1. At the exit $(M = 0.3)$

$$\frac{p_b}{p_{0_e}} \cdot \left(\frac{A}{A^*}\right)_e = 1.9119$$

Operating pressure ratio

$$\frac{p_b}{p_{0_i}} = \underbrace{\frac{p_b}{p_{0e}} \cdot \left(\frac{A}{A^*}\right)_e}_{1.9119} \cdot \underbrace{\frac{(A^* p_0)_e}{(A^* p_0)_i}}_{1} \cdot \underbrace{\frac{A^*_i}{A_t}}_{1} \cdot \underbrace{\frac{A_t}{A_e}}_{1/3.5}$$

(2.5 marks)

$$= 0.546$$

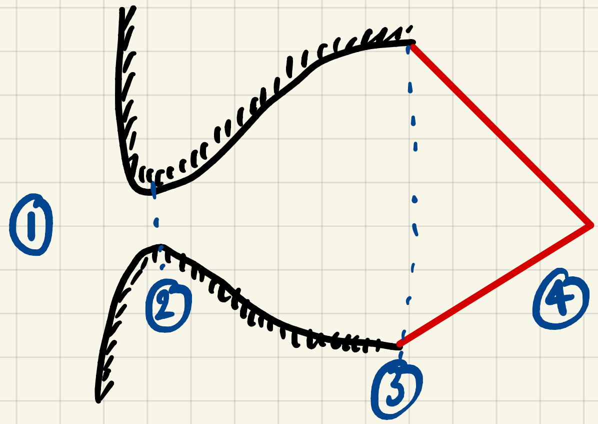
2. This question is scrapped (already solved in notes) and marks are reassigned as:

$Q_1 \rightarrow Q_1 + 0.5$

$Q_3 \rightarrow Q_3 + 1$

$Q_4 \rightarrow Q_4 + 0.5$

3.



At 3rd critical

$$\frac{A_3}{A_3^*} = \frac{A_3}{A_2} \cdot \underbrace{\frac{A_2}{A_2^*}}_{1} \cdot \underbrace{\frac{A_2^*}{A_3^*}}_{1} = 5.9$$

$M_3 = 3.35$, $\frac{p_3}{p_{01}} = 0.01625$

At second critical, normal shock at $M = 3.35$

$\Rightarrow \frac{p_4}{p_3} = 12.9263$

$\Rightarrow \frac{p_4}{p_{01}} = 12.9263 \cdot 0.01625$
$= 0.21$

Now, for the given problem $p_b/p_{01} = 0.147$

$\Rightarrow$ operating condition between 2nd and 3rd critical (1 mark)

Pressure ratio across the oblique shock $= \frac{14.7}{1.625} = 9.046$

$\Rightarrow$ From normal shock tables

$M_{3n} = 2.81$, $M_{4n} = 0.4875$

$\beta = \sin^{-1} \frac{M_{3n}}{M_3} = 0.8388$ or 57° (1 mark)

$\delta = 34^\circ$ (1 mark) and $M_4 = \frac{M_{4n}}{\sin(\beta - \delta)} = 1.25$ (1 mark)

4. $p_0 = 1$ atm , $T_0 = 293K$, $M_e = 1.5$, $D_e = 0.2m$

$\left(\frac{A}{A^*}\right)_e = 1.176$ (0.5 marks)

$\dot{m}_{max} = \rho^* A^* V^*$

$= \frac{A^* p_0}{\sqrt{RT_0}} \sqrt{\gamma \left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}$

$= 12.78$ kg/s (2 marks)

5. $\frac{A_1}{A_1^*} = \frac{0.04}{0.02} = 2$

$\Rightarrow M_1 = 2.2$ (1 mark)

We have $A_1^* p_{01} = A_2^* p_{02}$

$$\Rightarrow A_2^* = \left(\frac{p_{01}}{p_{02}}\right) A_1^*$$

From normal shock at $M = 2.2$

$$\frac{p_{02}}{p_{01}} = 0.6281$$

$$\Rightarrow A_2^* = 0.6281 \times 0.02 = 0.0318 \, m^2$$ (1 mark)

6. $T_0 = 300K$, $p_b = 1$ atm, $M_d = 2$

(a) $p_e = p_b \Rightarrow$ at $M_e = M_d = 2$ $\frac{p_e}{p_0} = 0.1278$

$\Rightarrow p_0 = 7.82$ atm (0.5 marks)

(b) Maximum possible overexpansion occurs when the oblique shock is the strongest for an $M=2$ flow at the exit.

From oblique shock (strong) relations

$$\frac{p_b}{p_1} = 3.971, \; M_2 = 0.802$$

$$\Rightarrow p_1 = 0.25 \text{ atm}$$

$$\Rightarrow p_0 = \frac{0.25}{0.1278} = 1.9656 \text{ atm}$$ (1.5 marks)

(c) $\frac{p_b}{p_1} = 4.5 \Rightarrow p_1 = 0.222$ atm

$\Rightarrow p_0 = 1.74$ atm (0.5 marks)

(d) $\frac{A}{A^*} = 1.5 \Rightarrow M_1 = 1.85, \frac{p_1}{p_{01}} = 0.1612, \frac{T_1}{T_{01}} = 0.5936$

From normal shock tables

$\frac{T_2}{T_1} = 1.5693, \frac{p_2}{p_1} = 3.8262, \frac{p_{02}}{p_{01}} = 0.7902, M_2 = 0.6057$

$\Rightarrow T_2 = 279.34$

$V_2 = M_2 a_2 = M_2\sqrt{\gamma R T_2} = 203$ m/s (2 marks)

p_0 ? TRICK QUESTION as information is insufficient (0.5 marks)