16.50 Propulsion Systems
HWK #7

We argued in class that the best velocity ratio between core and bypass streams in a turbofan is unity, but sometimes that requires to much pressure ratio across a single stage fan, and two-stage fans are too heavy. In this HWK we explore the effects of accepting a lower fan load, and therefore departing from the equal-velocity rule.

Consider a design Mach number of 0.9, an external temperature of 220K, and a peak temperature parameter of θ_t=6.25. The design bypass ratio is α=6. For a design with equal velocities, and with the compressor ratio selected for maximum thrust, , calculate the fan temperature and pressure ratios, the turbine temperature ratio, the normalized thrust $F / \dot{m} a_0$ (overall and the portions contributed by core and bypass), the common jet speed, the specific impulse and the propulsive, overall and thermodynamic efficiencies.

Suppose now the fan pressure ratio is limited to no more than Π_t=2, but the peak temperature and the bypass ratio are kept the same. By examining the thrust contribution of both streams, show that the same compressor ratio as before still provides maximum thrust. Calculate the two jet velocities, the two thrust contributions in normalized form and the total normalized thrust, and comment on the amount lost compared to the equal-velocity design. Calculate also the new specific impulse, the new propulsive, thermodynamic and overall efficiencies. Notice that the definition of the propulsion and thermodynamic efficiencies must account for the two different jet velocities.

<u>Conceptual questions</u>

1) You will find that the thermodynamic efficiency is unchanged when reducing the fan temperature ratio. Trace the reason for this behavior. You can do this algebraically, by using the appropriate expressions to show that τ_f does not affect η_{Th}, or, preferably, by some overall argument not involving algebra.
2) You will also find that, although the two velocities are now quite different, the loss in thrust and specific impulse is limited. Explain why the low sensitivity. Hint: think generally about the variation of any quantity near a smooth maximum.

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