open Calculator

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

ex $$2.42345 = 1 + \frac{2 \cdot 1.4}{1.4 + 1} \cdot \left((1.49)^2 - 1\right)$$

26) Shock Strength

Open Calculator

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

$$1.42345 = \left(\frac{2 \cdot 1.4}{1+1.4}\right) \cdot \left((1.49)^2 - 1\right)$$

27) Static Enthalpy Ratio across Normal Shock

Open Calculator

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

$$1.313571 = \frac{1 + \left(\frac{2\cdot 1.4}{1.4+1}\right) \cdot \left((1.49)^2 - 1\right)}{(1.4+1) \cdot \frac{(1.49)^2}{2+(1.4-1)\cdot(1.49)^2}}$$

28) Temperature Ratio across Normal Shock

Open Calculator

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

$$1.313571 = \frac{1 + \left(\frac{2\cdot 1.4}{1.4+1}\right) \cdot \left((1.49)^2 - 1\right)}{(1.4+1) \cdot \frac{(1.49)^2}{2+\left((1.4-1)\cdot(1.49)^2\right)}}$$

Upstream Shock Waves

29) Density ahead of Normal Shock using Normal Shock Momentum Equation

Open Calculator

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

$$5.399992\text{kg/m}^3 = \frac{110\text{Pa} + 5.5\text{kg/m}^3 \cdot (79.351\text{m/s})^2 - 65.374\text{Pa}}{(80.134\text{m/s})^2}$$

30) Density Upstream of Shock Wave using Continuity Equation

Open Calculator

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

ex $$5.446259\text{kg/m}^3 = \frac{5.5\text{kg/m}^3 \cdot 79.351\text{m/s}}{80.134\text{m/s}}$$

31) Enthalpy ahead of Normal Shock from Normal Shock Energy Equation

Open Calculator

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

ex $$199.8656\text{J/kg} = 262.304\text{J/kg} + \frac{(79.351\text{m/s})^2 - (80.134\text{m/s})^2}{2}$$

32) Flow Velocity Upstream of Shock Wave using Continuity Equation

Open Calculator

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

ex $$80.82046\text{m/s} = \frac{5.5\text{kg/m}^3 \cdot 79.351\text{m/s}}{5.4\text{kg/m}^3}$$

33) Static Pressure ahead of Normal Shock using Normal Shock Momentum Equation

Open Calculator

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

ex $$65.32364\text{Pa} = 110\text{Pa} + 5.5\text{kg/m}^3 \cdot (79.351\text{m/s})^2 - 5.4\text{kg/m}^3 \cdot (80.134\text{m/s})^2$$

34) Velocity ahead of Normal Shock by Normal Shock Momentum Equation

Open Calculator

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

ex $$80.13394\text{m/s} = \sqrt{\frac{110\text{Pa} - 65.374\text{Pa} + 5.5\text{kg/m}^3 \cdot (79.351\text{m/s})^2}{5.4\text{kg/m}^3}}$$

35) Velocity ahead of Normal Shock from Normal Shock Energy Equation

Open Calculator

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

ex $$80.12979\text{m/s} = \sqrt{2 \cdot \left(262.304\text{J/kg} + \frac{(79.351\text{m/s})^2}{2} - 200.203\text{J/kg} \right)}$$

Variables Used

- 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)*
- γ Specific Heat Ratio
- ΔH Enthalpy Change *(Joule per Kilogram)*
- Δp_{str} Shock Strength
- ΔS Entropy Change *(Joule per Kilogram K)*
- ρ_1 Density Ahead of Normal Shock *(Kilogram per Cubic Meter)*

- ρ_2 Density Behind Normal Shock *(Kilogram per Cubic Meter)*
- ρ_r Density Ratio Across Normal Shock

Constants, Functions, Measurements used

- Function: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Function: **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

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- **Governing Equations and Sound Wave Formulas**
- **Normal Shock Wave Formulas**
- **Oblique Shock and Expansion Waves Formulas**

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