1)

a) $$\frac{\dfrac{K_p(1+T_d s)}{s^3+5s^2+12s-18}}{1+\dfrac{K_p(1+T_d s)}{s^3+5s^2+12s-18}} \times \frac{s^3+5s^2+12s-18}{s^3+5s^2+12s-18} =$$

$$\frac{K_p(1+T_d s)}{s^3+5s^2+12s-18+K_p(1+T_d s)}$$

Set $T_d = 0.5$

$$\frac{K_p + 0.5K_p s}{s^3+5s^2+(12+0.5K_p)s+K_p-18}$$

b) ~~This equat~~ The characteristic polynomial has no roots at 0, so it is a type 0 system. There is a steady state error of $\frac{1}{1+K_p}$ to a step inp[ut]. Increasing K_p or adding integral control will solve this.

c)

s^3	1	$12+0.5K_p$	0
s^2	5	K_p-18	0
s^1	$1.5K_p+78$	0	0
s^0	$18-K_p$	0	0

~~$-\begin{vmatrix} 5 & K_p-18 \\ 1.5K_p & \end{vmatrix}$~~

$$\frac{-\begin{vmatrix} 1 & 12+0.5K_p \\ 5 & K_p-18 \end{vmatrix}}{5} = \frac{-5(12+0.5K_p)+K_p-18}{-5} = 1.5K_p+78$$

$18-K_p > 0$ when $K_p > 18$

$1.5K_p+78 > 0$ when $K_p > -52$

The system is stable when $K_p > 18$

$$\frac{-\begin{vmatrix} 5 & K_p-18 \\ 1.5K_p+78 & 0 \end{vmatrix}}{1.5K_p+78} = -\frac{(K_p-18)(1.5K_p+78)}{1.5K_p+78}$$

2)

a) $A^2 = \begin{bmatrix} 100 & -11 & 2ki \\ 0 & 1 & -2ki \\ 0 & 0 & 0 \end{bmatrix}$

$\begin{bmatrix} C \\ CA \\ CA^2 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ -10 & 1 & 0 \\ 100 & -11 & 2ki \end{bmatrix}$ rank = 3 ∴ fully observable

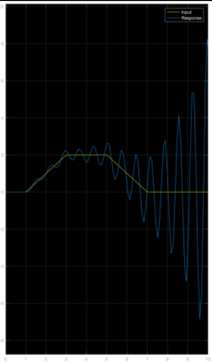
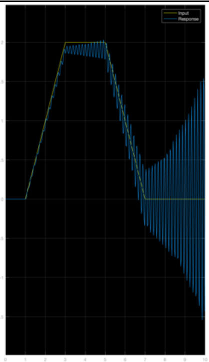
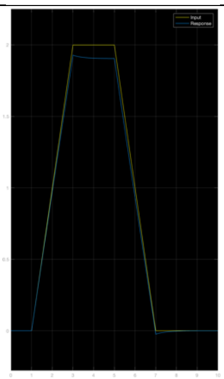
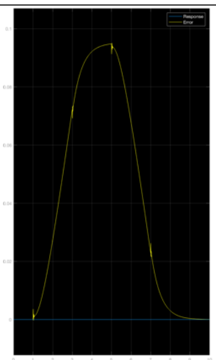
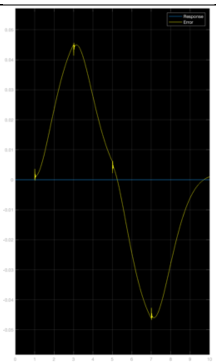
b) $G = \frac{Y(s)}{U(s)} = C[Is - A]^{-1}B$

$Is - A = \begin{bmatrix} s+10 & -1 & 0 \\ 0 & s+1 & 2k \\ 0 & 0 & s \end{bmatrix}$

$[Is - A]^{-1} = \begin{bmatrix} \frac{1}{s+10} & \frac{1}{(s+1)(s+10)} & +\frac{2k}{s(s+1)(s+10)} \\ 0 & \frac{1}{s+1} & -\frac{2k}{s(s+1)} \\ 0 & 0 & \frac{1}{s} \end{bmatrix}$ thank you MATLAB

$C[Is - A]^{-1} = \begin{bmatrix} \frac{1}{s+10} & \frac{1}{(s+1)(s+10)} & \frac{2k}{s(s+1)(s+10)} \end{bmatrix} = \text{temp}$

$\text{temp}\,B = \frac{2kp}{(s+1)(s+10)} + \frac{2ki}{s(s+1)(s+10)} = \frac{2s\,kp + 2ki}{s(s+1)(s+10)}$

	The response oscillates at increasing amplitude, so the drone will crash.
	The drone will still crash
	This stabilises the trajectory
	This shows the error without integral control
	This shows the error with integral control. The error decreases, visible on the scale