

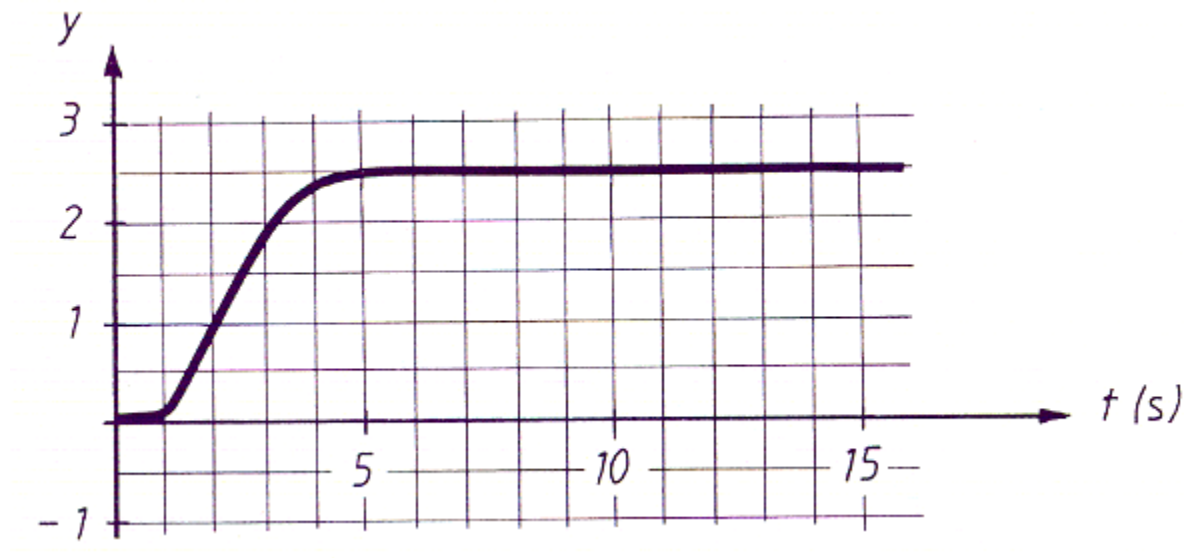
Reglerteknik Ö7



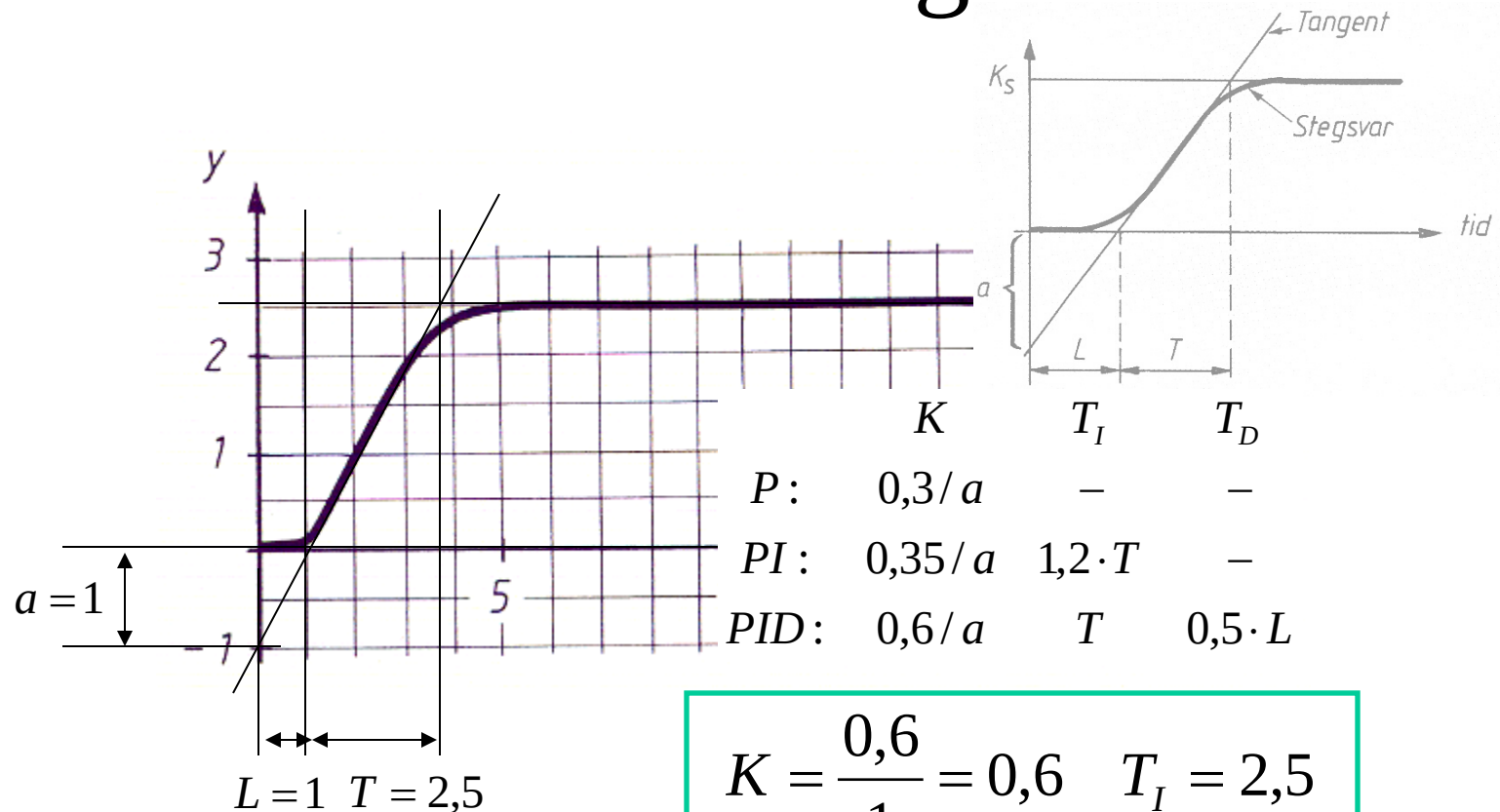
Köp övningshäfte på kårbokhandeln

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11.4 b PID-Stegsvarsmetod



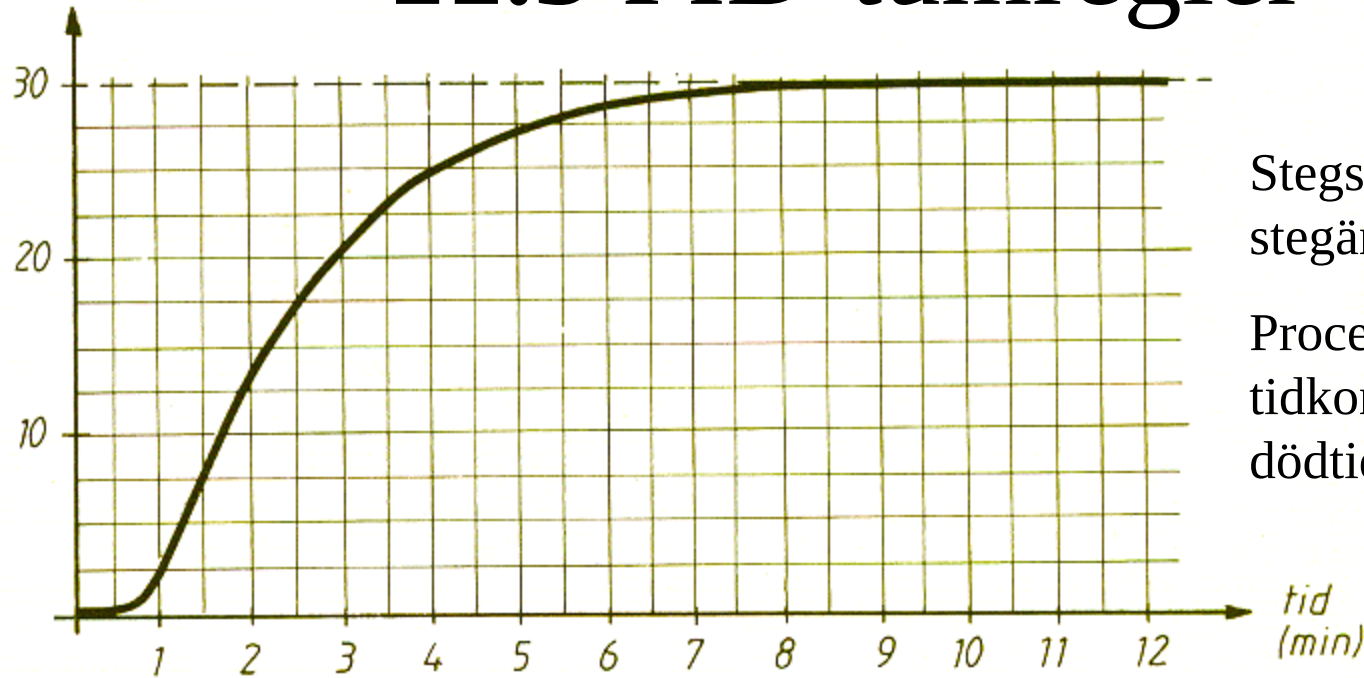
11.4 b lösn. PID-Stegsvarsmetod



$$K = \frac{0,6}{1} = 0,6 \quad T_I = 2,5$$

$$T_D = 0,5 \cdot 1 = 0,5$$

11.5 PID-tumregler



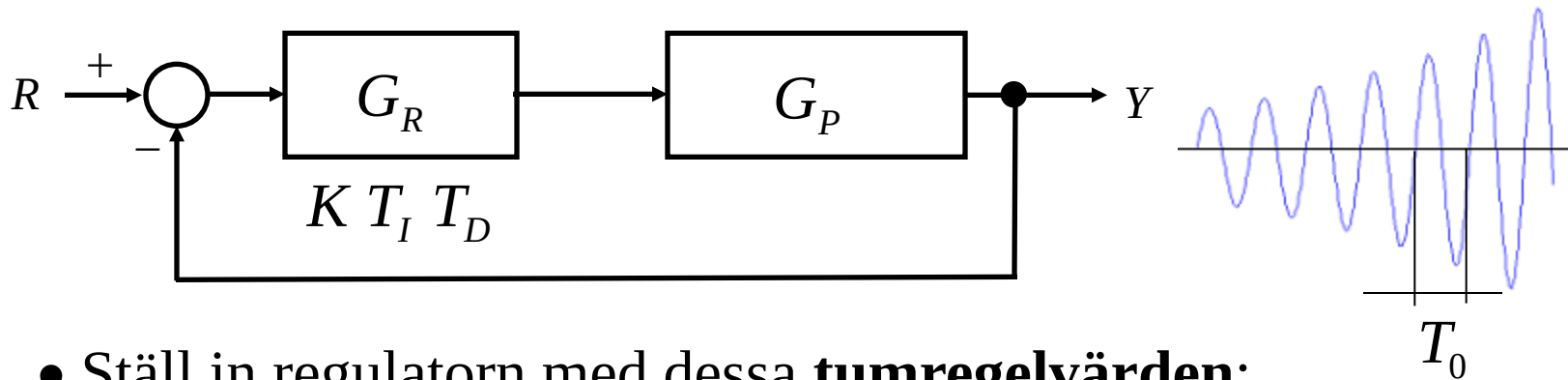
Stegsvar för ugn vid stegändring 1 kW.

Processen har två tidkonstanter och dödtiden är 0,5 min.

Ugnen ska PID-regleras. **a) ZN**-parametrar. **b) CHR**-parametrar. **c)** Vilken metod ger bäst dämpning av lågfrekventa processtörningar (dvs. har lägst J_V)?

$$J_V = \frac{T_I}{K}$$

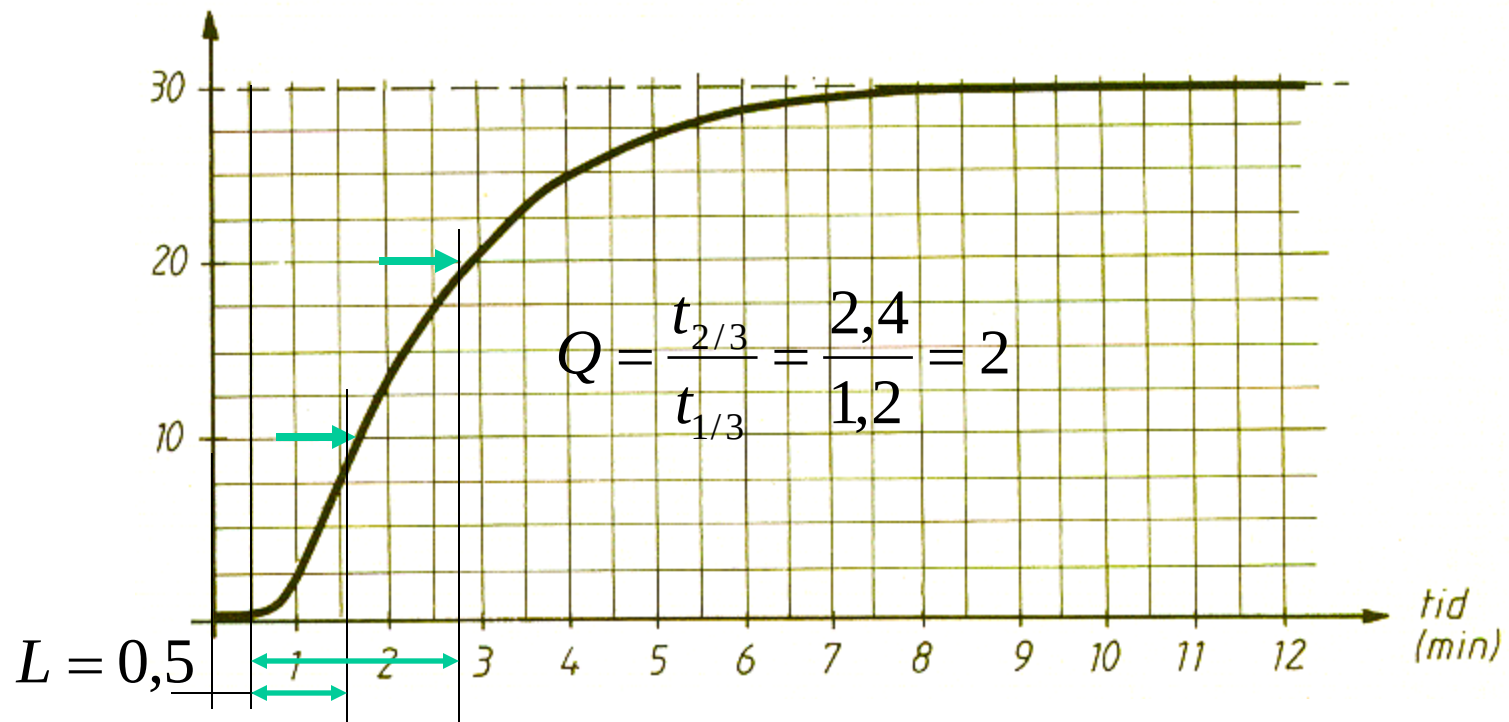
Ziegler-Nichols svängningsmetod



- Ställ in regulatoren med dessa **tumregelvärd**en:

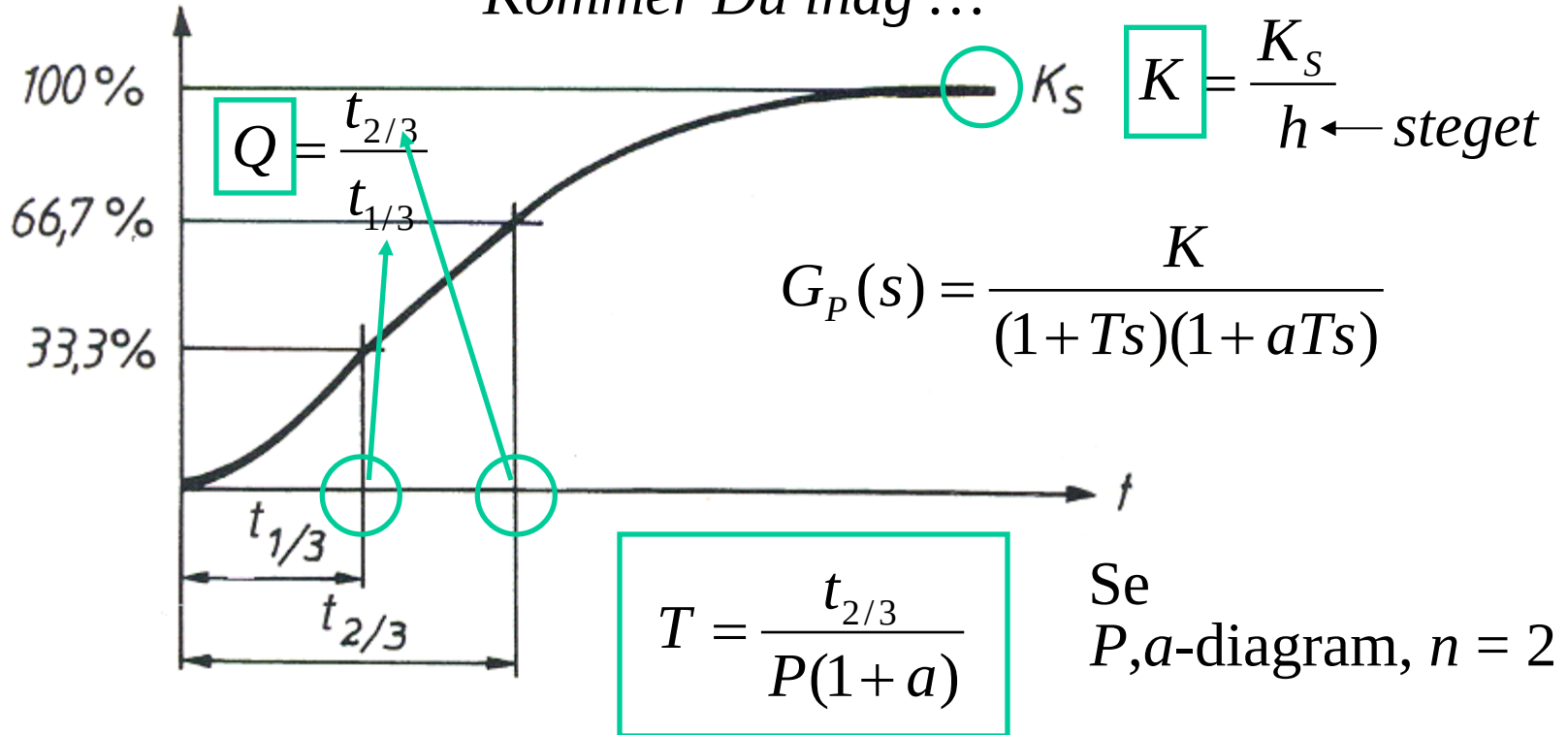
	K	T_I	T_D
P :	$0,5 \cdot K_0$	–	–
PI :	$0,45 \cdot K_0$	$0,85 \cdot T_0$	–
PID :	$0,6 \cdot K_0$	$0,5 \cdot T_0$	$0,125 \cdot T_0$

11.5 a lösn. PID-ZN



Processer med **två** tidkonstanter

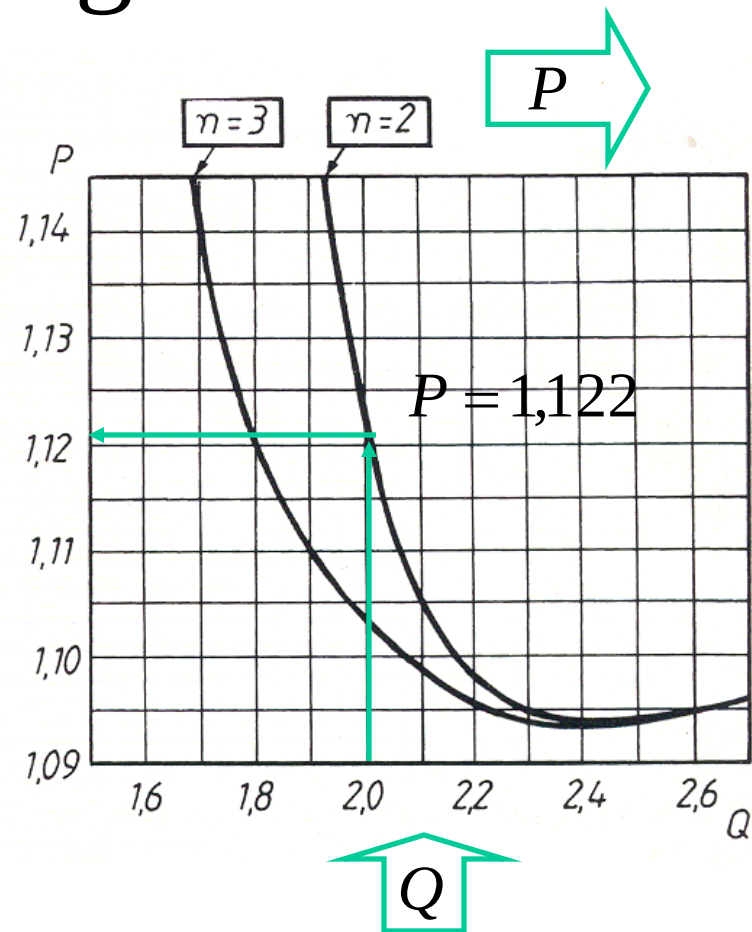
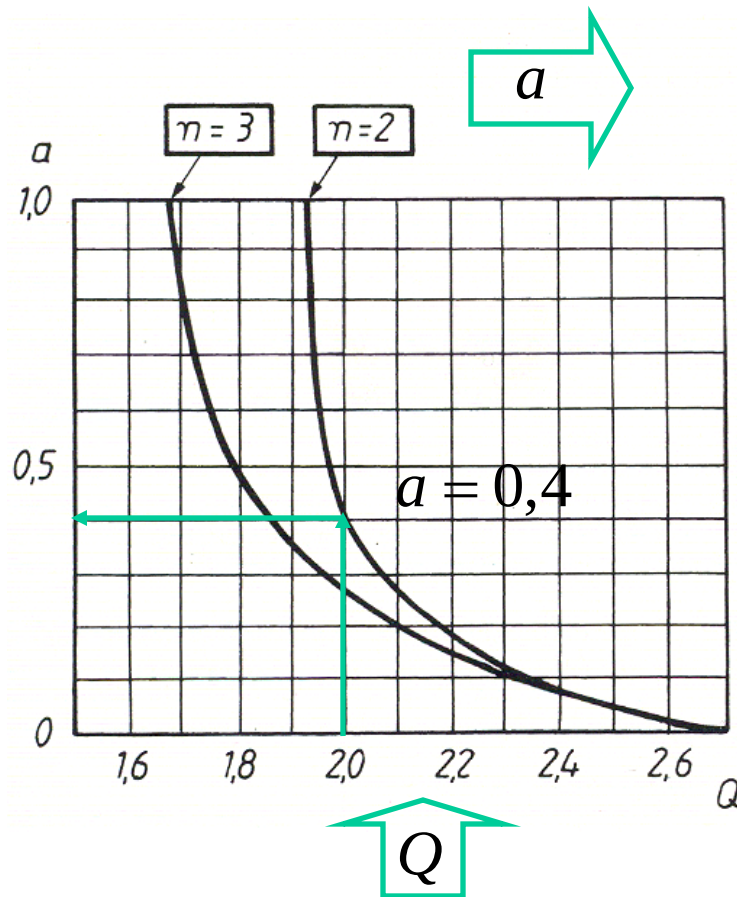
Kommer Du ihåg ...



$1,92 < Q < 2,71$ Ok med två tidkonstanter

P, a -diagram

$$Q = \frac{t_{2/3}}{t_{1/3}} = \frac{2,4}{1,2} = 2$$



11.5 a lösn. PID-ZN $G_P(s)$

$$T = \frac{t_{2/3}}{P(1+a)} = \frac{2,4}{1,122 \cdot (1+0,4)} = 1,5$$

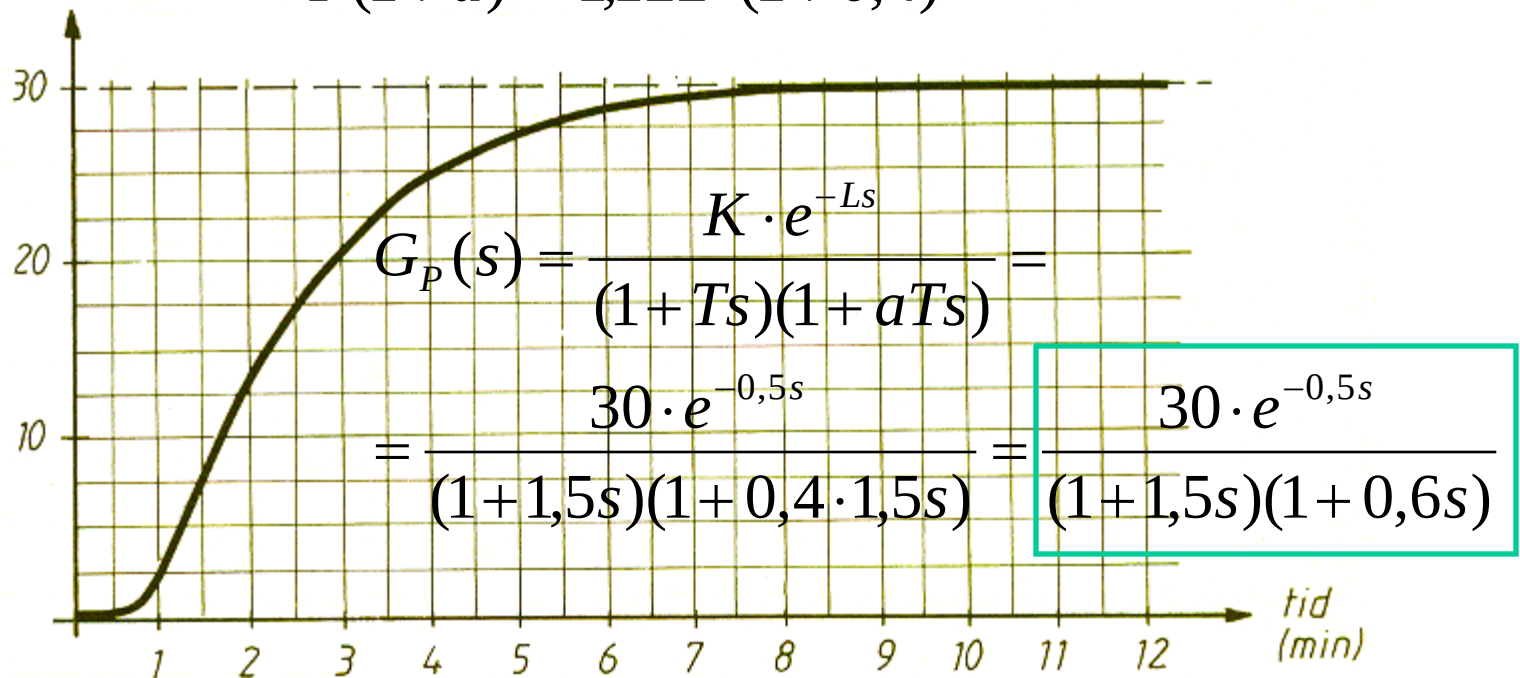
$$L = 0,5$$

$$t_{2/3} = 2,4$$

$$t_{1/3} = 1,2$$

$$a = 0,4$$

$$P = 1,122$$



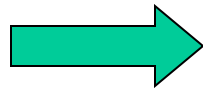
11.5 a lösn. PID-ZN $\omega_\pi = ?$

$$G_P(s) = \frac{30 \cdot e^{-0.5s}}{(1+1.5s)(1+0.6s)}$$

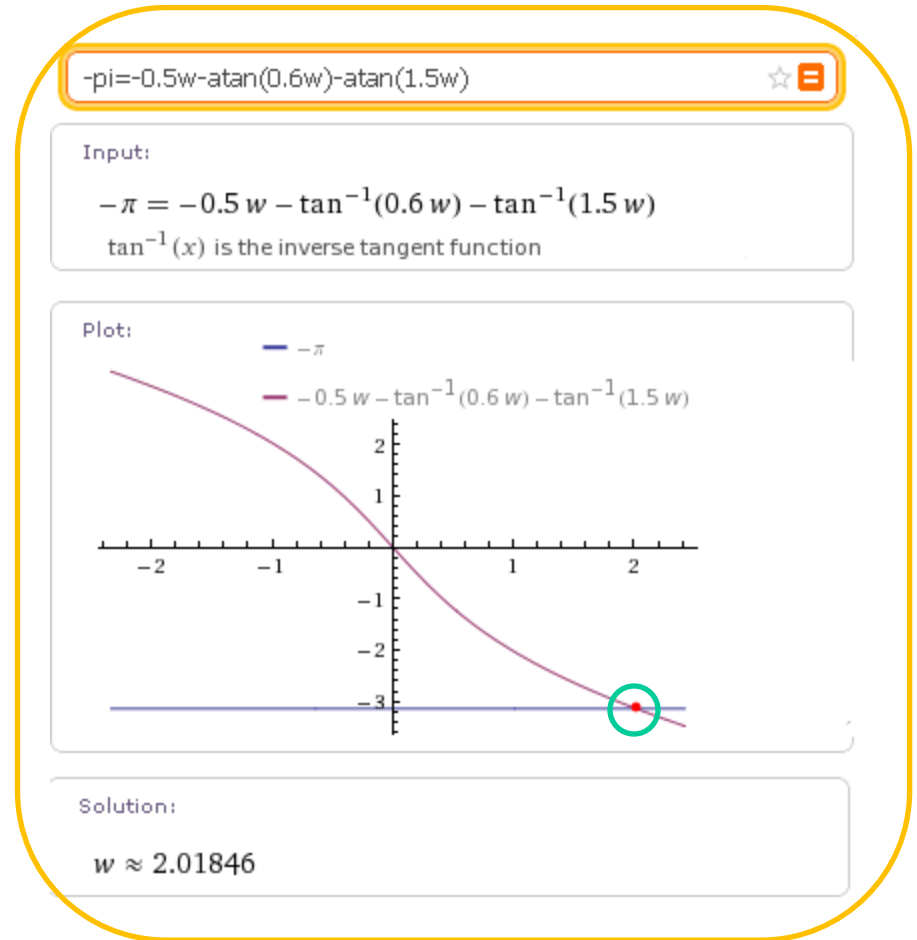
$$\arg[G_P(j\omega)] = -0.5 \cdot \omega - \arctan(0.6\omega) - \arctan(1.5\omega)$$

$$\pi = +0.5 \cdot \omega_\pi + \arctan(0.6\omega_\pi) + \arctan(1.5\omega_\pi)$$

WolframAlpha



$$\omega_\pi = 2 \Rightarrow T_0 = \frac{2\pi}{\omega_\pi} = \frac{2\pi}{2} = \pi$$



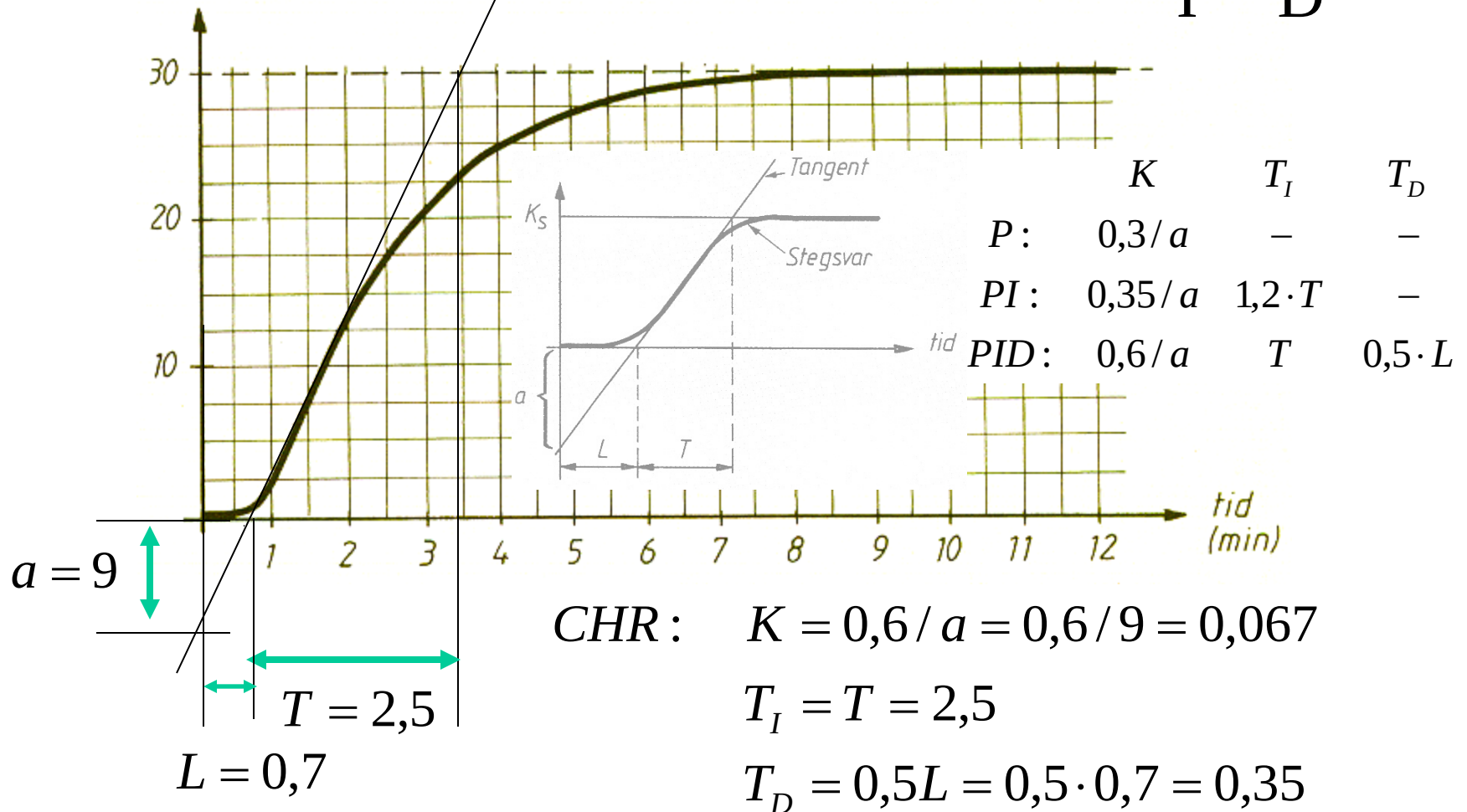
11.5 a lösn. PID-ZN $K T_I T_D$

$$G_P(s) = \frac{30 \cdot e^{-0,5s}}{(1+1,5s)(1+0,6s)} \quad T_0 = \pi$$

$$\begin{aligned} 1 = K_0 \cdot G_P(\omega_\pi) &\Rightarrow K_0 = \frac{1}{G_P(\omega_\pi = 2)} = \\ &= \frac{\sqrt{1+1,2^2} \cdot \sqrt{1+3^2}}{30} = 0,16 \end{aligned}$$

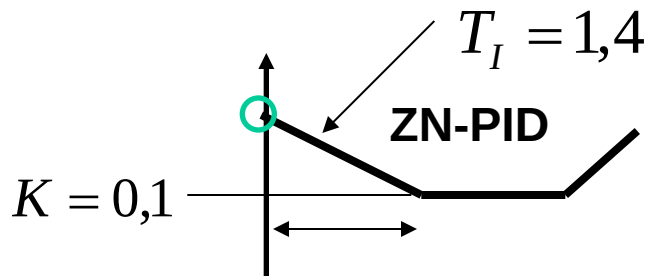
$$\begin{aligned} \text{ZN : } K &= 0,6K_0 = 0,6 \cdot 0,16 = 0,1 \\ T_I &= 0,5T_0 = 0,5\pi = 1,6 \\ T_D &= 0,125T_0 = 0,125\pi = 0,4 \end{aligned}$$

11.5 b lösn. PID-CHR $K T_I T_D$

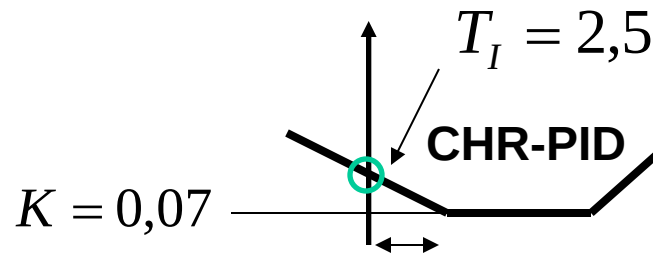


11.5 c lösn. PID jämförelse

- Störningsdämpningen bestäms av regulatorns **lågfrekvensegenskaper**.



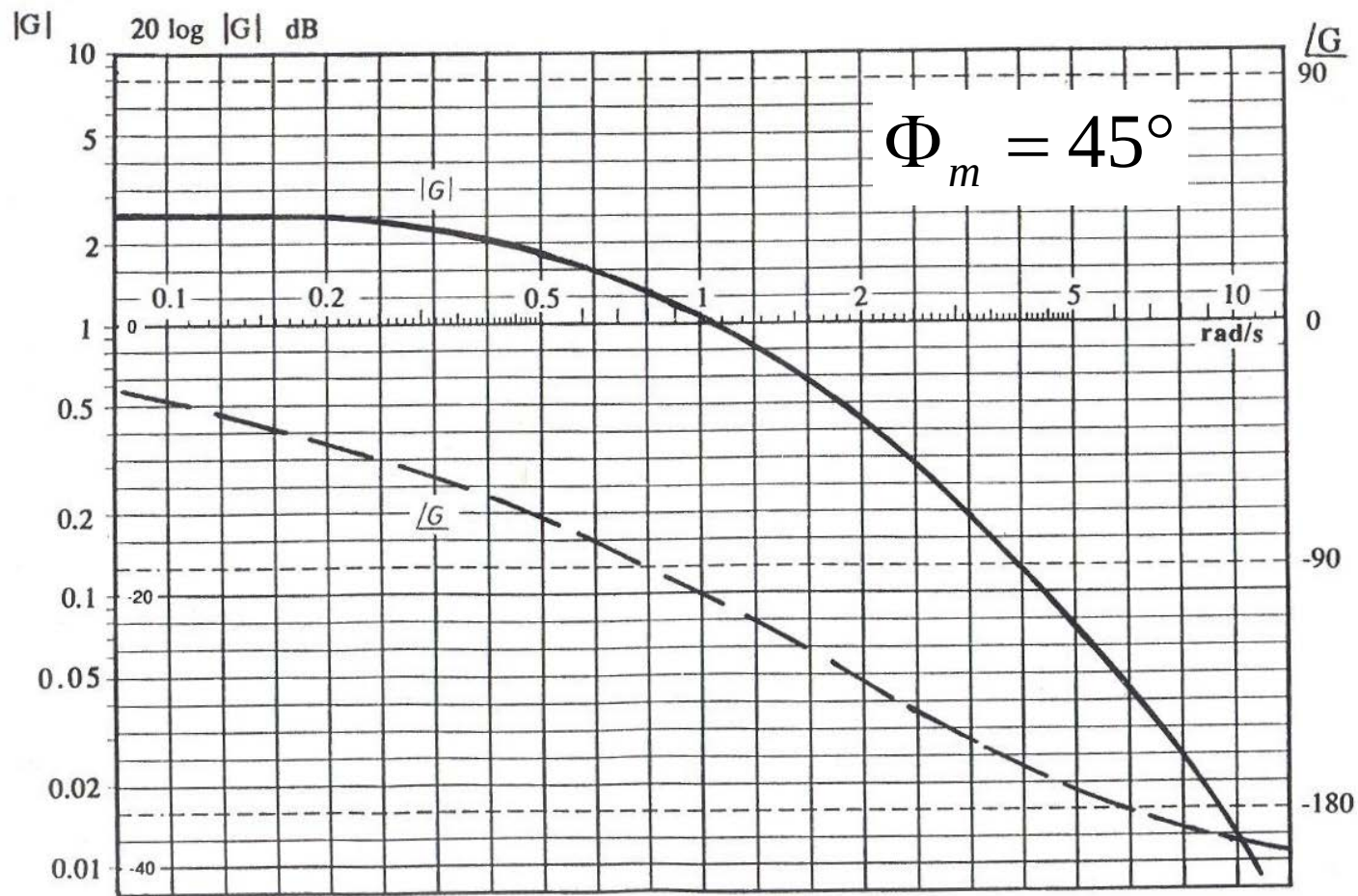
$$J_V = \frac{T_I}{K} = \frac{1,4}{0,1} = 14$$



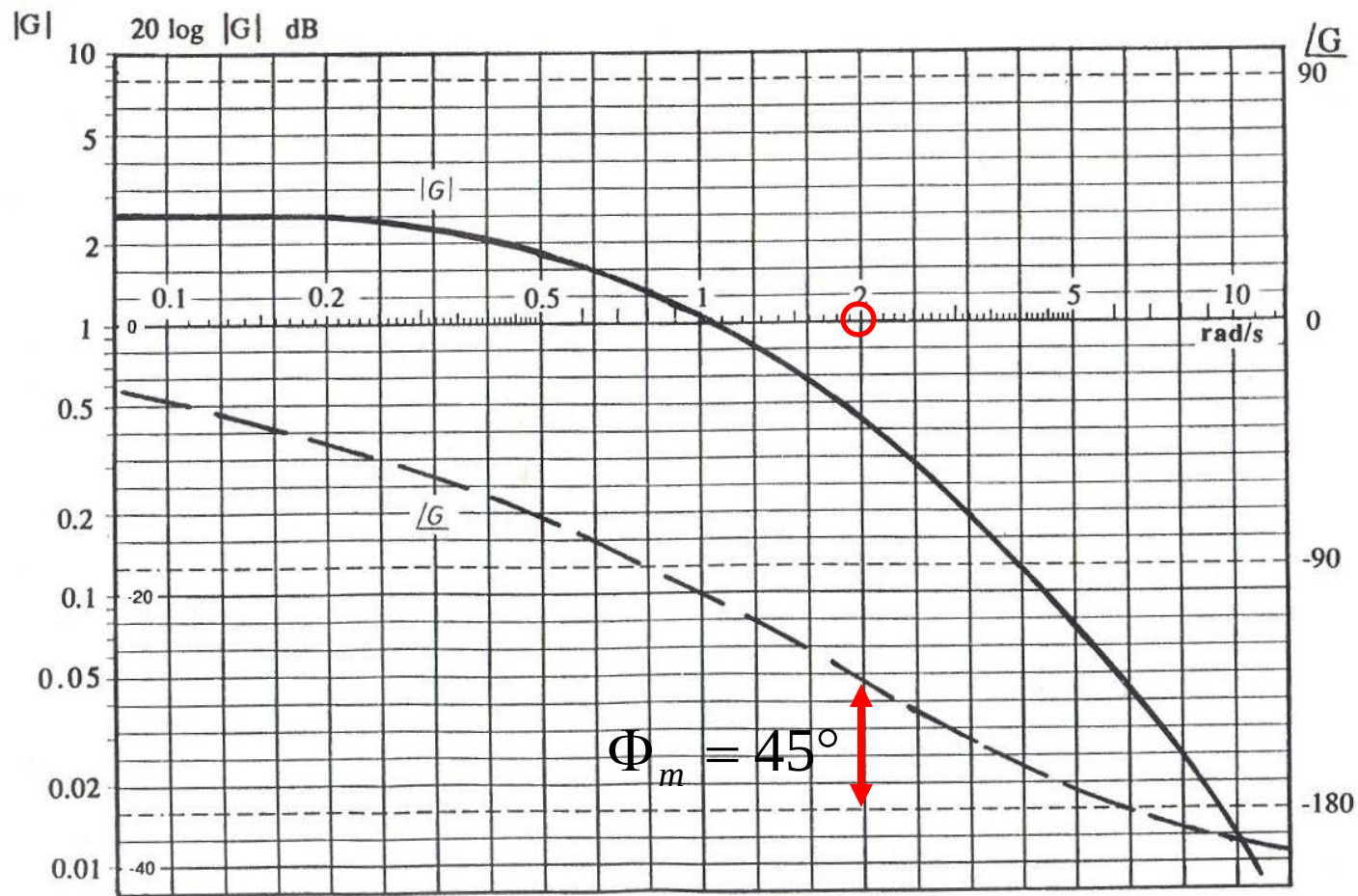
$$J_V = \frac{T_I}{K} = \frac{2,5}{0,067} = 37$$

- Lägsta J_V -värdet har högsta lågfrekvensförstärkningen.

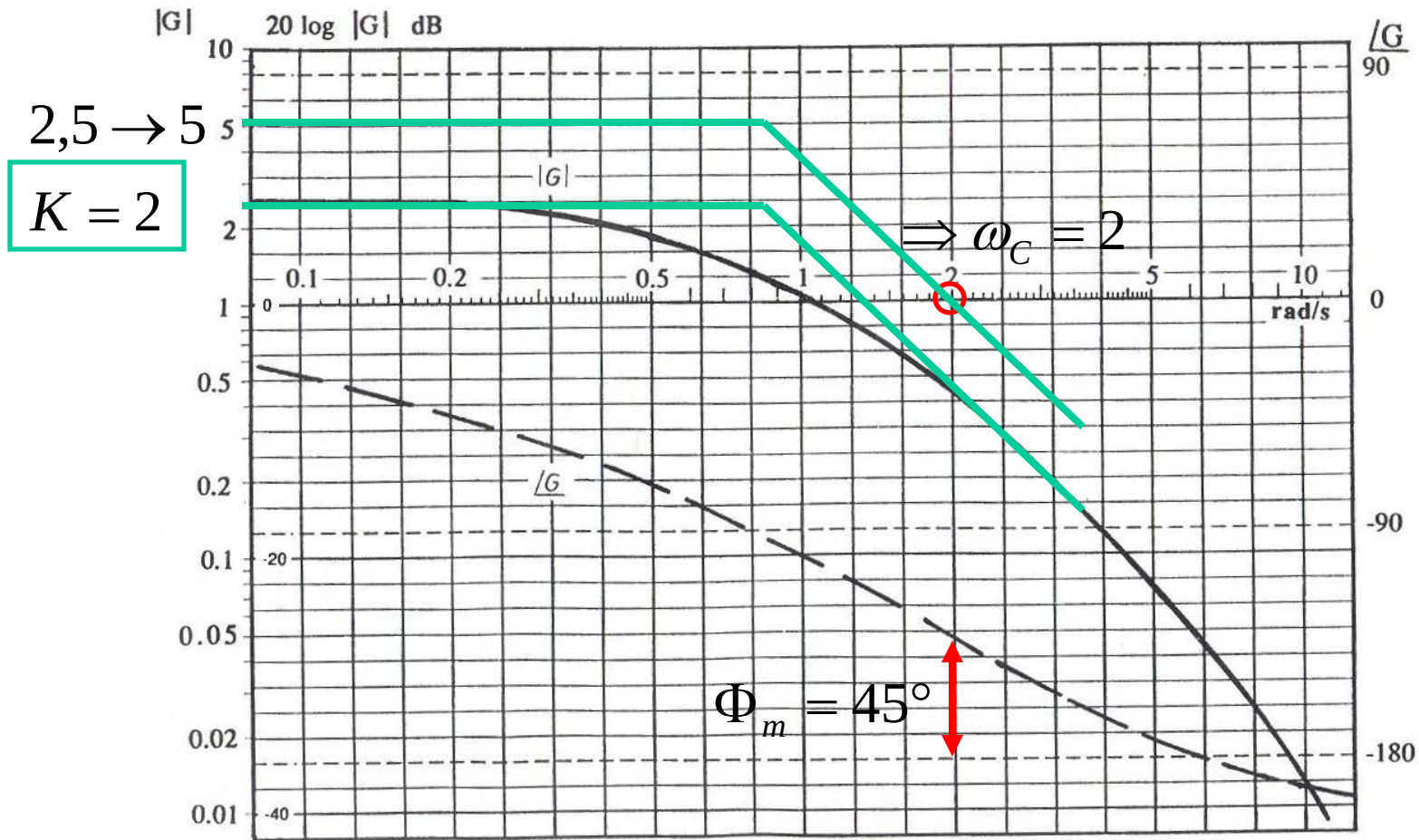
11.6 P-regulator Bodediagram



11.6 P-regulator lösning



11.6 P-regulator lösning



11.6 P-regulator lösning

Hur stort blir felet vid stegformad och rampformad börvärdesändring?

$$e_0 = \lim_{s \rightarrow 0} \frac{1}{1 + G_R \cdot G_P} = \frac{1}{1 + 2 \cdot 2,5} = 0,17$$

$$e_1 = \infty \quad \text{Ingen integrering!}$$

11.10 P-regulatorer

$$G_P = \frac{3}{(1+s)(1+5s)} \quad G_{R(P)} = K$$

Bestäm K för $\Phi_m = 45^\circ$.

11.10 lösn. P-regulator

$$G_P \cdot G_{R(P)} = \frac{3K}{(1+s)(1+5s)} \quad G(\omega) = \frac{3K}{\sqrt{1+\omega^2} \cdot \sqrt{1+25\omega^2}}$$

$$\varphi(\omega) = -\arctan(\omega) - \arctan(5\omega)$$

$$\Phi_m = 45^\circ: \quad (-180^\circ + 45^\circ) \frac{\pi}{180^\circ} = -\arctan(\omega_m) - \arctan(5\omega_m)$$

$$\Rightarrow \omega_m = 1.35 [\text{rad} / \text{s}]$$

$$1 = \frac{3K}{\sqrt{1+\omega_m^2} \cdot \sqrt{1+25\omega_m^2}} \Rightarrow K = \frac{\sqrt{1+1,35^2} \cdot \sqrt{1+25 \cdot 1,35^2}}{3} = 3,8$$

Med $K = 3,8$ blir $\omega_C = 1,35$ och $\Phi_m = 45^\circ$.

11.10 visualisering med Matlab

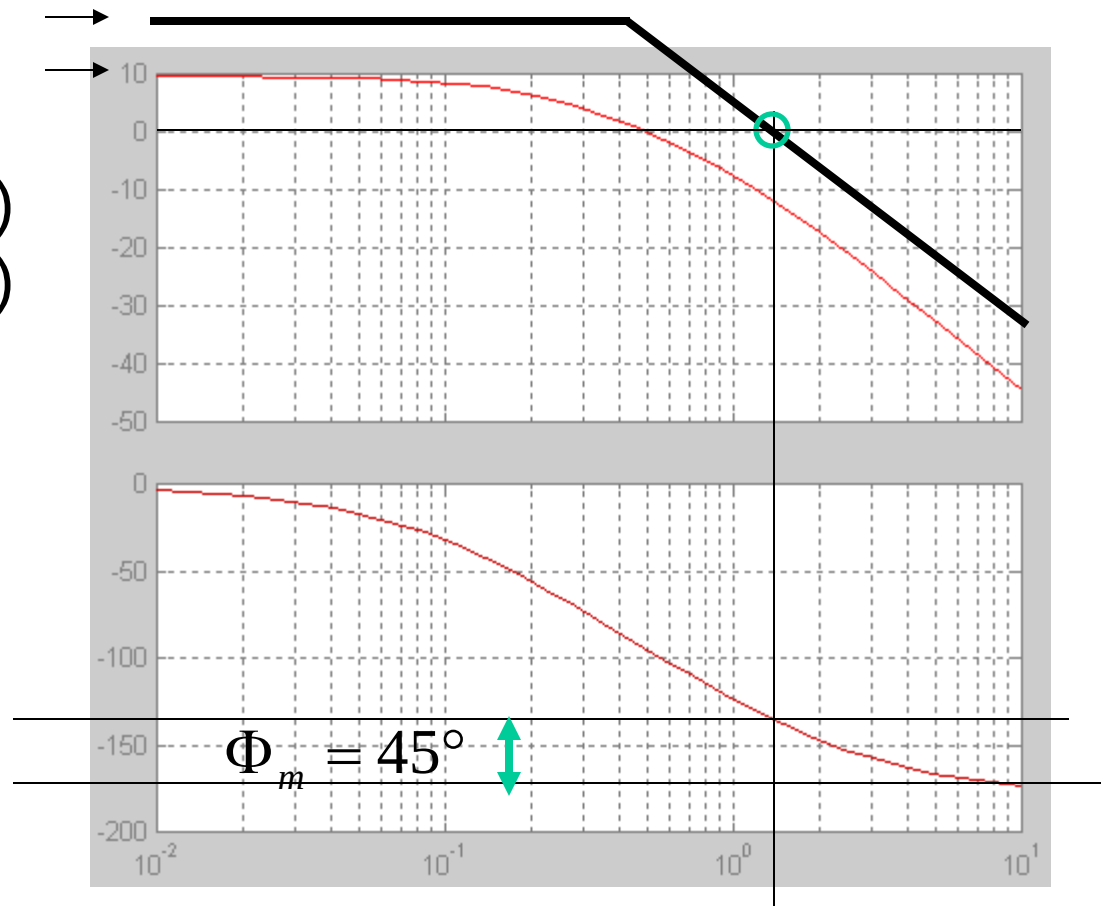
$$G_P = \frac{3}{(1+s)(1+5s)}$$

```
G1=tf([1],[1,1])
```

```
G2=tf([3],[5,1])
```

```
G=G1*G2
```

```
bode(G)
```

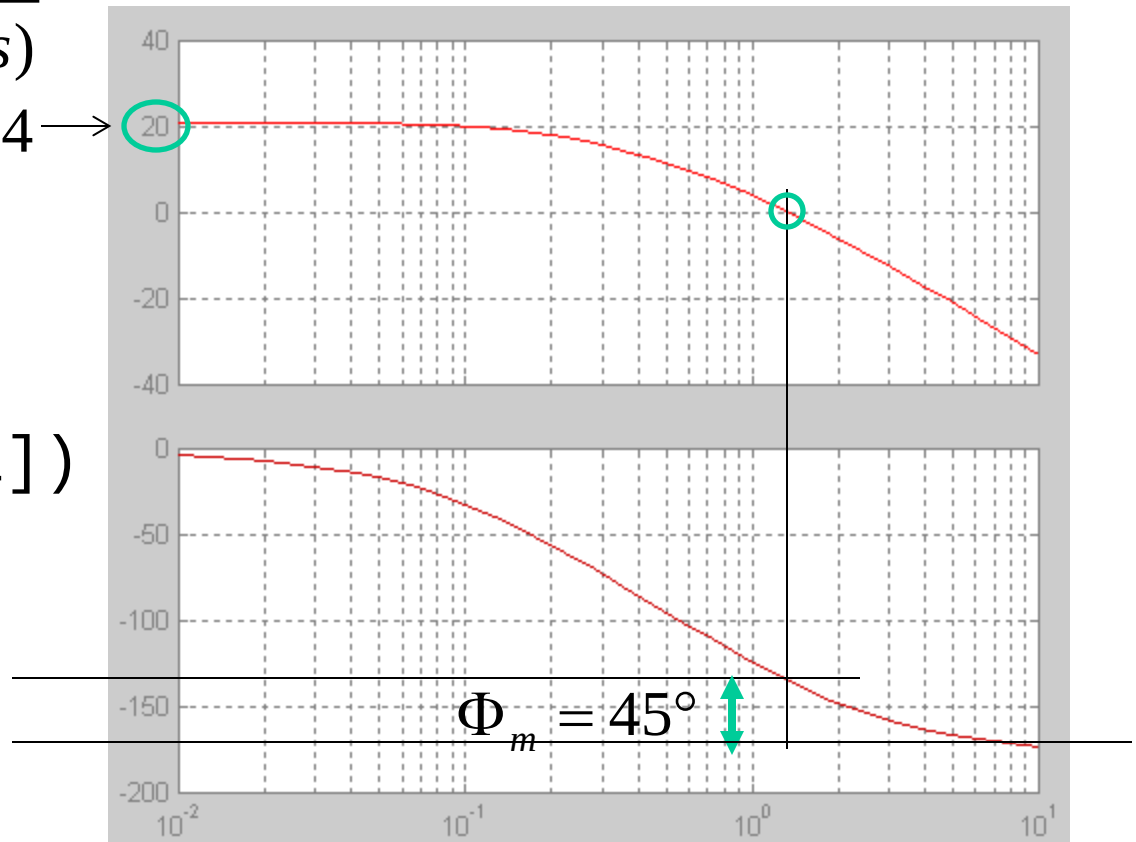


11.10 visualisering med Matlab

$$G_P \cdot G_{R(P)} = \frac{3,8 \cdot 3}{(1+s)(1+5s)}$$

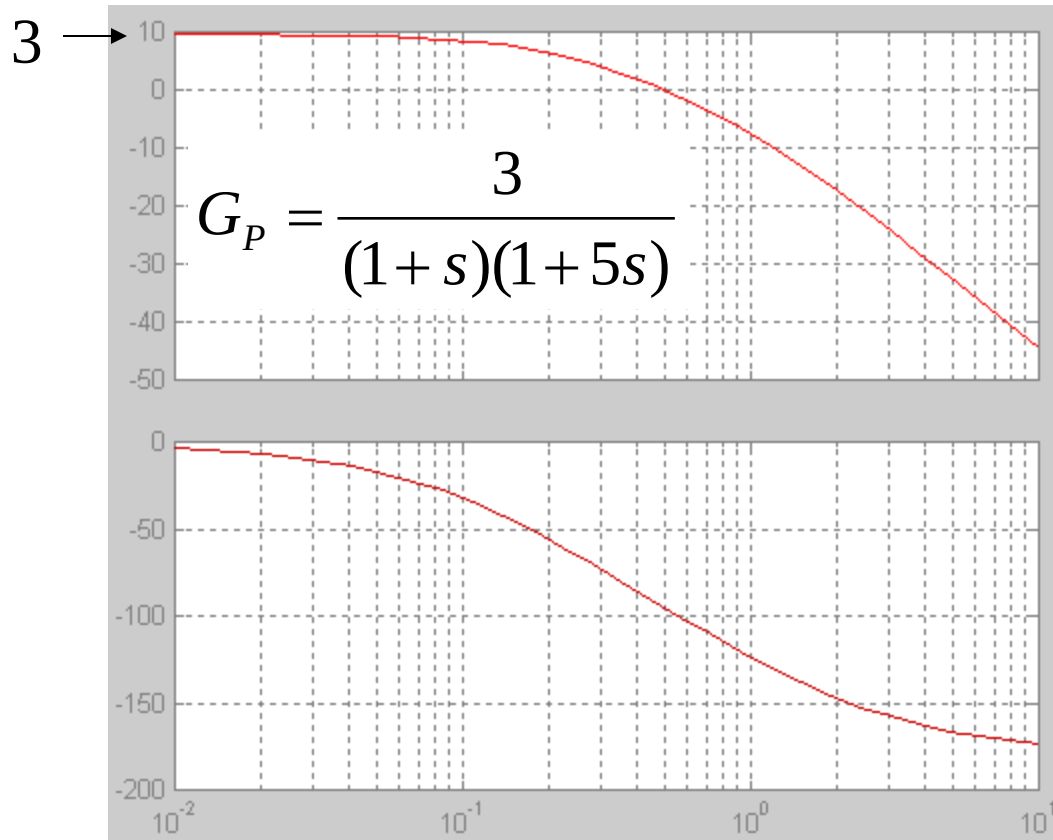
11,4 →

```
G1=tf([3.8],[1,1])  
G2=tf([3],[5,1])  
G=G1*G2  
bode(G)
```



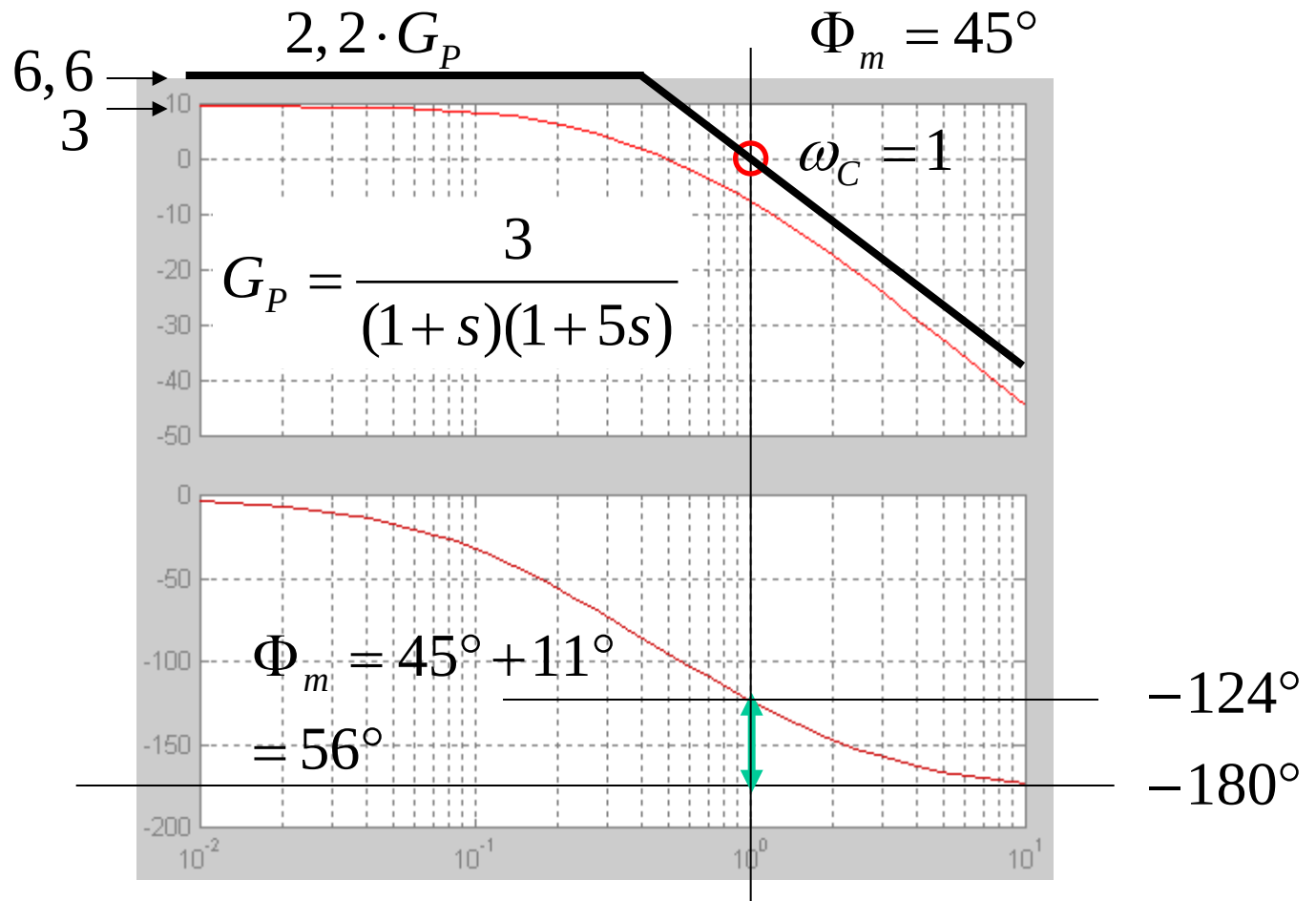
11.11 b PI-regulator

$$\Phi_m = 45^\circ$$



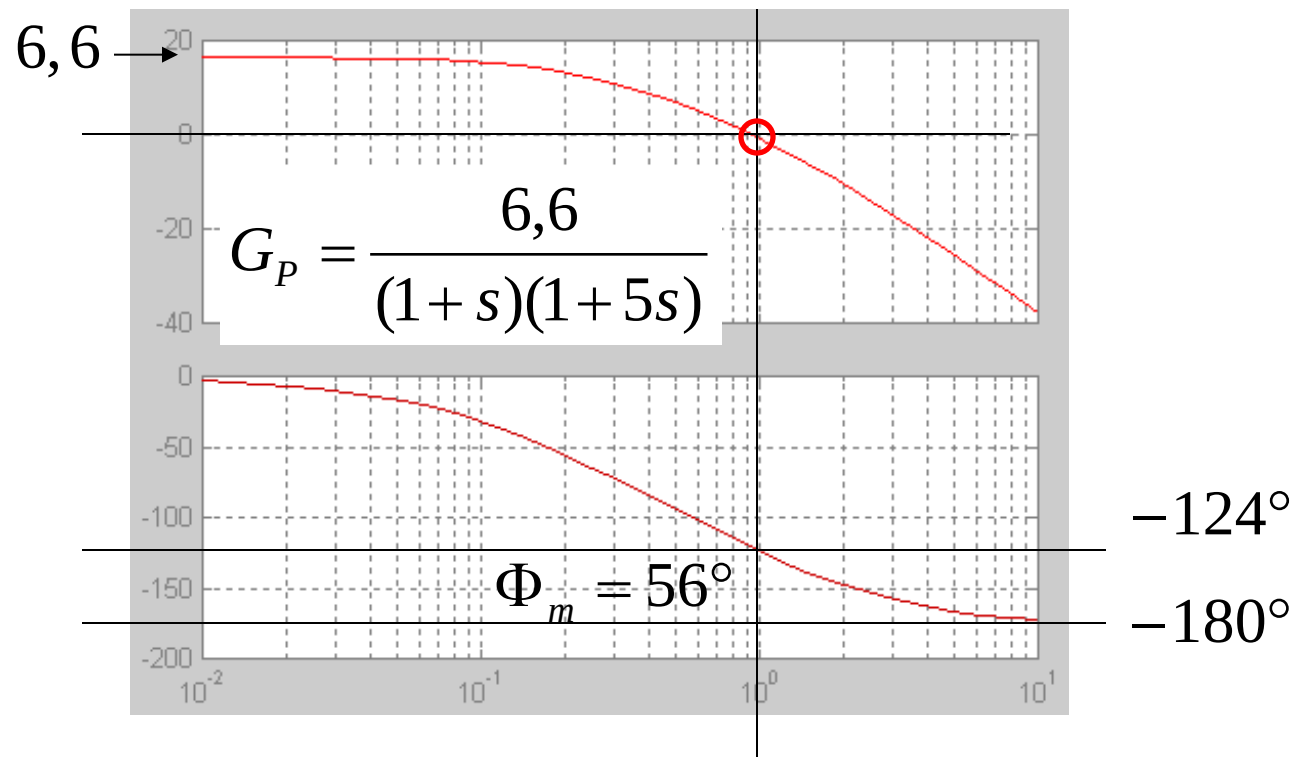
11.11 b lösn. PI-regulator

$$K = 2,2$$



11.11 b lösn. PI-regulator

$$\omega_C = 1 \quad \Phi_m = 45^\circ$$



11.11 b lösn. PI-regulator

$$G_P = K \cdot \left(1 + \frac{1}{T_I s} \right)$$

Välj: $\omega_b = 0,2 \cdot \omega_C = 0,2$ $T_I = \frac{1}{\omega_b} = \frac{1}{0,2} = 5$

PI: $G = G_R G_P = 2,2 \cdot \left(1 + \frac{1}{5s} \right) \cdot \frac{3}{(1+s)(1+5s)}$

11.11 b lösn. PI-regulator

$$\omega_C = 1$$

$$G = 2,2 \cdot \left(1 + \frac{1}{5s}\right) \cdot \frac{3}{(1+s)(1+5s)}$$

6,6
1

$$\omega_b = 0,2$$

$$\Phi_m = 45^\circ$$

$$-135^\circ$$

$$-180^\circ$$

