King Abdulaziz University

Aerospace Engineering Department

AE 362-Flight Dynamics

Spring 2021-Final Exam

(1) Consider the function

$$f(x,\theta) = x^3\cos\theta - x^2\sin\theta + x\theta \qquad (1)$$

(a) Apply the assumptions of the small disturbance theorem to expand $f(x,\theta)$ about the point $(1, \frac{\pi}{6})$.
(b) Extract the linearized version $f_L(x,\theta)$ of the function $f(x,\theta)$ about the point $(1, \frac{\pi}{6})$.
(c) Linearize $f(x,\theta)$ about the point $(1, \frac{\pi}{6})$ by using Taylor series expansion. You should obtain the same linear function $f_L(x,\theta)$!

(2) Assume you are the pilot of an airplane on the route from Jeddah to Dhahran. Somewhere on the way you received the following information from air traffic control center: Eastbound velocity 600 km/h, Northbound velocity 250 km/h, descending at 50 m/sec. The attitude sensors of the airplane give the following information: pitch $\theta =$ 10 deg, roll $\phi =$ -10 deg, and yaw $\psi =$ 30 deg. The rate sensors give the following information: $\dot{\theta} =$ 2 deg/sec, $\dot{\phi} =$ 3 deg/sec and $\dot{\psi} =$ 5 deg/sec.

(a) What are the components of the velocity $\overrightarrow{V}$ of the airplane, expressed in the wind reference frame?
(b) What are the components of the velocity $\overrightarrow{V}$ of the airplane, expressed in the reference frame fixed in the airplane defined by Euler's angles rotations sequence?
(c) What are the values of the angles of attack and sideslip based on the information provided by the air traffic control center and attitude sensors.
(d) What are the components of the angular velocity of the airplane, expressed in the earth-fixed (NED) reference frame?
(e) If the weight of the airplane is 3×10^3kg, what are the components of the weight in the same airplane-fixed reference frame?

(3) A launch vehicle (LV) is fired from a point on the earth's equator line. The displacement vector of the launch vehicle from the earth's center is given by

$$\overrightarrow{\mathbf{r}} = -6371\hat{\mathbf{k}}_e + (1000\hat{\mathbf{j}}_e - 2000\hat{\mathbf{k}}_e)(t - te^{-0.01t})\text{km} \qquad (2)$$

where $\hat{\mathbf{i}}_e$, $\hat{\mathbf{j}}_e$, and $\hat{\mathbf{k}}_e$ are respectively earth-fixed unit vectors in the local north, local east, and downward direction at the point of LV firing. The earth's center is assumed fixed with respect to the sun during the launch vehicle's firing time period. Hence, the angular velocity of the earth with respect to the sun is taken to be one revolution per day, i.e.,

$$\overrightarrow{{}^S\boldsymbol{\omega}^E} = \frac{\pi}{12}\hat{\mathbf{i}}_e \ \text{rad/hr.} \qquad (3)$$

Find

(a) The LV velocity with respect to the earth $\overrightarrow{{}^E\mathbf{v}^c} = \frac{{}^E d\overrightarrow{\mathbf{r}}}{dt}$.
(b) The LV acceleration with respect to earth $\overrightarrow{{}^E\mathbf{a}^c} = \frac{{}^E d\overrightarrow{{}^E\mathbf{v}^c}}{dt}$.
(c) The LV velocity with respect to the sun $\overrightarrow{{}^S\mathbf{v}^c} = \frac{{}^S d\overrightarrow{\mathbf{r}}}{dt}$.
(d) The LV acceleration with respect to sun $\overrightarrow{{}^S\mathbf{a}^c} = \frac{{}^S d\overrightarrow{{}^S\mathbf{v}^c}}{dt}$.