DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course	:	Avionics I (ae4-393)
Date	:	January 21, 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) **INERTIAL SENSORS: OPTICAL GYROSCOPES**

   (a) What are the main advantages of optical gyroscopes over their mechanical counterparts? (2 points)

   (b) In strapdown inertial navigation systems only optical gyroscopes are used. Why can't mechanical gyroscopes be used in this particular system, i.e. what particular property of optical gyroscopes makes them superior in this case? (2 points)

   (c) How many optical gyroscopes are used in strapdown inertial navigation systems? What do they measure? (2 points)

   (d) Describe, at the hand of a sketch, the way in which a Ring Laser Gyro (RLG) operates. What are the basic principles? (7 points)

   (e) What is the 'lock-in' effect and what is done to overcome it? (2 points)

2. (15 points) **THE NAVIGATION EQUATIONS**

   (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.

      i. How is the Earth-Centered Earth-Fixed reference frame defined?

      ii. 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.)

      iii. Consider Figure 1. 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

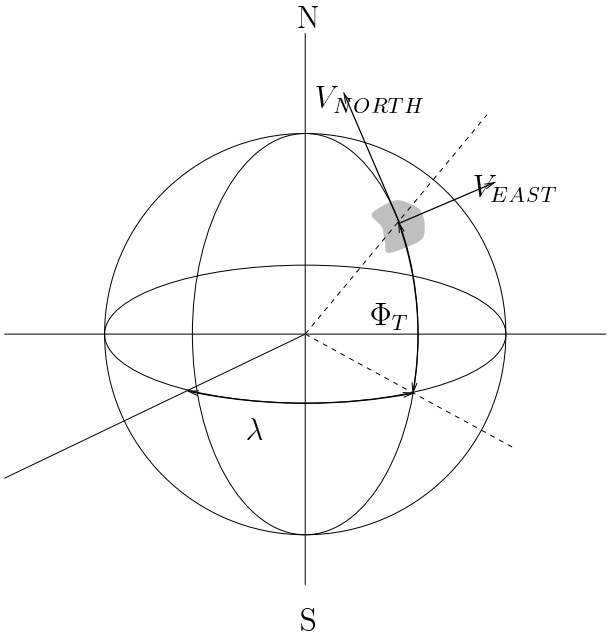

Figure 1: *An aircraft is located at altitude h above the Earth surface (h not shown in this figure), at longitude λ and (geodetic) latitude Φ_T. The velocity of the aircraft towards the North is indicated by V_{NORTH}, the velocity of the aircraft towards the East is indicated by V_{EAST}*

and the geodetic latitude Φ_T, using the two radii of curvature introduced above.

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

i. Give a definition of both categories, clearly indicating the main differences between them.

ii. Give one typical example of a navigation system for each category.

iii. Discuss the advantages and the disadvantages of dead reckoning navigation systems with respect to positioning navigation systems.

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

(a) ICAO has defined three categories of visibility for landing aircraft. Describe in detail how these categories are defined. (3 points)

(b) In low-visibility conditions, *how* does a pilot decide to continue or abort the landing? In other words, on which knowledge or information does a pilot base his or her decision? (2 points)

(c) Describe, using a sketch, the main components of the Microwave Landing System (MLS). (3 points)

(d) How does an MLS receiver determine its position relative to the runway? In other words, how does this system work? Explain your answer. (6 points)

(e) What are the main advantages of MLS over its predecessor, the Instrument

Landing System (ILS)? (1 point)

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

   (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)

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

   Compare the following navigation solutions in terms of: (1) position accuracy; (2) autonomy; (3) geographic coverage; (4) system capacity, and (5) integrity. If *ground* stations are used, how many ground stations are required to provide a *two-dimensional* position fix?

   (a) VOR

   (b) DME

   (c) GPS

   (d) LORAN-C

   (e) Inertial navigation

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

   (a) What are the three Air Traffic Services which together form the Air Traffic Management (ATM) service? Describe the fundamental differences between them. (3 points)

   (b) What are the CTR, the CTA, the UTA and the TMA? (3 points)

   (c) Sketch how the controlled airspace is structured into different parts. Which part (or 'team') of the Air Traffic Control is responsible for which part of the controlled airspace? (4 points)

   (d) What is a STAR? What is an SID? Why are they established? (3 points)

   (e) Sketch and describe in general terms how an airplane, coming from an arbitrary airway, lands at an arbitrary runway of an airport. Which parts of the airspace structure are passed during this flight? At what moments is the responsibility of Air Traffic Control handed over between the different ATC teams? (2 points)