

Past QE111 examination questions on open systems and application of steady flow energy equation:

February 2007 (End of Semester Examination - E05 batch)

3. A steady stream of steam at 2 bar and 250°C and a flow rate of 2 kg/s mixes with another steady stream of steam at 2 bar and dryness fraction 0.8 in a well-insulated mixing vessel. The mixing is adiabatic and all flow velocities are negligible. If the mixture leaves the vessel as dry saturated steam at 2 bar, find the rate of mass flow in the second stream of steam.

If the mass flow rates remain as above, but the insulation is not good and heat loss from the vessel is at the rate of 500 kW, what will be the state of the steam at exit?

4. A gas turbine receives hot gases at 5 bar and 1200 K at the rate of 35 kg/s and the gases after expansion leave the turbine at 1 bar and 820 K. The velocities at entry and exit are 40 m/s and 85 m/s, respectively. Neglecting heat losses from the turbine, and assuming that $R = 260 \text{ J/kg}\cdot\text{K}$ and $\gamma = 1.35$, calculate the power output of the turbine.

Also calculate the areas of the inlet and the exit of the turbine.

May 2006 (End of Special Session Examination - E04 batch)

4. a) With the help of simple sketches, state in less than 50 words the difference between a nozzle and a diffuser.

b) Compressed air ($R = 287 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) enters a diffuser at 5 bar and 400°C with a velocity of 300 m/s and leaves at 1 bar and 20 m/s. Assume steady adiabatic flow and determine the exit temperature.

c) If the round inlet to the diffuser in (b) above is of diameter 0.1 m, determine the mass flow rate.

5. A fully evacuated, well-insulated rigid tank has a cubic capacity of 10 litres. It is connected to an air supply line at 300 K and 20 bar and allowed to fill until the pressure in the tank is 15 bar. Assuming adiabatic conditions and ideal gas behaviour for air ($R = 287 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$), find the mass of air added and the final temperature of the tank.

If the cylinder is closed when the pressure reaches 15 bar and the air is cooled till the temperature is 300 K, what will be the final pressure?

February 2006 (End of Semester Examination - E04 batch)

3. A well-insulated and fully evacuated rigid cylinder of internal volume 100 litres and negligible heat capacity is filled with oxygen ($R = 260 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) from a supply at 8 MPa and 27°C. Find the mass of oxygen added when the cylinder reaches a pressure of 6 MPa, and the final temperature of the oxygen in the cylinder.

4. Two streams of steam, one at 2 bar and dryness fraction 0.9 flowing at a rate of 2700 kg/h and the other at 2 bar and 200°C flowing at the rate of 5500 kg/h, mix adiabatically in the mixing chamber. Find the specific enthalpy of the mixed stream leaving the mixing chamber.

If the mixed stream is expanded adiabatically in a turbine to 0.1 bar and dryness fraction 0.95, find the power output of the turbine.

June 2005 (End of Semester Examination - E03 batch)

3. a) State using simple sketches the essential difference between a nozzle and a diffuser.
- b) Air ($R = 287 \text{ J/kg}\cdot\text{K}$; $C_v = 718 \text{ J/kg}\cdot\text{K}$) at 15 bar and 1000°C enters a nozzle with a velocity of 80 m/s and leaves at 10 bar and 860°C . Assuming steady adiabatic flow, determine the exit velocity of the air.
- c) If the nozzle inlet is round and of diameter 0.3 m, determine the diameter of the exit, which is also round.
4. A sealed insulated vessel of internal volume 2.5 m^3 initially contained air ($R = 287 \text{ J/kg}\cdot\text{K}$; $C_v = 718 \text{ J/kg}\cdot\text{K}$) at 30°C and 1 bar, Compressed air from a supply line at 10 bar and 30°C was added to the vessel through a pressure reducing valve until the pressure in the vessel reached 5 bar. Find the mass of air added and the final temperature.

March 2004 (End of Special Session Examination / E02a batch)

3. Two pipes of 50 mm diameter carrying air ($R = 287 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) are joined to a mixing vessel so that they mix and leave as one uniform stream through a pipe of 100 mm diameter. The air in one of the 50 mm pipes is at 150 kPa and 450 K and that in the other is at 100 kPa and 300 K. The air flow rate is 360 g/s in each 50 mm pipe. The mixed flow through the 100 mm pipe is at 100 kPa and 375 K. Find the velocity of the air in each pipe and calculate the heat interaction with the surroundings in the mixing vessel.
4. A rigid cylinder has an internal volume of 20 litres and contains oxygen ($R = 260 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) at 25 bar and 30°C . Oxygen is removed from the cylinder until the pressure is reduced to 10 bar while the temperature of the oxygen in the cylinder is kept at 30°C . Find the heat interaction between the cylinder and the surroundings.

Would the temperature of the oxygen in the cylinder have changed if the cylinder were insulated? Why?

January 2004 (End of Semester Examination - E02a batch)

3. a) Steam enters a heat exchanger at 10 bar and 200°C and leaves it as saturated water at the same pressure. Feed-water enters the heat exchanger at 25 bar and 80°C and leaves at the same pressure and at a temperature 20°C less than the exit temperature of the steam. Write the steady flow energy equation, and determine the ratio of the mass flow rate of the steam to that of the feed-water, neglecting heat losses from the heat exchanger.

Enthalpy data for compressed water at 25 bar:

t ($^\circ\text{C}$)	20	40	80	120	160	200	220	$t_s = 223.9$
h (kJ/kg)	86.3	169.77	336.86	505.33	676.65	852.8	943.7	$h_f = 962.1$

- b) If the feed-water leaving the heat exchanger is fed directly to a boiler to be converted to steam at 25 bar and 300°C , find the heat required by the boiler per kg of feed-water.
4. A rigid tank of volume 1.2 m^3 contains nitrogen ($R = 297 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) at 1 bar and 300 K. Nitrogen at 20 bar and 600 K is pumped slowly into the tank until the pressure in the tank is 10 bar. If the tank is at 500 K at the end of filling, find the mass of nitrogen added and the heat interaction between the tank and the surroundings.

December 2003 (End of Special Session Examination / E02 batch)

3. Dry saturated steam at 300 kPa flowing at a mass flow rate of 1.1 kg/s and a velocity of 150 m/s and steam at 300 kPa and 200°C flowing at a mass flow rate of 0.9 kg/s and a velocity of 250 m/s are mixed in a mixing vessel. The mixture leaves the vessel at 280 kPa with an exit velocity of 300 m/s. Calculate the inlet areas for the two streams.

Neglect heat losses and find the exit enthalpy and temperature.

4. Air ($R = 287 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) was admitted from a supply pipe at 25 bar and 30°C to an initially empty insulated bottle of volume 20.0 litres until the pressure in the vessel reached 20 bar. Find the final temperature of the air in the cylinder, and the mass of air added to it.

August 2003 (End of Semester Examination - E02 batch)

4. a) With the help of a simple sketch, describe in fewer than fifty words the function of a nozzle in a turbojet aircraft engine.
 b) Steam enters a nozzle at 30 bar 400°C with a velocity of 80 m/s and leaves at 20 bar 300°C. Assume steady adiabatic flow and determine the exit velocity of steam.
 c) If the round inlet to the above nozzle is of diameter 0.3 m, determine the mass flow rate of steam through the nozzle.
5. A well-insulated tank contains 0.25 kg of air at 300 K and 200 kPa. It is allowed to discharge until the temperature in the tank reduces to 200 K. Assuming adiabatic conditions and ideal gas behaviour for air ($R = 287 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$), find the mass of air remaining inside the tank.

December 2002 (End of Special Session Examination - E01 batch)

3. One stream of air at 300 kPa and 100°C flowing at a mass flow rate of 1.2 kg/s and a velocity of 250 m/s and another stream of air at 300 kPa and 200°C flowing at a mass flow rate of 0.8 kg/s and a velocity of 350 m/s are mixed in a mixing vessel. The mixture leaves the vessel at 280 kPa with an exit velocity of 300 m/s. Calculate the inlet areas for the two streams.

Neglect heat losses and calculate the exit temperature.

4. Steam is admitted from a supply line at 5 bar to an initially empty insulated vessel of volume 20.0 litres. When the pressure in the vessel reaches 5 bar, the temperature of the steam inside is 160°C. Calculate the mass of steam added and the specific enthalpy of the steam in the supply line.

September 2002 (End of Semester Examination - E01 batch)

3. A gas cylinder of internal volume 0.01 m³ has oxygen ($R = 260 \text{ J/kg}\cdot\text{K}$; $\gamma = 1.4$) at 1 MPa and 30°C. It has to be recharged from a supply pipe carrying oxygen at 10 MPa and 25°C. Assuming that the cylinder is insulated and has negligible heat capacity, calculate the mass of oxygen in the cylinder when it reaches a pressure of 8 MPa. State your assumptions clearly.
4. Helium ($R = 2.077 \text{ kJ/kg}\cdot\text{K}$; $\gamma = 1.667$) at 5 bar and 600°C enters a insulated horizontal nozzle of inlet diameter 300 mm with a velocity of 50 m/s and leaves it at 400 m/s at a pressure of 3.0 bar. Find the mass flow rate through the nozzle.

Determine the temperature of the helium at the exit and estimate the exit diameter.