# AE 234/711 Aircraft Propulsion
# EndSem - Answers

The B2 stealth bomber cruises at Mach 0.85 at an altitude of 41,000 ft. The maximum take-off weight is 170,600 kg, and an empty weight of 71,700 kg. The maximum fuel that can be carried at the time of take-off is 75,750 kg. Assume that take-off and landing consume negligible quantity of fuel.

The aircraft is powered by four F118 engines, each of which weighs 1450 kg. An F118 engine has an overall compression ratio of 35.1 and can produce a maximum thrust of 85 kN. In this problem, we will treat it as a turbojet engine.

**Note:** The overall compression is defined as the ratio of the total pressure after compressor and the ambient air pressure. Also, assume $\eta_c = \eta_t = 0.90$, and $\mathcal{Q}_R = 45MJ/kg$ for the calculations.

**Information given during the exam**: $T_{t4} = 1400K$, $\mathcal{L}/\mathcal{D} = 20$.

Question 1 ..... 12 points

Draw a schematic of the engine, and number the various stages. Find out the properties at the end of each stage in the engine.

Properties are {T (K), s (kJ/kg-K), v ($m^3$/kg), p (kPa)} for each station number:
**a**: (216.7, 0, 3.5, 17.9) → **t2**: (248, 0, 2.5, 28.7) → **t3**: (637.8, 63.5, 0.3, 628.3) → **t4**: (1400, 855.8, 0.6, 628.3) → **t5**: (1010.2, 899.9, 1.7, 172.0) → **e**: (529.2, 899.9, 8.5, 17.9)

Question 2 ..... 4 points

Represent the various processes and stages in the engine using $p - v$ and $T - s$ plots. Mention the expressions for each of the process, and the units for each of these properties.

See Fig. 1

Question 3 ..... 3 points

Obtain the TSFC, the propulsive, thermal, and overall efficiencies for the engine.

TSFC is 23.2 gm/kN-s, Thrust is 0.73 kN-s/kg, $\eta_p = 0.41$, $\eta_{th} = 0.59$, $\eta_{ov} = 0.24$.

Question 4 ..... 1 points

If the engine intake diameter is 1.2 m, what is the engine thrust during cruise?

$\dot{m}_a = 78.6\ kg/s$, Thrust is $57.7\ kN$ at cruise.

Question 5 ..... 1 points

Obtain the Range value assuming the aircraft maintains constant attitude and speed.

Range is 12,870 km.

Question 6 ..... 4 points

How would the exhaust velocity, thrust, TSFC and range change if we consider $\gamma = 1.33$ for the flow after combustor in our calculations.

$V_e = 1034\ m/s$, Thrust is 61.6 kN or 0.78 kN-s/kg, TSFC is 27.8 gm/kN-s, and Range is 10,754 km. See Fig. 2

Question 7 ..... 5 points

One proposal to improve the engine is to increase the overall compression ratio to 45. What will be the thrust per unit mass and TSFC for this updated overall compression ratio (continue using $\gamma = 1.33$ for the flow after the combustor).

Considering $\gamma = 1.33$ Thrust is 60.7 kN or 0.77 kN-s/kg, TSFC is 26.8 gm/kN-s, and Range is 11,157 km. See Fig. 3

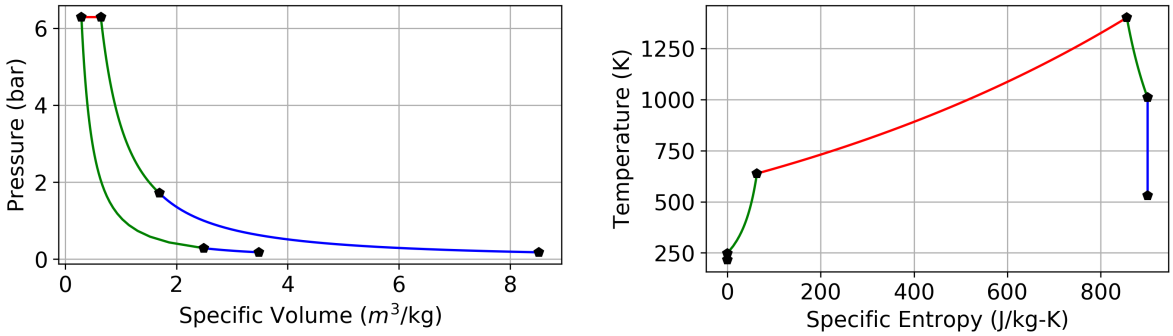


Figure 1: Questions $1-5$: $\pi_{tot} = 35.1$, $\gamma = 1.4$ after combustor

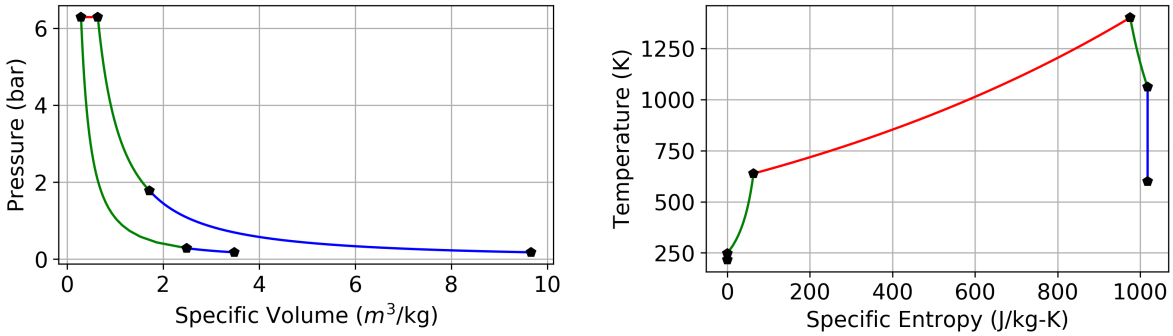


Figure 2: Question $6$: $\pi_{tot} = 35.1$, $\gamma = 1.33$ after combustor

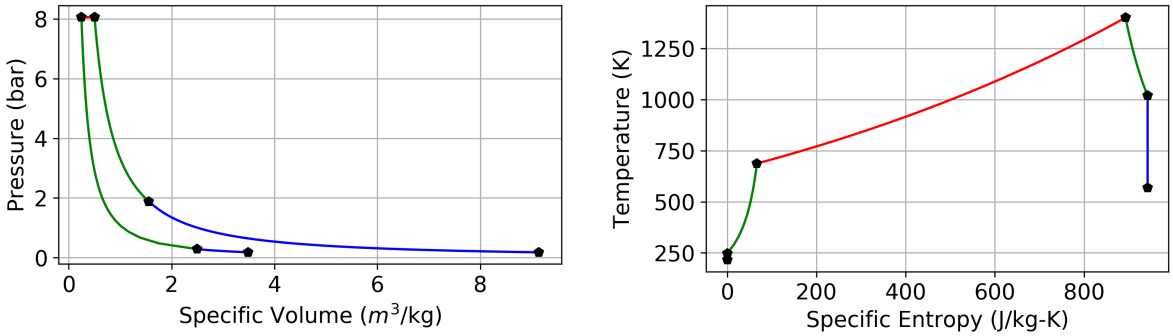


Figure 3: Question $7$: $\pi_{tot} = 45$, $\gamma = 1.33$ after combustor