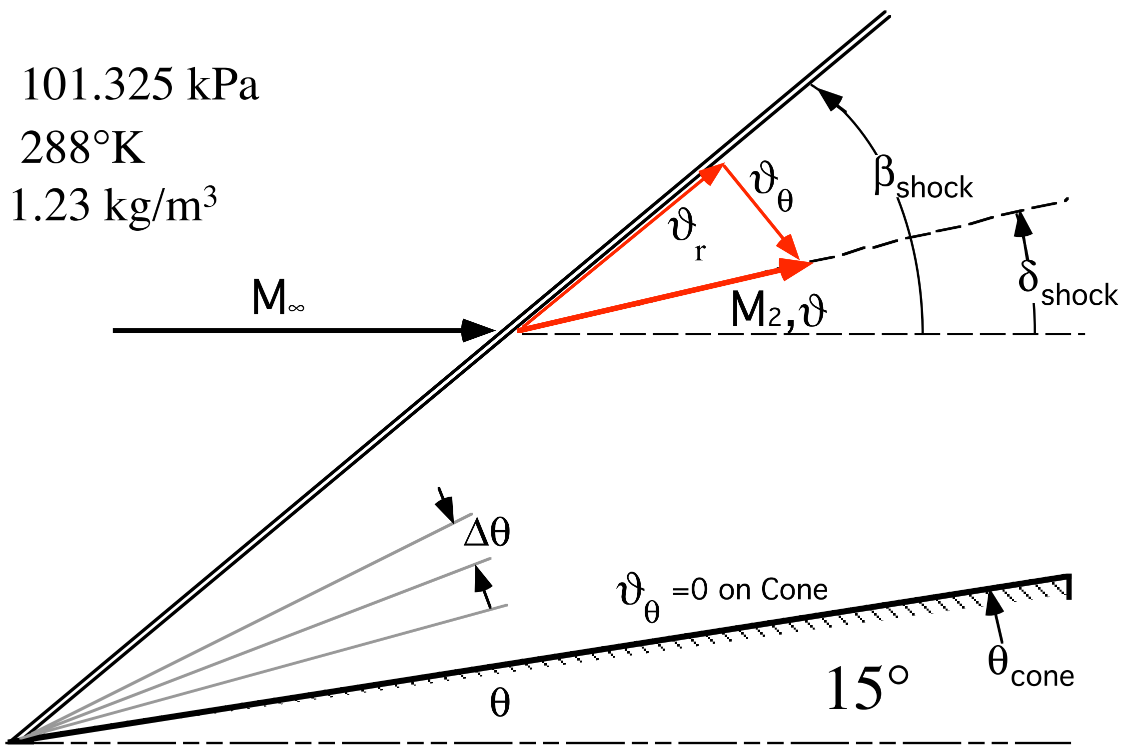
Conical Flow Example

- Code Taylor-Maccoll algorithm for cone flow
- Solve for flow conditions on surface of Cone at freestream Mach 2.0 with 15° half angle

p_∞	=	101.325 kPa
T_∞	=	288°K
ρ_∞	=	1.23 kg/m^3

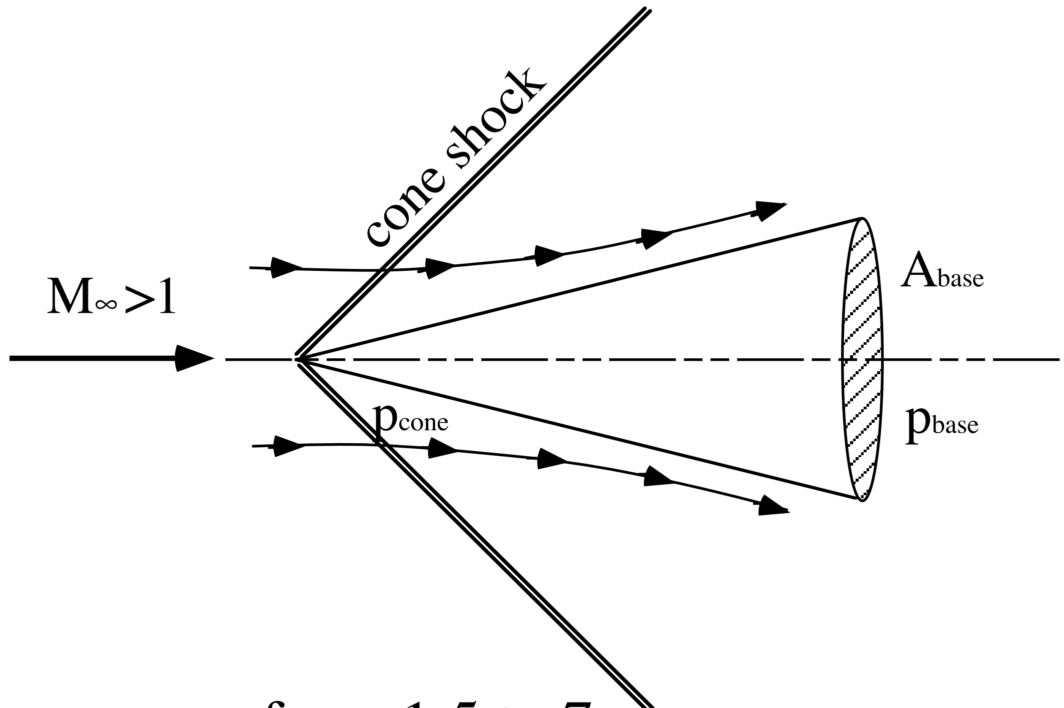


Homework 12 (Continued)

- Define $C_{D_{cone}} = \dfrac{D_{cone}}{\bar{q}_{\infty} A_{base}}$

• Hint: You'll have to do trial And error for each mach number to get the Shock angle correct

- Derive an expression for the cone wave drag as a function of the cone surface pressure (p_{cone}) and the base pressure (p_{base})



- Assume $p_{base} = p_{\infty}$
  plot $C_{D_{cone}}$ versus Mach over range from 1.5 to 7

Part 1 Solution

11.1 (a) $\theta_{shock} = 0.592$ rad = **33.897 deg.**

(b) $p_s/p_\infty = 1.286 \therefore p_s = 1.286\,(1.01 \times 10^5) = \boxed{1.3 \times 10^5 \text{ N/m}^2}$

$\rho_s/\rho_\infty = 1.196 \therefore \rho_s = 1.196\,(1.23) = \boxed{1.47 \text{ kg/m}^3}$

$T_s/T_\infty = 1.075 \therefore T_s = 1.075\,(288) = \boxed{310°K}$

$M_s = \boxed{1.835}$

(c) $p_c/p_\infty = 1.566$ $\boxed{p_c = 1.58 \times 10^5 \text{ N/m}^2}$

$\rho_c/\rho_\infty = 1.377$ $\boxed{\rho_c = 1.69 \text{ kg/m}^3}$

$T_c/T_\infty = 1.137$ $\boxed{T_c = 327°K}$

$\boxed{M_c = 1.707}$

Part 2 Solution

11.2

$$dA = 2\pi r ds = 2\pi r \frac{dx}{\cos\theta}$$

$$dD = p_c \left(2\pi r \frac{dx}{\cos\theta}\right) \sin\theta - 2\pi r\, p_b\, dr$$

$$\frac{r}{x} = \mathrm{Tan}\,\theta \;\therefore\; x = \frac{r}{\mathrm{Tan}\,\theta} \text{ and } dx = \frac{dr}{\mathrm{Tan}\,\theta}$$

$$dD = 2\pi r\, p_c\, dr - 2\pi r\, p_b\, dr$$

$$D = \int_o^{r_b} dD = 2\pi\,(p_c - p_b)\,\frac{{r_b}^2}{2} = \pi(p_c - p_b)\,{r_b}^2$$

$$C_D = \frac{D}{q_\infty A_b} = \frac{D}{q_\infty \pi {r_b}^2} = \frac{p_c - p_b}{q_\infty}$$

$$C_{D_{cone}} = \frac{D_{cone}}{\bar{q}_\infty A_{base}} = \frac{1}{\frac{\gamma}{2} {M_\infty}^2}\left[\frac{p_c}{p_\infty} - \frac{p_b}{p_\infty}\right]$$

10/1-3-94 JS (1)

SANDIA REPORT

SAND93–0280 • UC–706
Unlimited Release
Printed November 1993

A Review and Development of Correlations for Base Pressure and Base Heating in Supersonic Flow

J. Parker Lamb, William L. Oberkampf

Turbulent Cone/Base Flow Correlation

$$\frac{P_b}{P_\infty} = \left(\frac{P_e}{P_\infty}\right)^2 \left[0.025 + 0.906 \left(1 + \frac{\gamma - 1}{2} M_e^2\right)^{-1}\right]^J$$

where

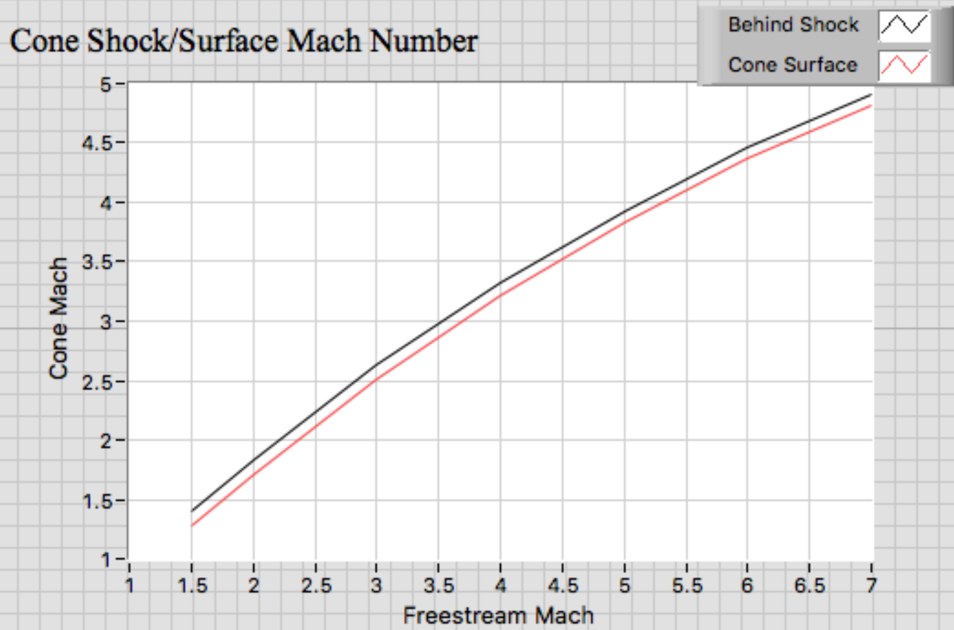
$$J = 1.7/\ln\left(\frac{21}{\theta_c}\right) \qquad \text{where } \theta_c \text{ is in deg.}$$

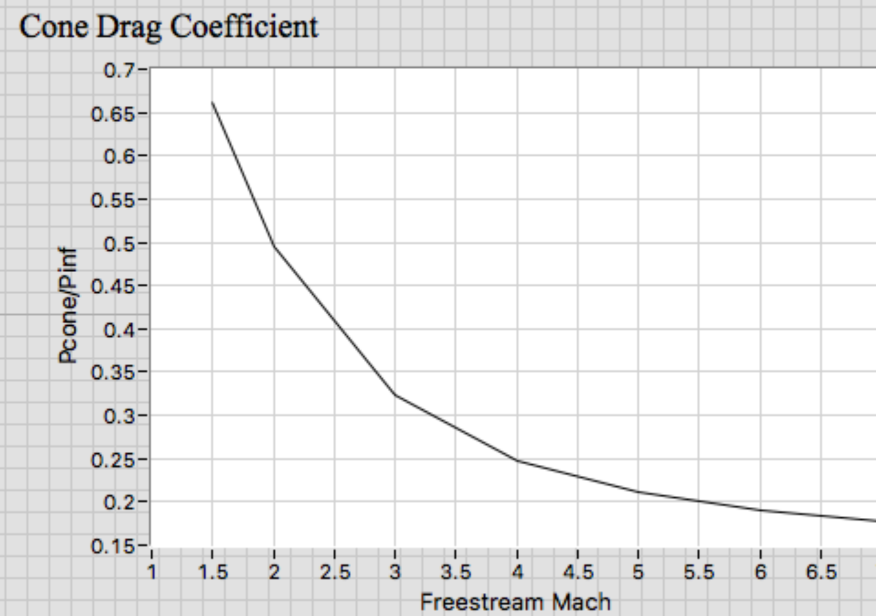
Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

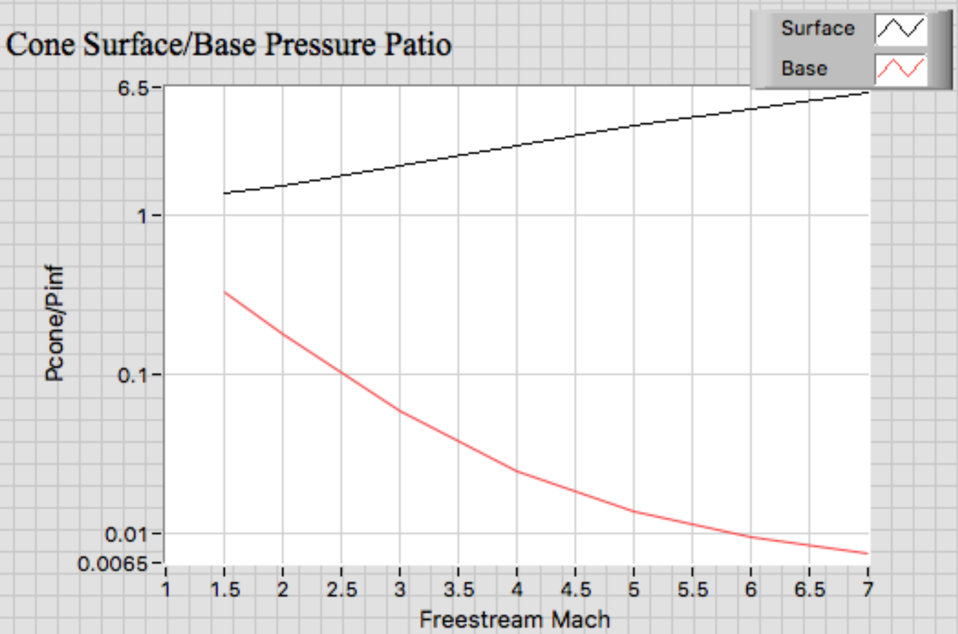
Part 2 Solution (cont'd)

For $\theta_c = 15°$

M_∞	$C_{D_{cone}}$
1.5	0.6614
2.0	0.4941
3.0	0.3225
4.0	0.2477
5.0	0.2106
6.0	0.1896
7.0	0.1766


Cone Shock/Surface Mach Number
Behind Shock
Cone Surface
Cone Mach
5
4.5
4
3.5
3
2.5
2
1.5
1
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7
Freestream Mach


Cone Drag Coefficient
Pcone/Pinf
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7
Freestream Mach


Cone Surface/Base Pressure Patio
Surface
Base
Pcone/Pinf
6.5
1
0.1
0.01
0.0065
1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7
Freestream Mach