

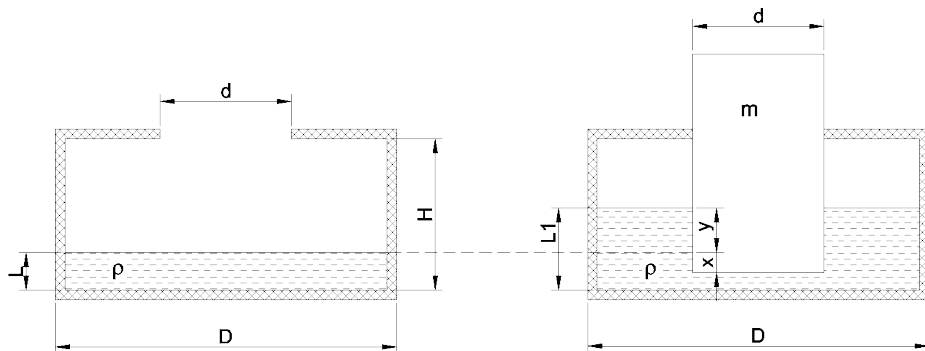
DRŽAVNO NATJECANJE MLADIH FIZIČARA

Brodarica, 25. – 28. travnja 2016.

Srednje škole – 2. skupina
Rješenja i smjernice za bodovanje

1. zadatak (17 bodova)

$p_{at}=100\,000\text{ Pa}$, $\rho = 1000\text{ kg/m}^3$, $D = 0.4\text{ m}$, $d = 0.1\text{ m}$, $H = 0.28\text{ m}$, $L = 0.14\text{ m}$, $L_1 = 0.15\text{ m}$, $g = 10\text{ m/s}^2$



$$V_o = \frac{D^2 \pi}{4} (H - L) \quad (0.01758\text{ m}^3) \quad (2\text{ boda})$$

$$V_1 = \frac{(D^2 - d^2) \pi}{4} (H - L_1) \quad (0.01531\text{ m}^3) \quad (2\text{ boda})$$

Izotermna kompresija:

$$p_o V_o = p_1 V_1 \quad (1\text{ bod})$$

$$p_1 = p_o \frac{D^2 (H - L)}{(D^2 - d^2) (H - L_1)} \quad (114\,871\text{ Pa}) \quad (2\text{ boda})$$

$$\frac{d^2 \pi}{4} x = \frac{(D^2 - d^2) \pi}{4} y \quad (2\text{ boda})$$

Za

$$y = L_1 - L = 0.01\text{ m}$$

dobije se:

$$x = 0.15\text{ m} \quad (1\text{ bod})$$

Klip miruje pa vrijedi:

$$mg = S \Delta p \quad (2\text{ boda})$$

$$S \Delta p = \frac{d^2 \pi}{4} [g \rho (y + x) + (p_1 - p_{at})] \quad (3\text{ boda})$$

Masa klipa je

$$m = \frac{d^2 \pi}{4} (\rho (y + x) + (p_1 - p_{at}) / g) \quad (1\text{ bod})$$

$$m = 12.930\text{ kg} \quad (13.156\text{ kg za } g = 9.81\text{ m/s}^2) \quad (1\text{ bod})$$

2. zadatak (20 bodova)

$V_1 = 6 \cdot 10^{-6}\text{ m}^3$, $L = 0.48\text{ m}$, $d = 0.0045\text{ m}$, $\gamma = 1.4$, $m = 0.0008\text{ kg}$, $p_{at} = 10^5\text{ Pa}$, $p_1 = 10^6\text{ Pa}$,
 $R = 8.314\text{ J/(mol}\cdot\text{K)}$

a) Volumen plina(zraka) u trenutku izlaska metka iz cijevi:

$$(*) \quad V_2 = V_1 + \frac{d^2 \pi}{4} L \quad (0.00001363\text{ m}^3) \quad (1\text{ bod})$$

Rad plina pri adijabatskom širenju ($Q = 0$):

$$W_{plina} = -\Delta U = -nC_V \Delta T \quad (1\text{ bod})$$

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Koristeći $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$ i $p_1 V_1^\gamma = p_2 V_2^\gamma$ za promjenu temperature se dobije:

$$\begin{aligned}\Delta T &= T_2 - T_1 = \frac{p_2 V_2 - p_1 V_1}{nR} \\ &= \frac{p_1 V_1}{nR} \left(\left(\frac{V_1}{V_2} \right)^{\gamma-1} - 1 \right)\end{aligned}\quad (1 \text{ bod})$$

Koristeći: $\gamma = \frac{C_p}{C_v}$ i $C_p = C_v + R \Rightarrow C_v = \frac{R}{\gamma-1} = 20.785 \frac{\text{J}}{\text{molK}}$ (1 bod)

$$W_{\text{plin}} = \frac{p_1 V_1}{R} \left(1 - \left(\frac{V_1}{V_2} \right)^{\gamma-1} \right) C_v \quad (W_{\text{plin}} = 4.197 \text{ J}) \quad (1 \text{ bod})$$

Rad vanjskog zraka: $W_{\text{at}} = p_{\text{at}} \Delta V = p_{\text{at}} (V_1 - V_2) = -p_{\text{at}} \frac{d^2 \pi L}{4} \quad (W_{\text{at}} = -0.763 \text{ J}) \quad (2 \text{ boda})$

Promjena kinetičke energije metka jednaka je ukupnom obavljenom radu:

$$\Delta E_{\text{kin}} = \frac{mv^2}{2} - 0 = W_{\text{plin}} + W_{\text{at}} \quad (3 \text{ boda})$$

Brzina metka na izlazu: $v = \sqrt{\frac{2}{m} (W_{\text{plin}} + W_{\text{at}})} = 92.65 \frac{\text{m}}{\text{s}} \quad (2 \text{ boda})$

b) Cijev ima smisla produživati dok se tlak plina ispred metka ne izjednači s atmosferskim:

$$p_2 = p_{\text{at}} \quad (3 \text{ boda})$$

$$V_2 = \left(\frac{p_1}{p_{\text{at}}} \right)^{1/\gamma} V_1 = 0.0000311 \text{ m}^3 \quad (1 \text{ bod})$$

Na temelju (*): $L_{\text{max}} = (V_2 - V_1) \frac{4}{d^2 \pi} = 1.58 \text{ m} \quad (2 \text{ boda})$

Brzina: $v = \sqrt{\frac{2}{m} (W_{\text{plin}} + W_{\text{at}})} = 108.66 \frac{\text{m}}{\text{s}} \quad (2 \text{ boda})$

3. zadatak (15 bodova)

$t = 100 \text{ s}$, $R = 0.005 \text{ m}$, $\rho = 2700 \text{ kg/m}^3$, $q = 1.6 \cdot 10^{-19} \text{ C}$, $U = 50\,000 \text{ V}$, $c = 900 \text{ J/(kgK)}$, $I = 3 \cdot 10^{-7} \text{ A}$, $D = 0.5 \text{ m}$, $m_e = 9.1 \cdot 10^{-31} \text{ kg}$.

a) Za jedan elektron: $E_{\text{kin}} = qU \quad (E_{\text{kin}} = 50 \text{ keV}) \quad (1 \text{ bod})$

$$I = \frac{Nq}{t} \Rightarrow N = \frac{It}{q} \quad (N = 1.875 \cdot 10^{14}) \quad (2 \text{ boda})$$

Kinetička energija jednaka je toplini predanoj kugli: $mc\Delta t = NE_{\text{kin}} \quad (3 \text{ boda})$

$$m = \frac{4}{3} R^3 \pi \rho \quad (m = 0.001413 \text{ kg}) \quad (1 \text{ bod})$$

$$\Delta t = \frac{3It}{4R^3 \pi \rho c} U \quad (1 \text{ bod})$$

$$\Delta t = 1.1795 \text{ K} \approx 1.18 \text{ K} \quad (1 \text{ bod})$$

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b) Vrijeme gibanja elektrona od izlaska iz topa do udara u kuglu:

$$t = \frac{D - R}{v} \quad (2 \text{ boda})$$

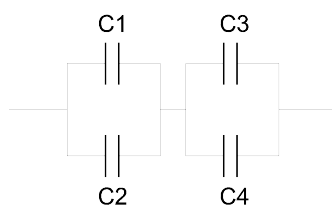
$$v = \sqrt{\frac{2E_{kin}}{m_e}} = 1.326 \cdot 10^8 \text{ m/s} \quad (1 \text{ bod})$$

$$t = \frac{D - R}{v} = 3.733 \text{ ns} \quad (1 \text{ bod})$$

Nakon 1 ns prvi elektron još nije udario o metu pa je povećanje temperature nula! (2 boda)

4. zadatak (18 bodova)

a) Ekvivalentna shema je:



(3 boda)

$$C_1 = \epsilon_o \epsilon_r \frac{xL}{D} = C_4, \quad C_2 = \epsilon_o \frac{L(L-x)}{D} = C_3 \quad (2 \text{ boda})$$

$$C_{12} = \epsilon_o \frac{L}{D} (\epsilon_r x + L - x) = C_{34} \quad (1 \text{ bod})$$

Ukupno:

$$C \equiv C_{1234} = \frac{C_{12}C_{34}}{C_{12} + C_{34}} = \epsilon_o \frac{L}{2D} (\epsilon_r x + L - x) \quad (2 \text{ boda})$$

b)
$$C_1 = \epsilon_o \epsilon_r \frac{(x + \Delta x)L}{D} = C_4, \quad C_2 = \epsilon_o \frac{L(L - x - \Delta x)}{D} = C_3 \quad (1 \text{ bod})$$

Istim postupkom kao u a) dobije se ukupni kapacitet:

$$C' = \epsilon_o \frac{L}{2D} (\epsilon_r x + \epsilon_r \Delta x + L - x - \Delta x) = \epsilon_o \frac{L}{2D} ((x + \Delta x)(\epsilon_r - 1) + L) \quad (2 \text{ boda})$$

c) Napon je stalan pa je
$$\Delta E = \frac{C'U^2}{2} - \frac{CU^2}{2} \quad (1 \text{ bod})$$

Uvrštavanjem izraza za C i C':
$$\Delta E = \frac{U^2}{4} \frac{\epsilon_o L}{D} \Delta x (\epsilon_r - 1) \quad (2 \text{ boda})$$

d) Naboj je stalan pa je
$$\Delta E = \frac{Q^2}{2C'} - \frac{Q^2}{2C} \quad (1 \text{ bod})$$

$$Q = CU = \epsilon_o \frac{LU}{2D} (\epsilon_r x + L - x) \quad (1 \text{ bod})$$

$$\Delta E = \frac{U^2}{4} \frac{\epsilon_o L}{D} \frac{\Delta x (\epsilon_r x + L - x)(1 - \epsilon_r)}{\epsilon_r x + \epsilon_r \Delta x + L - x - \Delta x} \quad (2 \text{ boda})$$