

Advanced physics exam 13/10/2022

Q1 a) $p_2 u_2 = p_1 u_1$ p is density and u is velocity on either side of the shock wave.

b) $D = a + b u$

$$D = 1.45 + 1.99 \times 0.5$$

$$D = 2.45 \text{ km s}^{-1}$$

$$(p_2 - p_1) = p_1 D u_1$$

$$(p_2 - 0) = 1000 \times 2.45 \times 0.5$$

$$p_2 = 1225 \text{ Pa}$$

$$p_1^2 u_1^2 = \frac{p_2 - p_1}{\frac{1}{p_1} - \frac{1}{p_2}}$$

$$\frac{p_1^2 u_1^2}{p_2 - p_1} = \frac{1}{\frac{1}{p_1} - \frac{1}{p_2}}$$

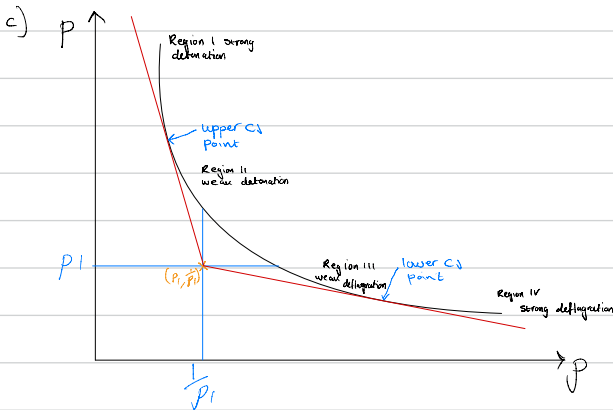
$$\frac{p_1^2 u_1^2}{p_2 - p_1} = p_1 - p_2$$

$$-p_2 = \frac{p_1^2 u_1^2}{p_2 - p_1} - p_1$$

$$-p_2 = -795.92$$

$$p_2 = 795.92 \text{ kg m}^{-3}$$

Use Hug. eqⁿ for material in stationary ref.



d) detonation are regions I and II on Hugoniot curve

Super sonic combustion waves

Specific volume decreases, Specific pressure increases across detonation

deflagration are regions III and IV on Hugoniot curve

Sub sonic combustion waves

Specific volume increases, Specific pressure decreases across deflagration

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02 a) That the 6 components of ~~stress~~ are linearly related to all 6 of the components of strain

(1)

b) i)

$$5.77 \times 10^{11} \begin{bmatrix} 0.7 & 0.3 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 & 0 \\ 0.3 & 0.3 & 0.7 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.4 \end{bmatrix}$$

(3)

b) ii) $\sigma_{xx} = 4.6 \times 10^6 \text{ pa}$

(3)

c) i) the deviatoric stress matrix is calculated by subtracting the hydrostatic value from each diagonal term in the stress matrix.

(3)

ii) the material displays equal distortion in all directions when a stress is applied.

$$\frac{10}{15}$$

(0)

0.3 a) $PV = nRT$

$$P = 2.5 \times 10^6 \text{ Pa}$$

$$T = 313 \text{ K}$$

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

$$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$n = ?$$

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(2.5 \times 10^6) \times 0.4}{8.31 \times 313}$$

$$n = 386.46 \text{ moles}$$

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b) i) $P_1 V_1 = P_2 V_2$

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

$$P_2 = \frac{(5 \times 10^5) \times 0.2}{0.15}$$

$$P_2 = 6.67 \times 10^6 \text{ Pa} = 6.67 \text{ MPa}$$

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

New pressure = P_3

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

$$P_3 = \frac{(6.67 \times 10^6) \times (0.15)^{1.4}}{(0.2)^{1.4}}$$

$$P_3 = 4.46 \times 10^6 \text{ Pa}$$

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b) iii) $\gamma = 1.4$ ($PV = nRT$ applied)

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

$$\therefore \log\left(\frac{P_3}{P_2}\right) = 1.4 \log\left(\frac{T_3 P_2}{T_2 P_3}\right)$$

$$\log\left(\frac{T_3 P_2}{T_2 P_3}\right) = \frac{1}{1.4} \log\left(\frac{P_3}{P_2}\right)$$

$$\frac{T_3 P_2}{T_2 P_3} = \exp\left(\frac{1}{1.4} \log\left(\frac{P_3}{P_2}\right)\right)$$

$$\left(\frac{2 \times 6.67 \times 10^6}{300 \times 4.46 \times 10^6}\right) = \exp\left(\frac{1}{1.4} \log\left(\frac{4.46 \times 10^6}{6.67 \times 10^6}\right)\right)$$

$$\frac{2 \times 6.67 \times 10^6}{300 \times 4.46 \times 10^6} = 0.75$$

$$2 \times 6.67 \times 10^6 = (0.75) \times (300 \times 4.46 \times 10^6)$$

$$2 = \frac{(0.75) \times (300 \times 4.46 \times 10^6)}{6.67 \times 10^6}$$

$$2 = 156.454$$

$$T_3 = 150.45 \text{ K}$$

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Q 4) a) First law of thermodynamics = $\Delta Q = \Delta U - \Delta W$

ΔQ = heat energy in

ΔU = increase in internal energy

ΔW = work done

(2)

b) adiabatically $\Delta W = \Delta U$

$$\therefore \Delta U = mC\Delta T$$

$$250 = (0.01) \times 500 \times x$$

$$\therefore x = \frac{-250}{0.01 \times 500}$$

$$\Delta T = 50 \text{ K}$$

(3)

c) $\Delta Q = \Delta U - \Delta W$

$$15 = x - 7$$

$$x = 15 + 7$$

$$\Delta U = 22 \text{ J}$$

(0)

d) change in entropy $\Delta S = \frac{\Delta Q}{T}$

$$\Delta Q = mC\Delta T$$

$$\Delta S = \frac{mC\Delta T}{T}$$

$$\Delta S = mC \int_{T_1}^{T_2} \frac{\Delta T}{T}$$

$$\Delta S = mC \int_{T_1}^{T_2} \ln T$$

$$\Delta S = mC [\ln T]_{T_1}^{T_2}$$

$$\Delta S = mC [\ln T]_{293.1}^{353.1}$$

$$\Delta S = mC [\ln(353.1) - \ln(293.1)]$$

$$\Delta S = mC \left[\ln \left(\frac{353.1}{293.1} \right) \right]$$

$$\Delta S = 7 \times (4.2 \times 10^3) \times \ln \left(\frac{353.1}{293.1} \right)$$

$$\Delta S = 5605.75 \text{ J}$$

$$\Delta S = 5.6 \text{ KJ}$$

✓ -

(4)

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