Frage 1: Erwärmung des Meerwassers

$$F(s) = \frac{k}{1+sT}$$

$$\arg(F(s)) = -\arctan(wT) = -2p\ \frac{55}{365{,}25} = -0{,}946\ \text{rad} = j$$

$$w = \frac{2p}{365{,}25 \cdot 86400} = 1{,}99 \cdot 10^{-7}\ \text{rad/sec}$$

$$T = \frac{-\tan j}{w} = \frac{\tan(0{,}946\,\text{rad})}{1{,}99 \cdot 10^{-7}\ \text{rad/sec}} = 6{,}97 \cdot 10^{6}\ \text{sec} \approx 81\,\text{d}$$

Frage 2: Geschlossener Regelkreis

Führung:

$$F_W(s) = \frac{\frac{3}{1+s}}{1+\frac{3}{1+s}} = \frac{3}{1+s+3} = \frac{3}{s+4} \quad \rightarrow \quad x_0 = \lim_{t\to\infty} x(t) = \lim_{s\to 0} s \cdot \frac{1}{s} \cdot \frac{3}{s+4} = \frac{3}{4}$$

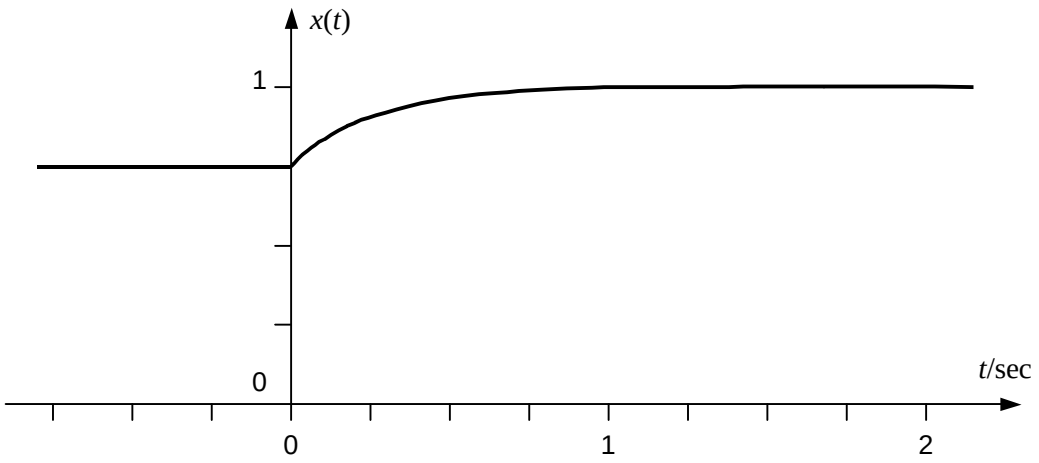
Störung:

$$F_W(s) = \frac{\frac{1}{1+s}}{1+\frac{3}{1+s}} = \frac{1}{1+s+3} = \frac{1}{s+4}$$

$$X_Z(s) = Z(s) \cdot F_Z(s) = \frac{1}{s} \cdot \frac{1}{s+4} = \frac{1}{4} \cdot \frac{1}{s(1+s/4)} \quad \rightarrow \quad x_Z(t) = x_0(t) = \frac{1}{4}(1-e^{-4t}) \cdot s \qquad (12)$$

Überlagerung:

$$x(t) = x_0 + x_Z(t) = \frac{3}{4} + \frac{1}{4}(1-e^{-4t}) \cdot s$$



Zusatzfrage: Phasenrand eines Regelkreises

$$\left|\frac{3}{s(1+3s)}\right| = 1 \quad \rightarrow \quad |s(1+3s)| = 3 \quad \rightarrow \quad |jw - 3w^2)| = 3 \quad \rightarrow \quad w^2 + 9w^4 = 9$$

$$w^4 + \frac{1}{9}w^2 - 1 = 0 \quad \rightarrow \quad w_{1,2}^2 = -\frac{1}{18} \pm \sqrt{\frac{1}{18^2} + 1} \quad \rightarrow \quad w_1^2 = 0{,}946 \quad \rightarrow$$

$$w_1 = 0{,}973\,\text{rad/sec}$$

$$j = -90° - \arctan(3w_1) = -90° - \arctan(2{,}919) = -161{,}1°$$

$$a_R = 180° - 161{,}1° = 18{,}9°$$