Reference Sheet

Machining:

Material Removal Rate: $MRR = (\pi DN)(Feed)(depth\ of\ cut)$,

$Feed = \frac{V_a}{N}$, V_a:Tool axial velocity, N: rotation speed
Shearing stress in turning: $\tau = G(\cot(\emptyset) + \tan(\emptyset - \alpha))$

Shearing angle: $\emptyset = \frac{\pi}{4} - \frac{\beta}{2} + \frac{\alpha}{2}$, α: Tool Rake angle
Friction angle $\beta = \tan^{-1}\mu$
Power consumption $P = \frac{MRR.SCE}{e}$, SCE: Specific Cutting Energy, e: efficiency
Shearing angle $\emptyset = tan^{-1}\left(\frac{r\cos(\alpha)}{1-r\sin(\alpha)}\right)$
$r = \frac{t_0}{t_c}$, t_0: depth of cut, t_c:chip thickness
Feed per tooth in milling: $f = \frac{V}{N.n}$, n: number of teeth, V: tool velocity, N: rotation speed

Tools and Vibrations:

A milling tool can be modeled as a cantilever beam. Deflection of a cantilever beam with lateral force F at the tip: $\delta = \frac{Fl^3}{3EI}$, $I = \frac{\pi}{64}d^4$, vibration of a single degree, non-damped, subjected to harmonic excitation: $x(t) = \frac{\frac{F}{K}}{1-(\frac{\omega}{\omega_n})^2}\sin\omega t$, resonance/chatter for tool happens at ω_n or $(\text{number of flutes}) \times \omega_n$

Sheet Metal Forming:

Required force for cutting a sheet width b, thickness h: $F = \frac{1}{3}b.h.TS$, TS: tensile strength
Required force for forming:

- V-Bending: $F = \frac{4.TS.w.t^2}{3D}$
- Edge-bending: $F = \frac{TS.w.t^2}{3D}$

Springback: $\Delta K = 1.5K_y\left(1 - \frac{1}{3}(\frac{K_y}{K_L})^2\right)$
$K_{final} = K_L - \Delta K$
Yield curvature: $K_y = \frac{\sigma_y}{E\frac{h}{2}}$, K_L: Mold curvature

Minimum allowable radius without tearing sheet stock: $r_{min} = \frac{E\frac{h}{2}}{TS}$

Injection Molding:

Consider a rectangular mold $W \times L \times h$. The pressure drops across the cavity (length L) can be estimated by:

$\Delta P = \frac{12\mu QL}{Wh^3}$, μ: molten plastic viscosity

The time to fill the mold: $t = \frac{LWh}{Q}$, Q: flow rate
From these two equations, the required time to fill in a rectangular mold is: $t = \frac{12\mu}{\Delta P}(\frac{L}{h})^2$
And the clamping force, can be estimated by: $F = \frac{1}{2}\Delta P \times WL$
Required time for injection molding parts to cool down: $t_{cool} = \frac{h^2}{10\alpha}Ln(\frac{4}{\pi} \times \frac{T_m - T_w}{T_e - T_w})$
T_m: molten plastic temperature, T_w: wall of the mold temperature, T_e: ejection temperature,
α (thermal diffusivity), $\alpha = \frac{K}{\rho C_p}$, K: thermal conductivity, ρ:density, C_p:specific heat.