Individual Thermal Solutions
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AB&Co

HANDY & FREQUENTLY USED FORMULAS

FOR THERMAL ENGINEERS

GEOMETRY & MATH | GEOMETRI & MATEMATIK

Cylindrical (Tube) Volume $V = p / 4 \cdot d^2 \cdot L$ [m^3]

Cylindrical (Tube) Surface $A = p \cdot d \cdot L$ [m^2]

Diameter $d = Ö(4 \cdot A / p)$ [m]

Right-angled Triangle A = 90°: Geometrical Vector Sum

$a^2 = b^2 + c^2$ Û $a = Ö(b^2 + c^2)$ [m]

$\cos B = c / a$; $\sin B = b / a$; $\tan B = b / c$

STRENGTH & STATICS | STYRKELÆRE & STATIK

Force $F = m \cdot a$ [N]

Stress $\sigma = F / A$ [N/m^2]

Stress $\sigma = \varepsilon \cdot E$ [N/m^2] Hook's Law

Strain $\varepsilon = \Delta L / L$ [-]

A = Cross section area [m^2]
E = Elasticity Modulus [N/m^2]
m = Mass [kg]
a = Acceleration / Gravity Acceleration [m/s^2]
ΔL = Deformation in Length [m] ; L= Length [m]

Bending Stress in beams $\sigma = M_T / W$ [N/m^2]
M_T = Torque [Nm]
W = Section Modulus [m^3] profile depending

Simple Supported Beam – Uniform spread load
Max. torque $M_{T,\,MAX} = P \cdot L / 8$ [N·m]
at middle of the beam
Max. Reflection $U = 5 \cdot M \cdot L^2 / (48 \cdot E \cdot I)$ [m]
at middle

Cantilever Beam – Uniform spread load
Max. torque $M_{T,\,MAX} = P \cdot L / 2$ [N·m]
at the fixed support in the wall
Max. Reflection $U = M_{T,\,MAX} \cdot L^2 / (4 \cdot E \cdot I)$ [m]
at free end of the beam

P = Total uniform load of beam [N]
I = Moment of Inertia [m^4]

HEAT & TEMPERATURES | VARME & TEMPERATUR

Absolute Temperature (Kelvin)

$\mathbf{T = t + 273{,}15}$ [K]

t = Temperature [°C]

Heat / Heat Content $\mathbf{Q = m \cdot C_p \cdot (t_2 - t_1)}$ [W] | [J]

m = Mass Flow [kg/s] / Mass [kg]

C_p = Specific Heat [J/(kgK]

t_1 and t_2 = Temperatures Inlet and Outlet [K] | [°C]

Linearly Heat Expansion of Materials

$\mathbf{DL = L \cdot a_L \cdot Dt}$ [m]

Volumetric Heat Expansion of Materials

$\mathbf{DV = V \cdot b_V \cdot Dt}$ [m^3]

L = Length [m] ; V = Volume [m^3] ;

α_L = Length Expansion Coefficient [1/°C]

β_V = Volume Expansion Coefficient [1/°C]

Δt = Temperature Change [°C]

For Ideal Gasses :

$\mathbf{p \cdot v = R \cdot T = p_0 \cdot v_0 \cdot (1 + t / 273{,}15)}$

Specific Volume $\mathbf{v = 1 / r}$ [m^3/kg]

p = Pressure (bar abs.) ; ρ = Density [kg/ m^3]

T = Absolute Temperature [K]

$p_0 \cdot v_0$: Pressure and Specific volume at 0°C

R = Gas Coefficient [J/(kg·K)] :

Air = 287,1 J/(kg·K) Steam = 461,5 J/(kg·K)

1 kmol equals a volume of 22,4138 m^3

$\mathbf{m = n \cdot M}$ [kg]

$\mathbf{V_n = n \cdot V_{mol}}$ [m_n^3] at 0°C and 1,01325 bar

$\mathbf{r = m / V_n}$ [kg/m_n^3]

M = Mol mass [kg/mol] ; ρ = Density [kg/m_n^3]

V_n = Normal Volume [m_n^3] ; n = Number of mol

V_{mol} = Molar Volume [m_n^3/mol] ; m = mass [kg]

HEAT TRANSFER | VARMEOVERFØRING

BY CONVECTION | VED KONVEKTION

Heat Transfer by Convection $Q = k \cdot F \cdot DJ$ [W]
F = Heat Surface – Total wall area [m^2]

Heat Transmission Coefficient
$k = 1 / (1/a_1 + 1/a_2 + e/l + f_1 + f_2)$ [W/(m^2·K)]
α_1 = Heat Transfer Coefficient – Fluid 1 [W/(m^2·K)]
α_2 = Heat Transfer Coefficient – Fluid 2 [W/(m^2·K)]
λ = Heat Conductivity Wall Material [W/(mK)]
e = Wall Thickness [m]
f_1 = Fouling Coefficient – for the wall of fluid 1 [m^2·K/W)]
f_2 = Fouling Coefficient – for the wall of fluid 2 [m^2·K/W)]

BY RADIATION | VED STRÅLING

Radiation Heat between two surfaces 1 and 2
$F = C_{12} \cdot F_1 \cdot ((T_1/100)^4 – (T_2/100)^4)$ [W]

Radiation Coefficient
$C_{12} = 1 / (1/C_1 + 1/C_2 - 1/C_S)$ [W/(m^2·K)]
$C = e \cdot C_S$ [W/(m^2·K)]
ε = Emission ratio [-]
C_S = Radiation Coefficient for the absolute black surface [-]
T = Absolute temperature [K]

Logarithmic Middle Temperature Difference
$DJ = (Dt_1 - Dt_2) / \ln (Dt_1/Dt_2)$; all values in [K] | [°C]
Δt_1 = Difference in Temperatures of Fluid1 and Fluid 2 at "1"
Δt_2 = Difference in Temperatures of Fluid1 and Fluid 2 at "2"
"1" and "2" being the physical positions of the inlets and outlets of heat exchanger in current or counter flow types

Nusselt's Number
$Nu = a \cdot L_F / l$ [-] Û $a = Nu \cdot l / L_F$
α = Heat Transfer Coefficient [W/(m^2·K)]
L_F = Flow Length [m] e.g. diameter or plate length
λ = Heat Conductivity Fluid [W/(m·K)]

General expression for forced circulation
$Nu = K_1 \cdot Re^{K2} \cdot Pr^{K3}$

General expression for natural circulation
$Nu = K_5 \cdot Gr^{K4} \cdot Pr^{K3}$
Prandtl's Number $Pr = r \cdot C_p \cdot n / l$ [-]

Grashoff's Number $Gr = g \cdot r \cdot DV \cdot Dt \cdot L_F^3 / n$ [-]

g= Gravity acceleration [m/s²]

K_1, K2, K3, K4 and K5 are different constants and equations based on tests and depending on the type of heat transfer.

MECHANICS OF FLUIDS | STRØMNING & VÆSKEFYSIK

Total pressure $p_T = p_S + p_D$ [N/m^2]

Dynamic pressure $p_D = ½ \cdot c^2 \cdot r$ [N/m^2]

Pressure Height $p_H = g \cdot r \cdot H$ [N/m^2]

p_S = Static pressure [N/m^2]
g = Gravity acceleration [m/s^2]
H = Height / Altitude [m]

Bernoulli's Law about constancy in pressure. All in [N/m^2]

$p_{S,1} + p_{D,1} + p_{H,1} = p_{S,2} + p_{D,2} + p_{H,2}$ Û

$p_{S,1} + ½ \cdot c_1^2 \cdot r + g \cdot r \cdot H_1 = p_{S,2} + ½ \cdot c_2^2 \cdot r + g \cdot r \cdot H_2$

For Ideal Gasses:

Dynamic Viscosity $h \ @ \ h_0 \cdot (273 + t) / 273$ [N·s/m^2]
t = Temperature [°C]

Dynamic Viscosity $h = n \cdot r$ [Pa·s] | [kg/(m·s)]

Reynold's Number $Re = c \cdot L_F / n$ [-]
ν = Kinematic Viscosity [m^2/s] ; ρ = Density [kg/m^3]
c = Velocity [m/s]; L_F = Flow Length [m]

Pressure Drop in tube $Dp_{TB} = l \cdot p_D \cdot L_T / d$
$= l \cdot ½ \cdot r \cdot c^2 \cdot L_T / d$ [N/m^2]
λ = Friction Coefficient [-]; L_T = Tube Length [m]
d = Internal Tube Diameter [m]; ρ = Density [kg/m^3]
c = Velocity [m/s]

Pump Capacity $P = h_T \cdot q_V \cdot S\, Dp$ [W]

Total Efficiency $h_T = (h_{PUMP} \cdot h_{MOTOR})$

Efficiency $h = P_{PERFORMED} / P_{ABSORB}$
q_V = Volume flow [m^3/s]
ΣΔp = Sum of all pressure drops in the circuit [Pa]

ELECTRICITY | ELECTRICITET

Power / Capacity of a 1-Phase System :

$$P = U_{PH} \cdot I_{PH} \quad [W]$$

Power / Capacity of a 3-Phase System :

$$P = \ddot{O}3 \cdot U_N \cdot I_N \cdot \cos j \quad [W]$$

U_N = Net Voltage [V] ; I_N = Net Current [A]
U_{PH} = Phase Voltage [V] ; I_{PH} = Phase Current [A]
$\cos \varphi$ = Phase Angel [-]

$\cos \varphi = 1$ for Heating elements and other simple resist.
$\cos \varphi < 1$ for Electrical Motors (inductive resistance).

Power, Voltage and Current in Conventional Resistances

Ohm's Law

$$U = R \cdot I \quad [V]$$

Power expressed by the resistance

$$P = U \cdot I = U^2 / R = I^2 \cdot R \quad [W]$$

U = Voltage [V] ; I = Current [A]
R = Resistance [Ω] | [Ohm]