SESA3029 Aerothermodynamics

2019-20 Examination Feedback

From the distribution of marks, this was an exam that was relatively straightforward to pass, but quite difficult to get high marks (in the end 10 students scored over 80, 37 over 70).

Q1. The first two parts were well done, but a surprising number of students struggled with the lift coefficient part that should also have been straightforward. (i) A/A*=2.403, p0=877 kPa, T0=525.1 K (ii) nearest value results: M2u=2.8, p2u=32.3 kPa M2l=2.04, p2l=104.7 kPa (iii) CL=0.074 (note that the force only acts over c/4) (iv) start from the definition of Cl as an integral of Cpl-Cpu and substitute Ackeret's formula (the only part of the integral that contributes is from 3c/4 to c where the angle is eta). (v) Ackeret gives CL=0.072 (using the formula from (iv) to save time) with only a 3% error compared to (iii). We expect the error to increase as eta increases and the small perturbation assumption breaks down.

Q2. Continuing the theme of trailing edge control devices, modelled as a flat plate with a flap. (i) Standard proof, but don't forget the last comment part of the question, which was worth two of the marks. (ii) P-G can be applied to any lift-derived quantities, including flap effectiveness, so we just divide by sqrt(1-0.75^2) giving 5.78 (iii) The main reason is that the flap/Kutta condition changes the whole pressure distribution in incompressible flow (recall that Laplace's equation is elliptic) whereas in supersonic flow there is no upstream propagation of waves and only the local flow over the flap contributes. As we can see from the numbers from this question compared to Q1 this makes a huge difference (an order of magnitude).

Q3 (i) R+=15.8 deg, R-=31.8 deg (ii) nu=23.8, theta=8, M=1.9 (iii) x1=1.26, x2=1.65, x3=0.31 (iv) we need to use substantially more characteristic lines to get the geometry. There was partial credit available provided you only made a small slip in the calculations, but it a was disappointing how many solutions were wrong all the way from part (i).

Q4. (i) No problems. (ii) The Reynolds number needs to be evaluated with free-stream properties. With $\mu(T_\infty)$=5.24e-5 Ns/m^2 and ρ_∞=0.43554 kg/m^3, we get Re=265500, i.e., laminar. (iii) a) The local heat flux is constant everywhere and is evaluated as q=8750 W/m^2. Using $T_s=T_\infty-q/h$ and Nu(x)=h x/k together with the Nusselt number relation for constant heat flux in a laminar boundary layer allows direct evaluation of T_s for every point on the upper surface: T_1=1200K, T_2=973.68K, T_7=808.0K. Integration of h(x) over distance (in order to obtain an average convective heat transfer coefficient) is not necessary in the constant heat flux case; however was still attempted by a large number of students. b) With Δx=0.2m and Δy=0.05m the standard central difference stencil gives T_5=580.38K, and with adjustment for the adiabatic boundary T_{11}=525.46K. A surprisingly large number of students struggled with evaluating the finite difference mesh widths correctly and used for instance Δx=0.8m/5=0.16m. (iv) A straightforward application of the exact same formulas as in the lecture evaluates the order of accuracy of the scheme as 1.9655 and (assuming uniform second-order-accurate convergence) estimates the exact temperature value as 428.9525K. Again, a surprisingly large number of students struggled realising that the finite difference mesh resolution was always exactly doubled (all mesh widths are reduced exactly by factor 1/2) between successive computations.

NDS/RD

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