DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	October 29, 2002 9:00 to 12:00 hour

Note	1	Put your name and all your initials on each sheet.
	2	Answer all questions and put your name on each sheet.
	3	Provide your answers in English or Dutch.

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

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

   (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)

3. (15 points) **SATELLITE RADIO NAVIGATION**

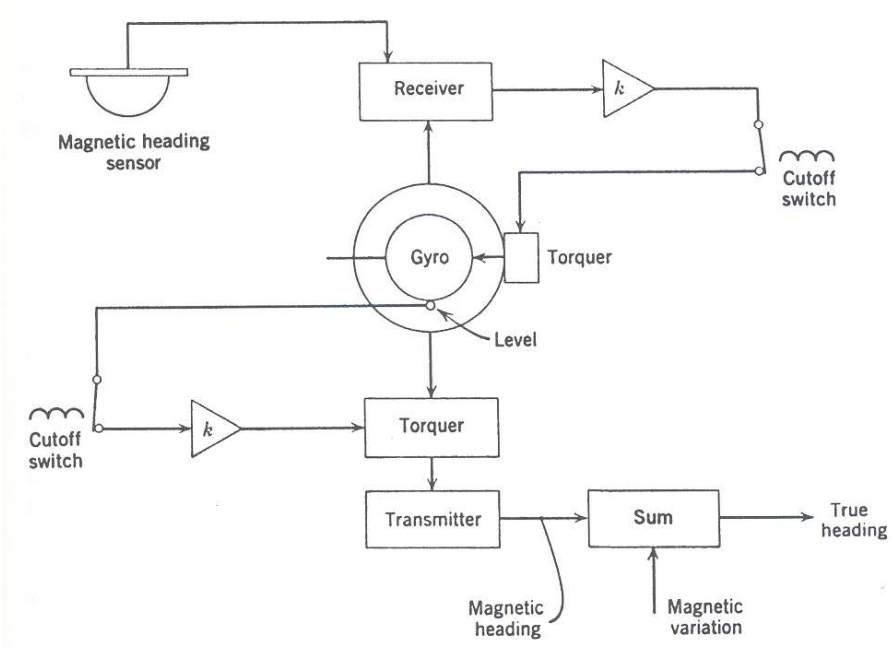

Figure 1: *The gyrosyn compass.*

(a) Describe in detail the main working principle of the Global Positioning System (GPS). (5 points)

(b) How do we get an estimation of our position? (2 points)

(c) How do we get an estimation of our velocity? (2 points)

(d) Describe in detail the principle of Differential GPS (DGPS). (2 points)

(e) When the GPS navigation system is used as a *sole means* navigation system, e.g. in the context of the Global Navigation Satellite System (GNSS), it needs to be *augmented*.

i. Why does it need to be augmented? (1 point)

ii. Describe the three main forms of augmenting GPS. (3 points)

4. (15 points) **FLIGHT MANAGEMENT SYSTEM**

(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)

(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.

i. What is RNAV? (2 points)

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

5. (15 points) **THE FUTURE AIR NAVIGATION SYSTEM (FANS)**

(a) What are the main *technical* shortcomings of the current generation of CNS (Communication, Navigation, Surveillance) systems? (3 points)

(b) Describe the future of Surveillance. In your answer, explain the main working principles, limitations, advantages of the SSR Mode S, ADS and ACAS systems and explain how these systems will work together in FANS. (10 points)

(c) What is ADS-broadcast? (2 points)

6. (15 points) **INERTIAL NAVIGATION SYSTEM**

(a) Make a sketch of a basic inertial navigation system. Clearly indicate in the sketch the main components of the INS. (1 points)

(b) What is the underlying principle of the INS? (1 point)

(c) What are the functions of the INS main components and how do they work together to enable the INS to generate a navigation solution? (2 points)

(d) Two elementary different forms exist of the INS. One of them is the so-called *strapdown inertial navigation system.*

i. What is the other form of implementing an INS called? (1 point)

ii. What is the crucial difference between both INS systems? (1 points)

iii. What are the advantages and disadvantages of both forms with respect to each other? (1 points)

(e) Consider Figure 2, which shows the basic 'analytic' functioning of a strapdown inertial navigation system in the situation of assuming a flat, non-rotating Earth.

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

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

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

(f) Again, consider Figure 2. 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.

i. Indicate, using a *clear and unambiguous sketch*, on the Figure of the examination, which parts of the Figure belong to the four computation blocks stated above. (2 points)

ii. In what order are these computations being executed? Explain your answer. (1 points)

iii. When you now consider your answer to the previous two questions, what do the calculations mean? That is, why are they necessary, why are they being done? For instance, what does 'resolution of the gravity vector' mean and why do we need to do this to make the strapdown INS a feasible system? (2 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:

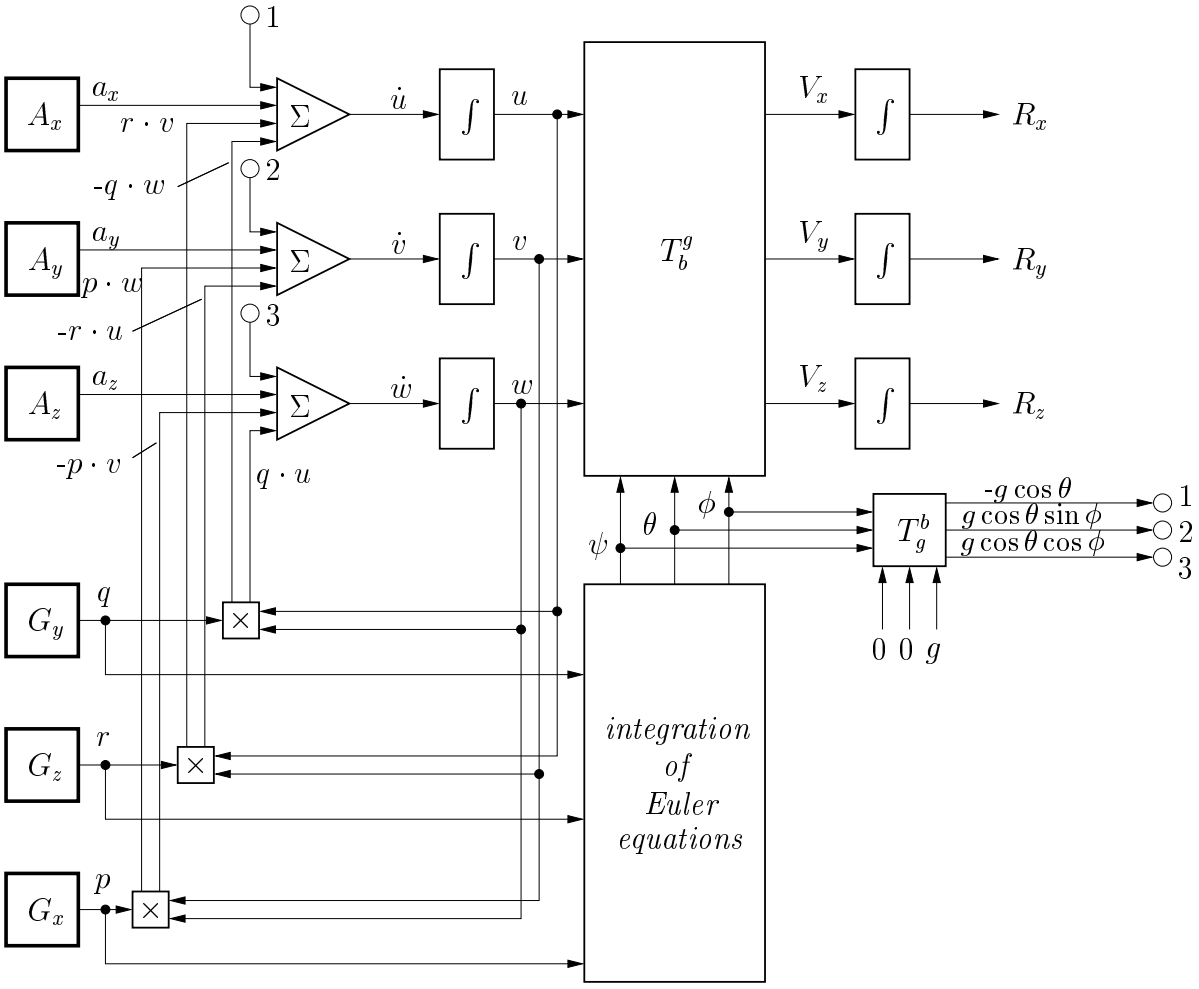

Figure 2: *Schematic diagram of the analytic platform. Note: the symbols used in this figure are identical to the ones used throughout the avionics lecture. They define the common aircraft flight dynamics and kinematics states. For instance, ψ, θ and ϕ are the aircraft Euler angles representing heading, pitch and roll.*