Physics 1 | Matter and Energy | Pavel Ghazaryan

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Written-answer Paper

Question 1

$A = 5mm^2 = 5 \cdot 10^{-6} m^2$

$L = 25 \cdot 10^{-2} m$

$Y = 6 \cdot 10^9 Pa$

$X = 0,1 \cdot 10^{-3} m$

F - ?

$$\frac{F}{A} = Y\left(\frac{X}{L}\right)$$

$$F = \frac{A \cdot Y \cdot X}{L} = \frac{5 \cdot 10^{-6} \cdot 6 \cdot 10^9 \cdot 10^{-4}}{25 \cdot 10^{-2}} =$$

$$= 1,2 \cdot 10^{-10} \cdot 10^9 \cdot 10^2 = 1,2 \cdot 10 = 12 = \underline{12,0\ N}$$

Question 2

$c_i = 2100$; $c_w = 4190$

$c_s = 234$

$\ell_f = 3,35 \cdot 10^5$

$\ell_v = 2,26 \cdot 10^6$

$m_i = 0,1\ kg$

$T_i = -30^\circ = 243\ K$

~~$m_s = 50^\circ C$~~

$T_s = 50^\circ C = 323\ K$

10% melted

m_s - ?

As some part of ice only melted $\Rightarrow T_{equilibrium} = 273K$

$$\Rightarrow c_i m_i (T_{eq} - T_i) + m_i \cdot \frac{10}{100} \cdot \ell_f = -c_s m_s \cdot (T_{eq} - T_s)$$

$$2100 \cdot 0,1 \cdot 30 + 0,01 \cdot 3,35 \cdot 10^5 = -234 \cdot m_s \cdot (-50)$$

$$6300 + 3,35 \cdot 10^3 = 11700 \cdot m_s$$

$$m_s = \frac{6300 + 3,35 \cdot 10^3}{11700} = 0,824786 \approx$$

$$\approx \underline{82,5 \cdot 10^{-2}\ kg} \text{ (3 sig. fig.)}$$

Question 3

$M_r = 20$

$V = 750\ ms^{-1}$

$T = 600K$

f(v) - ?

$$f(v) = \frac{4}{\sqrt{\pi}} \cdot a^{\frac{3}{2}} \cdot v^2 \cdot e^{-a \cdot v^2} \quad \text{where} \quad a = \frac{M}{2kT}$$

$$a = \frac{M_r u}{2kT} = \frac{20 \cdot 1,6605 \cdot 10^{-27}}{2 \cdot 1,381 \cdot 10^{-23} \cdot 600} =$$

$$= 0,02003 \cdot 10^{-4}$$

Continue next page

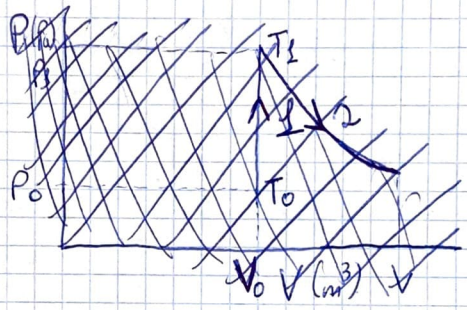
$$f(750) = \frac{4}{\sqrt{\pi}} \cdot 2,8368 \cdot 10^{-3} \cdot 10^{-6} \cdot 562500 \cdot e^{-av^2}$$

$$e^{-av^2} = e^{-0,02 \cdot 10^{-4} \cdot 562500} = 0,32465$$

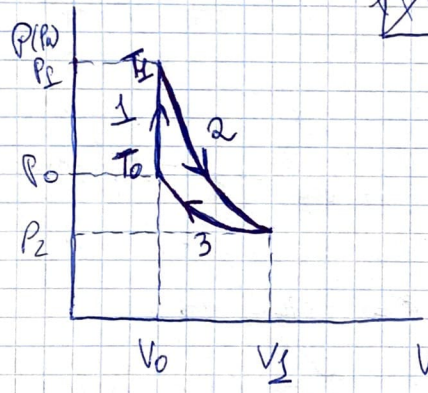
$$f(750) = 1,17 \cdot 10^{-3} \; s\,m^{-1}$$

Question 4

1 : (V const) Q_{in}
2 : (Q = 0) expansion
3 : (T const) compression



1 : isochoric
2 : adiabatic
3 : isothermal



Question 5

$m = 2,66 \cdot 10^{-26}$ Kg
$P = 100 \cdot 10^3$ Pa
$V = 2000 \cdot 10^{-8}\ m^3$
$T = 300$K

m_{TOTAL} – ?

$$M_r = \frac{m}{u} = 16,01 \approx 16 \Rightarrow M_M = M_r \cdot 10^{-3} = 0,016 \text{ kg}$$

$$PV = nRT$$

$$n = \frac{m_{TOTAL}}{M_M} \Rightarrow PV = \frac{m_T}{M_M} \cdot R \cdot T$$

$$m_T = \frac{PV \cdot M_M}{R \cdot T} =$$

$$= \frac{10^8 \cdot 16 \cdot 10^{-3} \cdot 2 \cdot 10^{-5}}{8,314 \cdot 300} =$$

$$= 0,0128 \cdot 10^{-3} = 128 \cdot 10^{-6} \text{ Kg}$$

Question 6

$h_0 = 5,00m$
$h_1 = 0$
$h_2 = 3,40m$
$W = 1,2J$
$\Delta U = 0,2J$

$m - ?$ in grams

$mgh_0 = mgh_2 + W + \Delta U$

$50m = 34m + 1,2 + 0,2$

$16m = 1,4$

$m = 0,0875kg = \underline{\underline{87,5g}}$

Question 7

$V(t) = \frac{U}{2}(e^{-bt} + 1)$

$V_1(10) = 0,75 \cdot V_0$

$V_0(0) = \frac{U}{2} \cdot (1+1) = U$

$V_1(10) = \frac{U}{2} \cdot (e^{-10b} + 1)$

$b - ?$

$\frac{U}{2} \cdot (e^{-10b} + 1) = 0,75 \cdot U$

$e^{-10b} + 1 = 1,5$

$e^{-10b} = 0,5$

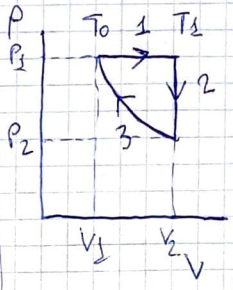
$-10b = \ln 0,5 \Rightarrow -10b = -0,69314 \Rightarrow$

$\Rightarrow b = 0,069314 = \underline{\underline{6,93 \cdot 10^{-2}}}$

Question 8

$n = 10^{-2} mol$
$c_p = 29,1 J mol^{-1} k^{-1}$
$T_0 = 466K$
$1 \rightarrow 2$: P const $\Delta V > 0$ $T_1 = 3T_0$
$2 \rightarrow 3$: V const $Q_{out} < 0$
$3 \rightarrow 1$: $\Delta V < 0$ $W_3 = 34,5J$

$W_1 - ?$
$\eta - ?$



$P_1 V_1 = nRT_0$

$P_1 V_2 = nRT_1 = nR3T_0$

$V_1 = \frac{nRT_0}{P_1}$

$V_2 = \frac{3nRT_0}{P_1}$

$W_1 = -P_1 \cdot \left(\frac{3nRT_0}{P_1} - \frac{nRT_0}{P_1}\right)$ (V_2, V_1)

$W_1 = -P_1 \cdot \frac{2nRT_0}{P_1} = -2nRT_0 \Rightarrow$

$\Rightarrow W_1 = -2nRT_0 = -2 \cdot 10^{-2} \cdot 8{,}314 \cdot 466 = -77{,}5\,J$

$Q_1 = nC_p(3T_0 - T_0) = nC_p \cdot 2T_0 = 10^{-2} \cdot 29{,}1 \cdot 2 \cdot 466 =$

$= 271{,}2\,J$

$W_{net} = W_1 + W_3 = -77{,}5 + 34{,}5 = -43$

$Q_{in} = 271{,}2$ as in Process 2 $Q_2 < 0$ and Process 3 $Q = 0$

$$\eta = \frac{|W_{net}|}{Q_{in}} = \frac{43}{271{,}2} = 0{,}15855 \approx \underline{0{,}159} \text{ or } \underline{15{,}9\%}$$

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