1. Thermal capacitance of 200 kg of water, c = 4180 (kJ/K)?

   _____ kJ/K

2. Speed per volt K/(bR + K^2) with K = 0.05, b = 1.0e-5, R = 1.2 (one decimal, rad/s per V)?

   _____ rad/s/V

3. Gain K_p for 0.398 K_p = 53.1 (V/rad, whole number)?

   _____ V/rad

4. Steady error with P only, d = 3.0 V, K_p = 134 V/rad (two decimals, degrees)?

   _____ deg

5. Hold phase at 74.4 rad/s, T = 1 ms (one decimal, degrees)?

   _____ deg

6. To improve this budget, first:

   ☐ buy a better sensor

   ☐ sample faster

   ☐ buy a 16-bit ADC

   ☐ raise the amplifier gain

7. Which candidate passes the spec?

   ☐ P only

   ☐ PI without anti-windup

   ☐ PI with clamping anti-windup

   ☐ none of them

8. After one time constant a first-order lag reaches:

   ☐ 95%

   ☐ 50%

   ☐ 63% of its final change

   ☐ 100%

9. In SI units the torque and back-emf constants are equal because:

   ☐ the gearbox makes them equal

   ☐ they are measured together

   ☐ the motor is small

10. A pole in the right half-plane means:

    ☐ it settles with overshoot

    ☐ it oscillates at constant size

    ☐ it decays faster

    ☐ the response grows

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1. **836 kJ/K**

   m c.

2. **19.9 rad/s/V**

   0.05 over 0.002512.

3. **134 V/rad**

   53.1 over 0.398.

4. **1.28 deg**

   3.0/134 rad in degrees.

5. **2.1 deg**

   omega T / 2 in degrees.

6. **buy a better sensor**

   The sensor term dominates.

7. **PI with clamping anti-windup**

   It reaches the band at 0.52 s without overshoot.

8. **63% of its final change**

   1 - e^-1.

9. **electrical power e i equals mechanical power T omega**

   Energy conversion is exact.

10. **the response grows**

    e to a positive power grows.

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