DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	November 2, 2004 from 9:00 until 12:00 hr
Remarks	:	Write your name, initials and student number on your work Answer all questions in English or Dutch and mark all pages with your name.

This examination consists of 6 questions. The number of points you can gain with each question is indicated below. Your grade will be equal to one plus the total number of points divided by ten.

READ THE QUESTIONS FIRST BEFORE ANSWERING THEM (some things might be asked twice, but in a different context).

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1. AVIONICS – GENERAL (10 points)

Give the exact meaning of the following acronyms and describe briefly what they stand for. (1 point each)
Example: PFD = **P**rimary **F**light **D**isplay.
The PFD is the main cockpit instrument, placed in front of the pilot, showing all primary flight information such as the aircraft attitude, airspeed and altitude.

1. AFTN
2. HSI
3. RNAV
4. ADS-B
5. EFIS
6. SID
7. AMSS
8. LAAS
9. ACC
10. ILS

2. THE EARTH MAGNETIC FIELD: COMPASSES (15 points)

1. What is a *magnetometer*? (1 point)
2. Describe in detail the working principle of the magnetometer. (7 points)
3. What are the advantages of the magnetometer with respect to a direct-reading magnetic compass? (1 point)

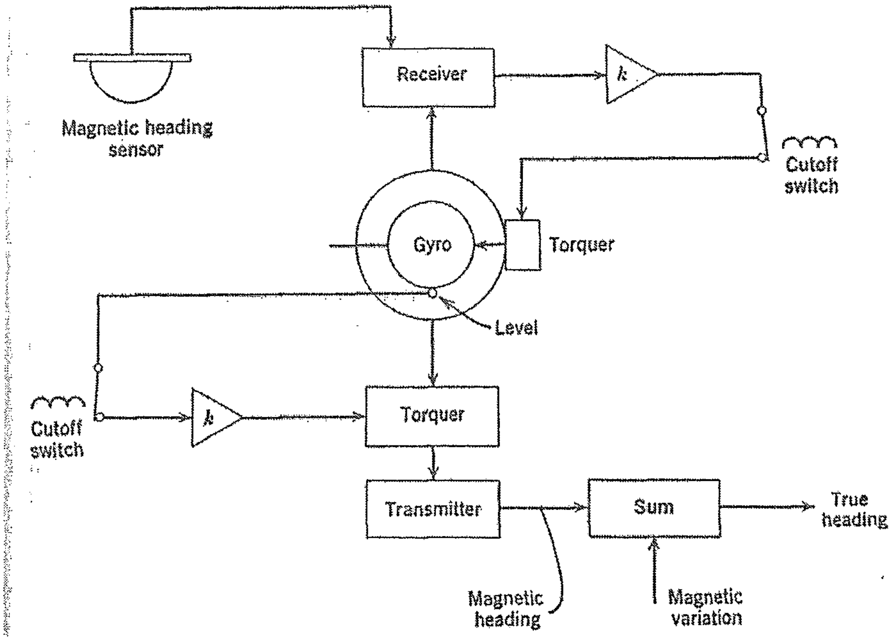

Figure 1: *The gyrosyn compass.*

4. Describe, at the hand of Figure 1, *how* the magnetometer is combined with a directional gyro to constitute a *gyrosyn* compass (i.e. a *Magnetic Heading Reference System* (MHRS)). In other words, how does this combination work? (4 points)

5. In the MHRS, how do the magnetometer and the directional gyro compensate for each other's deficiencies? (2 points)

3. THE NAVIGATION EQUATIONS (15 points)

[a] The Earth shape can be modelled as a rotated ellipsoid. The position of a vehicle with respect to the Earth-Centered Earth-Fixed reference frame can be expressed with three variables, i.e. the longitude λ, the geodetic latitude Φ_T and the altitude h.

1. How is the Earth-Centered Earth-Fixed reference frame defined? (3 points)
2. In the navigation equations, two radii of curvature are very important. What are the names of these two radii of curvature? How are they defined? (Note: no formulas are requested here.) (3 points)
3. Consider Figure 2. The aircraft is located at position (λ, Φ_T, h) and is flying with a ground velocity (V_{NORTH} to the North and V_{EAST} to the East). Derive the formulas for the *rate-of-change* of the longitude λ and the geodetic latitude Φ_T, using the two radii of curvature introduced above. (3 points)

[b] Two general categories exist of navigation systems, namely *Positioning systems* and *Dead Reckoning systems.*

1. Give a definition of both categories, clearly indicating the main differences

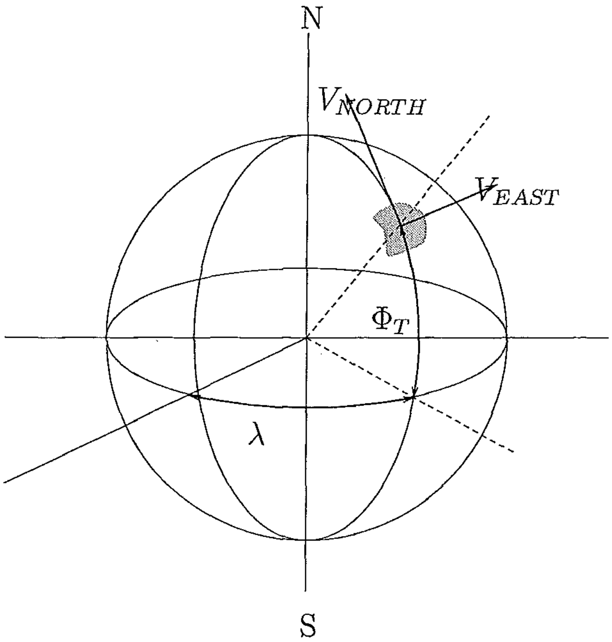

Figure 2: *An aircraft is located at altitude h above the Earth surface (h not shown in this figure), at longitude* λ *and (geodetic) latitude* Φ_T*. The velocity of the aircraft towards the North is indicated by* V_{NORTH}*, the velocity of the aircraft towards the East is indicated by* V_{EAST}*.*

between them. (3 points)

2. Give one typical example of a navigation system for each category. (1 points)
3. Discuss the advantages and the disadvantages of dead reckoning navigation systems with respect to positioning navigation systems. (2 points)

4. INERTIAL NAVIGATION SYSTEM (20 points)

[a] What are the main advantages of inertial navigation systems (INS) and what are the main disadvantages? (1 point)

[b] What is the underlying principle of inertial navigation? (1 point)

[c] Consider Figure 3, showing the two primary feedback control loops of a gimballed inertial navigation system. Describe *in detail* how these two loops work, i.e. what do they measure, what do they control, and why do we need them to make the gimballed inertial navigator practible. (6 points)

[d] The INS building blocks are accelerometers and gyroscopes. Both are inertial sensors which can have various inaccuracies. What is the main inaccuracy of the gyroscope and how does this gyroscope inaccuracy propagate into a position error? (3 points)

[e] Why do we call a typical INS a *Schuler tuned* system? Explain your answer. (3 points)

[f] When considering the sensor inaccuracy mentioned above, what effects does

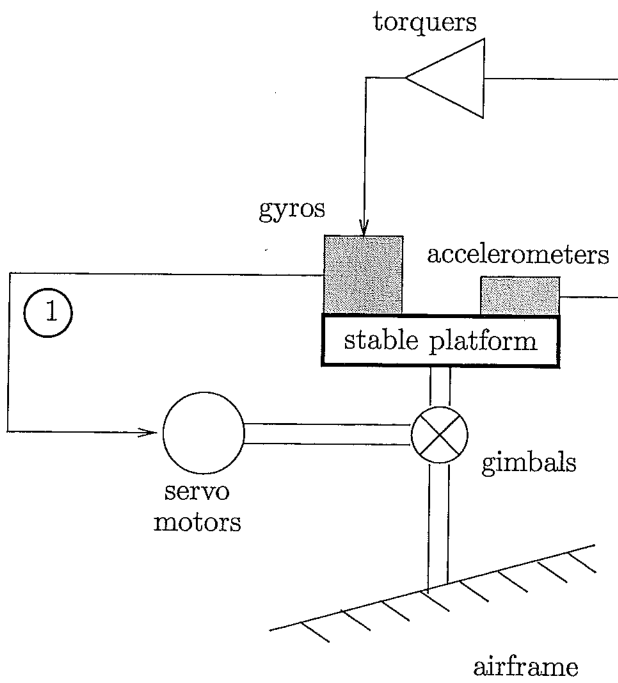

Figure 3: *A gimballed inertial navigation system platform. The circles with '1' and '2' indicate the two main INS feedback control loops.*

the Schuler tuning have on these inaccuracies. In other words, for a Schuler tuned INS how do the sensor inaccuracies propagate into the position error? (3 points)

[g] What are the characteristics of a typical INS in terms of accuracy, coverage, capacity and integrity? (2 points)

[h] What are the future trends in inertial navigation? (1 point)

5. **TERRESTRIAL RADIO NAVIGATION** (15 points)

[a] How do radio waves propagate on the Earth? Include in your answer the ground wave and sky wave propagation and the ways in which these two waves interfere. What are line-of-sight waves? (3 points)

[b] Describe the main working principle of a VHF Omni-directional Radio Range (VOR) beacon. How is the VOR information presented to the pilot? (6 points)

[c] Consider Figure 4 showing two VOR beacons from above.

- What is GDOP? (1 point)
- Explain the concept of GDOP using Figure 4. In your answer, place the aircraft receiver at positions A, B and C and describe if and how the GDOP changes. (3 points)

[d] With what other beacon is the VOR often collocated? Why is that? (2 points)

6. **AIR TRAFFIC CONTROL & MANAGEMENT** (15 points)

Since 1995, all aircraft with more than 30 passenger seats operating in the United

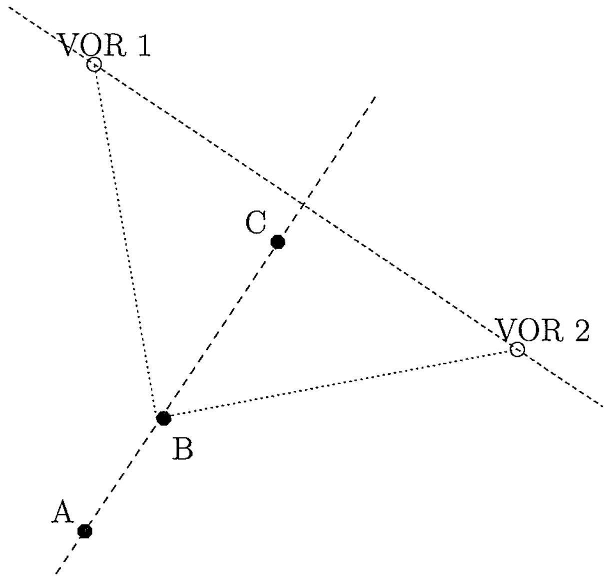

Figure 4: *Top view of a situation with two VOR beacons.*

States airspace are required to be equipped with an ACAS.

[a] What does the acronym ACAS stand for? (1 point)

[b] How does an ACAS work? What is the main reason why the ACAS needs to be installed in aircraft? (8 points)

[c] What information does an ACAS provide to the pilot? (3 points)

[d] What is the main problem with current ACAS systems? (2 points)

[e] What is the name of the most-widely used ACAS system? (1 point)