DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	June 27, 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) When using a conventional direct-reading magnetic compass, several errors are involved in the magnetic heading presented by the compass. Three of these errors are the *variation*, the *inclination* and the *deviation*. Give a definition of all three error sources, and, if possible, the countermeasures to decrease them.

   (b) What is a *magnetometer*? Briefly describe the working principle of the magnetometer. What are the advantages of the magnetometer with respect to the direct-reading magnetic compass?

   (c) Describe, using a simple but clear sketch, how the magnetometer can be combined with a directional gyro to constitute a *Magnetic Heading Reference System* (MHRS).

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

2. (15 points) **INERTIAL SENSORS: GYROSCOPES**

   (a) What are the disadvantages of mechanical gyroscopes with respect to optical gyroscopes?

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

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

   (d) Consider Figure 1, 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

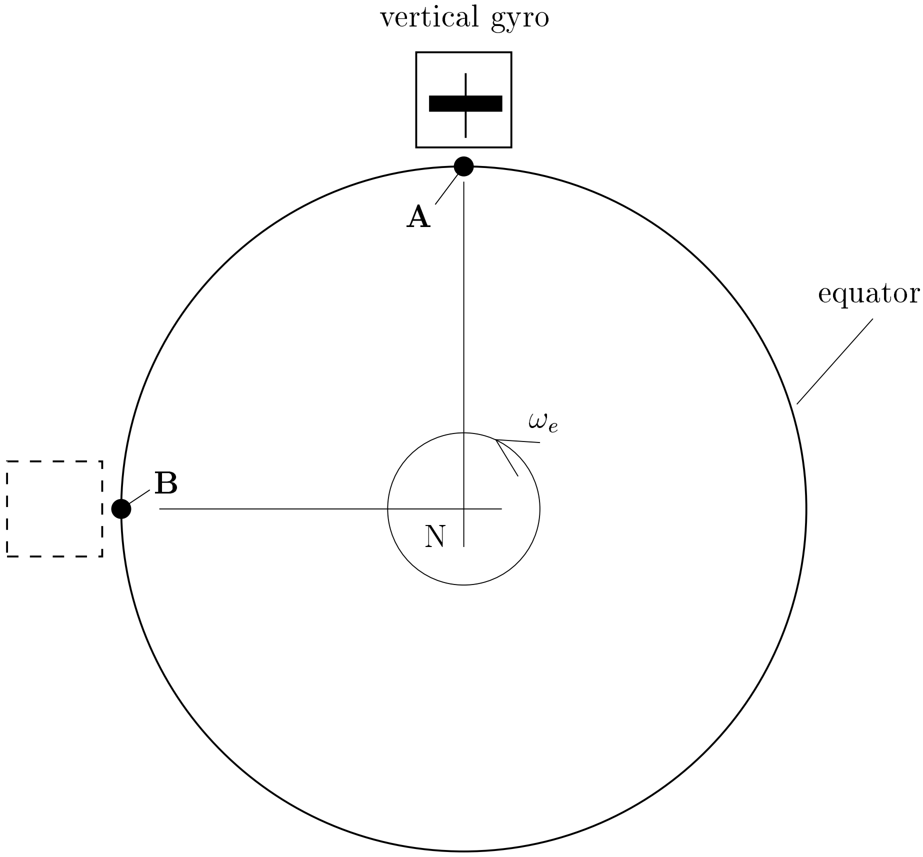

Figure 1: View to the Earth, looking from above the North Pole to the Earth's center. A vertical gyroscope is placed at the Earth equator at point **A**. ω_e is the Earth rotation velocity.

located at point **B**. Make a simple but clear sketch showing the gyroscope at point **B**. What has happened?

(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?

(f) What are gyro *erection systems*? What are they used for?

3. (15 points) **LANDING GUIDANCE SYSTEMS**

(a) What does ILS mean?

(b) Describe the three main components of an ILS system, and make a sketch indicating where these components are positioned with respect to the runway.

(c) Describe in general terms the antenna patterns generated by an ILS. How are they used by the on-board equipment?

(d) Consider Figure 2, showing the localizer antenna. Using this figure, explain the various steps of how the ILS localizer signals are modulated. What signals are sent by the central antenna, the left antenna and the right antenna?

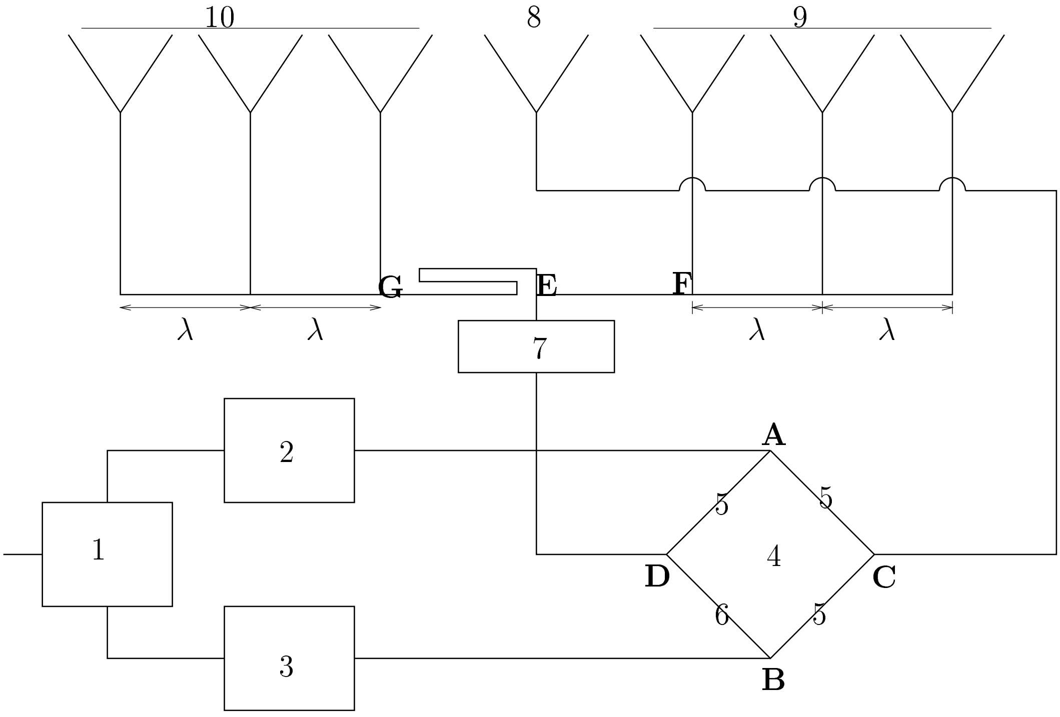

Figure 2: *The ILS localizer antenna. In this figure, the numbers indicate the following antenna components:* **1** *carrier wave generator,* **2** *90 Hz modulator,* **3** *150 Hz modulator,* **4** *antenna bridge,* **5** *length* $\frac{1}{4}\lambda$*,* **6** *length* $\frac{3}{4}\lambda$*,* **7** *90 degrees phase addition,* **8** *central antenna,* **9** *right antenna,* **10** *left antenna.*

(e) Consider Figure 3, showing the localizer antenna of the previous question and an aircraft located in front of the antenna.

i. What signals are received when the aircraft is located at position A? Explain your answer.

ii. What signals are received when the aircraft is located at position B? Explain your answer.

(f) Why can a conventional ILS installation only be used on flat terrain?

4. (15 points) **SATELLITE RADIO NAVIGATION**

(a) Describe the *space* segment, the *user* segment and the *control* segment of the Global Positioning System. Which types of precision are provided by the GPS?

(b) Describe in detail the principle of determining the aircraft *position* using GPS. How many GPS satellites at least do we need? Explain your answer.

(c) Describe in detail the principle of determining the aircraft *velocity* using GPS. How many GPS satellites at least do we need? Explain your answer.

(d) GPS is often used together with the Inertial Navigation System (INS). Why is that, i.e. what benefits can be achieved with integrating the GPS and INS systems?

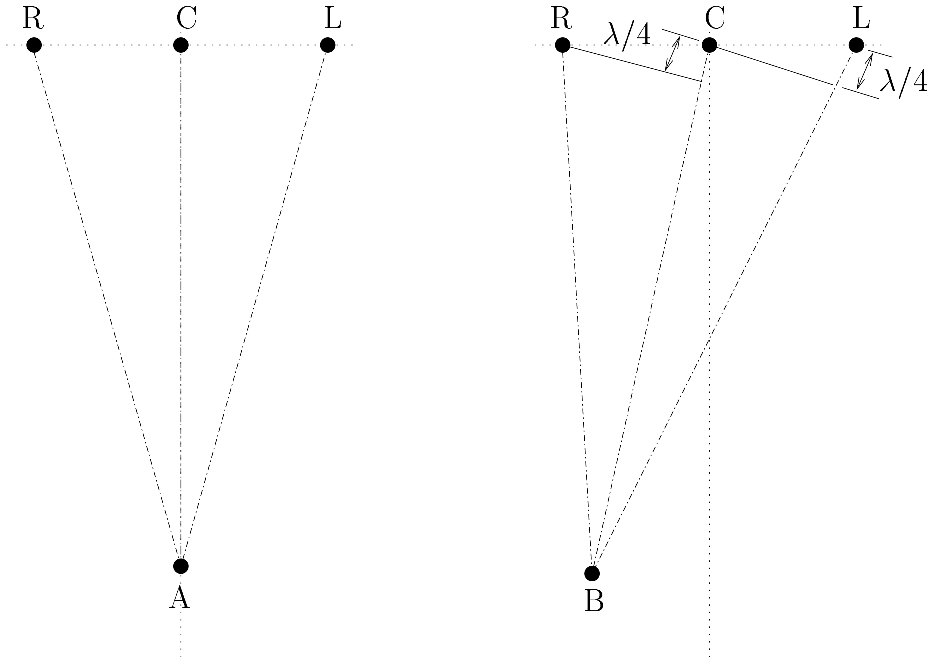

Figure 3: *Top view of the ILS localizer antenna. The aircraft can be located at either position A (left) or position B (right). Note: 'L', 'R' and 'C' indicate the positions of the left, right and central antenna, respectively.*

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

In this question we consider the DME radio beacon.

(a) What does the acronym DME stand for? (1 point)

(b) How does the DME system work? In your answer, include:

i. a description of the ground equipment and the airborne equipment (if any),

ii. the basic working principle of the DME,

iii. the DME signal characteristics,

iv. the different modes in which the DME can work,

v. the characteristics of the DME in terms of accuracy, integrity, availability, capacity and autonomy.

(8 points)

(c) Explain *in detail* how the aircraft equipment can distinguish between replies of the DME station for other aircraft and the replies of the DME station to the owncraft. (4 points)

(d) What is the DME reading in an aircraft that is flying at a horizontal distance of 20.4 NM from a DME station, at an altitude of 31000 feet? (1 ft = 0.3048 m, 1 NM = 1852 m). (1 point)

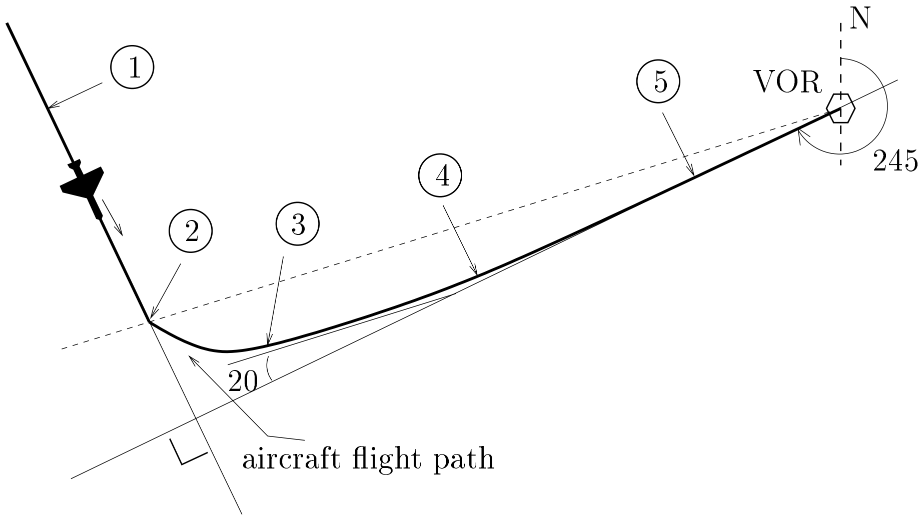

Figure 4: The aircraft flight path to the VOR beacon.

(e) What elements have to be added to a DME station to create a TACAN station? (1 point)

6. (15 points) **AIRCRAFT INTEGRATED INSTRUMENTS**

(a) Describe the Attitude Director Indicator (ADI).

(b) Describe the Horizontal Situation Indicator (HSI). In a sketch, make clear how the HSI shows the aircraft position and heading with respect to a selected VOR radial.

(c) Modern commercial aircraft are equipped with a Flight Director. Describe the Flight Director system. In your answer, include the following:

- What does a Flight Director do?
- What information does it use and where does it obtain this information?
- On what display is the Flight Director information presented?
- What are the tasks of the pilot when using the Flight Director?

(d) Assume the pilot wants to fly to a VOR beacon, using the Flight Director. Further assume that there is *no wind*. Figure 4 shows the aircraft flight path, and the numbers 1 – 5 along the path depict five moments in time at which a photograph is made of the cockpit instrument panel, most importantly the ADI and the HSI, see for example Figure 5.

For all five moments in time, make a clear sketch of the photographs showing the ADI and HSI. **Describe all steps in detail**, i.e. what does the pilot do?, what does the Flight Director do?, how and why did the instruments change along the path? Start at phase 1. Assume that *just before* this phase, the pilot has selected the desired VOR radial.

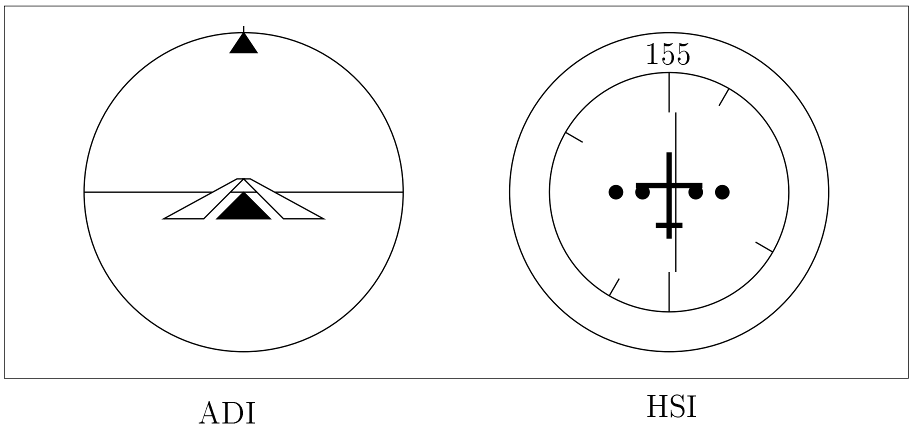

Figure 5: A photograph showing the ADI and the HSI display, *before* the aircraft flight towards the VOR beacon (i.e. before moment 1).