Answers to All Problems in ***Aircraft Propulsion, 2nd Edition***

Chapter 1

Problem 1.1

Thermal efficiency is 85.6%

Problem 1.2

Thermal efficiency is 66.7%

Problem 1.3

$$\eta_{th-Brayton} \approx 66.7\%$$

$$\eta_{th-Humphrey} \approx 70.8\%$$

Problem 1.4

N=3,250,000 rpm

Problem 1.5

$$Fuel\big|_{AB-Off} = 5,467 \ lbm$$

$$Fuel\big|_{AB-On} = 18,375 \ lbm$$

Chapter 2

Problem 2.1

$$u_1 \simeq 592 \ m/s$$

$$M_2^* \approx 0.615$$

Problem 2.2

$$\frac{p_2}{p_1} \approx 1.458$$

$$\frac{p_3}{p_1} \approx 2.06$$

$$C_d \approx 0.036$$

Problem 2.3

$$p_{t,3} \approx 683 \ kPa$$

Problem 2.4

$M_1 = 2.6$

$$M_2 \approx 2.19$$

$$M_3 \approx 1.70$$

Problem 2.5

$$p_2 \approx 21.54 \ kPa$$

$p_3 \approx 9.50 \ kPa$

$p_4 = 12.59 \ kPa$

Problem 2.6

$M_2 \approx 3.4$

$\dfrac{A_2}{A_1} = 3.664$

$\delta = 42.9°$

Problem 2.7

First, we state that regions 2 and 3 are on the top and region 4 is on the bottom surface of the half-diamond airfoil. Region 1 is the free stream condition.

$p_{t,2'} \approx 53.4 \ kPa$

$p_{t,3'} \approx 6.02 \ kPa$

$p_{t,4'} \approx 32.8 \ kPa$

Problem 2.8

$\dfrac{c_l}{c_d} = 1.732$

$c_{m,LE} = 0.3694$

Problem 2.9

$a^* \approx 416.7 \ m/s$

$u_2 \approx 255.2 \ m/s$

$a_t \approx 456.5 \ m/s$

$h_2 \approx 488.4 \ kJ/kg$

Problem 2.10

$a_{T.S.} = 253.6 \ m/s$

$F_{glass} = 1.744 \ kN$

Problem 2.11

$c_d \approx 0.977$

Problem 2.12

$\theta_{wall} = 32.15°$

$\dfrac{V_2}{V_1} = 1.264$

Problem 2.13

$$\left(\frac{x}{c}\right)_{(t/c)_{\max}} \approx 0.373$$

$$\delta \approx 9.06°$$

p_1/p_∞=1.0, $\frac{p_2}{p_\infty} = 0.14478$, $\frac{p_3}{p_\infty} \approx 2.389$

Problem 2.14

$$p_{t,2} = 157.59\ kPa$$

Problem 2.15

$$\dot{m} \approx 11.88\ kg/s$$

$$L_{\max} \approx 5.35\ m$$

$\frac{p_{t2}}{p_{t1}} \approx 0.746$; i.e. 25.4% total pressure loss.

Problem 2.16

$$q^* = 121.49\ kJ/kg$$

Problem 2.17

$$C_f \approx 0.00267$$

$\frac{p_2}{p_1} \approx 0.468$ and static pressure drop is ~53.23%

Problem 2.18

$$T_{t1} \simeq 941\ K$$

$\frac{p_2}{p_1} = 5.667$. Therefore, static pressure rise is 466.7%

Problem 2.19

$$\frac{T_{\max}}{T^*} \approx 1.0285$$

$$\frac{p_{@T_{\max}}}{p^*} \approx 1.2073$$

Problem 2.20

$$p_2 = 47.9\ kPa$$

$$\rho_2 = 0.5\ kg/m^3$$

Problem 2.21

$$\rho_2 \approx 0.5\ kg/m^3$$

$$p_2 \approx 90\ kPa$$

Problem 2.22

$L = 7.712\ m$

Problem 2.23

$L^* \approx 2.54\ m$

~ 40.7% total pressure loss

Problem 2.24

$M_2 = 1.0$

$p_2 = p^* = 33.52\ psia$

$p_{t2} = p_t^* = 63.46\ psia$

$T_2 = T^* \approx 1439\ °R$

$q_{1'}^* = 300\ BTU/lbm$

Problem 2.25

$M_1 \approx 0.24$

$T_{t2} \approx 2,733\ °R$

Problem 2.26

$M_4 \approx 0.36$

Problem 2.27

$\frac{L^*}{D} \approx 53.455$

$M_{1'} \approx 0.48$

Problem 2.28

$\frac{x_s}{D} \approx 15.235$

$\frac{p_{ty}}{p_{t1}} = 0.6205$, i.e. 37.95% loss of total pressure

$\frac{I_2^* - I_1}{I_1} = -0.1093$ or ~11%.

Problem 2.29

$M_1 \approx 0.66\ or\ 2.0$

~ 37.2% static pressure drop

~ 145% static pressure rise

~ 6.35% loss of fluid impulse (subsonic) and ~10.93% loss of fluid impulse (supersonic)

Problem 2.30

$M_2 \approx 0.70$

$$\frac{T_2}{T_1} = 4.806$$

$p_{t2} / p_{t1} = 0.845$, therefore 15.5% total pressure loss

Problem 2.31

$$\dot{m} \approx 242.7 \ kg/s$$

$$M_2 \approx 0.52$$

$$C_{PR} \approx 0.4643$$

$$F_x\big|_{wall} \approx -20.26 \ kN$$

Problem 2.32

$$\left(F_x\right)_{vane} = 25 \ N$$

$$\left(F_y\right)_{vane} = -25 \ N$$

Problem 2.33

$$\frac{F_x\big|_{nozzle}}{p_1 A_1} \approx 0.2317$$

Problem 2.34

2.1 MJ/kg, which divides into700 kJ/kg per duct (for three ducts)

Problem 2.35

$M_{cone} \approx 2.4$

$$C_{p,cone} \approx 0.1887$$

$$C_{p,cone} = C_{D,cone}$$

Problem 2.36

$$\dot{m} \approx 81.8 \ kg/s$$

$$A_2 = 0.1973 \ m^2$$

$$p_2 \approx 161 \ kPa$$

$$I_1 = 90.75 \ kN$$

$$I_2 \cong 42.82 \ kN$$

$$F_x\big|_{wall} \cong 47.9 \ kN$$

Problem 2.37

$$M_2 \approx 1.83$$

$$\frac{p_2}{p_0} \approx 0.9706$$

$$\frac{F_{x,con-wall}}{p_{t1} A_{th}} \cong 0.185$$

$$\frac{F_{x,div-wall}}{p_{t1}A_{th}} \cong -0.1229$$

$$\frac{F_{x,nozzle}}{p_{t1}A_{th}} \cong 0.062$$

Problem 2.38

$$M_2 \approx 0.34$$

$$C_{PR} = 0.611$$

$$\frac{F_x\big|_{walls}}{p_1 A_1} = -0.507$$

Problem 2.39

$$\frac{F_x\big|_{walls}}{p_1 A_1} \approx -1.1675$$

Problem 2.40

$$\frac{F_x\big|_{walls}}{p_1 A_1} = 0.244$$

Problem 2.41

q_{min}=796.8 kJ/kg
T_2≈1911 K
Fuel-to-air ratio=0.00664 or 0.664%

Problem 2.42

$$\frac{q_1^*}{c_p T_{t1}} = 0.484$$

$$\frac{\Delta p}{p_1} \cong 3.99 \quad or \quad 399\%$$

Problem 2.43

Mass flow rate=0.07258 kg/s
D_h=0.02 m
M_2=0.66 (from Table)
Δp_t (%)=44.64

Problem 2.44

q_1^*≈1511 kJ/kg
f=1.275%

Problem 2.45

F_x (duct) ≈ 69 kN
Delta Power=-147.2 MW

Since the flow was adiabatic and the exit power is 147.2 MW less than the power of the flow in, therefore, there has been shaft power extraction, which means that the component is a turbine.

Problem 2.46

T_t1 (K)	1170
p-t1(kPa)	156.5
M_2 (from table)	1.42
%Delta p_t/p_t1	33.3
L_1*/D	15.25
Delta(s)/R	0.4044

Problem 2.47

pt1 (kPa)	118.6
u1 (m/s)	245.5
M2 (~)	0.8
Delta pt Loss (%)	8.50

Problem 2.48

M-2 (from Table)	1.4
Tt2 (K)	450
pt2 (kPa)	129.3

Problem 2.49

q-1 (kPa)	14.75
p-2 (kPa)	96.7
C-PR	0.84

Problem 2.50

$L_x/D = 13.57$

$L/D \approx 16.36$

~40.8% loss in total pressure due to wall friction and the NS

Problem 2.51

$q_1{}^* = 155.5$ kJ/kg

$T_{t2}{}^* = 1164$ K

$M_{1'} \approx 0.44$

Mass flow rate drops by about 20%.

Problem 2.52

$A_1 \approx 1.60$ m^2

$A_2 \approx 1.13$ m^2

$F_x)_{nozzle} \approx 31$ kN

Problem 2.53

L-x/D	8.447
L/D	18.855
L-x/L	0.448
(pt1-pt2)/pt1*100	40.8

Problem 2.54

T-t2 (K)	1981
M_2 (from Table)	1.2

p_2 (kPa)
69.4

Del (p_t)/p_t1 (%)
57.8

q* (kJ/kg)
616

Problem 2.55

q_0=75.6 kPa
A_1=2.117 m^2

$$\dot{m}_0 \approx 352.6\ kg/s$$

Chapter 3

Problem 3.1

$$f_{(\max\ A/B)} = \frac{w_f}{w_n} = 0.0144$$

$$f_{(\max\ A/B)} = \frac{w_f}{w_n} = 0.054$$

Maximum (A/B on): $\frac{p_{2.5}}{p_2} = 3.67$; $\frac{p_3}{p_{2.5}} = 3.0926$ and $\frac{p_5}{p_4} = 0.2279$

Military: $\frac{p_{2.5}}{p_2} = 3.67$; $\frac{p_3}{p_{2.5}} = 3.0926$ and $\frac{p_5}{p_4} = 0.2279$

Maximum (A/B on): $V_9 = 2{,}841\ \ ft/s$

Military: $V_9 = 1{,}974\ \ ft/s$

Maximum (A/B on): $\eta_{th} \approx 0.168$ or ~16.8%

Military: $\eta_{th} \approx 0.295$ or 29.5%

Maximum (A/B on): $TSFC = \frac{w_f}{F_n} = 2.103\ \ lbm/hr/lbf$

Military: $TSFC = \frac{w_f}{F_n} = 0.8353\ \ lbm/hr/lbf$

Maximum (A/B on): $\eta_{carnot} \approx 0.827$ or 82.7%

Military: $\eta_{carnot} \approx 0.744$ or 74.4%

$Percent\ thrust\ increase \approx 57\%$ and $Percent\ \ fuel\ \ flow\ rate\ increase \approx 295\%$

Problem 3.2

$$BPR = \alpha = \frac{\dot{w}_{fan}}{\dot{w}_{core}} = 1.359$$

$f = 0.01113$

$\dot{w}_f = 7{,}813\ lbm/hr$

$F_n)_{static} = 17{,}727\ lbs$

$\eta_{th} = 0.3658$

Thermal efficiency of this engine is higher than the engine in Problem 3.1. This difference can be attributed to the thermally-inefficient AB-on engine. Also, JT3D has a higher pressure ratio than J57; therefore its thermal efficiency is higher.

$TSFC = 0.4407\ lbm/hr/lbf$

$F_{SP} = 1.113$

$\eta_{carnot} = 0.721$

$\dfrac{p_{t3}}{p_{t2}} = 13.6$

$M_{13} = 0.858$

Problem 3.3

$f = \dfrac{\dot{w}_f}{\dot{w}_{core}} \Rightarrow \dot{w}_f = 2.199\ lb/s$

$F_n)_{exhaust} \approx 14{,}284\ lbs$

$\eta_{th} \approx 0.3232$

$\eta_{carnot} \approx 0.7621$

$TSFC \approx 0.554\ lbm/hr/lbf$

$\dfrac{p_{t3}}{p_{t2}} = 15.85$

$BPR = \alpha = \dfrac{\dot{w}_{fan}}{\dot{w}_{core}} = 1.1$

$\eta_{carnot} \approx 0.7621$

$M_9 \approx 0.87$

$\dfrac{p_{t2.5}}{p_{t2}} \approx 4.082$

$\dfrac{p_{t3}}{p_{t2.5}} \approx 3.88$

Problem 3.4

$\dfrac{p_{t3}}{p_{t2}} = 21.5$

$F_g)_{fan} = 34{,}300\ lbs$

$f = 0.017$

$$F_g\Big)_{core} = 9,284\ \ lbf$$
$$F_g\Big)_{total} = 43,584\ \ lbf$$
$$\eta_{th} = 0.335$$
$$TSFC = 0.351\ \ lbm/hr/lbf$$
$$BPR = \alpha = \frac{\dot{w}_{fan}}{\dot{w}_{core}} = 5.06$$
$$\eta_{carnot} = 0.786$$
$$\frac{p_{t3}}{p_{t2}} = 2.18$$
$$\frac{p_{t4}}{p_{t3}} = 9.84$$
$$M_{19} = 0.788$$
$$M_9 \approx 0.70$$

Problem 3.5

$$D_{ram} \approx 14.971\ \ kN$$
$$F_g \approx 27.040\ \ kN$$
$$F_n\Big)_{un-installed} \approx 12.1\ \ kN$$
$$TSFC \approx 0.2237\ \ \frac{kg/hr}{N}$$
$$\eta_{th} \approx 0.303$$
$$\eta_p \approx 0.726$$
$$\eta_{oveall} \approx 0.22$$

Problem 3.6

$$\wp_{s,\ \ prop} = 1,000\ \ kW = 1\ \ MW$$
$$V_9 = 200\ \ m/s$$
$$\eta_p = 0.9$$

Problem 3.7

$$\frac{A_0}{A_1} = 10.0$$
$$\frac{p_1}{p_0} = 0.9505$$
$$\frac{D_{add}}{A_1 p_0} \approx 0.0405$$

Problem 3.8

$F = 175\ kN$

$I_s = 356.8\ s$

Problem 3.9

$D_{ram} \approx 19.1\ kN$

$F_{gc} \approx 7.5\ kN$

$F_{gf} \approx 33.4\ kN$

$F_{net} \approx 21.8\ kN$

$\eta_p \approx 0.663$

Problem 3.10

$D_{ram} \simeq 5.99\ kN$

$F_g\big)_{nozzle} \approx 15.5\ kN$

$F_{net} \approx 9.5\ kN$

$\eta_p = 0.583$

Problem 3.11

$D_{ram} \approx 30\ kN$

$F_g\big)_{nozzle} \approx 61.5\ kN$

$F_{net} \approx 31.5\ kN$

$\eta_{th} \approx 0.133$

$\eta_p \approx 0.677$

$Range \approx 860\ km$

No!

Problem 3.13

$\wp_s \approx 13.986\ MW$

Problem 3.14

$F = 3.924\ MN$

$V_9 = 3{,}924\ m/s$

$F_{rocket} = 3.924\ MN$

Problem 3.15

$F_p \approx 318.4\ kN$

Problem 3.16

$A_2 = 0.508\ m^2$

$I_1 = 182.61\ kN$

$I_2 = 157.26\ kN$

$$F_x\big|_{walls} = 25.35\ kN$$

Problem 3.17

$$A_7 \approx 0.67\ m^2$$
$$I_7 \approx 38.1\ kN$$
$$I_8 \approx 31.1\ kN$$
$$F_x\big)_{nozzle} \approx 7.1\ kN$$

Problem 3.18

$F_{total}=F_{core}+F_{prop}=50$ kN
$$\wp_{thrust} = 10\ MW$$
$$\wp_{shaft} = 11.765\ MW$$

Problem 3.19

$$V_9 \approx 1200\ m/s$$

Problem 3.20

$$\dot{m}_f \approx 1.59\ kg/s$$
$$I_s = 2,569\ s$$
$$f \approx 0.0371$$

Problem 3.21

D_r (kN)
68.0

F_g (kN)
137.0

F_n (kN)
69.0

TSFC (mg/NS)
60.86

Eta-th	Eta-p	D_r (lbf)	F_g (lbf)
0.340	0.174	15294	30808

TSFC (lbm/hr/lbf)
2.148

Problem 3.22

D_r (kN)	F_g (kN)	TSFC (mg/NS)
26.0	97.4	35.0

Eta-th	Eta-p	D_r (lbf)	F_g (lbf)	TSFC (lbm/hr/lbf)
0.401	0.433	5845	21891	1.24

Chapter 4

Problem 4.1

$$\pi_d \approx 0.80$$

$$\eta_d \approx 0.889$$

$$\frac{\Delta s}{R} \approx 0.223$$

Problem 4.2

$$T_{t3} = 661.6\ K$$

$$\eta_c = 0.8484$$

$$\wp_c = 42.5\ MW$$

Problem 4.3

$$f \approx 0.02$$

$$T_{t4} \approx 1,485\ K$$

$$p_{t4} \approx 3.104\ MPa$$

Problem 4.4

$$T_{t5} = 976.2\ K$$

$$\tau_t = 0.6573$$

$$e_t \approx 0.813$$

$$p_{t5} = 1,102\ kPa$$

$$\wp_t \cong 60\ MW$$

Problem 4.5

$$T_{t,mixed-out} \approx 1,185\ K$$

Problem 4.6

$$T_{tg} = 1,643.60\ K$$

$$T_{tc} = 900.4\ K$$

$$p_{t,mixed-out} = 2.09\ MPa$$

$$\frac{\Delta s}{R} = -1.2687$$

Problem 4.7

$$\pi_n \approx 0.818$$

$A_9/A_8 \approx 2.506$

$$\therefore M_9 \approx 2.15$$

Problem 4.8

$$\eta_p \approx 0.0952$$
$$\eta_p \approx 0.5455$$

Problem 4.9

$$f = 0.02141$$
$$M_9 \approx 1.830$$
$$\frac{F}{\dot{m}_0} \approx 781.26\ N/kg/s$$
$$\eta_{th} \approx 0.3157$$
$$\eta_p \approx 0.6147$$

Problem 4.10

$$V_0 = 631.5\ m/s$$
$$A_0 = 1.128\ m^2$$
$$p_{t0} = 78.2\ kPa$$
$$p_{t4} = 66.9\ kPa$$
$$T_{t4} = 1{,}368.7\ K$$
$$p_{t9} = 61.5\ kPa$$
$$M_9 \approx 1.59$$
$$V_9 \approx 967\ m/s$$
$$A_9 \approx 1.965\ m^2$$
$$F_g = 109.4\ kN$$
$$V_{9_{efff}} \approx 1{,}062\ m/s$$
$$\eta_{th} = 0.3231$$
$$\eta_p = 0.7654$$

Problem 4.11

$$D_r \approx 16.46\ kN$$

T_{t2}=438.9 K
p_{t2}=90.9 kPa
p_{t3}=1363.3 kPa
T_{t3}= 1036.8 K
$T_{t13} \approx$ 499.15 K
p_{t15}=p_{t13}= 136.3 kPa
$f \approx 0.01586$
$T_{t5}\approx$925.7 K
p_{t5}=136.3 kPa
$\alpha =$ 2.043

$$\dot{m}_0 \approx 8.213\ kg/s$$
$$\dot{m}_{fan} \approx 16.787\ kg/s$$

$T_{t6M}\approx$640.8 K, p_{t6M}=133 kPa

$M_9 \approx 2.272$ and $V_9 \approx 808.5$ m/s

$F_g \approx 20.32\, kN$

$\frac{F_n}{\dot{m}_0(1+\alpha)a_0} \cong 0.5158$

$TSFC \cong 33.76 \;\; mg/s/N$

$\eta_{th} \cong 50.13\%$

$\eta_p \approx 91\%$ and $\eta_o \approx 45.6\%$.

Problem 4.12

$D_{ram} \approx 25.8 \;\; kN$

$\wp_c = 39.57 \;\; MW$

$f = 0.02$

$T_{t4} \approx 1{,}508 \;\; K$

$\tau_t = 0.7437$

$\wp_t = 39.57 \;\; MW$

$\tau_{\lambda AB} = 8.522$

$f_{AB} = 0.0272$

$F_g \approx 154$ kN

TSFC=36.92 mg/s/N

$F_n \approx 128$ kN

$\eta_{th} = 0.477$

$\eta_p \approx 0.341$

Problem 4.13

$p_{t3} \approx 722 \;\; kPa$

$T_{t13} \approx 331 \;\; K$

$f \approx 0.0215$

$T_{t5} \approx 935 \;\; K$

$M_{19} \approx 1.24$

$M_9 \approx 3.1$

$V_9 \approx 1{,}108 \;\; m/s$

$V_{19} \approx 396 \;\; m/s$

$V_0 \approx 271 \;\; m/s$

$\frac{F_{fan}}{F_{core}} \approx 0.826$

Problem 4.14

$T_{t6M} = 522.7 \;\; K$

$M_9 \approx 1.00$

$V_9 \approx 502 \;\; m/s$

$$\frac{F_g}{\dot{m}_5} \approx 1{,}506 \;\; N/kg/s$$

Problem 4.15

$$\frac{A_{8-on}}{A_{8-off}} \approx 1.821$$

Problem 4.16

$$p_5 = p_{15} = 370.4 \;\; kPa$$

$$p_{6M} \approx 404.3 \;\; kPa$$

Problem 4.17

$$p_{t3} = 3{,}009 \;\; kPa$$

$$T_{t3} \approx 848 \;\; K$$

$$T_{t4} \approx 1{,}729 \;\; K$$

$$\tau_t \approx 0.663$$

$$\pi_c\big|_{off-design} \approx 23.0$$

Problem 4.18

$$f = 0.0232$$

$$\tau_t = 0.705$$

$$\pi_{c-Off-Design} \approx 18.6$$

Problem 4.20

$$M_0 = \sqrt{\left(\frac{2}{\gamma-1}\right)(\tau_\lambda - 1)}$$

Problem 4.21

$$M_{0,opt} = \sqrt{\frac{2}{\gamma-1}\left(\sqrt[3]{\tau_\lambda} - 1\right)}$$

Problem 4.24

$$\tau_\lambda = 7.588$$

$$f = 0.033$$

$$\frac{F_n}{\dot{m}_0 a_0} = 2.1324$$

$$\eta_p = 0.68$$

$$\eta_{th} \approx 0.415$$

Problem 4.25

$$\frac{\wp_c}{\wp_f} = 2.304$$

$$f \approx 0.0181$$

$V_{19}/V_9 = 0.6758$

$$\frac{F_{n-fan}}{F_{n-core}} \cong 2.537$$

$\eta_{th} \approx 39.8\ \%$

$\eta_p \approx 75.0\%$

$$TSFC \approx 18.47\ mg/s/N$$

$$I_s \approx 5{,}523\ s$$

Problem 4.26

$$\eta_n = 0.901$$

$$\frac{V_9}{a_0} = 3.72$$

$$\frac{(p_9 - p_0)A_9}{\dot{m}_9 a_0} = 0.0913$$

Problem 4.28

$$f = 0.044$$

$$M_9 = 2.363$$

$$\frac{F_n}{\dot{m}_0 a_0} = 2.588$$

Problem 4.29

$$\eta_{th} \approx 0.313$$

$$\eta_{th} \approx 0.504$$

Problem 4.30

$$\wp_t = 9.096\ MW$$

$$F_{g_{core}} = 8.96\ kN$$

$$M_8 = \frac{V_8}{a_8} = 1.00$$

$$F_{n_{core}} = 4.648\ kN$$

$$\eta_n = 0.935$$

$$\eta_{LPT} = 0.900$$

Problem 4.31

$$\frac{\dot{m}_{15}}{\dot{m}_5} = 4.0$$

$$\frac{A_{6M}}{A_5} = 3$$

$$p_{6M}(1+\gamma M_{6M}^2) = 164.106\ kN$$

$$\frac{T_{t6M}}{T_{t5}} = 0.40$$

Problem 4.32

$$\wp_t = 7.15\ MW$$

$$\wp_{prop} = 7.01\ MW$$

$$F_{prop} \simeq 56.1\ kN$$

Problem 4.34

$M_{0,opt} \approx 2.40$

The effect of fuel heating value on optimum flight Mach number is negligibly small

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Problem 4.35

$M_9 \approx 3.81$

$$\frac{D_r}{p_0 A_1} \approx 50.4$$

$$\frac{F_g}{p_0 A_1} \approx 64.0$$

$I_s \approx 2{,}841$ s

Problem 4.36

Percent change in fuel-to-air ratio = +78.95%
Percent change in TSFC = +30.1%
Percent change in nozzle exit temperature = +72.8%
Percent change in thrust = +37.6%
Percent change in exhaust speed = +27.5%
Percent change in thermal efficiency = - 5.64%

Problem 4.37

D_r=3.5546 kN
η_c=0.8482

$\wp_{HPT}$ =0.9562 MW

$\wp_f$ =0.4387 MW

$F_{g,c} \approx 1.718$ kN
$F_n \approx 2.444$ kN
TSFC≈20.155 mg/s/N

$\eta_{th} \approx 49\%$

$\eta_p \approx 60\%$

Problem 4.38

T-t3 (K)	f	Tau-Lamb	p-t4 (kPa)	h-t-4.5	T-t-4.5 (K)	Tau-t-HPT	Pi-t-HPT
883	0.0256	7.338	1552	1317110	1143	0.6929	0.1575

p-t-4.5	h--t5	T-t5	Tau-LPT	e-t (LPT)	p-t5	P-LPT(MW)	F-prop (kN)
244.5	964340	837	0.73216	0.8590	56.6	18.09	57.4

T-9i (K)	T-9 from eff.	V-9 from eff.	a-9 from eff	M-9 (exact)	pt-9 from eff	Pi-n
715.0	721	517	523	0.987	54.7	0.966

F-core (kN)	F-total (kN)	P-prop (MW)	P-core (MW)	PSFC (mg/s/kW)	TSFC (mg/s/N)	Etha-thermal	Etha-propuls
13.3	70.7	17.8	5.1	55.7	18.1	0.427	0.814

Problem 4.39

$$\eta_{th}\big|_{regen.} \approx 70.3\%$$

$$\eta_{th}\big|_{Brayton} \approx 48.2\%$$

Problem 4.40

Tau-r	Pi-r	a-0 (m/s)	V-0 (m/s)	p-t0 (kPa)	T-t0 (K)	p-t2 (kPa)	p-t13 (kPa)
2.25	17.0859	309	773	427	535.5	363	545

Tau-f	T-t13 (K)	p-t3 (kPa)	Tau-c	T-t3 (K)	p-t4 (kPa)	f	p-t15 (kPa)
1.137371	609	4357	2.20	1179	4095	0.02233	539

Pi-t	Tau-t	T-t5 (K)	T-5 (K)	a-5 (m/s)	p-t5 (kPa)	p-5 (kPa)	Alpha
0.131649	0.6687	1204	1156	663	539	458	0.293

h-t6M (J/kg)	M-15	T-15 (K)	a-15 (m/s)	p-15 (kPa)	A15/A5	c-p6M	gama-6M
1213921.4	0.488	581	483	458.1	0.203261	1119.03	1.343423

C1	T-t6M (K)	C2	C	M-6M	p-6M	p-t6M-i (kPa)	Pi-M (ideal)
1.332673	1084.8	0.51551	6.683	0.511	451.8	536.5	0.995

p-t6M (kPa)	Pi-M	p-t7 (kPa)	f-AB	p-t9 (kPa)	M-9	T-9 (K)	a-9 (m/s)	V-9 (m/s)
509.7	0.9453	468.9	0.0387	445.4	1.93	1411	725	1400

V-9eff	F-n/(1+Alfa)m.a0	TSFC (mg/s/N)	Eta-therm	Eta-prop	Eta-overall	f+f-AB
1577	2.842	53.7	0.497	0.677	0.336	0.061

Problem 4.41

p-t-0 (kPa)	**T-t-0 (K)**	**Tau-r**	**Pi-r**	**a-0 (m/s)**	**V-0 (m/s)**	**p-t-2 (kPa)**	**p-t-3 (kPa)**	**Tau-c**
107	439	1.968	10.6927	299.3	658.4	94.10	753	1.935

T-t-3 (K)	**T-t-4 (K)**	**p-t-4 (kPa)**	**f**	**Tau-t**	**T-t-5 (K)**	**Pi-t**	**p-t-5 (kPa)**

849.2	1449.5	692.5	0.01518	0.7064	1024.0	0.2627	182

p-t-7 (kPa)	T-t-7 (K)	f-AB	p-t-9 (kPa)	M-9	T-9 (K)	a-9 (m/s)	V-9 (m/s)
164	2007	0.0264	155.6	2.440	916.2	606.6	1480.0

Fn/m-a0	TSFC (mg/s/N)	Eta-th	Eta-p (exact)	Eta-p (approx)	Eta-thermal
2.95	47.1	0.52854	0.6293	0.6158	0.5285

D-ram (kN)		Power-comp (MW)		F-g (kN)
6.58		4.120		15.42

$A_9 \approx 0.203\ m^2$

Problem 4.42

M_0
1.992

M_9
1.67

V_9 (m/s)
1088

Problem 4.43

A_9 (m^2)	F_g (N)	V_9eff	F_TO (kN)	I_s (s)
0.233	115137	1112.4	115.1	3357

Problem 4.44

$f \approx 0.0275$

$p_{t5} \approx 507$ kPa

$f_{AB} \approx 0.0359$

$M_9 \approx 1.61$

Problem 4.45

Power_i (MW)	p_t5	T_t5
26.83	30	676.5

Power-LPT (MW)	T_9 (K)	V_9 (m/s)
22.31	619	363

Problem 4.46

Eta-propulsive
0.935

Problem 4.47

f	Tau-t	T-t-5 (K)	Pi-t	m-dot-f
0.02683	0.7299	1285	0.2248	2.683

p-t-9 (kPa)	M-9	T-9 (K)	D-ram (kN)	F-net (kN)
525.0	2.62	604	60.5	68.3

Problem 4.48

V-9 (m/s)
634

V-9 (m/s)
750

Problem 4.49

D-r (kN)	T-t2 (K)	p-t0 (kPa)	p-t2 (kPa)	T-t3 (K)
11.045	240	43.6	42.70	638.7

T-t4 (K)	Pi-c	p-t3 (kPa)	p-t4 (kPa)	T-t4.5 (K)
1509	21.74	928	882.0	1169

p-t4.5	T-t5 (K)	Pi-LPT	p-t5 (kPa)	F-prop(kN)	p-t9 (kPa)	Power-LPT (MW)	M-9
263	826.0	0.203541	53.52	74.24	52.99	20.41	0.960

F-c (kN)	TSFC (mg/s/N)
14.73	15.74

Problem 4.50

T-t3	e_c
686	0.900

Problem 4.51

V_0	f
627	0.0347

V_9	F_g/D_r
1477	2.354

Problem 4.52

D-r (kN)	F-g (fn) kN
127.4	142.1

F-n (kN)	Eta-th	Eta-p	TSFC (mg/s/N)
47.2	0.34	0.82	22.2

Problem 4.53

c-p6M (J/kg.K)	gamma-6M	T-t6M (K)	M-15
1042	1.38	605.4	0.390

A-15/A-5
2.200

Problem 4.54

f
0.021

T-t-5 (K)
1170

p-t-5 (kPa)
394

f-AB
0.026

TSFC (mg/s/N)	Eta-th	Eta-p (exact)	Eta-p (approx)	Eta-thermal
53.42	0.493	0.666	0.648	0.493

D-ram (kN)	Power-comp (MW)	F-g (kN)
37.41	18.75	81.64

Problem 4.55

m-dot-f (kg/s)	f	P-c (kW)	P-t (kW)	P-f (kW)	Alpha	T-t6M (K)	M-8
0.62	0.0248	9849	18965	9116	7.844	404	0.691

T-8 (K)	a-8 (m/s)	V-8 (m/s)	F-n (kN)
369	385	266	59

Problem 4.56

Delta-h_t (kJ/kg)	Delta-T-t (K)	P-prop (MW)	F-prop (kN)
441.9	383.6	4.44	18.87

Problem 4.57

Shaft Power (MW)	A-2 (m^2)
121.0	1.125

Rho-3 (kg/m^3)	Delta (s)/R
13.18	0.40

Problem 4.58

Tau-r	Pi-r	T-t4 (K)	Tau-Lamb
1.8	7.82	1885.0	10.19

Press. Thrust/mom. Thrust	V-9eff (m/s)
0.26	1236

Eta-p	TSFC (mg/s/N)
0.679	72.5

Problem 4.59

p-t-13 (kPa)	M-19	p-19 (kPa)	T-t-13 (K)
73.09	1	37.45	315.7

a-19=V-19 (m/s)	V-19-eff (m/s)	Since p-19>p-0, then M-19 is 1.
325.0	371.2	

Problem 4.60

Power-LPT/m-dot (kJ/kg)
147

V-9 (m/s)
114.9

Problem 4.61

p-t-5 (kPa)	Shaft Power (MW)	Eta-t
171.3	90.5	0.89

Problem 4.62

gamma-6-M	c-p-6M (J/kg.K)	T-t-6M (K)
1.386	1030	463

Problem 4.63

Tau_r	Pi_r	T_t4	Tau_L
1.8	7.82	1885.0	10.19

V_9	Pressure thrust/Nozzle momentum thrust
978	0.264

V_9eff	Eta_p	TSFC (mg/s/N)
1236	0.680	72.50

Problem 4.64

D-ram (kN)	p-t3 (kPa)
24.3	1084

Power-c (MW)	Eta-d
20.97	0.866

Problem 4.65

q_0
9.856

T-t3 (K)
854.4

f
0.026

T-t-4.5 (K)
1157

p-t-4.5
205

T-t5
780.3

p-t5
33.6

M-9 (exact)
0.80

V-9 from eff.
415.3

F-prop (kN)
49.15

Problem 4.66

Tau-Lamb	9.30
V-9 (m/s)	1351
f	0.0394
F-n/(m-dot)(a0)	2.576
Eta-p	0.663
Eta-th	0.440

Problem 4.67

D_ram (kN)	28.54
Tau_fan	1.161

A_18 (m^2)	F_g(fn) (kN)	V_18_eff
0.588	35.57	356
A_8 (m^2)	**F_g(cn) (kN)**	**V_8_eff**
0.163	11.93	586

Pi_fan
1.60

TSFC (mg/s/N)	Eta_th (%)	Eta_p (%)
19.40	40.8	70.2

Problem 4.68

D-r (kN)	p-t4 (kPa)	T-t4 (K)
74.5	313	2003

M-9	V-9 (m/s)	F-g (kN)	TSFC (mg/s/N)
2.27	1472	154.6	62.46

Eta-th
0.410

Eta-p
0.694

Chapter 5

Problem 5.1

BHP = IHP*η_{mech} = 481.70 HP

IHP = 535.2 HP

FHP =53.5 HP

BMEP = 144.00 psi

Compression Ratio = 7.54

Problem 5.2

BHP = 171.27 HP

Problem 5.3

BSFC = 0.43 lbs/hp/hr

$\eta_{thermal}$ = 29.69%

Problem 5.4

BMEP = 115.6 psi

IMEP = 128.44 psi

Problem 5.5

245^{o}

Problem 5.6

373^{o}

Chapter 6

Problem 6.1

$\pi_d \approx 0.968$

$\eta_d \approx 0.928$

Problem 6.2

Pi-d

0.948

A2/A0

1.385

p2/p0

1.2814

Problem 6.3

$C_{p,stag}=1.170$

$M_1 \approx 0.66$

$A_1/A_{th}=1.062$

$A_2/A_{th}=1.317$

$$\frac{D_{add}}{p_0 A_1} \approx 0.0061$$

Problem 6.4

$$\frac{D_{add}}{p_0 A_1} \approx 0.01246$$

Problem 6.5

$\tau_r=1.8$

$\Delta s/R \approx 0.1056$

$\eta_d \approx 0.933$

Problem 6.6

$M_2 \approx 0.485$

$C_{pR} \approx 0.473$

Problem 6.7

$M_1 \approx 0.65$

$D_{add} \approx 935$ N

$\dot{m}_0 \approx 254.5\, kg/s$

$D_r \approx 68.3\ kN$

$A_2 \approx 3.58\ m^2$

Problem 6.8

$A_0/A_2 \approx 2.557$

Problem 6.9

$D_{add} \approx 5376$ N

Problem 6.10

$M_{th} \approx 0.53$

Below critical throat Mach number of 0.75, therefore, there is no adverse shock boundary layer interaction due to the convex throat geometry.

Problem 6.11

$A_M/A_1 \approx 4.16$

Problem 6.12

$$\overline{p}_{t,area-avg} = p + \left(\frac{\rho}{2}\right)(0.948\, V_1^{\,2})$$

$$\overline{p}_{t,mass-avg} = p + \left(\frac{\rho}{2}\right)(0.9545 V_1^{\,2})$$

Problem 6.13

$M_1 \approx 0.52$

$M_2 \approx 0.36$

$p_1/p_0 \approx 1.2677$

$p_2/p_1 \approx 1.0994$

Problem 6.14

$$C_{D,cowl} = 2\left(\frac{A_1}{A_M}\right)\left(1 - \frac{A_{spil}}{A_1}\right)\left(\frac{V_1}{V_0} - 1\right) + \frac{2}{\gamma M_0^{\,2}}\left(\frac{p_1}{p_0} - 1\right)$$

Problem 6.15

% opening is $=(A_{th'} - A_{th})/A_{th} \approx 621\%$

Problem 6.16

$p_{t2}/p_{t0} = 0.900$

$A_2/A_{th} = 1.2378$

Problem 6.17

$M_1 \approx 0.56$

$\pi_d \approx 0.850$

Problem 6.18

M-Des	A1/A-th (geo)	M0 sub. (choked)	M0>M0 sub	A0/Ath sub	% spillage (sub)
1.6	1.250	0.56	0.7	1.0944	12.47

M-y (NS)des	Ay/A*	% spill.(sup)	My-overspeed	A/A*-oversp	M-th-oversp
0.668	1.1192	10.48	2.108	1.850	2.1

Problem 6.19

$M_{over\text{-}speed} \approx 2.92$
$q_0 \approx 119.37$ kPa

Problem 6.20

M-Design	**A-1/A***	**A-1/A-th**	**M-y (NS)**	**A-y/A***	**A-1/A-th'**	**% opening**
3	4.2345	4.234	0.475	1.390	1.390	204.5

Problem 6.21

% opening is ≈369.6%
$M_{th}' \approx 3.1$

Problem 6.22

A1/Ath (design)	M-th (started)	M-y (NS-th)	pt-recovery(best)
1.2165	1.55	0.684	0.913

Problem 6.23

$A_1/A_{th} \approx 1.1446$
$M_{th}' \approx 1.45$
$\pi_d \approx 0.945$

Problem 6.24

A1/Ath (design)	M-th (started)	M-y (NS-th)	pt-recovery(best)
1.4145	1.75	0.628	0.835

Problem 6.25

$M_x \approx 1.85$
% gain in total pressure recovery≈13.3%

Problem 6.26

M-Design	**A-1/A***	**A-1/A-th**	**M-y (NS)**	**A-y/A***	**A-1/A-th'**
1.6	1.250	1.250	0.668	1.119	1.119

% opening	**A-th'/A***	**M-th'**	**pt-recov (best)**
11.71	1.117	1.4	0.958

Problem 6.27

$M_{over\text{-}speed} \approx 1.784$

Problem 6.28

M-design	M-y (NS)	A1/Ath (design)	M-th (started)	M-y (NS-th)	pt-recovery(best)
2	0.577	1.216	1.55	0.684	0.913

Problem 6.29

Loss~8.5%

Problem 6.30

M-Design	**A-1/A***	**A-1/A-th**	**M-y (NS)**	**A-y/A***	**A-1/A-th'**
2.6	2.896	2.896	0.504	1.332	1.332

% opening	**A-th'/A***	**M-th'**	**pt-recov (best)**
117.3	2.17	2.25	0.606

Problem 6.31

% opening is =38.72%

Problem 6.32

$M_{x, \text{shock}}=2$

$p_y=211.3$ kPa

$p_{ty}=264.8$ kPa

$A_2/A_1=0.8694$

Problem 6.33

$P_{ty}/p_{tx}=0.785$

$\pi_d \approx 0.697$

$\pi_d \approx 0.7464$

$q_0=72.65$ kPa

Problem 6.34

$p_{t3}/p_{t0}=0.813$

Normal shock at Mach 2.5 gives π_d=49.9%, therefore two external ramps improve the inlet recovery significantly. Compare 81.3% to 49.9%.

Problem 6.35

$\theta_1 \approx 12.2^o$

$\theta_2 \approx 13.87^o$

Problem 6.36

A9/A-th (spec)	M9 (isen)	p9/pt-9	Neu-9 (deg)	Plume angle (deg)-given	Neu-10 (deg)
2	2.15	0.101	30.42	15	45.42

M10	p10/pt-10	p0/pt9	NPR(perfect)	NPR(actual)
2.75	0.0398	0.0398	9.89	25.1

In the over-expanded mode:

A9/A-th (spec)	M9 (isen)	p9/pt-9	NPR (perfect)	NPR (NS at the lip)
2	2.15	0.101	9.89	1.892

Problem 6.37

p_0= 46.4 kPa
T_y=708 K
$\dot{m} \cong 36.96$ kg/s

Problem 6.38

Altitude is ~8 kft
Altitude is ~26 kft
Altitude is ~ 1400 ft.

Problem 6.39

A_9/A_8=8.17
M_9=3.7
V_9=1715 m/s

Problem 6.40

A9/A-th (spec)	M9 (isen)	p9/pt-9
2.4	2.35	0.0739

plume angle (deg)	Beta (deg)	M9.sin(beta)	p-y/p-x	NPR
15.95	40	1.510	2.495	5.418

Problem 6.41

M_{10}=4
$\theta \approx 7.26^o$
$\mu \approx 14.48^o$

Problem 6.42

A9/A-th (spec)	M9 (isen)	p9/pt-9
3.5	2.79	0.0374

plume angle (deg)	Beta (deg)	M9.sin(beta)	p-y/p-x	NPR
15	33.5	1.54	2.60	10.3

p_{t7} = 102.8 kPa

Problem 6.43

P_9=224.6 kPa
T_9=817 K
V_9=556 m/s
$\eta_n \approx 0.97$
V_{9s}=564 m/s
% gross thrust gain=2.43
C_{D8}=0.98

Problem 6.44

C_A(conical)=(1+cosα)/2=0.953

$C_A(2D)=\sin\alpha/\alpha=0.968$ ➡ 2D rectangular nozzle produces ~1.6% higher gross thrust than the conical nozzle

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Problem 6.45

$T_m/T_c=1.444$
% F_g improvement ≈3.4%

Problem 6.46

a) $p_0=p_9=2.656$ kPa

b) $p_0=39.7$ kPa

c) $A_9=3.95\ m^2$

d) $F_g= 44$ kN

e) $F_g= 24$ kN

f) $F_g=46.6$ kN

Problem 6.47

$A_j=27.98\ cm^2$
$A=111.92\ cm^2$
$A_1=83.94\ cm^2$
Percent increase in mass flow rate = 147.1%
Percent drop in exit temperature = 40.4%
Gross thrust with ejector = 896.2 N
Gross thrust of the jet = 784.6 N

Problem 6.48

$M_9 \approx 1.56$

$\eta_n \approx 0.975$

Problem 6.49

$p_t/p_0=61.5$
NPR=19.8
NPR (actual)=255.2
NPR (perfect)=61.5

Problem 6.50

NPR ~ 654

Problem 6.51

$$\frac{F_{g-CD}}{F_{g-Conv.}} \approx 1.0918$$

Gross thrust is enhanced by ~9.2% in de Laval vs. convergent

Problem 6.52

$M_{th} \approx 1.54$
$M_x \approx 1.8$
Two-Shock Total Pressure Recovery ≈ 0.756

Problem 6.53

M_9 (from isentropic table)	p_9 (kPa)	Pressure thrust/momentum thrust
2.52	7.71	0.0425

Problem 6.54

Pi-KD (NS table)	Pi-NS (NS table)	% gain in Pi	M-th (table)
0.936	0.856	9.3841	~ 1.48

Problem 6.55

A-spillage/A-1	Pi-d
0.061	0.930

Problem 6.56

q-1 (kPa)
14.75

p-2 (kPa)	C-PR
96.7	0.839

Problem 6.57
I_0=21.25 kN
I_1=23.73 kN
D_{add}=2.48 kN
$D_r \approx 10$ kN

Problem 6.58

q_1 (kPa)	p_2 (kPa)	p_t2 (kPa)	A_2/A_1
11.2	108.4	110.31	3.745

Problem 6.59

M1	p-1/p0	V-1/V0
0.64	1.230	0.767

Problem 6.60

Pi_shock	M_3
0.939	0.786

Problem 6.61

% Opening
621

Problem 6.62
% spillage = 7.93

Problem 6.63

$M_8=1.0$
$p_8/p_0=1.60$

Problem 6.64

$M_9=2.82$
$p_9/p_{t7}=0.033$
$p_y/p_x=1.502$

Problem 6.65

M-8	p-8 (kPa)	V-8 (m/s)
1	40.9	441

Problem 6.66

p-t-2 (kPa)	p-th (kPa)	q-th (kPa)
73.6	54.1	18.55

Problem 6.67

$M_8=0.78$
$V_8=373$ m/s

Problem 6.68

$M_1=0.62$
M_2-0.5

Problem 6.69

$C_{fg}=0.90$
% Increase in $F_g=3.96$

Problem 6.70

$\pi_d=0.732$

Problem 6.71

$M_9=2.4$
$A_9/A^*=2.653$

Problem 6.72

$D_r=22.5$ kN
$\pi_d=0.75$

Problem 6.73

$D_r=25.75$ kN
$A_0=0.9585$
$p_1=34.43$ kPa
$T_1=268.3$ K
$A_1=1.05$ m^2
$D_{add}=228.3$ kN

Problem 6.74

M_9=2.52
p_9=11.7 kPa
β=34.3°

Problem 6.75
M_1=0.62
M_{th}=0.68
M_2=0.52
C_{PR}=0.648

Problem 6.76
M_9=2.52
p_0=77.6 kPa

Problem 6.77
A_1/A_{th}=1.09
p_{t2}/p_{t1}=0.976
M_{th}=1.32

Problem 6.78
A_0=0.930 m^2
$\dot{m} = 112.2\ kg/s$

Problem 6.79
M_1=1.6
p_{t2}/p_{t0}=0.895
p_3=50.6 kPa

Problem 6.80
D_{add}/p_0A_1=0.0229

Problem 6.81
$M_{HL}\approx0.6$

Problem 6.82
D_{add}/p_0A_1=0.0352 for A_0/A_1=0.82
D_{add}/p_0A_1=0.0578 for A_0/A_1=0.76

Problem 6.83
p_1=50 kPa, p_2=30 kPa and p_3=25 kPa
D'=6.75 kN/m
$M_0\approx1.7$

Problem 6.84
p_{t2}/p_{t1}=0.979 per shock
$\pi_{shock\ system} = 0.920$
$\pi_{inlet} = 0.915$
$\pi_{4-shock\ optimum} = 0.920$
$M_0\approx2.6$

Chapter 7

Problem 7.1

$$n_{CO_2} = 1\ kmol$$
$$n_{N_2} = 4\ kmol$$
$$n_{O_2} = 1\ kmol$$
$$\chi_{O_2} = \frac{1}{6}$$
$$p_{CO_2} = 0.167 bar$$
$$p_{N_2} = 0.667 bar$$
$$p_{O_2} = 0.167 bar$$
$$MW_m = 31.3\ kg/kmole$$
$$\frac{V_{CO_2}}{V_m} = \frac{1}{6}$$
$$\frac{V_{N_2}}{V_m} = \frac{2}{3}$$
$$\frac{V_{O_2}}{V_m} = \frac{1}{6}$$

Problem 7.2

f_{stoich}=0.029

Problem 7.3

$$\frac{n_{O_2}}{n_m} = 0.22; \quad \frac{n_{N_2}}{n_m} = 0.33; \quad \frac{n_{CO_2}}{n_m} = 0.45$$

$$MW_m \approx 36.08\ kg/kmole$$

Problem 7.4

f_{stoich}=0.0684

Problem 7.5

$$LHV \approx 44,879\ kJ/kg$$
$$HHV \approx 48,350\ kJ/kg$$

Problem 7.6

Since N_2 is assumed to have no chemical reaction, the LHV and HHV are the same as problem 7.5.

Problem 7.7

2700 K

2500 K

Problem 7.8

$$\phi = 0.9091$$

Problem 7.9

$$\frac{mass_{fuel}}{mass_{air}} \approx 0.0554$$

$$\left(\frac{mass_{fuel}}{mass_{air}}\right)_{stoich} \approx 0.0664$$

$$\phi \approx 0.834$$

$$T_2 \approx 2032\ \ K$$

Problem 7.10

$$\chi_{O_2} = 0.254$$

$$\chi_{O_2} = 0.629$$

Problem 7.11

$$\chi_{H_2} = 0.927$$

$$\chi_{H_2} = 0.9921$$

Problem 7.12

p=1.18 atm

Problem 7.14

M_e=0.225 with p_{te}/p_{ti}=0.982 (Dry Mode)
M_e=0.438 with p_{te}/p_{ti}=0.916 (Wet Mode)

Problem 7.15

$$M_2 \approx 0.23$$

Problem 7.16

$$LHV \approx 21{,}128\ \ kJ/kg$$

$$HHV \approx 23{,}877\ \ kJ/kg$$

Problem 7.17

$$LHV \approx 46{,}454\ \ kJ/kg$$

$$HHV \approx 50{,}452\ \ kJ/kg$$

Problem 7.18

f=0.01457

$$T_{af} \approx 1{,}522\ \ K$$

Problem 7.20

$$\frac{A_2}{A_1} = 4$$

$$\frac{\Delta p_t}{p_{t1}} = 0.0796$$
$$M_2 = 0.0954$$

Problem 7.22

$$\frac{\Delta u}{\overline{u}} = 0.4$$
$$u_{2,upper} = 24.5\ m/s$$
$$u_{2,lower} = 33.2\ m/s$$
$$\frac{\Delta u}{\overline{u}} = 0.3$$
$$u_{2,upper} = 14.14\ m/s$$
$$u_{2,lower} = 26.46\ m/s$$

Problem 7.23

$$0.05 < f < 0.225$$

Problem 7.24

$$\frac{p_e}{p_i} = 0.969$$

$$M_e = 0.234$$
$$\frac{T_e}{T_i} = 0.9693$$
$$\frac{p_{te}}{p_{ti}} = 0.9788$$

Problem 7.25

$$M_e = 0.3078$$
$$\frac{p_e}{p_i} = 0.9297$$
$$\frac{p_{te}}{p_{ti}} \approx 0.9603$$
$$M_e = 0.3078$$

Problem 7.26

$$\sim 97,200\ kg$$

Problem 7.27

$$\eta_b \approx 0.9819$$
$$\eta_b = 0.95$$

Problem 7.29

MW_air (hot)	f
21.76	0.092

Problem 7.30

$Q_R \approx 1906$ kJ/kg

Problem 7.31

f=0.039

ϕ=0.667

T_{af}=1783 K

Problem 7.32

HHV=23.95 MJ/kg

Problem 7.33

T_{af}=2266 K

Problem 7.34

Q_R=114,868 kJ/kg

LHV=114,868 kJ/kg

T_{af}=4794 K

Problem 7.35

f	f_stoich	Phi
0.05281	0.06500	0.8125

Problem 7.36

f	f_stoich	Phi
0.041	0.067	0.62

T_adiabatic flame (K)
1728

LHV in kJ/kg (comb. in air)
44327

Problem 7.37

HHV=50.32 MJ/kg

Problem 7.38

T_adiabatic flame (K)
1879

Problem 7.39

A_1=3.855 m^2

D_{fh}=7.614 kN

p_2=29.6 kPa

T_2=670 K

Problem 7.40

a) T_{af}=2410 K
b) T_{af}=2295 K

Problem 7.41

f=0.039
ϕ=0.5952
T_{af}=1529 K

Problem 7.42

T_{af}=2065 K
LHV=27,772 kJ/kg
HHV=30,640 kJ/kg

Problem 7.44

f=0.0685

Chapter 8

Problem 8.1

$$w_c = 30.83\ kJ/kg$$

$$\frac{\tau}{\dot{m}} = 56.4\ m^2/s$$

Problem 8.2

ω=4074 rpm
$C_{\theta 2m}$=228 m/s
w_{cm}=51.2 kJ/kg
W_{2m}=299.3 m/s
τ_s=- τ_r=-120 m^2/s
ψ_m=0.78125
ϕ_m=0.605

Problem 8.3

$$W_{\theta 1} = 179.6\ m/s$$

$$W_{\theta 2} = 81.6\ m/s \uparrow$$

$$W_{1m} = 250.8\ m/s$$

$$W_{2m} = 193.1\ m/s$$

$$D_{rm} = 0.393$$

$$\Gamma_m = 4.9\ m^2/s$$

$$L' = 1,059.7\ N/m$$

$$C_\ell = 0.0337$$

$$w_{cm} \approx 20.58\ kJ/kg$$

$$\psi_m = 0.467$$

$$^o R_m = 0.622$$

Problem 8.4

$W_2 > 0.72\ W_1 \quad \to \quad W_{2,\min} = 126\ m/s$

$C_p \approx 0.442$

Problem 8.5

$\tau_s = 1.1609$

$\eta_s = 0.8932$

Problem 8.6

$w_{cm} = 20.87\ kJ/kg$

$\frac{T_{t3}}{T_{t1}} = 1.072$

$M_{2r} = 0.49$

$\frac{p_{t2}}{p_{t1}} = 1.264$

$\frac{p_{t3}}{p_{t2}} = 0.996$

$\eta_s = 0.945$

${}^oR = 0.5$

Problem 8.7

$w_c = 68.54\ kJ/kg$

${}^oR = 0.5$

Problem 8.8

$M_2 = 0.682$

p_{t3}=149.3 kPa

M_3=0.47

$\tau_s = -8,000\ N \cdot m$

$p_3 - p_2 = 18.35\ kPa$

$T_3 - T_2 = 12.75\ K$

$\frac{s_3 - s_2}{R} = 0.00478$

Problem 8.9

$w_c = 43.86\ kJ/kg$

$\pi_s = 1.515$

$\pi_c \simeq 5.27$

$\wp_m = 4.387\ MW$

$D_{rm} = 0.62$

Problem 8.10

$\alpha_{1m}=29^o$
$\beta_{1m}=-35.8^o$
$\alpha_{2m}=35.8^o$
$\beta_{2m}=-29^o$
$w_c=6.9$ kJ/kg

$$\frac{\tau_r}{\dot{m}}=1.5\ m^2/s$$

Problem 8.11

$$T_0=224\ K$$
$$T_1=212.8\ K$$
$$\omega\approx 5{,}585\ rpm$$

Problem 8.12

$${}^oR_m=0.34$$
$$\frac{p_{t2}}{p_{t1}}=1.789$$

Problem 8.13

$$w_c=33.58\ kJ/kg$$
$$\psi_m=1$$
$$\phi_m=0.954$$
$$M_{1r,m}=0.766$$
$$\pi_s=1.424$$

Problem 8.14

$$\eta_c=0.85$$
$$\wp_c=57.6\ MW$$

$T_{t3}=870$ K
$\pi_{stage}=1.40$

Problem 8.15

$$\tau_c=2.82$$
$$\pi_c=26.2$$
$$\dot{m}_{c2}=102.6\ kg/s$$
$$\eta_c=0.847$$

Problem 8.16

$e_c\approx0.90$

Problem 8.17

$$T_{t2}=1{,}413\ {}^oR$$

$\eta_c = 0.878$

$w_c = \left(h_{t3} - h_{t2}\right) = 214.32 \; BTU/lbm$

$\wp_c = 21,432 \; BTU/s$

Problem 8.18

π_s=1.495

η_s=0.915

τ_c=2.717

Problem 8.20

$W_{\theta 2m} = 288.7 \; fps$

$C_{\theta 2m} = 911.3 \; fps$

$\frac{\tau}{\dot{m}} = 911.3 \; ft^2/s$

$\frac{\Delta T_t}{T_{t1}} = 0.347$

$a_2 = 1216 \; fps$

$M_{2m} = 0.855$

$p_1 = 12.8 \; psia$

p_{t2}=38.1 psia

C_{pm}=0.864

ω=11,460 rpm

$\frac{\tau}{\dot{m}} = 911.3 \; ft^2/s$

$F_z\Big|_{blade} = -518.4 \; lbf$

$F_\theta\Big|_{blade} = -323.5 \; lbf$

$\frac{L'}{D'} = 1.878$

$w_c = 109,360 \; ft^2/s^2$

Problem 8.21

$\mathrm{Re}_c = 2.46 \times 10^6$

Problem 8.22

$\Gamma = 337.1 \; ft^2/s$

Ideal Lift=674 lbf/ft

Actual Lift=671 lbf/ft

% Loss of Ideal lift=0.445

Problem 8.23

$U_m = 188.5 \; m/s$

$C_{\theta 2m} = 109.57 \; m/s$

$$C_{\theta 2}(r) = 365.23r\ m/s$$

$$^{o}R(r) = 1 - \frac{0.0261}{r^2}$$

Problem 8.24

M_{1r}=0.544
T_{t1}=305 K
w_c=12.0 kJ/kg
T_{t2}=317 K
M_{2r}=0.448
π_s=1.135
^{o}R=0.5

Problem 8.25

$$T_0 = 286.8\ K$$

$$p_0 = 87.45\ kPa$$

$$p_{t1} = 99.76\ kPa$$

$$q_0 = 11.96\ kPa$$

$$T_1 \approx 284\ K$$

$$p_1 = 84.291\ kPa$$

$$p_{t1r} = 107.22\ kPa$$

$$M_{2r} = 0.4912$$

$$\overline{p}_{t2r} = 106.59\ kPa$$

p_2 = 90.37 kPa
$p_{t2} \approx$ 114.4 kPa

Problem 8.26

w_c=1.414x10^6 ft.lbf/slug

Problem 8.27

$$\gamma^{\circ} = 32^{\circ}$$

Problem 8.28

ρ_3/ρ_2=12.05
A_3/A_2=0.083

Problem 8.29

$$r_{t1} \simeq 0.487\ m \quad ; r_{h1} \simeq 0.244\ m$$

$$\omega \approx 8,504\ rpm$$

$$C_{\theta 2m} \approx 326\ m/s$$

$$T_{t2m} \approx 394\ K$$

$$p_{t2m} = 281\ kPa$$

$$p_{t2m} = 281\ kPa$$

$$\rho_{2m} = 1.3\ kg/m^3$$

$^{o}R_{tip} = 0.5$

$^{o}R_{hub} = 0.5$

$D_{rm} = 0.99$

$r_h = 0.3\ m$

Problem 8.30

$\sigma_t = 1.4$

$\sigma_h = 3.5$

$^{o}R_m = 0.463$

$D_{rm} = 0.78$

$$\text{De-Haller Criterion} = \frac{\mathrm{W_{2m}}}{\mathrm{W_{1m}}} = 0.56 < 0.72 \qquad \textit{therefore not met}$$

$\psi_m = 0.725$

$\phi_m = 0.57$

$D_t = 0.82$

$^{o}R_h = 0.463$

$rC_\theta = cons\tan t$

$C_z = cons\tan t$

Therefore, $C_2(r) \neq$ constant

Problem 8.31

$\beta_{1m} = -51.34^\circ$

$\beta_{2m} = 0^\circ$

$^{o}R_m = 0.5$

Problem 8.32

$\gamma_h^\circ = \beta_{1h} = 54.4^\circ$

$$\gamma^\circ(r) = \beta_1(r) = \tan^{-1}\left\{\frac{418.9\ r}{150\left[\dfrac{r - r_h}{0.1}\right]^{1/7}}\right\}$$

Problem 8.33

$\pi_c \approx 9.54$

Problem 8.34

3,083 Hz
3,417 Hz

Problem 8.35

$$w_c = 21.26 \ kJ/kg$$

$$\frac{\tau}{\dot{m}} = 38.9 \ m^2/s$$

$$^oR_m = 0.7786$$

Problem 8.36

$$W_{\theta 2m} = 58.75 \ m/s$$

$$C_{\theta 2}(r) = 376.7r \ \ (1/s) \qquad r \ in \ meters$$

$$^oR(r) = 0.64 = const.$$

Problem 8.37

$$\frac{\sigma_{bending}}{p} = 160.517$$

Problem 8.38

$$\omega \ (rpm) < 7{,}134$$

Problem 8.39

$$D_{rm} = 0.376$$

$$^oR(r_m) = 0.698$$

Problem 8.40

Stall Margin =11.8%

Problem 8.41

ω=6939 rpm
$C_{\theta 2}$=173 m/s
^0R_m=0.667
D_r=0.378
τ_s=1.124
π_s=1.445

Problem 8.42

M_{1r}=0.93
W_2=150 m/s
T_2=313.7 K
M_2=0.876
M_3=0.400
τ_s=1.256
π_s=2.07

Problem 8.43

De Haller=0.773
^oR=0.824
w_c=31.67 kJ/kg
D_r=0.4272

Problem 8.44
$Power=121\ MW$
$A_2=1.125\ m^2$
$\rho_3=13.18\ kg/m^3$
$\Delta s/R=0.395$

Problem 8.45
$\beta_1=63.4^o$
$\beta_2=53.4^o$
$C_{\theta 2}=98\ m/s$
$\psi=0.327$

Problem 8.46
$M_{1r}=0.97$
$W_2=193\ m/s$
$T_2=306\ K$
$M_2=0.74$
$M_3=0.485$
$\tau_s=1.18$
$\pi_s=1.66$

Problem 8.47
$T_{t3}= 680.4\ K$
$M_2= 0.481$
$M_3= 0.31$
$\rho_3/\rho_2= 6.78$
$A_3/A_2= 0.1475$

Problem 8.48
$M_1=0.523$
$M_{1r}=0.80$
$p_1=83\ kPa$
$T_{t1}=303.4\ K$
$C_{\theta 2}=192\ m/s$
$^oR_m=0.53$
$w_c=38.45\ kJ/kg$
$T_2=308.1\ K$
$M_2=0.738$
$a_3=362$
$M_3=0.491$

Problem 8.49
$\omega=5002\ rpm$
$w_c=42.2\ kJ/kg$
$M_2=0.563$

Problem 8.50
$C_{\theta 2}=155\ m/s$
$T_{t2}=325.8\ K$
$T_2=302.7\ K$
$M_2=0.62$

M_{2r}=0.62
q_{1r}=67.1 kPa
p_{t1r}=174.3 kPa
p_2=132.1 kPa
p_{t2}=170.9 kPa
D_r=0.524

Problem 8.51
$C_{\theta 2}$=102.1 m/s
$W_{\theta 1}$=-204.1 m/s
$W_{\theta 2}$=-102.1 m/s
De Haller=0.754
D_r=0.436

Problem 8.52
w_c=39.48 kJ/kg
ψ=0.4
ϕ=0.477
$M_{1r,m}$=1.04
$\pi_{s,m}$=1.51
$D_{r,m}$=0.458
De Haller=0.692<0.72, therefore not satisfied

Problem 8.53
$C_{\theta 2}$=106 m/s
w_c=20.8 kJ/kg
T_{t2m}=303 K
De Haller=0.709<0.72 not satisfied
D_r=0.56

Problem 8.54
M_1=0.50
Shaft Power= 39.415 MW
A_1=0.562 m^2
M_2=0.32
A_2=0.082 m^2

Chapter 9

Problem 9.1
Shaft Power ≈ 624 kW
$\Delta T_t \approx 62\ ^oC$ (or K)

Problem 9.2
$r_2 \approx$19.48 cm

Problem 9.4
Mass flow rate=33.95 kg/s
$C_{\theta 2}$=330 m/s
$w_c \approx$121 kJ/kg
Shaft Power=4109 kW

π_c=2.713
M_2=0.985
$C_{\theta 3}$≈257 m/s

Problem 9.5

$\wp_c \approx 1.279\ MW$

$\dot{m}r_2 C_{\theta 2} \approx$ 3.086 kN.m

Problem 9.6

$C_r(r)$=25/r where r is in meters an C_r is in m/s
$C_\theta(r)$=50/r where r is in meters an C_θ is in m/s

Problem 9.7

$p_{t3}/p_1 \approx 3.19$
$p_{t3}/p_{t1} = 3$

$\eta_{TS} \approx 0.8895$

$\eta_{TT} \approx 0.885$

$e_c \approx 0.9012$

Problem 9.8

$C_{\theta 1}$=1204.3 r in m/s where ris in meters

$\alpha_1(r) = \tan^{-1}(12.043r)$

The IGV exit blade angle is = δ+α
Where δ is the deviation angle and is specified to be constant and α(r) is described above. Therefore IGV twist is higher than the flow angle variation with span by a constant deviation angle.

Problem 9.9

$M_{1r} \approx 1.414$
C_{PR}=0.714

Problem 9.10

$A_3/A_2=r_3/r_2=4$
$C_{r3}/C_{r2}=1/4$
$C_{\theta 3}/C_{\theta 2}=r_2/r_3=1/4$
$C_{PR}=1-1/AR^2=1-1/16=0.937$

Problem 9.12

$p_{t3}/p_1 \approx 7.816$

$\frac{T_{t3}}{T_{t1}} \approx 1.953$

$\eta_{TS} = =0.7869$

Problem 9.13

$\varepsilon \approx 0.9365$
Π_M=1.076
w_c =100.7 kJ/kg
τ_s=1.348

$\pi_s \approx 2.53$

Problem 9.14

ε =0.971
Π_M=1.212
w_c = 177.8 kJ/kg
τ_s=1.653
$\pi_s \approx 4.79$

Problem 9.15

$A_{2eff} \approx 157.08$ cm^2
$A_{2eff} \approx 153.28$ cm^2
$A_{2eff} \approx 137.95$ cm^2

Problem 9.16

U_2=502.2 m/s
w_c=226.95 kJ/kg
T_{t2}=514 K
ω =19,183 rpm

Problem 9.17

$A_2 = 2\pi r_2 b - Ntb$
$A_{eff}=A_2 - (N-1)\theta_{wake} r_2 b$
$B_2=(N-1)\theta_{wake} r_2 b/A_2$

Problem 9.18

M_2=0.81
$C_{\theta 3}$=167 m/s (inviscid)
$C_{\theta 3}$=158 m/s (viscous)

Problem 9.19

Mach Index=1.482
$C_{\theta 2}$=410.4 m/s
M_2=1.21
τ_c=1.79
π_c=6.02

Problem 9.20

U_2=555 m/s
$C_{\theta 2}$=450.4 m/s
w_c= 250 kJ/kg
M_2=1.205
$C_{\theta 3}$=257.4 m/s
C_{r3}=114 m/s

Problem 9.21

$C_{\theta 2}$=356 m/s
M_2=1.02
C_{r3}=112.5 m/s
$C_{\theta 3}$=267 m/s

Problem 9.22

$C_{\theta 2}$=349 m/s

M_T=1.14

a_2=382 m/s

Problem 9.23

A_1=0.0236 m^2

C_{z1}=128 m/s

ρ_1=1.23 kg/m^3

Mass flow rate=3.71 kg/s

U_2=366.5 m/s

$C_{\theta 2}$=330.2 m/s

Shaft Power=449.2 kW

M_2=0.986

$C_{\theta 3}$=220.2 m/s

π_c=3.1

Problem 9.24

A_1=0.1114 m^2

r_{h1}=1.893 cm

r_{t1}=18.93 cm

ω=1403 rad/s ≈13,400 rpm

Problem 9.25

p_{t3}/p_{t1}=3.79

p_3/p_1=4.08

M_3=0.35

w_c=156.6 kJ/kg

Chapter 10

Problem 10.1

$C_1 \approx 412$ m/s

$M_2 = 1.287$

$\tau / \dot{m} \approx 318.8 \ m^2/s$

Problem 10.2

$\alpha_2 \approx 58.6^o$

Problem 10.3

$C_{z2} \approx$343 m/s

C_{z3} = 387 m/s

$U_m \approx$ 427.4 m/s

^oR_m= 0.0795

w_t = 269.4 kJ/kg

Problem 10.4

$\alpha_2 = 67.4^o$
$\alpha_2 = 78.2^o$
w_t= 360 kJ/kg
w_t=720 kJ/kg

Problem 10.5

w_t =320 kJ/kg
ψ_m= 2

Problem 10.6

w_t=154.2 kJ/kg
β_3= -49.1^o
${}^oR(r_m) \approx 0.070$

Problem 10.7

$T_1 \approx$ 1,936 K
M_1 = 0.4706
p_1 = 1,736 kPa

Problem 10.8

$\alpha_2 \approx 61.1^o$

Problem 10.9

T_2=1354 K
$C_{z2} \approx$ 268 m/s
$C_{\theta 2} \approx$ 735 m/s
$M_1 \approx$ 0.35
$p_{t2} \approx$ 2987 kPa
$p_2 \approx$ 1,450 kPa

Problem 10.10

M_2 = 1.267
M_{2r}= 0.829
${}^oR \approx 0.087$
w_t = 388.8 kJ/kg
$T_3 \approx$ 1464 K
M_{3r} = 0.907

Problem 10.11

$U_2 \approx$ 425 m/s
w_t= 229.3 kJ/kg
${}^oR \approx 0.366$
Γ = 26.94 m^2/s
M_2 = 0.86
ρ_2= 3.36 kg/m^3
M_{3r} = 0.767
p_{t3} = 1.6499 MPa
ρ_3= 2.901 kg/m^3

Problem 10.12

$T_{tc,r} \approx 661$ K

Problem 10.13

$\pi_t = 0.18736$

$\eta_t \approx 0.8735$

$A_5/A_4 = 5.02$

Problem 10.14

$C_z \approx 140.0$ m/s

$w_t = 90$ kJ/kg

$\psi = 1.0$

$\varphi = 0.466$

$T_1 - T_2 \approx 38.9$ K

$T_2 - T_3 \approx 38.9$ K

Problem 10.15

$\rho_5/\rho_4 = 0.361$

$A_5/A_4 = 2.77$

Problem 10.16

$T_{t2r} = 1918$ K

$T_2 = 1769$ K

$T_{awr} \approx 1902$ K

Problem 10.17

$\Delta\eta/\eta_o \approx 0.0299$

Problem 10.18

$\sigma_z \psi_Z \approx 1.466$

$\sigma_z \approx 1.833$

Problem 10.19

$T_{aw} \approx 1624$ K for turbulent boundary layer

$T_{tg} \approx 1639$ K

Problem 10.20

$T_{tg} = 1654$ K

$T_{aw} = 1628$ for TBL

$T_{aw} = 1616$ for LBL

$h_g = 125.34$ W/m^{2}K

$q_w = 53.65$ kW/m^2

Problem 10.21

$h_g = 3641$ W/m^{2}K

Problem 10.22

$\dot{m} / span(m) \approx 149$ (kg/s)/m

Problem 10.23

$\dot{Q} = 150.6$ kW

$c_{p,mixed} = 1237$ J/kg.K

$T_{mixed} \approx 1{,}796$ K

Problem 10.24

$M_{2r}=0.74$
$\beta_3=-48.8^o$
$\alpha_3=-11.1^o$
$^o R=0.1881$

Problem 10.25

$\Delta\eta$ (knife edge)=0.0092
$\Delta\eta$ (groove)=0.0103

Problem 10.26

$T_{tg}=1890$
$T_{aw}=1861$ K
% Error=1.53

Problem 10.27

$T_{t5,c} = \approx 1{,}324.5$ K

$p_{t5,c} \approx 227.4$ kPa

Problem 10.29

Throat opening, o =1.757 cm

Problem 10.30

$\sigma_c/\rho_{blade} = 1.76827\text{x}10^6$ ft^2/s^2

$$\frac{\sigma_c}{\rho_{blade}} = 1.7100 \text{ ksi/slug/ft}^3$$

Single crystal super alloy

Problem 10.31

$U_2=346$ m/s
$\Delta T_t=207$ K
$a_2=735$ m/s
$a_3=735$ m/s
$M_2=1.00$
$M_{3r}=0.583$

Problem 10.32

$\alpha_2=64.9^o$
$w_t=256$ kJ/kg
$T_{t2r}=1348$ K
$M_2=1.01$
$a_3=688$ m/s

M_{3r}=0.727

Problem 10.33

$C_{\theta 2}$=694.3 m/s
M_2=1.019
M_{3r}=0.65
ψ_m=1.7

Problem 10.34

Mean torque=27.5 kN.m
T_2=1452 K

Problem 10.35

$C_{\theta 2}$=728 m/s
M_2=1.03
β_2=51.1^o
w_t=291.2 kJ/kg
ψ_m=1.82
^{o}R=0.09
M_{3r}=0.641

Problem 10.36

M_2=1.05
β_{2m}=37.6^o
T_{t2r}=1485 K
^{o}R=0.154

Problem 10.37

T_{aw}=1747 LBL
T_{aw}=1756 TBL
T_{tg}=1776 K

Problem 10.38

ε≈0.043

Problem 10.40

No. of cycles to failure ~ 800 for conventionally cast Rene 80
~ 4000 for DS Rene 150
~ 10^4 for DS eutectic

Chapter 11

Problem 11.1

$\dot{m}_{c2} \simeq 110.2\, kg/s$
$N_{c2} \approx$ 6,637 rpm
$\dot{m}_{fc} \approx$ 2.37 kg/s
F_c= 131.2 kN
$TSFC_c \approx$ 17.88 mg/s/N

Problem 11.2

$M_{z2} \approx 0.50$
$A_0 \approx 0.758\ m^2$

Problem 11.3

$p_{t4}/p_{t2} = 9.5$
$T_{t4}/T_{t2} \approx 5.613$
$A_4 = 0.1957\ m^2$
$\dot{m}_{c4} = 46.4\, kg/s$
$\dot{m}_4 = 186\ \ kg/s$

Problem 11.4

$\dfrac{\dot{m}_{c4}}{\dot{m}_{c5}} = 0.3847$

$\dfrac{\dot{m}_{c4}}{\dot{m}_{c3}} = 1.455$

Problem 11.5

$N_{c2} = 8{,}000$ rpm
$N_{c4} \approx 3{,}266$ rpm
$\pi_c = 32.7$
$\wp_c = \approx 211$ MW
$f \approx 0.0284$
$T_{t5}/T_{t4} = 0.71487$
$p_{t5}/p_{t4} \approx 0.1926$

$\dfrac{p_{t5}}{p_{t2}} = 5.922$

$\dfrac{T_{t5}}{T_{t2}} = 4.289$

Problem 11.7

$A_4 = 0.3375\ m^2$
$A_5 = 1.1973\ m^2$
$f_{AB} \approx 0.0514$
$A_{8\text{-dry}} \approx 0.946\ m^2$
$A_{8\text{-wet}} \approx 1.4838\ m^2$
$A_{9\text{-dry}}/A_{8\text{-dry}} \approx 1.579$
$(A_9/A_8)_{wet} = 1.634$
$F_{g\text{-dry}} = 698.4$ kN
$F_{g\text{-wet}} \approx 1014$ kN

Problem 11.8

$f = 0.0232$
$\tau_t = 0.7044$
$\pi_{c-OD} \approx 22.4$

$\dfrac{N_{c2,O-D}}{N_{c2,D}} \approx 1.11$

$$\frac{\dot{m}_{c2,O-D}}{\dot{m}_{c2,D}} \approx 0.8037$$

$M_{z2\text{-}OD} \approx 0.378$
$TSFC)_{design}$=23.5 mg/Ns
$TSFC)_{OD}$=33.4 mg/Ns

Problem 11.9
$\pi_{cH} \approx 10.90$
$\pi_f \approx 1.537$
$\alpha \approx 5.97$

Problem 11.10
$V_{9\text{-}Des}$=1133 m/s
η_{th}=0.4314 at Design Point
$TSFC)_{Des.}$=30.8 mg/Ns
$\pi_{c\text{-}OD}$=27.85
$V_{9,OD}$=1143 m/s
η_{th}=0.4704 at Off-Design Point (cruise)
η_p=0.355 at cruise
$TSFC)_{cruise}$=34.4 mg/Ns

Problem 11.13
$\pi_f \approx 1.515$
$\pi_{cH} \approx 17.21$
$\alpha \approx 7.818$

Problem 11.14
$\pi_{c\text{-}OD} \approx 6.83$
$\dot{m}_{c2,O-D} \approx 13.9\ \ kg/s$
$N_{c2,O\text{-}D}$=4,710 rpm
$M_{z2,OD} \approx 0.261$

Problem 11.15
$\pi_{c\text{-}OD} \approx 7.564$
$\dot{m}_{c2,O-D} \approx 36.4\, kg/s$
$\dot{m}_{2,O-D} \approx 57.2\, kg/s$
$f \approx 0.03$
V_9=1801 m/s
TSFC (DP) = 47.3 mg/s/N
TSFC (O-D) = 56.1 mg/s/N

Problem 11.16
A_2=0.557 m^2

Problem 11.17
$\pi_{c\text{-}Des} \approx 34$
$\pi_{c\text{-}OD} \approx 12.9$

Problem 11.18

Stall Margin≈10.25 %
$M_{z2@stal}$≈0.465

Problem 11.19
C_1=0.2130
C_2=0.1659
C_3=28.209
$\tau_{cH\text{-}OD}$=2.192
$\tau_{f\text{-}OD}$=1.111
$\pi_{f\text{-}OD}$=1.394
$\pi_{cH\text{-}OD}$=11.85
α_{OD}=5.63
$\dot{m}_{c2-OD} = 475\ kg/s$

Problem 11.20
$\dot{m}_{c0} = 199\frac{kg}{s}$
A_0=0.844 m^2
$\dot{m}_0 = 65.75\frac{kg}{s}$
A_{th}=0.905
D_r=16.56 kN

Chapter 12

Problem 12.1
$D_2 \approx 5.598$ ft

Problem 12.2
A_2/A_{th}=36.871
c=3305 m/s
F=7.908 MN
Pressure Thrust=4924 kN

Problem 12.3
F=3.5 MN
$I_s \approx 357$ s

Problem 12.4
C_F≈1.5965
F=344,863 lbf
M_2≈3.19
A_2/A_{th}=8.87

Problem 12.5
$n_{O_2} = 1.488$
r = 1.707
MW=44.258 kg/kmol

Problem 12.7
$\Delta V \approx 110{,}100$ m/s neglecting gravity

$\Delta V \approx 104{,}300$ m/s with gravity

Problem 12.8

$\Delta V = 8082$ m/s

Problem 12.9

$$\Delta V\Big|_{\text{single-stage}} \cong 7{,}888\ \ m/s$$

$$\Delta V\Big|_{2-stage} \approx 12{,}525\ \ m/s$$

Problem 12.10

c = 3,283 m/s

$\eta_p \approx 0.964$

$\eta_o \approx 0.439$

Problem 12.11

$A_0/A_f = 1.665$

$V_o = 13$ m/s

$V_f = 26.6$ m/s

Problem 12.12

r=0.037 m/s

$t_{burning} \approx 96.5$ s

Problem 12.14

$T_g = 2679$ K

$V_{g,\,th} = 1096$ m/s

$h_g = 8.936$ kW/m^{2}K

Problem 12.15

$A_2/A_1 = 35.2$ at SL

$A_2/A_1 = 30{,}862$ at Alt

Problem 12.16

Pressure Thrust=21.68 MN

c=2168 m/s

Problem 12.17

Ratio of Specific Impulse=0.988

Problem 12.18

$\Delta L = 0.015$ m

Problem 12.20

$T_2/T_0 = 3.49$

$T_4 = 5731$ K

$p_4/p_2 = 1$

f=0.0621

$M_{10} = 2.98$

$D_r/p_0A_1 = 50.4$

F_g/p_0A_1=85.2
I_s=2124 s
A_4/A_2=6.76
A_{10}/A_4=7.1
η_{th}=0.531
η_p=0.817