DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	November 1, 2005 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).

---

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

[a] What is a *magnetometer*? (1 point)

[b] Describe in detail the working principle of the magnetometer. (7 points)

[c] What are the advantages of the magnetometer with respect to a direct-reading magnetic compass? (1 point)

[d] 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)

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

2. AIR TRAFFIC CONTROL & MANAGEMENT (15 points)

Since 1995, all aircraft with more than 30 passenger seats operating in the United 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? (7 points)

[c] What information does an ACAS provide to the pilot? (2 points)

[d] What is the main problem with current ACAS systems? (1 points)

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

[f] What does the acronym ASAS stand for? What kind of system is this and how does it relate to an ACAS? (3 points)

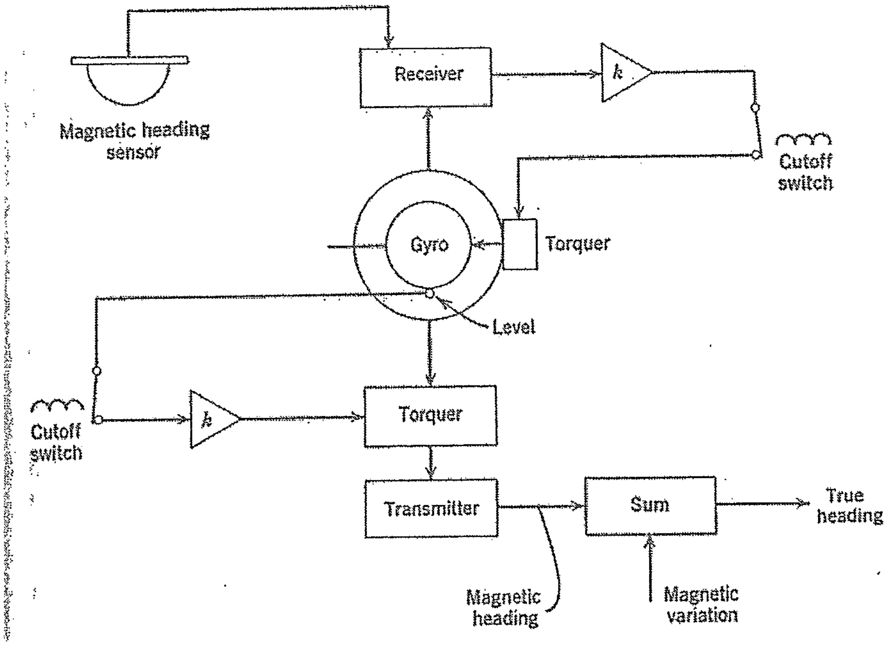

Figure 1: *The gyrosyn compass.*

3. INERTIAL SENSORS: GYROSCOPES (15 points)

[a] What are the disadvantages of mechanical gyroscopes with respect to optical gyroscopes? (1 point)

[b] What aircraft state variables can be measured with a vertical (mechanical) gyroscope? (1 point)

[c] The two fundamental properties of mechanical gyroscopes are *rigidity* and *precession*. Describe, using a simple sketch, what these two properties mean. (4 points)

[d] Consider Figure 2, showing a view from above the North Pole towards the Earth, where a not-moving observer located at the Earth equator (point **A**) is looking at a vertical gyroscope. After six hours of waiting the observer is located at point **B**. Make a simple but clear sketch showing the gyroscope at point **B**. What has happened? (2 points)

[e] In order to make a (mechanical) gyroscope useful for aircraft, it must be converted from what is called an *inertial machine* to an *Earth gyroscope*. What does this mean? And what are the two main corrections that have to be exerted on the gyroscope to make this possible? (6 points)

[f] What are gyro *erection systems*? What are they used for? (1 points)

4. FLIGHT MANAGEMENT SYSTEM (15 points)

[a] Describe in detail, preferably at the hand of a sketch, the three main components of a Flight Management System. What are the functions of these three components of the FMS? (5 points)

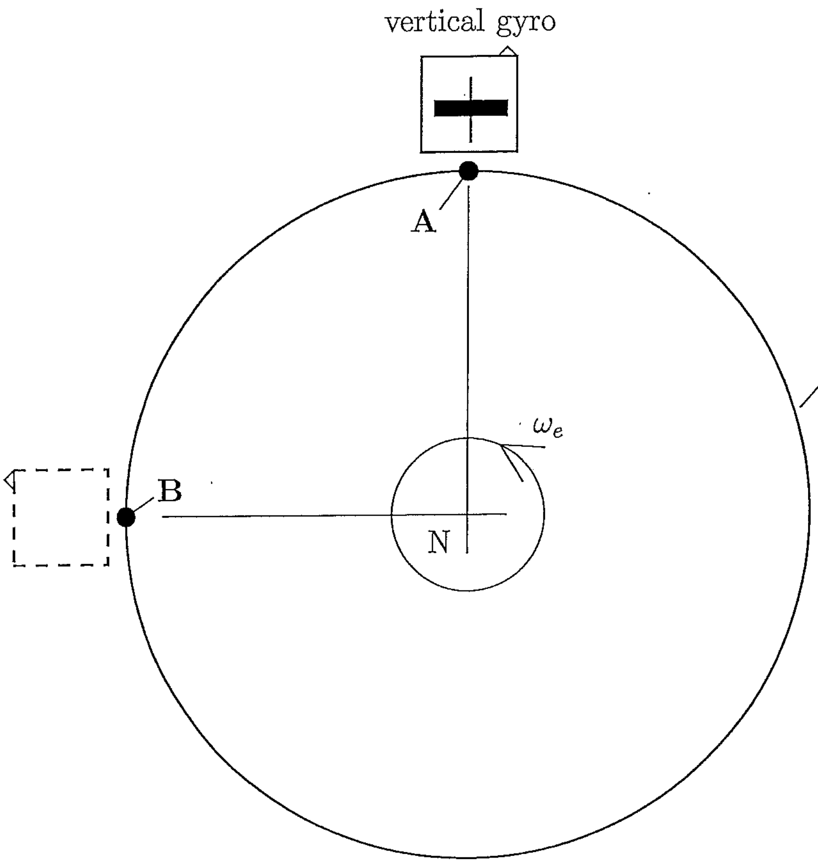

Figure 2: View to the Earth, looking from above the North Pole to the Earth's center. A vertical gyroscope is placed at the Earth equator at point **A**. ω_e is the Earth rotation velocity.

[b] What are the three general functions of the FMS? Explain how the three FMS components are used to serve these functions. (4 points)

[c] What is the relation between the FMS and the automatic flight control systems? Are they one and the same? If so, explain *how* they are integrated. If not, explain *why* they are not integrated. (2 points)

[d] One of the relatively 'new' functions of an FMS is that it employs the so-called RNAV function.

1. What is RNAV? (2 points)
2. What are the main virtues of RNAV with respect to the other modes of navigation? (2 points)

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 principle of the Automatic Direction Finder (ADF). What ground station is used in co-operation with the ADF? How is the ADF information presented to the pilot? (4 points)

[c] 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)

[d] In terms of aircraft navigation and guidance, what are the main differences between using an ADF and a VOR? (2 points)

6. INERTIAL NAVIGATION SYSTEM (15 points)

[a] What is the underlying principle of the INS? (1 point)

[b] What are the main INS components? What are their function and how do they work together to enable the INS to generate a navigation solution? (2 points)

[c] Two elementary different forms exist of the INS. One of them is the so-called *strapdown inertial navigation system*.

1. What is the other form of implementing an INS called?. (1 point)
2. What is the crucial difference between both INS systems? (1 point)
3. What are the advantages and disadvantages of both forms with respect to each other? (1 point)

[d] Consider Figure 3, which shows the basic 'analytic' functioning of a strapdown inertial navigation system in the situation of assuming a flat, non-rotating Earth.

1. What symbols in this figure represent the measurements (from the sensors)? In what reference frame do we measure them? Why? (1 point)

2. What symbols in this figure represent the navigation solution? In what reference frame are they defined? Why? (1 point)

3. In the strapdown inertial navigation system set-up as indicated by this figure, are we compensating for transport wander? Explain your answer. (1 point)

Again, consider Figure 3. The strapdown inertial system computations are done in four consecutive steps. These steps are, *in random (!) order*:

I Integration of the vehicle dynamics of motion.

II Resolution of the gravity vector.

III Computation of the navigation solution.

IV Integration of the Euler equations.

[e] Indicate, using a *clear and unambiguous sketch*, on the figure sheet (!) of the examination, which parts of the figure belong to the four computation blocks stated above. (1 point)

[f] In what order are these computations being executed? Explain your answer. (2 points)

Assume we have our strapdown inertial navigation system as indicated in Figure 3, but now the Earth is **not flat and is rotating**.

[g] What do we need to do to make this system work again? What are the consequences of these actions? (3 points)

NOTE: THIS FIGURE INCLUDING YOUR ANSWER TO THE QUESTION STATED ABOVE MUST BE HANDED OVER TOGETHER WITH THE REST OF YOUR ANSWERS!!!!

Name:

Student number:

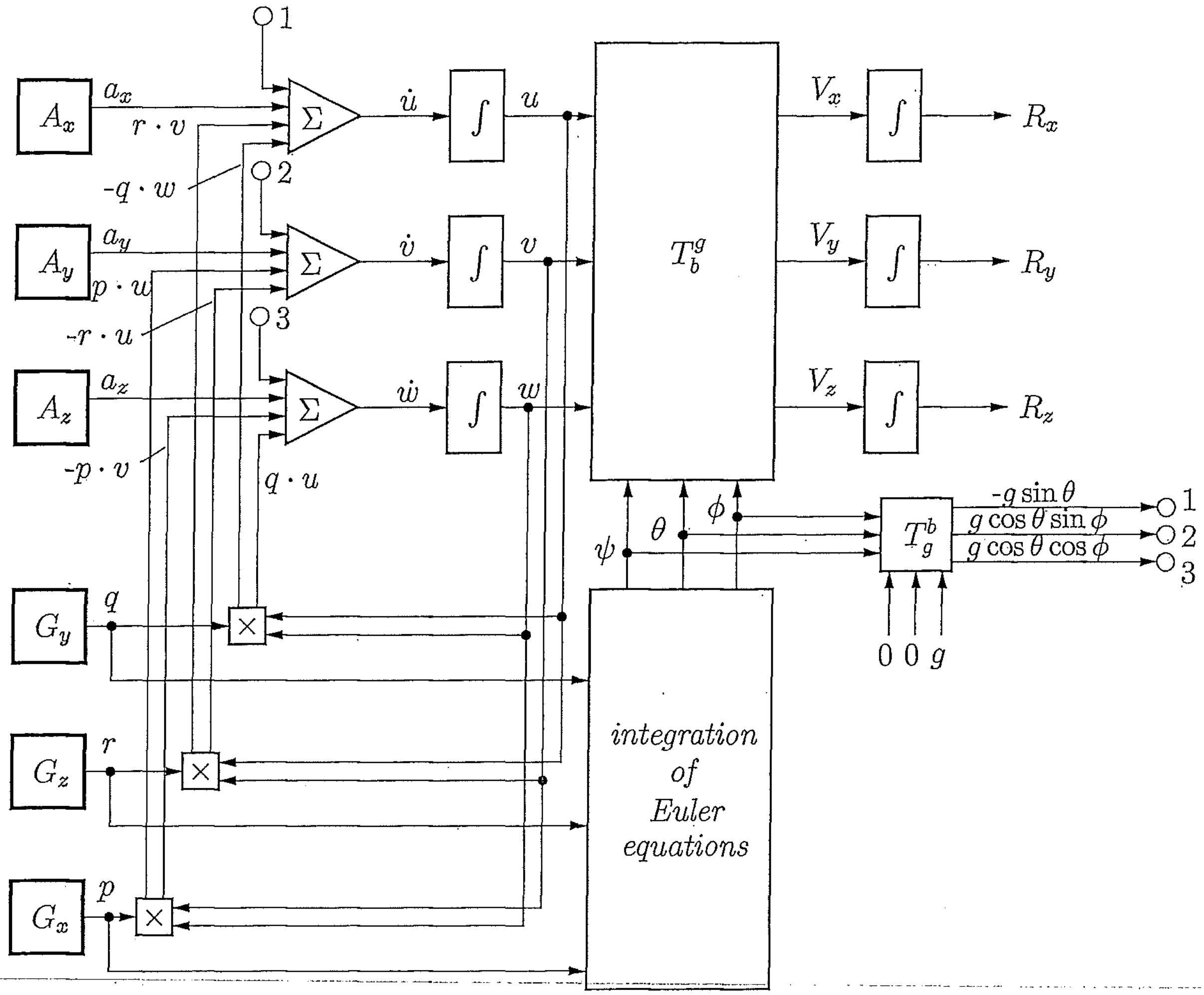

Figure 3: *Schematic diagram of the analytic platform. Note: the symbols used in this figure are identical to the ones used throughout the avionics lecture. They define the common aircraft flight dynamics and kinematics states. For instance, ψ, θ and ϕ are the aircraft Euler angles representing heading, pitch and roll.*