## DESIGN PROBLEMS

55. A model for an airplane's pitch loop is shown in Figure P6.12. Find the range

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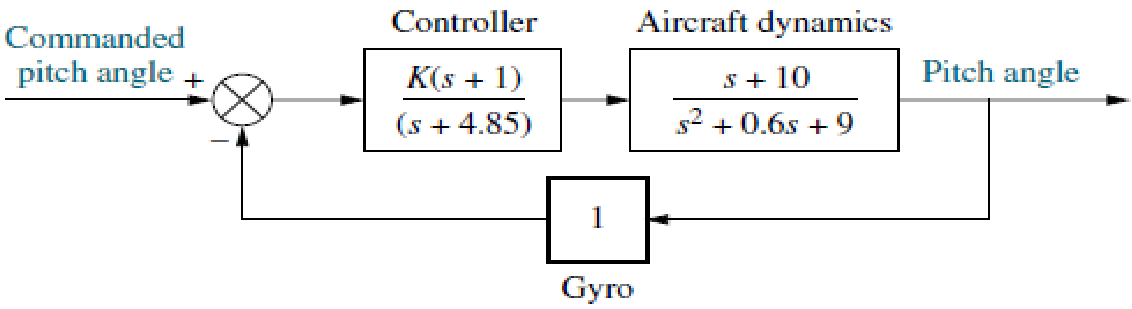


**FIGURE P6.12** Aircraft pitch loop model

**55.**

$$T(s) = \frac{K(s+1)(s+10)}{s^3 + (5.45+K)s^2 + (11.91+11K)s + (43.65+10K)}$$

| | | |
|---|---|---|
| $s^3$ | 1 | 11.91+11K |
| $s^2$ | 5.45+K | 43.65+10K |
| $s^1$ | $\frac{11K^2+61.86K+21.26}{5.45+K}$ | 0 |
| $s^0$ | 43.65+10K | 0 |

For stability, $-0.36772 < K < \infty$. Stable for all positive K.

find the range of amplifier gain, $K$, to keep the system stable.

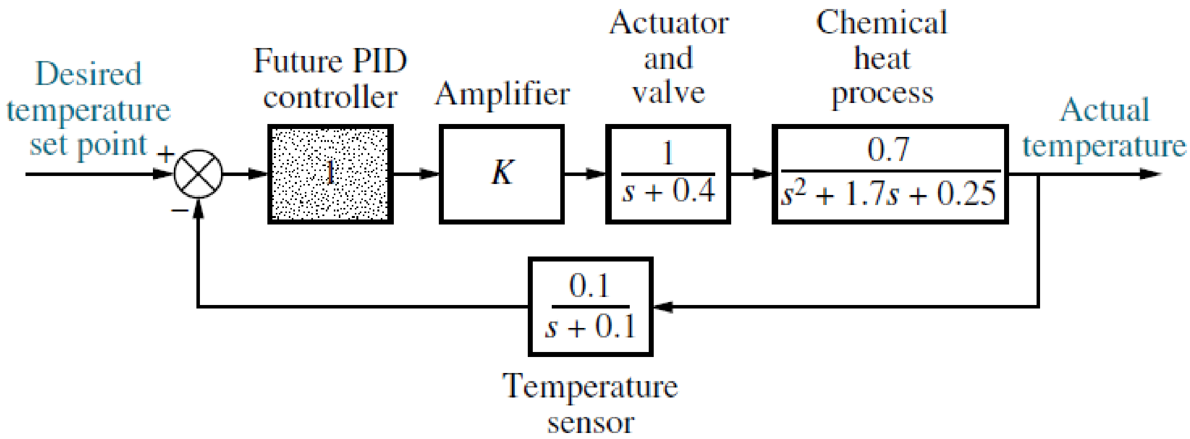


**FIGURE P6.13** Block diagram of a chemical process control system

$$T(s) = \frac{0.7K(s+0.1)}{s^4 + 2.2s^3 + 1.14s^2 + 0.193s + (0.07K+0.01)}$$

| | | | |
|---|---|---|---|
| $s^4$ | 1 | 1.14 | 0.07K+0.01 |
| $s^3$ | 2.2 | 0.193 | 0 |
| $s^2$ | 1.0523 | 0.07K+0.01 | 0 |
| $s^1$ | 0.17209 - 0.14635K | 0 | 0 |
| $s^0$ | 0.07K+0.01 | 0 | 0 |

For stability, $-0.1429 < K < 1.1759$

**58.** Often an aircraft is required to tow another vehicle, such as a practice target or glider. To stabilize the towed vehicle and prevent it from rolling, pitching, and yawing, an autopilot is built into the towed vehicle. Assume the block diagram shown in Figure P6.15 represents the autopilot roll control system (*Cochran, 1992*). Find the range of $K$ to keep the roll angle stable.

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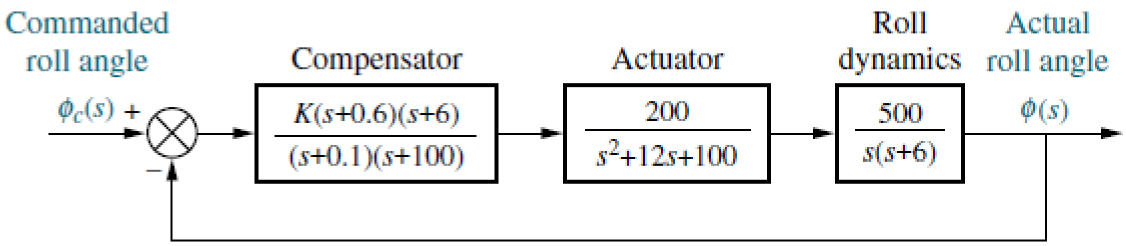


**FIGURE P6.15** Towed vehicle roll control

| | | | |
|---|---|---|---|
| $s^5$ | 1 | 1311.2 | 1000(100K+1) |
| $s^4$ | 112.1 | 10130 | 60000K |
| $s^3$ | 1220.8 | 99465K+1000 | 0 |
| $s^2$ | 10038-9133.4K | 60000K | 0 |
| $s^1$ | $99465\,\frac{(K+0.010841)(K-1.0192)}{(K-1.0991)}$ | 0 | 0 |
| $s^0$ | 60000K | 0 | 0 |

From $s^2$ row: $K < 1.099$

From $s^1$ row: $-0.010841 < K < 1.0192$; $K > 1.0991$

From $s^0$ row: $0 < K$

Therefore, $0 < K < 1.0192$