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1a) $P_1 u_1 = P_2 u_2$

$$P_1 + \rho_1 u_1^2 = P_2 + \rho_2 u_2^2$$

$$H_1 + \frac{u_1^2}{2} = H_2 + \frac{u_2^2}{2}$$

Assumptions (1)
on deviation
expected

1b) $0 = a + bu$

$$a = 1.45 \text{ km s}^{-1} = 1450 \text{ m s}^{-1}$$

$$b = 1.99$$

$$u = 0.5 \text{ km s}^{-1} = 500 \text{ m s}^{-1}$$

$$0 = 1450 + (1.99 \times 500)$$

$$0 = 2445$$

$$\rho_1 = 1000 \text{ kg m}^{-3}$$

$$P_1 = 0$$

$$P_2 - P_1 = \rho_1 D u_2$$

$$P_2 = 1000 \times 2445 \times 500$$

$$P_2 = 1.2225 \times 10^9$$

$$P_2 = 1.22 \text{ GPa} \quad (2 \text{ D.P.}) \quad \text{Specific Pressure}$$

$$\frac{\rho_1 D}{D - u_2} = \rho_2$$

$$\rho_2 = \frac{1000 \times 2445}{(2445 - 500)}$$

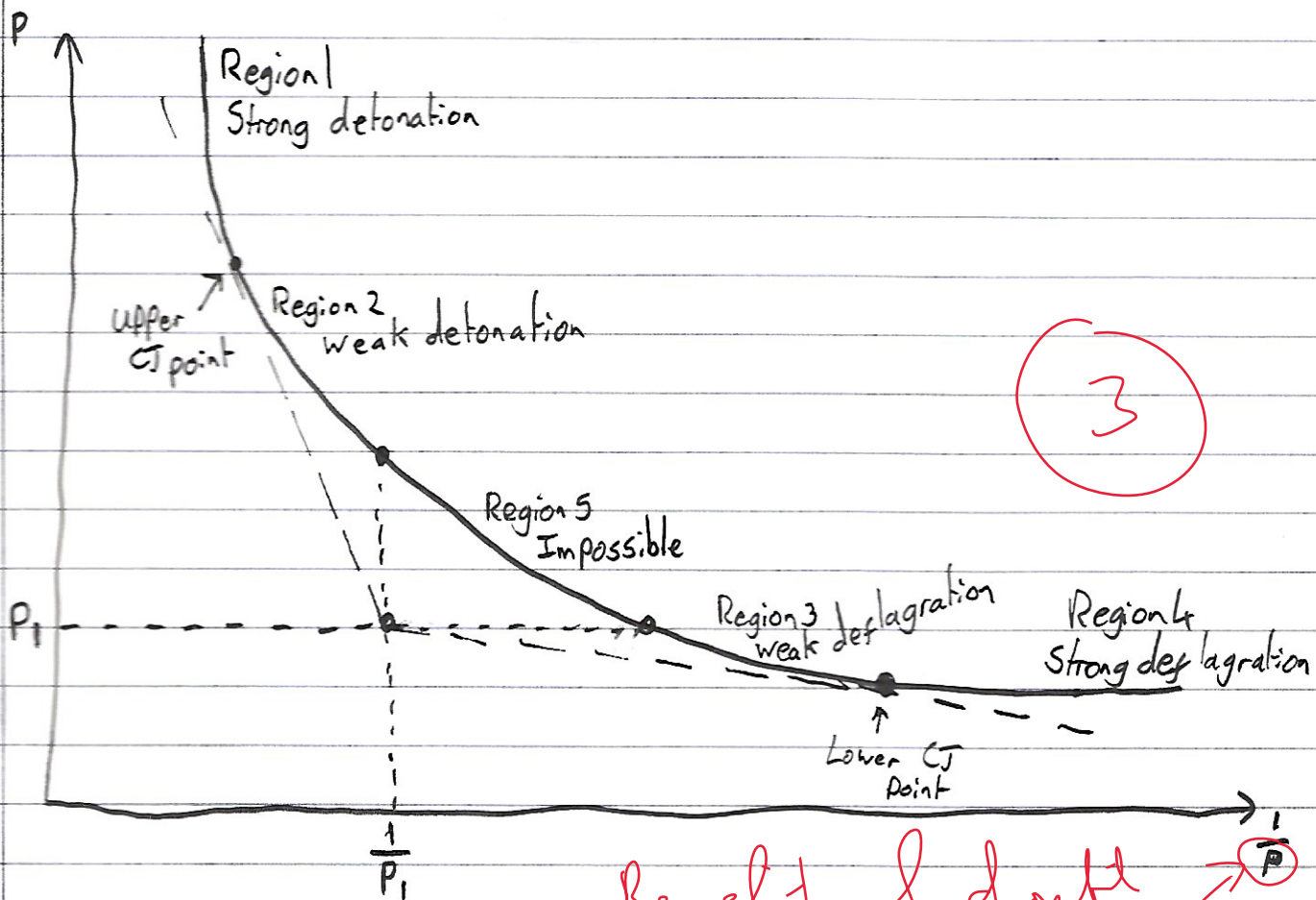
$$\rho_2 = 1257.069409$$

$$\text{Specific Density} = 1257.07 \text{ kg m}^{-3} \quad (2 \text{ D.P.})$$

$$\frac{1}{\rho_2} \therefore \text{Specific Volume} = 7.96 \text{ m}^3 \quad (2 \text{ D.P.})$$

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1c)



Benefit of doubt given to rho

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1d) Detonations are Supersonic combustion waves travelling 2000 m s^{-1} or more. Across a detonation the pressure increases. Region 1+2 on part c

Deflagrations are Subsonic combustion waves travelling around 100 m s^{-1} . Across a deflagration the pressure decreases. Region 3+4 on part c

what about density / specific vol?

$$\frac{12}{15}$$

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2a) Cauchy generalised Hooke's law (Stress = E x Strain) to 3D shapes and said that the 6 components of Stress are linearly related to the 6 components of Strain. 3

2b.i) $E = 300 \text{ GPa}$ $\nu = 0.3$ multiplier = 5.769×10^{11} (m)

$\frac{E}{m(1-\nu)}$	$m\nu$	$m\nu$	0	0	0
(4×10^{11})	1.7×10^{11}	1.7×10^{11}	0	0	0

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2b.ii) ~~stress~~ $\begin{pmatrix} 4 \times 10^{11} & 1.7 \times 10^{11} & 1.7 \times 10^{11} & 0 & 0 & 0 \\ 0.05 & 0.1 & 0.05 & 0.2 & 0.1 & 0.2 \end{pmatrix}$

~~stress~~ $(4 \times 10^{11} \times 0.05) + (1.7 \times 10^{11} \times 0.1) + (1.7 \times 10^{11} \times 0.05) = 4.55 \times 10^{10} \text{ Pa}$ 3

c.i) The deviatoric matrix is found by subtracting the stress from the diagonals in the stiffness matrix. 2

c.ii) Von-mises?! 0

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3a) $PV = nRT$

$$P = 2.5 \times 10^6$$

$$V = 0.4$$

$$R = 8.31$$

$$T = 313.16$$

$$n = \frac{PV}{RT}$$

~~384.26~~

$$n = 384.26 \quad (2 \text{ D.P.})$$

2

3b.i) $P_1 = 5 \times 10^6$

$$P_2 = ?$$

$$V_1 = 0.2$$

$$V_2 = 0.15$$

$$P_1 V_1 = P_2 V_2$$

$$P_2 = 6.67 \text{ MPa} \quad (2 \text{ D.P.})$$

3

3b.ii) $C_v = 657$

$$C_p = 919.8$$

$$\gamma = \frac{C_p}{C_v}$$

$$\gamma = 1.4$$

$$P_2 V_2^\gamma = P_3 V_1^\gamma$$

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

$$P_3 = 4.46 \text{ MPa} \quad (2 \text{ D.P.})$$

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$$3biii) P_2 V_2^\gamma = P_3 V_1^\gamma$$

$$\textcircled{1} \frac{P_2}{P_3} = \left(\frac{V_1}{V_2} \right)^\gamma$$

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$T_2 = 300$$

$$V_1 = \frac{nRT_3}{P_3}$$

$$V_2 = \frac{nRT_2}{P_2}$$

$$\frac{P_2}{P_3} = \left(\frac{\frac{nRT_3}{P_3}}{\frac{nRT_2}{P_2}} \right)^\gamma$$

$$\frac{P_2}{P_3} = \left(\frac{nRT_3}{P_3} \times \frac{P_2}{nRT_2} \right)^\gamma$$

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

$$\sqrt[\gamma]{\frac{P_2}{P_3}} = \frac{T_3 P_2}{P_3 T_2}$$

$$P_3 T_2 \sqrt[\gamma]{\frac{P_2}{P_3}} = T_3 P_2$$

$$T_3 = \frac{P_3 T_2 \sqrt[\gamma]{\frac{P_2}{P_3}}}{P_2}$$

$$T_3 = \frac{4.46 \times 10^6 \times 300 \times \sqrt[1.4]{\frac{6.67 \times 10^6}{4.46 \times 10^6}}}{6.67 \times 10^6}$$

$$T_3 = 267.41 \text{ Kelvin.}$$

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$$dQ = dU + dW$$

- 4a) dQ = heat energy supplied to system
 dU = increase in internal energy of system
 dW = work done by system

3

- 4b) $m = 0.01 \text{ kg}$ $dQ = 0$
 $c = 500$
 $dW = 250$

$$dQ = mc dT + dW$$

$$0 = 5dT - 250$$

$$\frac{250}{5} = dT$$

$$dT = 50 \text{ kelvin.}$$

3

- 4c) $15 = du + 7$ $dQ = 15$ $dW = 7$
 $du = 8 \text{ J}$ $du = ?$

3

- 4d) ~~$dS = mC \ln T$~~

$$dS = mC \left[\ln T \right]_{293.16}^{353.16}$$

$$= 7 \times 4.2 \times 10^3 \times (\ln 353.16 - \ln 293.16)$$

$$= 5474 \dots$$

$$= 5.47 \text{ kJ K}^{-1}$$

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