1. A system has K = 2 and τ = 1 s. The input steps from 0 to 10. What is x after 1 s? Give 2 decimal places.

   _____

2. $G_1 = 2/(s + 1)$ and $G_2 = 3/(s + 2)$ are in series. What is the DC gain (s = 0) of the pair?

   _____

3. A pole pair has ω_n = 6 rad/s and $\zeta = 0.5$. What is the real part of the poles?

   _____

4. Which set of closed-loop poles is stable?

   ☐ $-1, -2 \pm j3$

   ☐ $-1, +2 \pm j3$

   ☐ $0, -2$

   ☐ $\pm j2, -5$

5. At K = 0 every branch of the root locus sits on an open-loop pole.

   ☐ True ☐ False

6. Above both of its pole frequencies, a loop with two poles and no zeros falls at what slope, in dB per decade?

   _____

7. A loop oscillates at K_u = 20 with period T_u = 4 s. What integral time T_i does the Ziegler–Nichols PID row give, in s?

   _____ s

8. In companion form, $s^2 + 5s + 6$ gives A =

   [1, 0 , [−5, −6]]

   [0, 1 , [5, 6]]

   [−6, −5 , [0, 1]]

   [0, 1 , [−6, −5]]

9. A linear model taken at one operating point is accurate at every operating point.

   ☐ True ☐ False

10. In the one-loop example the gain rises from 6 to 14. What happens to ζ?

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   ☐ The loop becomes unstable

   ☐ It rises to 0.8

   ☐ It falls to 0.375, so the loop rings more

1. **12.64**

   The final value is $KU = 20$; after one time constant it has reached 63.2%: $20 \times 0.632 = 12.64$.

2. **3**

   Series multiplies: $G_1(0)G_2(0) = 2 \times 1.5 = 3$.

3. **-3**

   The real part is $-\zeta\omega_n = -0.5 \times 6 = -3$.

4. **−1, −2 ± j3**

   Every pole needs a negative real part. A pole at 0 or on the imaginary axis is only marginal, not stable.

5. **True**

   With no gain the loop is open, so the closed-loop poles are the open-loop poles. As K grows they move towards the zeros or to infinity.

6. **-40**

   Each pole adds −20 dB per decade, so two poles give −40.

7. **2 s**

   $T_i = T_u/2 = 2$ s, with $K_p = 0.6 \times 20 = 12$ and $T_d = T_u/8 = 0.5$ s.

8. **[[0, 1], [−6, −5]]**

   The top row shifts the states; the bottom row holds the negated coefficients, last first. Its eigenvalues are −2 and −3.

9. **False**

   The slope changes along the curve. The tank's slope is 0.5 at 4 m and 0.33 at 9 m, so each operating point needs its own model.

10. **It falls to 0.375, so the loop rings more**

    The denominator becomes $s^2 + 3s + 16$: $\omega_n = 4$ and $\zeta = 3/8 = 0.375$. More gain, less damping.

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