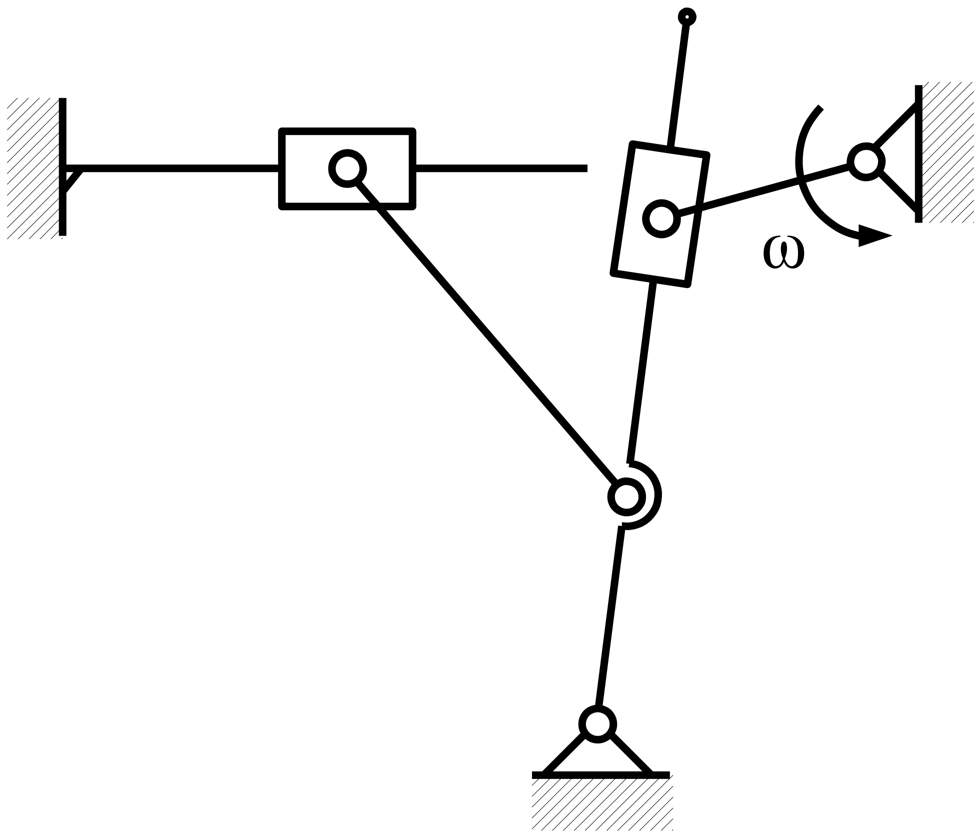
TMiPA - zima 2016/2017

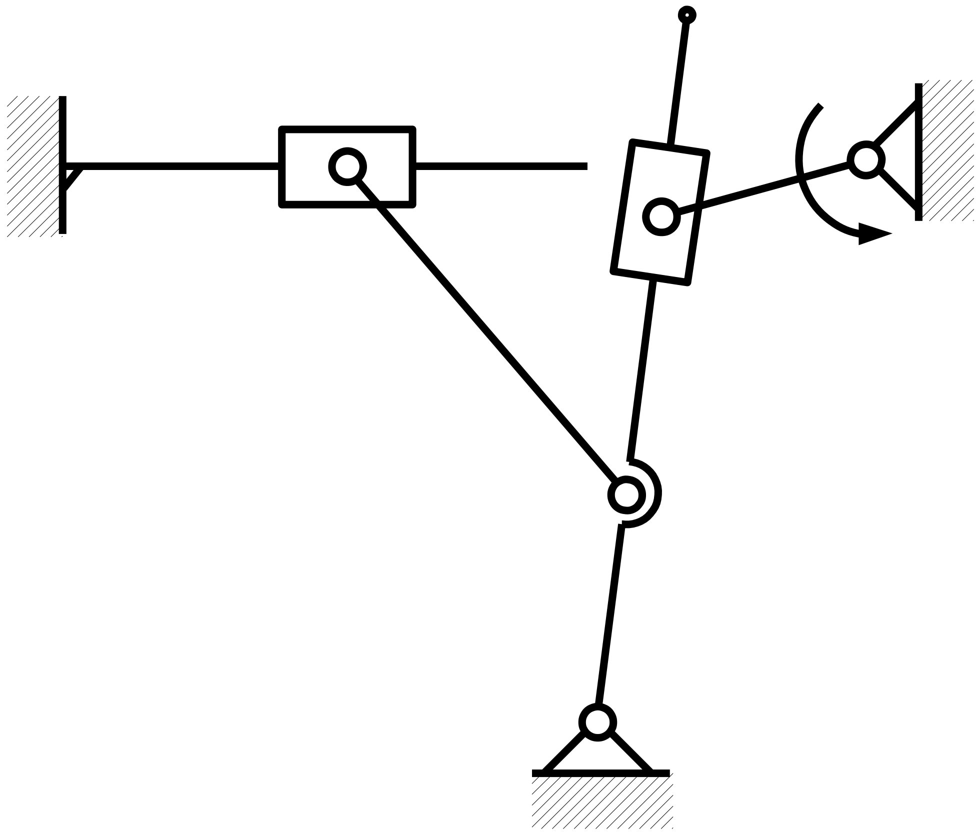
Przykład wyznaczania prędkości i przyspieszeń mechanizmu płaskiego metodą wykreślną

Dane: geometria mechanizmu (wymiary elementów, ich położenie i orientacja) oraz stała prędkość kątowa ω elementu napędowego

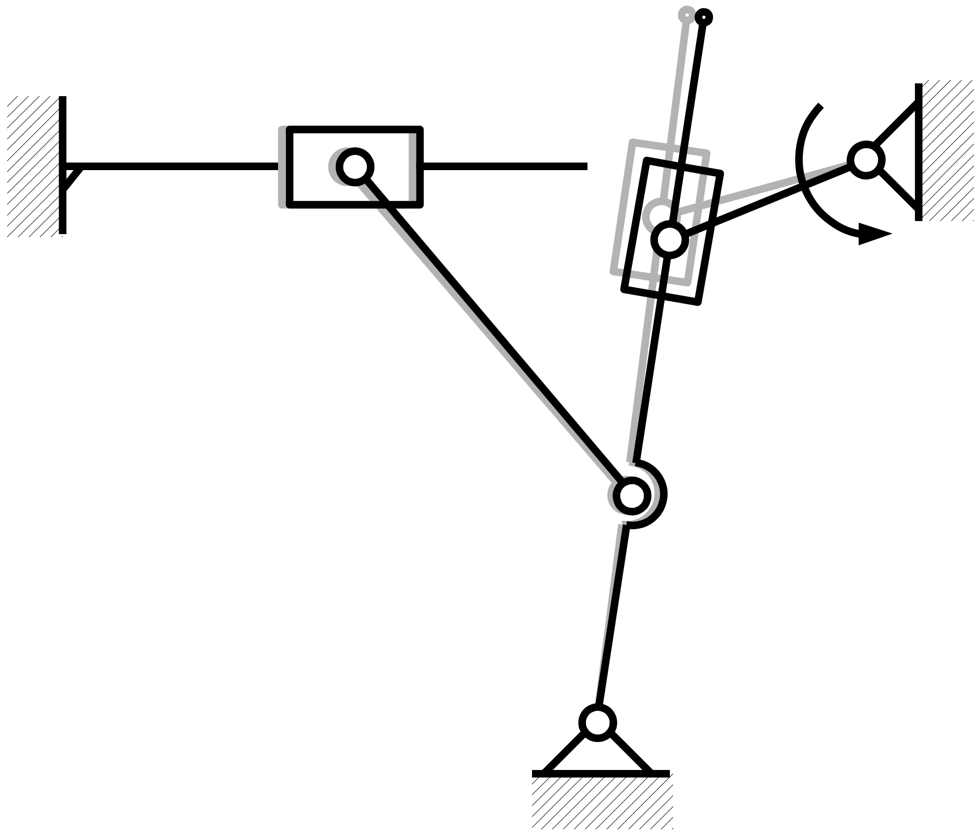


Wydział Samochodów i Maszyn Roboczych, Politechnika Warszawska,
Instytut Podstaw Budowy Maszyn, Zakład Mechaniki, mgr inż. Sebastian Korczak

Jak pracuje ten mechanizm?

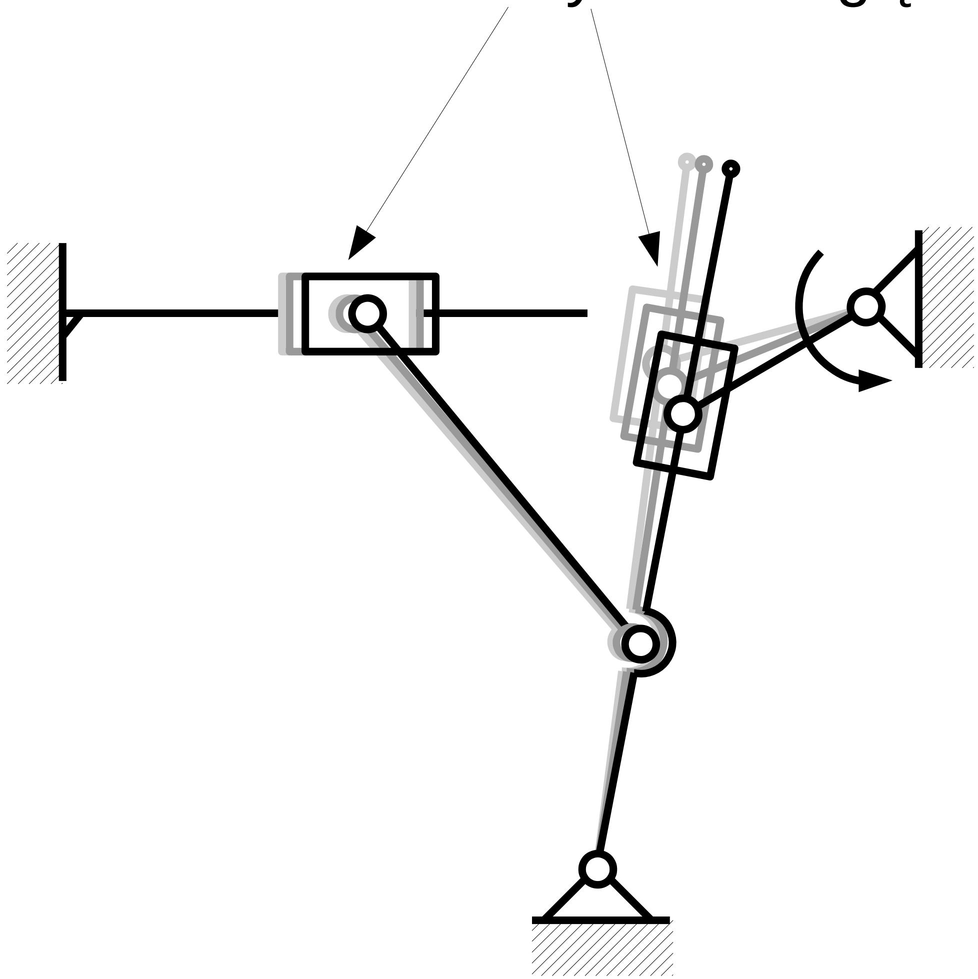


Jak pracuje ten mechanizm?

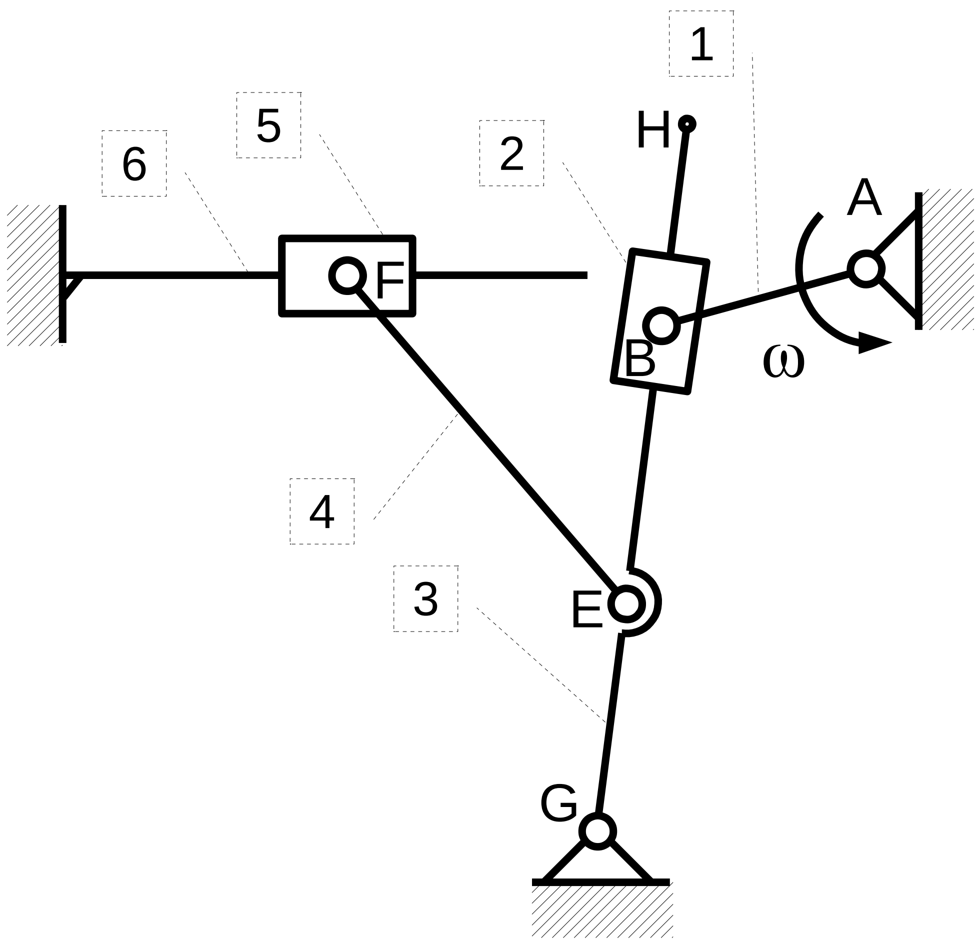


Jak pracuje ten mechanizm?

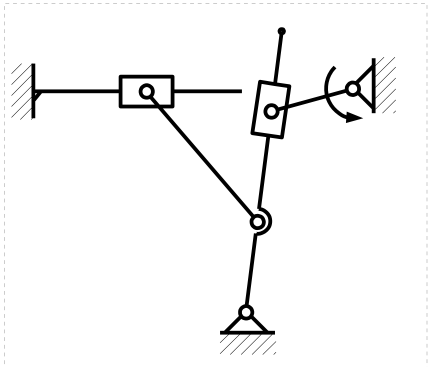
zauważamy ruch względny

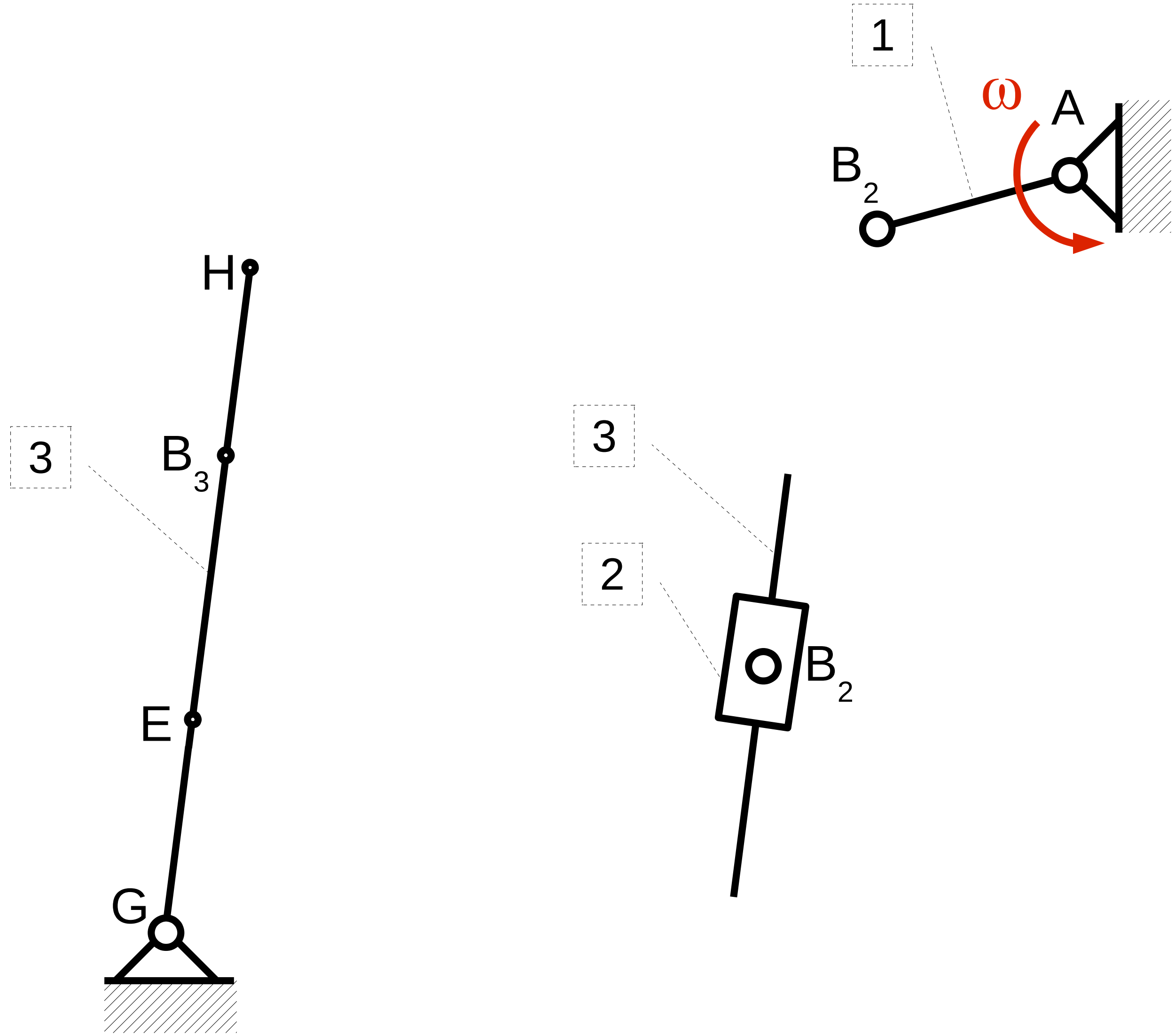


Wracamy do rozważanego położenia mechanizmu, numerujemy człony i nazywamy punkty

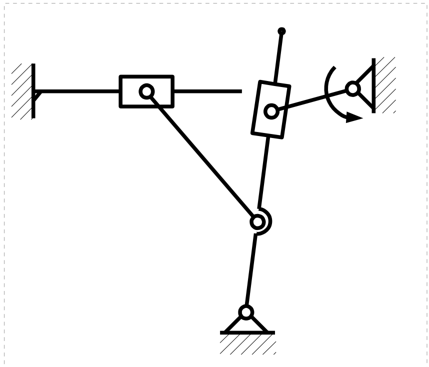


Ze względu na ruch względny suwaka 2 po pręcie 3 wprowadzamy oznaczenia punktów B_2 i B_3

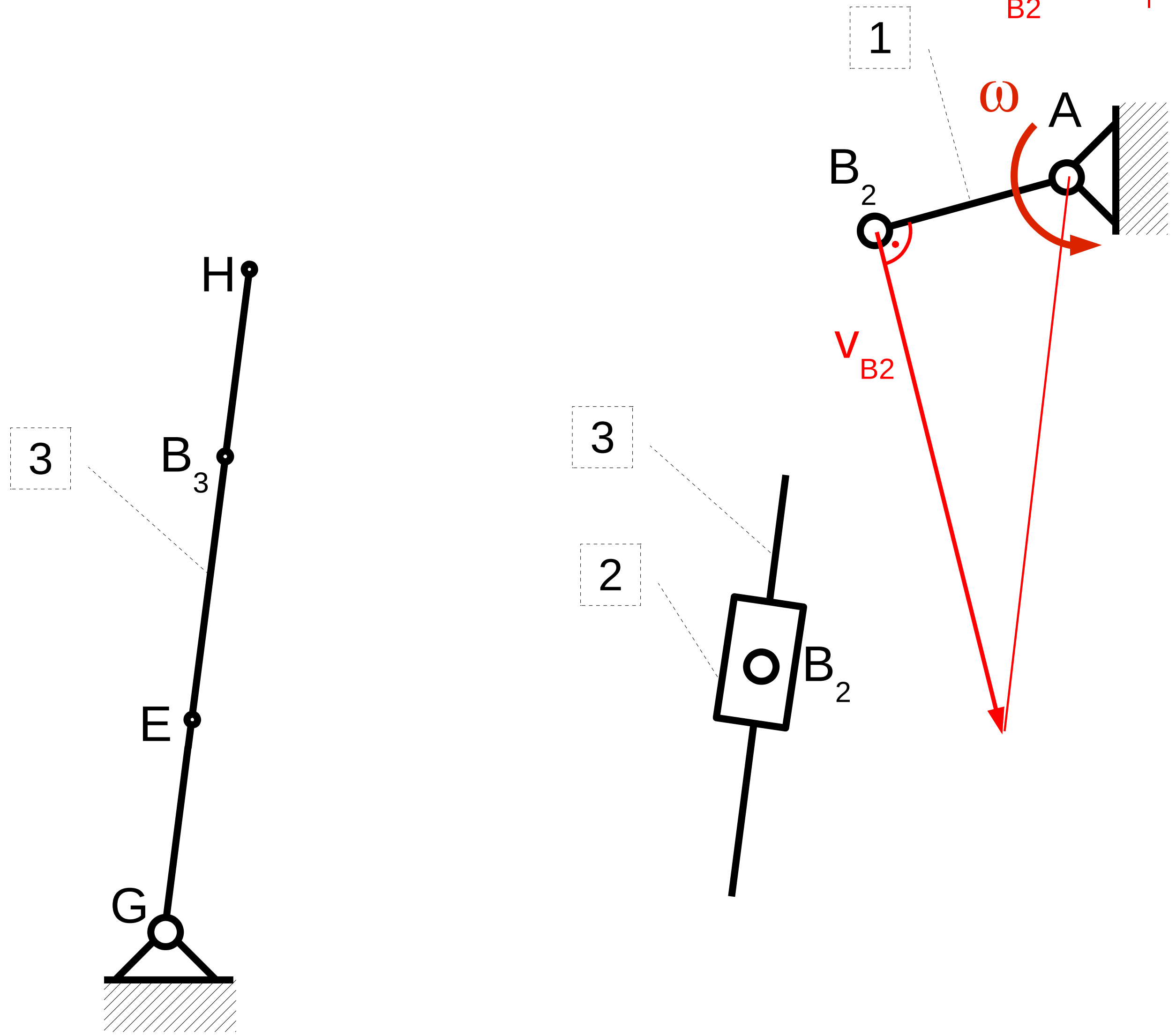




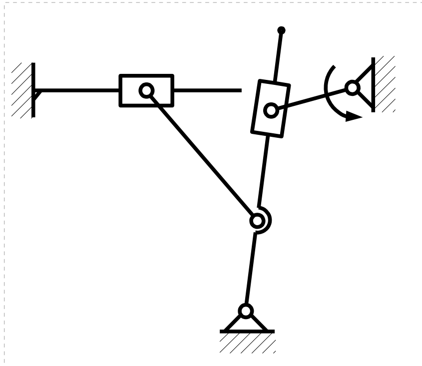
Wyznaczamy prędkość końca członu 1



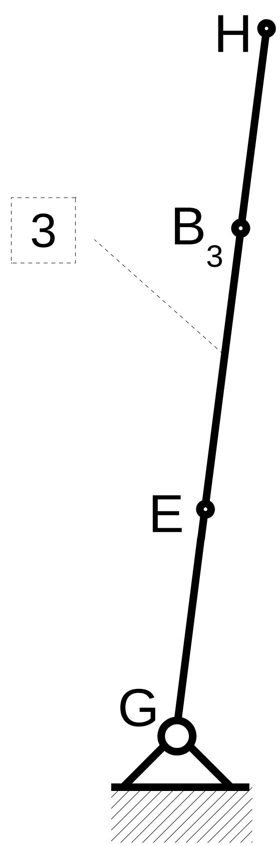
$$v_{B2} = \omega\,|B_2A|$$

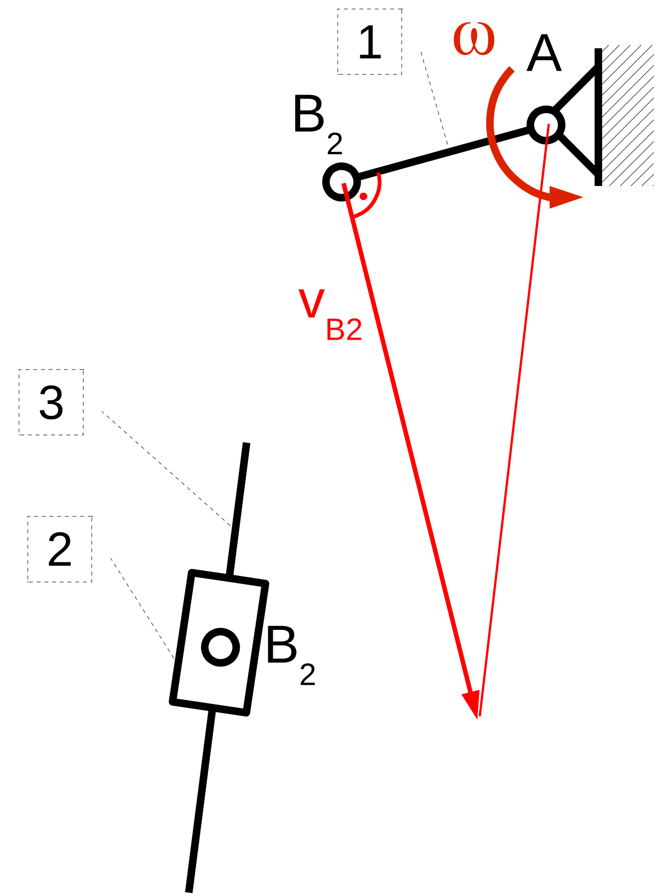


Przyjmujemy, że ruchem złożonym porusza się suwak 2, ruchem unoszenia jest zatem ruch pręta 3, a ruchem względnym - ruch suwaka wzdłuż pręta

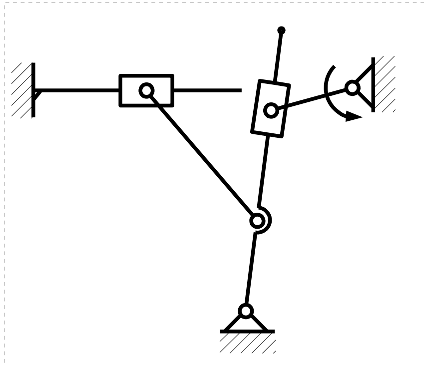


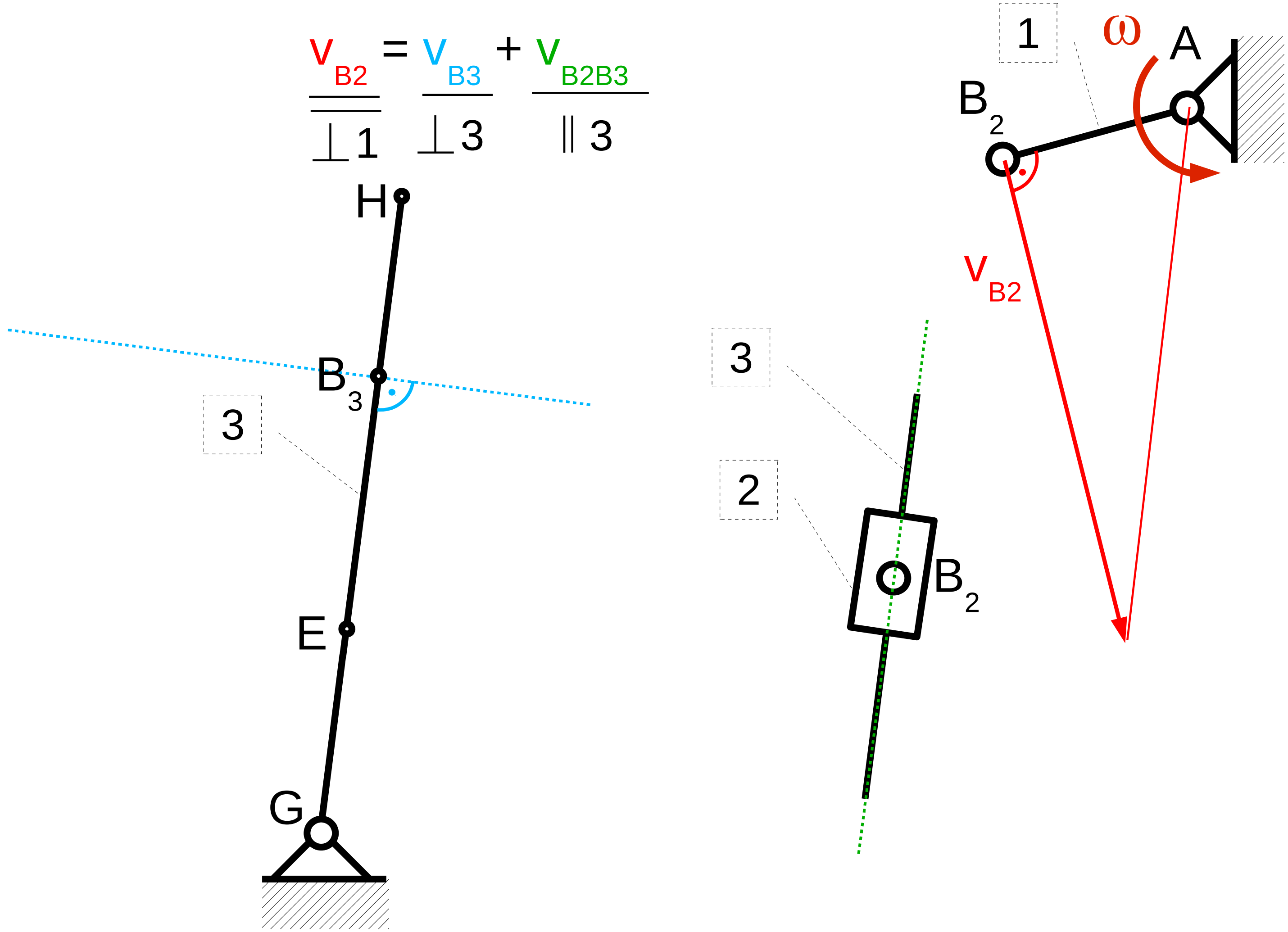
$$v_{B2} = v_{B3} + v_{B2B3}$$





Określamy kierunki prędkości w równaniu ruchu względnego





Plan prędkości

$$\underline{\underline{v_{B2}}} = \underset{\perp 3}{\underline{v_{B3}}} + \underset{\parallel 3}{\underline{v_{B2B3}}}$$

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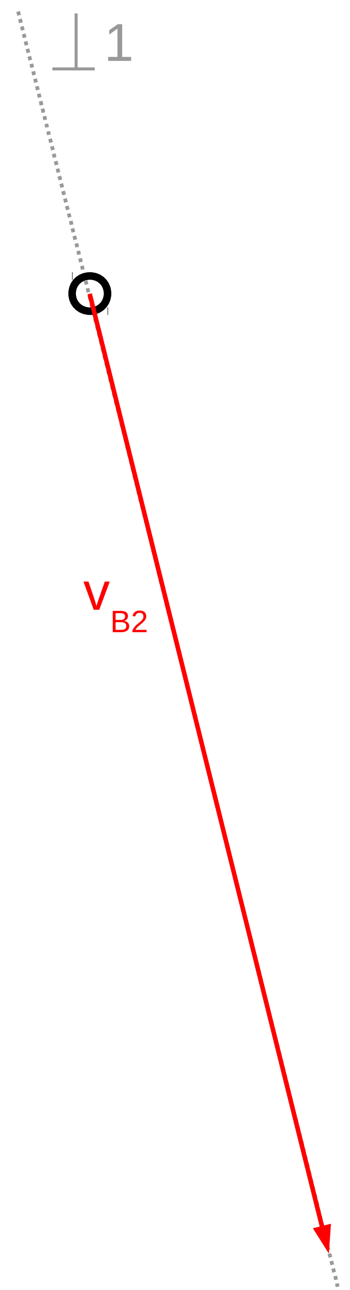

Plan prędkości

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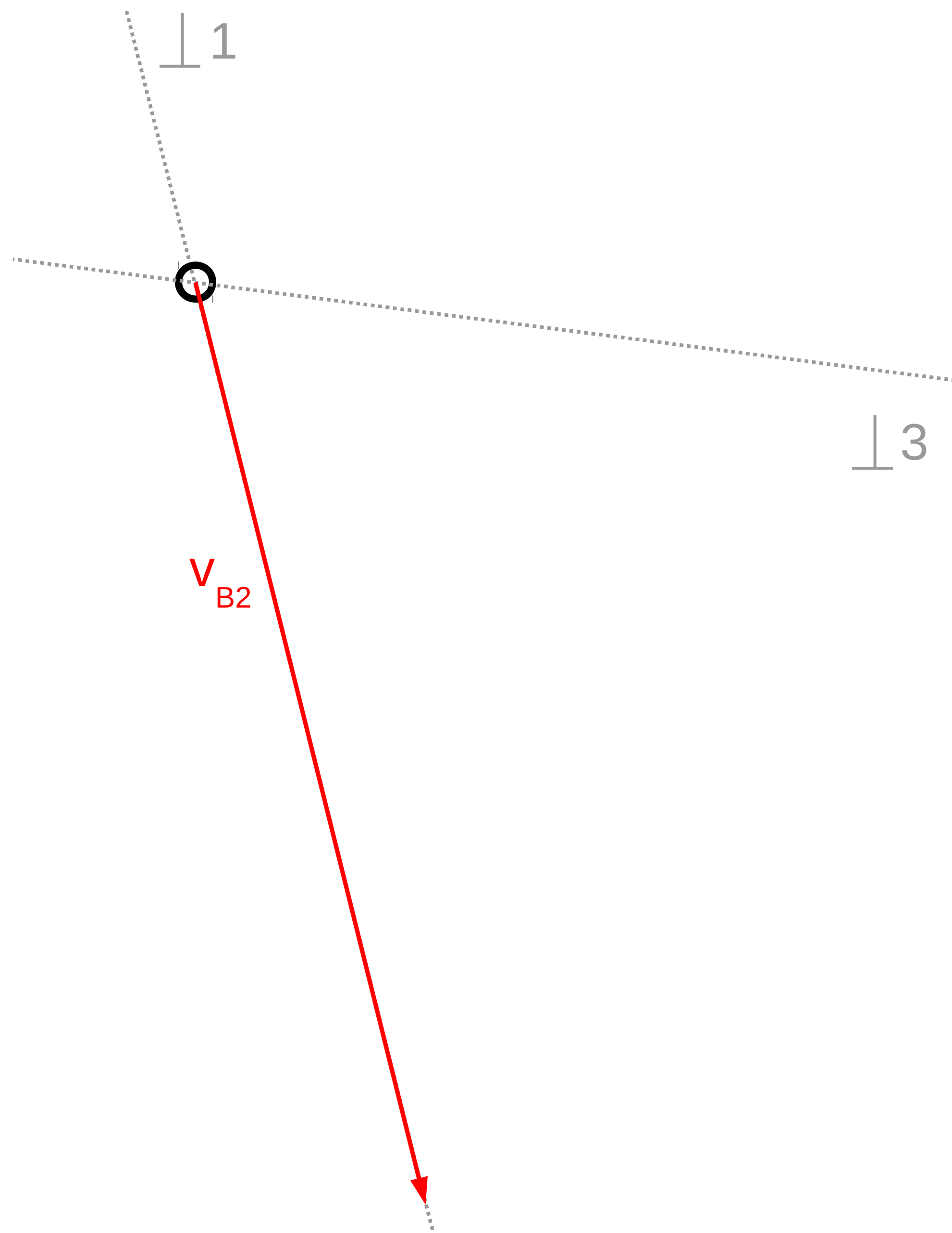

Plan prędkości

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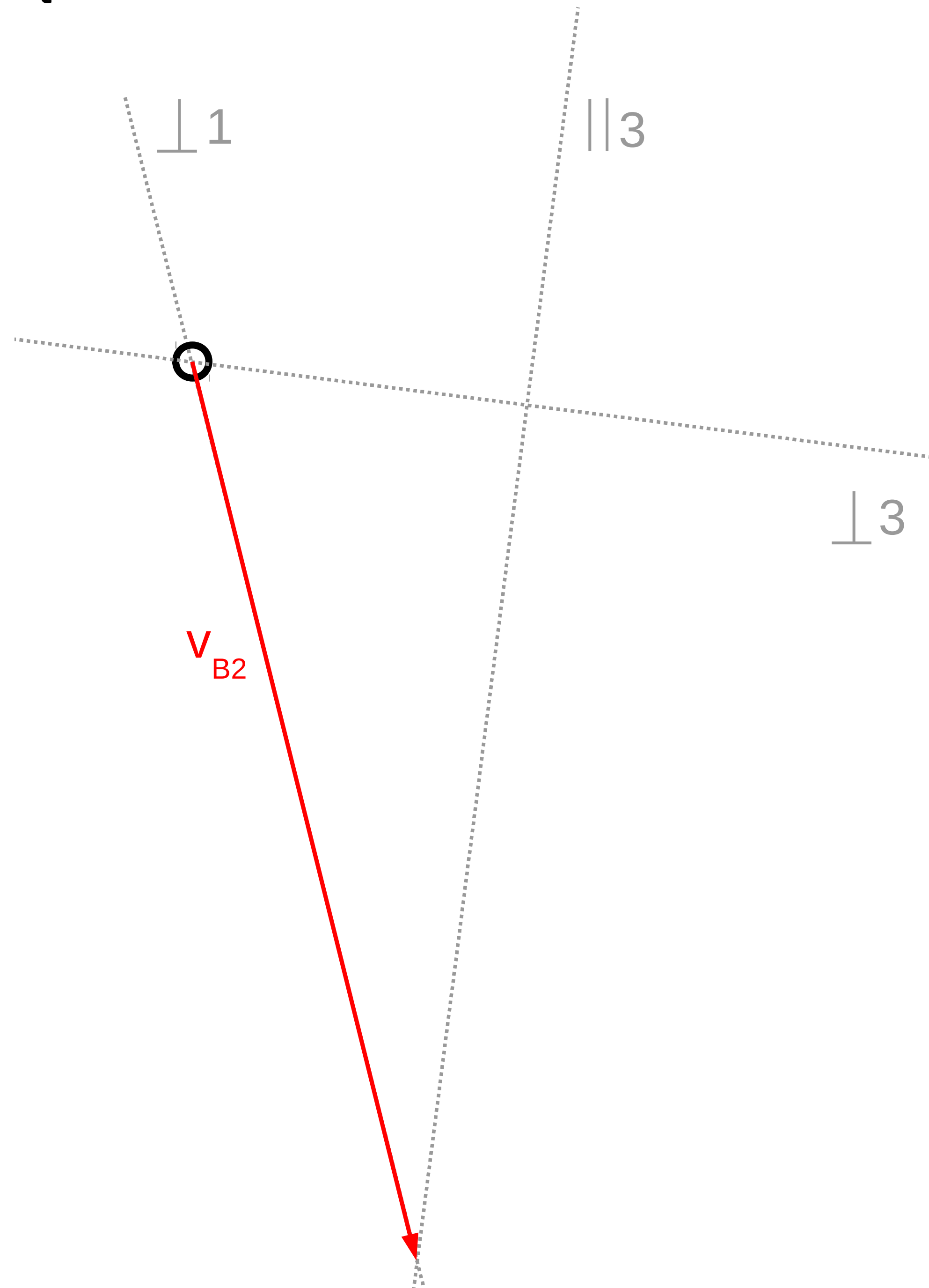

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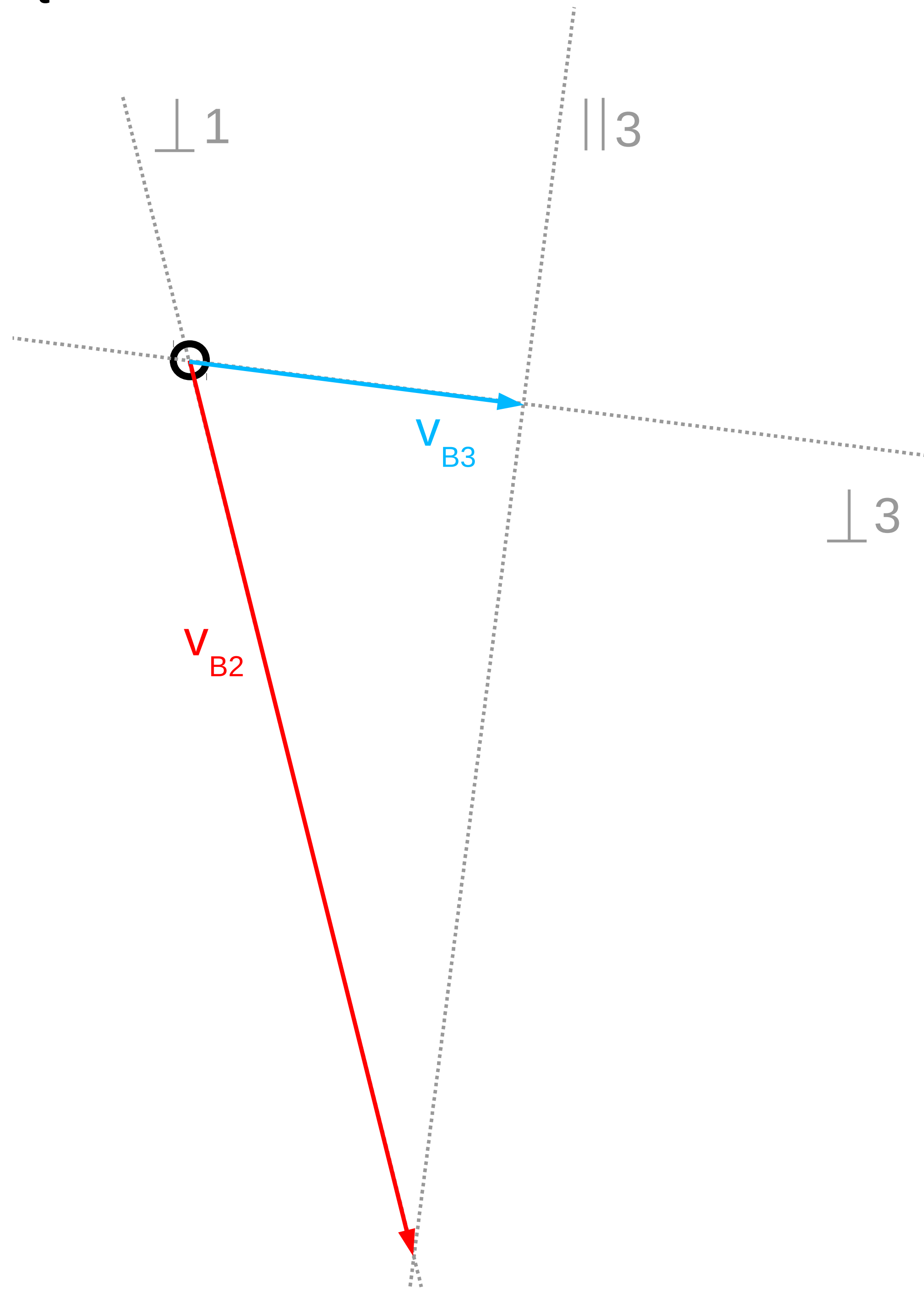
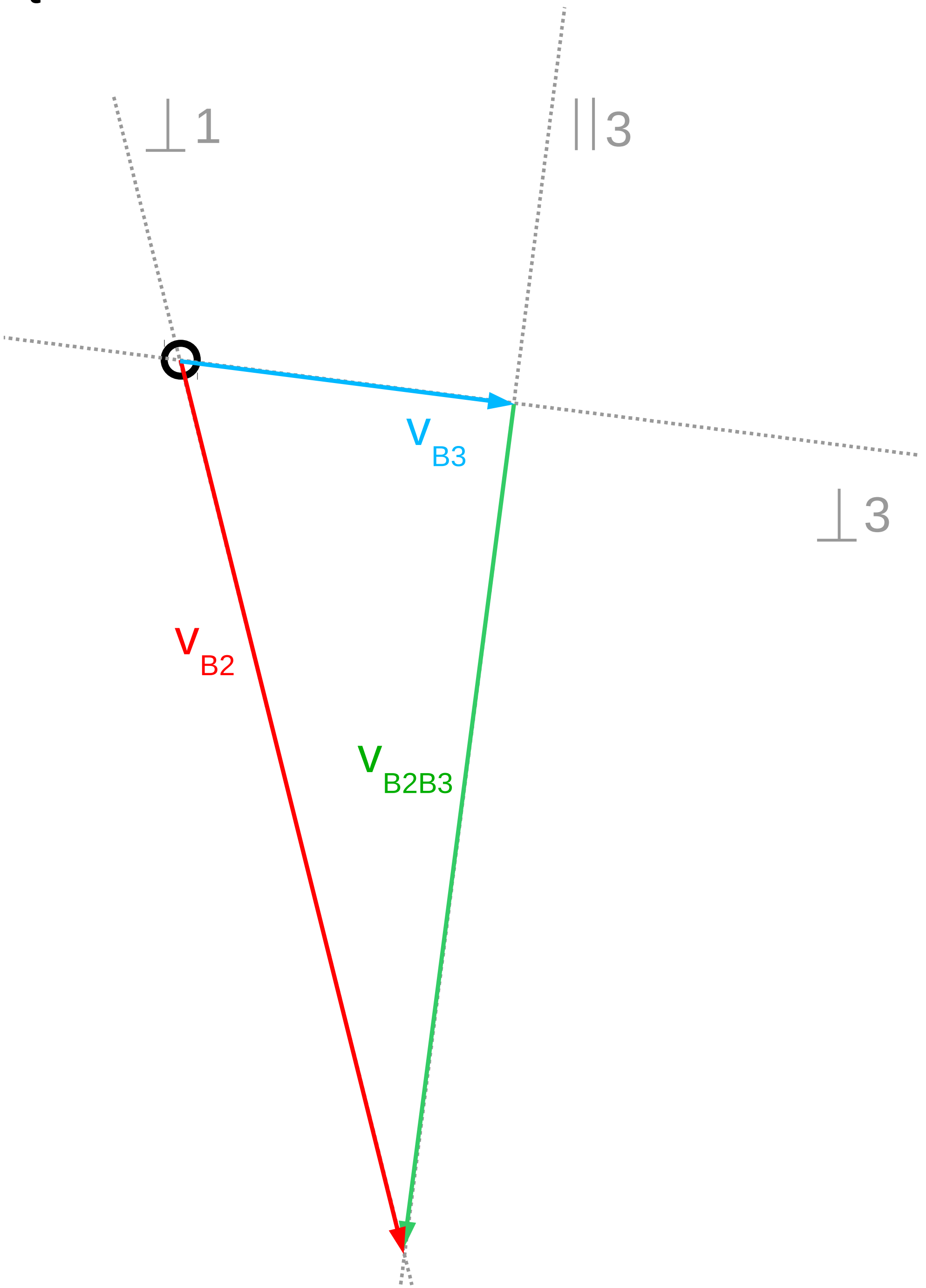
$$\underline{\underline{v_{B2}}} = \underset{\perp 3}{\underline{v_{B3}}} + \underset{\parallel 3}{\underline{v_{B2B3}}}$$

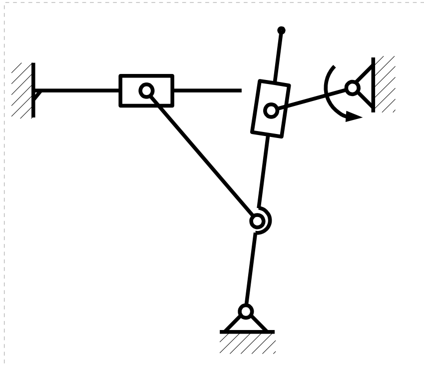


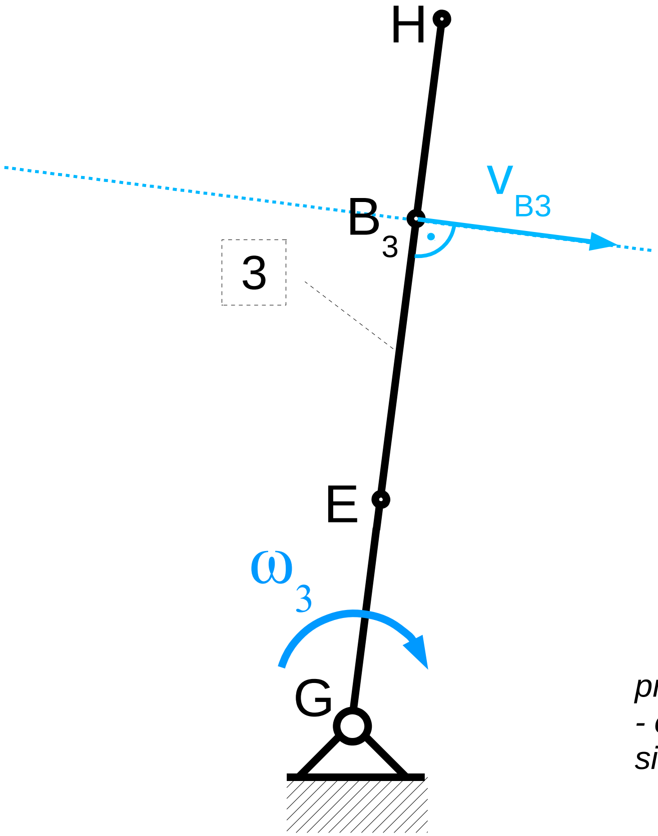
Plan prędkości

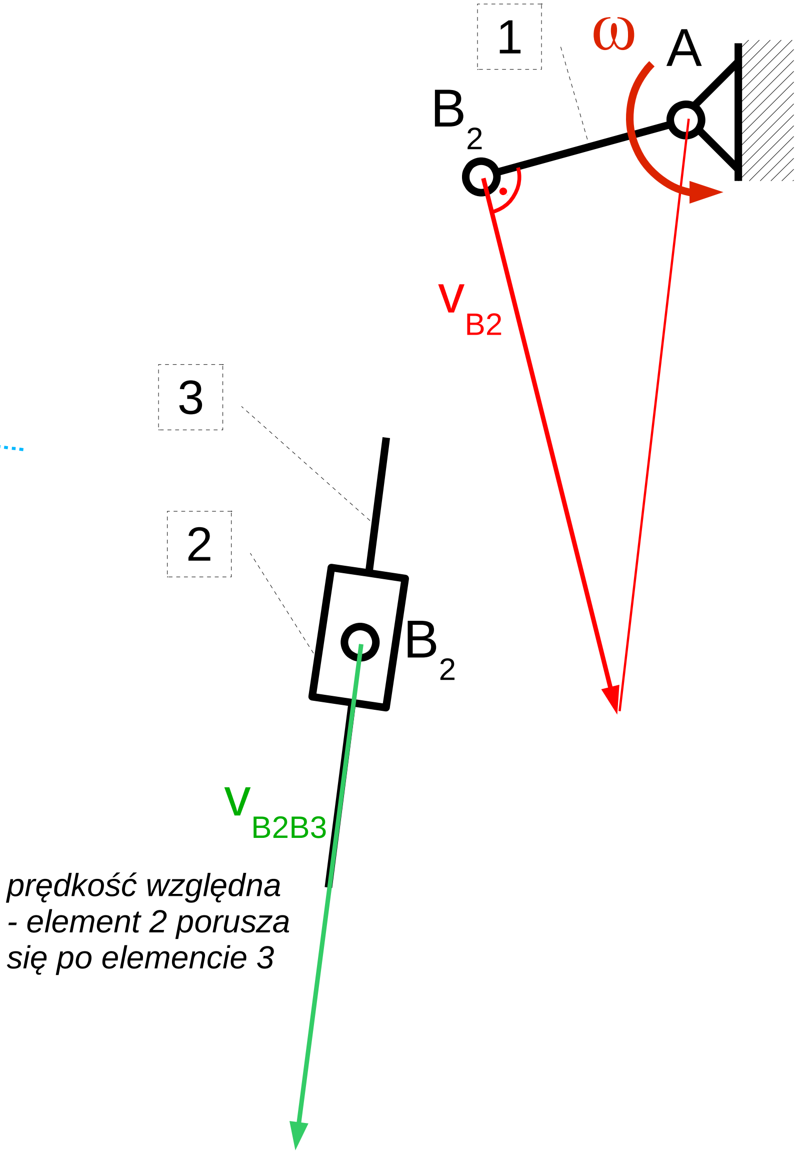
$$\underline{\underline{v_{B2}}} = \underset{\perp 3}{\underline{v_{B3}}} + \underset{\parallel 3}{\underline{v_{B2B3}}}$$



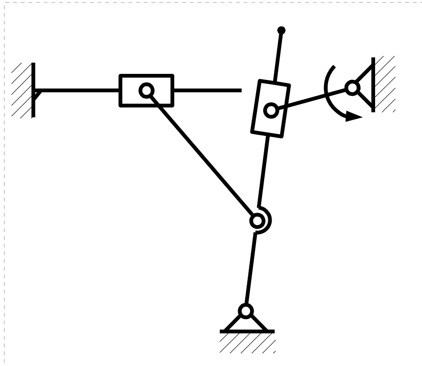
Wyznaczona prędkość punktu B_3 i prędkość względną



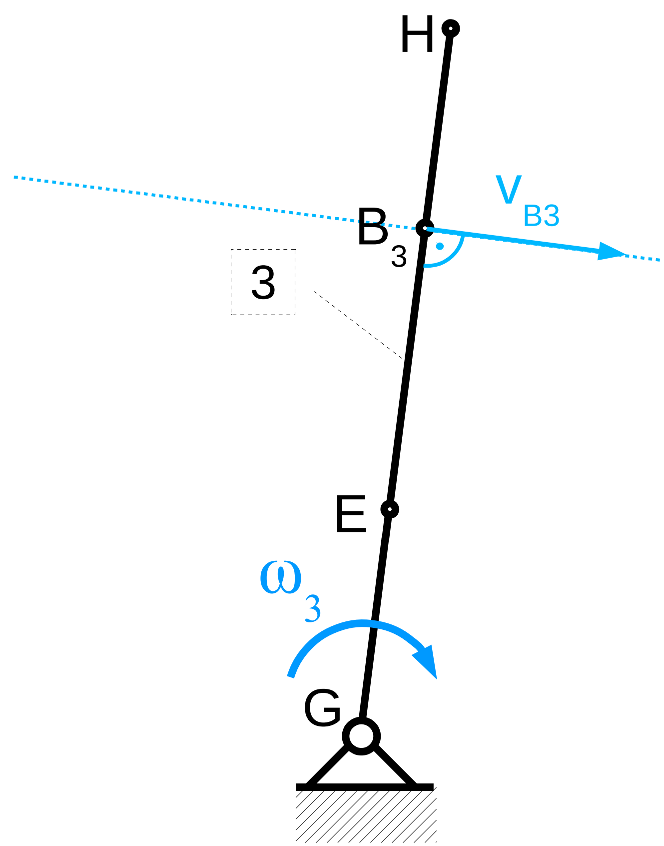


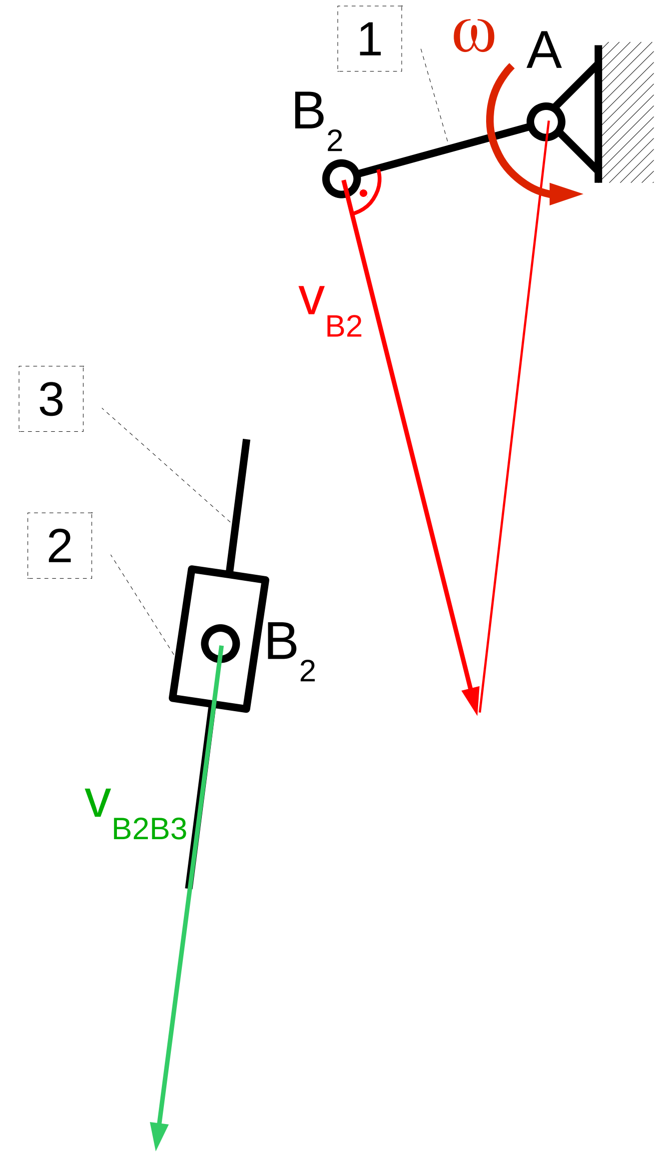


Z wyznaczonej prędkości punktu B_3 określamy prędkość kątową członu 3

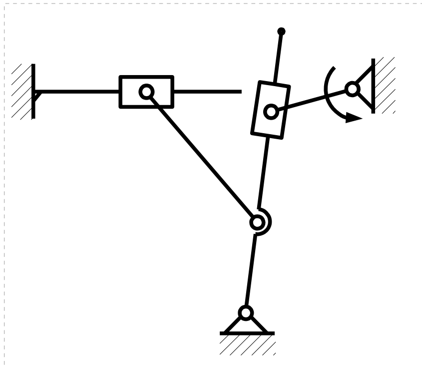


$$\omega_3 = \frac{v_{B3}}{|B_3G|}$$

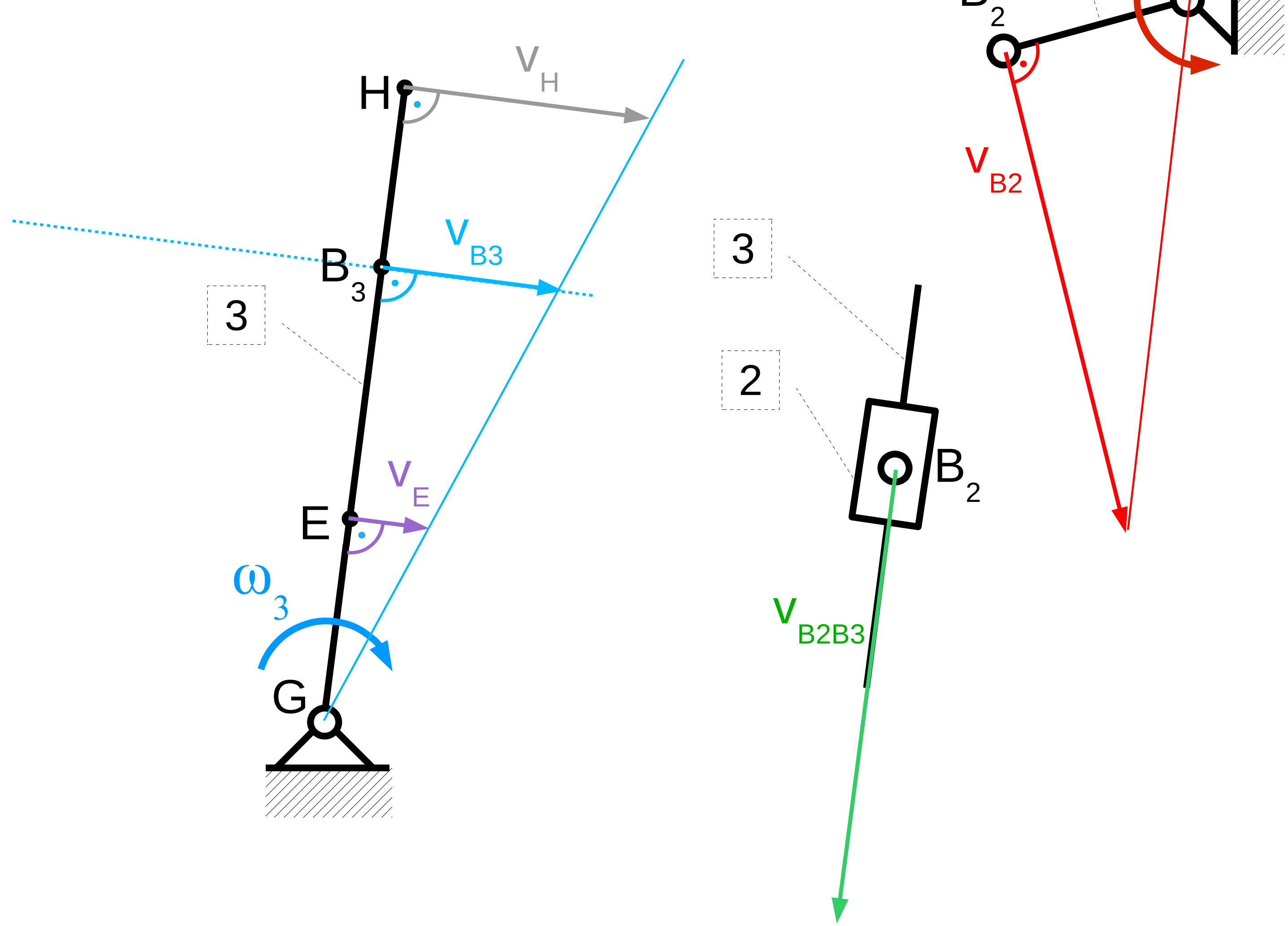




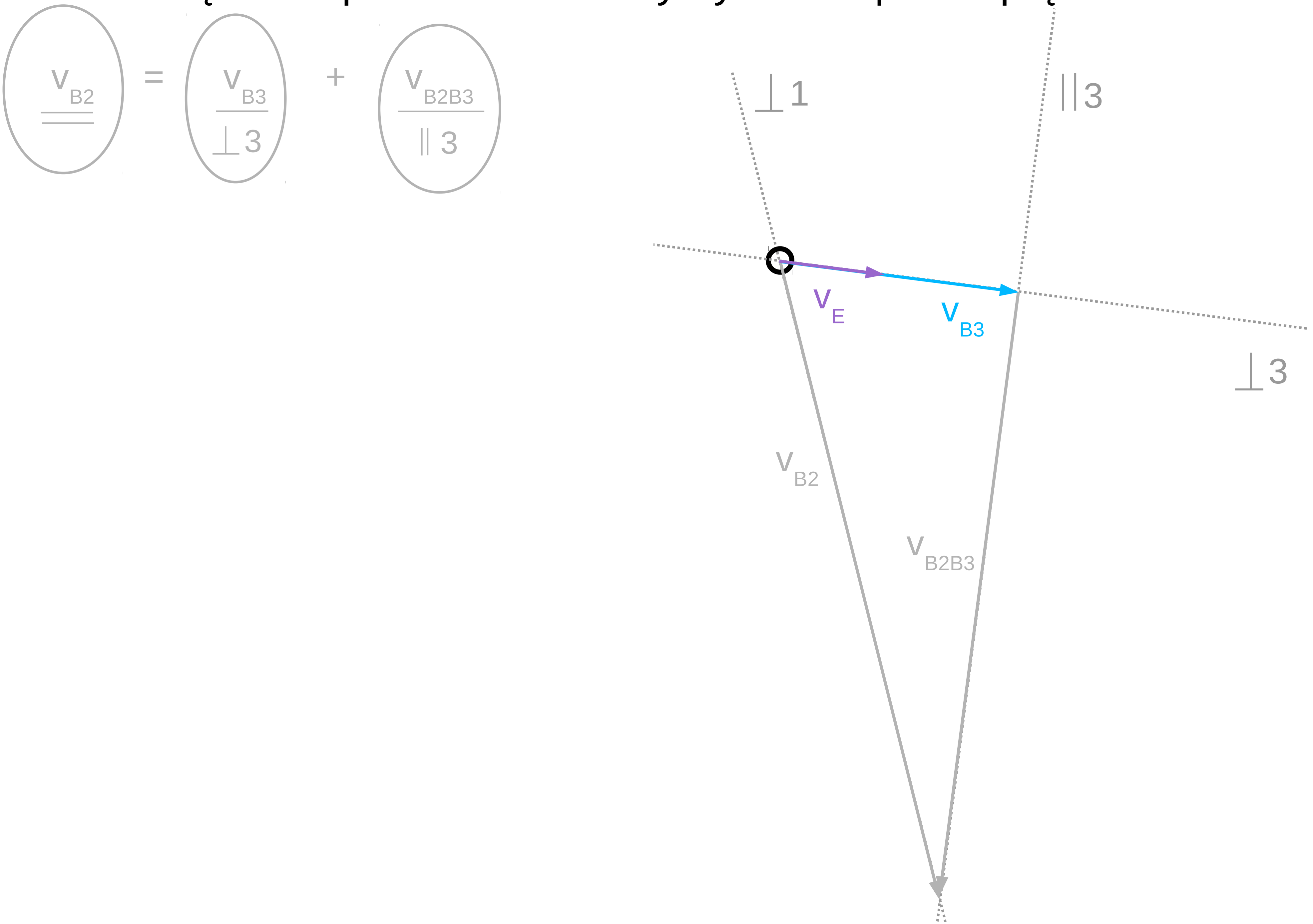
Dzięki wyznaczeniu prędkość kątową członu 3 znajdziemy teraz prędkość dowolnego punktu członu 3, np. punktu E i H



$$\omega_3 = \frac{v_{B3}}{|B_3G|} \qquad v_E = \omega_3 \, |EG|$$

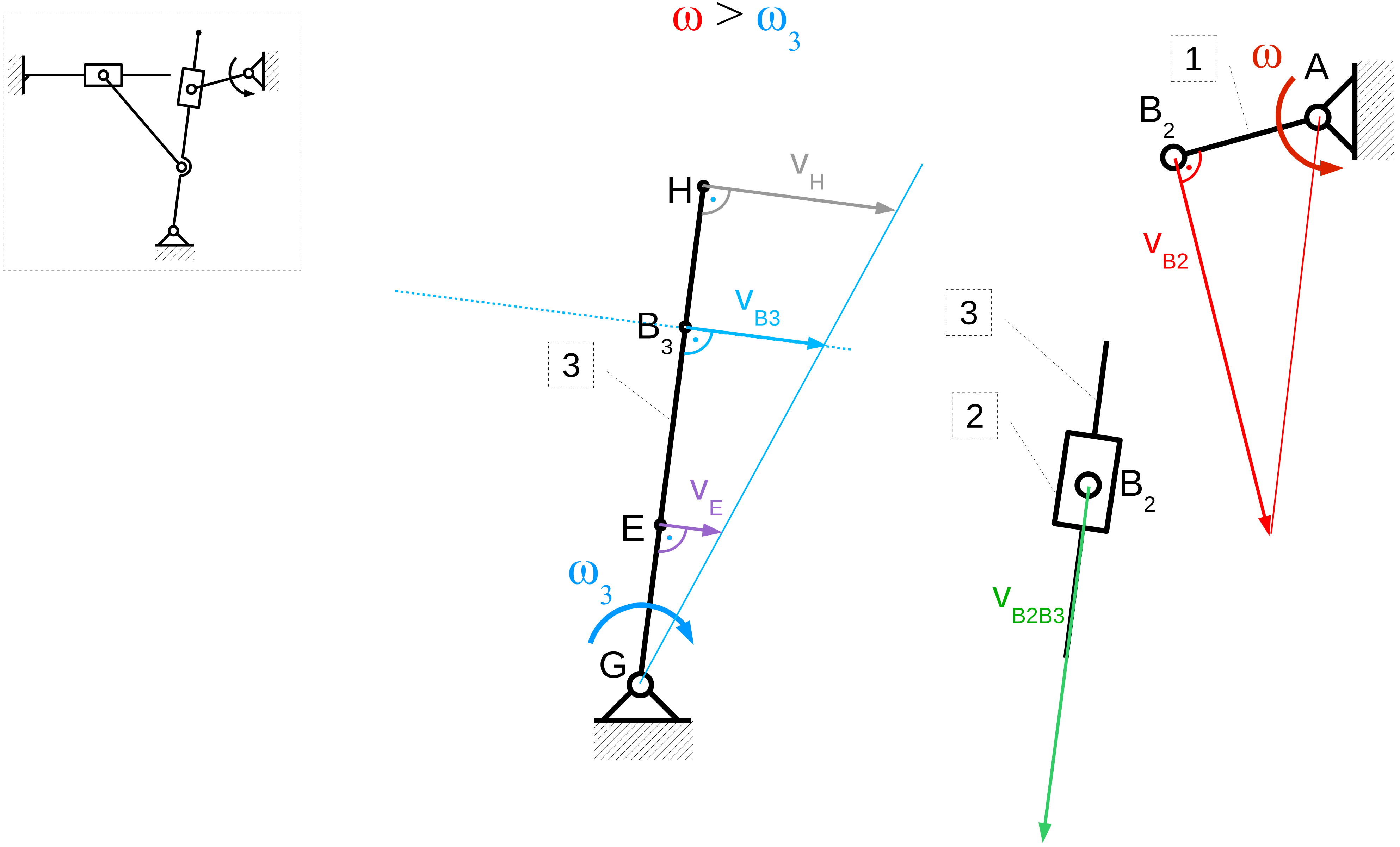


Prędkość punktu E oznaczymy też na planie prędkości

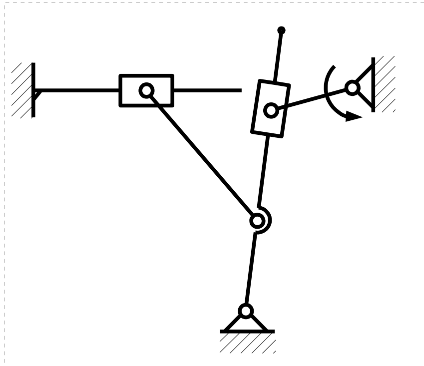


Z proporcji długości odcinków BG i BA oraz długości wektorów V_{B3} i V_{B2} wynika, że

$\omega > \omega_3$

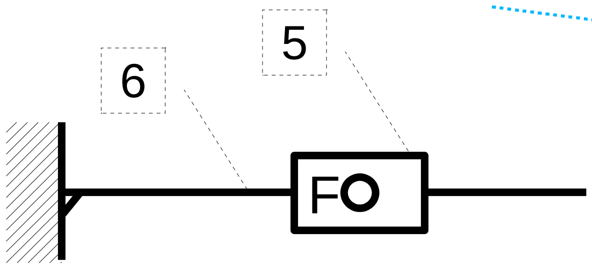


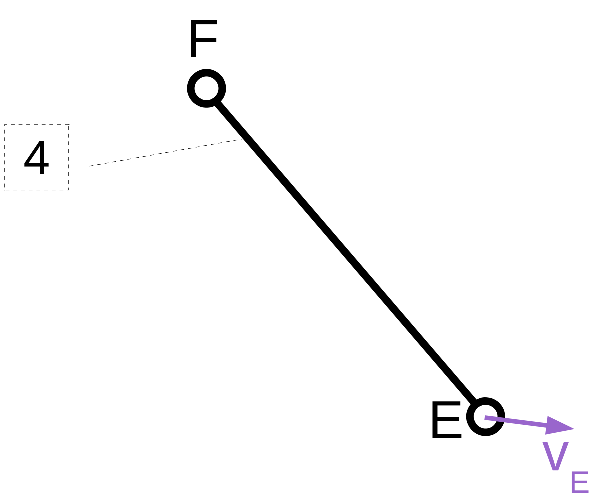
Rozważmy teraz ruch członu 4.
Prędkość punktu F wyznaczymy ze znajomości prędkości punktu E

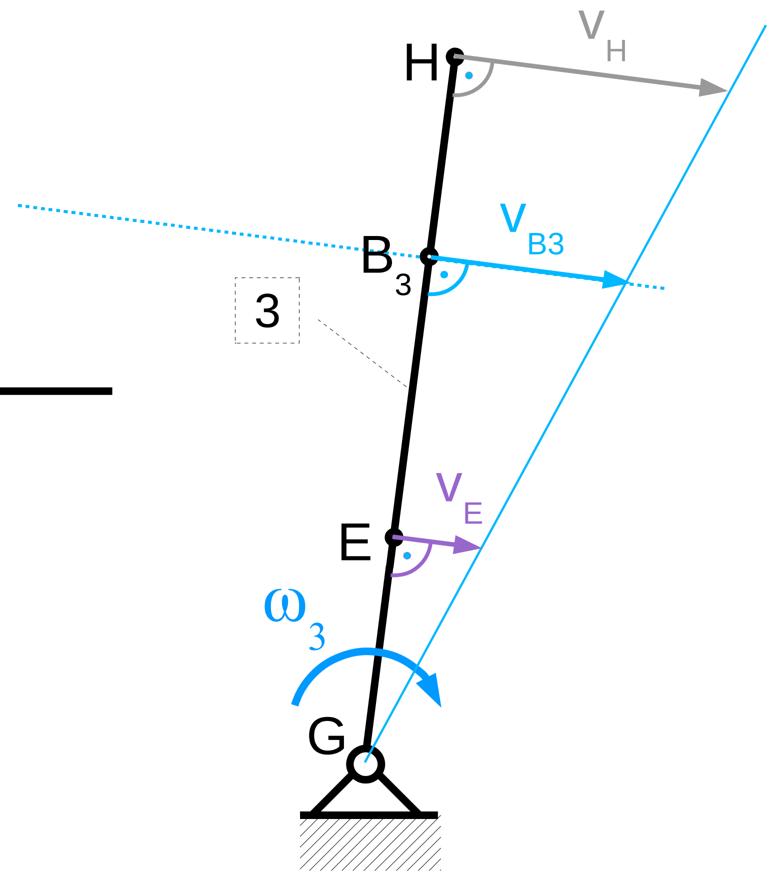


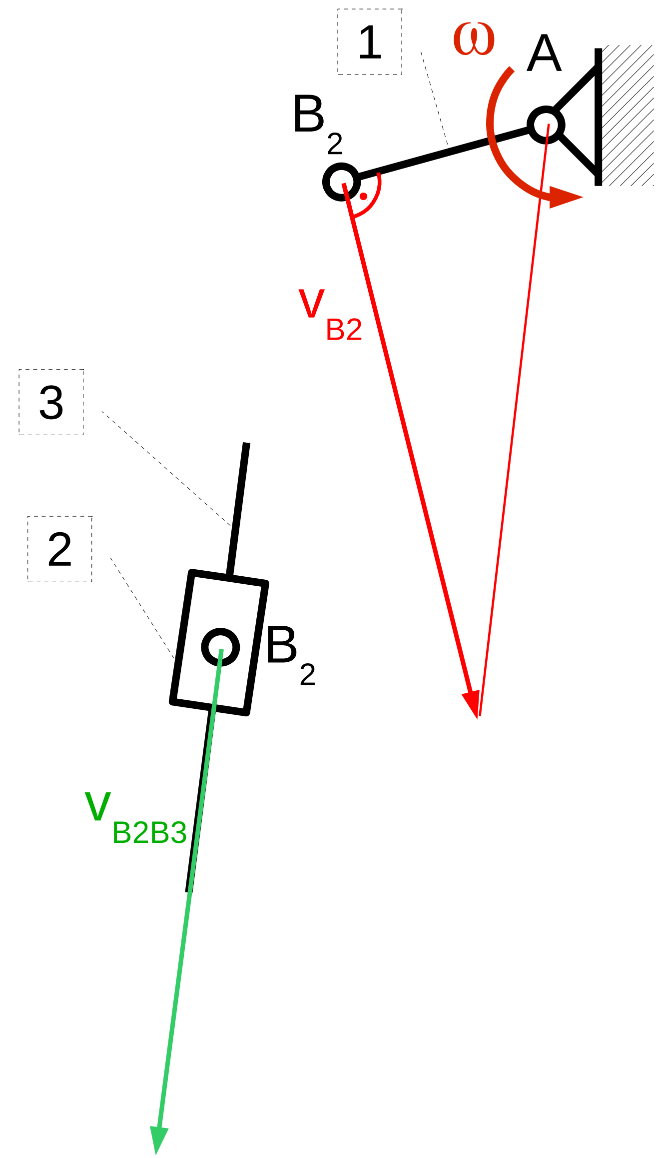
$$v_F = v_E + v_{FE}$$

$$\parallel 6 \quad \perp 3 \quad \perp 4$$



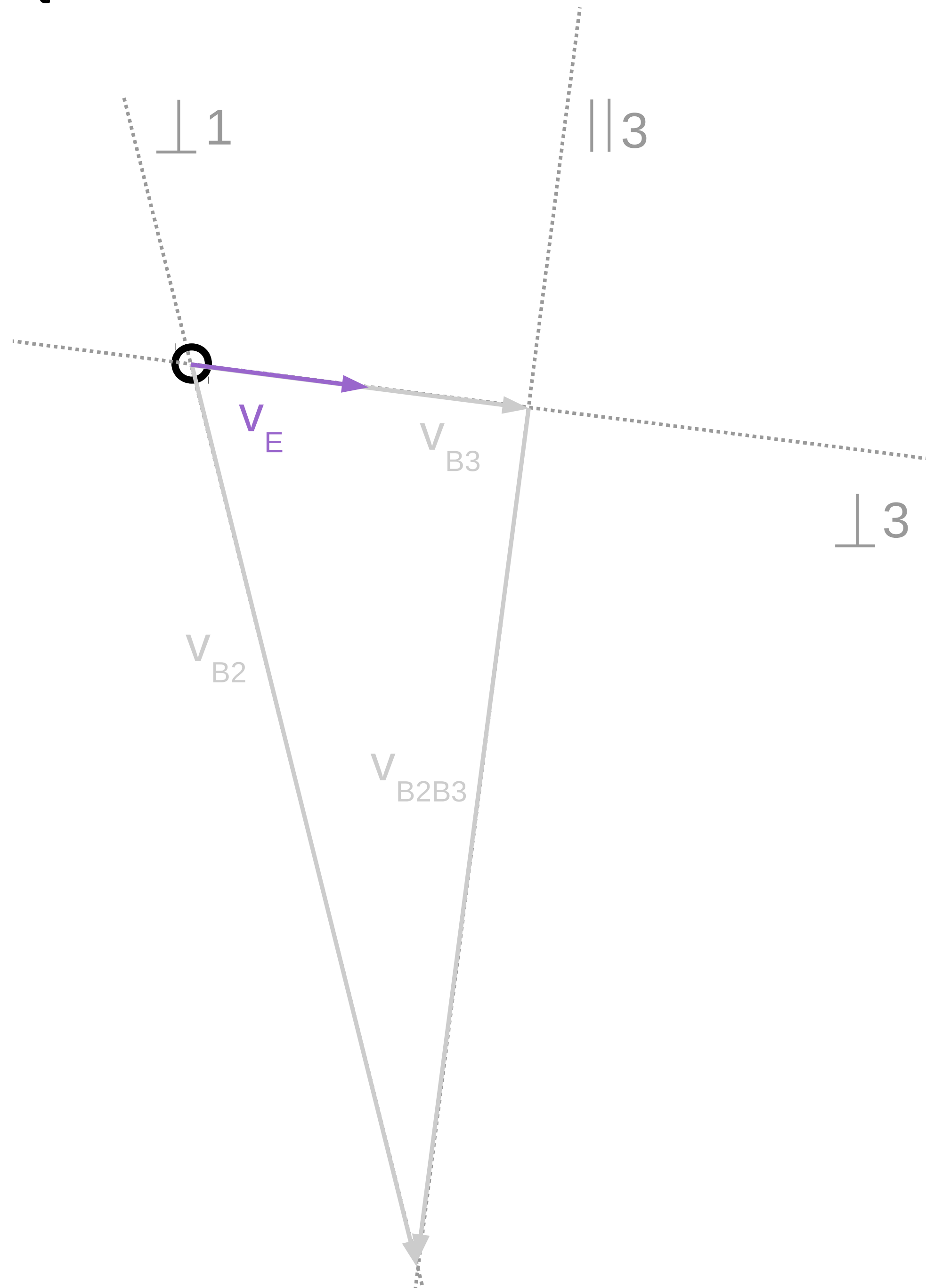






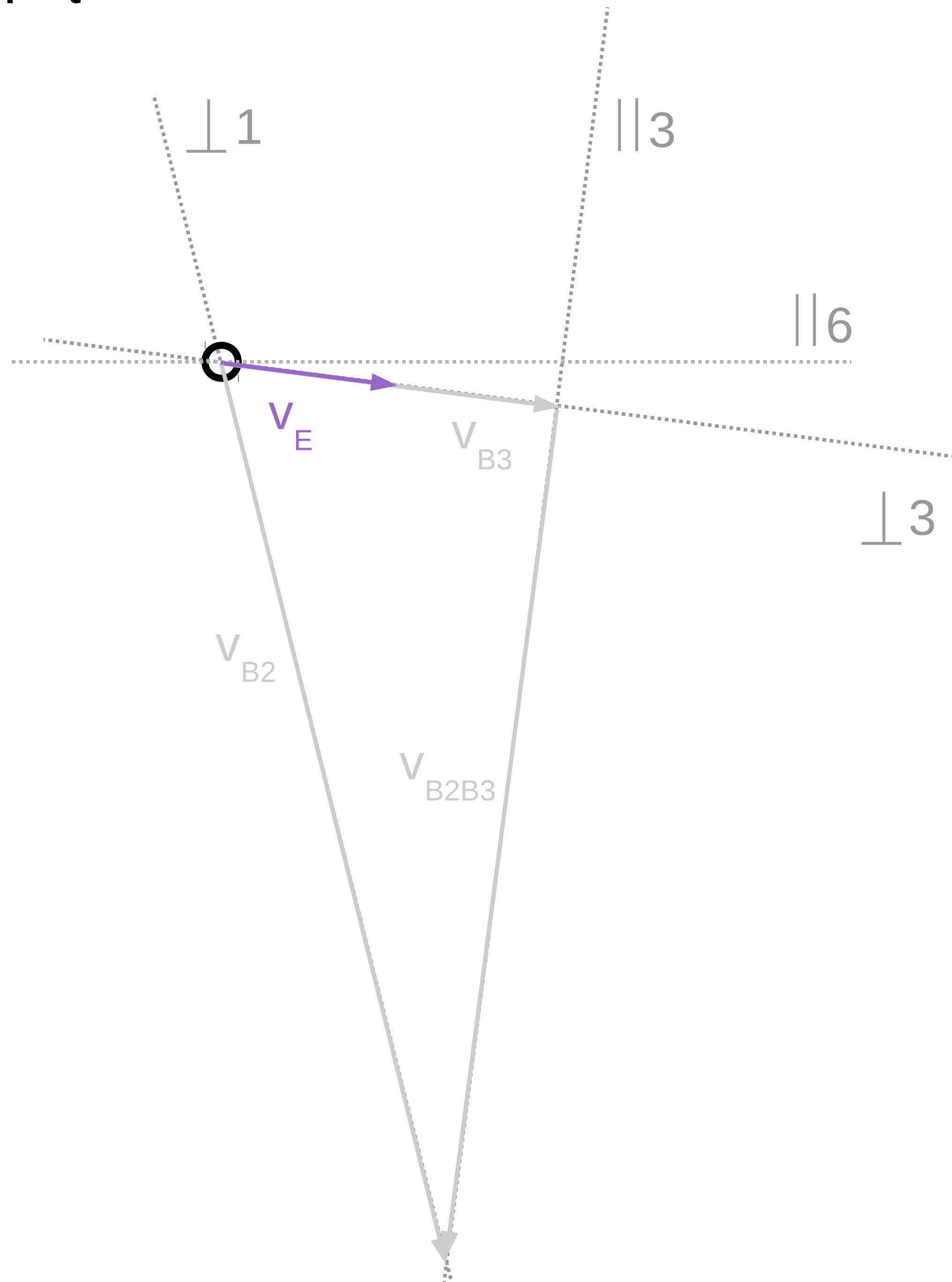
Plan prędkości

$$\underset{\parallel 6}{\underline{v_F}} = \underset{\perp 3}{\underline{\underline{v_E}}} + \underset{\perp 4}{\underline{v_{FE}}}$$



Plan prędkości

$$\underset{\parallel 6}{v_F} = \underset{\perp 3}{\underline{\underline{v_E}}} + \underset{\perp 4}{v_{FE}}$$



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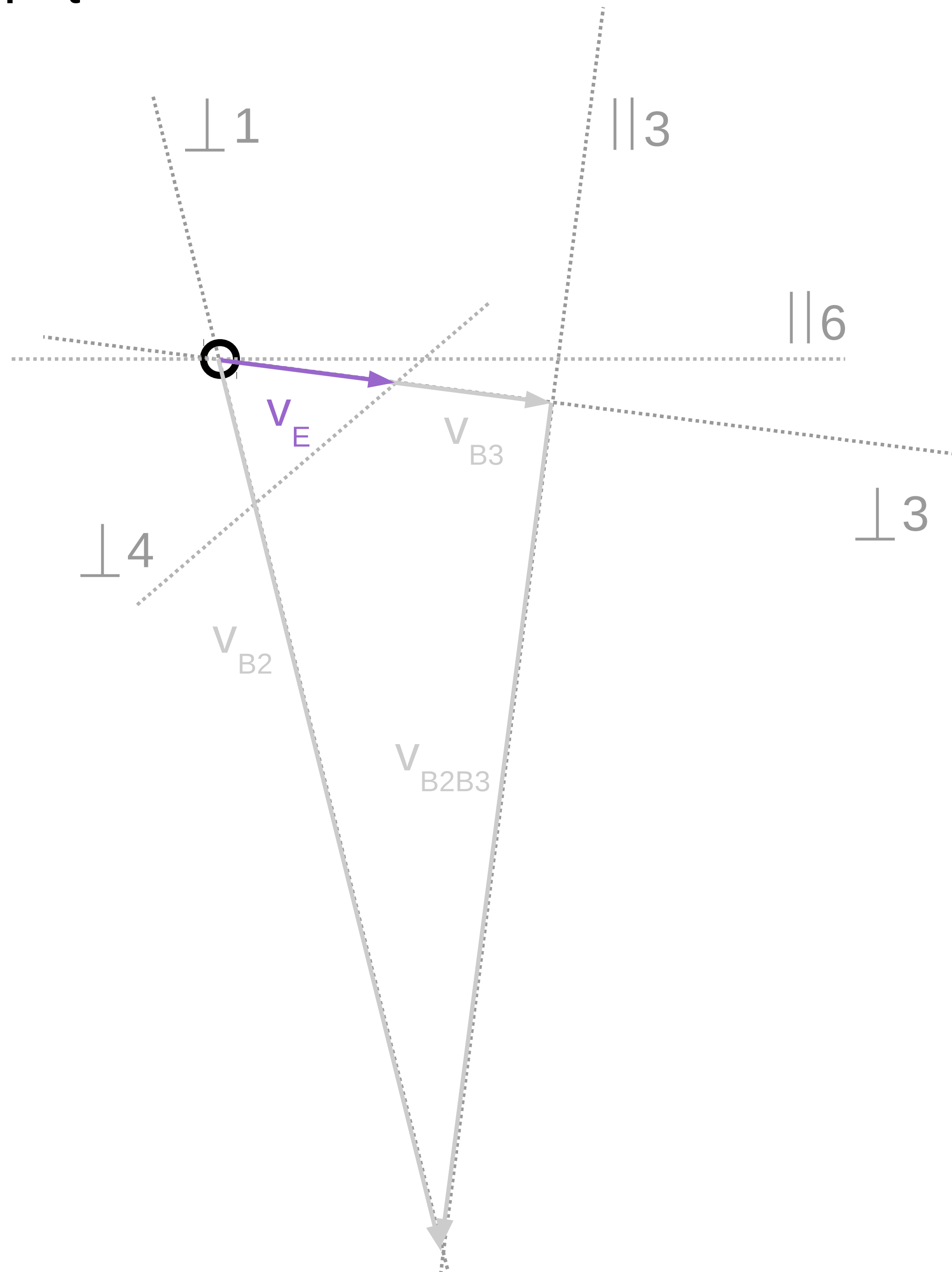

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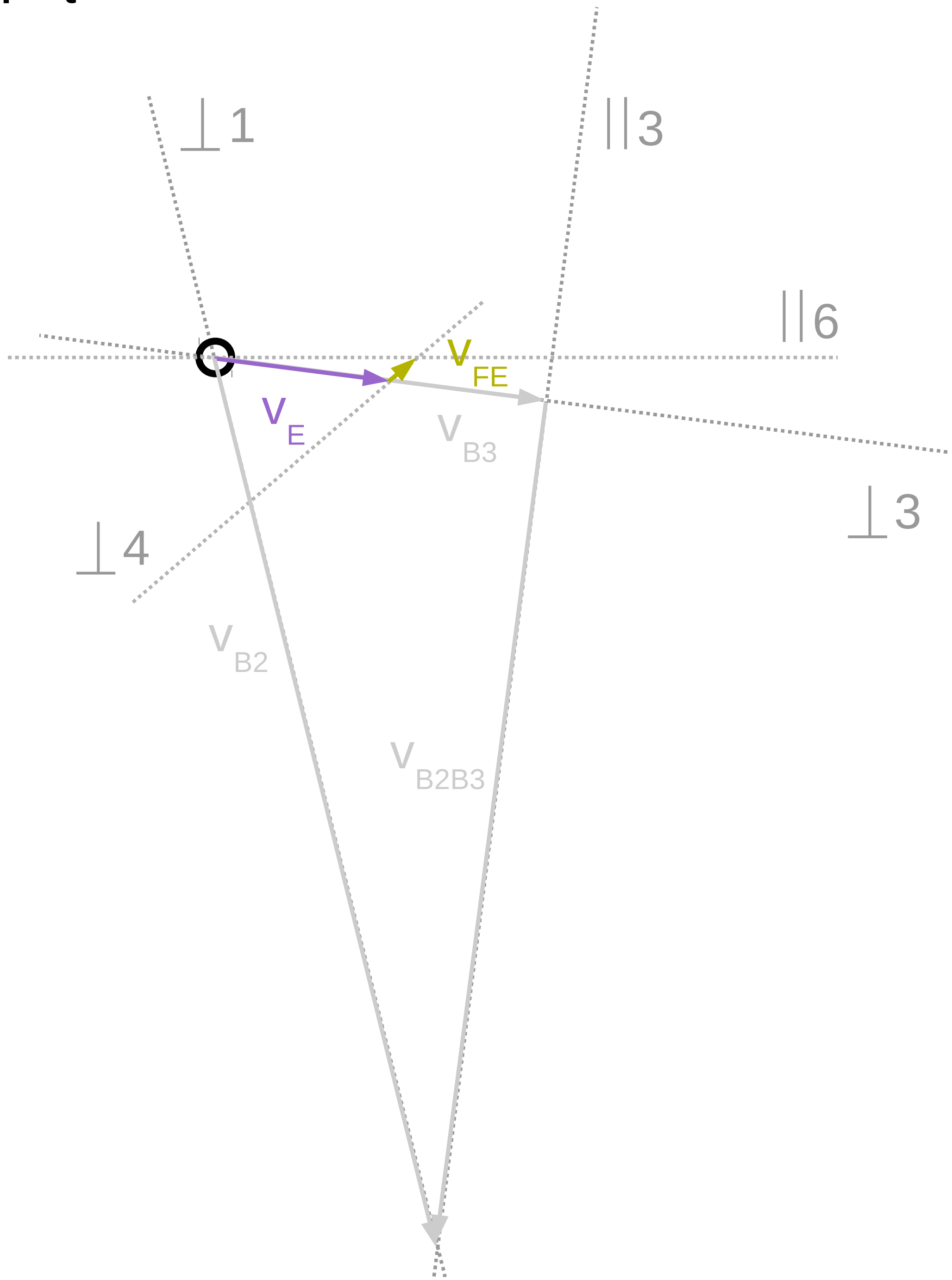

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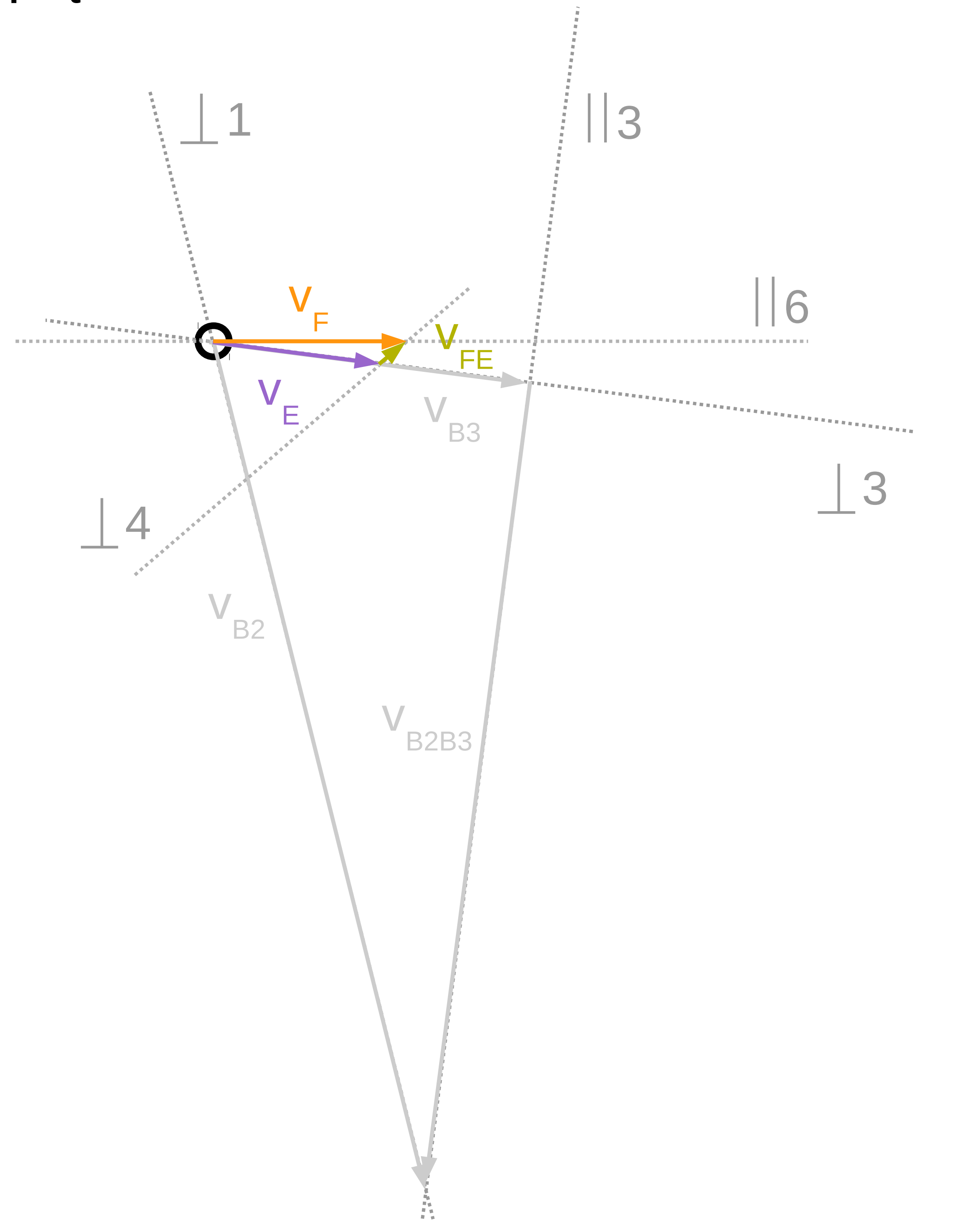
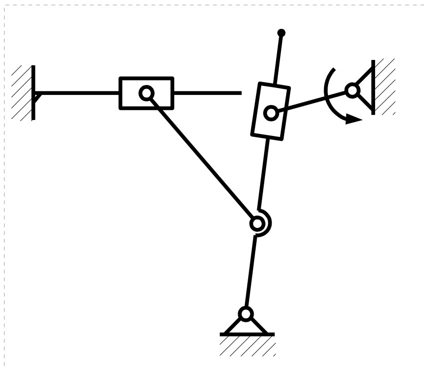
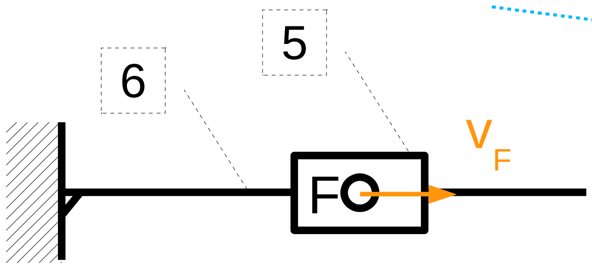


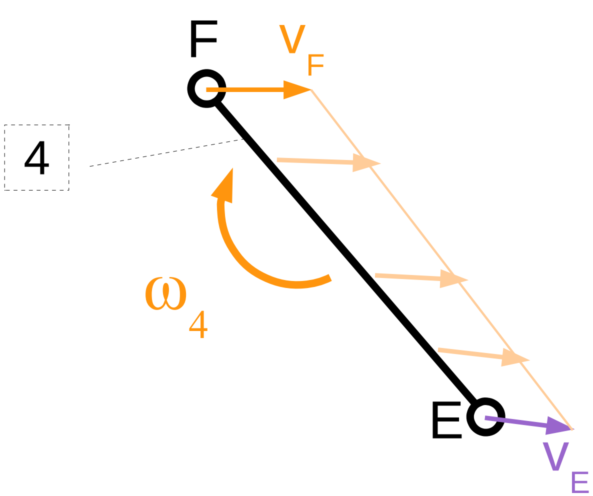
Na zakończenie znajdźmy prędkość kątową elementu 4, jej zwrot wynika ze zwrotu prędkości V_{FE} a jej wartość liczymy

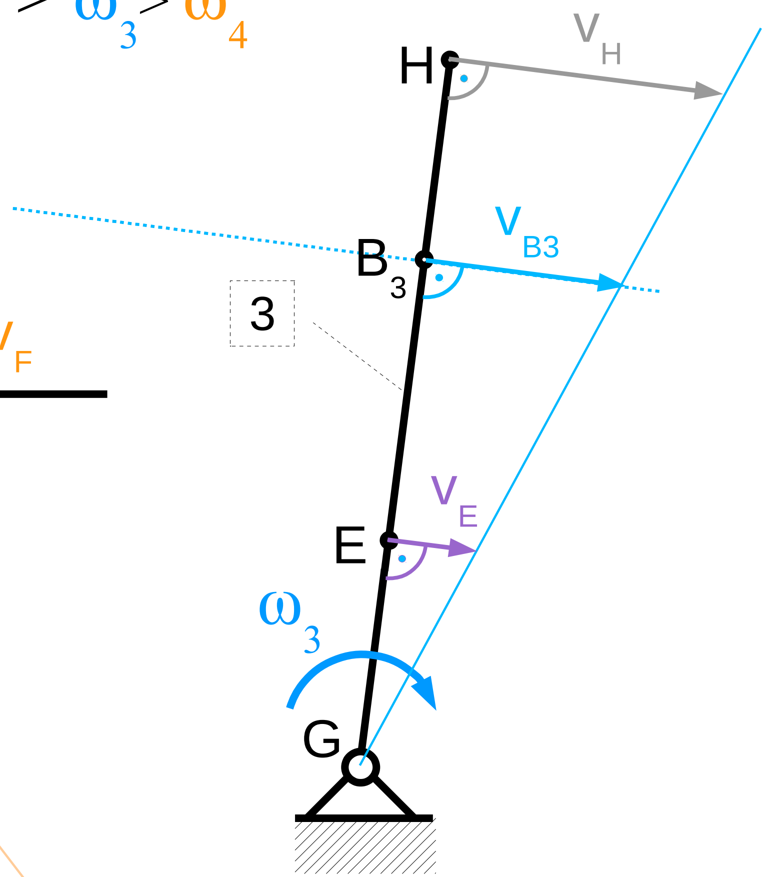
$$\omega_4 = \frac{V_{FE}}{|FE|}$$

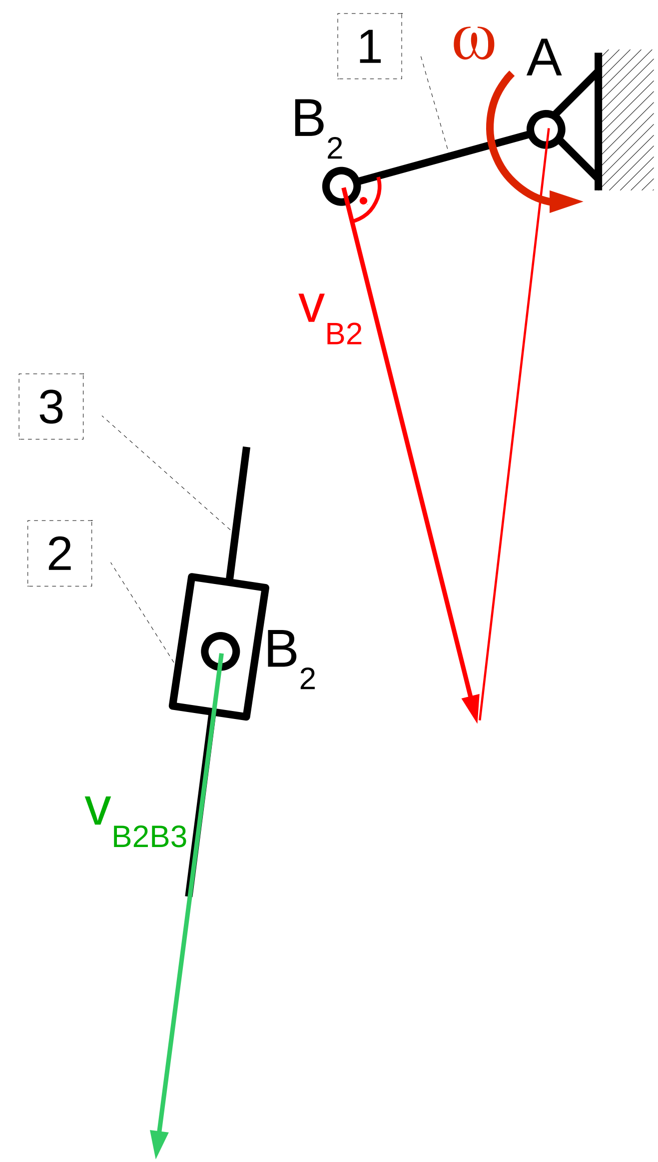
$$\omega > \omega_3 > \omega_4$$



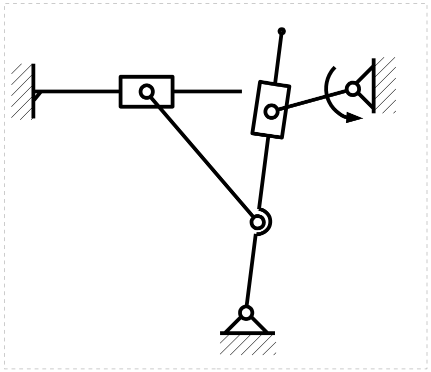


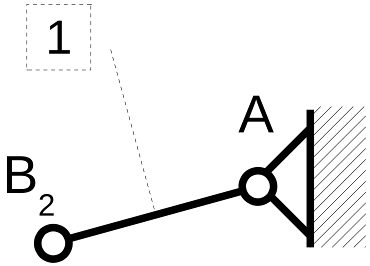




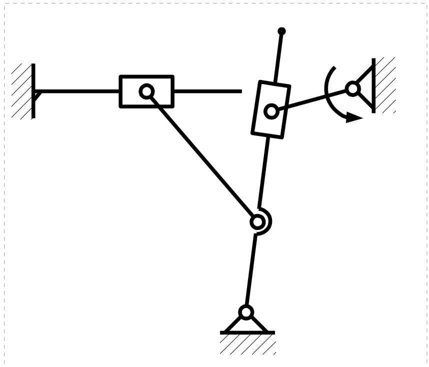


Rozpocznijmy analizę przyspieszeń od członu napędowego

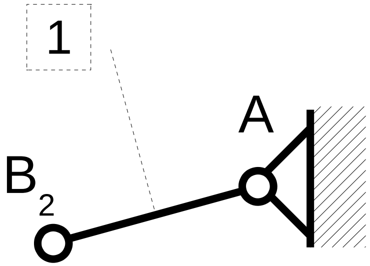




Rozpocznijmy analizę przyspieszeń od członu napędowego



$$p_{B2} = p_A + p^n_{B2A} + p^t_{B2A}$$



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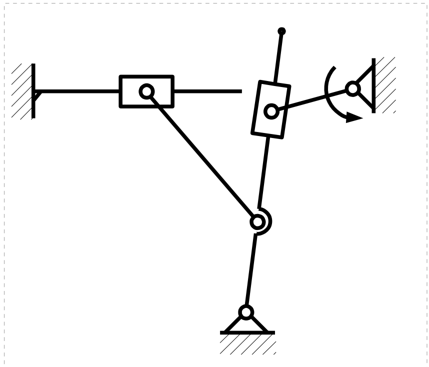
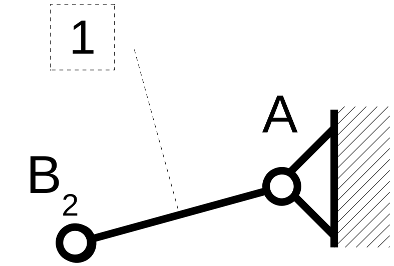


$$p_{B2} = \underline{\underline{p_A}} + \underline{\underline{p^n_{B2A}}} + \underline{\underline{p^t_{B2A}}}$$

$=0$ $\quad || 1$



$|p^n_{B2A}| = \omega^2 \, |B_2A|$

$|p^t_{B2A}| = \varepsilon \, |B_2A| = 0$

$$\varepsilon = \frac{d\,\omega}{dt} = 0$$

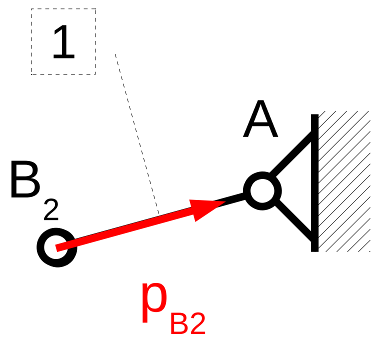
ω z założenia stałe

Rozpocznijmy analizę przyspieszeń od członu napędowego

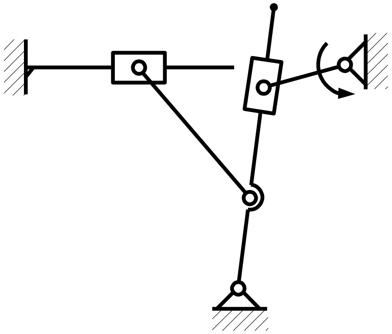
$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$$||1$$

$$|p^n_{B2A}| = \omega^2\,|B_2A|$$



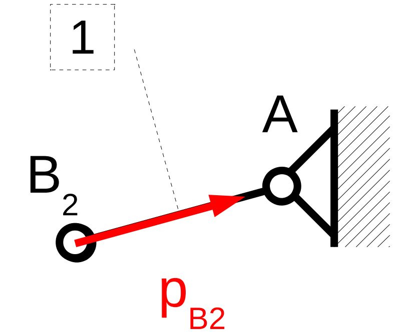
Rozpatrzmy ruch obrotowy elementu trzeciego



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$$\parallel 1$$

$$|p^n_{B2A}| = \omega^2 \, |B_2A|$$

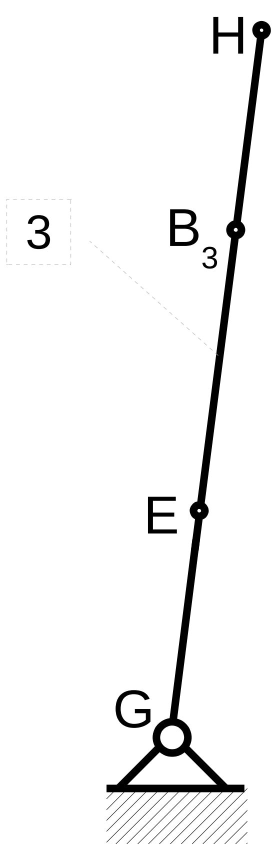


$$p_{B3} = \underline{\underline{p_G}} + \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

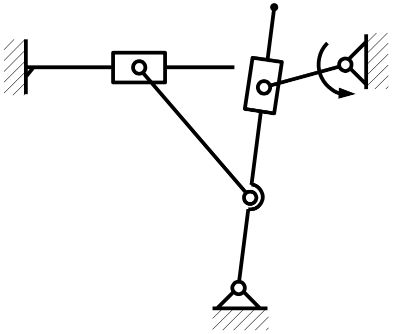
$$=0 \qquad \parallel 3 \qquad \perp 3$$

$$|p^n_{B3G}| = \omega_3^{\,2} \, |B_3G|$$

z planu prędkości



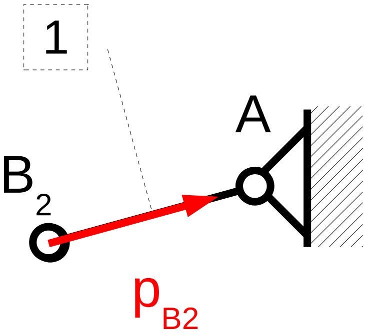
Rozpatrzmy ruch obrotowy elementu trzeciego



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$$\parallel 1$$

$$|p^n_{B2A}| = \omega^2 \, |B_2A|$$

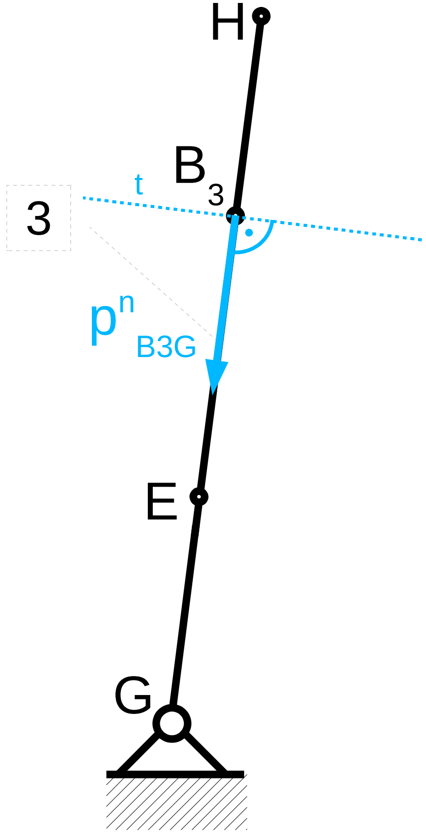


$$p_{B3} = \underline{\underline{p_G}} + \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

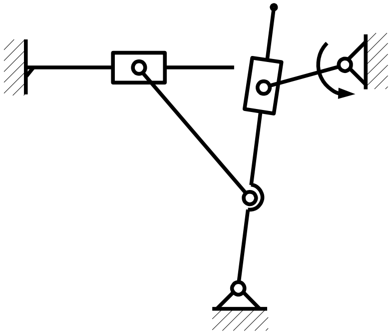
$$=0 \qquad \parallel 3 \qquad \perp 3$$

$$|p^n_{B3G}| = \omega_3^{\,2} \, |B_3G|$$

z planu prędkości



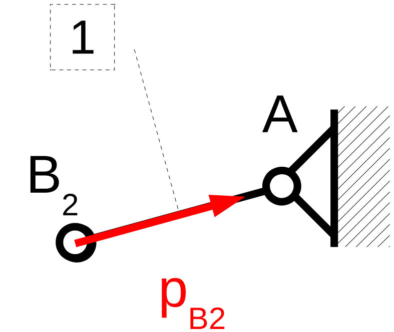
Rozpatrzmy ruch obrotowy elementu trzeciego



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$\|1$

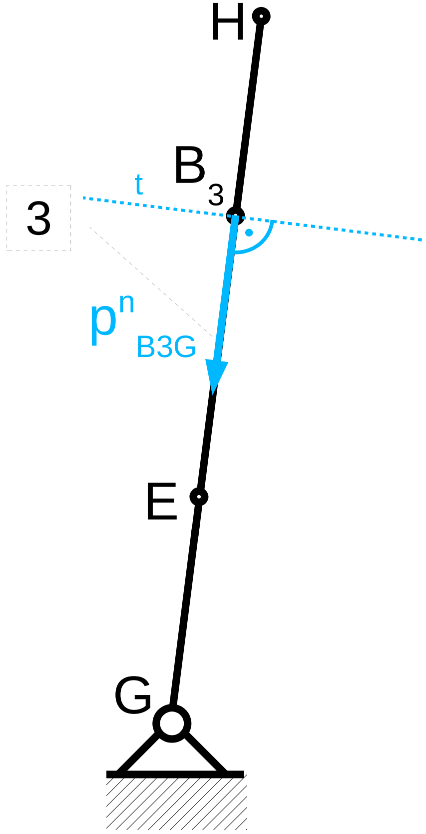
$$|p^n_{B2A}| = \omega^2\,|B_2A|$$



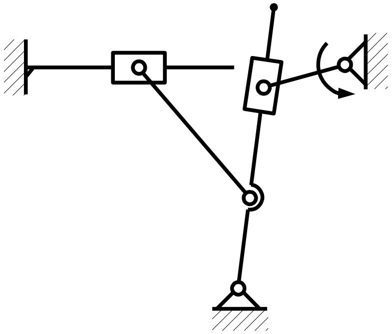
$$p_{B3} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$\|3$ $\perp 3$

$$|p^n_{B3G}| = \omega_3^{\,2}\,|B_3G|$$



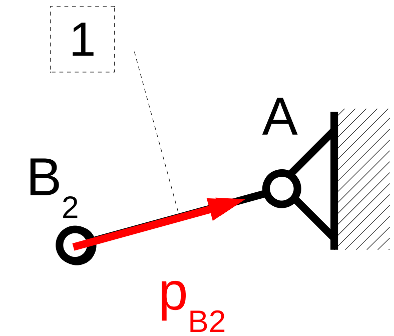
Rozpatrzmy ruch względny elementów 2 i 3



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$\parallel 1$

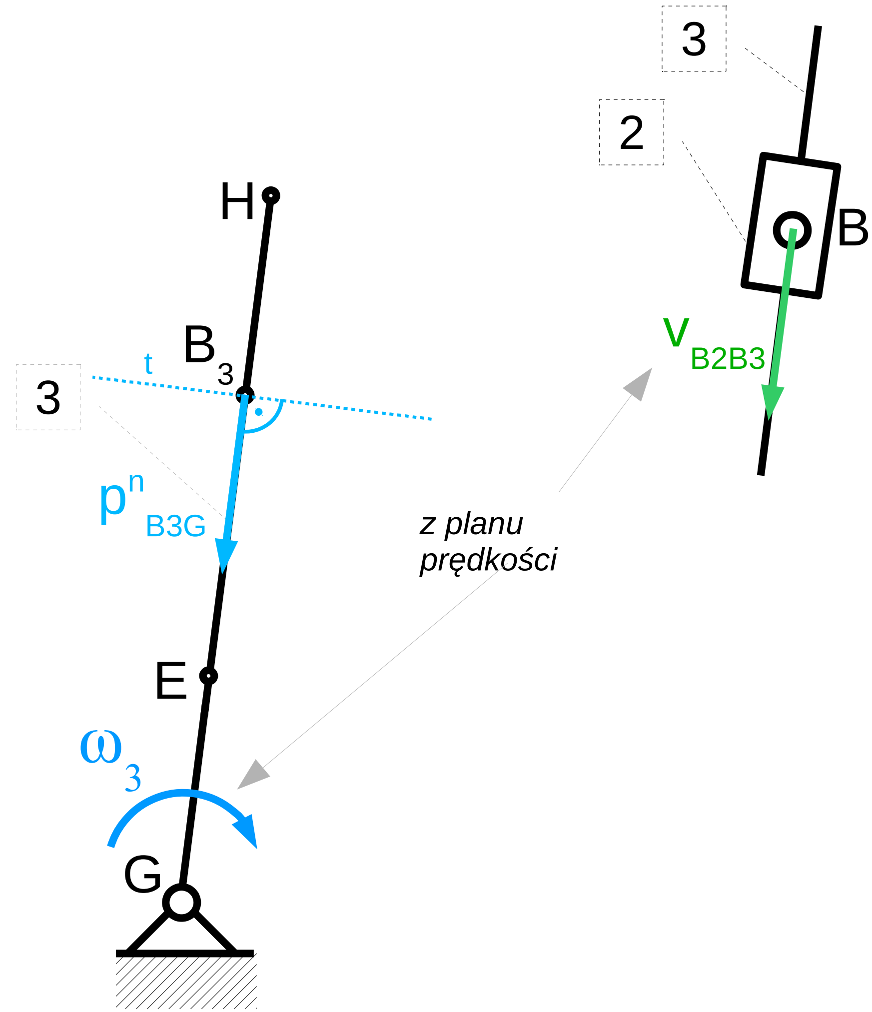
$$|p^n_{B2A}| = \omega^2\,|B_2A|$$



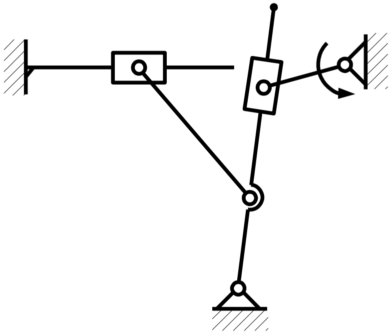
$$p_{B3} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$\parallel 3$ $\quad \perp 3$

$$|p^n_{B3G}| = \omega_3^{\,2}\,|B_3G|$$



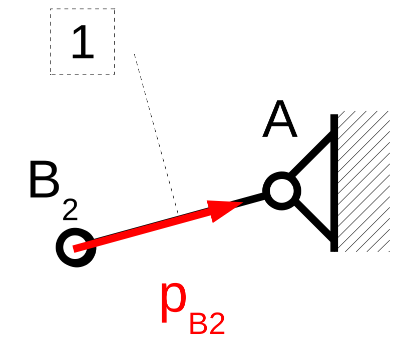
Rozpatrzmy ruch względny elementów 2 i 3



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$\parallel 1$

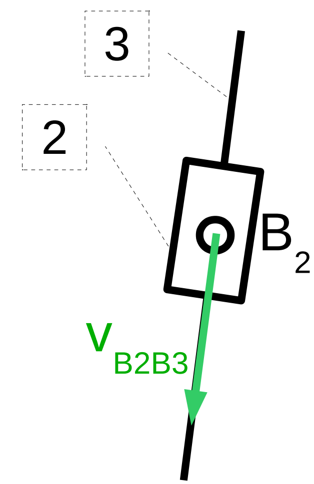
$$|p^n_{B2A}| = \omega^2 \, |B_2A|$$

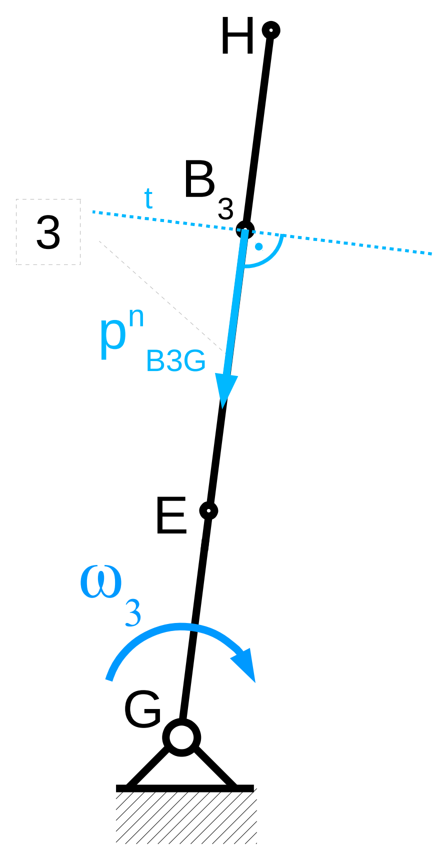


$$p_{B3} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$\parallel 3$ $\perp 3$

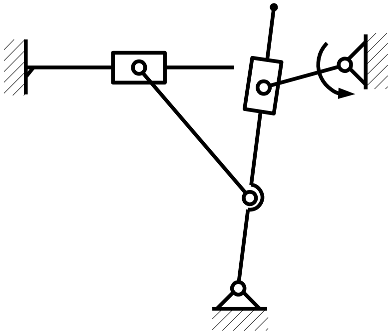
$$|p^n_{B3G}| = \omega_3^{\,2} \, |B_3G|$$





RUCH UNOSZENIA: ruch elementu 3
RUCH WZGLĘDNY: ruch elementu 2 wzdłuż elementu 3

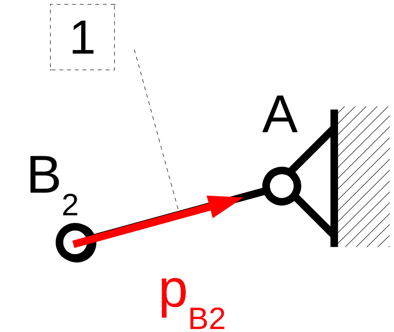
Rozpatrzmy ruch względny elementów 2 i 3



$$p_{B2} = p^n_{B2A}$$

$\parallel 1$

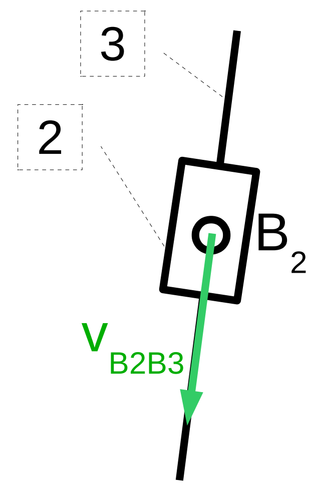
$$|p^n_{B2A}| = \omega^2 |B_2A|$$

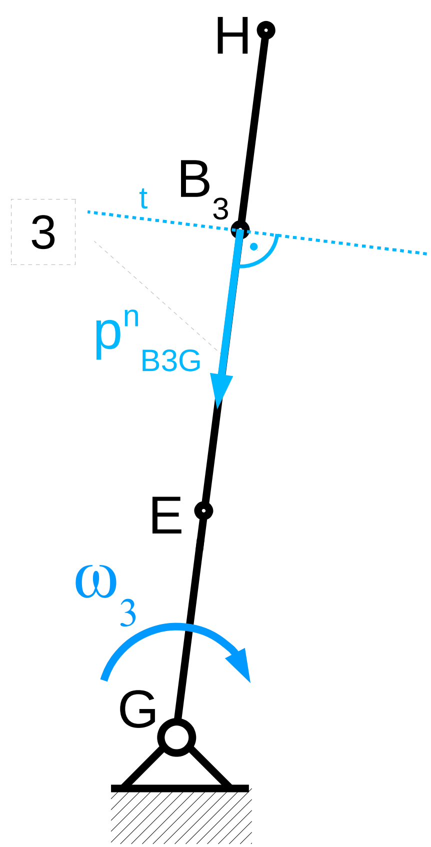


$$p_{B3} = p^n_{B3G} + p^t_{B3G}$$

$\parallel 3$ $\quad \perp 3$

$$|p^n_{B3G}| = \omega_3^2 |B_3G|$$



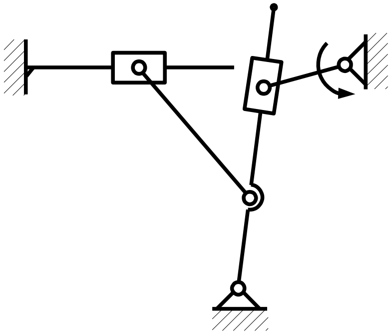


RUCH UNOSZENIA: ruch elementu 3
RUCH WZGLĘDNY: ruch elementu 2 wzdłuż elementu 3

RÓWNANIE RUCHU WZGLĘDNEGO:

$$p_{B2} = p^u_{B3} + p^w + p^c$$

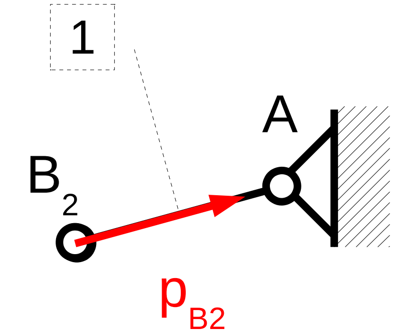
Rozpatrzmy ruch względny elementów 2 i 3



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$\parallel 1$

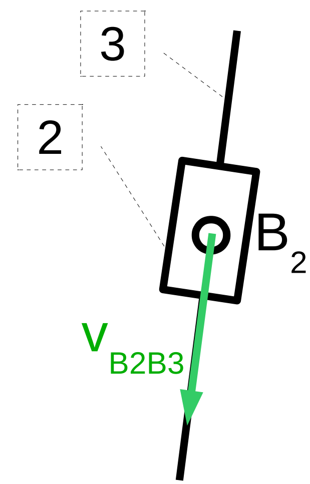
$$|p^n_{B2A}| = \omega^2 |B_2A|$$

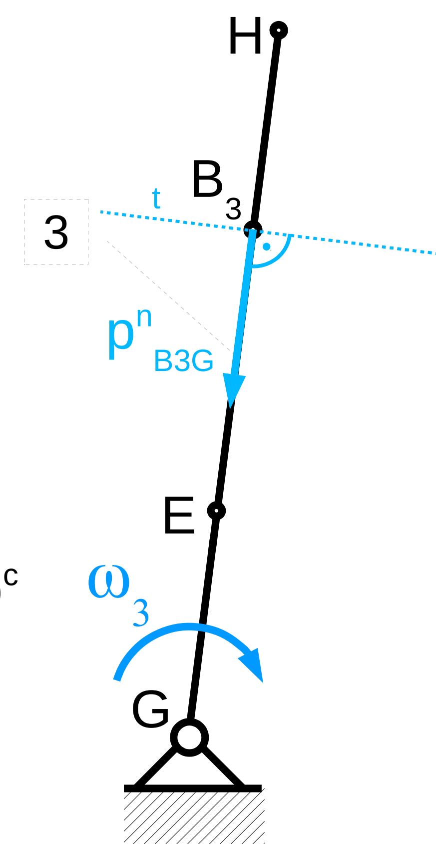


$$p_{B3} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$\parallel 3$ $\perp 3$

$$|p^n_{B3G}| = \omega_3^2 |B_3G|$$





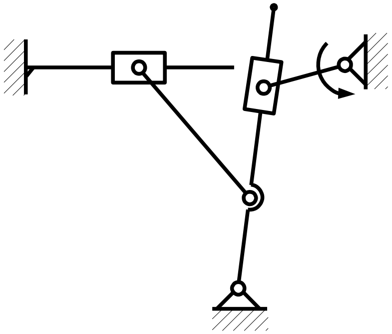
RUCH UNOSZENIA: ruch elementu 3
RUCH WZGLĘDNY: ruch elementu 2 wzdłuż elementu 3

RÓWNANIE RUCHU WZGLĘDNEGO:

$$p_{B2} = p^u_{B3} + p^w + p^c$$

$$p^n_{B2A} = p^n_{B3G} + p^t_{B3G} + p^w_{B2B3} + p^c$$

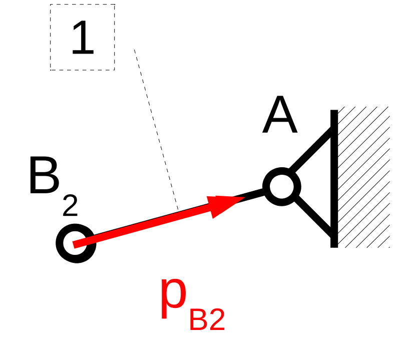
Rozpatrzmy ruch względny elementów 2 i 3



$$p_{B2} = \underline{\underline{p^n_{B2A}}}$$

$\parallel 1$

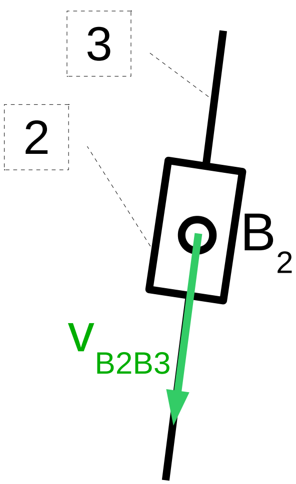
$$|p^n_{B2A}| = \omega^2 \, |B_2A|$$



$$p_{B3} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$\parallel 3$ $\quad \perp 3$

$$|p^n_{B3G}| = \omega_3^2 \, |B_3G|$$



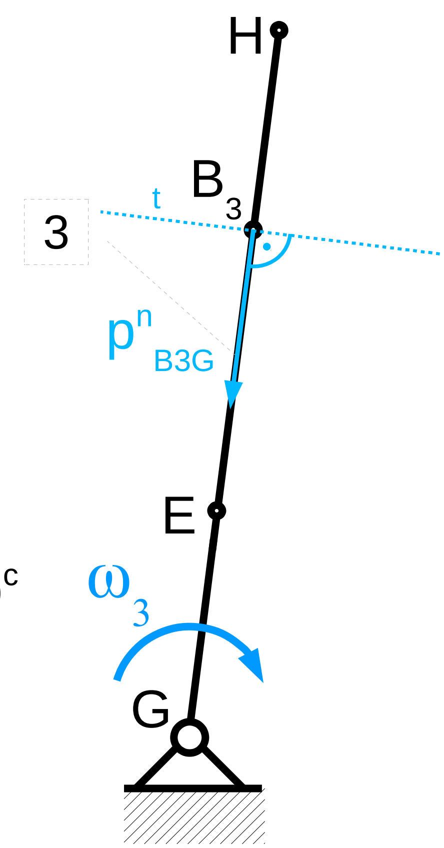
RUCH UNOSZENIA: ruch elementu 3
RUCH WZGLĘDNY: ruch elementu 2 wzdłuż elementu 3

RÓWNANIE RUCHU WZGLĘDNEGO:

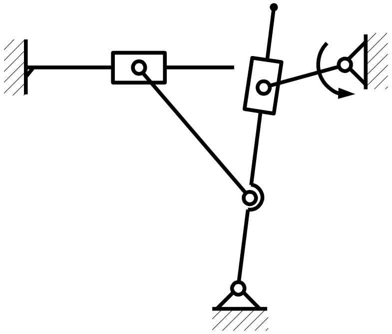
$$p_{B2} = p^u_{B3} + p^w + p^c$$

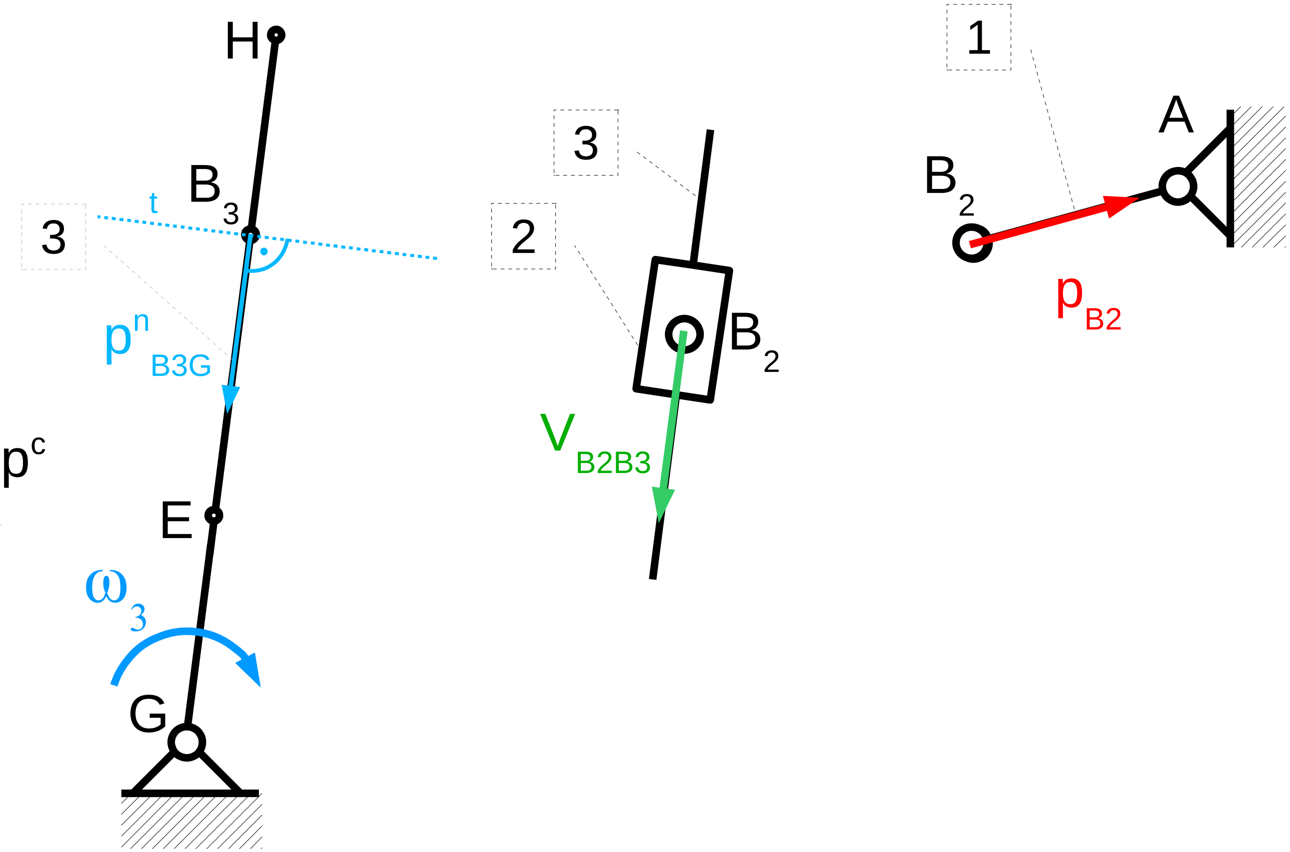
$$\underline{\underline{p^n_{B2A}}} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}} + \underline{p^w_{B2B3}} + p^c$$

$\parallel 1 \qquad \parallel 3 \qquad \perp 3 \qquad \parallel 3$



Przyspieszenie Coriolisa





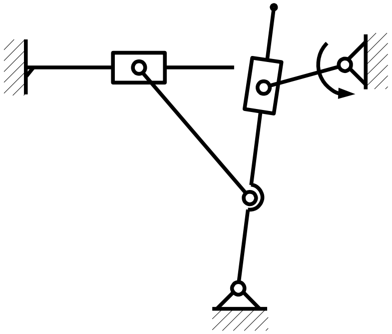
$$p_{B2} = p^{u}_{B3} + p^{w} + p^{c}$$

$$\underline{\underline{p^{n}_{B2A}}} = \underline{\underline{p^{n}_{B3G}}} + \underline{p^{t}_{B3G}} + \underline{p^{w}_{B2B3}} + p^{c}$$

$||1 \qquad ||3 \qquad \perp 3 \qquad ||3$

$$p^{c} = 2\omega_{3} \times V_{B2B3}$$

Przyspieszenie Coriolisa



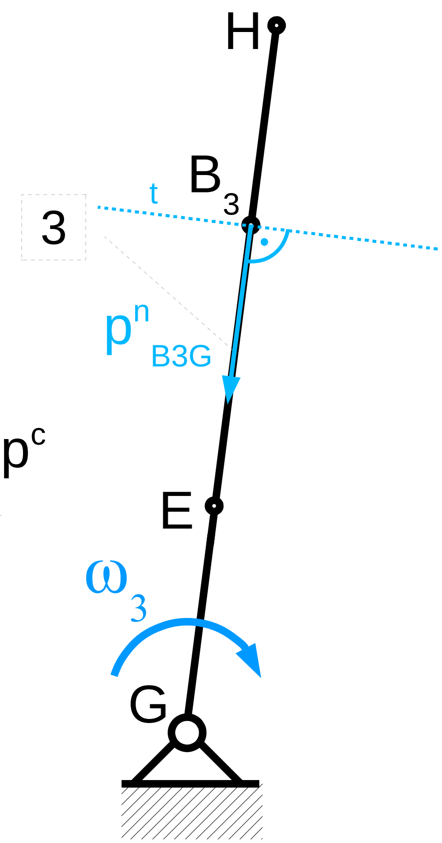
$$p_{B2} = p^{u}_{B3} + p^{w} + p^{c}$$

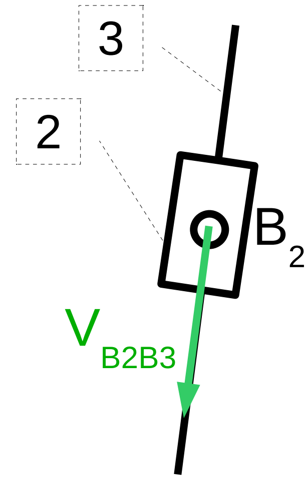
$$\underline{\underline{p^{n}_{B2A}}} = \underline{\underline{p^{n}_{B3G}}} + \underline{p^{t}_{B3G}} + \underline{p^{w}_{B2B3}} + p^{c}$$

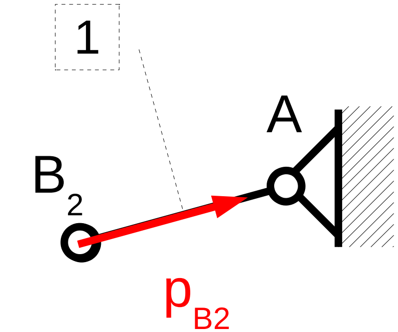
$||1$ $\quad$ $||3$ $\quad$ $\perp 3$ $\quad$ $||3$

$$p^{c} = 2\omega_3 \times V_{B2B3}$$

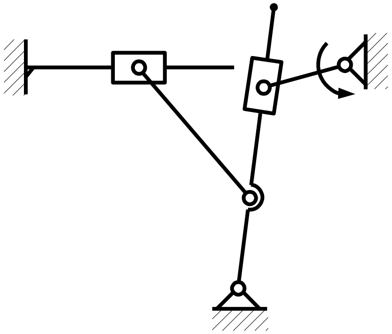
$$|p^{c}| = 2|\omega_3|\,|V_{B2B3}|\,\sin(\sphericalangle(\omega_3, V_{B2B3}))$$

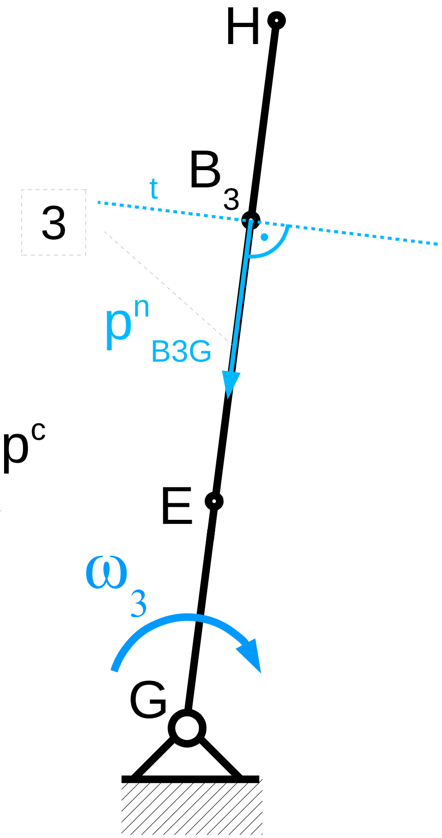


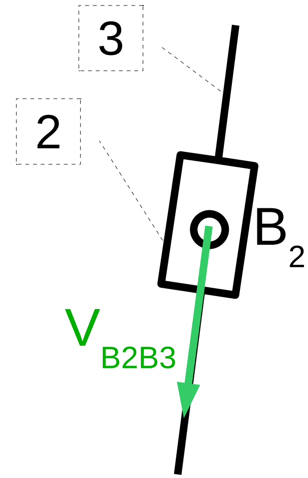


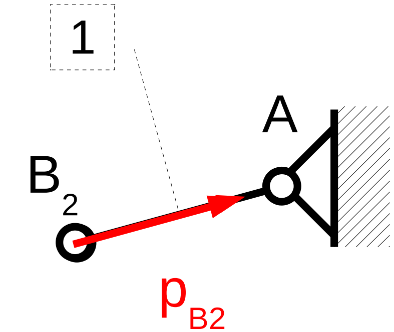


Przyspieszenie Coriolisa







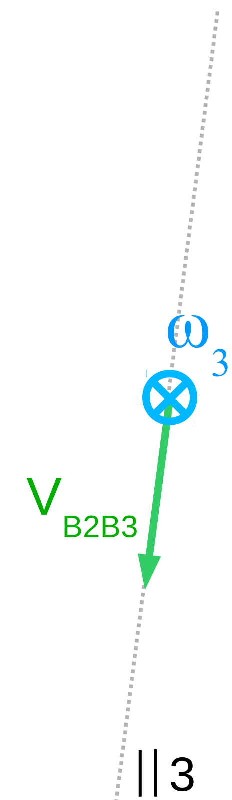


$$p_{B2} = p^{u}_{B3} + p^{w} + p^{c}$$

$$\underset{\parallel 1}{\underline{\underline{p^{n}_{B2A}}}} = \underset{\parallel 3}{\underline{\underline{p^{n}_{B3G}}}} + \underset{\perp 3}{\underline{p^{t}_{B3G}}} + \underset{\parallel 3}{\underline{p^{w}_{B2B3}}} + p^{c}$$

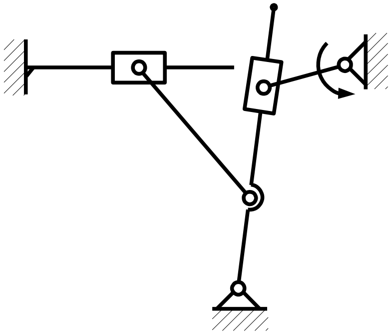
$$p^{c} = 2\omega_3 \times V_{B2B3}$$

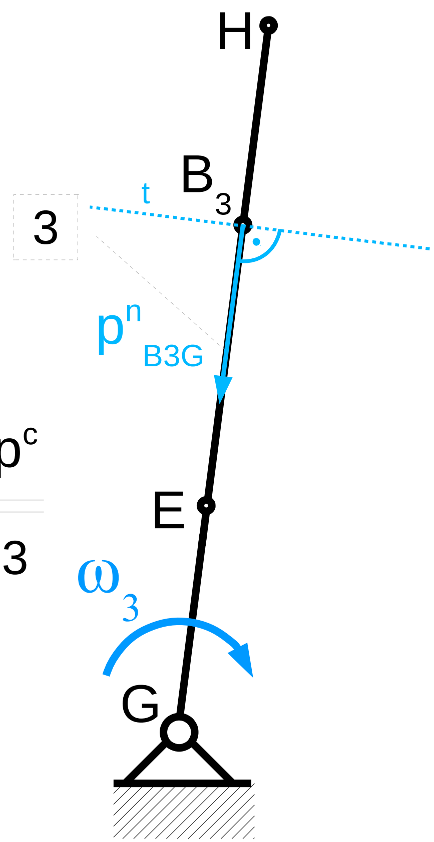
$$|p^{c}| = 2|\omega_3|\,|V_{B2B3}|\,\sin(\measuredangle(\omega_3, V_{B2B3}))$$

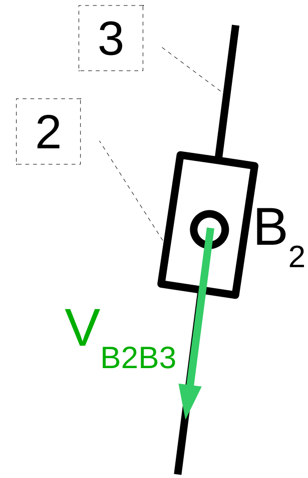


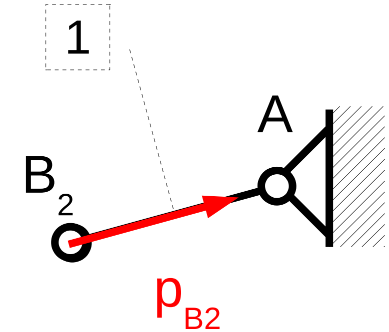
wektor prostopadły do płaszczyzny rysunku, zwrot za rysunek

Przyspieszenie Coriolisa









$$p_{B2} = p^{u}_{B3} + p^{w} + p^{c}$$

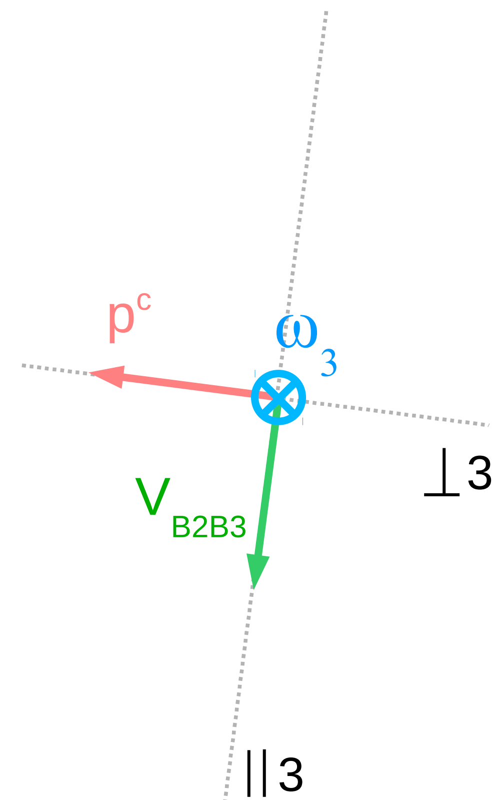
$$p^{n}_{B2A} = p^{n}_{B3G} + p^{t}_{B3G} + p^{w}_{B2B3} + p^{c}$$

$$||1 \qquad ||3 \qquad \perp 3 \qquad ||3 \qquad \perp 3$$

$$p^{c} = 2\omega_{3} \times V_{B2B3}$$

$$|p^{c}| = 2|\omega_{3}|\,|V_{B2B3}|\,\sin(\measuredangle(\omega_{3}, V_{B2B3})) = 2|\omega_{3}|\,|V_{B2B3}|$$

kąt prosty



Plan przyspieszeń

$$\underline{\underline{p^n_{B2A}}} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}} + \underline{p^w_{B2B3}} + \underline{\underline{p^c}}$$

$$\parallel 1 \qquad \parallel 3 \qquad \perp 3 \qquad \parallel 3 \qquad \perp 3$$

$$\underline{\underline{p^n_{B2A}}} - \underline{\underline{p^c}} - \underline{p^w_{B2B3}} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$$\parallel 1 \qquad \perp 3 \qquad \parallel 3 \qquad \parallel 3 \qquad \perp 3$$

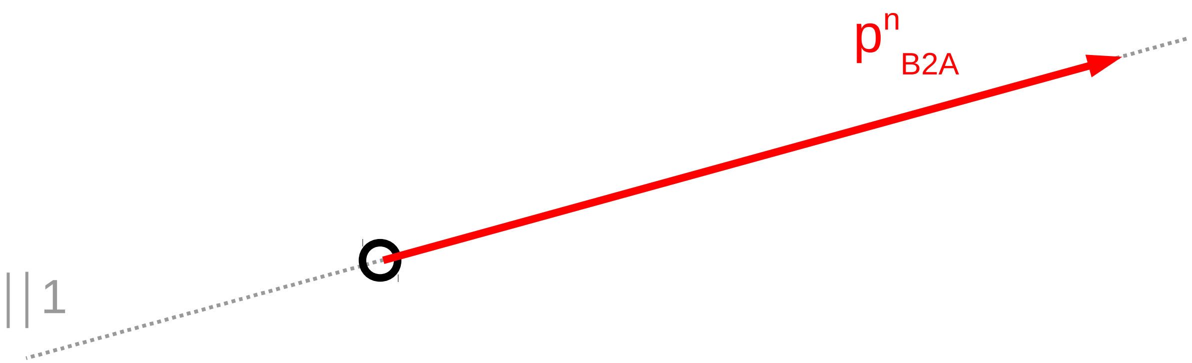
Plan przyspieszeń

$$\underset{\parallel 1}{\underline{\underline{p^{n}_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^{c}}}} - \underset{\parallel 3}{\underline{p^{w}_{B2B3}}} = \underset{\parallel 3}{\underline{\underline{p^{n}_{B3G}}}} + \underset{\perp 3}{\underline{p^{t}_{B3G}}}$$

Plan przyspieszeń

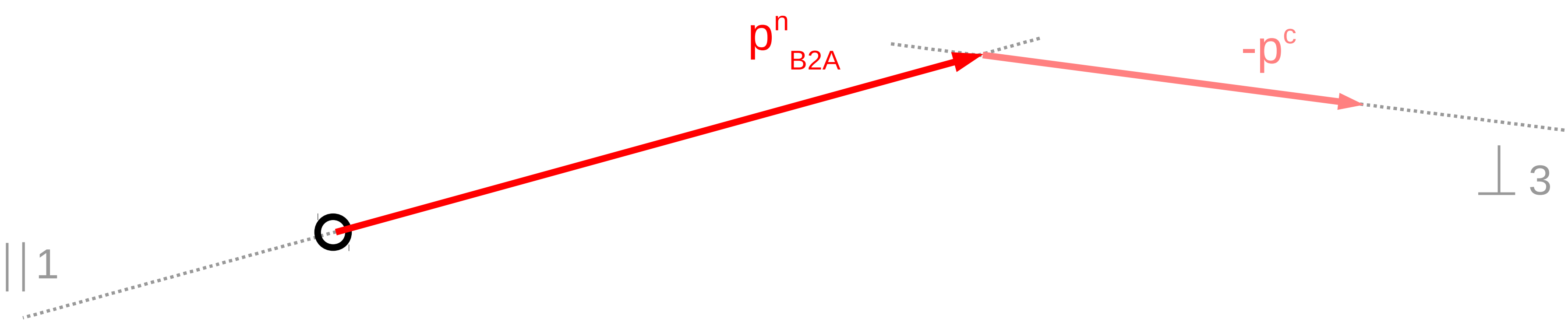
$$\underline{\underline{p^n_{B2A}}} - \underline{\underline{p^c}} - \underline{p^w_{B2B3}} = \underline{\underline{p^n_{B3G}}} + \underline{p^t_{B3G}}$$

$$\parallel 1 \quad\quad \perp 3 \quad\quad \parallel 3 \quad\quad \parallel 3 \quad\quad \perp 3$$



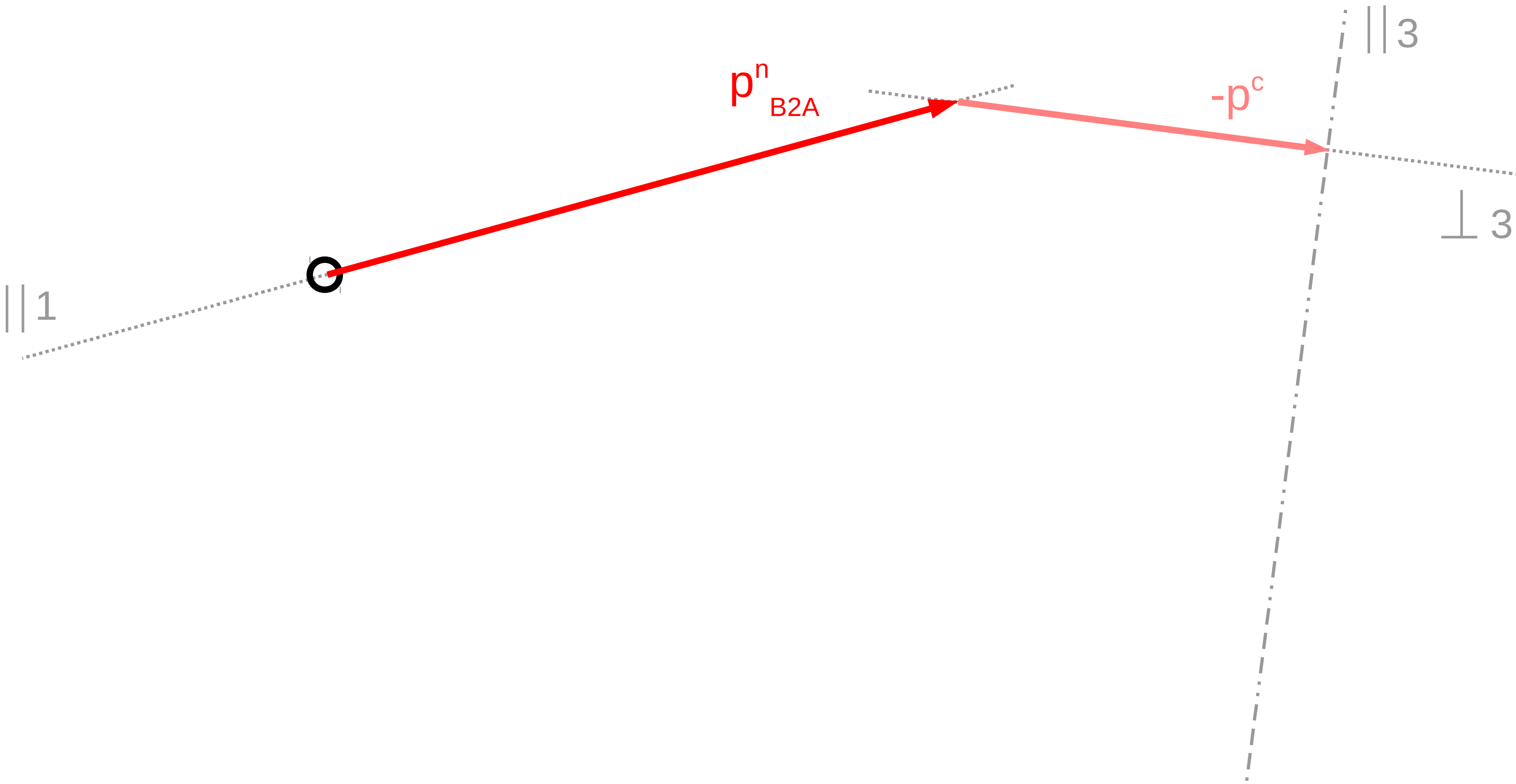
Plan przyspieszeń

$$\underset{||1}{\underline{\underline{p^n_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^c}}} - \underset{||3}{\underline{p^w_{B2B3}}} = \underset{||3}{\underline{\underline{p^n_{B3G}}}} + \underset{\perp 3}{\underline{p^t_{B3G}}}$$



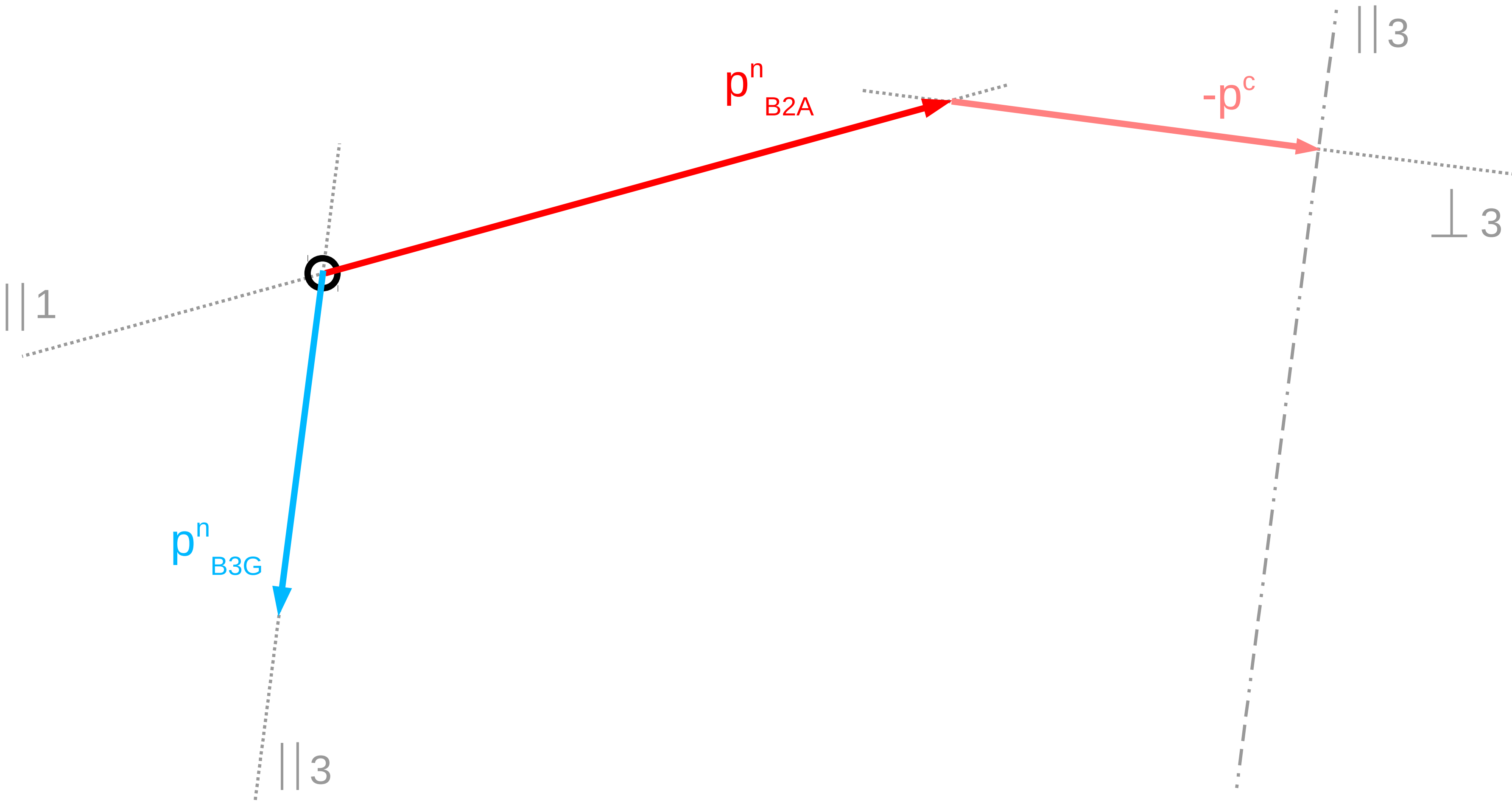
Plan przyspieszeń

$$\underset{||1}{\underline{\underline{p^{n}_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^{c}}}} - \underset{||3}{\underline{p^{w}_{B2B3}}} = \underset{||3}{\underline{\underline{p^{n}_{B3G}}}} + \underset{\perp 3}{\underline{p^{t}_{B3G}}}$$



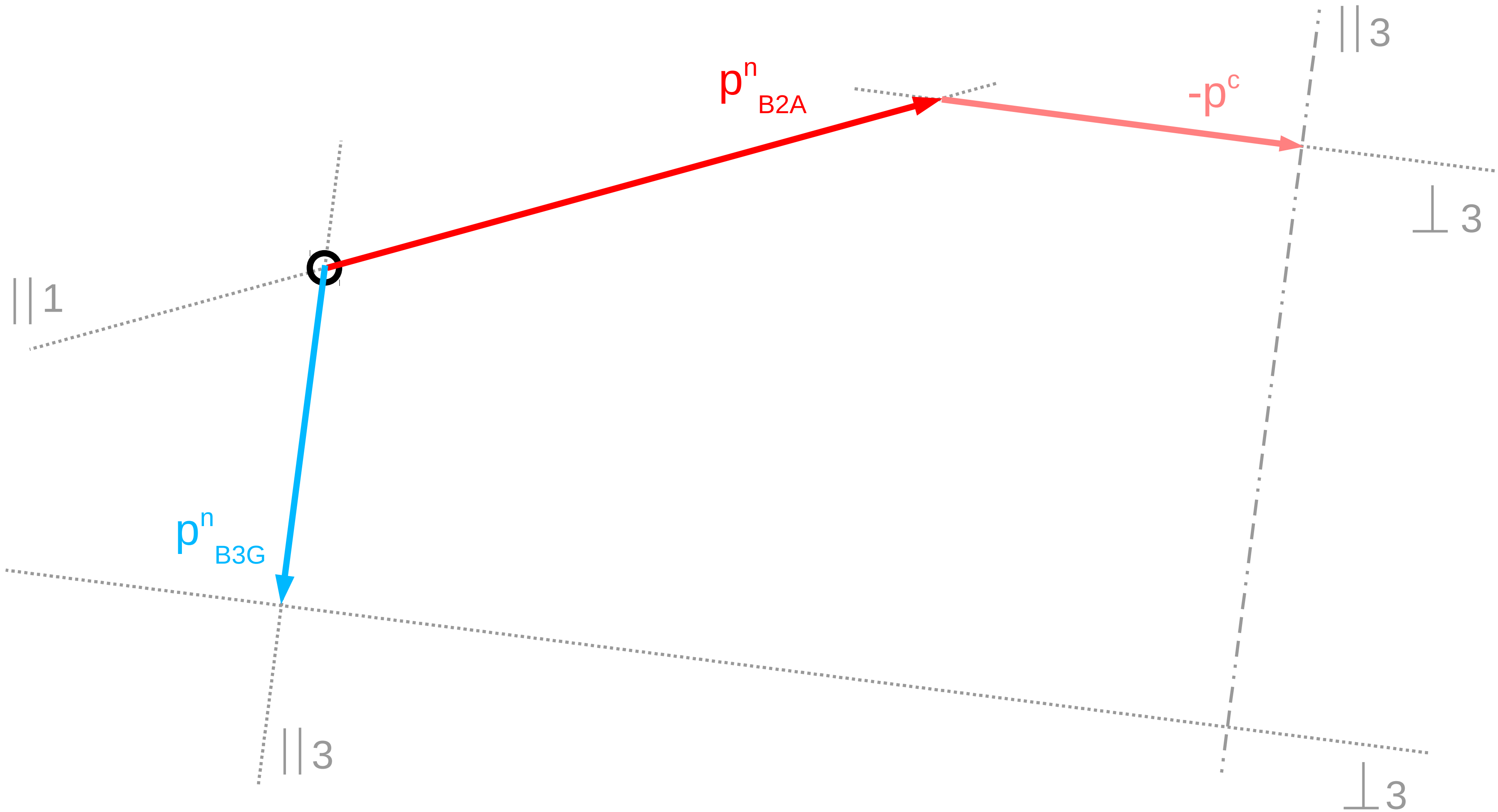
Plan przyspieszeń

$$\underset{\parallel 1}{p^{n}_{B2A}} - \underset{\perp 3}{p^{c}} - \underset{\parallel 3}{p^{w}_{B2B3}} = \underset{\parallel 3}{p^{n}_{B3G}} + \underset{\perp 3}{p^{t}_{B3G}}$$



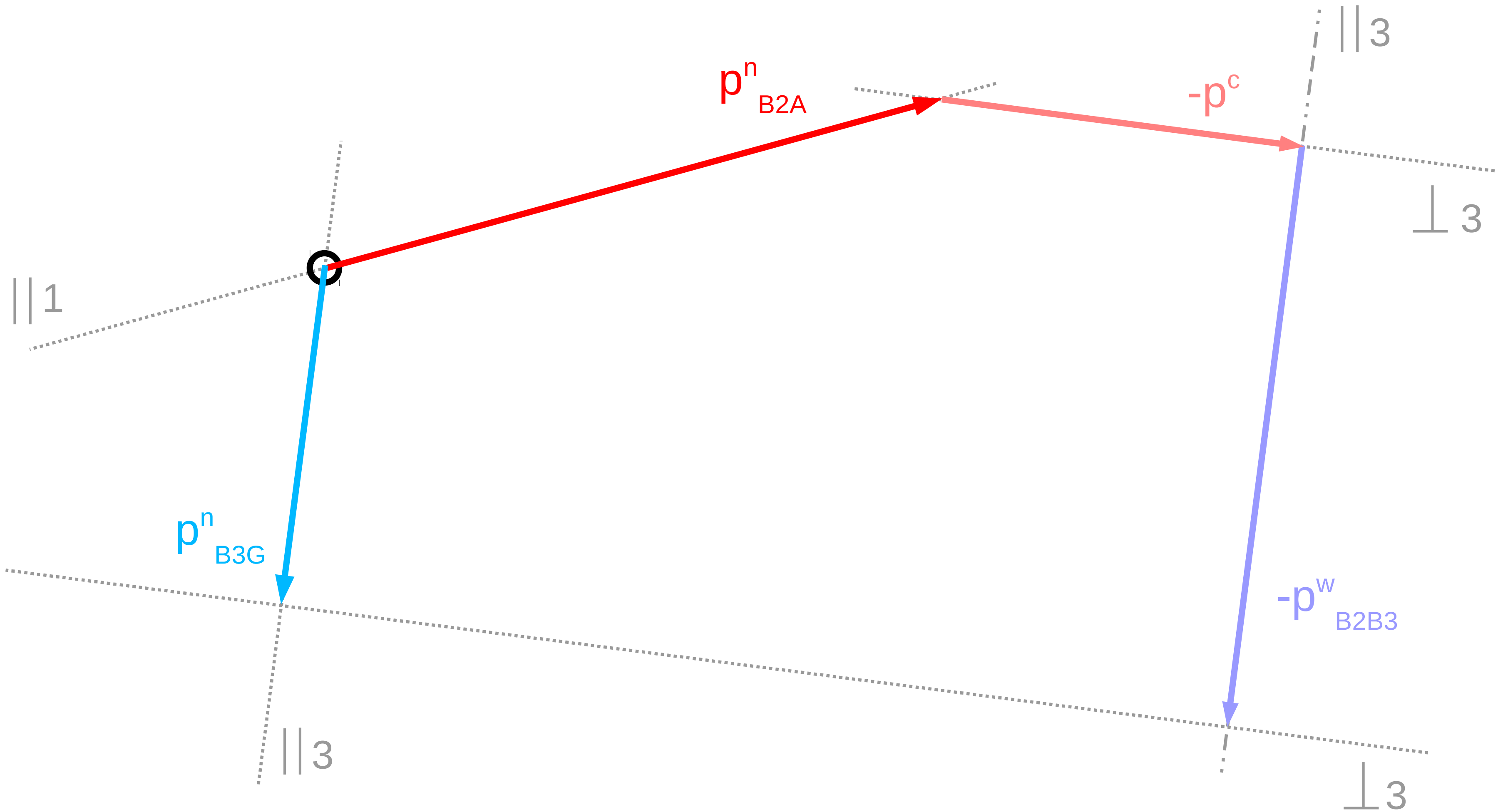
Plan przyspieszeń

$$\underset{\parallel 1}{\underline{\underline{p^n_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^c}}} - \underset{\parallel 3}{\underline{p^w_{B2B3}}} = \underset{\parallel 3}{\underline{\underline{p^n_{B3G}}}} + \underset{\perp 3}{\underline{p^t_{B3G}}}$$



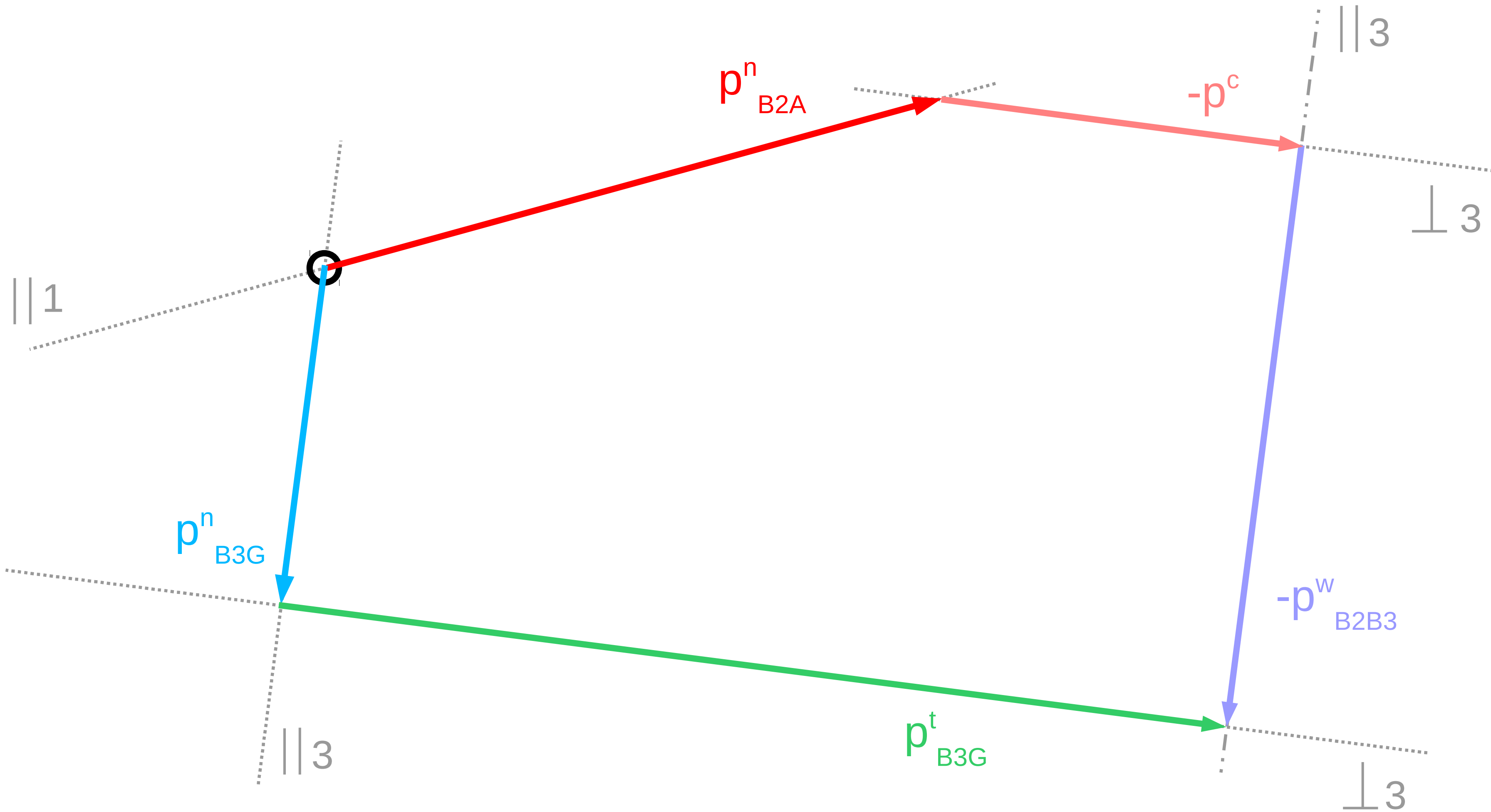
Plan przyspieszeń

$$\underset{\parallel 1}{\underline{\underline{p^n_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^c}}} - \underset{\parallel 3}{\underline{p^w_{B2B3}}} = \underset{\parallel 3}{\underline{\underline{p^n_{B3G}}}} + \underset{\perp 3}{\underline{p^t_{B3G}}}$$



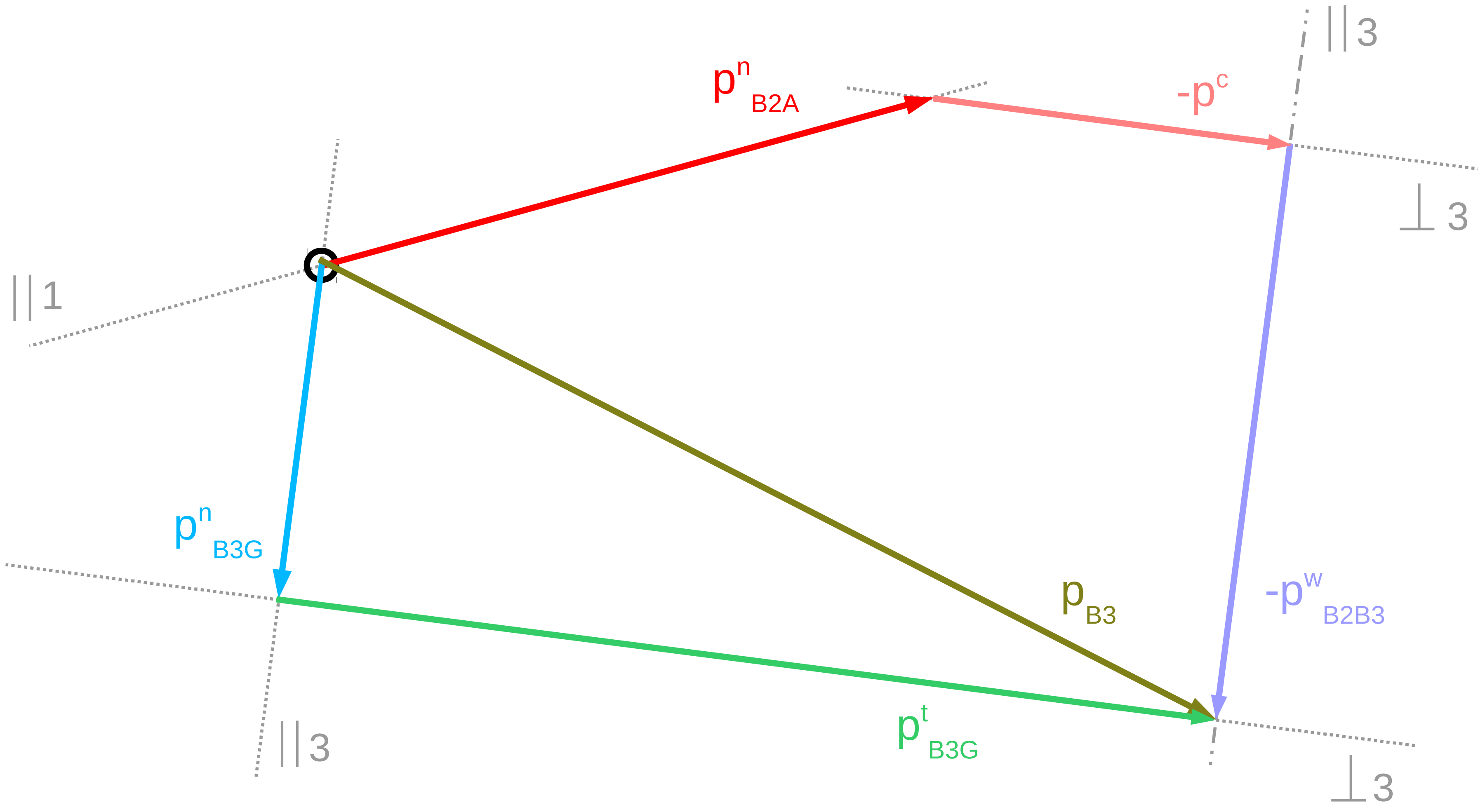
Plan przyspieszeń

$$\underset{\parallel 1}{\underline{\underline{p^n_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^c}}} - \underset{\parallel 3}{\underline{p^w_{B2B3}}} = \underset{\parallel 3}{\underline{\underline{p^n_{B3G}}}} + \underset{\perp 3}{\underline{p^t_{B3G}}}$$

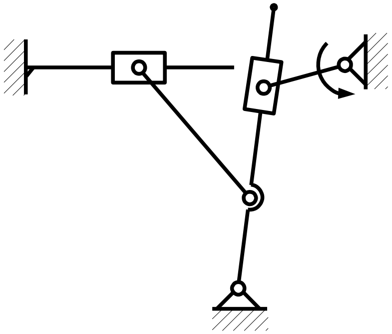


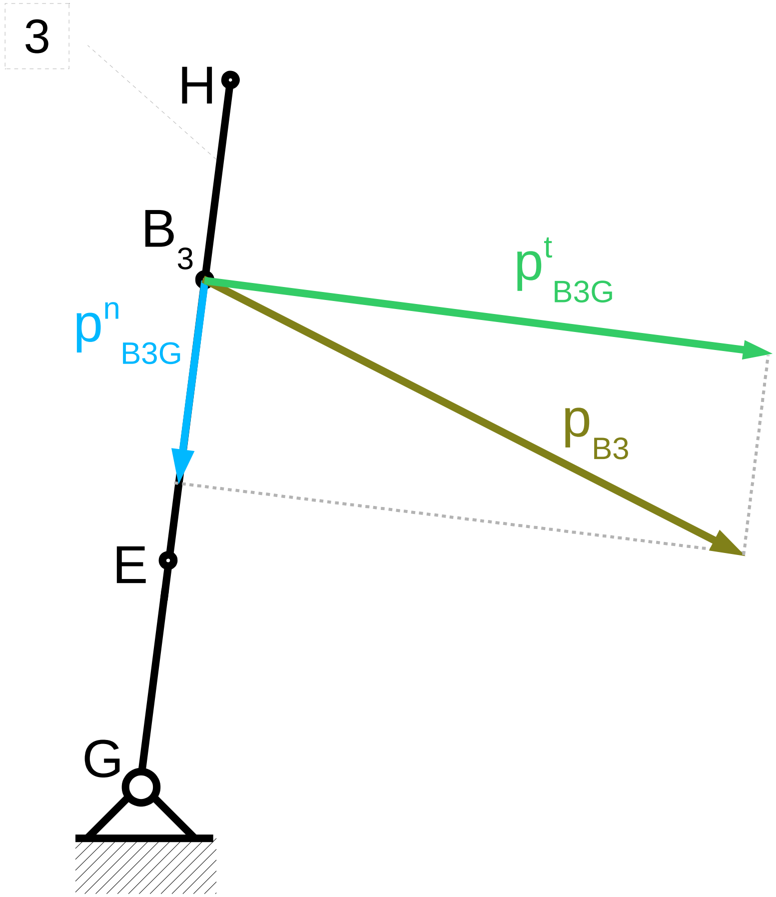
Plan przyspieszeń

$$\underset{||\,1}{\underline{\underline{p^{n}_{B2A}}}} - \underset{\perp 3}{\underline{\underline{p^{c}}}} - \underset{||\,3}{\underline{p^{w}_{B2B3}}} = \underset{||\,3}{\underline{\underline{p^{n}_{B3G}}}} + \underset{\perp 3}{\underline{p^{t}_{B3G}}}$$

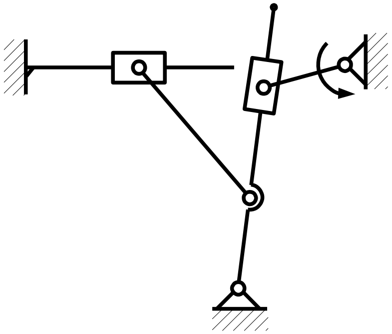


Przyspieszenia dla elementu 3

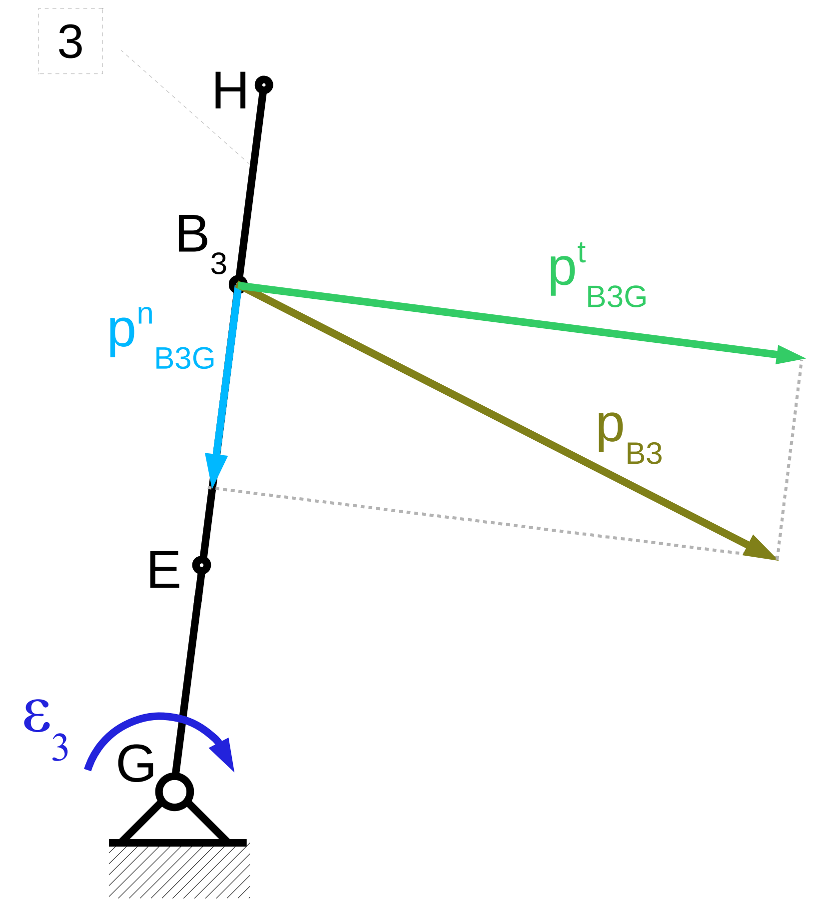




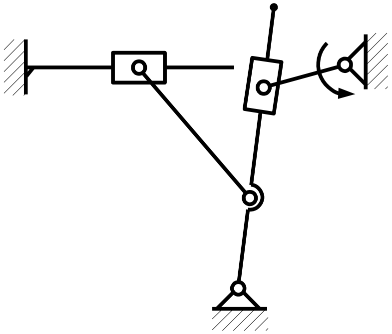
Przyspieszenia dla elementu 3



$$\varepsilon_3 = \frac{|p^t_{B3G}|}{|B_3G|}$$



Przyspieszenia dla punktu E

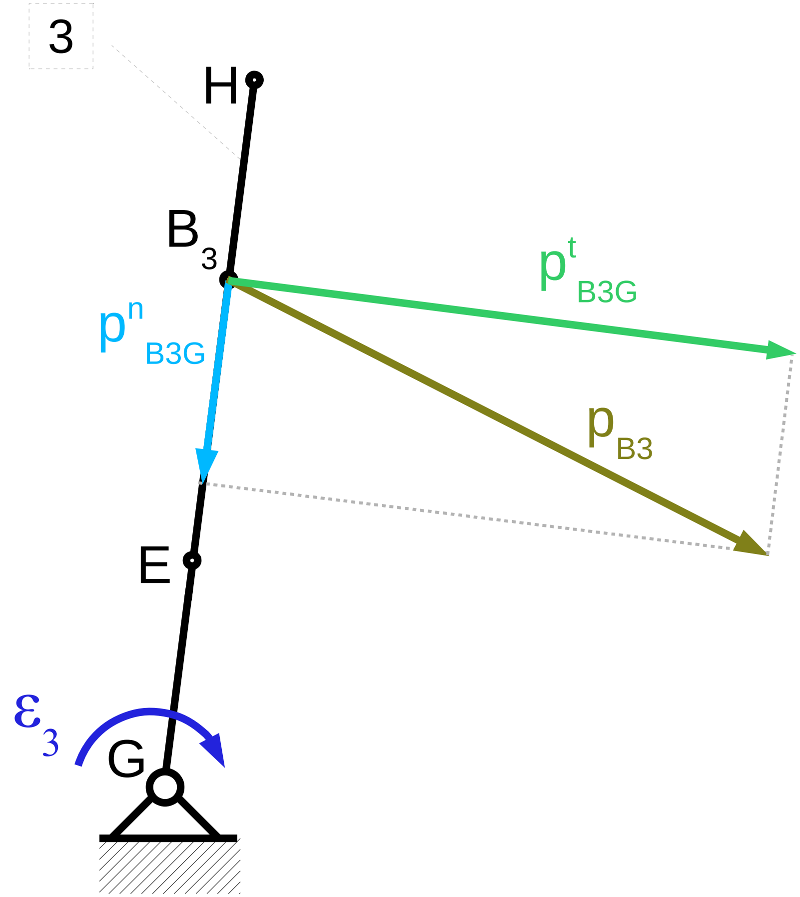


$$\varepsilon_3 = \frac{|p^t_{B3G}|}{|B_3G|}$$

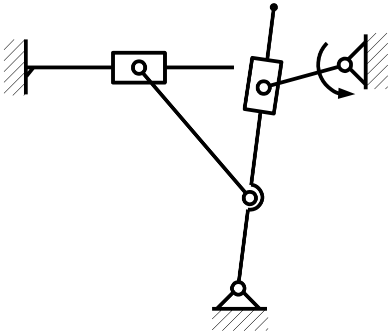
$$p_E = p_G + p^n_{EG} + p^t_{EG}$$

$$|p^n_{EG}| = \omega_3^{\ 2} \, |EG|$$

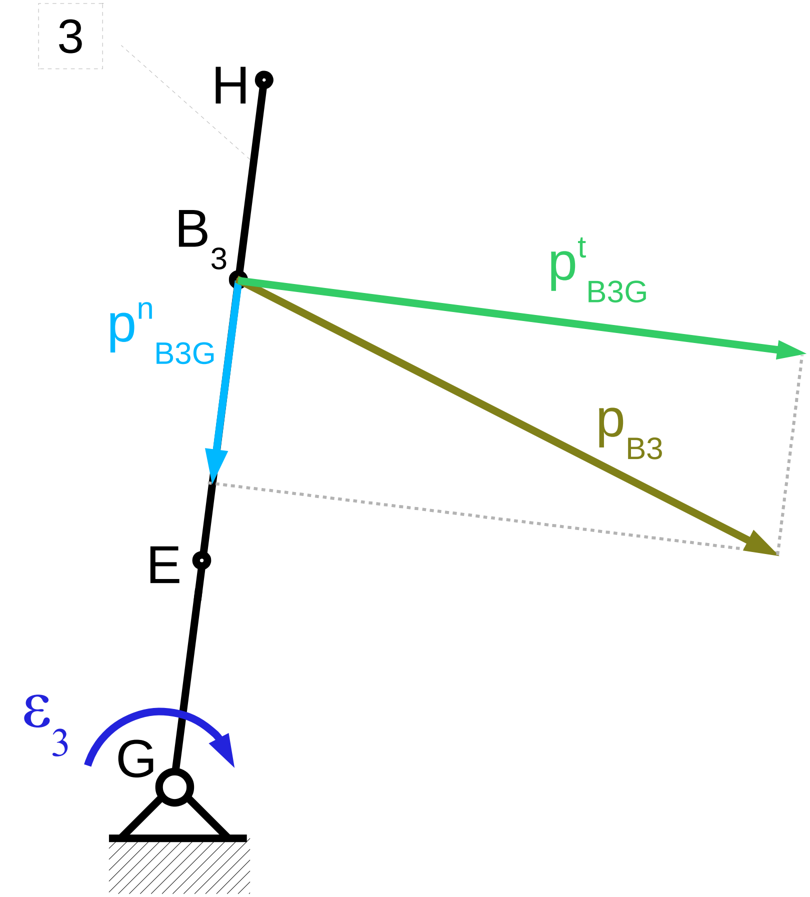
$$|p^t_{EG}| = \varepsilon_3 \, |EG|$$



Przyspieszenia dla punktu E



$$\varepsilon_3 = \frac{|p^t_{B3G}|}{|B_3G|}$$



$$p_E = p_G + p^n_{EG} + p^t_{EG}$$

$$|p^n_{EG}| = \omega_3^2\,|EG|$$

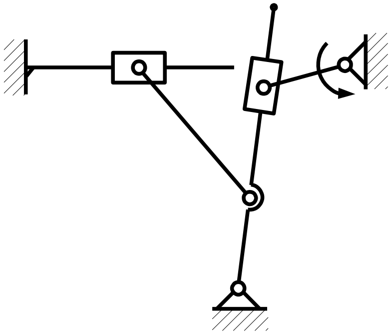
$$|p^t_{EG}| = \varepsilon_3\,|EG|$$

podstawiamy zależności

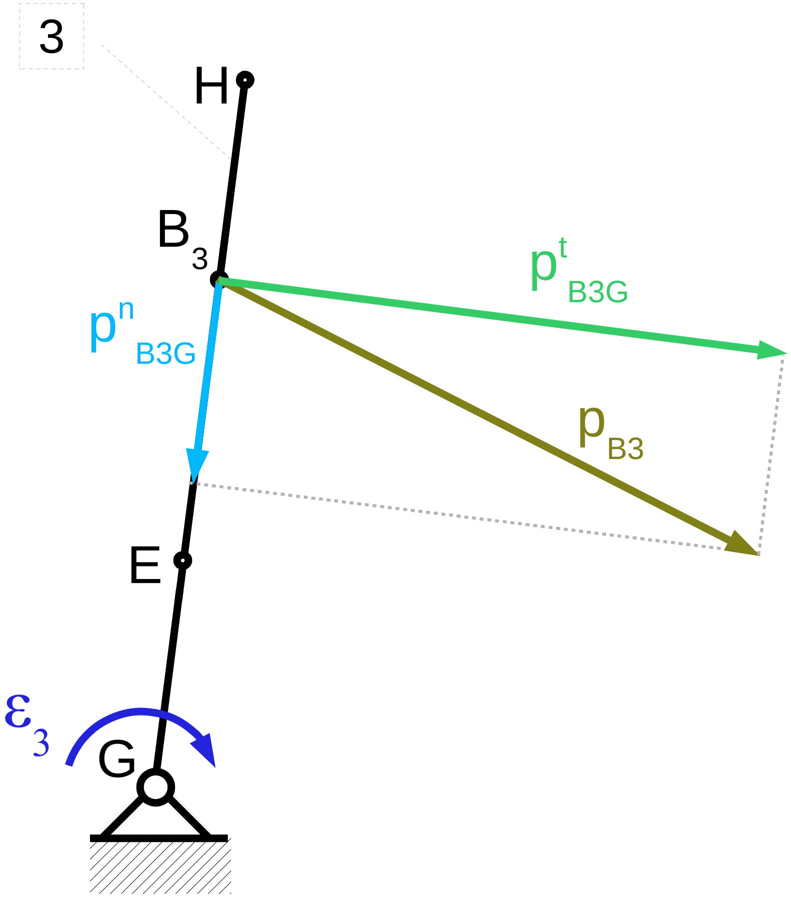
$$|p^n_{B3G}| = \omega_3^2\,|B_3G|$$

$$|p^t_{B3G}| = \varepsilon_3\,|B_3G|$$

Przyspieszenia dla punktu E



$$\varepsilon_3 = \frac{|p^t_{B3G}|}{|B_3G|}$$



$$p_E = p_G + p^n_{EG} + p^t_{EG}$$

$$|p^n_{EG}| = \omega_3^2 \, |EG| = |p^n_{B3G}| \frac{|EG|}{|B_3G|}$$

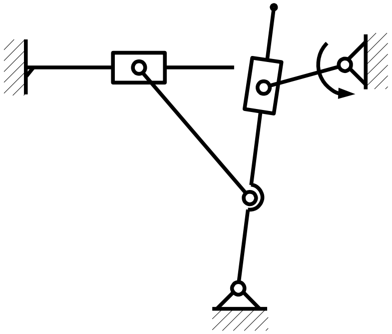
$$|p^t_{EG}| = \varepsilon_3 \, |EG| = |p^t_{B3G}| \frac{|EG|}{|B_3G|}$$

podstawiamy zależności

$$|p^n_{B3G}| = \omega_3^2 \, |B_3G|$$

$$|p^t_{B3G}| = \varepsilon_3 \, |B_3G|$$

Przyspieszenia dla punktu E



$$\varepsilon_3 = \frac{|p^t_{B3G}|}{|B_3G|}$$

$$p_E = p_G + p^n_{EG} + p^t_{EG}$$

$$|p^n_{EG}| = \omega_3^2 \, |EG| = |p^n_{B3G}| \, \frac{|EG|}{|B_3G|}$$

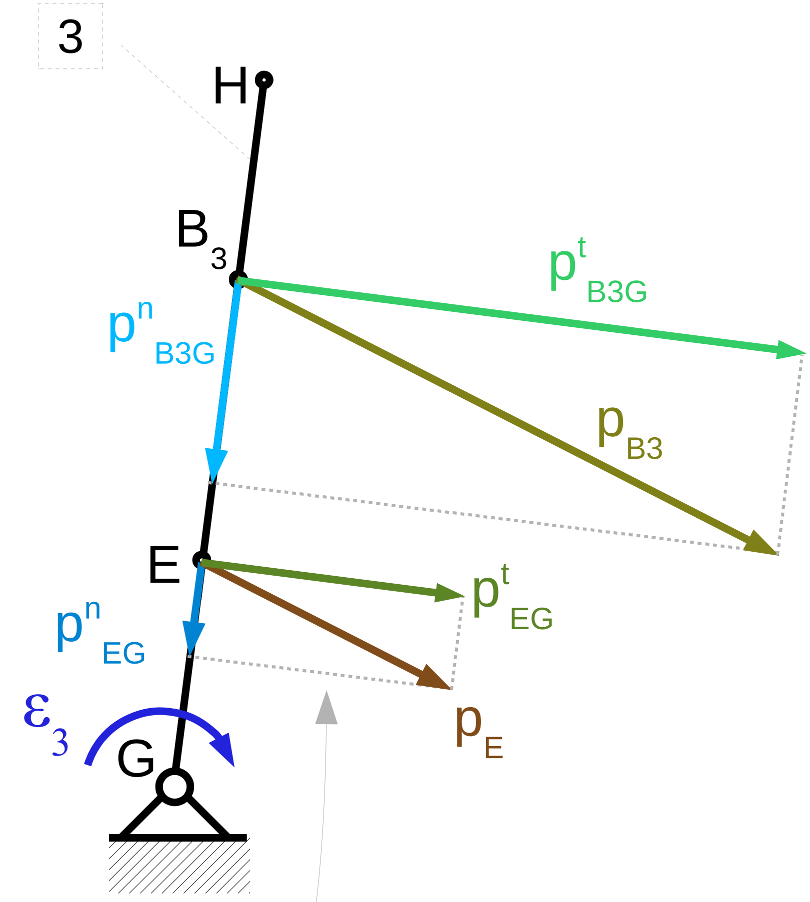
$$|p^t_{EG}| = \varepsilon_3 \, |EG| = |p^t_{B3G}| \, \frac{|EG|}{|B_3G|}$$

podstawiamy zależności

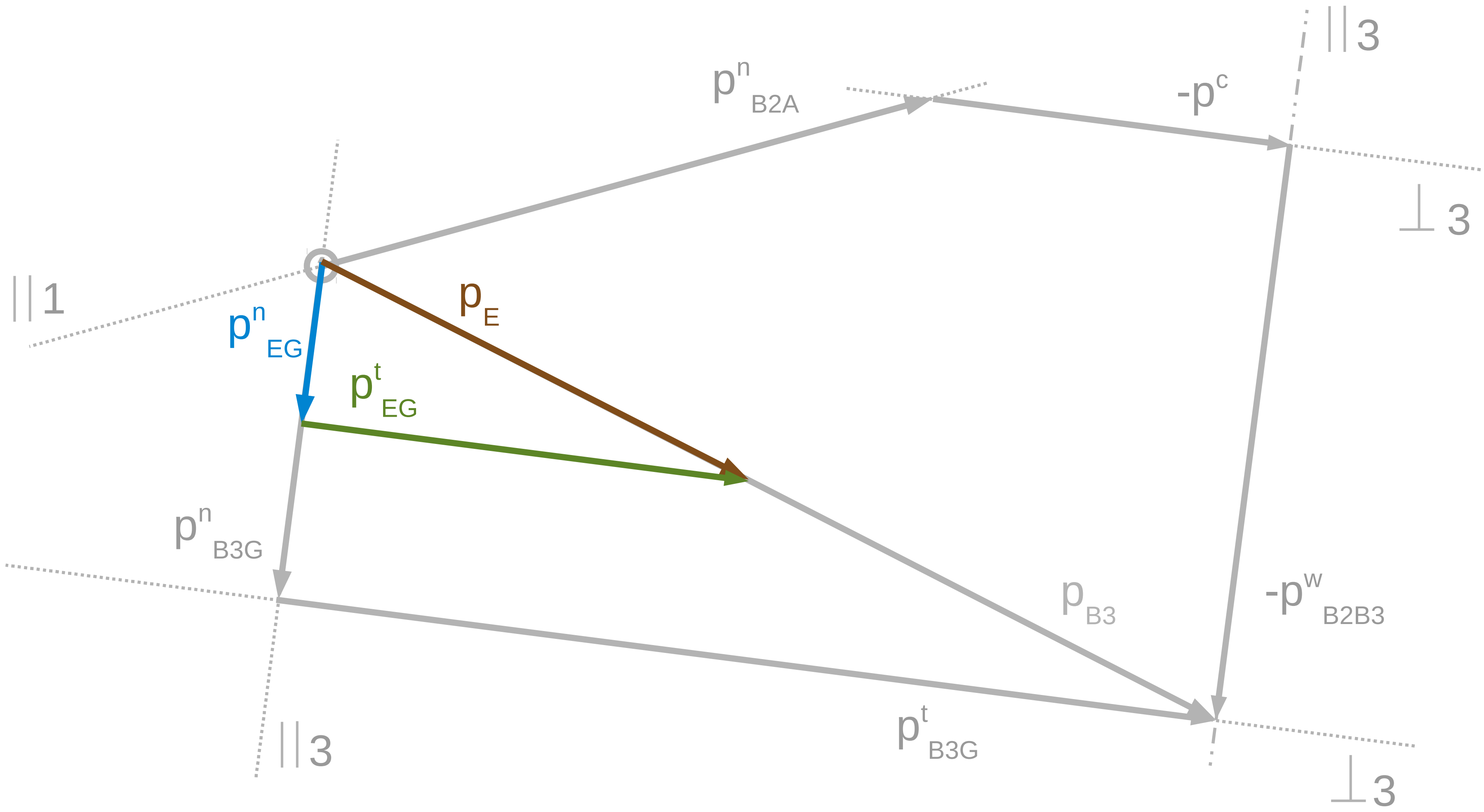
$$|p^n_{B3G}| = \omega_3^2 \, |B_3G|$$

$$|p^t_{B3G}| = \varepsilon_3 \, |B_3G|$$

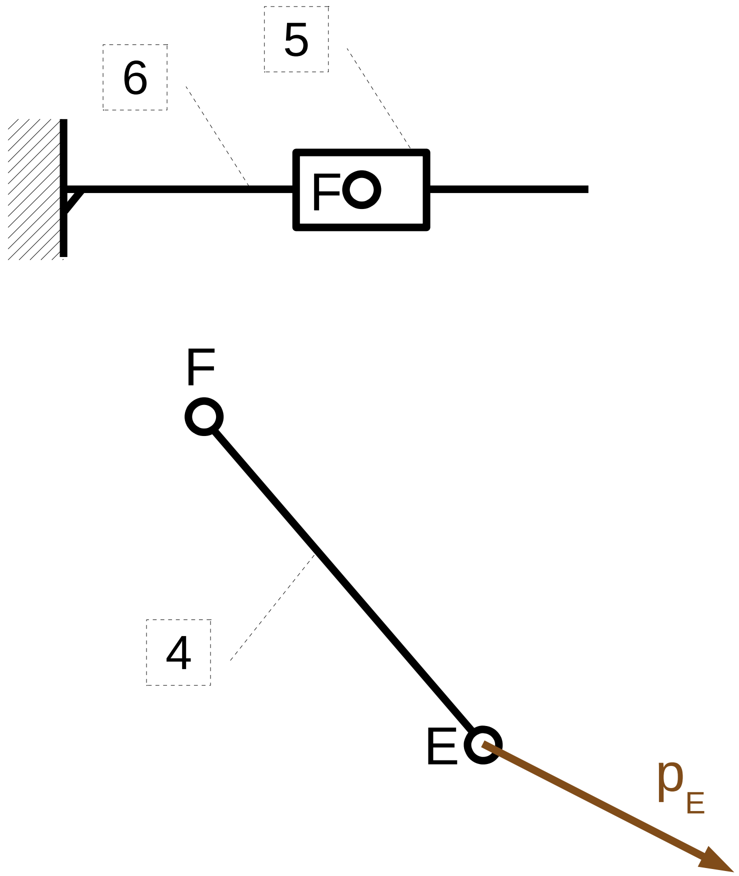
i mamy proporcjonalnie mniejsze przyspieszenia



Plan przyspieszeń

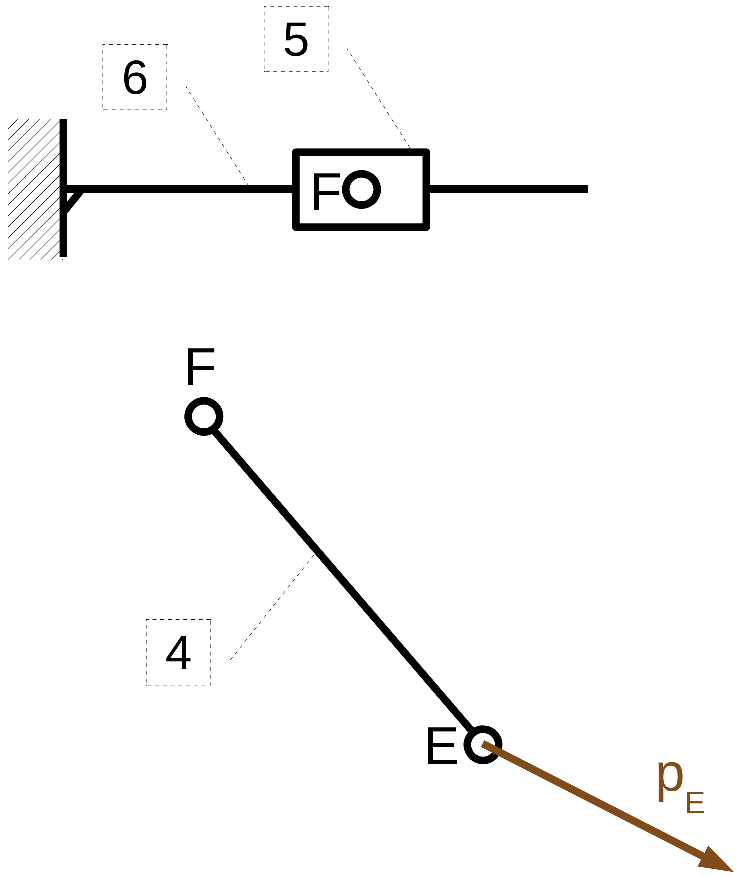


Przyspieszenia punktów elementu 4

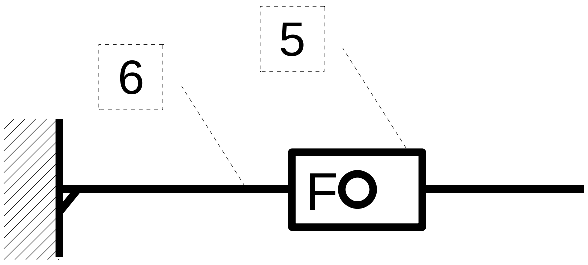


Przyspieszenia punktów elementu 4

$$p_F = p_E + p^n_{FE} + p^t_{FE}$$



Przyspieszenia punktów elementu 4

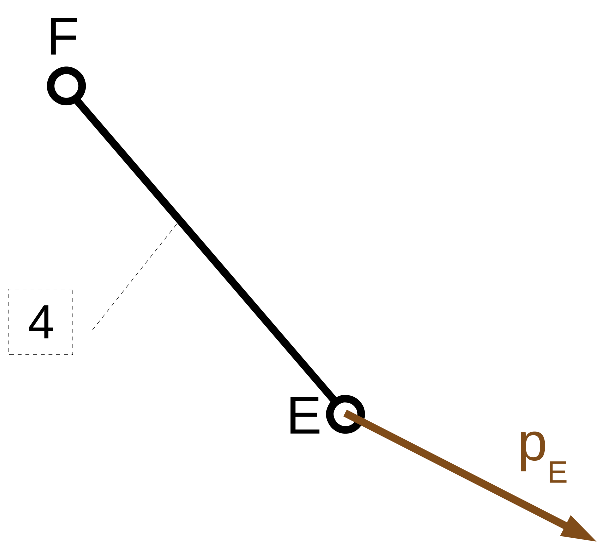


$$p_F = \underline{\underline{p_E}} + \underline{\underline{p^n_{FE}}} + \underline{p^t_{FE}}$$

$|| 4$ $\perp 4$

$$|p^n_{FE}| = \omega_4^{\,2}\,|FE|$$

z planu prędkości



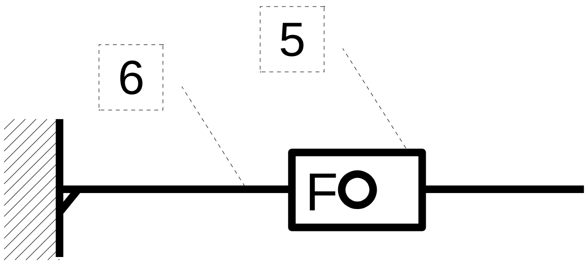
Przyspieszenia punktów elementu 4

$$\underline{p_F} = \underline{\underline{p_E}} + \underline{\underline{p^n_{FE}}} + \underline{p^t_{FE}}$$

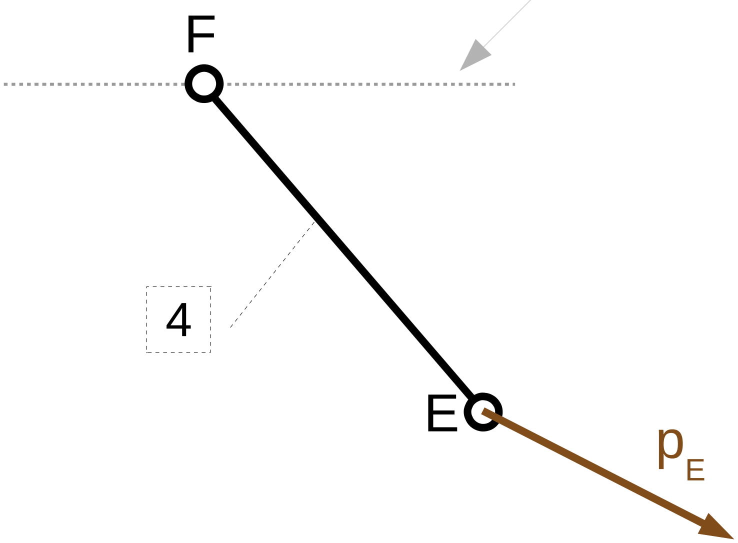
$\parallel 6$ $\quad\quad\quad\quad\quad\quad$ $\parallel 4$ $\quad$ $\perp 4$

$$|p^n_{FE}| = \omega_4^{\,2}\,|FE|$$

z planu prędkości



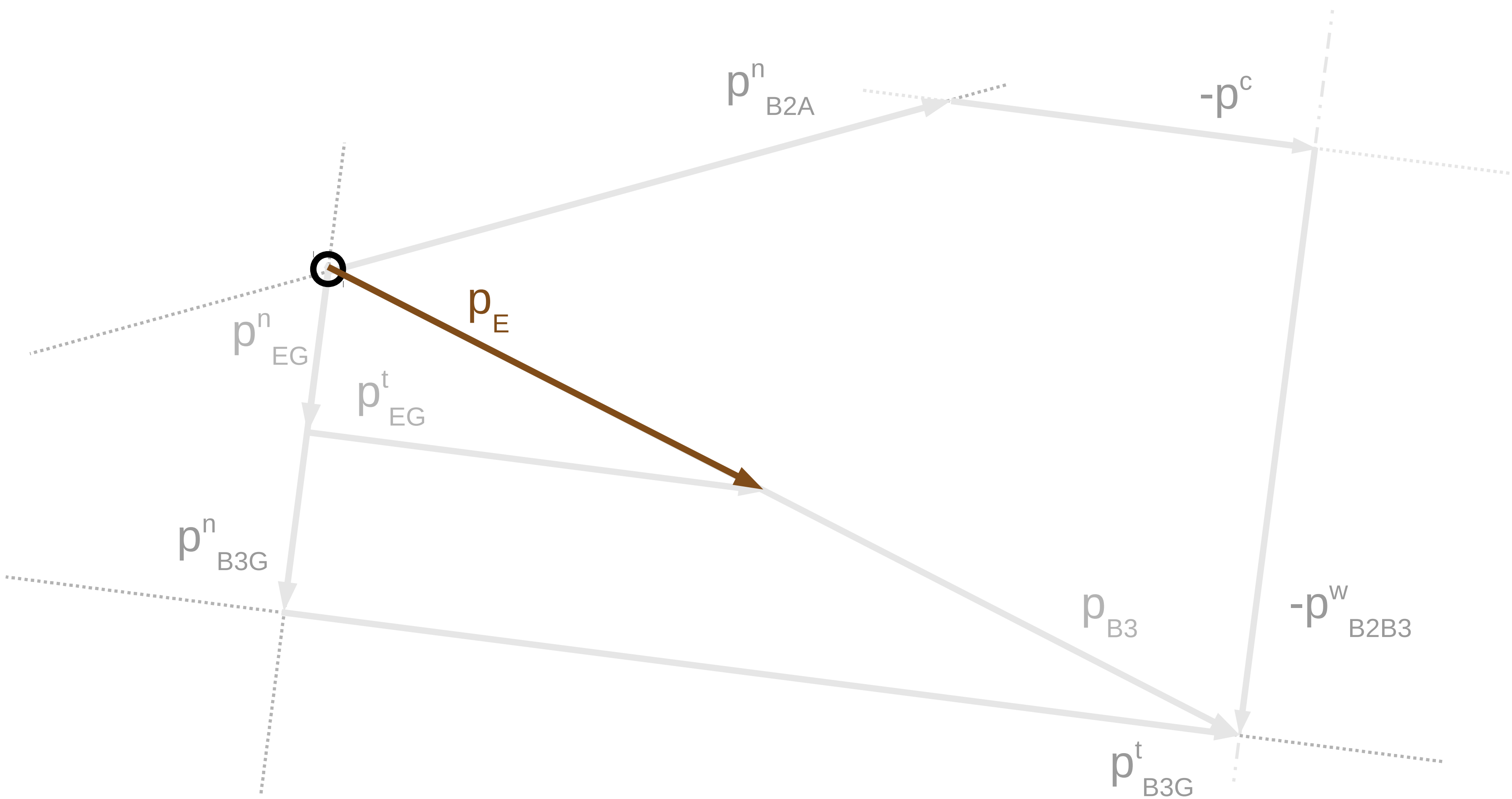
punkt F porusza się po nieruchomym elemencie 6 – przyspieszenie jest styczne do toru ruchu



Plan przyspieszeń

$$\underline{p_F} = \underline{\underline{p_E}} + \underline{\underline{p^n_{FE}}} + \underline{p^t_{FE}}$$

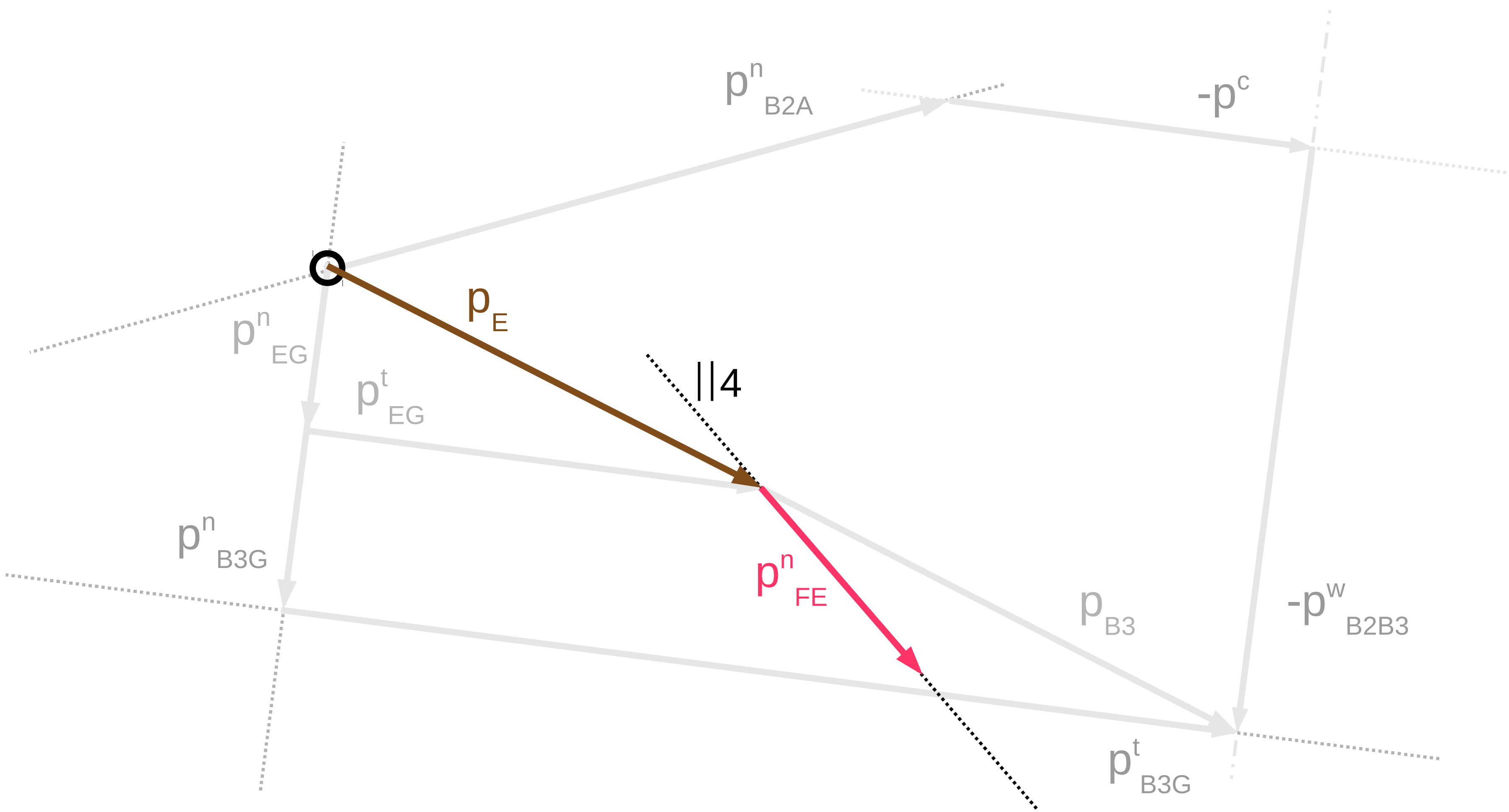
$$\parallel 6 \qquad\qquad\qquad \parallel 4 \qquad \perp 4$$



Plan przyspieszeń

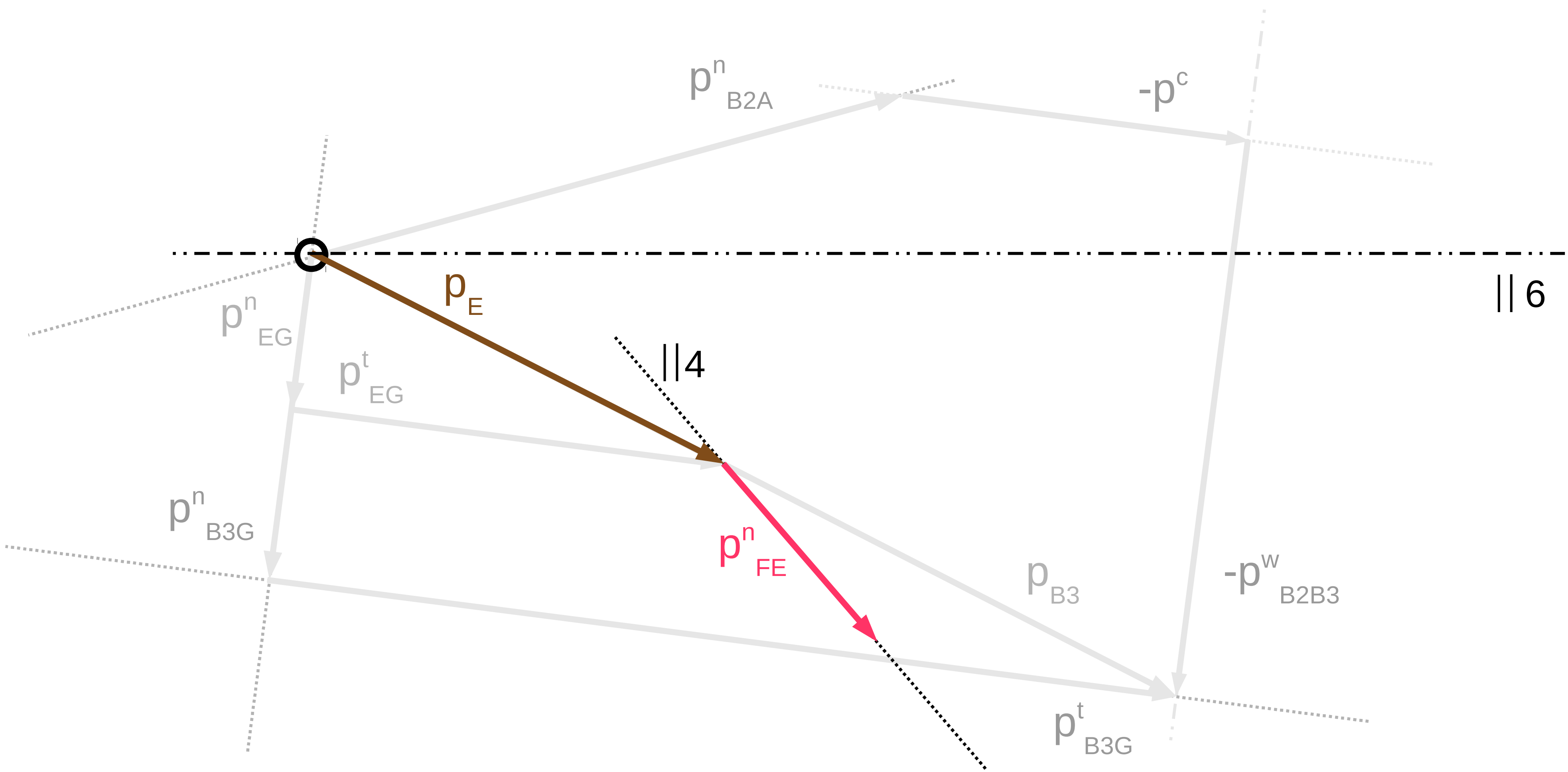
$$\underline{p_F} = \underline{\underline{p_E}} + \underline{\underline{p^n_{FE}}} + \underline{p^t_{FE}}$$

$|| 6$ $|| 4$ $\perp 4$



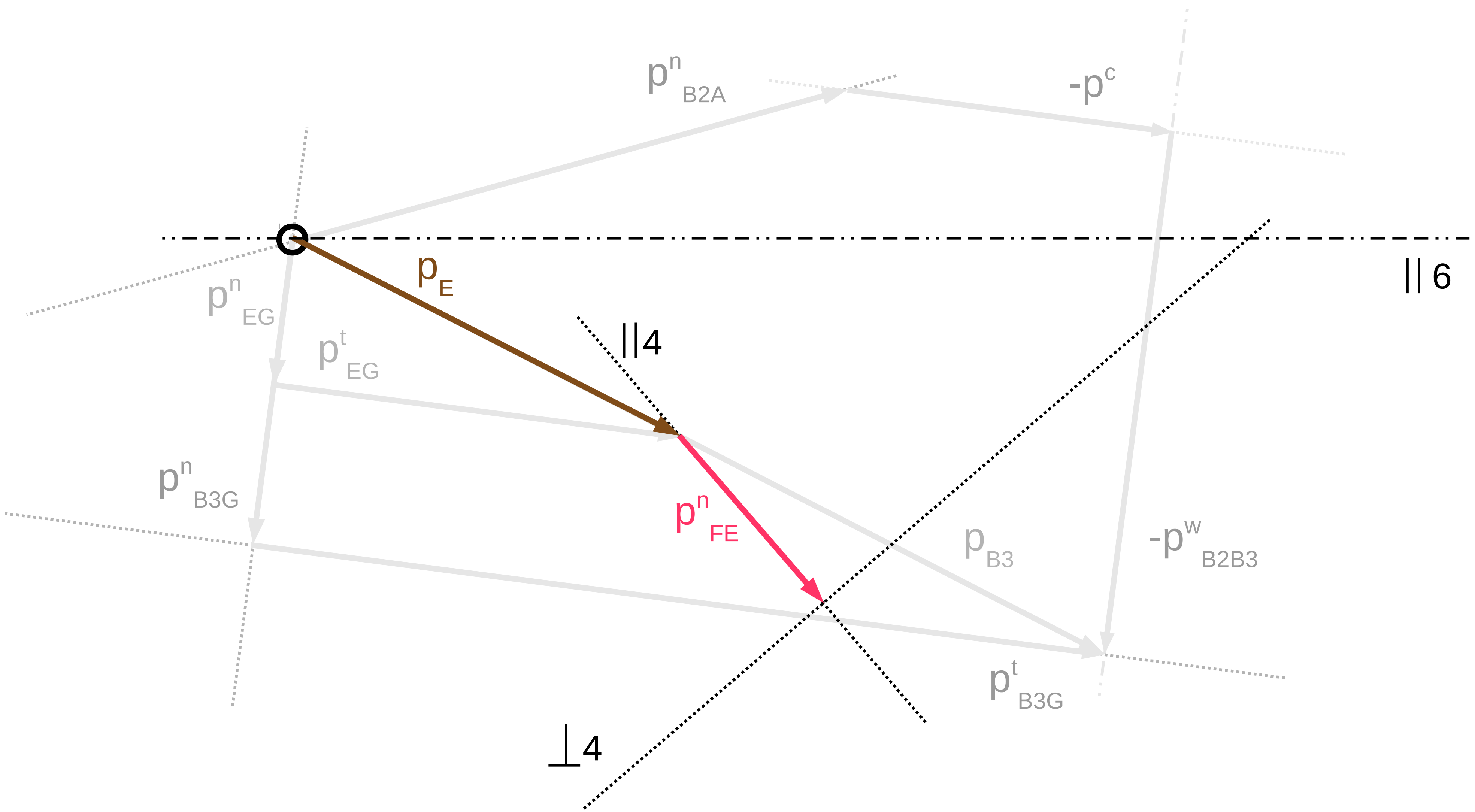
Plan przyspieszeń

$$\underset{||6}{\underline{p_F}} = \underset{}{\underline{\underline{p_E}}} + \underset{||4}{\underline{\underline{p^n_{FE}}}} + \underset{\perp 4}{\underline{p^t_{FE}}}$$



Plan przyspieszeń

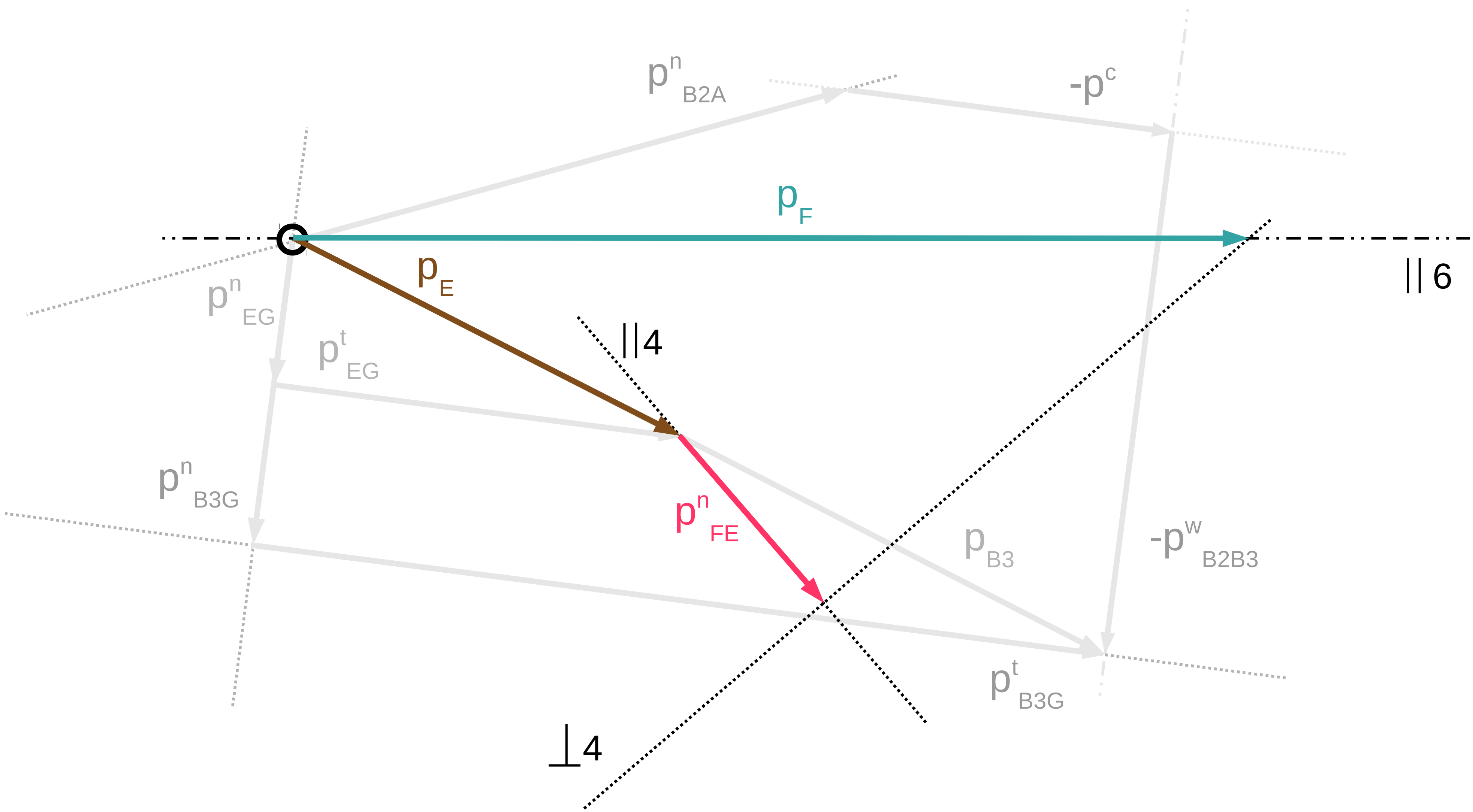
$$\underset{\parallel 6}{\underline{p_F}} = \underline{\underline{p_E}} + \underset{\parallel 4}{\underline{\underline{p^n_{FE}}}} + \underset{\perp 4}{\underline{p^t_{FE}}}$$



Plan przyspieszeń

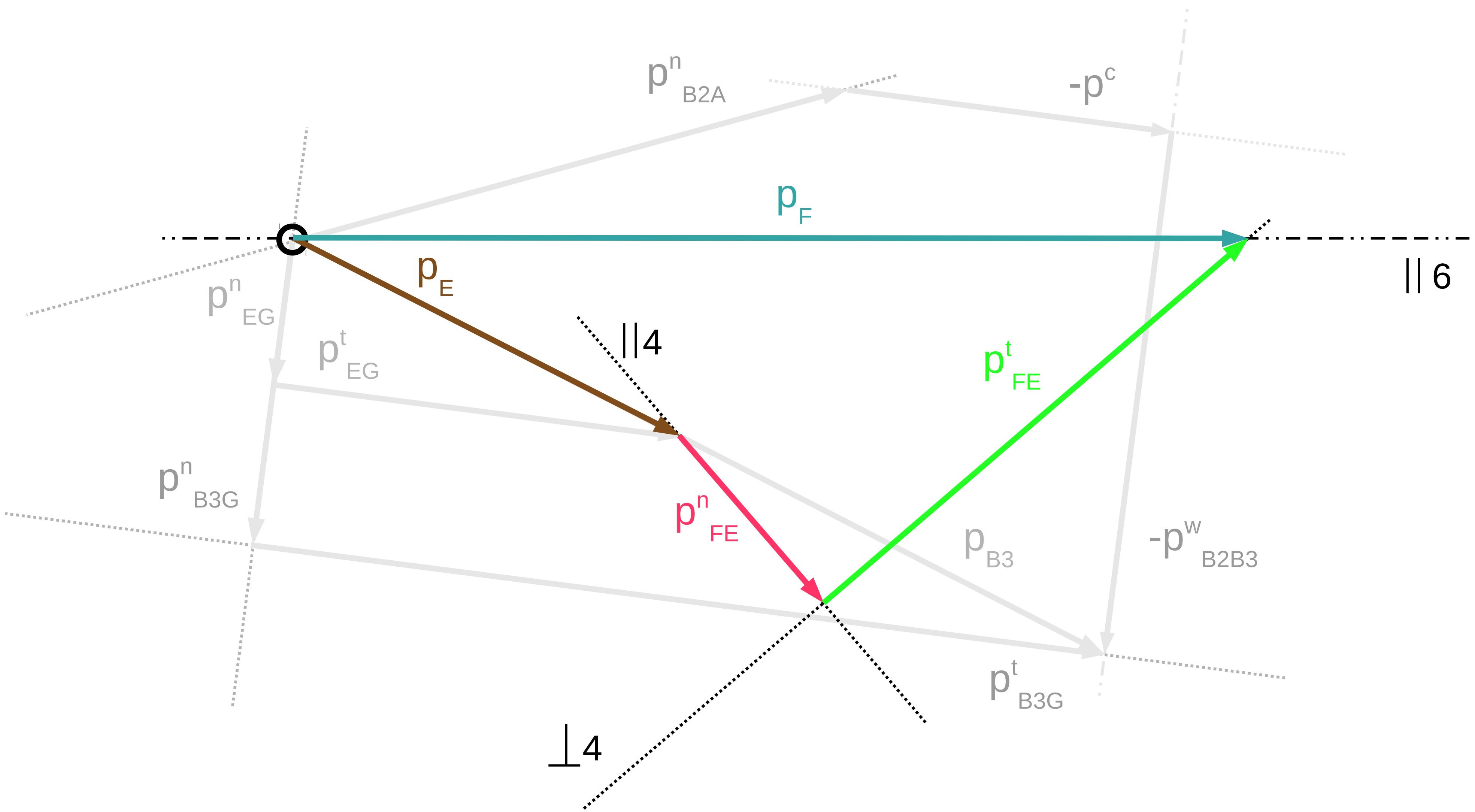
$$p_F = p_E + p^n_{FE} + p^t_{FE}$$

$\parallel 6$ $\parallel 4$ $\perp 4$

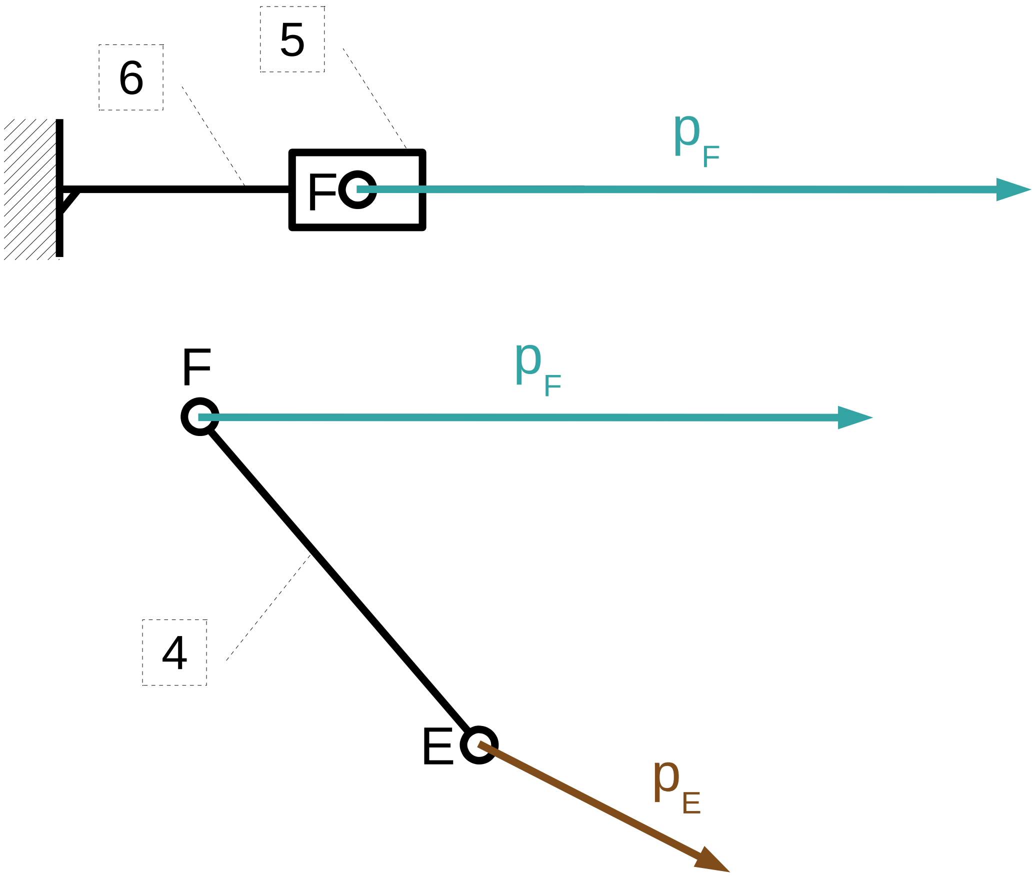


Plan przyspieszeń

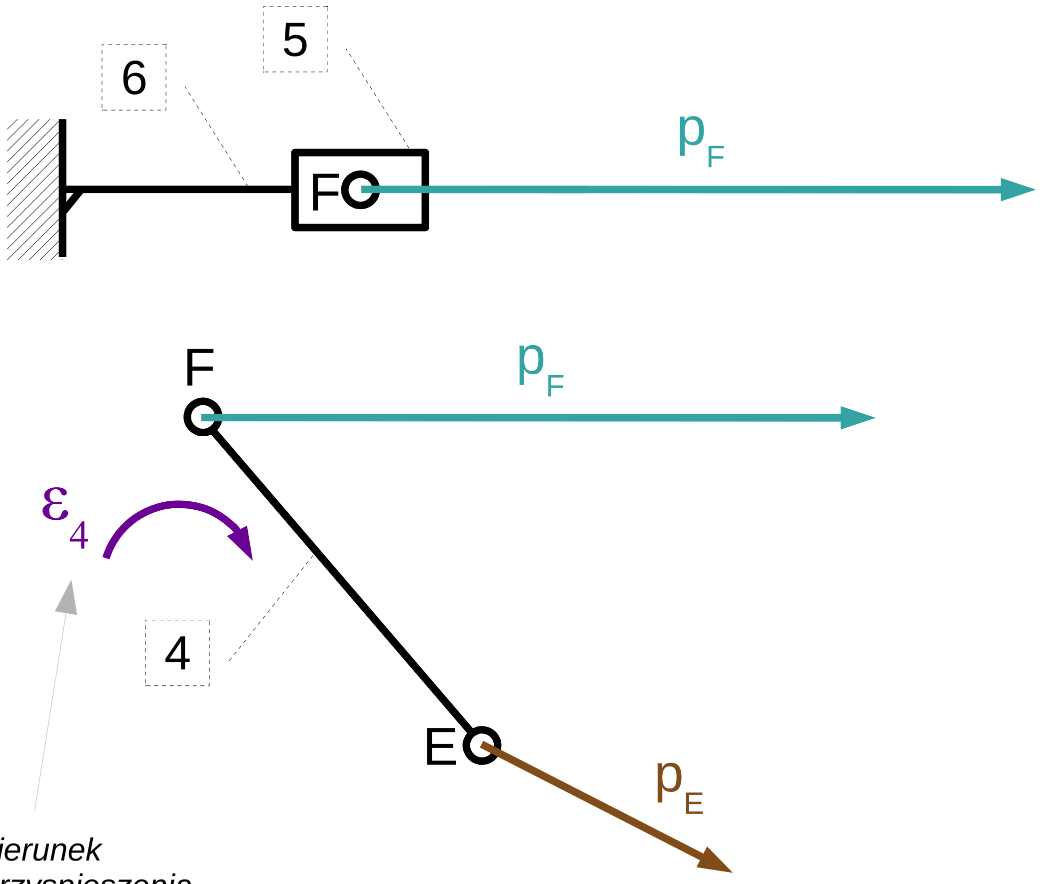
$$\underset{||6}{p_F} = \underset{}{p_E} + \underset{||4}{p^n_{FE}} + \underset{\perp 4}{p^t_{FE}}$$



Przyspieszenia punktów elementu 4

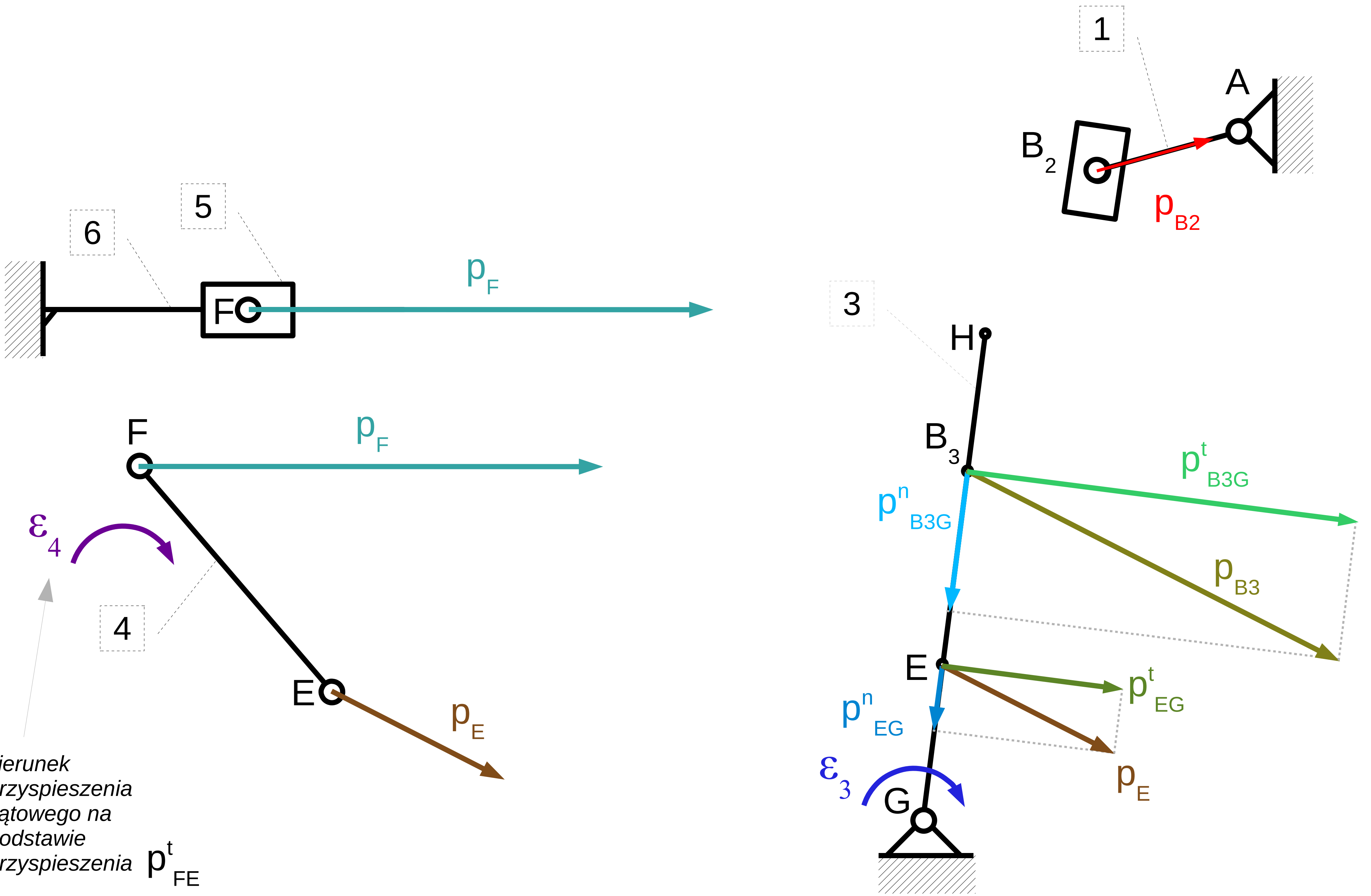


Przyspieszenia punktów elementu 4



kierunek przyspieszenia kątowego na podstawie przyspieszenia p^t_{FE}

Przyspieszenia w całym mechanizmie



kierunek przyspieszenia kątowego na podstawie przyspieszenia p^t_{FE}

Wybrane przyspieszenia w mechanizmie