Formula Sheet

Aircraft Propulsion

Total Temperature and pressure

$$T_O = T + \frac{V^2}{2C_P} = T\left(1 + \frac{\kappa - 1}{2} M^2\right)$$

$$P_O = P \cdot \left(\frac{T_O}{T}\right)^{\left(\frac{\kappa}{\kappa - 1}\right)}$$

Compression

Subscript 1 for inlet conditions and subscript 2 for exit conditions

Isentropic Efficiency

$$\frac{T_2}{T_1} = 1 + \frac{1}{\eta_{is}}\left[\left(\frac{P_2}{P_1}\right)^{\left(\frac{\kappa-1}{\kappa}\right)} - 1\right]$$

Expansion

Subscript 1 for inlet conditions and subscript 2 for exit conditions

Isentropic efficiency

$$\frac{T_2}{T_1} = 1 - \eta_{is}\left[1 - \left(\frac{P_2}{P_1}\right)^{\left(\frac{\kappa-1}{\kappa}\right)}\right]$$

Critical Pressure Ratio

$$\varepsilon_{Cr} = P_1 / P_2 = \left[\frac{1}{\left(1 - \left(\frac{1}{\eta_j}\right) \cdot \left(\frac{\kappa_g - 1}{\kappa_g + 1}\right)\right)^{\frac{\kappa_g}{\kappa_g - 1}}}\right]$$

Compressors and Turbine

Relations of angles:	Compressor	$\tan \alpha_1 + \tan \beta_1 = \tan \alpha_2 + \tan \beta_2$
	Turbine	$\tan \alpha_2 - \tan \beta_2 = \tan \beta_3 - \tan \alpha_3$
Degree of reaction:	Compressor	$\Lambda = \frac{C_a}{2U}(\tan \beta_1 + \tan \beta_2)$
	Turbine	$\Lambda = \frac{C_a}{2U}(\tan \beta_3 - \tan \beta_2)$

Simplified Combustion Chamber Heat Balance

$$\dot{m}_{air} \cdot c_{pg} \cdot \Delta T_{cc} = \eta_{cc} \cdot \dot{m}_{fuel} \cdot LHV_{fuel}$$

Part rocket propulsion

Energy equation open system (steady state)

$$Q + \left(E_{internal} + PE + KE + PV\right)_{in} = W + \left(E_{internal} + PE + KE + PV\right)_{out}$$

Isentropic relation

$$\frac{p}{\rho^{\gamma}} = \text{constant}$$

Vandenkerckhove function

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

Nozzle area or expansion ratio

$$\frac{A_e}{A^*} = \frac{\Gamma}{\sqrt{\frac{2\gamma}{\gamma-1} \cdot \left(\frac{p_e}{p_c}\right)^{\left(\frac{2}{\gamma}\right)} \left(1 - \left(\frac{p_e}{p_c}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}\right)}}$$

Flow separation criterion (Summerfield)

$$p_e / p_a > 0.35\text{-}0.45$$

Flow separation criterion (Schmucker)

$$p_e / p_a > (1.88\,M - 1)^{-0.64}$$

Pump power

$$P_p = \frac{m \cdot \Delta p}{\eta_p \cdot \rho} = \frac{Q \cdot \Delta p}{\eta_p}$$

Burning rate law (solid propellants)

$$r = a \cdot p^n$$

Kinetic energy of ion between two charged plates

$$E_k = q\Delta V = \frac{1}{2} m_q w^2$$

Ion mass

$$m_{ion} = m_q = \hat{M}/N_A$$

Utilization or ionization efficiency

$$\eta_m = \frac{m_i}{m}$$

Beam current

$$I_{beam} = N_{ions} \cdot q$$

Maximum ion current density

$$j = \frac{4\varepsilon_0}{9} \cdot \left(\frac{2q}{m_q}\right)^{1/2} \cdot \frac{V^{3/2}}{d^2}$$

Ionization power

$$P_{ion} = \eta_m \cdot m/\hat{M} \cdot N_A \cdot V_i$$

Magnetic induction

$$B = \mu \cdot H$$

MPD thrust

$$F_T = \frac{\mu I^2}{4\pi}\left(\ln\frac{r_a}{r_c} + \frac{3}{4}\right)$$

Part electrical power

Electrical power (DC)
$P_e = V\,I = I^2\,R$

Electrical power (AC)
$P_e = V_{RMS}\,I_{RMS}\,PF$

Voltage single armature generator
$U = N\,B\,A\,\omega \sin(\omega t) = U_o \sin(\omega t)$

AC RMS voltage
$V_{RMS} = V_{peak}/\sqrt{2}$

3-phase RMS voltage
$(V_{RMS})_{3\text{-phase}} = \sqrt{3} \times (V_{RMS})_{\text{single phase}}$

Output frequency alternator
$f = \frac{n\,p}{120}$

Rotational (mechanical) power
$P_{mech} = T\,\omega$

Wind power
$P_{wind} = \rho_{air} \times (D_{blade})^2 \times (v_{wind})^3 \times \text{constant}$

Power from solar collector
$P_{collector} = \eta_{collector}\,S_{illum}\,A_{collector}$

TEC efficiency
$\eta_{TEC} = f\,\frac{\Delta T}{T_{hot}}$

Current in photovoltaic cell
$I = I_{ph} - I_d = I_{ph} - I_o\left(e^{V_d/V_T} - 1\right)$

Electrical energy in battery cell
$E_e = C \times V$

Fuel cell system power output
$P_{fc} = \eta_{fc} \times m_{fuel} \times HV$

Capacitance
$C = Q/V$

Capacitance parallel plate capacitor
$C = \varepsilon A/d$

Energy in charged capacitor
$E = (1/2)\,Q\,V = (1/2)\,C\,V^2 = Q^2/2C$

Series regulator
$V_{out} = V_{in} - (R_{series})\,I_{load}$

Shunt regulator
$V_{out} = V_{in} - R\,(I_{load} + I_{shunt})$

TRU efficiency
$\eta_{TRU} = \eta_{transformer}\,\eta_{rectifier}$

Wire resistance
$R = \rho\,\frac{L}{A_{cross}}$

Values of some important constants

Gravitational acceleration at sea level:	$g_o = 9.81\ m/s^2$
Absolute gas constant:	$R_A = 8.3143$ J/(mol-K)
Elementary charge:	$e = 1.6 \times 10^{-19}$ C
Vacuum permittivity:	$\varepsilon_o = 8.854 \times 10^{-12}$ F/m
Magnetic permeability of vacuum:	$\mu_o = 4\pi \times 10^{-7}$ H/m
Avogadro's number:	6.0×10^{23}