

Dejan Zupan

IZPITNE NALOGE IN REŠITVE NALOG S POSTOPKOM IZ PREDMETA STATIKA NA
VISOKOŠOLSLEM ŠTUDIJU GRADBENIŠTVA

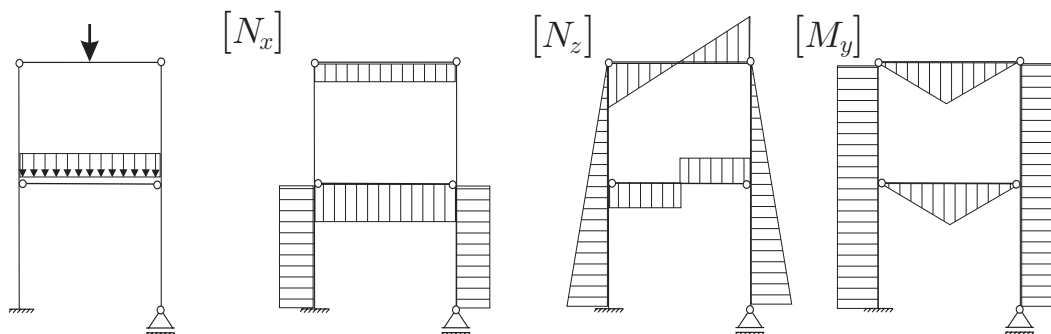
Igor Planinc

VPRAŠANJA IZ TEORIJE PRI PREDMETU STATIKA NA
UNIVERZITETNEM ŠTUDIJU GRADBENIŠTVA

ŠTUDIJSKO LETO: 2006/07

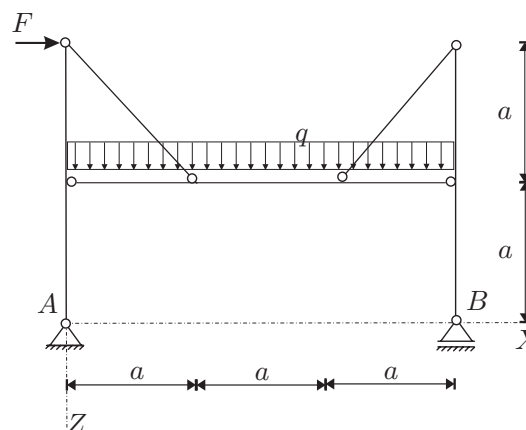
RAČUNSKI DEL IZPITA:

1. Janezek je na izpitu iz statike padel. Njegovi diagrami so polni napak. Pomagaj Janezku in poišči (BREZ RAČUNANJA) vse napake v spodnjih diagramih! Namig: katere reakcije so enake nič? (OBVEZNA NALOGA! 20%)



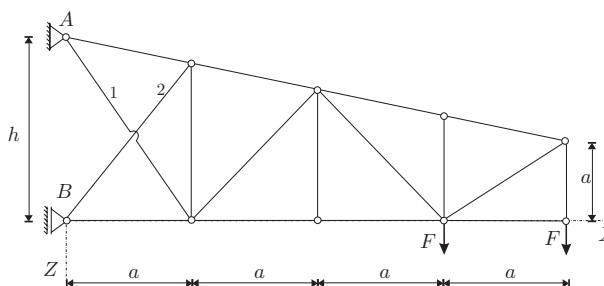
2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti, reakcije in notranje statične količine (N_x, N_z, M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!

Podatki: $a = 3\text{ m}$,
 $F = 12\text{ kN}$, $q = 4\text{ kN/m}$.
 (OBVEZNA NALOGA! 50%)



3. Za palično konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti in osne sile v vseh palicah! Palici 1 in 2 sta izvedeni tako, da se med sabo ne ovirata. Namig: najprej poišči palice, v katerih so osne sile nič. (30%)

Podatki: $a = 2\text{ m}$, $h = 4\text{ m}$, $F = 3\text{ kN}$.

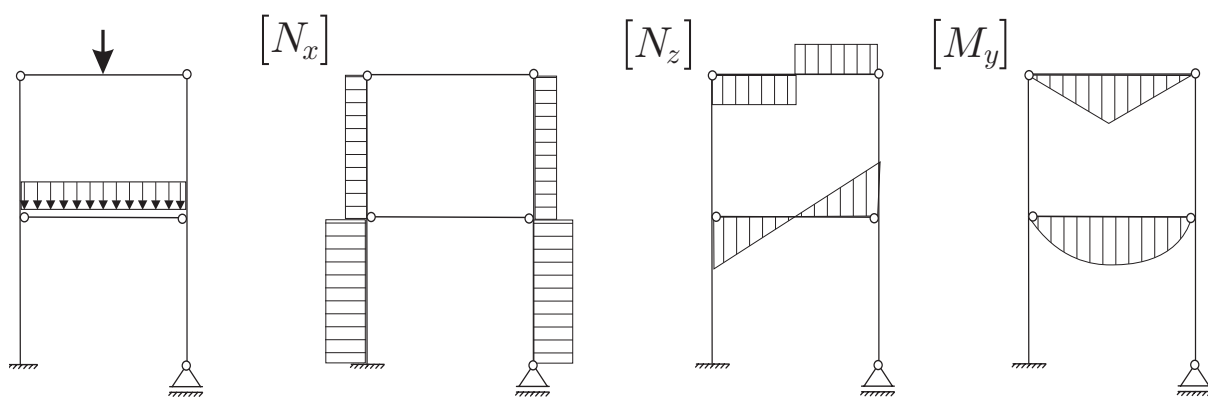


TEORETIČNI DEL IZPITA:

Izmed treh zastavljenih vprašanj si izberete dve, na kateri boste odgovarjali. Izbrani vprašanji jasno označite! Pišite čitljivo.

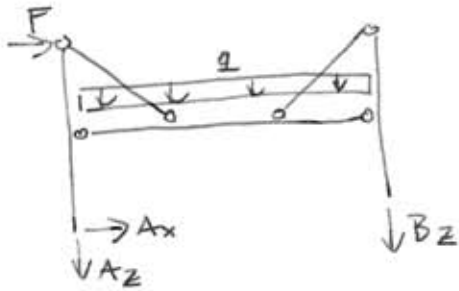
1. Računski modeli za opis medsebojnega vpliva med telesi!
2. Ravnotežni pogoji za linijski element z ravno osjo (izpeljava diferencialnih enačb)! Ravnotežne pogoje izpeljite za raven ravninski nosilec, ki je obtežen samo z linijsko obtežbo prečno na os nosilca! Kaj so statični robni pogoji pri prostoležečem nosilcu, ki je obtežen samo z linijsko obtežbo?
3. Izpeljite in opišite izraz za število odvzetih prostostnih stopenj, ki jih vez odvzame k nepovezanim telesom! Obravnavajte tudi primer, ko imajo vsa telesa na mestu vezi enake nekatere kinematične količine, preostale kinematične količine pa so možne za vsa telesa! (ilustracija s karakterističnimi primeri)

1. Naloga: PRAVILNI DIAGRAMI



a.) $\tilde{m}_{PB} = 3 \cdot 5 - 2 - 1 - 6 \cdot 2 = 0$

b.) REAKCIJE



$$A_x = -F$$

$$A_x = -12 \text{ kN}$$

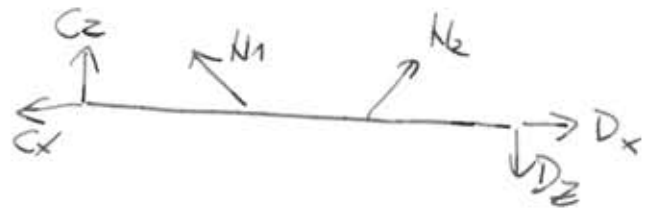
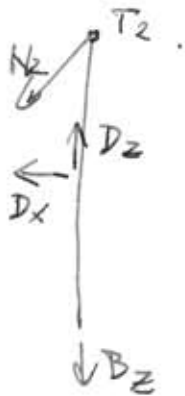
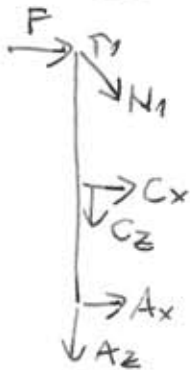
$$A_z + B_z = -q \cdot 3a$$

$$-B_z \cdot 3a - q \cdot 3a \cdot \frac{3a}{2} - F \cdot 2a = 0$$

$$B_z = -26 \text{ kN}$$

$$A_z = -10 \text{ kN}$$

c.) RAZREZ



$$\sum M_{BT_2}^{T_2} : D_x = 0$$

$$\sum M_{BT_1}^{T_1} : C_x \cdot a + A_x \cdot 2a = 0 \quad C_x = -2A_x$$

$$C_x = 24 \text{ kN}$$

$$\sum X_{BT_2} : N_2 \cdot \frac{\sqrt{2}}{2} + D_x = 0 \quad N_2 = 0$$

$$\sum X_{AT_1} : A_x + C_x + F + N_1 \cdot \frac{\sqrt{2}}{2} = 0$$

$$N_1 = -\frac{48}{\sqrt{2}} = -33.9 \text{ kN}$$

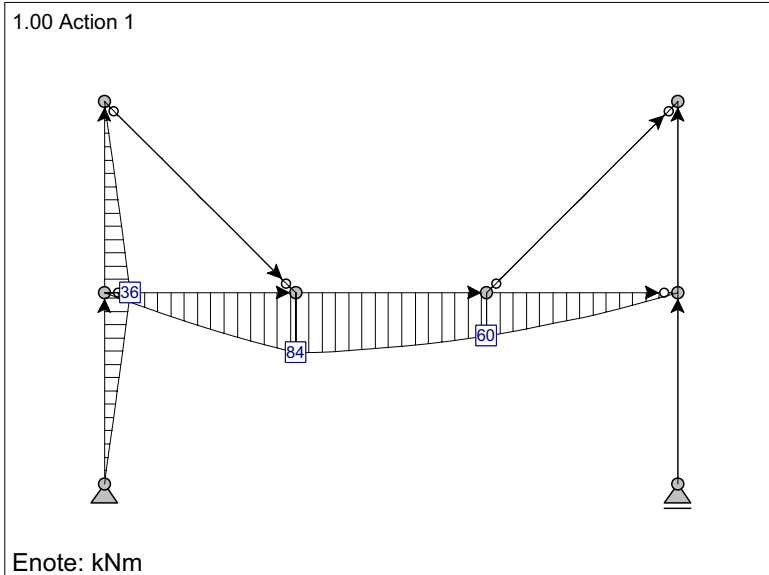
$$\sum Z_{BT_2} : B_z - D_z + N_2 \cdot \frac{\sqrt{2}}{2} = 0$$

$$D_z = B_z = -26 \text{ kN}$$

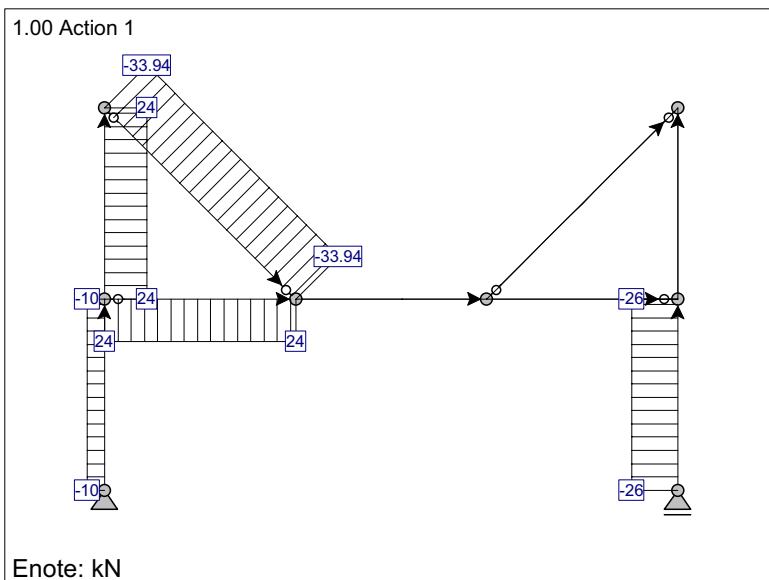
$$\sum Z_{AT_1} : A_z + C_z + N_1 \cdot \frac{\sqrt{2}}{2} = 0$$

$$C_z = 10 + 24 = 34 \text{ kN}$$

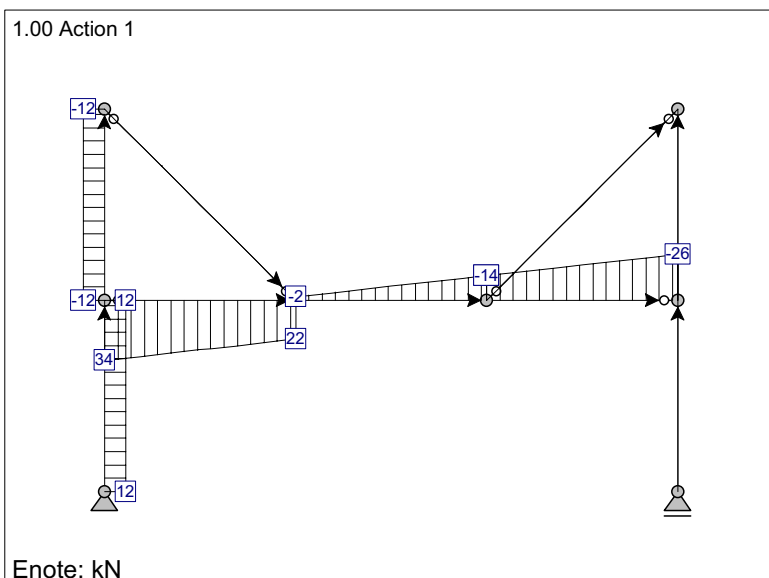
LC1: Load case 1: Upogibni moment My



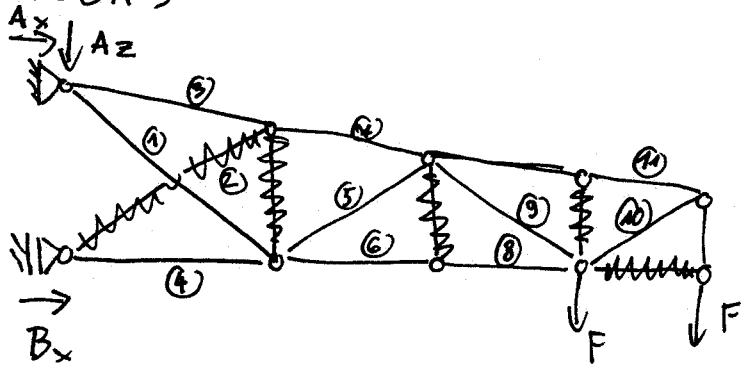
LC1: Load case 1: Osna sila Fx



LC1: Load case 1: Prečna sila Fz



NALOGA 3



$$A_x + B_x = 0$$

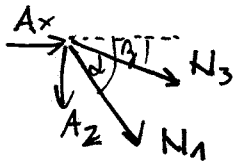
$$A_z + 2F = 0$$

$$-A_x \cdot h - F \cdot 3a - F \cdot 4a = 0$$

$$A_x = -\frac{7Fa}{h}$$

$$\Rightarrow \begin{cases} A_x = -\frac{21}{2} \text{ kN} \\ B_x = \frac{21}{2} \text{ kN} \\ A_z = -6 \text{ kN} \end{cases}$$

vozlina A

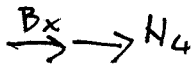
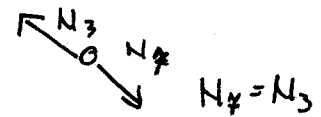


$$N_1 \cos \alpha + N_3 \cos \beta = -A_x$$

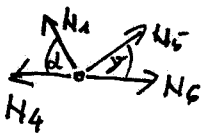
$$N_1 \sin \alpha + N_3 \sin \beta = -A_z$$

$$\tan \alpha = \frac{4}{2}$$

$$\tan \beta = \frac{h-a}{4a} = \frac{1}{4}$$



$$N_4 = -\frac{21}{2} \text{ kN}$$



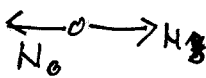
$$\tan \gamma = \frac{3}{2}$$

$$N_1 \sin \alpha + N_5 \sin \delta = 0$$

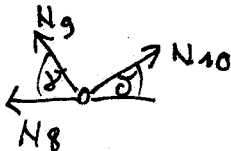
$$N_5 =$$

$$N_1 \cos \alpha + N_4 = N_5 \cos \delta + N_6$$

$$N_6 =$$



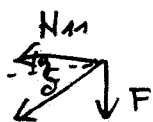
$$N_8 = N_6$$



$$\tan \delta = 1$$

$$N_9 \sin \delta + N_{10} \sin \epsilon = 0$$

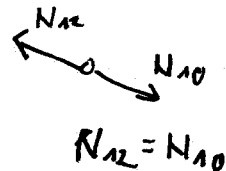
$$N_8 + \cos \delta \cdot N_9 = N_{10} \cos \delta$$



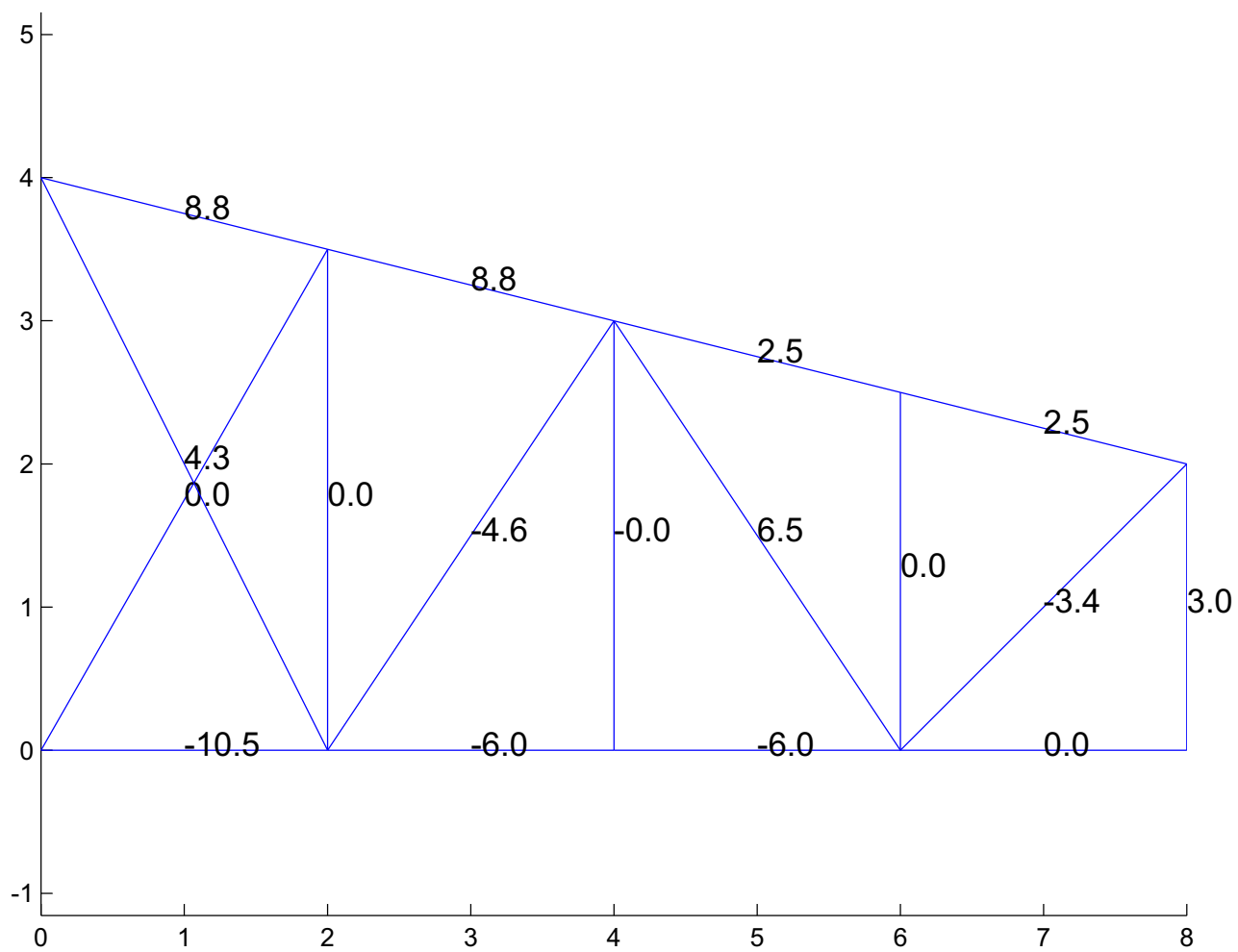
$$N_{10}$$

$$N_{10} \sin \delta + F + N_{11} \sin \zeta = 0$$

$$N_{10} \cos \delta + N_{11} \cos \zeta = 0$$

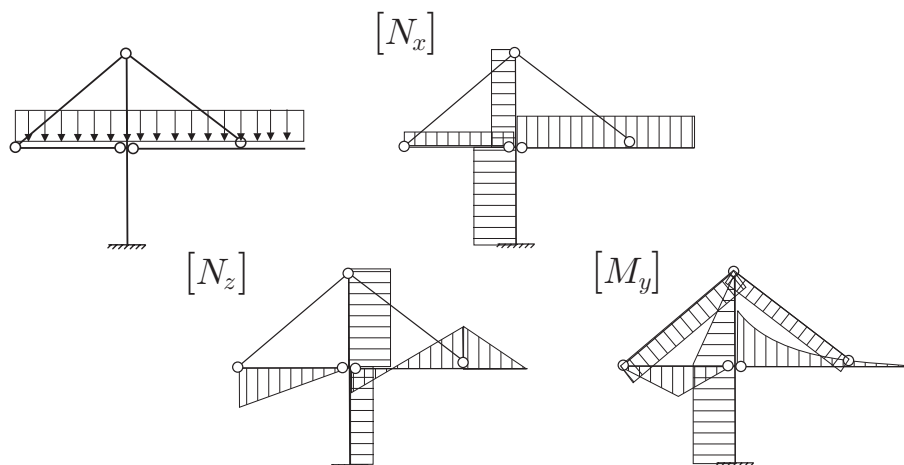


$$N_{12} = N_{11}$$



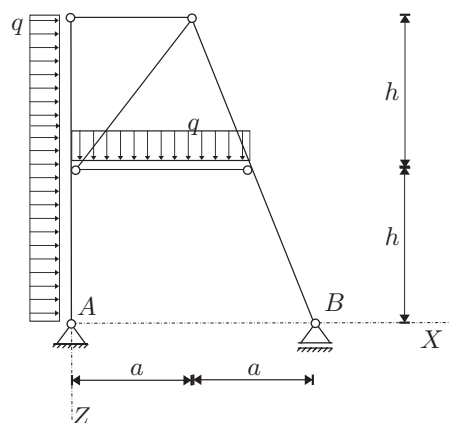
RAČUNSKI DEL IZPITA:

1. Janezek je na izpitu iz statike padel. Njegovi diagrami so polni napak. Pomagaj Janezku in poišči (BREZ RAČUNANJA) vse napake v spodnjih diagramih! (OBVEZNA NALOGA! 25%)

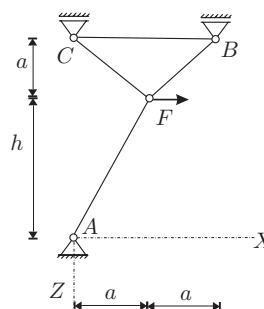


2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti, reakcije in notranje statične količine (N_x, N_z, M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!

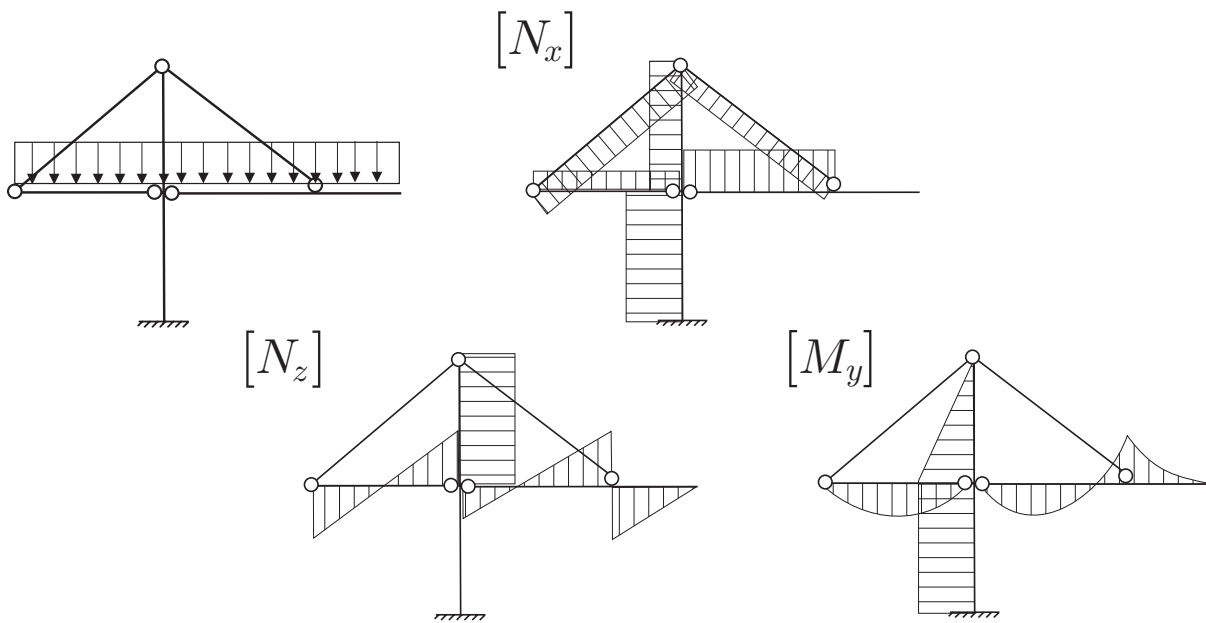
Podatki: $a = 2\text{ m}$,
 $h = 2.5\text{ m}$, $q = 8\text{ kN/m}$.
 (OBVEZNA NALOGA! 50%)



3. S principom virtualnega dela za konstrukcijo na sliki izrazite reakcije v podporah! (25%)



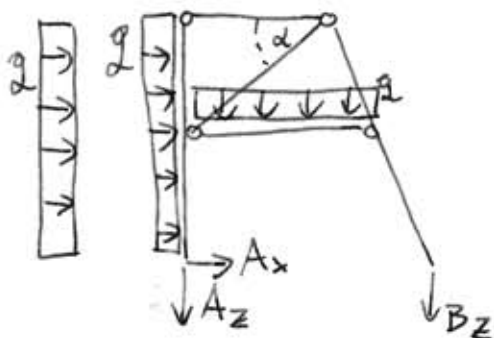
1. Naloga: PRAVILNI DIAGRAMI



2. NALOGA

a.) $\tilde{m}_{PS} = 5 \cdot 3 - 2 \cdot 1 - 2 \cdot 2 - 2 \cdot 4 = 0$

b.) REAKCIJE



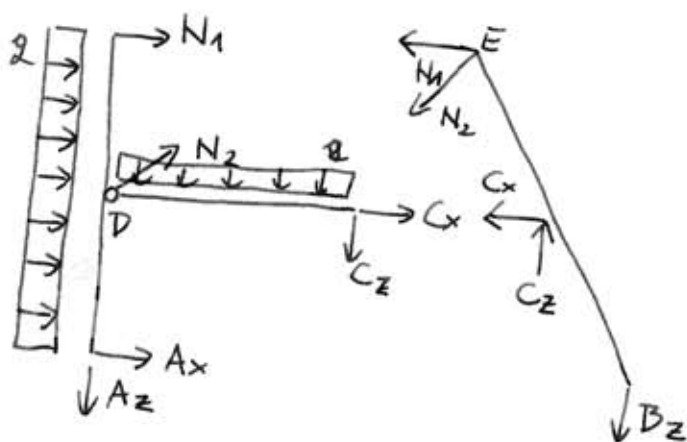
$\Sigma X: A_x + q \cdot 2h = 0$ $A_x = -40 \text{ kN}$

$\Sigma Z: A_z + B_z + g \cdot \frac{3}{2}a = 0$

$\Sigma M^A: -g \cdot 2h \cdot h - g \cdot \frac{3}{2}a \cdot \frac{3}{4}a - B_z \cdot 2a = 0$

$B_z = -34 \text{ kN}$ $A_z = +10 \text{ kN}$

c.) SILE V PALICAH IN RAZREZ



$\Sigma M_{CD}^D: -C_z \cdot \frac{3}{2}a - g \cdot \frac{3}{2}a \cdot \frac{3}{4}a = 0$

$C_z = -g \cdot \frac{3}{4}a$

$C_z = -12 \text{ kN}$

$\Sigma M_{BE}^E: -B_z \cdot a + C_z \cdot \frac{a}{2} - C_x \cdot h = 0$

$C_x = 22.4 \text{ kN}$

$\Sigma Z_{BE} \quad N_2 \cdot \sin \alpha - C_z + B_z = 0$

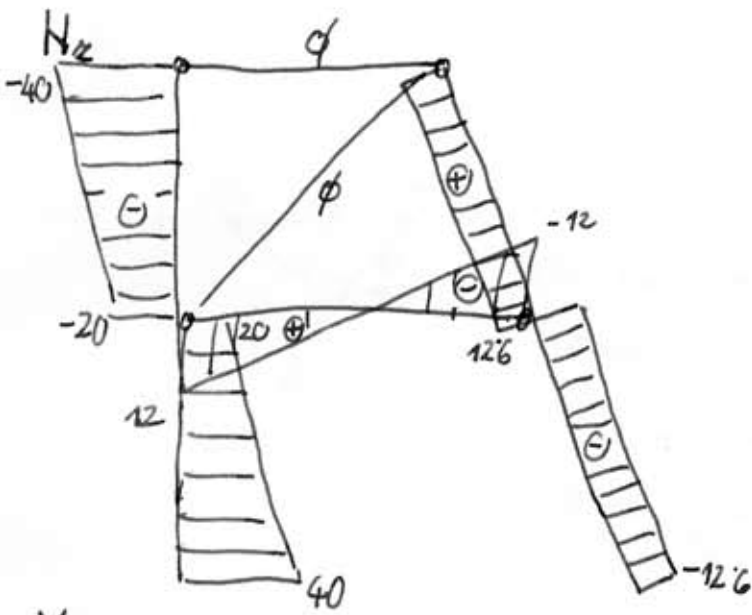
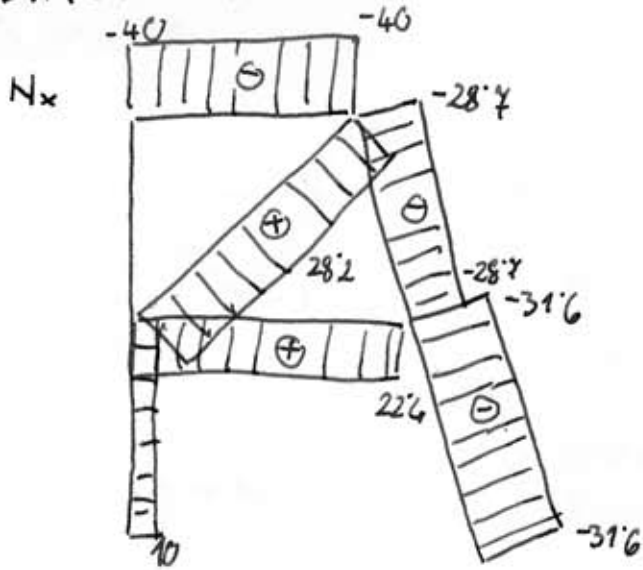
$\tan \alpha = \frac{h}{a} = \frac{2.5}{2}$
 $\alpha = 51.34^\circ$

$N_2 = 28.17 \text{ kN}$

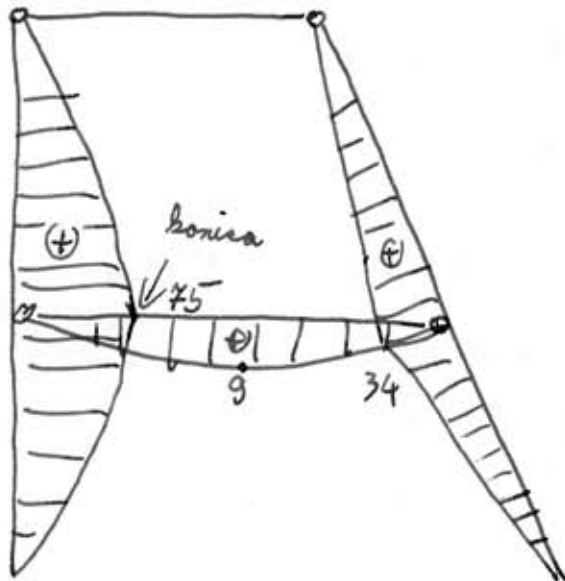
$\Sigma X_{BE} \quad N_1 + N_2 \cdot \cos \alpha + C_x = 0$

~~Net~~ $N_1 = -40 \text{ kN}$

DIAGRAMI

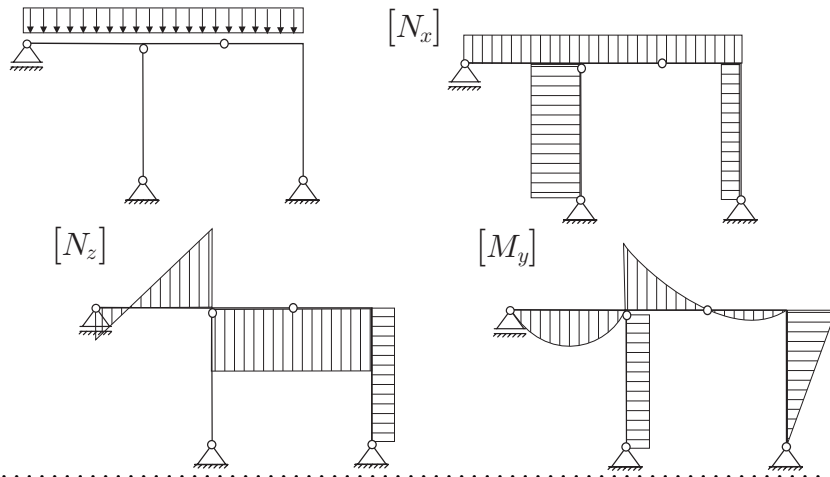


M_y



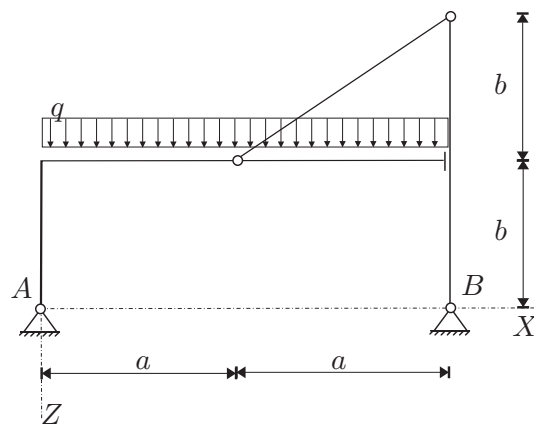
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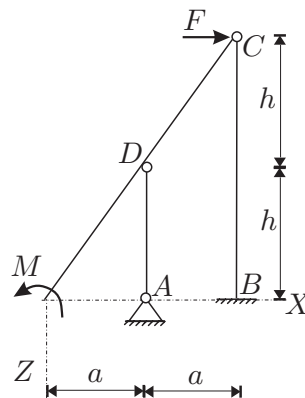


2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti, reakcije in notranje statične količine (N_x, N_z, M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!

Podatki: $a = 4 \text{ m}$, $b = 3 \text{ m}$,
 $q = 10 \text{ kN/m}$.
 (OBVEZNA NALOGA! 50%)



3. S principom virtualnega dela za konstrukcijo na sliki izrazite reakcije v podporah! (25%)

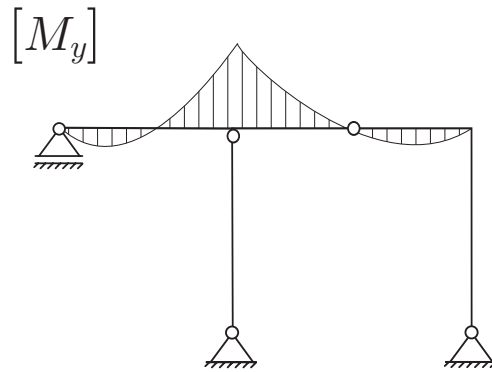
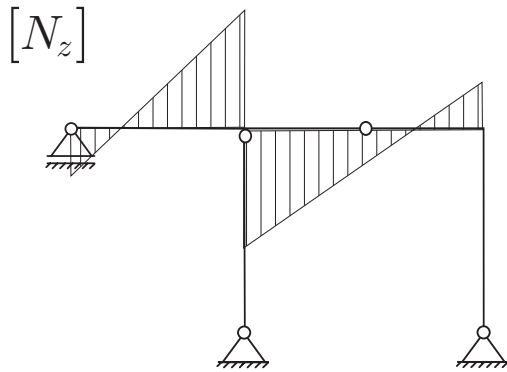
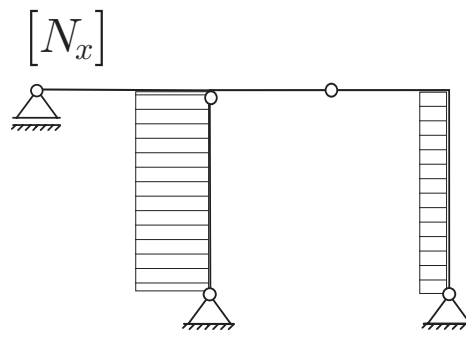
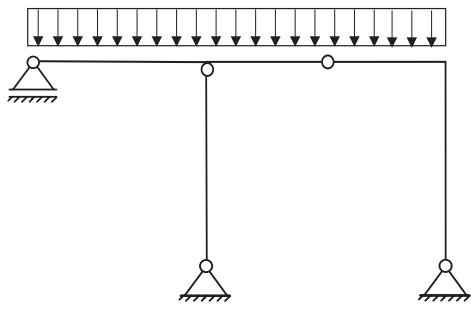


TEORETIČNI DEL IZPITA:

Izmed treh zastavljenih vprašanj si izberete dve, na kateri boste odgovarjali. Izbrani vprašanja jasno označite! Pišite čitljivo.

1. Izpeljite ravnotežne pogoje za sile, ki delujejo na sistemu delcev s togimi vezmi in togem telesu!
2. Pomiki in zasuki togega telesa (izpeljava enačb za ravninsko gibanje togega telesa)!
3. Opišite določanje reakcij in notranjih sil statično določenih linijskih konstrukcij z izrekom o virtualnih pomikih! Razumevanje ilustrirajte na obojestransko previsnem prostoležečem nosilcu s prečnima točkovnima silama na prostih robovih! Izračunajte vse reakcije ter notranje sile na sredini razpona!

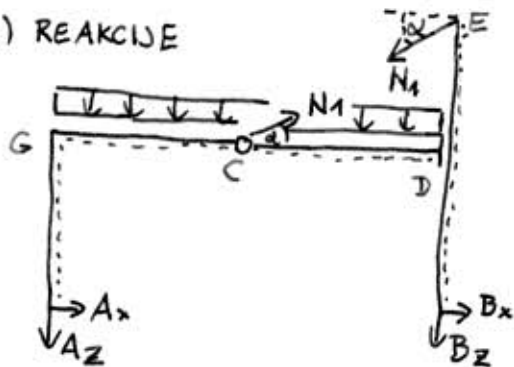
1. Naloga: PRAVILNI DIAGRAMI



2. NALOSA

a.) $\tilde{m}_{ps} = 4 \cdot 3 - 2 \cdot 2 - 4 - 2 - 2 = 0$

b.) REAKCIJE



$\Sigma X: A_x + B_x = 0$

$\Sigma Z: A_z + B_z + q \cdot 2a = 0$

$\Sigma M^A: -B_z \cdot 2a - q \cdot 2a \cdot a = 0$

$\Sigma M^C_{AC}: A_x \cdot b + A_z \cdot a + q \cdot a \cdot \frac{a}{2} = 0$

$A_z = -q \cdot a$	$= -40 \text{ kN}$
$B_z = -q \cdot a$	$= -40 \text{ kN}$

$A_x = \frac{80}{3} \text{ kN} = 26.7 \text{ kN}$

$B_x = -\frac{80}{3} \text{ kN} = -26.7 \text{ kN}$

$\cos \alpha = \frac{4}{5} \quad \sin \alpha = \frac{3}{5}$

$\Sigma Z_{BE}: B_z + N_1 \sin \alpha = 0$

$N_1 = -\frac{B_z}{\sin \alpha} = \frac{40 \cdot 5}{3} = 66.7 \text{ kN}$

a.) NOTRANJE SILE

polje AG



$x \in [0, 3]$

$N_x = A_z = -40 \text{ kN}$

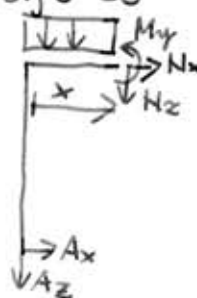
$N_z = -A_x = -26.7 \text{ kN}$

$M_y = -A_x \cdot x = -26.7 \cdot x$

$M_y(0) = 0$

$M_y(3) = -80 \text{ kNm}$

polje GC



$x \in [0, 4]$

$N_x = -A_x$

$N_z = -A_z - q \cdot x$

$M_y = -A_x \cdot b - A_z \cdot x - q \cdot x \cdot \frac{x}{2}$

$N_x = -26.7 \text{ kN}$
$N_z = 40 - 10x$

$M_y = -80 + 40x - 5x^2$

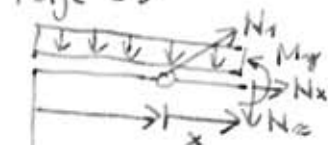
$N_z(0) = 40 \text{ kN}$

$N_z(4) = 0$

$M_y(0) = -80 \text{ kNm}$

$M_y(4) = 0 \text{ kNm (desetno)}$

polje CD



$N_x = -A_x - N_1 \cos \alpha$

$N_z = -A_z - q(a+x) + N_1 \sin \alpha$

$M_y = -A_x(a+x) - q \cdot \frac{(a+x)^2}{2}$

$+ N_1 \sin \alpha \cdot x - A_x \cdot b$

$N_x = -80 \text{ kN}$

$N_z = 40 - 10x$

$M_y = 40x - 5x^2$

$N_z(0) = 40 \text{ kN}$

$N_z(4) = 0$

$M_y(0) = 0$

$M_y(4) = 80 \text{ kNm (desetno)}$

polje ED (z desno)



$N_x = -N_1 \sin \alpha$

$N_z = -N_1 \cos \alpha$

$M_y = N_1 \cdot \cos \alpha \cdot \bar{x}$

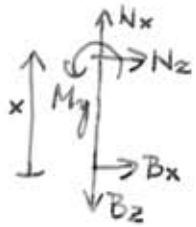
$N_x = -40 \text{ kN}$

$N_z = -\frac{160}{3} = 53.3 \text{ kN}$
--

$M_y = \frac{160}{2} \bar{x}$

$M_y(3) = 160 \text{ kNm}$

polje BD



$$N_x = B_z$$

$$N_z = -B_x$$

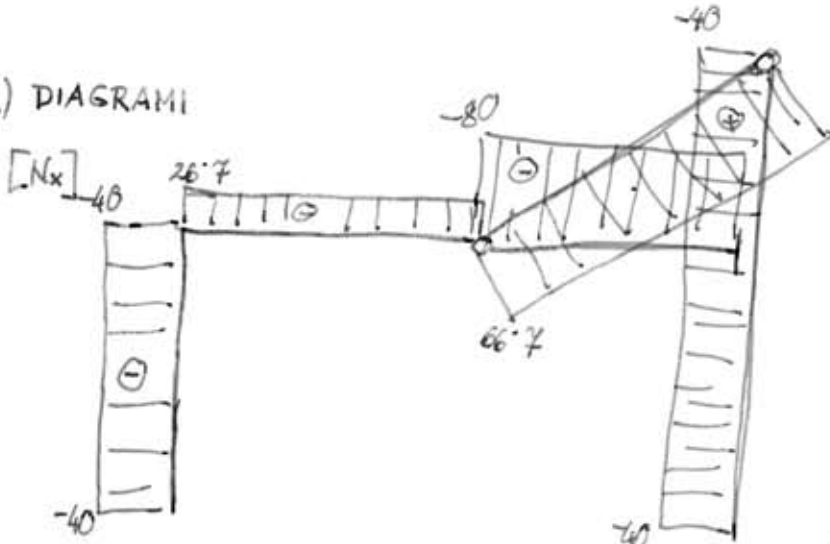
$$M_y = -B_x x$$

$$N_x = -40 \text{ kN}$$

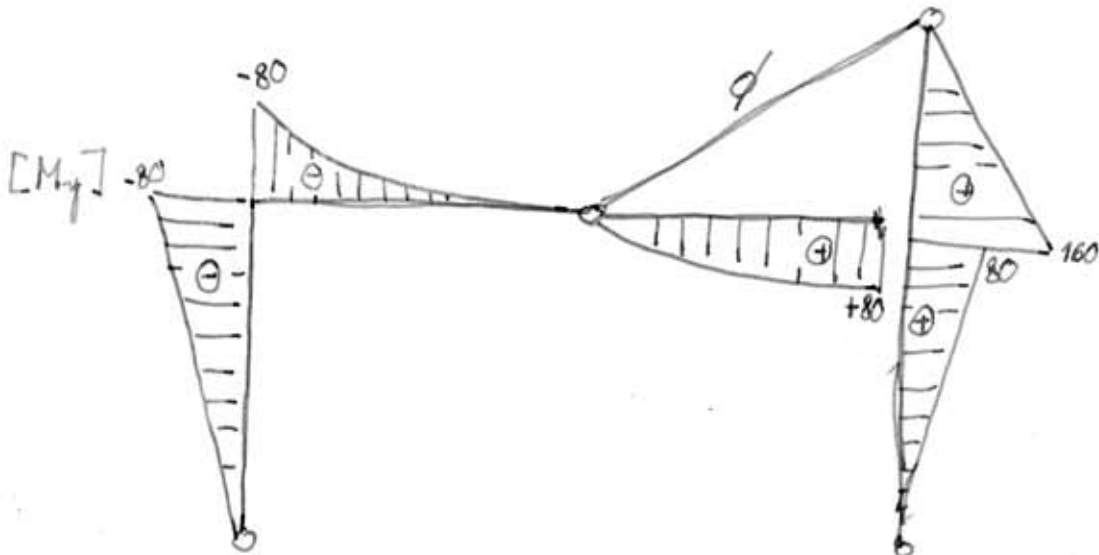
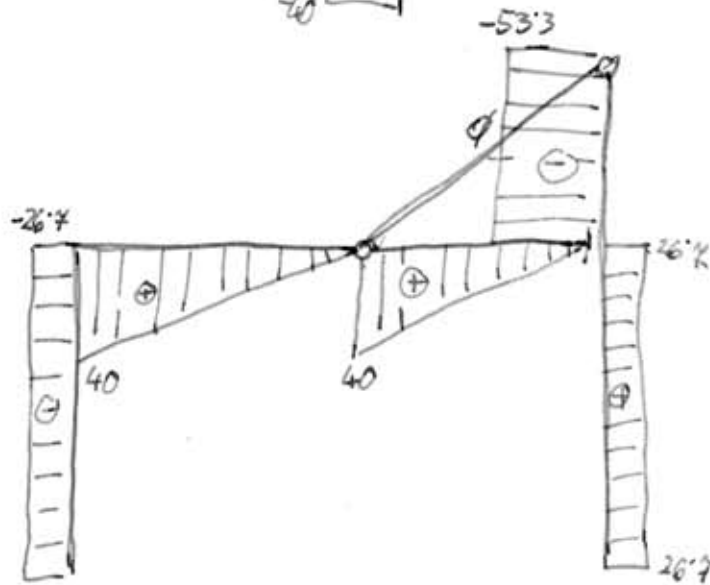
$$N_z = 26.7 \text{ kN}$$

$$M_y = +\frac{80}{3} x \quad M_y(3) = 80 \text{ kNm}$$

d.) DIAGRAMI

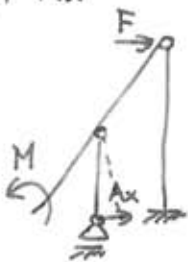


$[N_z]$



3. KALOGA

a.) A_x



$$\delta W = A_x \delta u_A + F \delta u_C + M \delta \varphi_E = 0$$

$$\delta u_C = \delta u_B - 2h \delta \varphi_B = 0 \quad \boxed{\delta u_C = 0}$$

$$\delta w_C = \delta w_E = 0 \quad \delta w_D = \delta w_A = 0$$

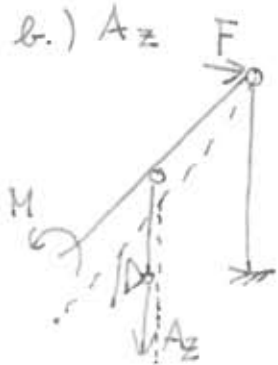
$$0 = \delta w_C = \delta w_E - 2a \delta \varphi_E \quad \delta w_D = \delta w_E - a \delta \varphi_E$$

$$\Rightarrow \delta w_E = 2a \delta \varphi_E \quad \delta w_E = a \delta \varphi_E \Rightarrow \boxed{\delta \varphi_E = 0}$$

$$A_x \delta u_A = 0$$

$$\boxed{A_x = 0}$$

b.) A_z



$$\delta W = A_z \delta w_A + F \delta u_C + M \delta \varphi_E = 0$$

$$\delta u_C = \delta u_B - 2h \delta \varphi_B = 0 \quad \delta w_C = \delta w_E = 0$$

$$\delta w_D = \delta w_A \quad \delta w_D = \delta u_A - h \delta \varphi_A$$

$$\delta w_B = \delta w_E - a \delta \varphi_E \Rightarrow -a \delta \varphi_E = \delta w_A - \delta w_E$$

$$\delta w_C = \delta w_E - 2a \delta \varphi_E \Rightarrow \delta w_E = 2a \delta \varphi_E$$

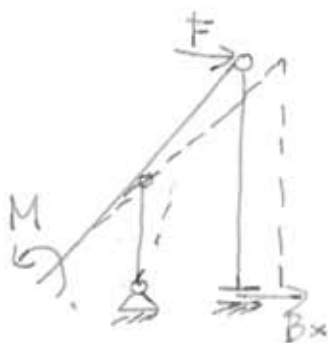
$$-a \delta \varphi_E = \delta w_A - 2a \delta \varphi_E \quad \boxed{\delta \varphi_E = \frac{\delta w_A}{a}}$$

$$A_z \delta w_A + M \cdot \frac{\delta w_A}{a} = 0$$

$$(A_z + M \cdot \frac{1}{a}) \delta w_A = 0$$

$$\boxed{A_z = -\frac{M}{a}}$$

c.) B_x



$$\delta W = B_x \delta u_B + M \delta \varphi_E + F \delta u_C = 0$$

$$\delta u_C = \delta u_B - 2h \delta \varphi_B \quad \boxed{\delta u_C = \delta u_B}$$

$$\delta w_C = \delta w_B = 0$$

$$\delta w_D = \delta w_A = 0$$

$$\delta w_D = \delta w_E - a \delta \varphi_E \quad \boxed{\delta \varphi_E = 0}$$

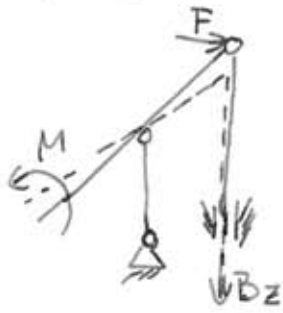
$$\delta w_C = \delta w_E - 2a \delta \varphi_E$$

$$B_x \delta u_B + F \delta u_B = 0$$

$$(B_x + F) \delta u_B = 0$$

$$\boxed{B_x = -F}$$

d.) B_z



$$\delta W = B_z \cdot \delta w_B + F \delta u_C + M \delta \varphi_E = 0$$

$$\delta u_C = \delta u_B - 2h \delta \varphi_B = 0 \quad \boxed{\delta u_C = 0}$$

$$\delta w_C = \delta w_B$$

$$\delta w_D = \delta w_A = 0$$

$$\delta w_C = \delta w_E - 2a \delta \varphi_E \quad \delta w_D = \delta w_E - a \delta \varphi_E$$

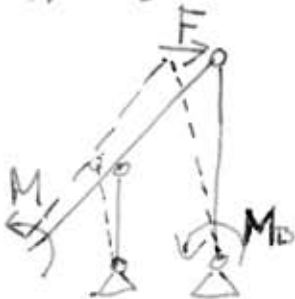
$$\delta w_E = a \delta \varphi_E$$

$$\delta w_B = -a \delta \varphi_E \quad \delta \varphi_E = -\frac{\delta w_B}{a}$$

$$B_z \cdot \delta w_B - M \frac{\delta w_B}{a} = 0$$

$$(B_z - \frac{M}{a}) \delta w_B = 0 \quad \boxed{B_z = \frac{M}{a}}$$

e.) M_B



$$\delta W = M_B \delta \varphi_B + F \cdot \delta u_C + M \delta \varphi_E = 0$$

$$\delta w_C = \delta w_D = 0$$

$$\delta u_C = \delta u_B - 2h \delta \varphi_B$$

$$\delta w_C = \delta w_E - 2a \delta \varphi_E = 0$$

$$\delta w_D = \delta w_A = 0$$

$$\delta w_D = \delta w_E - a \delta \varphi_E = 0$$

$$\delta u_C = -2h \delta \varphi_B$$

$$\boxed{\delta \varphi_E = 0}$$

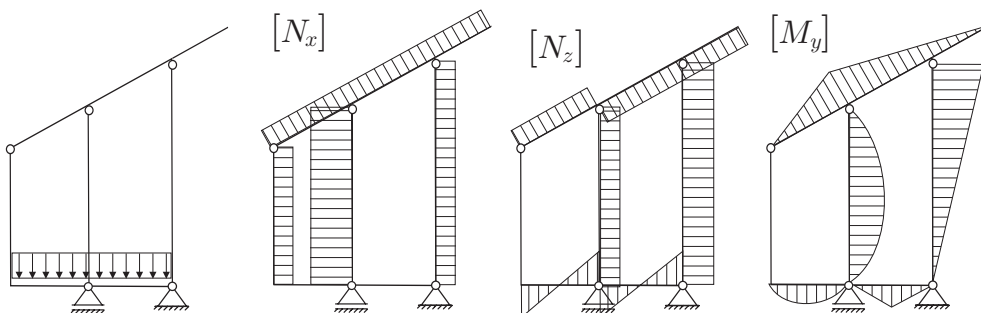
$$M_B \delta \varphi_B - F \cdot 2h \delta \varphi_B = 0$$

$$(M_B - 2hF) \delta \varphi_B = 0$$

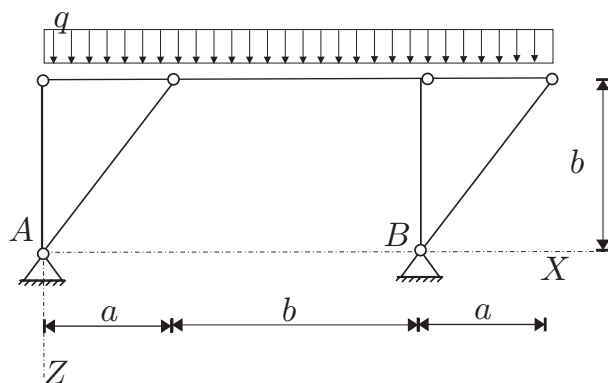
$$\boxed{M_B = 2hF}$$

RAČUNSKI DEL IZPITA:

1. Janezek je na izpitu iz statike padel. Njegovi diagrami so polni napak. Pomagaj Janezku in poišči (BREZ RAČUNANJA) vse napake v njegovih diagramih! Namig: katere reakcije so enake nič? (OBVEZNA NALOGA! 25%)

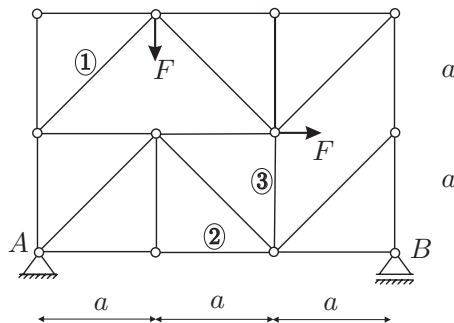


2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti, reakcije in notranje statične količine (N_x , N_z , M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!



Podatki: $a = 2 \text{ m}$, $b = 3 \text{ m}$,
 $q = 3 \text{ kN/m}$.
 (OBVEZNA NALOGA! 50%)

3. Za palično konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti in osne sile v palicah 1, 2 in 3! (25%)



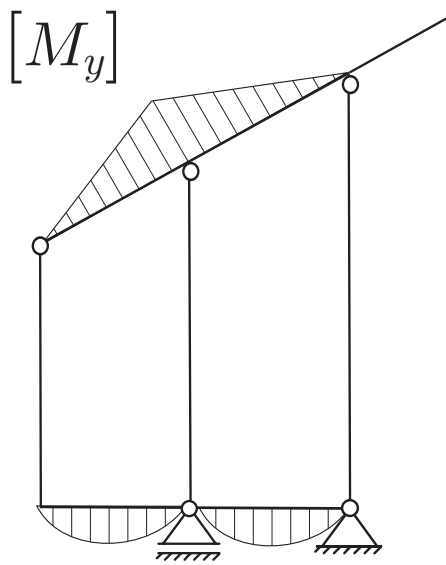
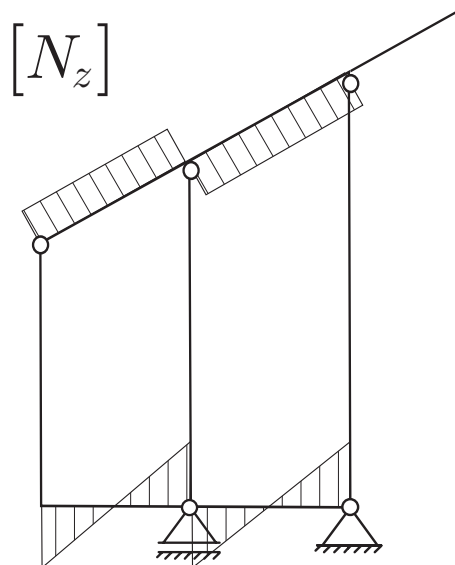
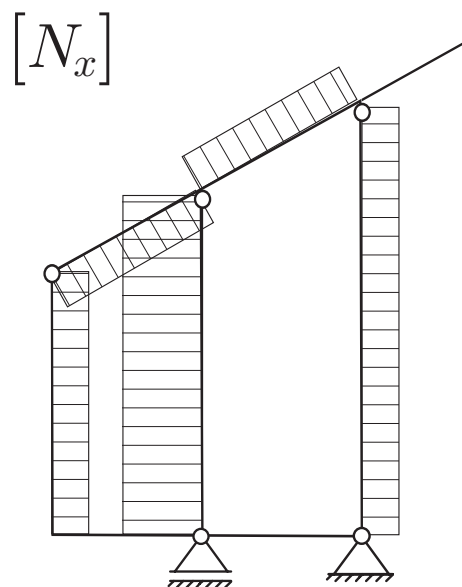
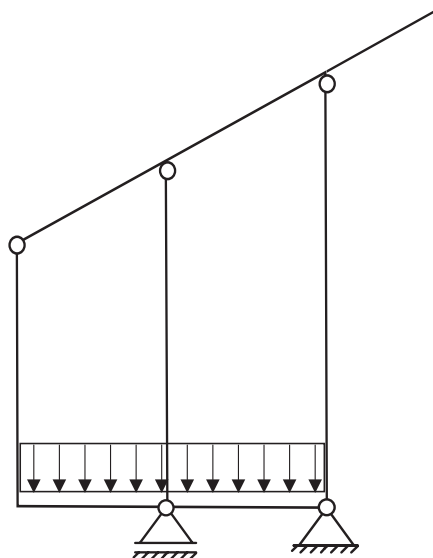
Podatki: $a = 3 \text{ m}$, $F = 5 \text{ kN}$.

TEORETIČNI DEL IZPITA:

Izmed treh zastavljenih vprašanj si izberete dve, na kateri boste odgovarjali. Izbrani vprašanji jasno označite! Pišite čitljivo.

1. Računski modeli za opis medsebojnega vpliva med telesi! Kaj predstavlja obtežna pri linijskem nosilcu?
2. Opišite kinematične enačbe sistema togih teles ter postopek računanja dejanskega števila prostostnih stopenj sistema togih teles! (Odgovor ilustrirajte s primerom!).
3. Opišite določanje reakcij in notranjih sil statično določenih linijskih konstrukcij z izrekom o virtualnih pomikih (Razumevanje ilustrirajte na enostransko previsnem prostoležečem nosilcu s horizontalno točkovno silo na previsnem robu. Izračunajte vse notranje sile v izbranem značilnem prečnem prerezu nosilca in vse reakcije)!

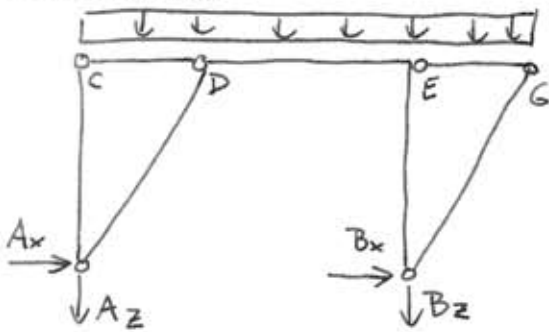
1. Naloga: PRAVILNI DIAGRAMI



2. NALOGA

a) $\sum \vec{m}_{D5} = 6 \cdot 3 - 5 \cdot 2 - 4 - 2 \cdot 2 = 0$

b.) REAKCIJE



$\sum X: A_x + B_x = 0$

$\sum Z: A_z + B_z + q(2a+b) = 0$

$\sum M^A: -B_z \cdot (a+b) - q \frac{(2a+b)^2}{2} = 0$

DODATNA

$\sum M^D_{ACD}: A_x \cdot b + A_z \cdot a + q a \frac{a}{2} = 0$

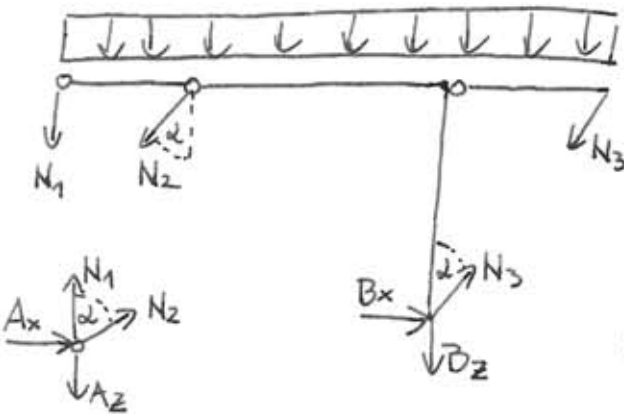
$B_z = -14.7 \text{ kN}$

$A_z = -6.3 \text{ kN}$

$A_x = 2.2 \text{ kN}$

$B_x = -2.2 \text{ kN}$

c.) IZREZ PALIC



$\sin \alpha = \frac{2}{\sqrt{13}} \quad \cos \alpha = \frac{3}{\sqrt{13}}$

$\sum M^D_{CD}: N_1 \cdot a + q \cdot a \frac{a}{2} = 0$

$N_1 = -\frac{q \cdot a}{2}$

$N_1 = -3 \text{ kN}$

$\sum M^E_{GE}: -N_3 \cdot \cos \alpha \cdot a - q \cdot a \frac{a}{2} = 0$

$N_3 = -\frac{q \cdot a}{2 \cdot 3} \cdot \sqrt{13} = -\sqrt{13}$

$N_3 = -3.6 \text{ kN}$

$\sum X: -N_2 \cdot \sin \alpha + B_x = 0$

$N_2 = \frac{B_x}{2} \cdot \sqrt{13} = -1.1 \cdot \sqrt{13}$

$N_2 = -3.966 \text{ kN}$

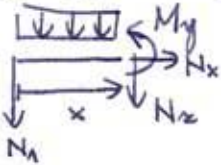
KONTROLA:

voznice A: $\sum X: A_x + N_2 \cdot \sin \alpha = 0$
 $2.2 - 1.1 \cdot \sqrt{13} \cdot \frac{2}{\sqrt{13}} = 0 \checkmark$

$\sum Z: N_1 + N_2 \cos \alpha - A_z = -3 - 1.1 \cdot \sqrt{13} \cdot \frac{3}{\sqrt{13}} + 6.3 = 0 \checkmark$

d.) NOTRANJE SILE TO POLJIM

POLJE CD $x \in [0, 2]$



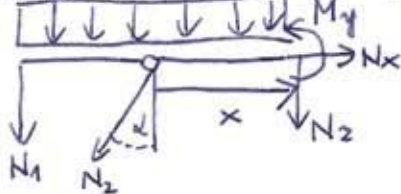
$$N_x = 0$$

$$N_z = -N_1 - g \cdot x \quad N_z = 3 - 3x \quad N_z(0) = 3 \text{ kN} \quad N_z(2) = -3 \text{ kN}$$

$$M_y = -N_1 x - g \frac{x^2}{2} \quad M_y = 3x - \frac{3}{2}x^2 \quad M_y(0) = 0 \quad M_y(2) = 0$$

$$M_y(1) = 1.5 \text{ kNm} \text{ ekstrem}$$

POLJE DE $x \in [0, 3]$



$$N_x = N_2 \cdot \sin \alpha \Rightarrow N_x = -2.2 \text{ kN}$$

$$N_z = -N_1 - N_2 \cos \alpha - g \cdot a - g \cdot x$$

$$= 3 + 3.3 - 6 - g \cdot x \Rightarrow N_z = 0.3 - 3x \quad N_z(3) = -8.7 \text{ kN}$$

$$M_y = -N_1(a+x) - N_2 \cos \alpha \cdot x - g(a+x) \frac{a+x}{2}$$

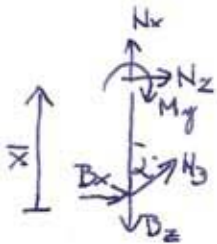
$$= 3 \cdot (2+x) + 3.3 \cdot x - 3(2+x) \frac{2+x}{2}$$

$$M_y = 0.3x - \frac{3}{2}x^2$$

$$M_y(0) = 0 \quad M_y(3) = -12.6 \text{ kNm}$$

$$M_y(0.1) = 0.015 \text{ kNm} \text{ ekstrem}$$

POLJE BE (2 derme)



$$N_x = -N_3 \cos \alpha + B_z \quad N_x = -11.7 \text{ kN}$$

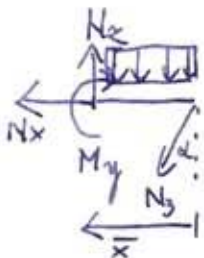
$$N_z = -B_x - N_3 \sin \alpha \quad N_z = 4.2 \text{ kN}$$

$$M_y = B_x \bar{x} + N_3 \sin \alpha \bar{x} \quad M_y = -4.2 \bar{x}$$

$$M_y(0) = 0 \quad M_y(3) = -12.6 \text{ kNm}$$

POLJE EG (2 derme)

$\bar{x} \in [0, 2]$



$$N_x = -N_3 \cdot \sin \alpha \quad N_x = 2 \text{ kN}$$

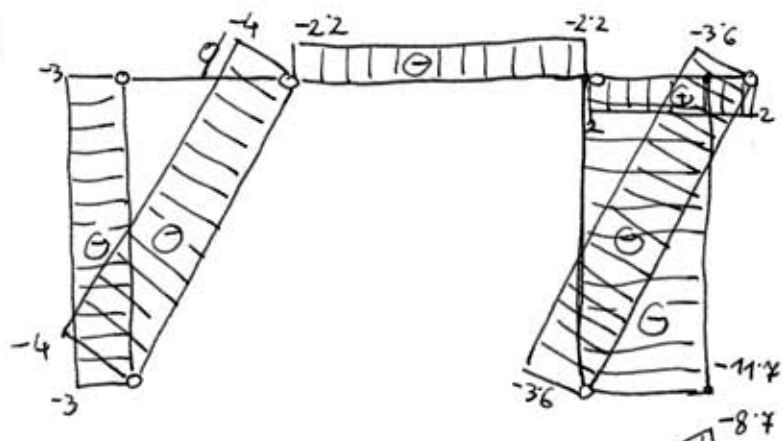
$$N_z = N_3 \cdot \cos \alpha + g \cdot \bar{x} \quad N_z = -3 + 3\bar{x} \quad N_z(0) = -3 \text{ kN} \quad N_z(2) = 3 \text{ kN}$$

$$M_y = -N_3 \cos \alpha \bar{x} - g \frac{\bar{x}^2}{2} \quad M_y = 3\bar{x} - \frac{3}{2}\bar{x}^2 \quad M_y(0) = 0 \quad M_y(2) = 0$$

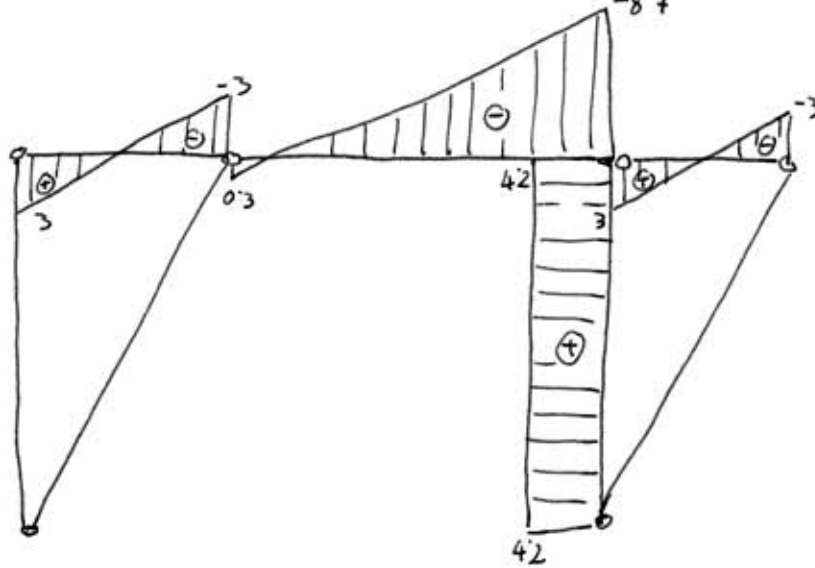
$$M_y(1) = 1.5 \text{ kNm}$$

2.) DIAGRAMI

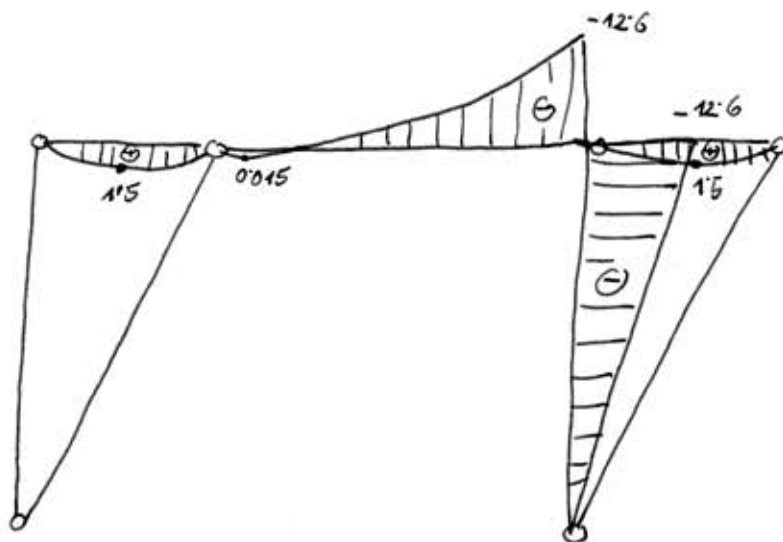
[N_x]



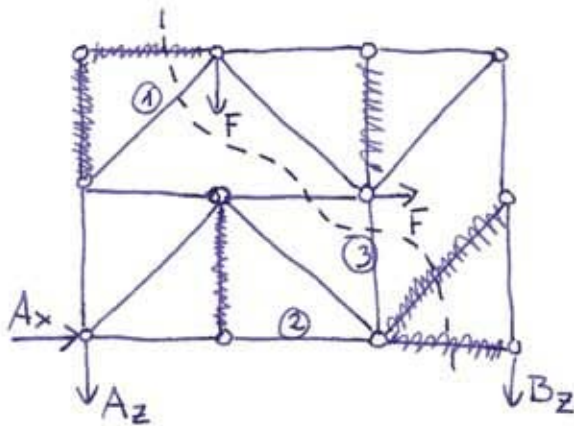
[N_e]



[M_y]



3. NALOGA



$$\sum X: \boxed{A_x = -F}$$

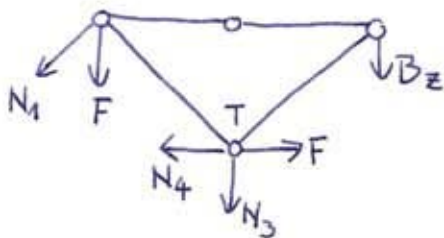
$$\sum Z: A_z + B_z + F = 0$$

$$\boxed{A_z = -\frac{F}{3}}$$

$$\sum M^A: -B_z \cdot 3a - F \cdot a - F \cdot a = 0$$

$$\boxed{B_z = -\frac{2F}{3}}$$

REZ PREKO 1-3



$$\sum M^T: N_1 \cdot a \cdot \sqrt{2} + F \cdot a - B_z \cdot a = 0$$

$$N_1 = \frac{-\sqrt{2}}{2} \frac{5F}{3}$$

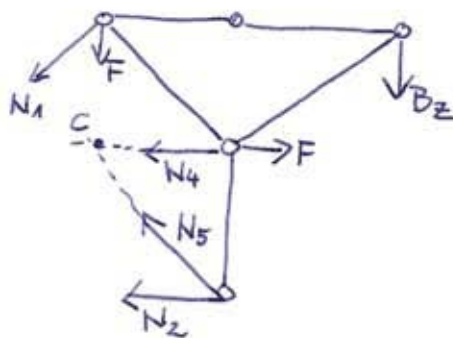
$$\boxed{N_1 = -5.9 \text{ kN}}$$

$$\sum Z: F + B_z + N_1 \cdot \frac{\sqrt{2}}{2} + N_3 = 0$$

$$N_3 = -\frac{F}{3} + \frac{5F}{6} = \frac{3F}{6}$$

$$\boxed{N_3 = 2.5 \text{ kN}}$$

REZ PREKO 1-2



$$\sum M^C: N_1 \cdot \frac{\sqrt{2}}{2} \cdot a - B_z \cdot 2a - N_2 \cdot a = 0$$

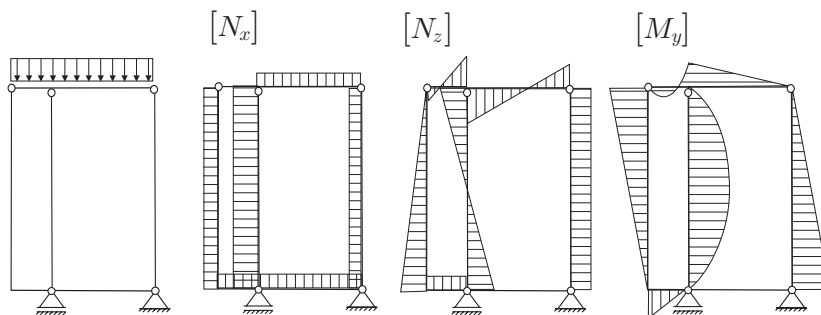
$$N_2 = \frac{-5F}{6} + \frac{4F}{3}$$

$$N_2 = \frac{3F}{6}$$

$$\boxed{N_2 = 2.5 \text{ kN}}$$

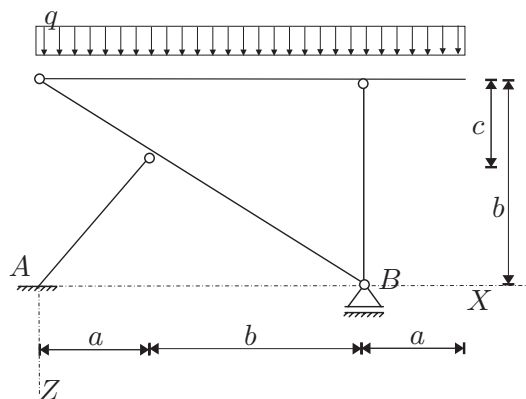
RAČUNSKI DEL IZPITA:

1. Janezek je na izpitu iz statike padel. Njegovi diagrami so polni napak. Pomagaj Janezku in poišči (BREZ RAČUNANJA) vse napake v njegovih diagramih!
(OBVEZNA NALOGA! 25%)

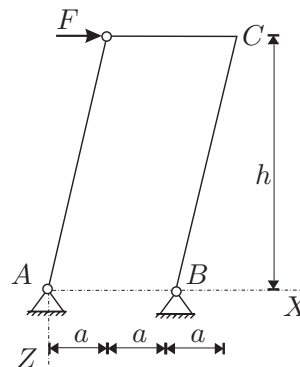


2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti, reakcije in notranje statične količine (N_x, N_z, M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!

Podatki: $a = 2\text{ m}$, $b = 3\text{ m}$, $c = 1.2\text{ m}$,
 $q = 5\text{ kN/m}$.
(OBVEZNA NALOGA! 50%)



3. S principom virtualnega dela za konstrukcijo na sliki izrazite reakcije v podporah in notranji moment v točki C – M_C ! (25%)

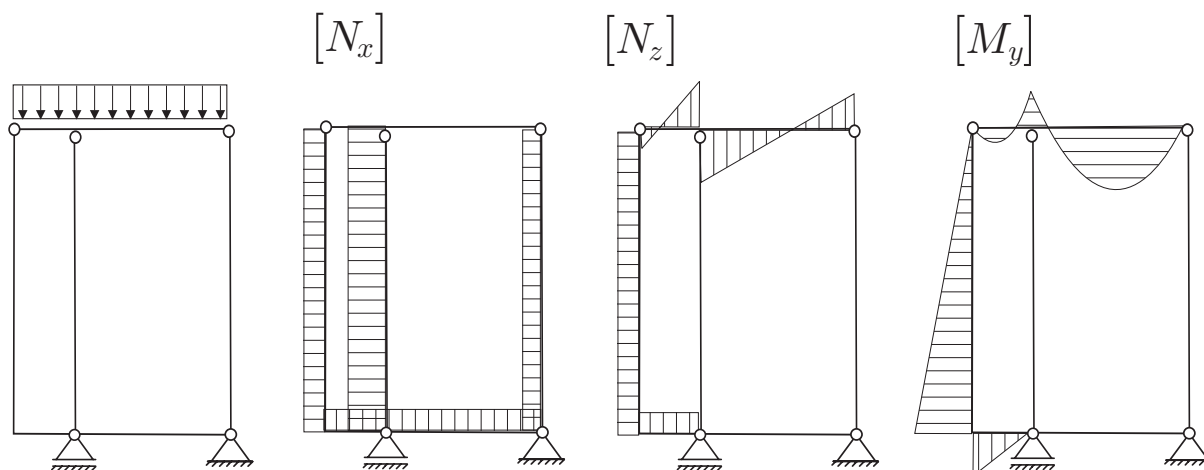


TEORETIČNI DEL IZPITA:

Izmed treh zastavljenih vprašanj si izberete dve, na kateri boste odgovarjali. Izbrani vprašanja jasno označite! Pišite čitljivo.

- Opišite kinematične enačbe sistema togih teles ter postopek računanja dejanskega števila prostostnih stopenj sistema togih teles! Opišite tudi razliko med dejanskim in računskim številom prostostnih stopenj! Kdaj je konstrukcija statično določena in kdaj je statično nedoločena? Vse izpeljave ilustrirajte z značilnim računskim primerom!
- Izpeljite in opišite obe obliki nadomestnih ravnotežnih pogojev! Rezultate ilustrirajte na primeru kontinuirnega nosilca!
- Opišite določanje reakcij in notranjih sil statično določenih linijskih konstrukcij z izrekom o virtualnih pomikih! Kot ilustracijo, izračunajte vse reakcije in notranje statične količine na konzoli s točkovnim momentom na prostem robu!

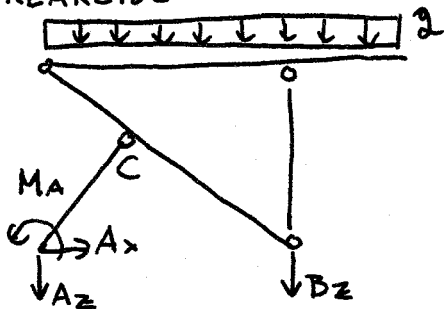
1. Naloga: PRAVILNI DIAGRAMI



2. NALOGA

a.) $\tilde{m}_{PS} = 3 \cdot 4 - 3 - 1 - 4 \cdot 2 = 0$

b.) REAKCIJE



$\Sigma X: A_x = 0$

$\Sigma Z: A_z + B_z + q \cdot 7 = 0$

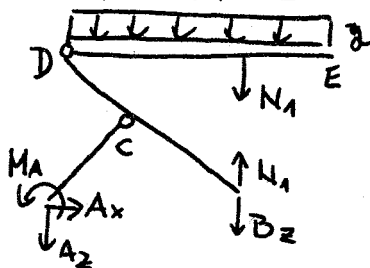
$\Sigma M^A: M_A - B_z \cdot 5 - q \cdot 7 \cdot \frac{7}{2} = 0$

DODATNA:

$\Sigma M^C_{AC}: A_z \cdot 2 + M_A = 0$

$B_z = -\frac{35}{2} \text{ kN}$	$M_A = 35 \text{ kNm}$
$A_z = -\frac{35}{2} \text{ kN}$	

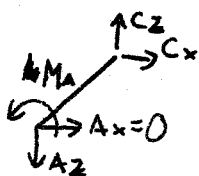
c.) IZREZ PALICE



$\Sigma M^D_{DE}: -N_1 \cdot 5 - q \cdot 7 \cdot \frac{7}{2} = 0$

$N_1 = -\frac{49}{2} \text{ kN}$

VEZ C:



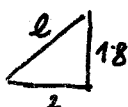
$\Sigma X: C_x = 0$

$\Sigma Z: C_z = A_z \Rightarrow C_z = -\frac{35}{2} \text{ kN}$

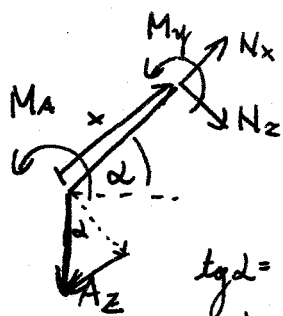
$\Sigma M^C_{AC}: A_z \cdot 2 + M_A = 0 \checkmark$

d.) NOTRANJE SILE PO POLJIH

POLJE AC



$l = \sqrt{2^2 + 1.8^2}$
 $x \in [0, l]$



$\Sigma X: N_x - A_z \cdot \sin \alpha = 0$

$\Sigma Z: N_z + A_z \cdot \cos \alpha = 0$

$\Sigma M^T: M_y + M_A + A_z \cdot x \cdot \cos \alpha = 0$

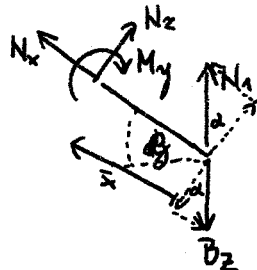
$\tan \alpha = \frac{1.8}{2}$
 $\alpha = 42^\circ$

$N_x = -11.71 \text{ kN}$
$N_z = 13 \text{ kN}$
$M_y = -35 + 13x$

$M_y(0) = -35 \text{ kNm}$
 $M_y(l) = 0$

POLJE BC (z desno)

$x \in [0, 3.5]$



$\tan \beta = \frac{1.8}{3}$

$\beta = 30.96^\circ$

$\Sigma X: N_x - B_z \cdot \sin \alpha + N_1 \cdot \sin \alpha = 0$

$\Sigma Z: N_z - B_z \cdot \cos \alpha + N_1 \cdot \cos \alpha = 0$

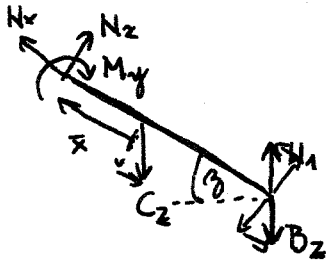
$\Sigma M^T: -M_y - B_z \cdot \bar{x} \cdot \cos \alpha + N_1 \cdot \bar{x} \cdot \cos \alpha = 0$

$N_x = 3.6 \text{ kN}$
$N_z = 6 \text{ kN}$
$M_y = -6x$

$M_y(0) = 0$

$M_y(3.5) = -21 \text{ kNm}$

POLJE CD (2 deo)



$$\sum Z: N_x - C_z \sin \beta - B_z \sin \beta + N_1 \sin \beta = 0$$

$$\sum x: N_z - C_z \cos \beta - B_z \cos \beta + N_1 \cos \beta = 0$$

$$\sum MT: -M_y - C_z \cdot x \cos \beta - B_z \cdot (x \cos \beta + 3) + N_1 \cdot (x \cos \beta + 3) = 0$$

$$x \in [0, 3.23]$$

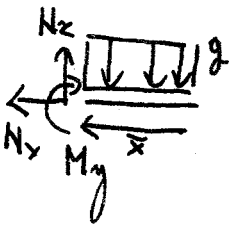
$$N_x = -5.4 \text{ kN}$$

$$N_z = -9 \text{ kN}$$

$$M_y = -421 + 9 \cdot x$$

$$M_y(3.23) = 0$$

POLJE EN1 (2 deo)



$$\sum x: N_x = 0$$

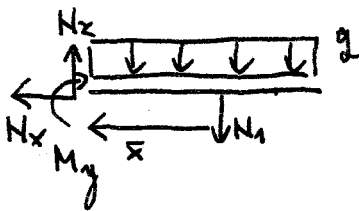
$$\sum Z: N_z = +q \cdot x$$

$$\sum MT: M_y = -q \frac{x^2}{2}$$

$$N_z(2) = 10 \text{ kN}$$

$$M_y(2) = -10 \text{ kNm}$$

POLJE N1D (2 deo)



$$\sum x: N_x = 0$$

$$\sum Z: N_z = q(x+2) + N_1$$

$$\sum MT: M_y = -q(x+2) \frac{x+2}{2} - N_1 \cdot x$$

$$N_z = -14.5 + 5x$$

$$N_z(5) = 10.5 \text{ kN}$$

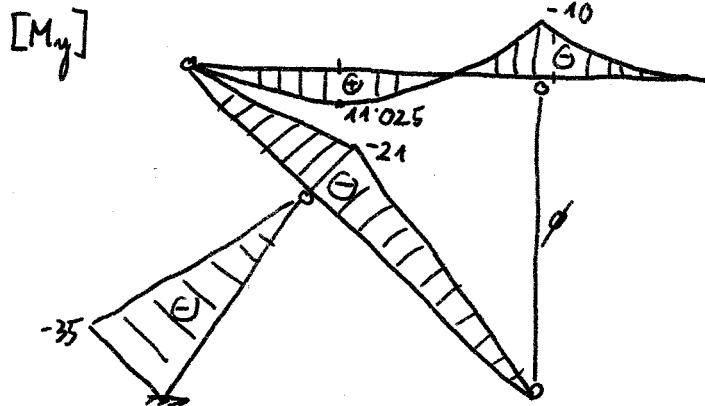
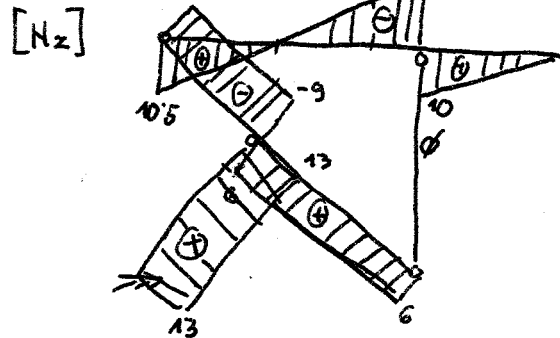
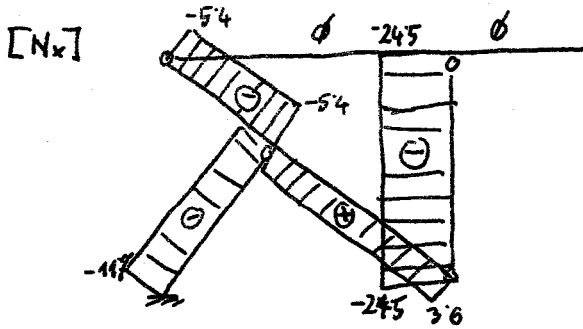
$$M_y = -5 \frac{x^2}{2} + 14.5x - 10$$

$$M_y(0) = -10 \text{ kNm}$$

$$M_y(5) = 0 \text{ (relativno)}$$

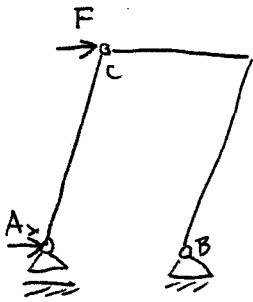
$$M_y(2.9) = 11.025 \text{ kNm (relativno)}$$

e.) DIAGRAMI



3. NALOGA

a.) REAKCIJA A_x



$$\delta W = A_x \cdot \delta u_A + F \delta u_C = 0$$

$$\delta u_C = \delta u_A - h \delta \varphi_A \quad \delta u_C = \delta u_B - h \delta \varphi_B$$

$$\delta w_C = \delta w_A - a \delta \varphi_A \quad \delta w_C = \delta w_B + a \delta \varphi_B$$

$$-\delta \varphi_A = \delta \varphi_B$$

$$\delta u_C = h \delta \varphi_A$$

$$\delta u_C = \delta u_A - h \delta \varphi_A$$

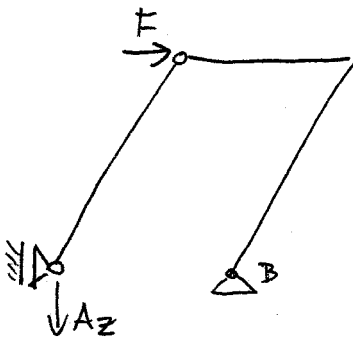
$$2 \delta u_C = \delta u_A \Rightarrow \delta u_C = \frac{1}{2} \delta u_A$$

$$A_x \delta u_A + \frac{F}{2} \delta u_A = 0$$

$$(A_x + \frac{F}{2}) \delta u_A = 0$$

$$A_x = -\frac{F}{2}$$

b.) REAKCIJA A_z



$$\delta W = A_z \cdot \delta w_A + F \delta u_C = 0$$

$$\delta u_C = \delta u_A - h \delta \varphi_A$$

$$\delta u_C = \delta u_B - h \delta \varphi_B$$

$$\delta w_C = \delta w_A - a \delta \varphi_A$$

$$\delta w_C = \delta w_B + a \delta \varphi_B \Rightarrow \delta w_C = a \delta \varphi_A = a \delta \varphi_B$$

$$\delta \varphi_A = \delta \varphi_B \Rightarrow 2 \delta w_C = \delta w_A$$

$$\delta w_C = \frac{1}{2} \delta w_A$$

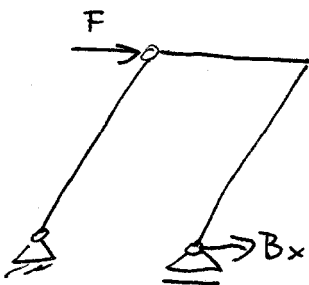
$$\delta u_C = -h \cdot \frac{\delta w_C}{a} = -\frac{h}{2a} \delta w_A$$

$$\delta u_C = -\frac{h}{2a} \delta w_A$$

$$A_z \delta w_A - F \cdot \frac{h}{2a} \delta w_A = 0$$

$$A_z = F \frac{h}{2a}$$

c.) REAKCIJA B_x



$$\delta W = B_x \cdot \delta u_B + F \delta u_C = 0$$

$$\delta u_C = \delta u_A - h \delta \varphi_A$$

$$\delta u_C = \delta u_B - h \delta \varphi_B$$

$$\delta w_C = \delta w_A - a \delta \varphi_A$$

$$\delta w_C = \delta w_B + a \delta \varphi_B$$

$$-\delta \varphi_A = \delta \varphi_B$$

$$\delta u_C = h \delta \varphi_B$$

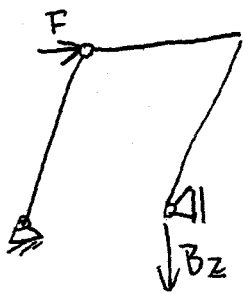
$$\Rightarrow 2 \delta u_C = \delta u_B$$

$$\delta u_C = \frac{1}{2} \delta u_B$$

$$(B_x + \frac{F}{2}) \delta u_B = 0$$

$$B_x = -\frac{F}{2}$$

d.) REAKCIJA B_z



$$\delta W = F \cdot \delta u_c + B_z \cdot \delta w_B = 0$$

$$\delta u_c = \delta u_A^{\perp} - h \delta \varphi_A$$

$$\delta w_c = \delta w_A^{\perp} - a \delta \varphi_A$$

$$\delta u_c = \delta u_B^{\perp} - h \delta \varphi_B$$

$$\delta w_c = \delta w_B + a \delta \varphi_A$$

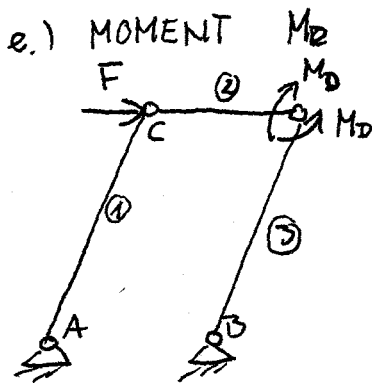
$$\delta \varphi_A = \delta \varphi_B$$

$$\delta w_B = -2a \delta \varphi_A = -2a \delta \varphi_B$$

$$\boxed{\delta u_c = + \frac{h}{2a} \delta w_B}$$

$$\left(F \cdot \frac{h}{2a} + B_z \right) \delta w_B = 0$$

$$\boxed{B_z = -F \frac{h}{2a}}$$



$$\delta u_D = \delta u_B^{\perp} - h \delta \varphi_B$$

$$\delta w_D = \delta w_B - a \delta \varphi_B$$

$$\delta \varphi_D^{\textcircled{3}} = \delta \varphi_B^{\textcircled{3}} = 0$$

$$\delta u_c = \delta u_D$$

$$\delta w_c = \delta w_D + 2a \delta \varphi_D^{\textcircled{2}}$$

$$\delta \varphi_c^{\textcircled{2}} = \delta \varphi_D^{\textcircled{2}}$$

$$\delta u_c = \delta u_A^{\perp} - h \delta \varphi_A$$

$$\delta w_c = \delta w_A^{\perp} - a \delta \varphi_A$$

$$\delta \varphi_c^{\textcircled{2}} = \delta \varphi_A^{\textcircled{2}}$$

analost δu_c : $-h \delta \varphi_A = -h \delta \varphi_B$

$$\boxed{\delta \varphi_A = \delta \varphi_B}$$

analost δw_c : $-a \delta \varphi_A = -a \delta \varphi_B + 2a \delta \varphi_D^{\textcircled{2}}$

$$\boxed{\delta \varphi_D^{\textcircled{2}} = 0}$$

$$\boxed{\delta \varphi_D^{\textcircled{3}} = \delta \varphi_B^{\textcircled{3}}}$$

$$\delta u_c = -h \delta \varphi_D^{\textcircled{3}}$$

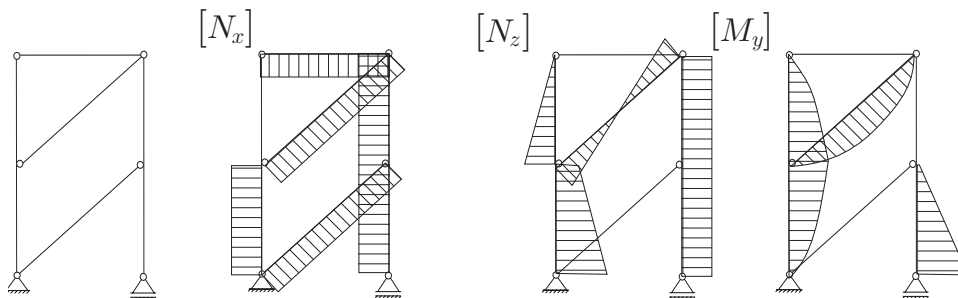
$$\delta W = F \cdot \delta u_c + M_D \delta \varphi_D^{\textcircled{3}} - M_D \delta \varphi_D^{\textcircled{2}} = 0$$

$$(-Fh + M_D) \delta \varphi_D^{\textcircled{3}} = 0$$

$$\boxed{M_D = -F \cdot h}$$

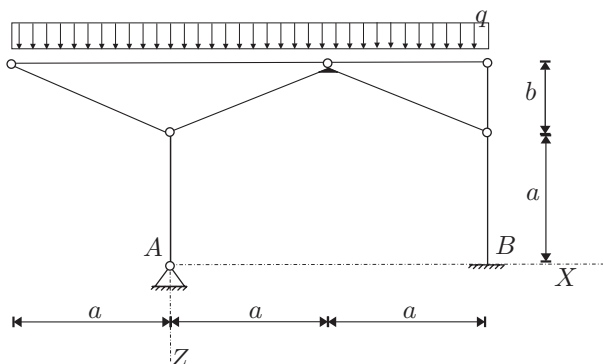
RAČUNSKI DEL IZPITA:

1. Janezek še vedno ne naredi izpita iz statike. Njegovi diagrami so polni napak. Pomagaj Janezku in označi vse napake v njegovih diagramih! **Napake oštevilči in utemelji vsako napako!** (OBVEZNA NALOGA! 25%)



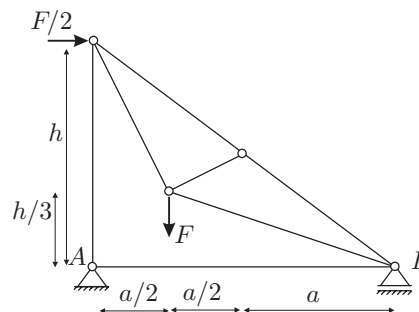
2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločnosti, reakcije in notranje statične količine (N_x , N_z , M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!

Podatki: $a = 2.4$ m, $b = 1$ m,
 $q = 4$ kN/m.
 (OBVEZNA NALOGA! 50%)



3. Za palično konstrukcijo na sliki izračunajte stopnjo statične nedoločnosti in osne sile v palicah! (25%)

Podatki: $a = 4$ m, $h = 6$ m, $F = 5$ kN.

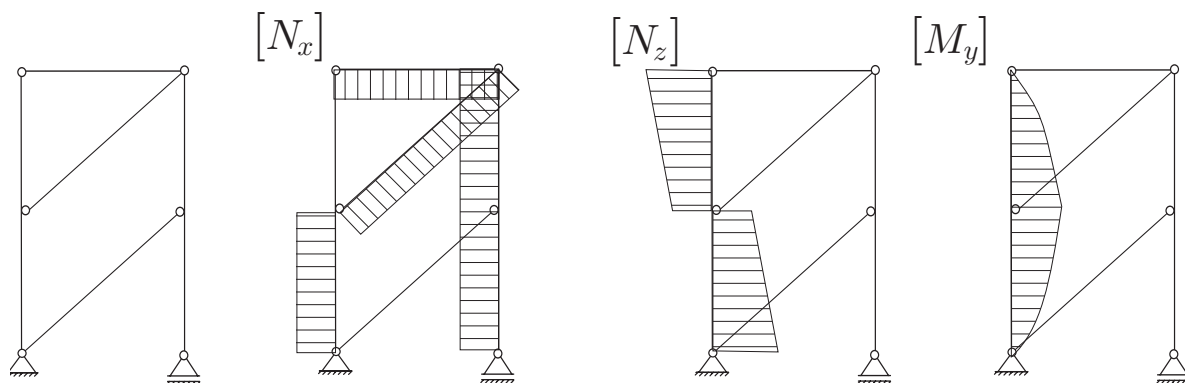


TEORETIČNI DEL IZPITA:

Izmed treh zastavljenih vprašanj si izberete dve, na kateri boste odgovarjali. Izbrani vprašanji jasno označite! Pišite čitljivo.

1. Računski modeli za opis medsebojnega vpliva med telesi!
2. Ravnotežni pogoji za linijski element z ravno osjo (izpeljava diferencialnih enačb)! Ravnotežne pogoje izpeljite za raven nosilec, ki je obtežen samo z linijsko obtežbo prečno na os nosilca! Kaj so statični robni pogoji pri prostoležečem ravninskem nosilcu, ki je obtežen samo z linijsko obtežbo?
3. Opišite določanje reakcij in notranjih sil statično določenih linijskih konstrukcij z izrekom o virtualnih pomikih (Razumevanje ilustrirajte na enostransko previsnem nosilcu s prečno in horizontalno točkovno silo na previsnem robu. Izračunajte vse notranje sile v izbranih značilnih točkah nosilca in vse reakcije)!

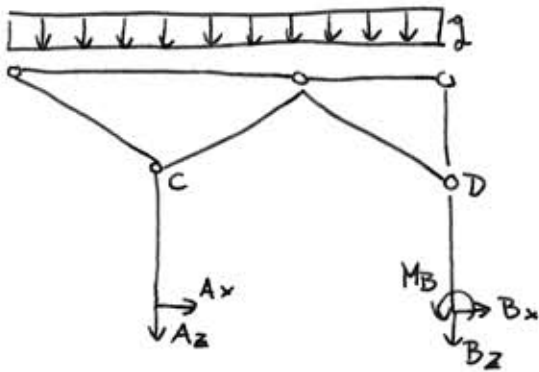
1. Naloga: PRAVILNI DIAGRAMI



2. NALOGA

a.) $\tilde{m}_{ps} = 4 \cdot 3 - 2 \cdot 3 - 2 \cdot 2 - 3 \cdot 4 = 0$

b.) REAKCIE



$\sum X: A_x + B_x = 0$

$\sum Z: A_z + B_z + g \cdot 3a = 0$

$\sum M^B: A_z \cdot 2a + M_B + g \cdot 3a \cdot \frac{3a}{2} = 0$

$\sum M^C: A_x \cdot a = 0$

$A_x = 0 \quad B_x = 0$

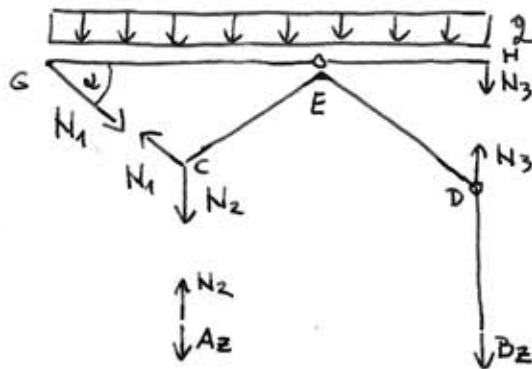
$\sum M^D: B_x \cdot a + M_B = 0$

$M_B = 0$

$A_z = -\frac{9ag}{4} = -216 \text{ kN}$

$B_z = -\frac{3ag}{4} = -42 \text{ kN}$

c.) SILE V PALICAH



$\text{tg } \alpha = \frac{1}{2.4}$
 $\alpha = 22.62^\circ$

$\sum Z: N_2 = A_z$

$N_2 = -216 \text{ kN}$

$\sum M^E: N_1 \cdot \sin \alpha \cdot 2a + g \cdot 2a \cdot a = 0$

$N_1 = -\frac{ga}{\sin \alpha}$

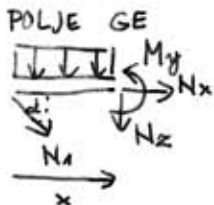
$N_1 = -2496 \text{ kN}$

$\sum M^E: -N_3 \cdot a - g \cdot a \cdot \frac{a}{2} = 0$

$N_3 = -\frac{ga}{2}$

$N_3 = -48 \text{ kN}$

d.) NOTRANJE SILE



$\sum X: N_x + N_1 \cdot \cos \alpha = 0$

$N_x = 23 \text{ kN}$

$\sum Z: N_2 + N_1 \cdot \sin \alpha + gx = 0$

$N_2 = -N_1 \cdot \sin \alpha - gx$

$N_2 = 96 - 4x$

$N_2(0) = 96 \text{ kN} \quad N_2(4.8) = -96 \text{ kN}$

$\sum M^I: M_y + g \cdot x \cdot \frac{x}{2} + N_1 \cdot \sin \alpha \cdot x = 0$

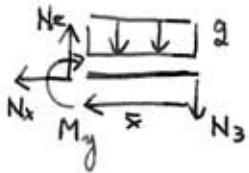
$M_y = -N_1 \cdot \sin \alpha \cdot x - g \cdot \frac{x^2}{2}$

$M_y = 96x - 2x^2$

$M_y(0) = M_y(4.8) = 0$

$M_y(2.4) = 11.52 \text{ kNm}$
ekstrem

POLJE HE (z desne)



$$\Sigma x: N_x = 0$$

$$\Sigma z: N_z = N_3 + q \cdot \bar{x}$$

$$N_z = -4.8 + 4\bar{x}$$

$$N_z = -4.8 \text{ kN} \quad N_z(2.4) = 4.8 \text{ kN}$$

$$\Sigma M^T: -M_y - N_3 \bar{x} - q \bar{x} \frac{\bar{x}}{2} = 0$$

$$M_y = 4.8\bar{x} - 2\bar{x}^2$$

$$M_y(0) = M_y(2.4) = 0$$

$$M_y(1.2) = 2.9 \text{ kNm}$$

elastorem

POLJE BD



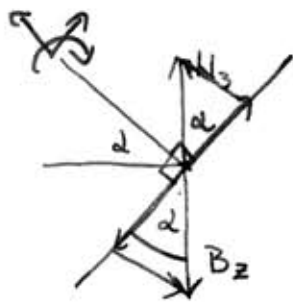
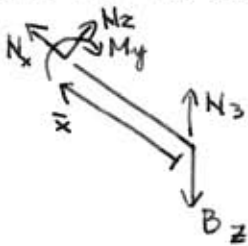
$$N_x = B_z$$

$$N_z = 0$$

$$M_y = 0$$

$$N_x = -7.2 \text{ kN}$$

POLJE ED (z desne)



$$\Sigma x: N_x - B_z \cdot \sin \alpha + N_3 \cdot \sin \alpha = 0$$

$$\Sigma z: N_z - B_z \cdot \cos \alpha + N_3 \cdot \cos \alpha = 0$$

$$\Sigma M^T: -M_y - B_z \bar{x} \cdot \cos \alpha + N_3 \bar{x} \cos \alpha = 0$$

$$N_x = -0.92 \text{ kN}$$

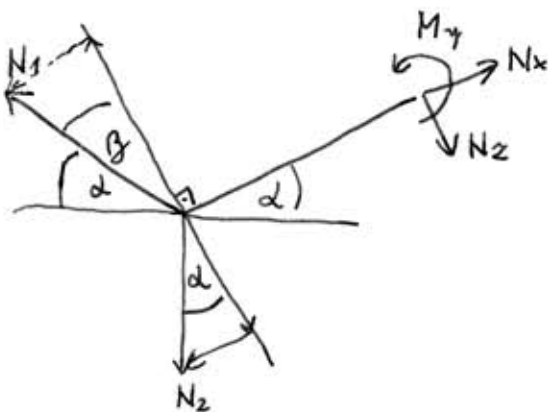
$$N_z = -2.2 \text{ kN}$$

$$M_y = 2.2\bar{x}$$

$$M_y(0) = 0$$

$$M_y(2.6) = 5.7 \text{ kNm}$$

POLJE CE



$$\Sigma x: N_x - N_2 \cdot \sin \alpha - N_1 \cdot \sin \beta = 0$$

$$\Sigma z: N_z + N_2 \cos \alpha - N_1 \cos \beta = 0$$

$$\Sigma M^T: M_y + N_2 x \cos \alpha - N_1 \cos \beta x = 0$$

$$N_x = 25.9 \text{ kN}$$

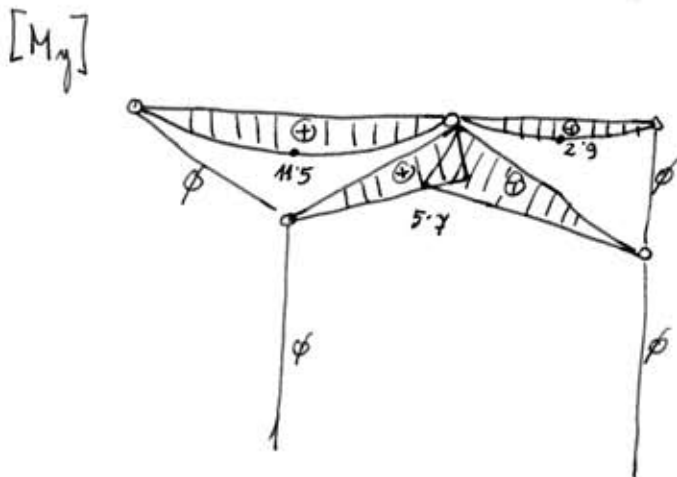
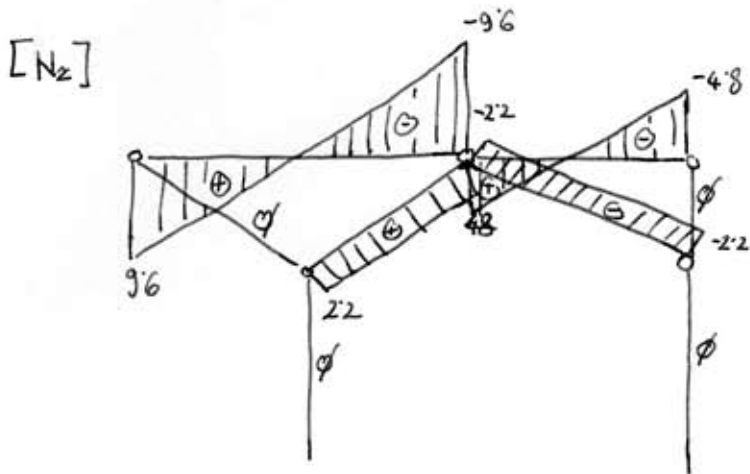
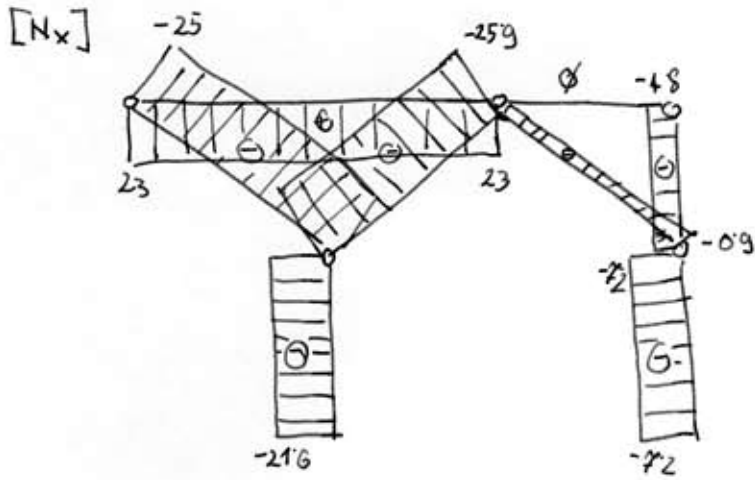
$$N_z = 2.2 \text{ kN}$$

$$M_y = 2.2\bar{x}$$

$$\beta = 180 - 90 - 2\alpha = 44.76^\circ$$

$$\alpha = 22.62^\circ$$

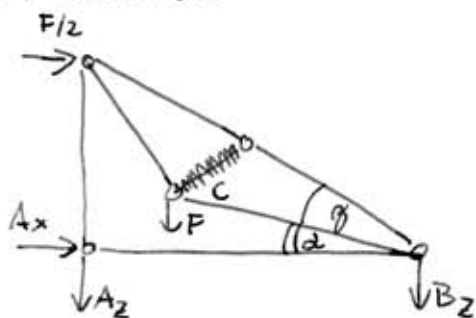
e.) DIAGRAMI



3. HALOG A

a.) $\tilde{m}_{PS} = 7 - 3 \cdot 2 - 1 = 0$

b.) REAKCIJE



$\sum X: A_x = -\frac{F}{2}$ $A_x = -2.5 \text{ kN}$

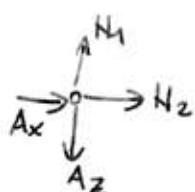
$\sum Z: A_z + B_z + F = 0$

$\sum M^A: -B_z \cdot 2a - F \cdot \frac{a}{2} - \frac{F}{2} \cdot h = 0$

$B_z = -3.125 \text{ kN}$

$A_z = -1.875 \text{ kN}$

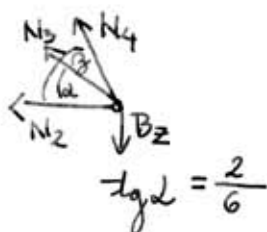
vozl. A:



$N_1 = -1.875 \text{ kN}$

$N_2 = 2.5 \text{ kN}$

vozl. B



$\tan \alpha = \frac{2}{6}$

$\tan \beta = \frac{3}{4}$

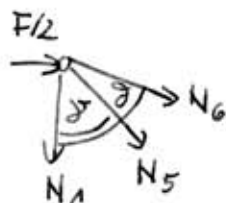
$N_2 + N_3 \cdot \cos \alpha + N_4 \cdot \cos \beta = 0$

$N_3 \cdot \sin \alpha + N_4 \cdot \sin \beta = B_z$

$N_3 = 3.16 \text{ kN}$

$N_4 = -6.88 \text{ kN}$

vozl. C



$N_1 + N_5 \cdot \cos \gamma + N_6 \cdot \cos \delta = 0$

$N_5 \cdot \sin \gamma + N_6 \cdot \sin \delta + \frac{F}{2} = 0$

ZA KONTROLO

$N_6 = N_4$

$\tan \gamma = \frac{2}{4}$

$N_5 = 6.71 \text{ kN}$

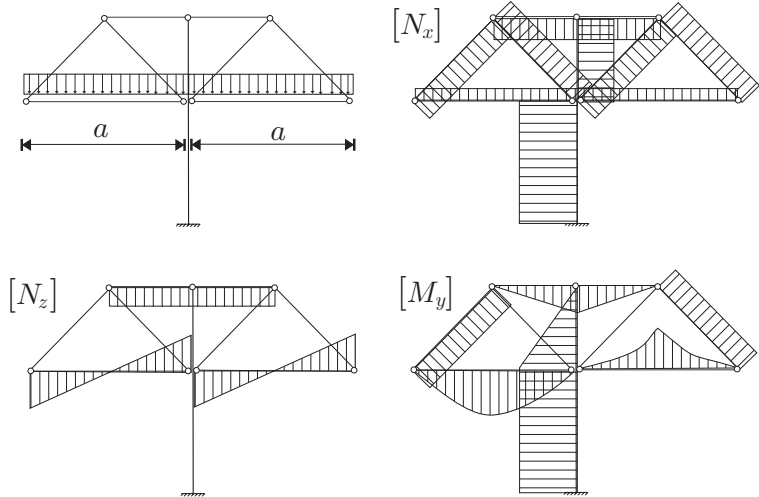
$N_6 = -6.88 \text{ kN}$

$\tan \delta = \frac{4}{3}$

✓

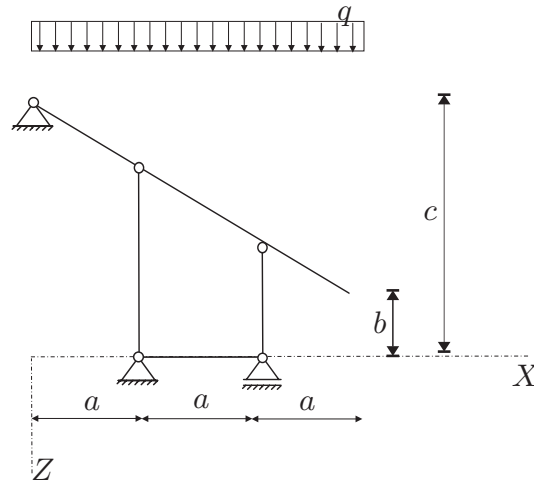
RAČUNSKI DEL IZPITA:

1. Janezek je na izpitu iz statike padel. Njegovi diagrami so polni napak. Pomagaj Janezku in poišči (BREZ RAČUNANJA) vse napake v njegovih diagramih! **Napake oštevilči in utemelji vsako napako!** (OBVEZNA NALOGA! 25%)

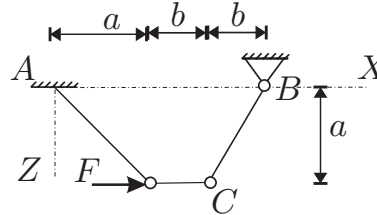


2. Za konstrukcijo na sliki izračunajte stopnjo statične nedoločenosti, reakcije in notranje statične količine (N_x, N_z, M_y)! Rezultate notranjih statičnih količin prikažite z diagrami!

Podatki: $a = 2\text{ m}$, $b = 1\text{ m}$,
 $c = 4\text{ m}$, $q = 5\text{ kN/m}$.
 (OBVEZNA NALOGA! 50%)



3. S principom virtualnega dela za konstrukcijo na sliki izrazite reakcije v podporah! (25%)



TEORETIČNI DEL IZPITA:

Izmed treh zastavljenih vprašanj si izberete dve, na kateri boste odgovarjali. Izbrani vprašanji jasno označite! Pišite čitljivo.

1. Izpeljite ravnotežne pogoje za sile, ki delujejo na sistemu delcev s togimi vezmi in togem telesu!
2. Opišite kinematične enačbe sistema togih teles ter postopek računanja dejanskega števila prostostnih stopenj sistema togih teles (ilustracija z značilnim primerom)!
3. Opišite določanje reakcij in notranjih sil statično določenih linijskih konstrukcij z izrekom o virtualnih pomikih (pomagajte si s primerom)!

1. Naloga: PRAVILNI DIAGRAMI

