PID Control — Question Set

Discrete PID form: $u[k] = Kp \cdot e[k] + Ki \cdot \Sigma e + Kd \cdot (e[k]-e[k-1])$. Sampling time = 1 s unless stated.

A. Concept checks

Q1. What is a PID controller and why do we use all three terms?
Answer: PID combines three actions on the error e: Proportional Kp·e for fast response, Integral Ki·sum(e) to remove steady state error, and Derivative Kd·(e[k]-e[k-1]) to anticipate change and damp overshoot. Together they balance speed, accuracy, and stability.

Q2. Why can a pure proportional controller leave steady state error?
Answer: With only Kp·e, a constant disturbance/bias requires a nonzero error to generate the needed output, leaving an offset. The integral term accumulates error to drive that offset to zero.

Q3. What practical role does the derivative term play, and what is a common drawback?
Answer: Kd reacts to the rate of change of error, adding damping and reducing overshoot, but it is noise sensitive and often needs filtering or small gain.

Q4. Name two ways to obtain PID gains in practice.
Answer: Relay autotuning using sustained oscillations; or manual/iterative tuning by adjusting Kp, then Ki, then Kd while watching rise time, overshoot, and settling.

B. Quick computations

Q5. Proportional only. Desired altitude 60 m, actual 10 m, Kp=10. What is u?
Answer: $e=50 \rightarrow u=Kp \cdot e=10\times 50=500$.

Q6. PI step. Errors e[k]=10, e[k-1]=12, e[k-2]=11 with Kp=8, Ki=0.5, Kd=0. Compute u[k].
Answer: Sum=33 $\rightarrow u=8\cdot 10 + 0.5\cdot 33 = 96.5$.

Q7. Add derivative. Same errors as Q6 with Kd=4. Compute u[k].
Answer: Derivative=10−12=−2 $\rightarrow u=80 + 16.5 + 4\cdot(-2) = 88.5$.

Q8. Tracking improvement. Ponly control leaves steady error due to a constant draft. What change removes it and why?
Answer: Add integral action; the running sum rises until the disturbance is countered, driving steady state error toward zero.

C. Design & reasoning

Q9. Increase Kp from 5 to 20 on a lightly damped quad. Predict effects on rise time, overshoot, and settling.
Answer: Rise time decreases (faster). Overshoot increases. Settling time can increase unless damping is added (e.g., via Kd).

Q10. Which term best rejects a constant sensor bias and which best suppresses sudden gusts?
Answer: Integral rejects constant bias; derivative helps with sudden changes by adding damping.

Q11. During takeoff the motor saturates and the integrator keeps accumulating, causing a big overshoot later. What is this and one fix?
Answer: Integral windup. Use anti windup (stop/slew the integrator on saturation or back calculation).

D. Short “choose-gains” cases

Q12. You want a faster response with the same steady state error. Which gain to change first?
Answer: Increase Kp; add a little Kd if overshoot grows; keep Ki the same.

Q13. You have zero steady state error but oscillate around the setpoint. What change helps most?
Answer: Increase Kd or reduce Ki to cut oscillations.

Q14. The loop is sluggish but must keep overshoot minimal. What to try?
Answer: Raise Kp moderately and add a small Kd; keep Ki low.

E. Mini problem

Q15. A drone uses Kp=6, Ki=0.8, Kd=3. Error history: e[0]=22, e[1]=15, e[2]=11, e[3]=8 (1s sampling). Compute u[3].
Answer: Sum=22+15+11+8=56. Derivative=8−11=−3. u[3]=6·8 + 0.8·56 + 3·(−3)=48+44.8−9=83.8.