

Q1

$$a) \frac{\partial}{\partial t} \begin{pmatrix} \rho \\ \rho u \\ E \end{pmatrix} + \frac{\partial}{\partial x} \begin{pmatrix} \rho u \\ \rho u^2 + p \\ u \left(\rho u + \frac{p}{\gamma} \right) + p \end{pmatrix} = 0$$

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} = 0$$

$$\therefore \frac{\partial \rho}{\partial t} = - \frac{\partial}{\partial x} (\rho u)$$

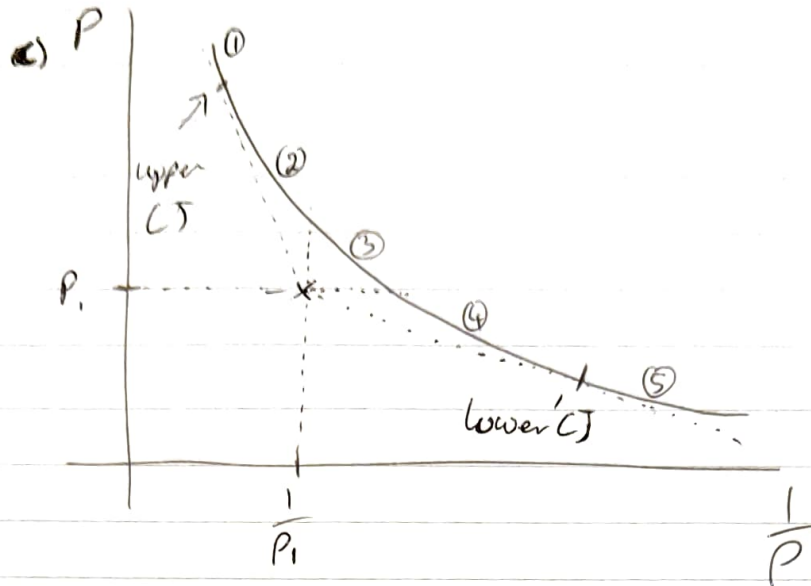
0

b)

0

0

Q1



- ① strong detonation
- ② weak detonation
- ③ Impossible
- ④ weak deflagration
- ⑤ strong deflagration

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- d) i) Detonation (① & ②)
Supersonic waves

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- ii) Deflagration (④ & ⑤)
Subsonic waves

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- iii) impossible - (③)

Q2 a) All of the stress components are a combination of all of the strain components. (3)

b) $E = 300 \text{ GPa}$ ($\times 10^9$)
 $\nu = 0.3$

i)
$$\begin{bmatrix} 0.7 & 0.3 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.3 & 0.7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.4 \end{bmatrix}$$

ii)
$$\begin{aligned} \sigma_{xx} &= \frac{300 \times 10^9}{(1.3 \times 0.4)} \times ((0.05 \times 0.7) + (0.1 \times 0.3) + (0.05 \times 0.3)) \\ &= 576.92 \times 10^9 \times 0.8 \\ &= 461.54 \times 10^9 \end{aligned}$$

c) i) Deviatoric Stress matrix is the Stress matrix minus the Hydrostatic stress (3)

ii) Distortion (0)

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Q3

b) iii) $T_1 = 300\text{K}$

$$P_1 = 5\text{MPa}$$

$$V_1 = 0.2\text{m}^3$$

$$T_1 = 300\text{K}$$

$$P_2 = 6.6\text{MPa}$$

$$V_2 = 0.15\text{m}^3$$

$$T_2 = 300\text{K}$$

$$P_3 = 4.41\text{MPa}$$

$$\frac{P_3}{P_2} = \left(\frac{V_2}{V_1}\right)^\gamma = \left(\frac{T_3 P_2}{T_2 P_3}\right)^\gamma$$

$$\ln\left(\frac{P_3}{P_2}\right) = \gamma \ln\left(\frac{T_3 P_2}{T_2 P_3}\right)$$

$$\frac{T_3 P_2}{T_2 P_3} = \exp\left(\frac{1}{\gamma} \ln\left(\frac{P_3}{P_2}\right)\right)$$

$$= \exp\left(\frac{1}{1.4} \ln\left(\frac{4.41 \times 10^6}{6.6 \times 10^6}\right)\right) = 0.17$$

$$T_3 = \frac{0.17 \times T_2 \times P_3}{P_2} = \frac{0.17 \times 300 \times 4.41}{6.6} = 34.09\text{K}$$

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Q3

a) $PV = NRT$

$$\therefore N = \frac{PV}{RT}$$

$$P = 2.5 \text{ MPa}$$

$$V = 0.4 \text{ m}^3$$

$$T = 40^\circ\text{C} = 313.16 \text{ K}$$

$$R = 8.315 \text{ mol}^{-1} \text{ K}^{-1}$$

$$\frac{2.5 \times 10^6 \times 0.4}{8.31 \times 313.16} = 384.27 \text{ mol}$$

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b) i) $V_2 = 0.15 \text{ m}$

$$P_1 = 5 \text{ MPa}$$

$$V_1 = 0.2$$

$$P_1 V_1 = P_2 V_2$$

$$P_2 = \frac{P_1 V_1}{V_2}$$

$$\frac{5 \times 10^6 \times 0.2}{0.15} = 6.6 \times 10^6 \text{ Pa}$$
$$= 6.6 \text{ MPa } (P_2)$$

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ii) $pV^\gamma = \text{constant}$

$$P_3 V_3^\gamma = P_2 V_2^\gamma$$

$$\gamma = \frac{C_p}{C_v} = \frac{919.8}{657} = 1.4$$

$$P_2 = 6.6 \text{ MPa}$$

$$\frac{6.6 \times 0.15^{1.4}}{0.2^{1.4}} = P_3 = 4.41 \text{ MPa}$$

$$V_3 = V_1 = 0.15$$

$$V_2 = 0.2$$

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- Q2 a) dQ = The energy input into the system
 dU = The energy increase within the system
 dW = The work done by the system.

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$$b) dQ = mCdt + dW$$

$$dQ = 0$$

$$dW = -250 \text{ J}$$

$$mCdt = 10 \times 500 \times dt$$

$$\therefore 0 = 5000dt - 250$$

$$\frac{250}{5000} = dt = 50$$

$$dt = \underline{50 \text{ s}}$$

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$$c) dQ = 15 \text{ J}$$

$$dU = ?$$

$$dW = +7 \text{ J}$$

$$15 = dU + 7$$

$$\therefore dU = 15 - 7$$

$$dU = \underline{8 \text{ J}}$$

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$$d) \cancel{dt = 80 - 20 = 60 \text{ K}} \quad m = 7 \text{ kg} \quad C = 4.2 \times 10^3$$

$$\frac{dS}{T} = \int_{293.16}^{353.16} \frac{mC}{T} dt$$

$$dS = 7 \times 4.2 \times 10^3 \times \ln\left(\frac{353.16}{293.16}\right) = 5.47 \text{ kJ K}^{-1}$$

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