

CONDITIONS FOR SHOCK WAVE DETACHMENT AND FOR SUBSONIC FLOW BEHIND NOSE SHOCK WAVES ON CONES AT ZERO INCIDENCE AND ON WEDGES

1. NOTATION AND UNITS

		SI	British
M_1	Mach number in uniform flow upstream of shock wave		
M_2	Mach number at surface of cone or behind shock wave for wedge		
δ	semi-vertex angle of cone or wedge angle	deg	deg

2. NOTES

This Item is concerned with the shock wave formed at the nose of a right-circular cone at zero incidence or a two-dimensional wedge in supersonic airflow. The ratio of specific heat capacities for air is taken as 1.4. For certain ranges of M_1 and δ the shock wave is conical for the cone and plane for the wedge and is attached to the nose.

Under these conditions its properties are given in detail by Item Nos Aero S.00.03.13, 70008, 9 and 10 for the cone and Aero S.00.03.09, 10 and 11 for the wedge. When, however, for a given value of δ , the free-stream Mach number M_1 is reduced, the value of M_2 falls steadily until it becomes unity and the type of flow considered in these Items is no longer possible for a cone or wedge of finite length. After a further reduction in M_1 , the shock wave becomes detached from the nose and its generators become curved.

Figure 1 gives the values of M_1 and δ for shock detachment and for sonic flow on the cone surface and downstream of the shock for the wedge.

The curves are useful in assessing the limits of applicability of theory that assumes completely supersonic flow for the estimation of the aerodynamic characteristics of wings or bodies (see for example Item No. Aero B.S.02.03.01).

3. DERIVATION

- KOPAL, Z. *Tables of supersonic flow around cones.* Massachusetts Institute of Technology, tech. Rep. 1, 1947.
- ROSENHEAD, L. *A selection of graphs for use in calculations of compressible airflow.* Clarendon Press. 1954.

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4. EXAMPLES

- 4.1 Compare the values of free-stream Mach number at which (a) the flow is entirely supersonic and (b) shock detachment occurs for a two-dimensional wedge of angle 15° and a cone of semi-vertex angle also 15° .

From Figure 1, with $\delta = 15^\circ$,

- (a) $M_2 > 1.0$ when $M_1 > 1.63$ for the wedge

and $M_1 > 1.22$ for the cone.

Also,

- (b) shock detachment occurs when

$$M_1 = 1.61 \text{ for the wedge}$$

and $M_1 = 1.12$ for the cone.

- 4.2 Find the incidence at which shock wave detachment occurs for a 6 per cent thick symmetrical double-wedge aerofoil at a free-stream Mach number of 2.0.

From Figure 1, with $M_1 = 2.0$, shock wave detachment occurs at

$$\delta = 23^\circ.$$

The half angle at the nose of the wedge is given by

$$\tan^{-1} 0.06 = 3.4^\circ.$$

Hence, the incidence for shock wave detachment

$$= 23^\circ - 3.4^\circ$$

$$= 19.6^\circ.$$