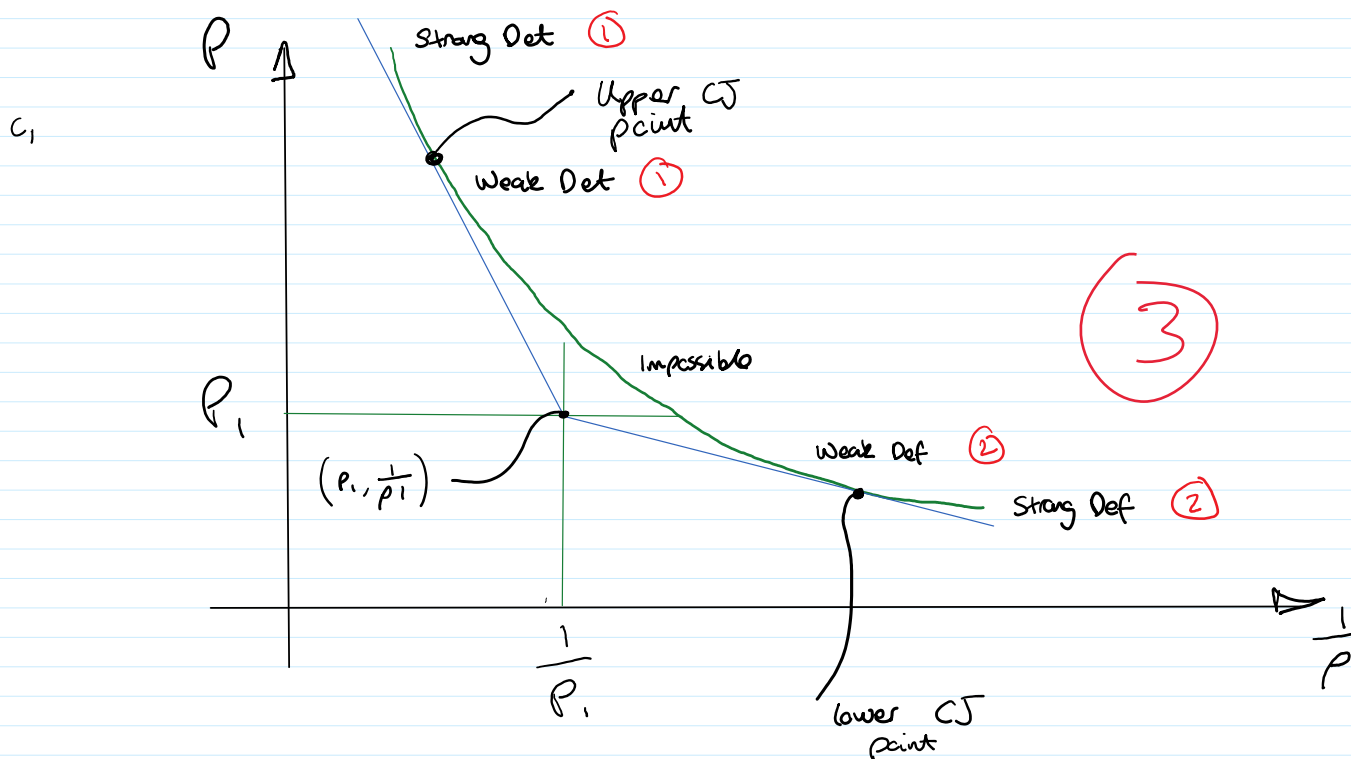


where ρ and u are density and velocity
either side of the shock

$$\begin{aligned} p_1 &= 0 \\ u_2 &= 0.5 \text{ km s}^{-1} \therefore 500 \text{ m s}^{-1} \\ \rho_1 &= 1000 \text{ kg m}^{-3} \\ D &= 2.445 \text{ km s}^{-1} \therefore 2445 \text{ m s}^{-1} \end{aligned}$$

DP

$$\begin{aligned}
 p_1 u_1 &= p_2 u_2 & u_2 &= 2445 - 500 \\
 & & &= 1945 \\
 1000 \times 2445 &= p_2 (1945) \\
 p_2 &= \frac{1000 \times 2445}{1945} \\
 &= 1257.069 \quad \therefore \frac{1}{\rho_2} = 0.0007955 \text{ m}^3 \text{ kg}^{-1}
 \end{aligned}$$



d, a detonation can be observed as a supersonic combustion wave, with a velocity of around 2000 ms^{-1}

during a detonation, the pressure increases whilst the volume decreases.

$$\frac{1}{p_2} < \frac{1}{p_1}$$

see point 1 on graph

a deflagration can be observed as a subsonic combustion wave, with a velocity of between 1 and 100 ms^{-1}

during a deflagration, the pressure decreases whilst the volume increases.

$$\frac{1}{p_2} > \frac{1}{p_1}$$

see point 2 on graph

very fast!

13/15

Q2 a, Cauchy stated that each stress component is a linear combination of all the strain components, such that:

$$\sigma_{xx} = C_{11} \epsilon_{xx} + C_{12} \epsilon_{yy} + C_{13} \epsilon_{zz} \text{ etc.}$$

$$b, i \quad \begin{bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{yz} \\ \sigma_{zx} \\ \sigma_{xy} \end{bmatrix} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & \nu & 0 & 0 & 0 \\ \nu & 1-\nu & \nu & 0 & 0 & 0 \\ \nu & \nu & 1-\nu & 0 & 0 & 0 \\ 0 & 0 & 0 & 1-2\nu & 0 & 0 \\ 0 & 0 & 0 & 0 & 1-2\nu & 0 \\ 0 & 0 & 0 & 0 & 0 & 1-2\nu \end{bmatrix} \begin{bmatrix} 0.05 \\ 0.1 \\ 0.05 \\ 0.2 \\ 0.1 \\ 0.2 \end{bmatrix}$$

$$E = 300 \text{ GPa} \quad \nu = 0.3$$

ii

$$\begin{bmatrix} 0.7 & 0.3 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.3 & 0.7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.4 \end{bmatrix} \begin{bmatrix} 0.05 \\ 0.1 \\ 0.05 \\ 0.2 \\ 0.1 \\ 0.2 \end{bmatrix}$$

$$\frac{E}{(1+\nu)(1-2\nu)}$$

$$\textcircled{1} = 576.9 \times 10^9$$

$$0.7 \times \textcircled{1} = 39.683 \times 10^9 \quad \textcircled{2}$$

$$0.3 \times \textcircled{1} = 17.007 \times 10^9 \quad \textcircled{3}$$

$$\sigma_{xx} = (\textcircled{2} \times 0.05) + (\textcircled{3} \times 0.1) + (\textcircled{3} \times 0.05) \\ = 45.35 \times 10^9 \text{ Pa}$$

c, i deviatoric stress matrix is determined by subtracting the hydrostatic stress value from each diagonal term in the stress matrix

ii

Q3 a, $PV = nRT \therefore n = \frac{PV}{RT}$

$$= \frac{2.5 \times 10^6 \times 0.4}{8.31 \times 313.15}$$

$$= 384.28 \text{ moles.}$$

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

$$V = 0.4$$

$$R = 8.31$$

$$T = 313.15$$

3

b, i $P_2 = \frac{P_1 V_1}{V_2} = 6.67 \times 10^6 \text{ Pa}$

$$P_1 = 5 \times 10^6$$

$$V_1 = 0.2$$

$$V_2 = 0.15$$

3

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

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

$$= 4.46 \times 10^6 \text{ Pa}$$

$$\frac{C_p}{C_v} = \frac{91.9.8}{65.7} = 1.4$$

4

iii $P_2 V_2 = P_3 V_1^\gamma$

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

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

$$PV = nRT \quad T_2 = 300$$

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

$$V_1 = \frac{nRT_2}{P_3}$$

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

$$= \frac{4.46 \times 10^6 \times 300 \sqrt{\frac{6.67 \times 10^6}{4.46 \times 10^6}}}{6.67 \times 10^6}$$

$$= 261.41 \text{ K}$$

5

Q4 a, $\Delta Q = \Delta u + \Delta W$

heat energy to system increase in internal energy energy (w.p) by system

3

b, $dQ = mCdT + dW$

$$0 = 0.01 \times 500 \times dT - 250$$

$$dT = \frac{250}{5} = 50 \text{ K}$$

3

c, $15 = du + 7$

$$du = 8 \text{ J}$$

3

d, $dS = \int_{20}^{80} \frac{dQ}{T}$

$$d, dS = \int_{20}^{\infty} \frac{dQ}{T}$$

$$= \int_{20}^{10} \frac{mc dT}{T} = mc \int_{20}^{10} \frac{dT}{T}$$

$$= mc \left[\log T \right]_{20}^{10}$$

$$= 7 \times 4.2 \times 10^3 \left[\log \frac{353.15}{293.15} \right]$$

$$= 5.47 \times 10^3 \text{ JK}^{-1}$$

6

15 / 15