I) Без фазовых переходов.

№3 → №5 → №6 → №8

№3.

$t_{в_1} = 40°C$; $t_0 = 18°C$; $t_1 = 36°C$

$t_2 - ?$

$C = mc$

$C_м \cdot (\underbrace{t_1 - t_{в_1}}_{-4°C}) + C_б (\underbrace{t_1 - t_0}_{18°C}) = 0$

$C_м \cdot 4°C = C_б \cdot 18°C$

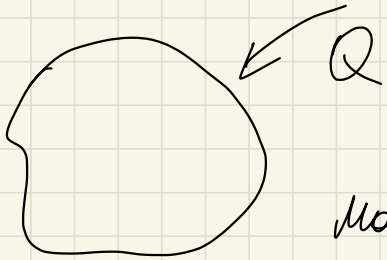
$C_м = 4{,}5\, C_б$

$$t = \frac{m_1 c_1 t_1 + m_2 c_2 t_2 + \dots}{m_1 c_1 + m_2 c_2 + \dots} = \frac{C_м \cdot t_1 + C_б t_0}{C_м + C_б} =$$

$$= \frac{4{,}5\, C_б\, t_1 + C_б t_0}{4{,}5\, C_б + C_б} = \frac{4{,}5 t_1 + t_0}{5{,}5} =$$

$$= \frac{4{,}5 \cdot 36 + 18}{5{,}5}\,°C \approx 32{,}7°C$$

N 5



τ – время

Θ – температура

Мощность

$$m \cdot c \cdot \Delta t = P \cdot \tau \quad (\Delta t > 0)$$

$$\begin{cases} C \cdot (t_1 - t_0) = P \cdot \tau_1 \\ \frac{C}{2} \cdot (t_2 - t_1) = P \cdot \tau_2 \end{cases}$$

(t_0 = 20°, t_1 = 40°, t_2 = 55°, τ_1 = 2 мин, τ_2 = 3 мин)

$$\Rightarrow 20C = P \cdot 2$$

$$\Rightarrow 15C = 2P$$

$$\begin{cases} (C_2 + C_6) \cdot 20^\circ C = P \cdot 120c \\ \left(C_2 + \frac{1}{2} C_6\right) \cdot 15^\circ C = P \cdot 60c \end{cases} :$$

$$\frac{C_2 + C_6}{C_2 + \frac{1}{2} C_6} \cdot \frac{4}{3} = 2$$

$$4(C_2 + C_6) = 3 \cdot 2 \cdot \left(C_2 + \frac{1}{2} C_6\right)$$

$$C_6 = 2 C_2$$

$$(C_2 + 2 C_2) = 6P \Rightarrow C_2 = 2P$$

$$\left(C_2 + \frac{1}{4} C_6\right) \Delta t_3 = \frac{1}{2} P \cdot \tau_3$$

$$\frac{1}{4} C_6 = \frac{1}{2} C_2 = P$$

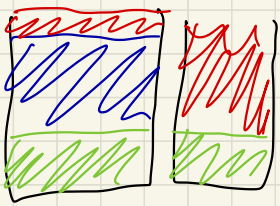
$$3P \cdot \Delta t_3 = \frac{1}{2} P \tau_3 \quad (\Delta t_3 = 45)$$

$$6 \cdot 45 = \tau_3$$

$$\tau_3 = 270\,c = 4{,}5\ \text{мин.}$$

$$№6 \rightarrow №8$$

№6. Уместь равенство объёмов



$V_{ол} = \frac{m_{ол}}{\rho_{ол}}$ $\quad m = \rho \cdot V$

$$\frac{m_{ол}}{\rho_{ол}} + V_{1б} = 10 \frac{m_{ол}}{\rho_{ол}}$$

$$V_{1б} = 9 \frac{m_{ол}}{\rho_{ол}}$$

$$M_б = V_{1б} \cdot \rho_б = 9 m_{ол} \cdot \frac{\rho_б}{\rho_{ол}}$$

$$M \cdot c \cdot 2°C + M_б \cdot c_б \cdot 2°C - m_{ол} \cdot c_{ол} \cdot 60°C = 0$$

$$M c + 9 m_{ол} \cdot \frac{\rho_б}{\rho_{ол}} \cdot c_б - 30 m_{ол} \cdot c_{ол} = 0$$

$$M \cdot c \cdot \Delta t + 10 m_{ол} \cdot c_{ол} \cdot (-\Delta t) = 0$$

$\Delta t = 0$

$$mc = 10\, m_{ст} \cdot c_{ст}$$

$$10\, m_{ст} \cdot c_{ст} + 9\, m_{ст} \cdot \frac{\rho_б}{\rho_{ст}} \cdot c_б - 30\, m_{ст} \cdot c_{ст} = 0$$

$$20 c_{ст} = 9 c_б \cdot \frac{\rho_б}{\rho_{ст}}$$

$$c_{ст} = \frac{9}{20} \cdot \frac{\rho_б}{\rho_{ст}} \cdot c_б \approx 1100\ Дж/кг \cdot °C$$

№ 8 → № 10 → № 12

$$c_1 (1 + \alpha t)\ °C$$

↑ безразм.

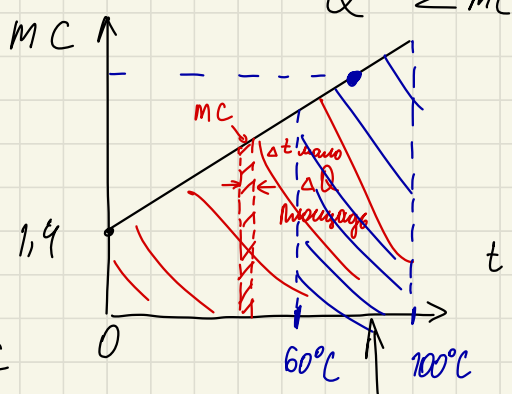
$$c = 1{,}4 \cdot 10^3 (1 + 0{,}014 t)$$

$$Q = \sum mc\Delta t$$

$$Q_{бр} = c_{ср} \cdot m \cdot (-40°C)$$

$$c_{ср} = c(80°C) =$$

$$= 1{,}4 \cdot 10^3 (1 + 0{,}014 \cdot 80) = 1{,}4 \approx 3 \cdot 10^3\ Дж/кг°C$$

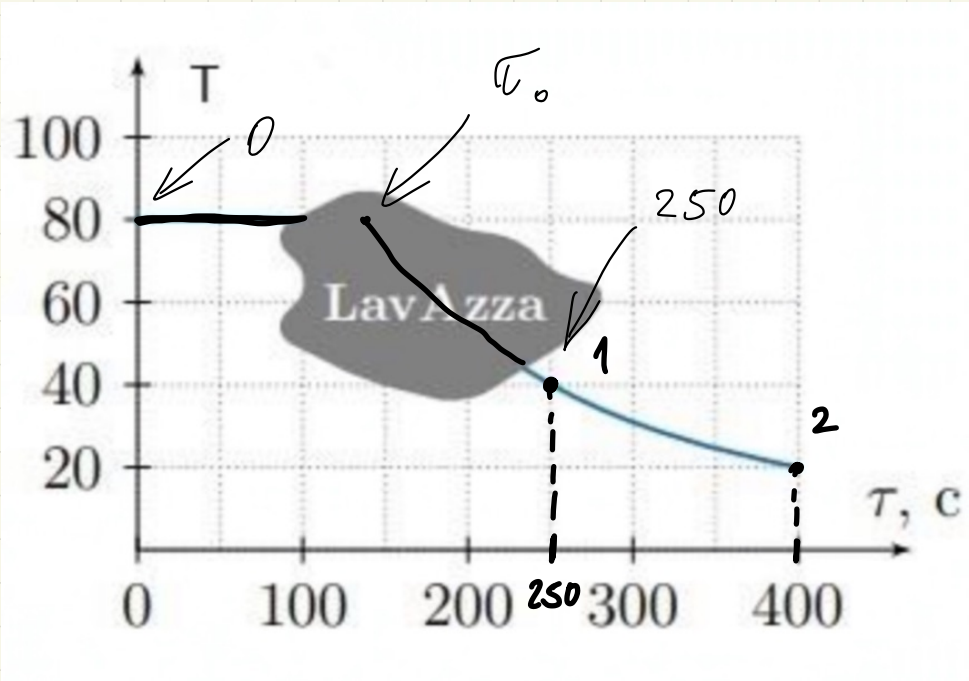


$$m_б c_б \cdot 40°C + m_{бр} \cdot c_{ср} \cdot (-40°C) = 0$$

$$m_б \cdot 4200 = 1\ кг \cdot 3000$$

$$m_б = \frac{3000}{4200}\ кг \approx 0{,}71\ кг$$

№10



в точке 1:

$$m_{v1} \cdot c \cdot (-40^\circ C) + m_{x1} \cdot c \cdot (40 - t_x) = 0$$

$m_{v1} \sim (\tau_0)$, $m_{x1} \sim (250 - \tau_0)$

$$-\tau_0 \cdot 40 + (250 - \tau_0) \cdot (40 - t_x) = 0$$

в точке 2:

$$-\tau_0 \cdot 60 + (400 - \tau_0) \cdot (20 - t_x) = 0$$

$$-\tau_0 \cdot 40 - \tau_0 \cdot 40 + \tau_0 t_x + 10000 - 250 t_x = 0$$

$$\tau_0 (80 - t_x) = 10000 - 250 t_x$$

$$\tau_0 = \frac{10000 - 250 t_x}{80 - t_x}$$

$$-60 \cdot 250 \cdot \frac{40 - t_x}{80 - t_x} + (20 - t_x) \cdot \left(400 - 250 \frac{40 - t_x}{80 - t_x}\right) = 0$$

$$-60 \cdot 250 \cdot (40 - t_x) + (20 - t_x)\,|\,400(80 - t_x) - 250(40 - t_x)\,| = 0$$

$$-300(40 - t_x) + (20 - t_x)\,|\,640 - 8t_x - 200 + 5t_x\,| = 0$$

$$440 - 3t_x$$

$$-12000 + 300 t_x + 8800 - 60 t_x - 440 t_x + 3 t_x^2 = 0$$

$$3 t_x^2 - 200 t_x - 3200 = 0$$

$$D = 40000 + 4 \cdot 3 \cdot 3200 = 78400 = 280^2$$

$$t_x = \frac{200 \pm 280}{6} \qquad t_x = -\frac{80}{6} = -13{,}3\,^\circ C$$

~~$t_x = 80\,^\circ C$~~

$$\tau_0 = \frac{10000 - 250 \cdot (-13{,}3)}{80 + 13{,}3} = 143\,c.$$

$$\frac{80\,^\circ C \cdot c_{\text{ж}} \cdot 143\,c - 13{,}3\,^\circ C \cdot c_{\text{ж}} \cdot (800 - 143)\,c}{800\,c \cdot c_{\text{ж}}} =$$

$$= 3{,}35\,^\circ C$$

Семинар 2.

$\lambda = 330 \cdot 10^3$ Дж/кг

$L = 2{,}3 \cdot 10^6$ Дж/кг

II $N15 \rightarrow N16 \rightarrow N21$

N15 $Q_{лв} + Q_{плв} + Q_{пб} + Q_{пв} + Q_{обп} = 0$

$Q_{лв} + Q_{плв} + Q_{пб} = 0$, $Q_{пв} + Q_{обп} = 0$

$m_л \cdot \lambda + m_л \cdot c_в \cdot (\Theta - 0°C) + m_в c_в \cdot (\Theta - 0°C) - m_п \cdot L + m_п \cdot c_в \cdot (\Theta - 100°C) = 0$

$\Theta - 100°C < 0$

$m_п (L + c_в \cdot 20°C) = 5\,кг \cdot \lambda + 20\,кг \cdot c_в \cdot 80°C$

$$m_п = \frac{5 \cdot 330 \cdot 10^3 + 20 \cdot 8 \cdot 42 \cdot 10^3}{2{,}3 \cdot 10^6 + 42 \cdot 2 \cdot 10^3} \text{ кг} =$$

$2{,}3 \cdot 10^6 = 2300$, $42 \cdot 2 = 84$

$= 3{,}5$ кг

$N16 \rightarrow N21 \rightarrow N24$

N16 $m_{вс} = m_0$

$250 \cdot c_в \cdot (-5°C) + (20_г - m_0) \cdot \lambda + 20_г \cdot c_в \cdot 10°C = 0$

$$m_0 = \frac{-250 \cdot 4200 \cdot 5 + 20 \cdot 330000 + 20 \cdot 4200 \cdot 10}{330\,000} =$$

$$= 6{,}6 \text{ кг.}$$

№21

случай 2:

$$m_в \cdot \underbrace{c_в}_{2c_л} \cdot \Delta t_в + m_л c_л \Delta t_л = 0$$

$$2\Delta t_в + \Delta t_л = 0$$

$$\Delta t_л = -2\Delta t_в$$

$$(0 - t_л) = -2(0 - t_в)$$

$$t_л = -2t_в$$

случай 1:

$$m_в \cdot c_в \cdot \Delta t_в + \frac{1}{2} m_в \cdot c_л \cdot \Delta t_л + l_2 \cdot \lambda = 0$$

$$m_в \cdot 2c_л \Delta t_в - m_в \cdot c_л \cdot \Delta t_в + l_2 \lambda = 0$$

$$l_2 \cdot \lambda = -m_в \cdot c_л \cdot \Delta t_в$$

случай 3:

$$m_в \cdot c_в \Delta t_в + 2 m_в c_л \Delta t_л - m_x \lambda = 0$$

$$m_в \cdot 2c_л \Delta t_в - 4 m_в c_л \Delta t_в - m_x \lambda = 0$$

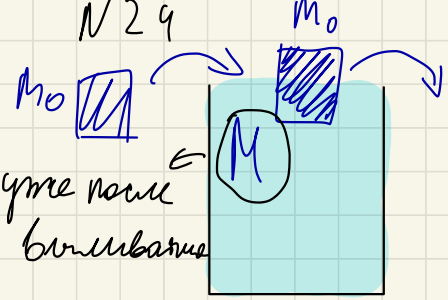
$$-2 m_б c_л \Delta t_б = m_х \lambda$$

$$+2 \cdot 1_г \cdot \lambda = m_х \lambda$$

$$m_{зс} = 2_г$$

$m_з' = 42_г$

№24



$\Delta m_б = m_0$

$Q_л = m c_б \cdot 11°C - m_0 c_б \cdot 33°C$

1) $M \cdot c_б \cdot (-11°C) + m_0 \cdot c_л \cdot (0°C - t_л) + m_0 \lambda + m_0 c_б \cdot 33°C = 0$

2) $(M - m_0) c_б \cdot \Delta t + 2 m_0 c_л (0°C - t_л) + 2 m_0 \lambda + 2 m_0 c_б (44°C + \Delta t) = 0$

Δt ↑ 0

$2 Q_л$

$\Delta t = t_{кон} - 44°C \Rightarrow t_{кон} = 44°C + \Delta t$

88

$M c_б \Delta t + m_0 c_б \Delta t + 2 (M c_б \cdot 11°C - m_0 c_б \cdot 33°C) + 2 m_0 c_б \cdot 44°C = 0$

$- c_б$

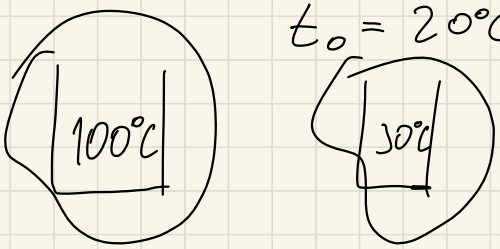
$M \Delta t + m_0 \Delta t + 22°C \cdot m_0 + 22°C \cdot M = 0$

$\Delta t (M + m_0) + 22°C (M + m_0) = 0$

$\Delta t = -22°C$

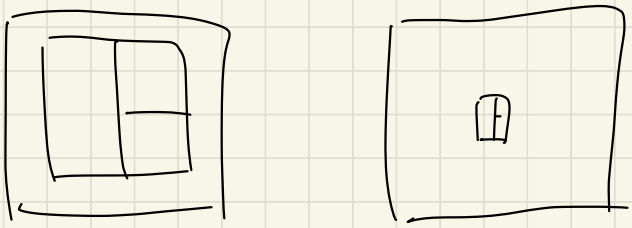
$t_2 = 22°C$

III 3-й Ньютона – Рихмана



1 $P_{передач} \sim (T - t_{о.с.})$

$P_{передач} \sim \Delta t$

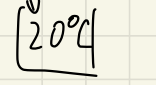


2 $P \sim S$

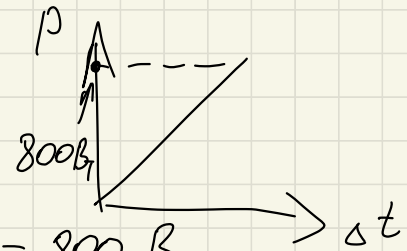
$P \sim S \Delta t$

$P = \alpha \cdot S \cdot \Delta t$ α – размерный коэффициент

№28 $P = 800$ Вт



20°C



$P_{потерь} = P_{нагр} = 800$ Вт

$\Delta T = const$ (в небольшом интервале)

$P_{потерь} = const$

$$m_в \cdot c_в \cdot \underbrace{\Delta t_в}_{-1^\circ C = 0} = -P_{потерь} \cdot \tau$$

$$\tau = \frac{10л \cdot 4200 \, Дж/кг \cdot ^\circ C \cdot 1^\circ C}{800 Вт} = 52{,}5 с$$

№29 → №31 → №32.

$$m \cdot c \cdot \Delta T = (P - P_{потерь}) \cdot \tau_1$$

$$m \cdot c \cdot (+\Delta T) = + P_{потерь} \cdot 2\tau_1$$

$\Delta T > 0$

$$P_{потерь} = \frac{mc\Delta T}{2\tau_1}$$

$$mc\Delta T = P\tau_1 - \frac{mc\Delta T}{2}$$

$$P = \frac{3}{2} mc\Delta T / \tau_1 = \frac{\frac{3}{2} \cdot 0{,}5 \cdot 1 \cdot 4200}{100} = 31{,}5 Вт$$

№31

$$S = 2\pi r \cdot \underbrace{l}_{h} \quad (\text{боковой пов-ти})$$

$$S = 2\pi r^2 \quad (\text{обоих оснований})$$

$$P_{потерь} = \alpha S \Delta T$$

$$P = \alpha \left(2\pi r h_0 + 2\pi r^2 \right) \cdot 60°C$$

$$P = \alpha \left(2\pi r \cdot 2h_0 + 2\pi r^2 \right) \cdot 40°C$$

$$(h_0 + r) \cdot 3 = (2h_0 + r) \cdot 2$$

$$3h_0 + 3r = 4h_0 + 2r$$

$$r = h_0$$

$$P = \alpha \left(2\pi r \cdot 4h_0 + 2\pi r^2 \right) \cdot \Delta T_x$$

$$\underbrace{(h_0 + r)}_{2r} \cdot 60°C = \underbrace{(4h_0 + r)}_{5r} \Delta T_x$$

$$2 \cdot 60°C = 5 \Delta T_x \Rightarrow \Delta T_x = 24°C$$

$$T_x = T_0 + \Delta T_x = 44°C$$