# Quiz IV

This is a 50 minute closed-book exam. Please put your name on the top sheet. Answer all three questions. Explain your working and state any assumptions you have made.

**1** (3 points) Circle the correct answer.

1. For a perfect gas, entropy
   - remains a constant.
   - is a function of pressure, temperature and electric field.
   - is a thermodynamic function of state.
   - depends only on the area of a nozzle.
   - decreases through shocks.
2. The Mach number
   - depends on the state via temperature alone for an ideal gas.
   - is constant in space for a given flow.
   - is all that is needed to compute the state of the fluid.
   - depends only on the area of a nozzle.
   - is never 1 in a converging-diverging nozzle.
3. Isentropic flow in a duct
   - only has shocks at locations with maximum area.
   - corresponds to vertical lines on a $T$-$s$ diagram.
   - has constant pressure.
   - has increasing velocity as the duct area decreases in all cases.
   - is always supersonic.

**2** (7 points) The stagnation pressure in a Mach 2 wind tunnel operating with air is 900 kPa. A sphere of diameter 1 cm positioned in the wind tunnel has a drag coefficient of 0.95. Calculate the drag force on the sphere.

**3** (10 points) A converging-diverging nozzle discharges air at supersonic speeds. The flow has velocity $V_1 = 150\ \mathrm{ms}^{-1}$, pressure $p_1 = 100$ kPa and temperature $T_1 = 20°\mathrm{C}$ at section 1 upstream of the throat. The area at the throat is 0.1 $\mathrm{m}^2$. Compute the mass flow rate.

# Useful values and parameters

**Units and constants**
1 hp = 550 lb ft/s
1 in = 2.54 cm
1 mile = 1609 m
1 mph = 88 ft/min
Acceleration of gravity: $g = 9.81$, $g = 32.2$ ft/s$^2$
°R = °F + 459.67

**Material properties (SI unless otherwise stated)**
Air: $\rho = 1.23$ and $\mu = 1.79 \times 10^{-5}$ at 15°C
Air: $\rho = 2.38 \times 10^{-3}$ slugs/ft$^3$ and $\mu = 3.47 \times 10^{-7}$ lb·s/ft$^3$ at 59°F
Air (ideal gas): $c_p = 1004$, $R = 287.1$ (SI), $R = 1,716.5$ ft lb/slug °R (BG), $R = 53.35$ ft lb/lbm °R (EE)

**Isentropic flow of an ideal gas with $k = 1.4$**

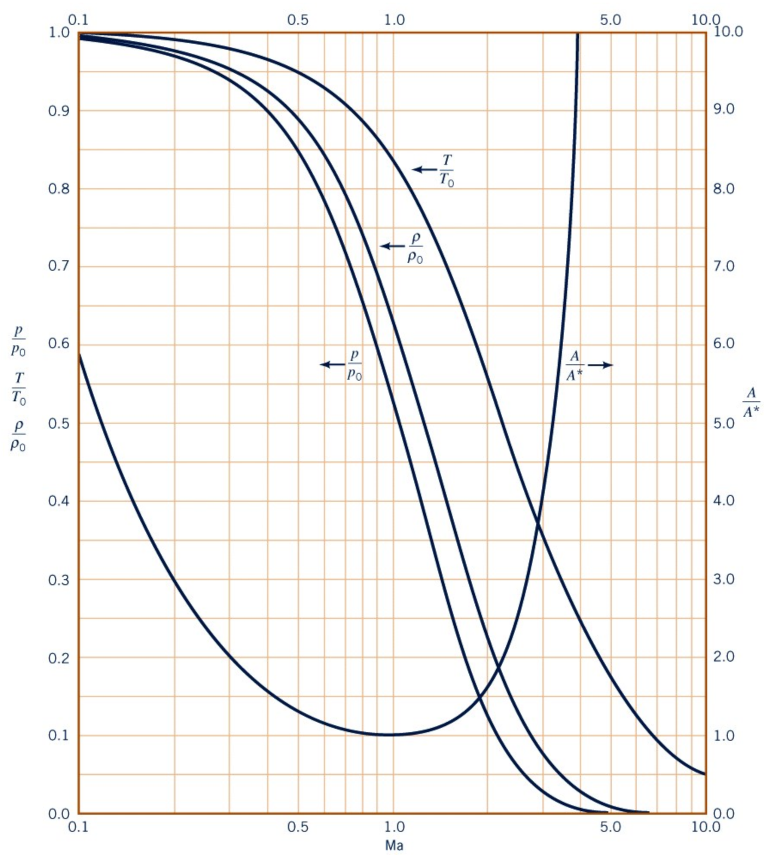


**Figure D.1**
**Graph provided by Dr. Bruce A. Reichert**