

Consider the attached representation of a hypersonic air-breathing (scramjet-powered) vehicle (modeled after the X-43 or X-51). The vehicle is 'one meter width', where width is into the paper (i.e., this is analyzed as a '2-D' vehicle). The top figure shows the vehicle configuration and related nomenclature for sizing the vehicle, etc. The bottom sketch provides a view of the vehicle at angle of attack, in flight, with shock-on-lip condition at cowl lip (leading edge of the cowl) and reflected shock cancellation at combustor entrance (2-shock inlet, with contained shocks). For this vehicle, the cowl extends to the exit plane of the nozzle (trailing edge of vehicle) as shown. The combustor (from ci to ce) has constant cross-sectional area.

The vehicle to be analyzed has the following characteristics (referred to the vehicle configuration as shown on following page):

$x_{linlet} = 5$ m (inlet length from leading edge of vehicle, i, to combustor entrance, ci)

$x_{lcomb} = 0.5$ m (combustor length from ci – combustor entrance - to ce – combustor exit)

$x_{lnoz} = 3$ m (nozzle length from nozzle entrance at ce to exit plane of vehicle at e)

height of engine exit plane (at e) = 1.2903 m

wing setting angle = 5 degrees

total wing planform area = 14.5 m²

combustor entrance height (A_{ci}) = 0.156 m (also = A_{ce} ; constant area heat addition)

top surface angle = 3.50298 degrees

inlet angle = 7 degrees

$x_{lforcowl}$ (length of portion of cowl forward of combustor entrance) = 1.213243 m

A_i (height of captured air streamtube at vehicle leading edge at angle of attack = 4 degrees) = 1.0322 m

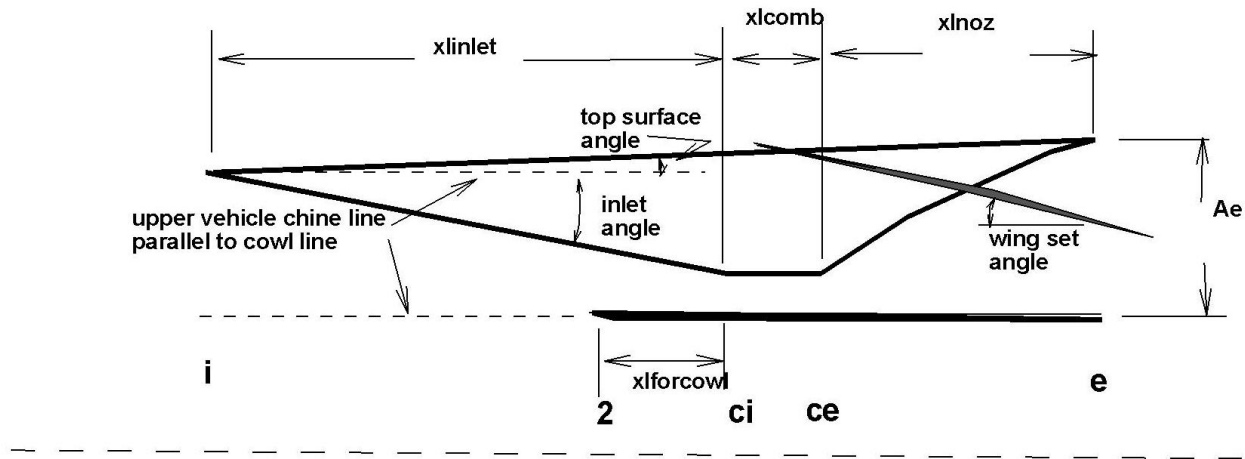
For this vehicle operating at 4 degrees angle of attack with a velocity of 3048.0 m/s at 30 km altitude (use ambient $T = 231.24$ K and ambient $P = 1185.5$ N/m²), find 1) the heat rate in the combustor and 2) the vehicle mass (use $g = 9.81$ m/s²) **required for cruise** at these conditions.

Also provide/tabulate Mach, pressure, temperature, total pressure, total temperature, and velocity magnitude at all relevant stations (i, 2, ci, ce, e) in the propulsive flow path, as well as all give the oblique shock angles and flow conditions behind all shocks and expansions on all relevant vehicle surfaces.

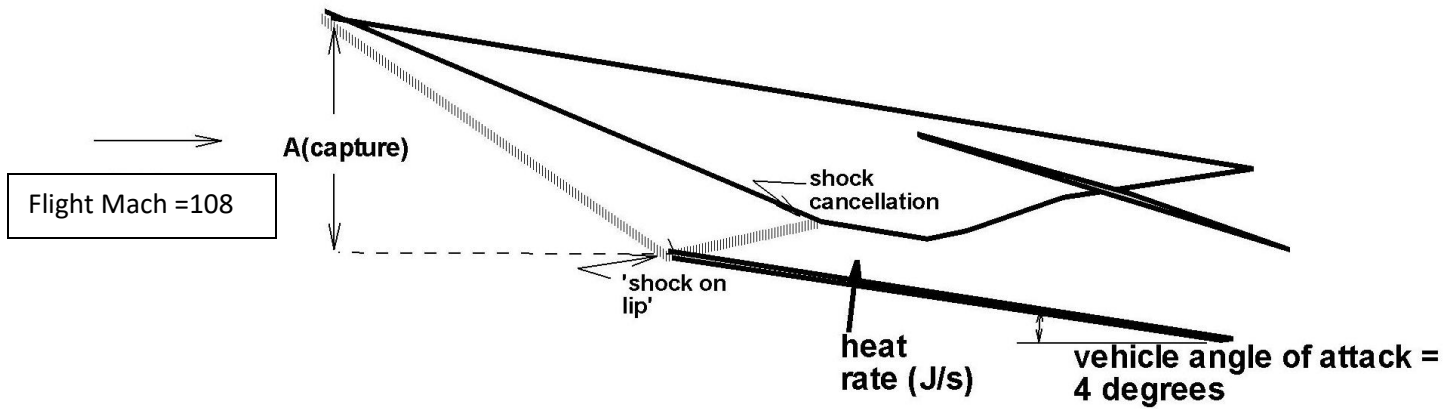
Provide a full and comprehensive break-down of all component forces (inlet, combustor-nozzle, top surface, wing top, wing bottom, cowl bottom) in terms of axial and vertical contributions to the overall axial and vertical aerodynamic forces experienced by the vehicle.

Modeling assumptions: Use constant ratio of specific heats $\gamma = 1.4$, R (gas constant) = 287 J/kg-K, and $C_p = 1004.5$ J/kg-K everywhere. Assume that ALL wetted surfaces of this vehicle (internal and external) are inviscid (i.e. no friction). Assume isentropic flow in the nozzle (from c_e to c_i). Use the equations for oblique shocks and Prandtl-Meyer expansion waves (as appropriate) in order to calculate the conditions necessary to do the force analysis; also use equations (**not tables or charts**) to calculate all necessary aspects of engine and airframe flow; all analysis in this project is done using basic compressible flow theory and techniques. Use one-dimensional inviscid heat addition ('Rayleigh') analysis in combustor.

vehicle configuration



vehicle in flight (angle of attack = 4 degrees)



Results Summary (Please fill out and put this in your submission)

M_i (Flight Mach number) =

\dot{Q} required to cruise =

\dot{m} (air flow rate captured by vehicle and processed in engine) =

Mass of vehicle required for cruise =

Aerodynamic forces (summary):

Component	F_x (N)	F_y (N)
Inlet*		
Combustor-nozzle (ci to e)		
Wing top		
Wing bottom		
Wing total		
Bottom of vehicle (cowl bottom)		
Top of vehicle		
Overall vehicle (total)		

* actual force associated **with captured stream** tube on inlet surfaces from i to ci!

Fluids summary: β is shock angle, θ is turning angle (if not relevant to a station or region, enter X)

[illegible]