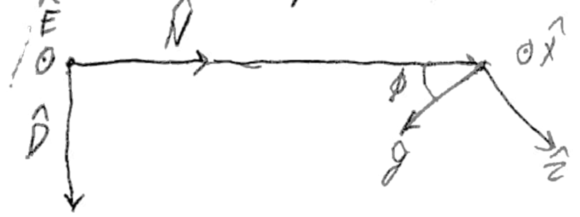
Samuel Razumovskiy | ASEN 3128 HW2 | due 9-19-19



1. ψ is the azimuth angle between the plane perpendicular to $\hat{E}$ and the $\hat{x}$ direction. In this case it is 90°

θ is the elevation angle between the plane normal to $\hat{D}$ and the $\hat{x}$ direction. It is 0° in this case

ϕ is the bank angle between the plane normal to $\hat{D}$ and the $\hat{y}$ direction. It is ϕ in this case.

2. $\dot{\psi}$ is the azimuth angle rate of the body frame.

$C = 2\pi r = 200\pi\,m$ $\quad \frac{C}{V} = \frac{200\pi}{10} = 20\pi\,s$ $\quad \frac{360°}{20\pi s} = \frac{18}{\pi}\frac{deg}{s}$

$$\boxed{\dot{\psi} = \frac{18}{\pi}\frac{deg}{s}}$$

$\dot{\theta}$ is the elevation angle rate of the body frame which is 0 in this case

$\dot{\phi}$ is the bank angle rate of the body frame which is 0.

3. p is the roll rate of the aircraft. It is the $\hat{x}$ component of ω_B^{EB}

q is the pitch rate of the aircraft. It is the $\hat{y}$ component of ω_B^{EB}.

r is the yaw rate of the aircraft. It is the $\hat{z}$ component of ω_B^{EB}

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & \sin\phi\tan\theta & \cos\phi\tan\theta \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi\sec\theta & \cos\phi\sec\theta \end{bmatrix}^{-1} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ \frac{18}{\pi} \end{bmatrix}$$

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$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \frac{18}{\pi} \end{bmatrix} = \begin{bmatrix} 0 \\ 5.73\sin\phi \\ 5.73\cos\phi \end{bmatrix} = \begin{bmatrix} p \\ q \\ r \end{bmatrix}$$

4. $\dot{p}$ is the time rate of change of the roll rate.
$\dot{q}$ is the time rate of change of the pitch rate.
$\dot{r}$ is the time rate of change of the yaw rate.
$\dot{p}, \dot{q}, \dot{r} = 0$

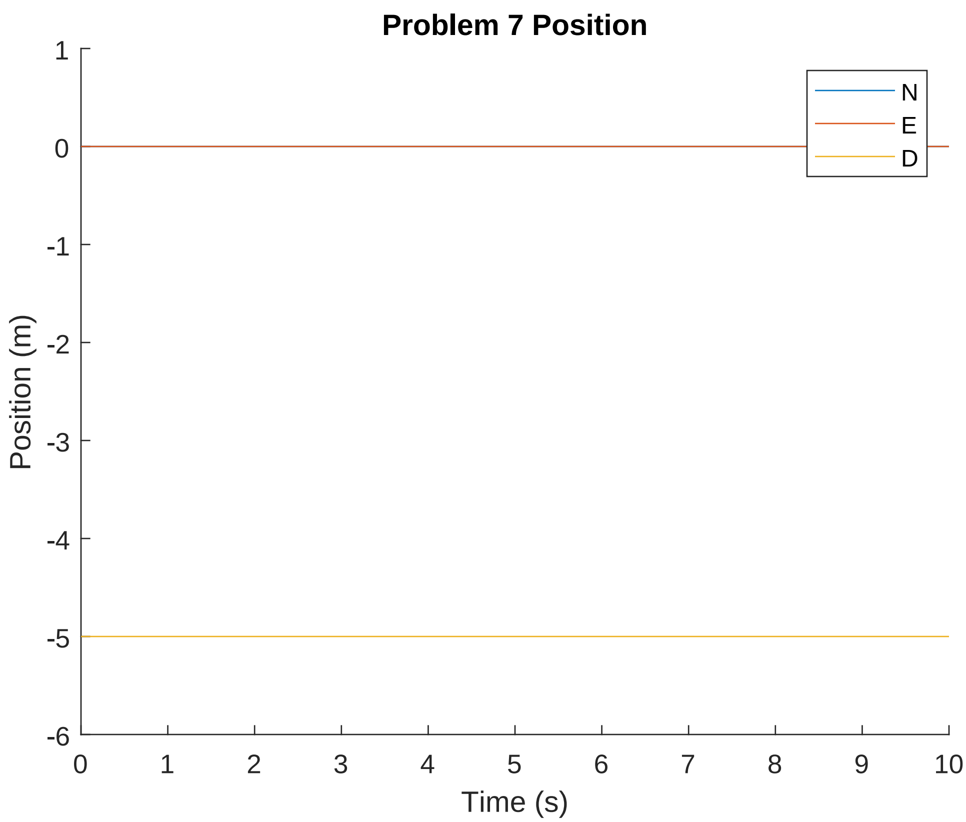
5. $\vec{G} = \frac{d^E}{dt} \vec{h}^E$ from question 6 below we know that $\vec{h}$ is not fixed in E and is fixed in B. Since $\vec{G}$ is only dependent on $\vec{h}$ it will also not be fixed in E and fixed in B.

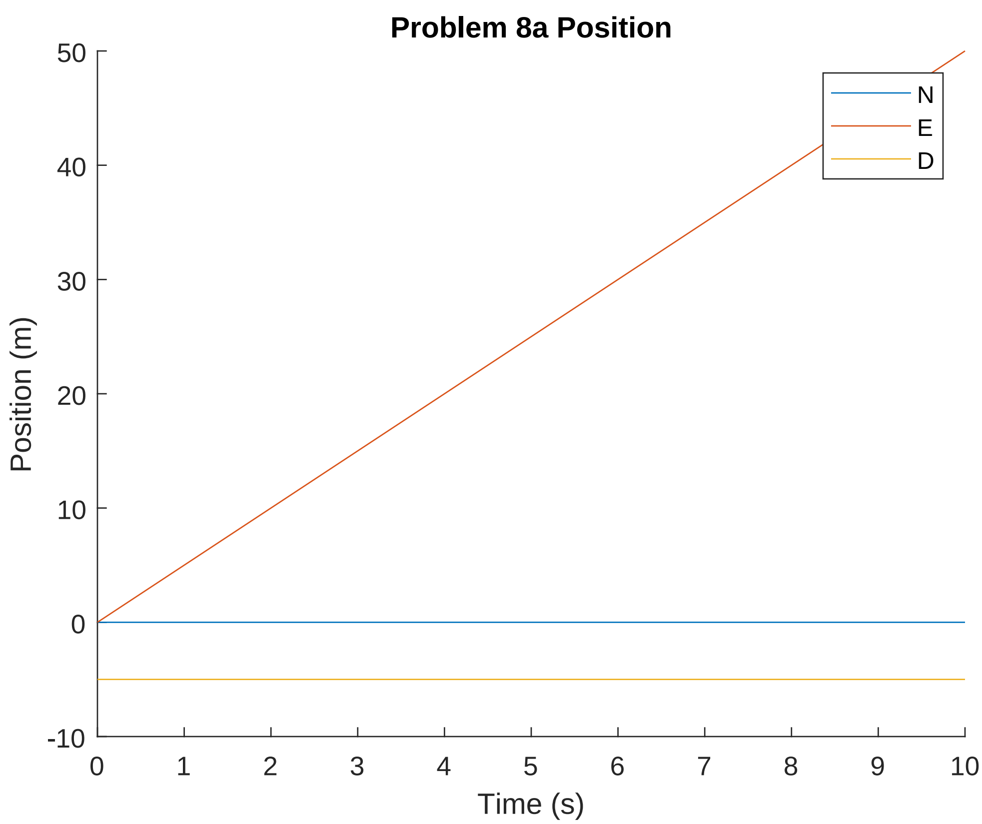
6. $\vec{h}^E = I \cdot \omega^{EB}$ $\vec{h}^E_E = (I \cdot \omega^{EB})_E$ $\vec{h}^E_B = (I \cdot \omega^{EB})_B$
I_E is not constant in E therefore $\vec{h}^E_E$ is not constant
I_B is constant in B therfere $\vec{h}^E_B$ is constant.

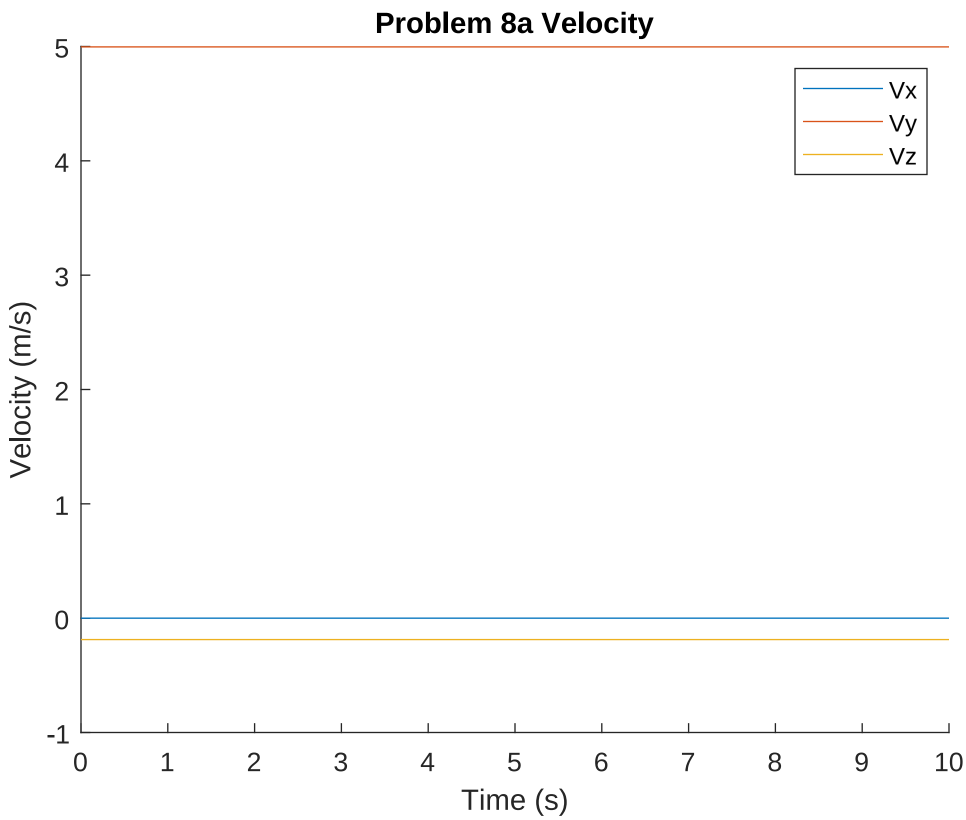
7. No movement and holds at $-5\,m\,\hat{B}$ $f_{1234} = \begin{bmatrix} 0 \\ 0 \\ -1.668 \end{bmatrix} N$

8. When switching to $\psi = 90°$ instead of having a change in ϕ you have a change in theta. $\psi = 0°$ $\theta = 0°$ $\phi = 2.14°$, $V^E_B = \begin{bmatrix} 0 \\ 4.997 \\ -0.188 \end{bmatrix} \frac{m}{s}$ $f_{1234} = \begin{bmatrix} 0 \\ 0 \\ -1.669 \end{bmatrix} N$

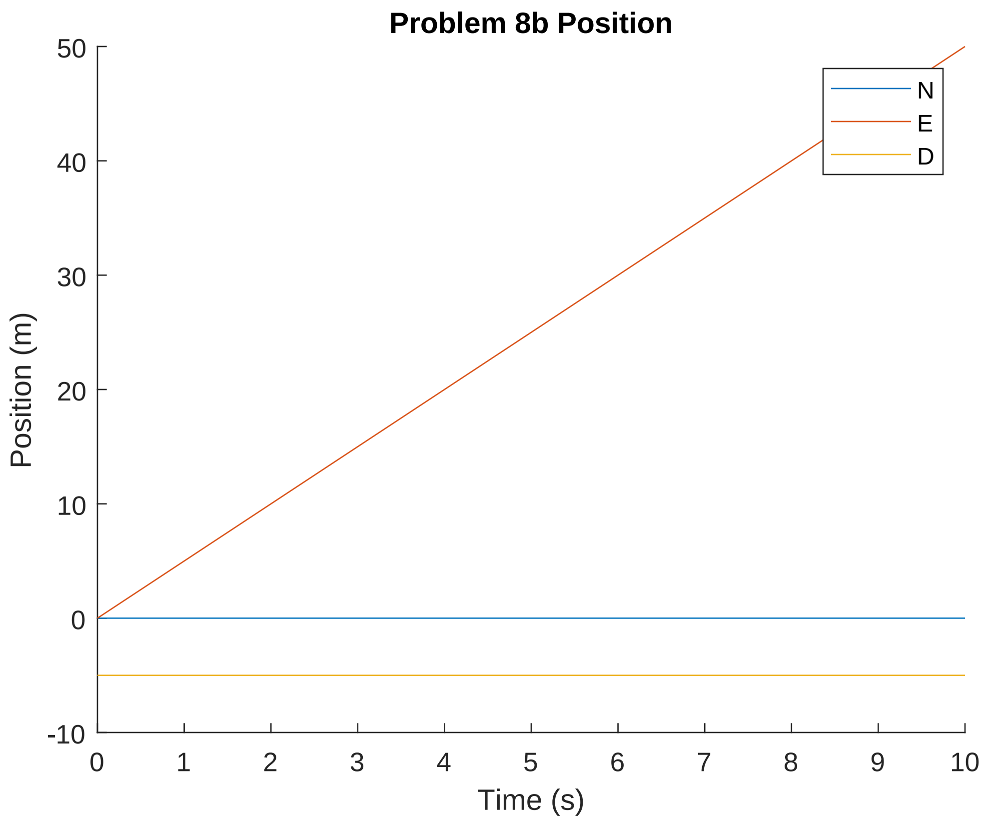
9. No since adding a slight angle causes the quad copter to loose equilibrium entirely

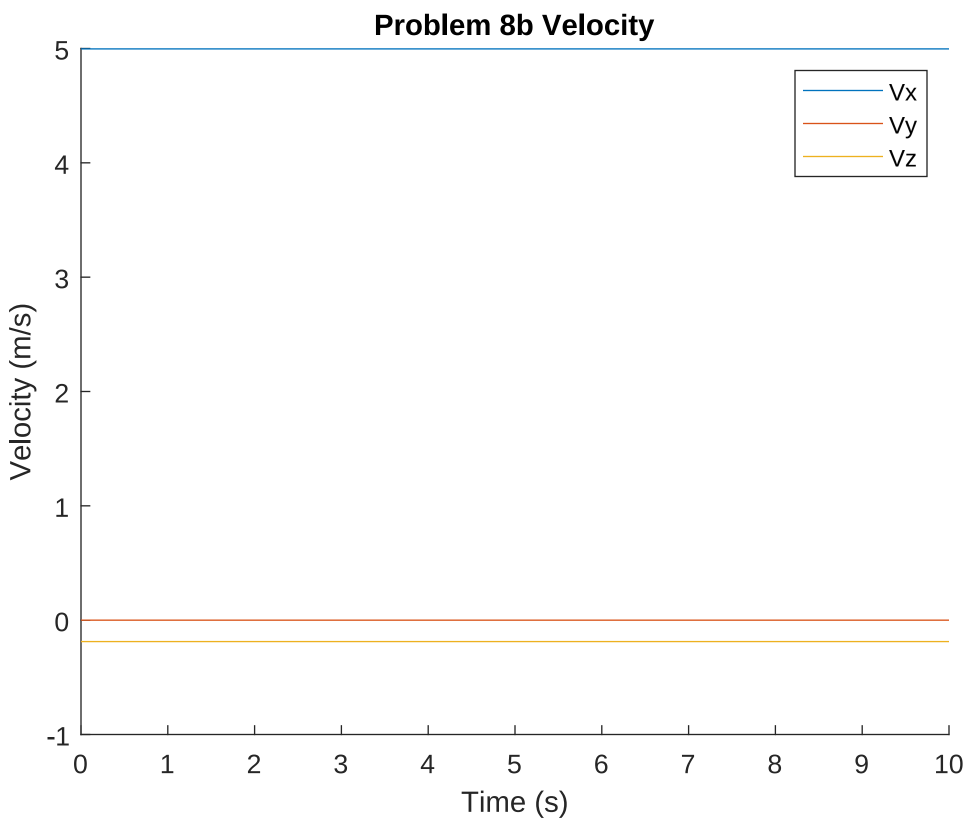

Problem 7 Position
N
E
D
Position (m)
1
0
-1
-2
-3
-4
-5
-6
0
1
2
3
4
5
6
7
8
9
10
Time (s)

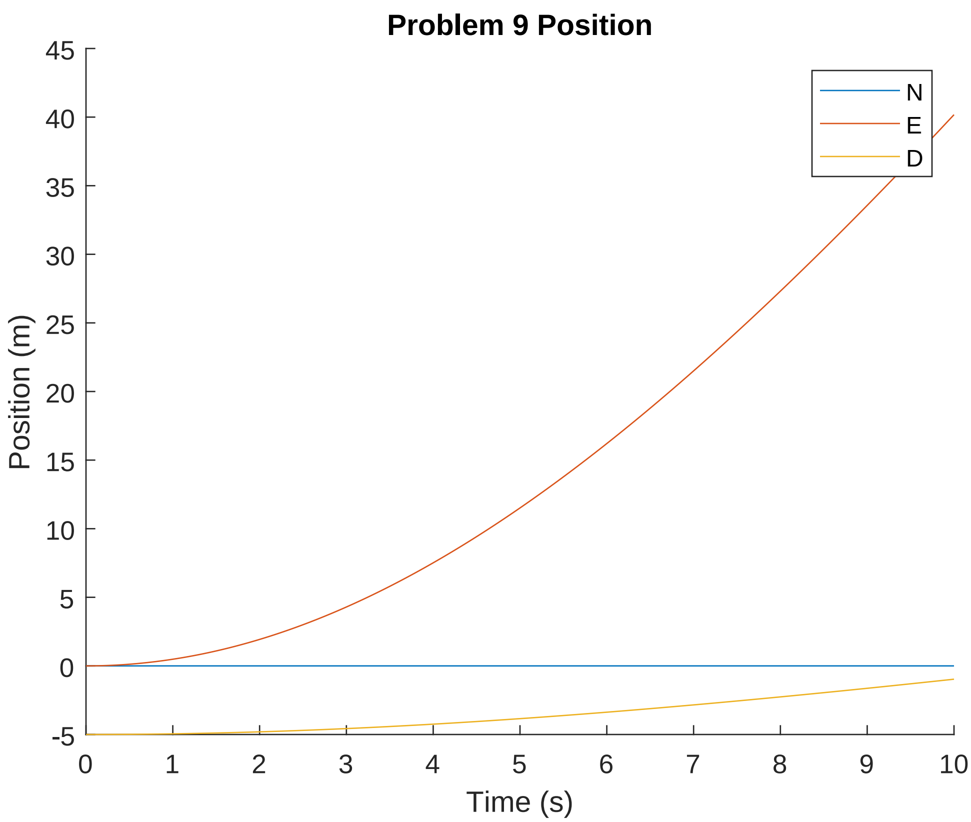

Problem 8a Position
Position (m)
Time (s)
N
E
D
50
40
30
20
10
0
-10
0
1
2
3
4
5
6
7
8
9
10

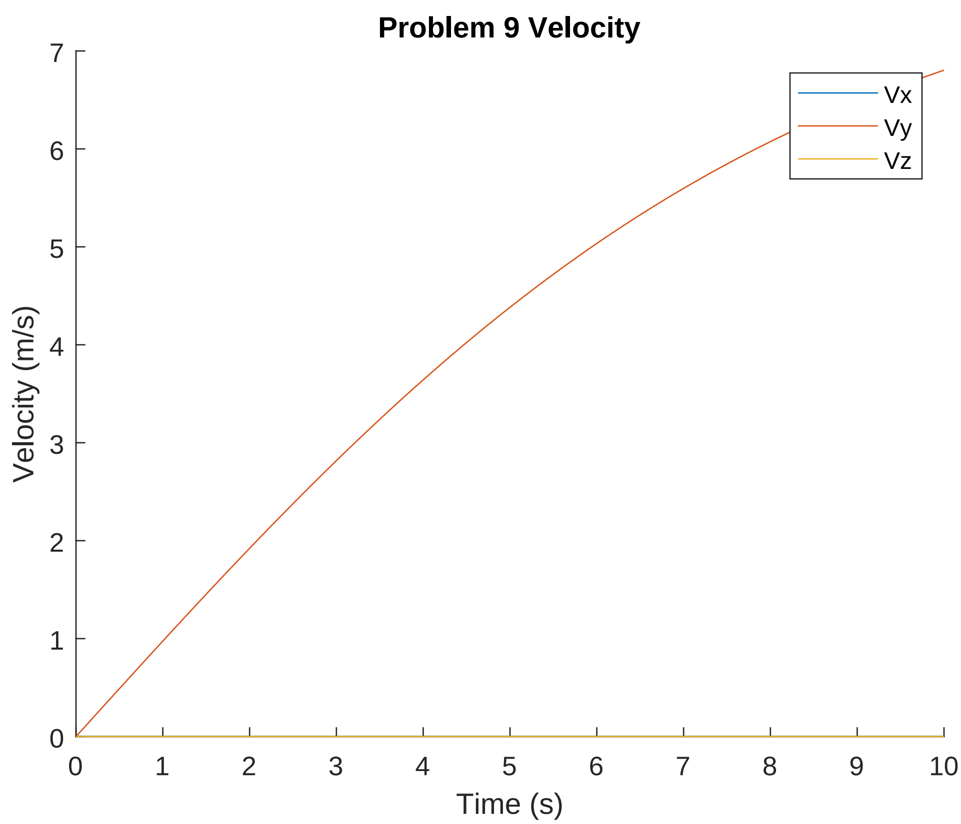


Problem 8a Velocity
Velocity (m/s)
Time (s)
Vx
Vy
Vz
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
8
9
10


Problem 8b Position
Position (m)
Time (s)
N
E
D
50
40
30
20
10
0
-10
0
1
2
3
4
5
6
7
8
9
10


Problem 8b Velocity
Velocity (m/s)
Time (s)
Vx
Vy
Vz
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
8
9
10


Problem 9 Position
Position (m)
Time (s)
N
E
D
45
40
35
30
25
20
15
10
5
0
-5
0
1
2
3
4
5
6
7
8
9
10


Problem 9 Velocity
Vx
Vy
Vz
Velocity (m/s)
Time (s)
0
1
2
3
4
5
6
7
8
9
10