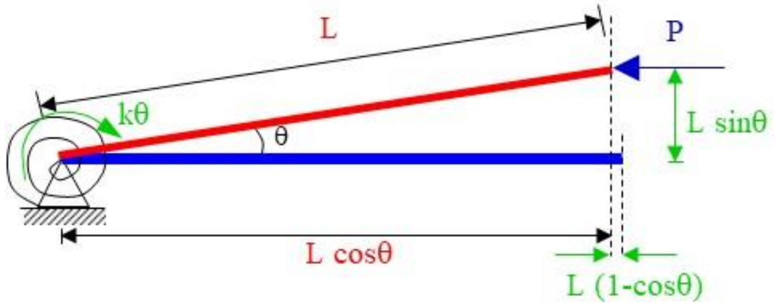


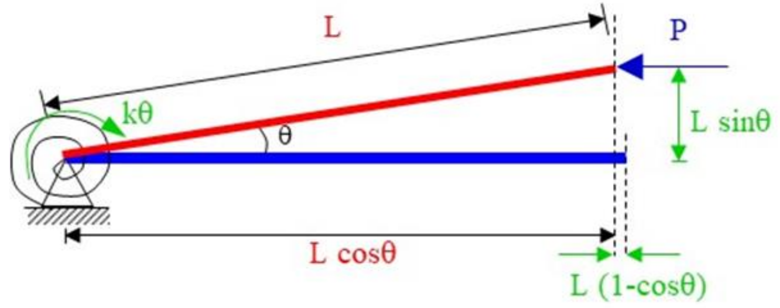
KONSTRUKCIJSKI SUSTAVI SASTAVLJENI OD KRUTIH ŠTAPOVA

Stabilnost konstrukcija

π

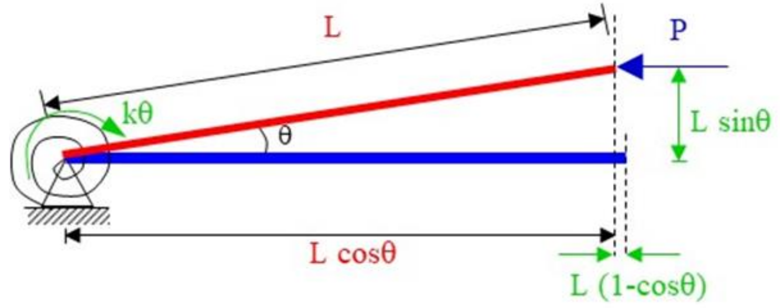
Konstrukcijski sustavi sastavljeni od krutih štapova

- Konstrukcija se sastoji od
  - krutih elemenata (štapova beskonačne krutosti)
  - lokaliziranih opruga (točaka koncentrirane elastične deformacije)
  - ležajnih zglobova.
- Diskretni konstrukcijski sustavi s jednim, dva ili više stupnjeva slobode.
- Stupanj slobode odnosi se na generalizirane koordinate koje predstavljaju broj neovisnih koordinata (pomaka ili rotacija) koje je potrebno odrediti kako bi se u cijelosti definirao novi položaj (konfiguracija) sustava.
- Neovisna se koordinata može mijenjati bez promjene ostalih koordinata.



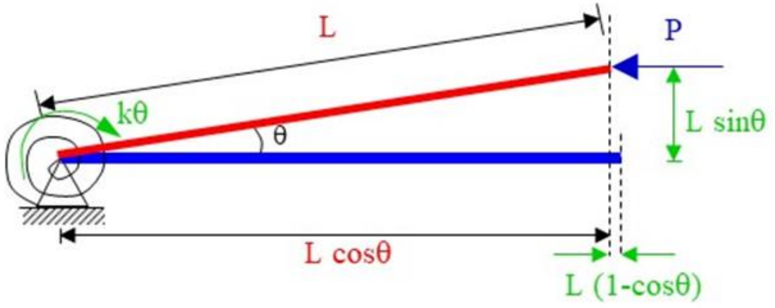
Konstrukcijski sustavi sastavljeni od krutih štapova
METODE PRORAČUNA

- Metode proračuna se temelje na statičkom pristupu:
  - Konstrukcija je u stanju ravnoteže / mirovanja prije i nakon izvijanja.
- Uvjet primjene:
  - Vanjske sile su konzervativne (imaju potencijal).
- Cilj primjene:
  - Predvidjeti oblik gubitka stabilnosti i tome pripadajuće opterećenje.
- Dva su pristupa:
  - Ravnotežni pristup
  - Energetski pristup.

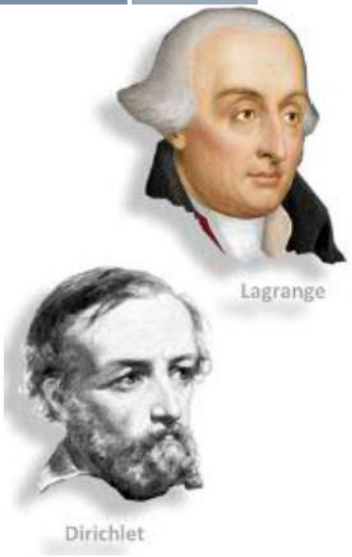


Konstrukcijski sustavi sastavljeni od krutih štapova
PRINCIP STATIČKE RAVNOTEŽE

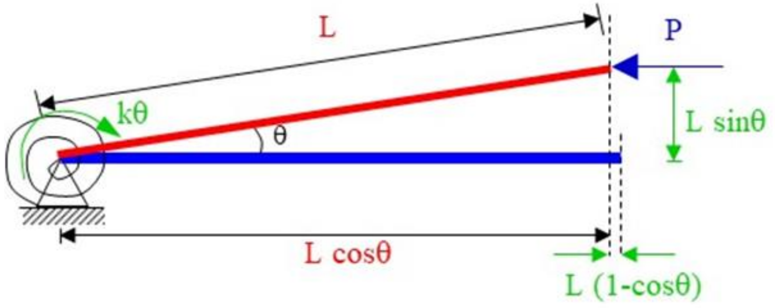
- Analiziramo oblik ravnoteže idealiziranog sustava.
- Određujemo opterećenje / veličinu sile pri kojem sustav zauzima blizak ali dovoljno različit oblik ravnoteže.
- Pretpostavljamo male pomake s infinitezimalno malim kutovima zaokreta.



Konstrukcijski sustavi sastavljeni od krutih štapova
ENERGETSKI PRISTUP



- Temelji se na principu minimuma potencijalne energije:
- Lagrange – Dirichletov teorem stabilnosti:
  - Konzervativni sustav je u položaju stabilne ravnoteže ako i samo ako je veličina ukupne potencijalne energije minimalna u odnosu na susjedna bliska stanja, tj. matematički rečeno – pozitivno definitna.
- Konzervativni sustav je u stanju ravnoteže ako je akumulirana energija jednaka radu vanjskih sila
  - Zapravo se radi o određivanju graničnog / kritičnog opterećenja pri kojem će odziv sustava prestati biti u položaju stabilne ravnoteže.



Konstrukcijski sustavi sastavljeni od krutih štapova
ENERGETSKI PRISTUP

› Virtualni pomak: prihvatljivi oblik pomaka koji zadovoljava geometrijske i rubne uvjete sila.

› Virtualni rad vanjskih sila: $\delta W_{ex} = -P\Delta$.

– Δ – virtualni pomak točke djelovanja vanjske sile (komponenta pomaka u smjeru djelovanja sile),

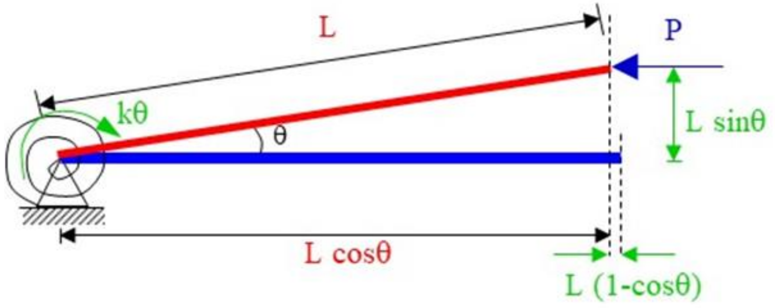
– δU – energija deformiranja uslijed unutarnjeg rada.

› Princip virtualnog rada:

$$\delta U = \delta W_{ex}$$
$$\delta U - \delta W_{ex} = 0$$

› Prirast vanjskog rada na virtualnim pomacima možemo prikazati i promjenom potencijalne energije:

$$\delta V = -\delta W_{ex}$$
$$\delta(U+V) = \delta\Pi = 0 \quad \rightarrow \quad U + V = \Pi = const.$$



Konstrukcijski sustavi sastavljeni od krutih štapova
ENERGETSKI PRISTUP

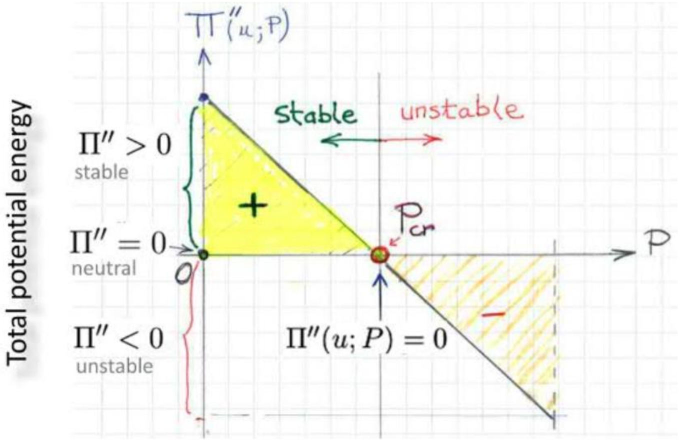
- $\Pi = U + V$: ukupni potencijal ili potencijal sustava.
- Kada je konstrukcijski sustav u stanju statičke ravnoteže, ukupna potencijalna energija sustava poprima stacionarnu vrijednost što znači da je njena prva varijacija jednaka nuli, tj. $\delta\Pi = 0$.

$\delta^2\Pi > 0 \quad \rightarrow \quad \textit{stabilna ravnoteža}$

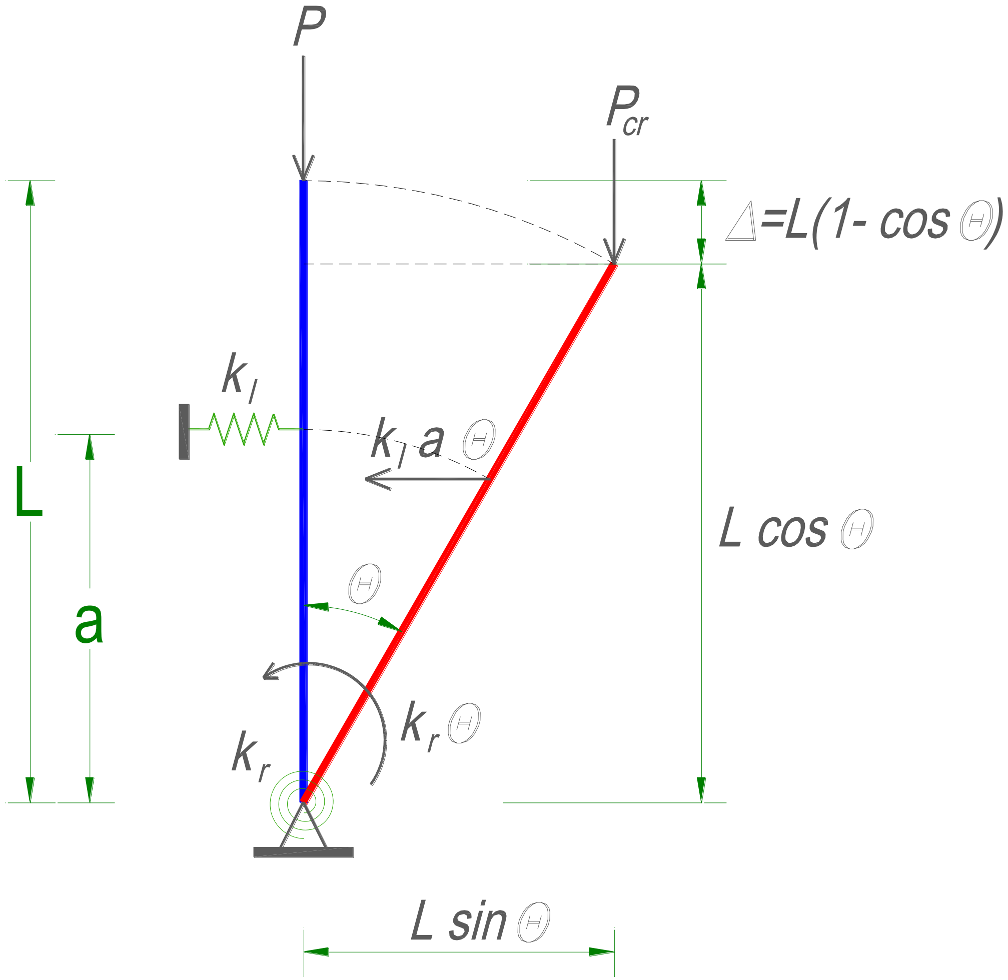
$\delta^2\Pi = 0 \quad \rightarrow \quad \textit{indiferentna ravnoteža}$

$\delta^2\Pi < 0 \quad \rightarrow \quad \textit{nestabilna ravnoteža}$

(ukupna potencijalna energija idealiziranog sustava prestaje biti pozitivno definitna).

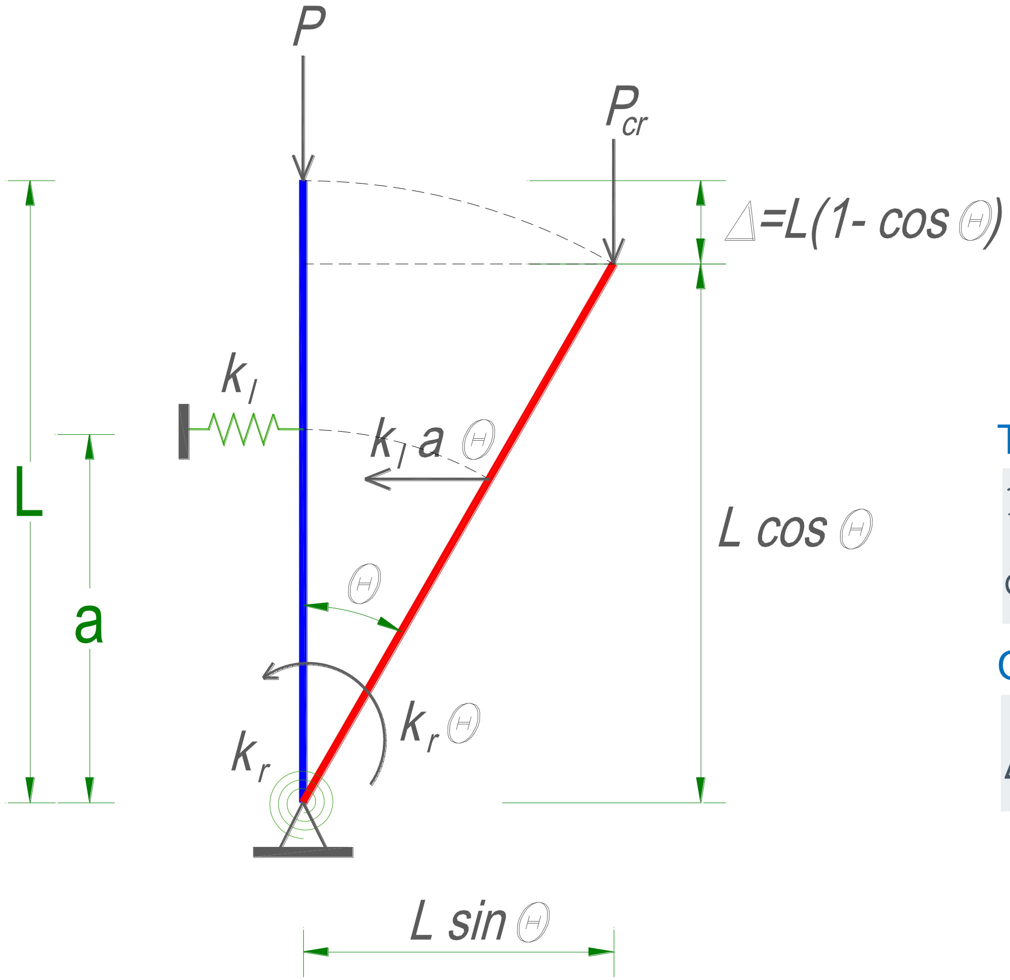


Primjer #1.



- $P < P_{cr}$: prestankom djelovanja sile, štap se vraća u početni položaj *(reakcijski moment opruga veći je od momenta prevrtanja kojeg proizvodi vanjska sila);*
- $P > P_{cr}$: narušavanje stanja ravnoteže → *slom ili prevrtanje*.
- Θ – dovoljno mali kut zaokreta.

Primjer #1. *Princip statičke ravnoteže*



› Moment vanjskih sila = moment otpornosti sustava:

$$P_{cr}L\theta = (k_l a\theta)a + k_r\theta$$
$$P_{cr} = \frac{k_l a^2 + k_r}{L}$$

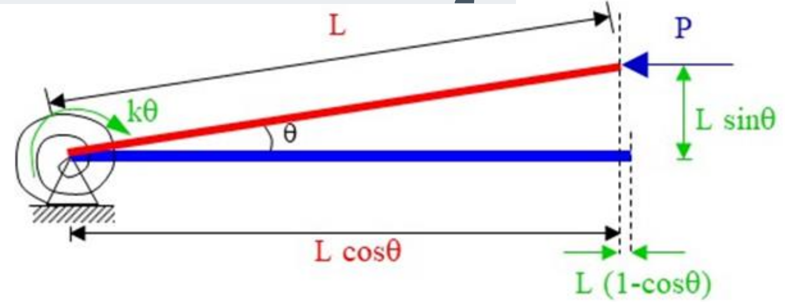
Trigonometrijske transformacije:

$$1 - cos \propto = 2sin^2\frac{\propto}{2}$$

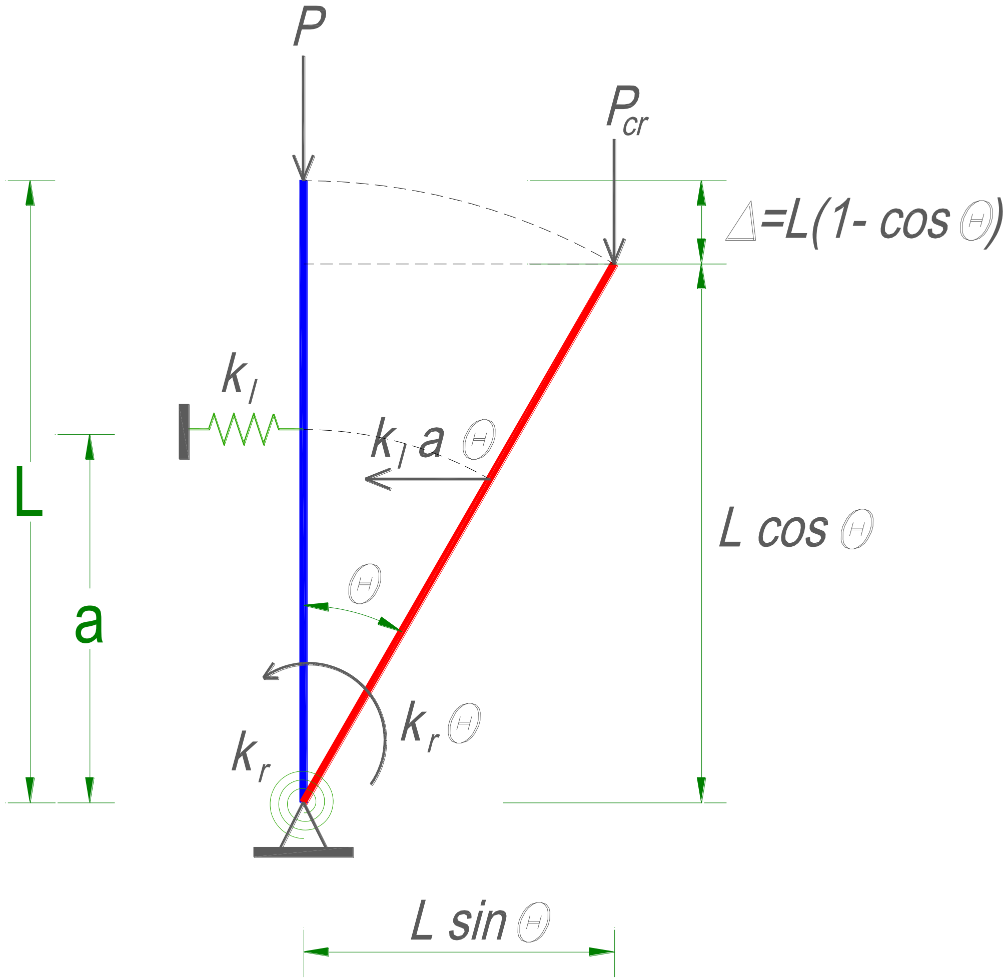
$$\propto \to 0: \quad sin\alpha \approx \propto \quad \to \quad 1 - cos\alpha = 2\frac{\alpha^2}{4} = \frac{\propto^2}{2} \quad \text{ili}$$

Geometrijski red:

$$\Delta = L - Lcos \propto = L - L\left(1 - \frac{\propto^2}{2} + \cdots\right) \approx \frac{L \propto^2}{2}$$



Primjer #1. *Energetski pristup – 1.put*



› Princip virtualnih pomaka:

Ako sustavu u stanju ravnoteže pod djelovanjem vanjskih sila zadamo virtualni pomak (pomak kompatibilan s rubnim uvjetima), ukupan rad sila mora biti jednak nuli.

- Rekonstrukcija svih sila sustava
- Zadavanje malog virtualnog pomaka po svakom stupnju slobode
- Izjednačavanje rada s nulom tj.

za virtualni pomak θ $\rightarrow$ $\delta W_{ex} = \delta U$.

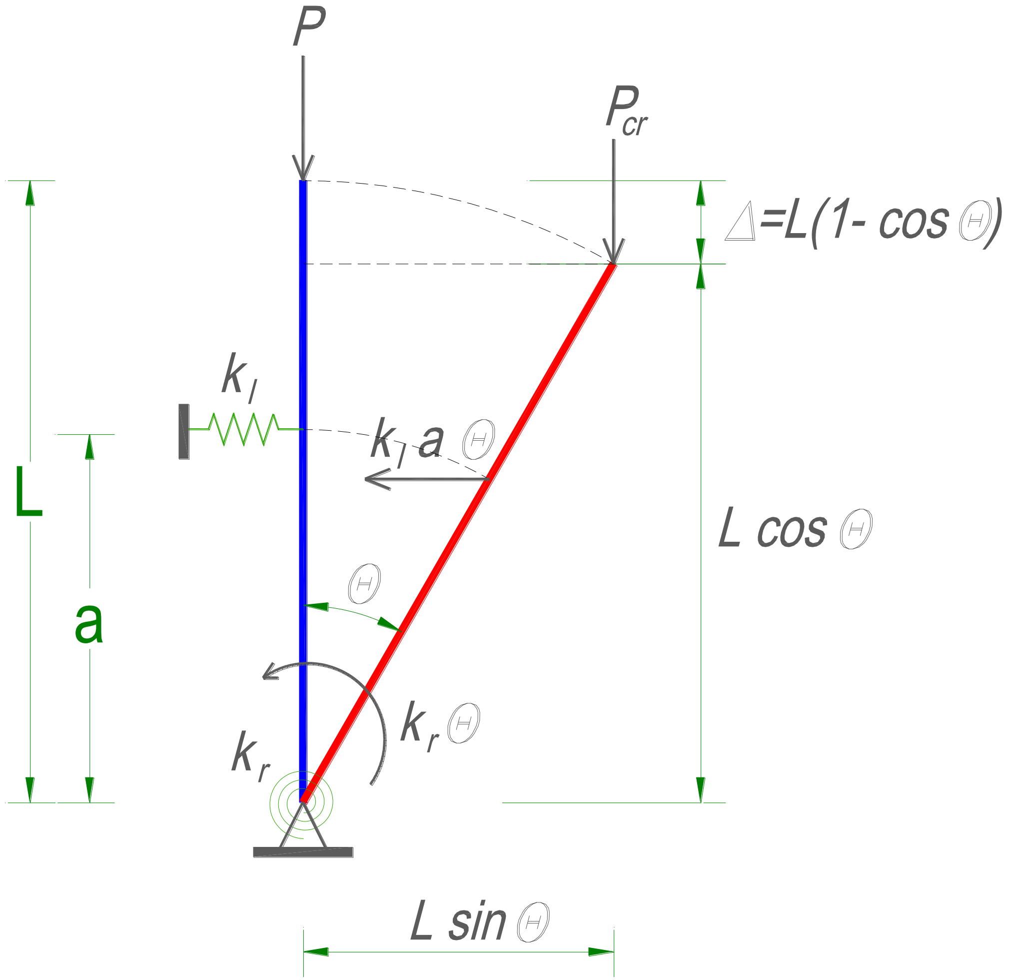
$$\delta W_{ex} = P\Delta = P\frac{L\theta^2}{2}$$

$$\delta U = \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

$$\frac{1}{2}P_{cr}L\theta^2 = \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

$$P_{cr} = (k_l a^2 + k_r)/L$$

Primjer #1. *Energetski pristup – 2. put*



- Zakon očuvanja/održanja energije:

Rad vanjskih sila jednak je unutarnjoj energije sustava.

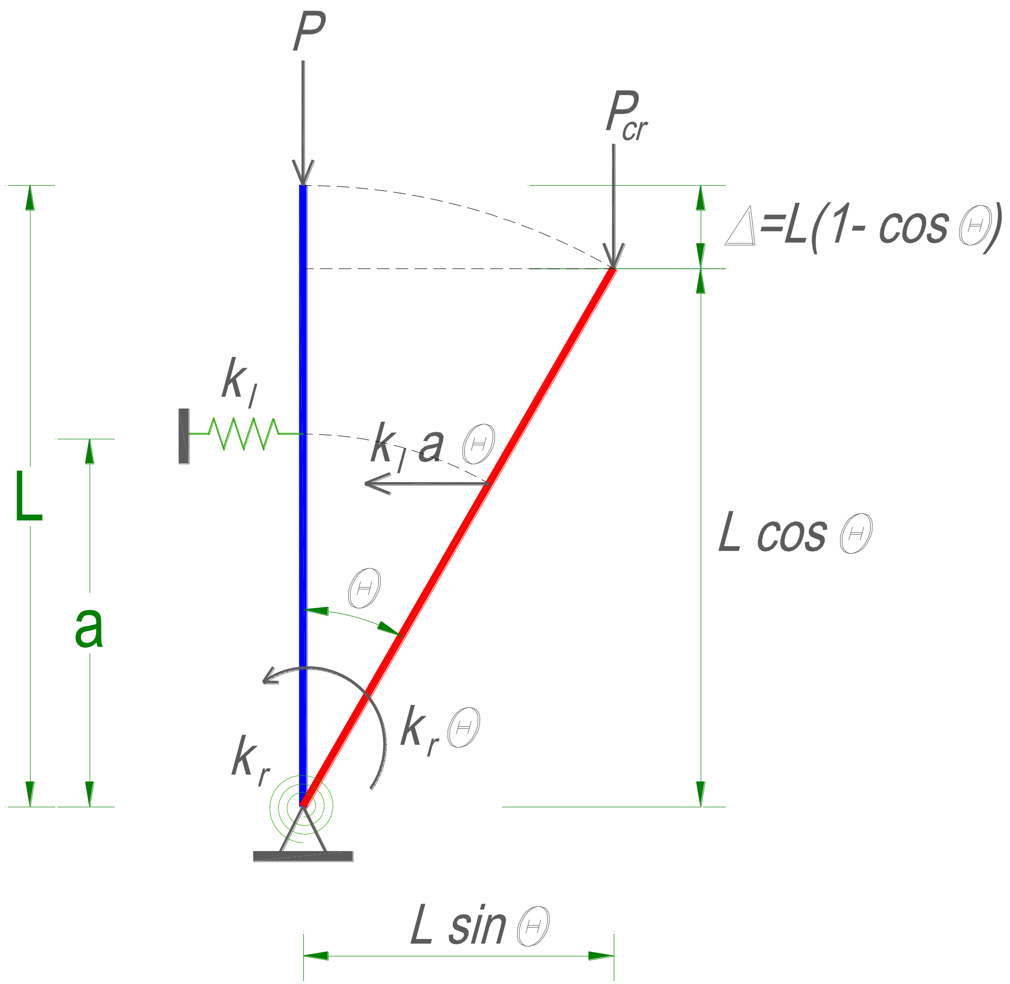
$$W_{ex} = P\Delta = P\frac{L\theta^2}{2}$$

$$W_{in} = \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

$$\frac{1}{2}P_{cr}L\theta^2 = \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

$$P_{cr} = (k_l a^2 + k_r)/L$$

Primjer #1. *Energetski pristup – 3. put*



› Princip stacionarne potencijalne energije u stanju statičke ravnoteže:

Potencijalna energija vanjskih sila

$$V = -P\Delta = -P\frac{L\theta^2}{2}$$

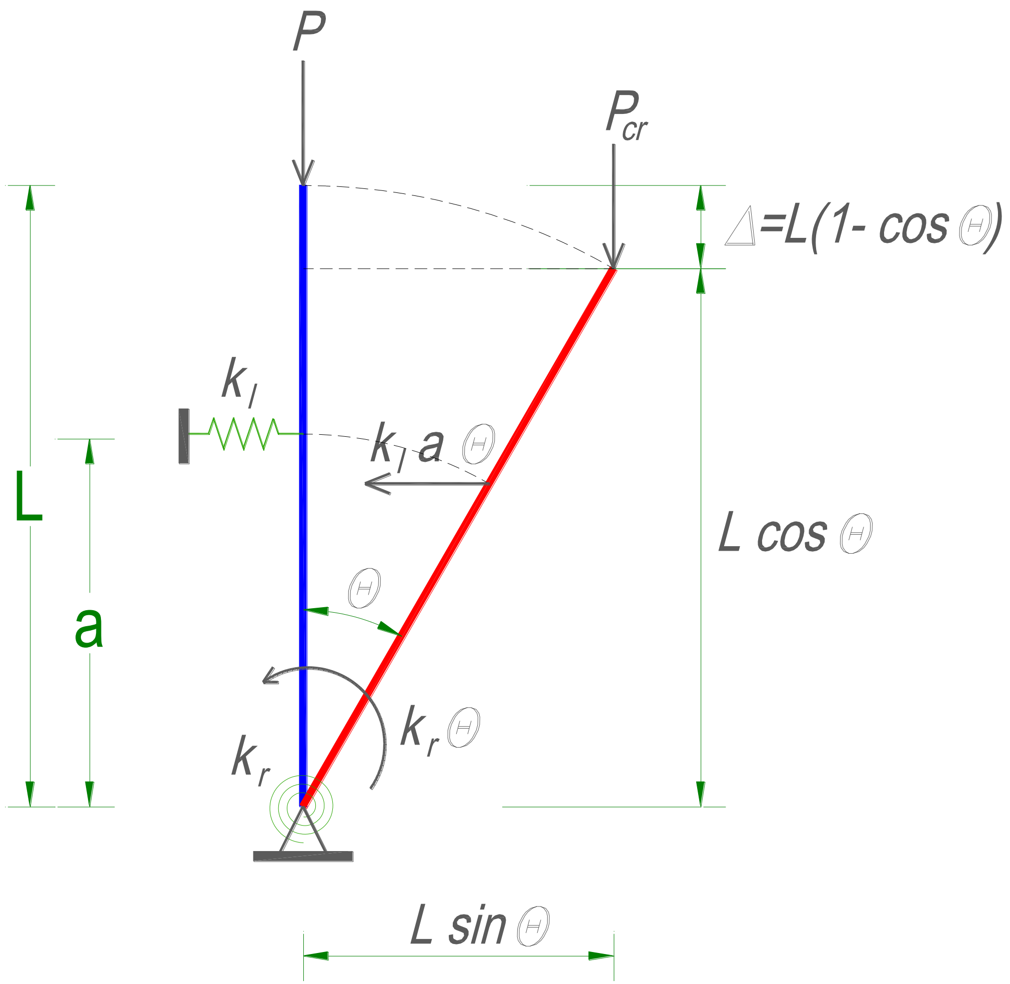
Potencijalna energija unutarnjih sila –energija deformacije opruga (štapovi su kruti i nemaju elastičnu energiju deformacije)

$$U = \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

Ukupna potencijalna energija sustava: $\Pi = V + U$

$$\Pi = -P\frac{L\theta^2}{2} + \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

Primjer #1. *Energetski pristup – 3. put*



- Princip stacionarne potencijalne energije u stanju statičke ravnoteže:

$$\Pi = -P\frac{L\theta^2}{2} + \frac{1}{2}k_l a^2\theta^2 + \frac{1}{2}k_r\theta^2$$

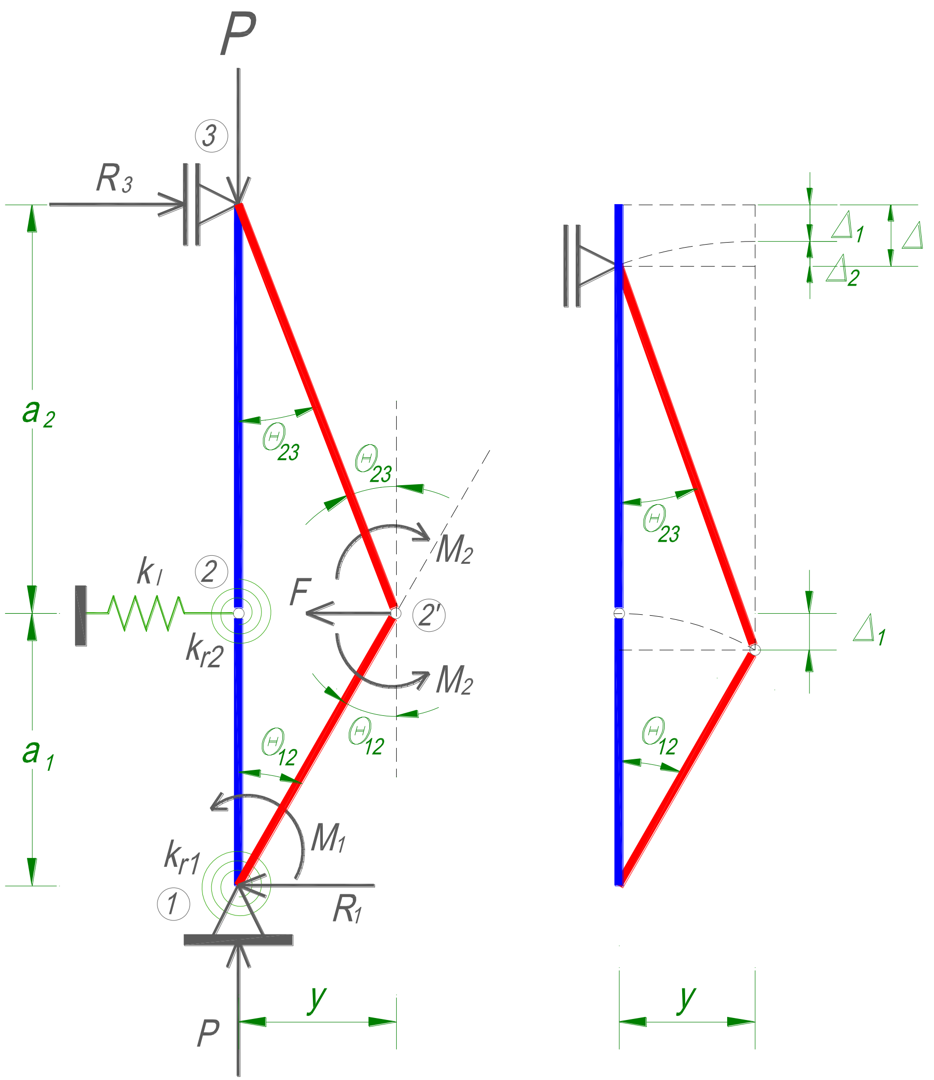
$$\delta\Pi = \frac{\partial\Pi}{\partial\theta}\delta\theta = (-PL\theta + k_l a^2\theta + k_r\theta)\delta\theta = 0$$

Netrivijalno rješenje:

$$-PL\theta + (k_l a^2 + k_r)\theta = 0$$

$$P = P_{cr} = \frac{k_l a^2 + k_r}{L}$$

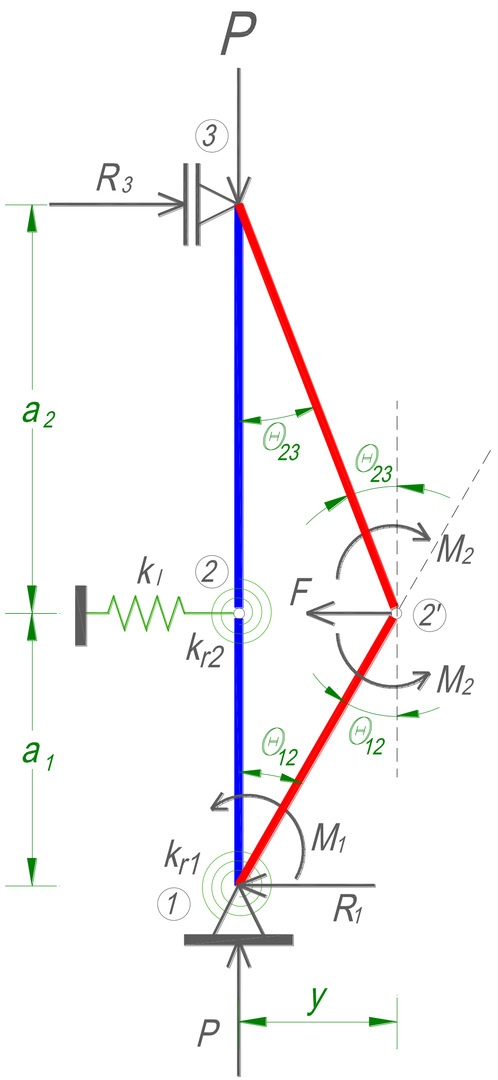
Primjer #2.



$$L = a_1 + a_2$$
$$F = k_l y$$
$$M_1 = k_{r1}\theta_{12} = k_{r1}\frac{y}{a_1}$$
$$M_2 = k_{r2}\theta_2 = k_{r2}(\theta_{12} + \theta_{23}) = k_{r2}\left(\frac{y}{a_1} + \frac{y}{a_2}\right)$$

$$\Delta = \Delta_1 + \Delta_2 = \frac{a_1}{2}\theta_{12}^2 + \frac{a_2}{2}\theta_{23}^2 = \frac{a_1}{2}\frac{y^2}{a_1^2} + \frac{a_2}{2}\frac{y^2}{a_2^2} =$$
$$= \frac{y^2}{2}\left(\frac{1}{a_1} + \frac{1}{a_2}\right)$$

Primjer #2. *Princip statičke ravnoteže*



$$\sum M_3 = -R_1 L - F a_2 + M_1 = 0 \rightarrow R_1 = \frac{-F a_2 + M_1}{a_1 + a_2}$$

$$\sum M_{2'} = -Py - R_1 a_1 + M_1 + M_2$$

$$-Py - \frac{\frac{k_{r1} y}{a_1} - k_l y a_2}{a_1 + a_2} a_1 + \frac{k_{r1} y}{a_1} + \frac{k_{r2} y}{a_1} + k_{r2} \frac{y}{a_2} = 0$$

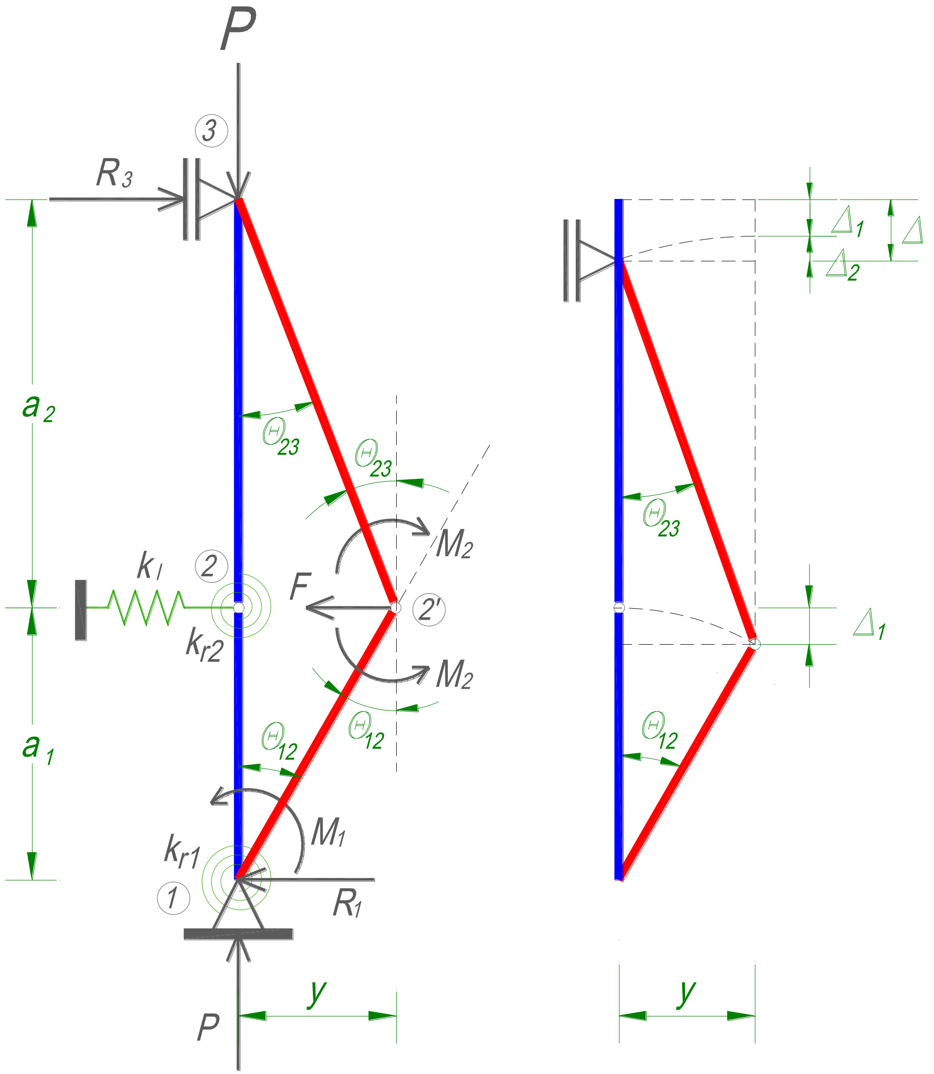
$$P a_1 a_2 (a_1 + a_2) =$$
$$= k_l a_1^2 a_2^2 - k_{r1} a_1 a_2 - k_{r1} a_2 (a_1 + a_2) + k_{r2} a_2 (a_1 + a_2) + k_{r2} a_1 (a_1 + a_2)$$

$$P a_1 a_2 (a_1 + a_2) = k_l a_1^2 a_2^2 + k_{r1} a_2^2 + k_{r2} (a_1 + a_2)^2$$

$$P(a_1 + a_2) = k_l a_1 a_2 + k_{r1} \frac{a_2}{a_1} + k_{r2} \frac{(a_1 + a_2)^2}{a_1 a_2}$$

Za npr. a_1=a_2=a: $$P_{cr} = \frac{k_l a^2 + k_{r1} + 4k_{r2}}{2a}$$

Primjer #2. *Energetski (min. potencijalne energije)*



$$V=-P\frac{y^2}{2}\left(\frac{1}{a_1}+\frac{1}{a_2}\right)$$

$$U=\frac{1}{2}k_l y^2+\frac{1}{2}k_{r1}\frac{y^2}{a_1^2}+\frac{1}{2}k_{r2}\left(\frac{y^2}{a_1^2}+\frac{2y^2}{a_1a_2}+\frac{y^2}{a_2^2}\right)$$

$$\Pi=U+V=$$

$$=\frac{1}{2}k_l y^2+\frac{1}{2}k_{r1}\frac{y^2}{a_1^2}+\frac{1}{2}k_{r2}\frac{y^2}{a_1^2}+k_{r2}\frac{y^2}{a_1a_2}+\frac{1}{2}k_{r2}\frac{y^2}{a_2^2}$$

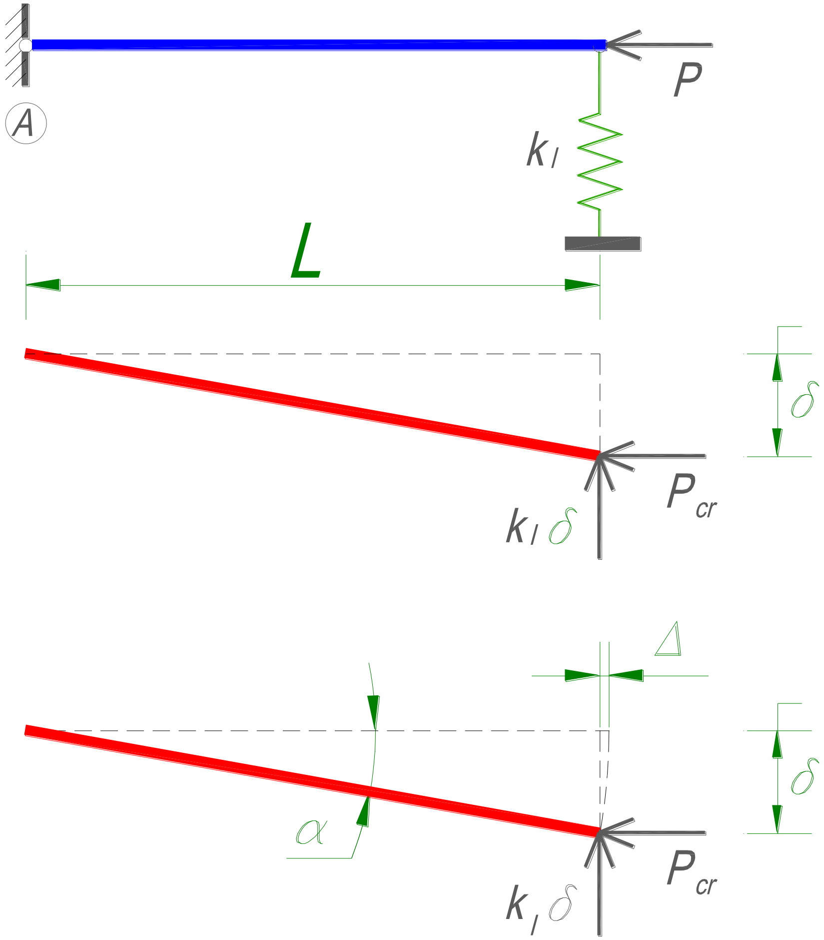
$$-P\frac{y^2}{2a_1}-P\frac{y^2}{2a_2}$$

$$\delta\Pi=\frac{\partial\Pi}{\partial y}\delta y=0$$

$$\frac{\partial\Pi}{\partial y}=k_l y+k_{r1}\frac{y}{a_1^2}+k_{r2}\frac{y}{a_1^2}+2k_{r2}\frac{y}{a_1a_2}+k_{r2}\frac{y}{a_2^2}-P\frac{y}{a_1}-P\frac{y}{a_2}=0$$

$$P_{cr}(a_1+a_2)=k_l a_1a_2+k_{r1}\frac{a_2}{a_1}+k_{r2}\frac{(a_1+a_2)^2}{a_1a_2}$$

Primjer #3.



Statički:

$$\sum M_A = P\delta - k_l \delta L = 0$$

$$P_{cr} = k_l L$$

Energetski:

$$V = -P\Delta = -P\frac{L\alpha^2}{2}$$

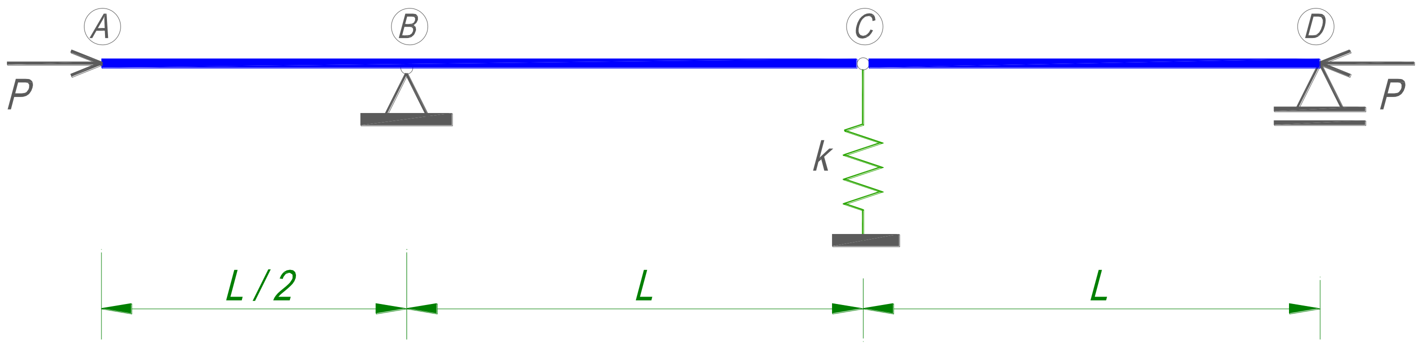
$$U = \frac{1}{2}k_l\delta^2$$

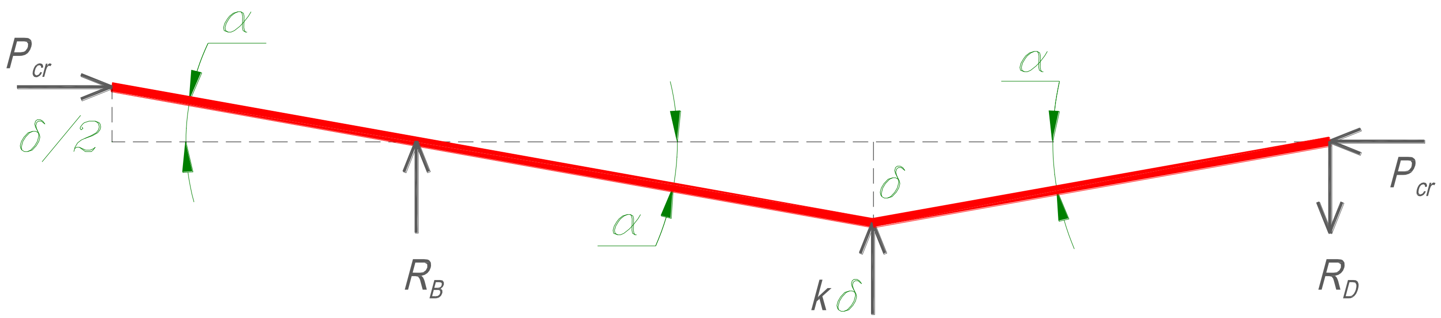
$$\Pi = V + U = -P\frac{L\alpha^2}{2} + \frac{1}{2}k_l\delta^2 = -P\frac{L\alpha^2}{2} + \frac{1}{2}k_l L^2\alpha^2$$

$$\frac{\partial \Pi}{\partial \alpha} = -PL\alpha + k_l L^2 \alpha = 0$$

$$P_{cr} = k_l L$$

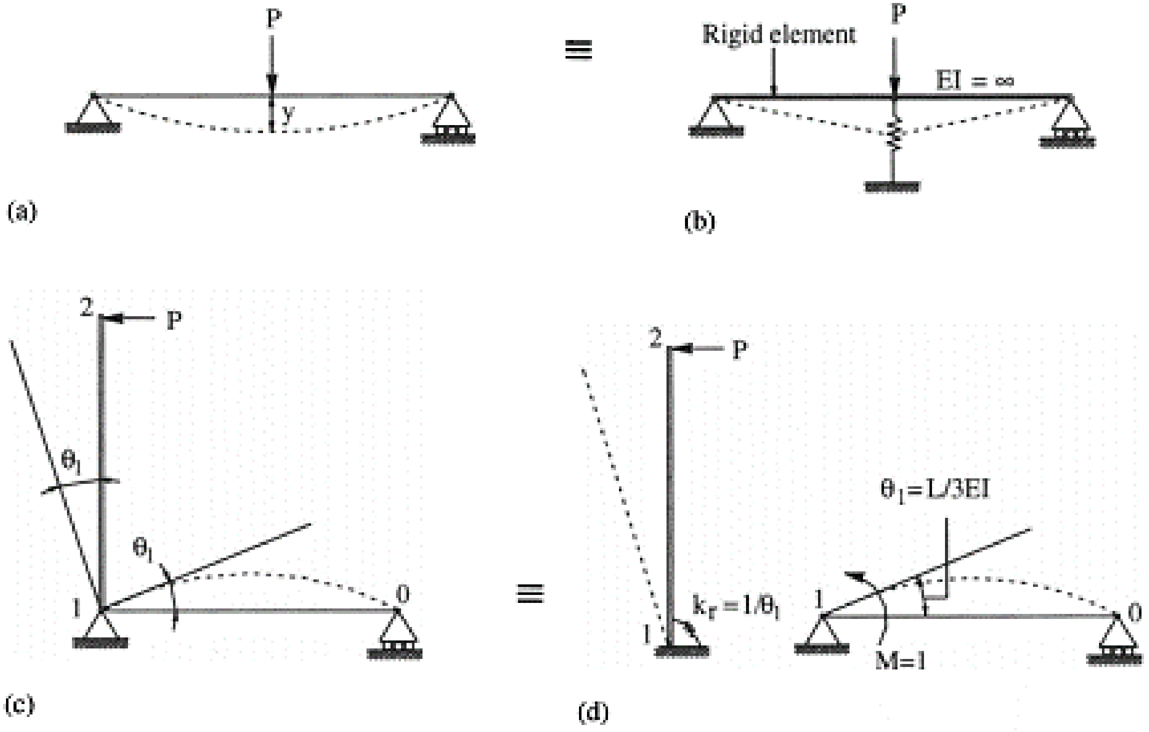
Primjer #4.



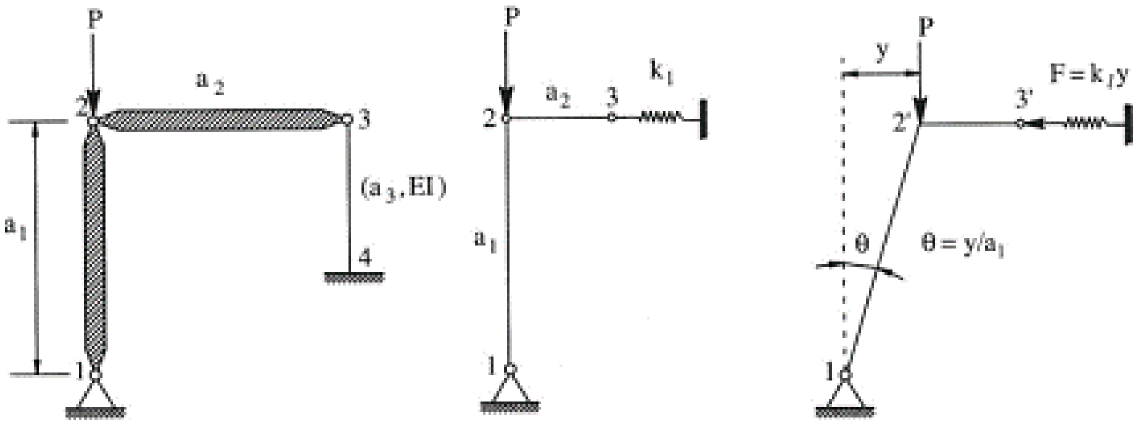


Rješenje: $$P_{cr} = \frac{2}{5} k_l L$$

Modeliranje elastično deformabilnih elemenata pomoću zamjenjujućih opruga



Primjer #5.



Okvir na slici sastoji se od dva kruta štapa 12 i 23 te jednog elastično deformabilnog štapa 34 krutosti na savijanje EI. Svi su štapovi međusobno spojeni zglobovima. Potrebno je odrediti kritičnu silu sustava.

Statički:

$$\sum M_1 = Py - k_l y a_1 \quad \rightarrow \quad P_{cr} = k_l a_1 = \frac{3EI}{a_3^3} a_1$$

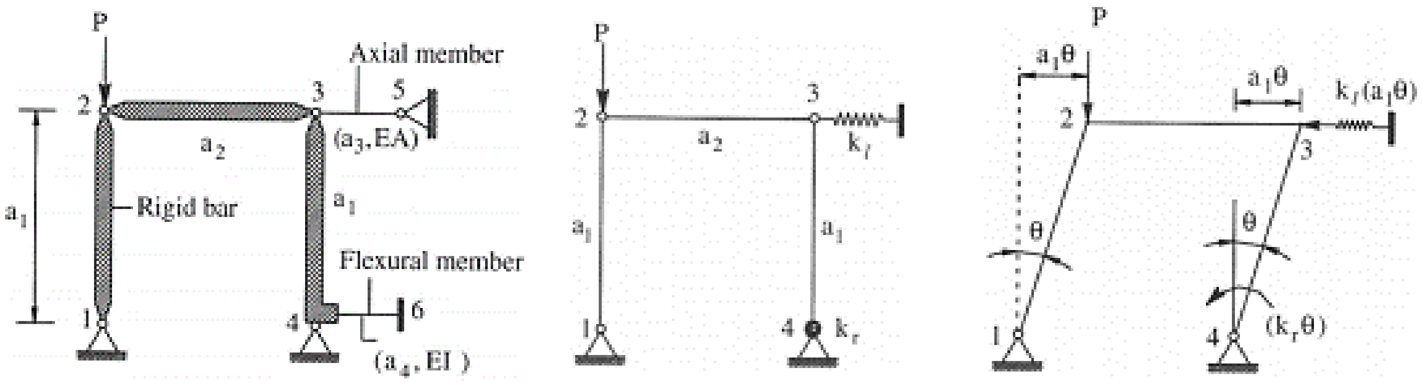
Energetski:

$$V = -P\Delta = -P\frac{1}{2}a_1\theta^2 = -P\frac{1}{2}a_1\frac{y^2}{a_1^2} = -P\frac{y^2}{2a_1}, \qquad U = \frac{1}{2}k_l y^2$$

$$\Pi = \frac{1}{2}k_l y^2 - P\frac{y^2}{2a_1},$$

$$\delta\Pi = \frac{\partial\Pi}{\partial y}\delta y = \left(k_l y - P\frac{y}{a_1}\right)\delta y = 0 \quad \rightarrow \quad P_{cr} = k_l a_1 = \frac{3EI}{a_3^3} a_1$$

Primjer #6.



- *3 kruta štapa: 12, 23, 34*
- *1 uzdužno popustljivi štap 35*
- *kraj 4 štapa 34 kruto je spojen sa savitljivim štapom 46*

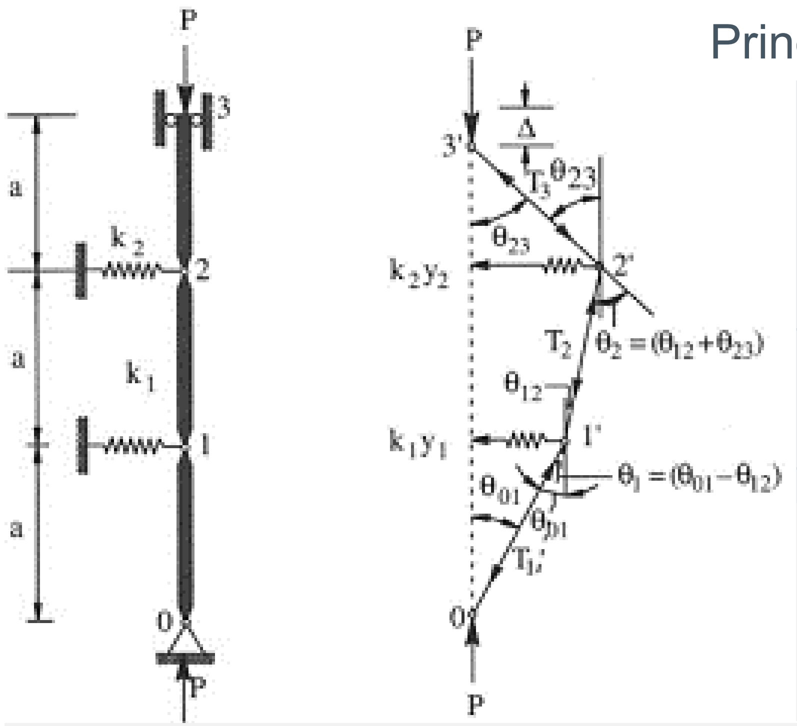
$$\Pi = V + U = -P\frac{1}{2}a_1\theta^2 + \frac{1}{2}k_r\theta^2 + \frac{1}{2}k_l a_1^2\theta^2$$

$$\delta\Pi = \frac{\partial\Pi}{\partial\theta}\delta\theta = (-Pa_1\theta + k_r\theta + k_l\, a_1^2\theta)\delta\theta = 0$$

$$\rightarrow \qquad P_{cr} = k_l a_1 + \frac{k_r}{a_1} = \frac{EA}{a_3}a_1 + \frac{4EI}{a_4}\frac{1}{a_1}$$

Sustav krutih štapova s dva stupnja slobode

- *Dvije generalizirane koordinate*
- *Dva oblika izvijanja s pripadajućim kritičnim silama*



Princip statičke ravnoteže

$$\sum M_3 = 0 = R_0 3a - k_1 y_1 2a - k_2 y_2 a \;\rightarrow\; R_0 = \frac{k_1 y_1 2a + k_2 y_2 a}{3a}$$

$$\sum M_1 = 0 = R_0 a - P y_1 \quad \rightarrow \quad R_0 = \frac{P y_1}{a}$$

$$\sum M_2 = 0 = R_0 2a - k_1 y_1 a - P y_2$$

$$3a\frac{P y_1}{a} - k_1 y_1 2a - k_2 y_2 a = 0$$

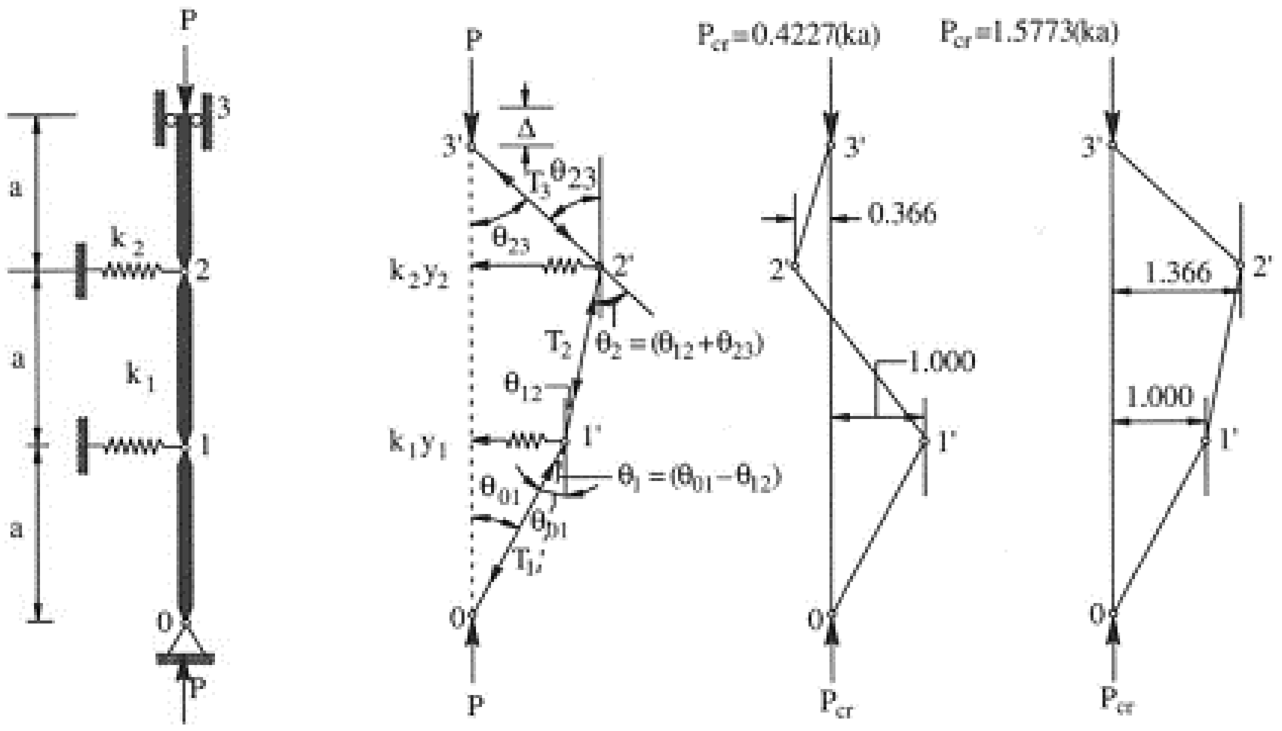
$$2a\frac{P y_1}{a} - k_1 y_1 a - P y_2 = 0$$

$$\begin{bmatrix} 3P - 2ak_1 & -ak_2 \\ 2P - ak_1 & -P \end{bmatrix} \begin{Bmatrix} y_1 \\ y_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

$$det[\quad] = 0 = (3P - 2ak_1)(-P) - (-ak_2)(2P - ak_1) = -3P^2 + 2ak_1 P + 2ak_2 P - a^2 k_1 k_2$$

$$3P^2 - 2a(k_1 + k_2)P + k_1 k_2 a^2 = 0$$

Sustav krutih štapova s dva stupnja slobode



- *Pretpostavimo npr. da su $k_1 = k$ i $k_2 = 2k$*

$$3P^2 - 2a(k_1 + k_2)P + k_1k_2a^2 = 0$$
$$3P^2 - 6akP + 2k^2a^2 = 0$$

$$P_{cr\,1,2} = \frac{6ak \pm \sqrt{36a^2k^2 - 24a^2k^2}}{6}$$
$$P_{cr,1} = \frac{6ak - 3{,}464ak}{6} = 0{,}423ka$$
$$P_{cr,2} = \frac{6ak + 3{,}464ak}{6} = 1{,}577ka$$

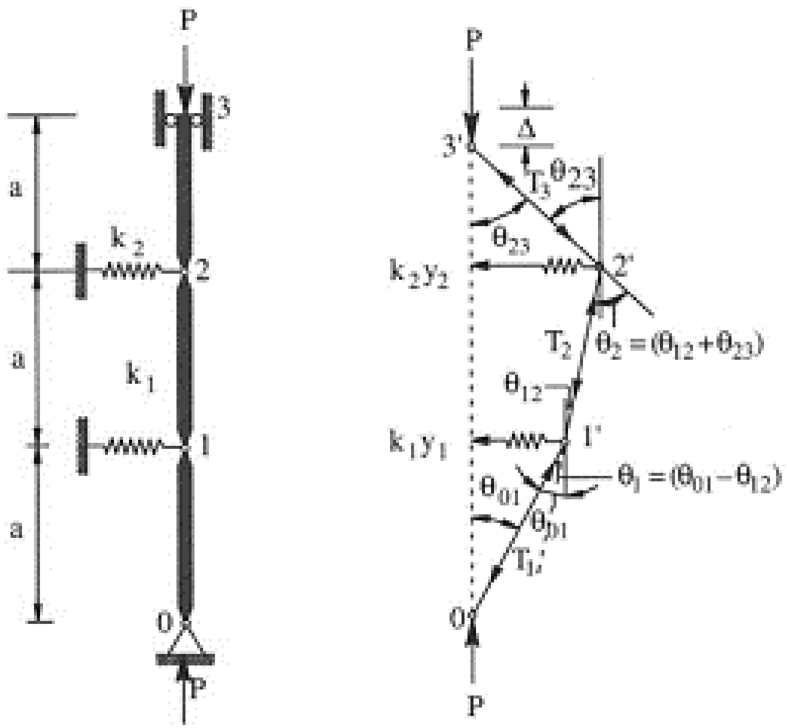
Proračun oblika izvijanja:

$$(2P - ak)y_1 - Py_2 = 0$$
$$\frac{y_2}{y_1} = \frac{2P - ak}{P} = 2 - \frac{ak}{P}$$

I. oblik izvijanja (P_{cr1}): $\frac{y_2}{y_1} = 2 - \frac{ak}{0{,}423ak} = -0{,}364, \quad za\ y_1 = 1{,}000 \rightarrow y_2 = -0{,}364$

II. oblik izvijanja (P_{cr2}): $\frac{y_2}{y_1} = 2 - \frac{ak}{1{,}577ak} = 1{,}366, \quad za\ y_1 = 1{,}000 \rightarrow y_2 = 1{,}366$

Sustav krutih štapova s dva stupnja slobode



Energetski pristup

$$\Delta = \Delta_1 + \Delta_2 + \Delta_3 = \frac{a}{2}\theta_{01}^2 + \frac{a}{2}\theta_{12}^2 + \frac{a}{2}\theta_{23}^2$$

$$\Delta = \frac{a}{2}\frac{y_1^2}{a^2} + \frac{a}{2}\frac{(y_2 - y_1)^2}{a^2} + \frac{a}{2}\frac{y_2^2}{a^2} = \frac{1}{2a}\left[y_1^2 + (y_2 - y_1)^2 + y_2^2\right]$$

$$V = -P\Delta = -\frac{P}{2a}\left[y_1^2 + (y_2 - y_1)^2 + y_2^2\right]$$

$$U = \frac{1}{2}(k_1 y_1^2 + k_2 y_2^2)$$

$$\Pi = V + U = -\frac{P}{2a}\left[y_1^2 + (y_2 - y_1)^2 + y_2^2\right] + \frac{1}{2}(k_1 y_1^2 + k_2 y_2^2)$$

Stacionarna potencijalna energija

$$\delta\Pi = \frac{\partial\Pi}{\partial y_1}\delta y_1 = \left\{-\frac{P}{2a}\left[2y_1 - 2(y_2 - y_1)\right] + k_1 y_1\right\}\delta y_1 = 0$$

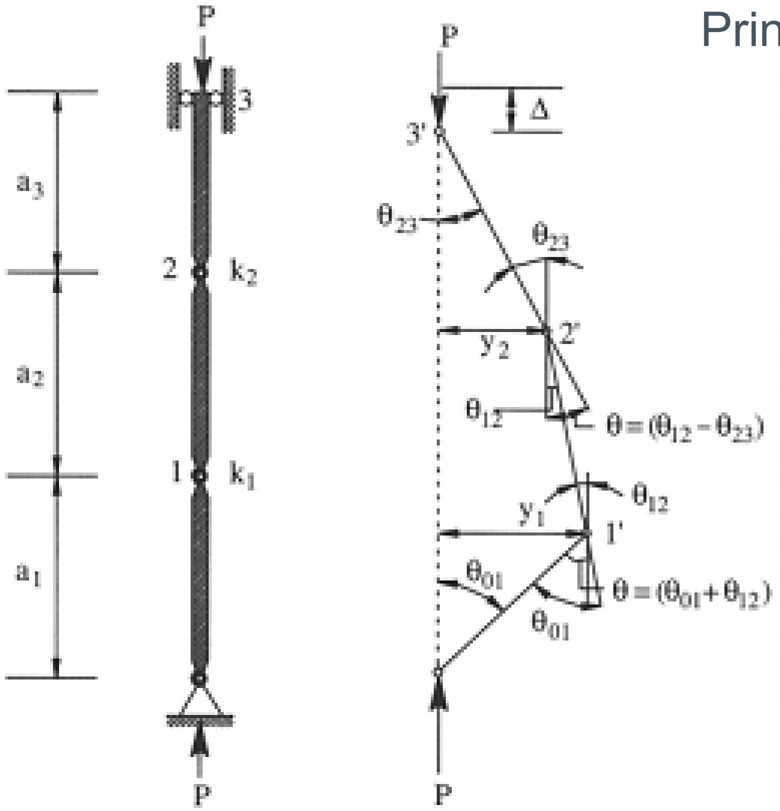
$$\delta\Pi = \frac{\partial\Pi}{\partial y_2}\delta y_2 = \left\{-\frac{P}{2a}\left[2(y_2 - y_1) + 2y_2\right] + k_2 y_2\right\}\delta y_2 = 0$$

$$(2P - ak_1)y_1 - Py_2 = 0$$
$$-Py_1 + (2P - ak_2)y_2 = 0$$

$$4P^2 - 2ak_2P - 2ak_1P + a^2k_1k_2 - P^2 = 0$$
$$3P^2 - 2a(k_1 + k_2)P + k_1k_2a^2 = 0$$

Sustav krutih štapova s dva stupnja slobode

- *Dvije generalizirane koordinate*
- *Dva oblika izvijanja s pripadajućim kritičnim silama*



Princip statičke ravnoteže

$$\sum M_1 = 0 = -Py_1 + k_1\theta_1 \;\rightarrow\; Py_1 = k_1(\theta_{01}+\theta_{12}) = k_1\left(\frac{y_1}{a_1}+\frac{y_1-y_2}{a_2}\right)$$

$$\left(P-\frac{k_1}{a_1}-\frac{k_1}{a_2}\right)y_1 + \left(\frac{k_1}{a_2}\right)y_2 = 0 \qquad (1)$$

$$\sum M_2 = 0 = -Py_2 + k_2\theta_2 \;\rightarrow\; Py_2 = k_2(\theta_{23}-\theta_{12}) = k_2\left(\frac{y_2}{a_3}-\frac{y_1-y_2}{a_2}\right)$$

$$\left(\frac{k_2}{a_2}\right)y_1 + \left(P-\frac{k_2}{a_3}-\frac{k_2}{a_2}\right)y_2 = 0 \qquad (2)$$

$$\begin{bmatrix} \left(P-\frac{k_1}{a_1}-\frac{k_1}{a_2}\right) & \left(\frac{k_1}{a_2}\right) \\ \left(\frac{k_2}{a_2}\right) & \left(P-\frac{k_2}{a_3}-\frac{k_2}{a_2}\right) \end{bmatrix} \begin{Bmatrix} y_1 \\ y_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

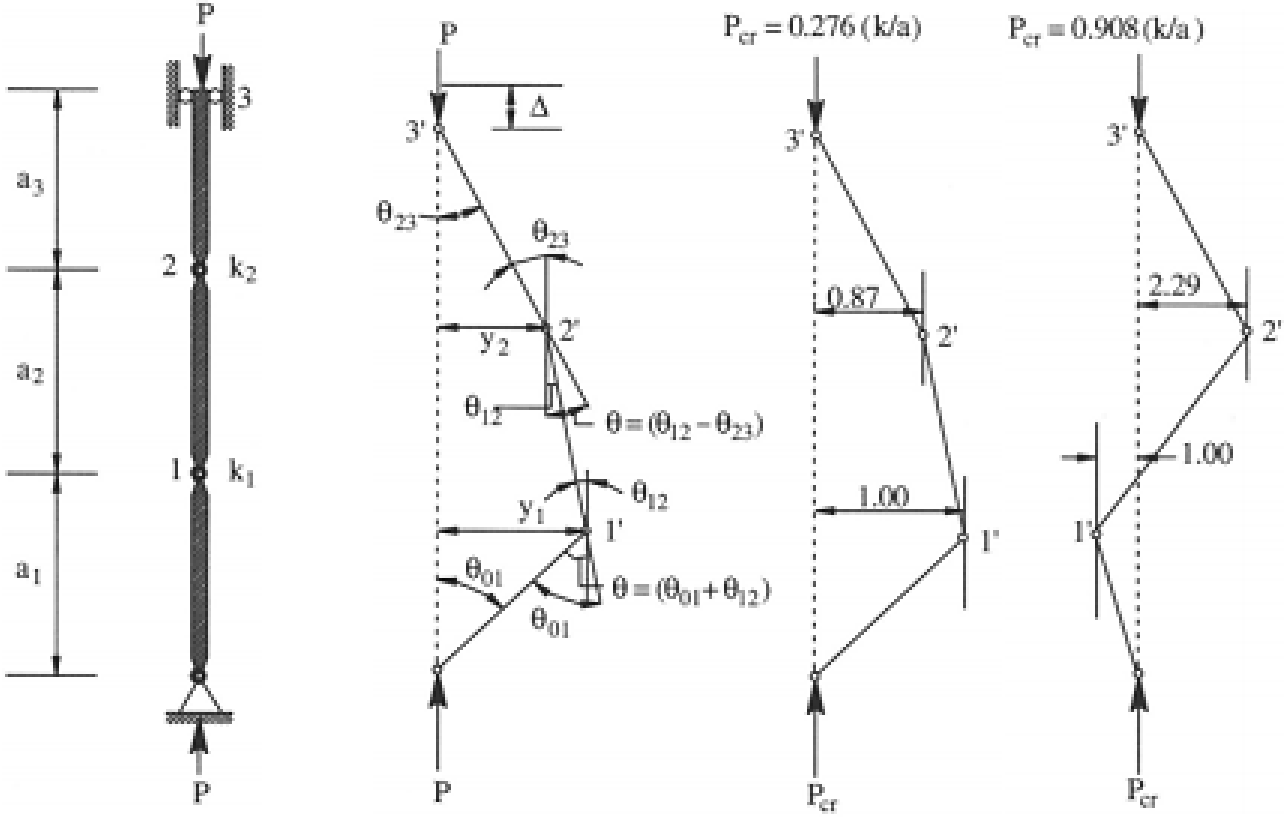
$$det[\quad] = 0 = \left(P-\frac{k_1}{a_1}-\frac{k_1}{a_2}\right)\left(P-\frac{k_2}{a_3}-\frac{k_2}{a_2}\right) - \frac{k_1}{a_2}\frac{k_2}{a_2} = 0$$

$$P^2 - \frac{k_2}{a_2}P - \frac{k_2}{a_3}P - \frac{k_1}{a_1}P + \frac{k_1}{a_1}\frac{k_2}{a_2} + \frac{k_1}{a_1}\frac{k_2}{a_3} - \frac{k_1}{a_2}P + \frac{k_1}{a_2}\frac{k_2}{a_2} + \frac{k_1}{a_2}\frac{k_2}{a_3} - \frac{k_1}{a_2}\frac{k_2}{a_2} =$$

$$= P^2 - \left(\frac{k_1}{a_1}+\frac{k_1}{a_2}+\frac{k_2}{a_2}+\frac{k_2}{a_3}\right)P + \frac{k_1}{a_1}\frac{k_2}{a_2} + \frac{k_1}{a_1}\frac{k_2}{a_3} + \frac{k_1}{a_2}\frac{k_2}{a_3} = 0$$

Sustav krutih štapova s dva stupnja slobode

- *Pretpostavimo npr. da su $a_1=4a$, $a_2=5a$, $a_3=6a$ i $k_1 = k$ i $k_2 = 2k$*



$$P^2 - \left(\frac{k}{4a} + \frac{k}{5a} + \frac{2k}{5a} + \frac{2k}{6a}\right)P + \frac{2k^2}{20a^2} + \frac{2k^2}{24a^2} + \frac{2k^2}{30a^2} = 0 \rightarrow P^2 - \frac{71k}{60a}P + \frac{15k^2}{60a^2} = 0$$

$$P_{cr\ 1,2} = \frac{1{,}183\frac{k}{a} \pm \sqrt{1{,}400\frac{k^2}{a^2} - 4 \cdot 0{,}250\frac{k^2}{a^2}}}{6}$$

$$P_{cr,1} = \frac{1}{2}(1{,}183 - 0{,}633)\frac{k}{a} = 0{,}275\frac{k}{a}$$

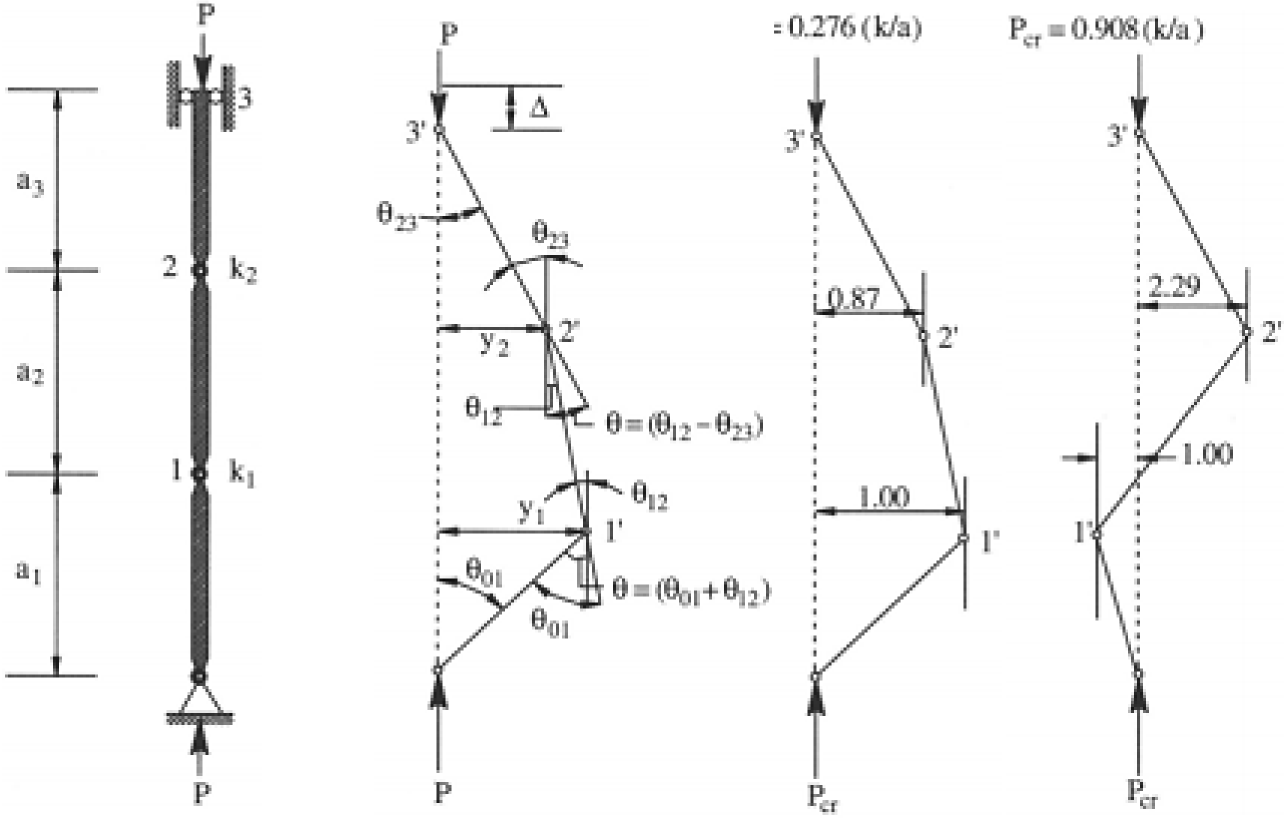
$$P_{cr,2} = \frac{1}{2}(1{,}183 + 0{,}633)\frac{k}{a} = 0{,}908\frac{k}{a}$$

- *Uvrštavanjem rješenja u npr. jednadžbu (1), dobijemo sljedeće relativne odnose, tj. :*

I. oblik izvijanja (P_{cr1}): $\frac{y_2}{y_1} = 0{,}875 \quad za\ y_1 = 1{,}000 \rightarrow y_2 = 0{,}875$

II. oblik izvijanja (P_{cr2}): $\frac{y_2}{y_1} = -2{,}290 \quad za\ y_1 = 1{,}000 \rightarrow y_2 = -2{,}290$

Sustav krutih štapova s dva stupnja slobode



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Domaći rad

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M.L.Gambhir: Stability Analysis and Design of Structures

- *Problem 3.1*
- *Problem 3.2*
- *Problem 3.3*
- *Problem 3.4*
- *Problem 3.5*
- *Problem 3.6*
- *Problem 3.7*
- *Problem 3.8*
- *Problem 3.9*
- *Problem 3.10*