Aersp 450 Final Exam Outline

Date/Time: Friday Dec. 20, 12:20-2:10PM
Last name A-I – 319 Sackett
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Exam will consist of 2 parts:

1. **Part 1 -- 2 problems, 10 points each – two equation sheets allowed for this part.**
   These problems will be *extraordinarily similar* to those on your homework sets and Test #3. You will complete this part of the exam first and hand it in along with your equation sheets.

2. **Part 2 – 20 multiple-choice questions, 4 points each – no equation sheets allowed for this part.**

**Multiple-Choice Questions**

(The final exam will include 20 of these, with some modifications to the choice and order of the answers.)

Q101. What is the *minimum* number of scalar quantities needed to specify the orientation of one coordinate system with respect to another?
   a. 2
   b. 3
   c. 4
   d. 9
   e. none of the above

Q102. A satellite undergoes a sequence of rotations 30\(^\circ\), 47\(^\circ\), and 132\(^\circ\), arriving at a final orientation.
   The final orientation
   a. is independent of the order in which the rotations occur.
   b. depends upon the rate at which the rotations occur.
   c. will be different for each specific sequence.
   d. is sensitive to the specific sequence only for very small angles.
   e. none of the above

Q103. The total number of Euler-angle sequences for rotations about the body axes and about the space-fixed axes is
   a. 2
   b. 3
   c. 4
   d. 12
   e. 24
   f. none of the above
Q104. A direction cosine matrix can be generated from
   a. 3 Euler angles, plus a specified sequence
   b. 4 Euler parameters
   c. a quaternion
   d. 9 angles between basis vectors in two coordinate systems
   e. all of the above

Q105. Which of the following could be a direction cosine matrix relating two right-handed
   coordinate systems?

   a. \[
   \begin{bmatrix}
   1 & 0 & 0 \\
   0 & -1 & 0 \\
   0 & 0 & 1 \\
   \end{bmatrix}
   \]
   b. \[
   \begin{bmatrix}
   1 & 1 & -1 \\
   -1 & 1 & 1 \\
   1 & -1 & 1 \\
   \end{bmatrix}
   \]
   c. \[
   \begin{bmatrix}
   1 & 0 & 1/2 \\
   0 & 1 & 0 \\
   -1/2 & 0 & 1 \\
   \end{bmatrix}
   \]
   d. \[
   \begin{bmatrix}
   0 & 0 & -1 \\
   0 & 1 & 0 \\
   1 & 0 & 0 \\
   \end{bmatrix}
   \]
   e. all of the choices a,b,c and d

Q106. For a direction cosine matrix, the determinant equals +1
   a. if the coordinate systems are both right-handed
   b. if one coordinate system is right-handed and the other is left-handed.
   c. regardless of the handedness of the coordinate systems
   d. if the coordinate systems are both composed of unit vectors
   e. never

Q107. The eigen-axis corresponding to the direction cosine matrix \( C_{B/A} \) is
   a. a vector composed of the Euler parameters
   b. an angle of equivalent rotation from A to B
   c. a vector whose components are the same in B and A
   d. an eigenvalue of \( C_{B/A} \)
   e. none of the above

Q108. Select the one false statement from among the following:
   a. There is always a unique set of Euler parameters corresponding to a given DCM.
   b. There is always a unique set of Euler angle rates corresponding to a given angular
      velocity \( \dot{\omega} \)
   c. There is always a unique angular velocity \( \dot{\omega} \) corresponding to a given set of Euler
      angle rates.
   d. There is never a set of Euler parameters for which \( q_1^2 + q_2^2 + q_3^2 + q_4^2 < 1 \).
   e. There is always a unique DCM corresponding to a given set of Euler angles and
      specified rotation sequence.
Q109. A satellite undergoes a sequence of 5 rotations in order to observe 5 different stars of astronomical interest: from $N$ to $P$, $P$ to $Q$, $Q$ to $R$, $R$ to $S$, and $S$ to $T$. The angle between $\hat{n}_3$ and $\hat{s}_1$ is given by

a. $C_{13}^{S/N}$
b. $\cos^{-1}(C_{13}^{S/N})$
c. $C_{31}^{S/N}$
d. $\cos^{-1}(C_{31}^{S/N})$
e. none of the above

Q110. Select the one true statement from among the following:

a. The elements of a DCM are unrelated.
b. A DCM is equal to its inverse.
c. The minimum number of scalar quantities needed to create a DCM is 2.
d. The capital of North Carolina is Charlotte.
e. none of the above

Q111. A satellite whose body axes $\mathbf{b}$ are originally aligned with the Newtonian axes $\mathbf{n}$ undergoes a sequence of 2 rotations: $\theta_1$ about the 1-axis, then $\theta_2$ about the 3-axis. The $\hat{b}_3$ axis is then pointing at a star. In terms of the Newtonian axes, what is the direction $\hat{s}$ to the star?

a. $\hat{s} = 0\hat{n}_1 + 0\hat{n}_2 + 1\hat{n}_3$
b. $\hat{s} = 0\hat{n}_1 - \sin\theta_1\hat{n}_2 + \cos\theta_1\hat{n}_3$
c. $\hat{s} = 0\hat{n}_1 + \cos\theta_2\hat{n}_2 + \sin\theta_2\hat{n}_3$
d. $\hat{s} = \sin\theta_1\sin\theta_2\hat{n}_1 + \sin\theta_1\cos\theta_2\hat{n}_3$
e. none of the above

Q112. Which of the following cannot be an inertia matrix for a physical object?

a. $I = \begin{bmatrix} 20 & -2 & 4 \\ -2 & 30 & -3 \\ 4 & -3 & 40 \end{bmatrix} (kg \cdot m^2)$
b. $I = \begin{bmatrix} 25 & -2 & -10 \\ 2 & 35 & 4 \\ -10 & -4 & 45 \end{bmatrix} (kg \cdot m^2)$
c. $I = \begin{bmatrix} 7000 & 0 & -8 \\ 0 & 7000 & 0 \\ -8 & 0 & 9532 \end{bmatrix} (kg \cdot m^2)$
d. $I = \begin{bmatrix} 3000 & 0 & 0 \\ 0 & 3000 & 0 \\ 0 & 0 & 3000 \end{bmatrix} (kg \cdot m^2)$
e. $I = \begin{bmatrix} 309 & 0 & 0 \\ 0 & 450 & 0 \\ 0 & 0 & 550 \end{bmatrix} (kg \cdot m^2)$
Q113. A spacecraft is an axisymmetric prolate spinner if
a. It spins about the principal axis having minimum moment of inertia and the other two axes have equal, larger moments of inertia.
b. It spins about the principal axis having maximum moment of inertia and the other two axes have equal, smaller moments of inertia.
c. It spins about any principal axis, but there are no conditions on the relative sizes of the moments of inertia.
d. It spins about the principal axis having minimum moment of inertia and the other two axes have unequal, larger moments of inertia.
e. none of the above.

Q114. For an axisymmetric, oblate spacecraft that is spinning about its axis of maximum inertia ($\hat{b}_3$) and precessing in the absence of torque, which one of the following quantities is not constant?
a. $\omega_3$
b. $\omega_{12}$
c. $H = |\vec{H}|$
d. $\dot{H} \cdot \hat{b}_3$
e. none of the above

Q115. For any type of axisymmetric spacecraft that is spinning about its unique symmetry axis $\hat{b}_3$ and precessing in the absence of torque, which one of the following statements is true?
a. $\vec{H}, \vec{\omega}$, and $\hat{b}_1$ all lie in the same plane.
b. $\vec{H}, \vec{\omega}, \hat{b}_1$, and $\hat{b}_3$ all lie in the same plane.
c. $\vec{H}, \vec{\omega}, \hat{b}_1, \hat{b}_2$, and $\hat{b}_3$ all lie in the same plane.
d. $\vec{H}, \vec{\omega}$, and $\hat{b}_3$ all lie in the same plane.
e. none of the above

Q116. For an asymmetric spacecraft (unequal principal moments of inertia), spin stability is best achieved by spinning the vehicle about
a. its minor axis of inertia (minimum inertia)
b. its intermediate axis of inertia
c. its major axis of inertia (maximum inertia)
d. any axis except a principal axis
e. its eigen-axis.
Q117. In a non-rigid, spinning spacecraft, in the absence of torques
a. angular momentum and kinetic energy are constant wrt the Newtonian frame.
b. angular momentum is constant wrt the Newtonian frame, but kinetic energy is not.
c. angular momentum is not constant wrt the Newtonian frame, but kinetic energy is.
d. neither angular momentum nor kinetic energy is constant wrt the Newtonian frame.
e. it is impossible to conclude whether angular momentum or kinetic energy are constant wrt the Newtonian frame.

Q118. In the figure below, an axisymmetric spacecraft with radius $r$ is spinning about its $\hat{b}_3$ axis. Thrusters mounted on the vehicle’s exterior at locations $+r\hat{b}_2$ and $-r\hat{b}_2$, with thrust $\vec{F}$ directed along $+\hat{b}_3$ and $-\hat{b}_3$, respectively, fire just as the $\hat{b}$ axes become aligned with the respective $\hat{n}$ axes. The resulting change in the angular momentum $\Delta \vec{H}$ is along
a. $\hat{n}_1$
b. $\hat{n}_2$
c. $\hat{n}_3$
d. $\hat{n}$ does not change because of gyroscopic stiffness
e. insufficient information given to determine $\Delta \vec{H}$

Q119. Gravity gradient torque depends upon radial distance $r$ from Earth’s center in which way?
a. Proportional to $r$
b. Independent of $r$
c. Proportional to $1/r$
d. Proportional to $1/r^2$
e. Proportional to $1/r^3$
Q120. Gravity gradient torque is maximum for a pitch angle of
a. 0 degrees
b. 30 degrees
c. 45 degrees
d. 60 degrees
e. 90 degrees

Q121. For small pitch, roll, and yaw angles, a spacecraft is gravity-gradient stable if its principal moments of inertia obey which relationship?
   a. $I_{\text{roll}} > I_{\text{pitch}} > I_{\text{yaw}}$
   b. $I_{\text{yaw}} > I_{\text{roll}} > I_{\text{pitch}}$
   c. $I_{\text{pitch}} > I_{\text{yaw}} > I_{\text{roll}}$
   d. $I_{\text{pitch}} > I_{\text{roll}} > I_{\text{yaw}}$
   e. none of the above

Q122. To maintain an inertially fixed spin axis (also the direction of its rotational angular momentum), in the presence of gravity-gradient effects, a spacecraft must be oriented
   a. with its spin axis in the orbital plane and aligned toward Earth’s center.
   b. with its spin axis in the orbital plane and aligned perpendicular to the orbital radius vector.
   c. with its spin axis in the orbital plane and aligned at 45 degrees to the orbital radius vector.
   d. with its spin axis perpendicular to the orbital radius vector and aligned at 45 degrees to the orbital plane.
   e. none of the above

Q123. For which combination of values does a satellite have the highest gyroscopic stiffness?
   a. low inertia about the spin axis, low spin rate
   b. low inertia about the spin axis, high spin rate
   c. high inertia about the spin axis, high spin rate
   d. high inertia about the spin axis, low spin rate
   e. arbitrary inertia about the spin axis, zero spin rate

Q124. Which type of attitude control device depends directly upon the satellite’s orbital radius?
   a. reaction wheel
   b. magnetic torquer
   c. momentum wheel
   d. thruster
   e. control moment gyro
Q125. The process by which a momentum or reaction wheel is slowed to prevent it from exceeding maximum speed is called
   a. torque precession
   b. nutation control
   c. momentum dumping
   d. libration control
   e. none of the above

Q126. An Earth sensor provides attitude information by
   a. measuring the Earth’s magnetic field strength.
   b. measuring radio signal strengths from two different ground stations.
   c. using timing data from at least four different GPS satellites.
   d. measuring light from Earth.
   e. none of the above

Q127. To completely determine its attitude wrt an inertial coordinate system, a satellite must make use of which data?
   a. Two angles (from Earth and sun sensors), the time, and the satellite’s orbital position
   b. The time and the satellite’s orbital inclination
   c. Two angles (from Earth and sun sensors) and the time
   d. The time, the satellite’s orbital position, and the satellite’s orbital inclination
   e. none of the above

Q128. Which of the following attitude control devices is normally not spinning?
   a. dual-spin spacecraft
   b. reaction wheel
   c. momentum wheel
   d. control moment gyro
   e. none of the above

Q129. Compare the following statements regarding a spin-stabilized satellite using a pair of thrusters to reorient its spin axis through an angle $\Delta \theta$. Which one statement is correct?
   a. Short thruster pulses are more efficient and the maneuver takes longer.
   b. Short thruster pulses are more efficient and the maneuver takes less time.
   c. Longer thruster pulses are more efficient and the maneuver takes longer.
   d. Longer thruster pulses are more efficient and the maneuver takes less time.
   e. It is impossible to reorient the satellite because of its gyroscopic stiffness.
Q130. In science fiction, the bad guys prefer symmetric spacecraft. In *Star Wars*, the Empire uses the Death Star, essentially a sphere of 120 km diameter (a little-known fact from www.starwars.com); in *Star Trek – The Next Generation*, the Borg use a cube-shaped spacecraft (but did not feel inclined to post the dimensions on their website). Assuming a uniform distribution of mass within each of these spacecraft, their principal moments of inertia are all equal – that is, $I_1 = I_2 = I_3$. What is the consequence for the gravity-gradient torque and its effects on these vehicles?

![Death Star – preliminary design](image1) ![The Borg-collective ship – conceptual design](image2)

a. The resulting gravity-gradient torque will cause the vehicles to librate and spoil their aim as they try to wreak planetary destruction.

b. The gravity-gradient torque will change depending upon each vehicle’s distance from the planet that it is trying to destroy.

c. There will be no effect on the gravity-gradient torque since it does not depend upon the moments of inertia.

d. As each vehicle rotates, its body rates will be coupled in a complicated way.

e. There will be no gradient-gradient torque, but the good guys win anyway.