AER 307S: Test I

1. Given the Navier-Stokes equations in the form

$$\frac{\partial}{\partial t}\begin{bmatrix}\rho \\ \\ \rho\vec{v} \\ \\ \rho E\end{bmatrix} + \vec{\nabla}.\begin{bmatrix}\rho\vec{v} \\ \\ \rho\vec{v} \quad \vec{v} + p\overline{\overline{I}} - \overline{\overline{\tau}} \\ \\ \rho\vec{v}H - \overline{\overline{\tau}}.\vec{v} - k\vec{\nabla}T\end{bmatrix} = \begin{bmatrix}0 \\ \\ \rho\vec{f}_e \\ \\ W_f + q_H\end{bmatrix}$$

identify the flux and source terms as fluxes or sources of mass, momentum, or energy, and give the physical process described. (20 marks)

2. Starting with the form given in question 1, write the energy equation in two-dimensional Cartesian coordinates. Do not assume a Newtonian fluid, i.e. leave the elements of $\overline{\overline{\tau}}$ in the form τ_{xx}, τ_{xy}, τ_{yx}, τ_{yy}.(20 marks)

3. True or false? (1 mark for a correct answer, -1 for a wrong answer, max. 10, min. 0)

(a) A turbulent boundary layer separates more easily than a laminar boundary layer.

(b) The isentropic relations can be applied in a boundary layer.

(c) The pitching moment coefficient about the quarter-chord point for a symmetric airfoil at zero angle of attack is zero.

(d) Streamlines and particle paths are identical in a steady flow.

(e) For a perfect gas, the speed of sound is a function of temperature.

(f) Pressure is a surface source of momentum.

(g) Heat conduction is a diffusive process.

(h) The work done by viscous forces is a source of momentum.

(i) The Euler equations give accurate solutions for flows with separation.

(j) Flows at low Reynolds numbers are more likely to be laminar than those at high Reynolds numbers.