DELFT UNIVERSITY OF TECHNOLOGY
FACULTY OF AEROSPACE ENGINEERING

Course : Avionics and Operations (AE4-393)
Date : November 11, 2011 from 09:00 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. **AVIONICS – GENERAL** (10 points)

   Give the exact meaning of the following acronyms and describe briefly what they
   stand for.
   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. FIR

   2. SID

   3. ADI

   4. AHRS

   5. ACAS

   6. SSR

   7. VGU

   8. AOM

   9. DME

   10. FDSU

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

   [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)

3. INERTIAL SENSORS: ACCELEROMETERS (15 points)

[a] Why is the name 'accelerometer' regarded to be a misnomer? In other words, what does it actually measure? (1 point)

[b] The most common type of accelerometer is a torque balance pendulous accelerometer (Figure 1). Briefly describe at the hand of Figure 1 how it works. (3 points)

[c] Before using accelerometer outputs in an Inertial Navigation System (INS) three corrections are needed first. What are these corrections? (Note: no formulas are requested here.) (3 points)

[d] In a strapdown INS accelerometers are used together with optical gyroscopes. How many accelerometers and optical gyroscopes are used in such a navigation system? What do they measure? And in what reference frame? (3 points)

[e] Describe the three *consecutive* computation steps (and in the correct order!) of an analytic platform in which optical gyroscopes and accelerometers are used together to derive the navigation solution. (5 points)

4. AIRCRAFT INTEGRATED INSTRUMENTS (15 points)

[a] Make a clear sketch of a generic cockpit of a modern large civil air transport aircraft. Indicate the locations of the following entities: the Primary Flight Display (PFD), the Navigation Display (ND), the Head-Up-Display (HUD), the Engine Indication and Crew Alerting System (EICAS) display, the Multi-Function Display (MFD) and the Control/Display Units (CDU). (4 points)

[b] Sketch a generic Primary Flight Display and describe the different indicators and/or display elements on the PFD. (4 points)

[c] The pilot must perceive and integrate many different sources of information from various instruments. He or she then uses this information to control the aircraft along the preferred track. When *automating* the pilot's control task, commonly two possibilities are being applied, i.e. the use of an *Auto Pilot* or the use of a *Flight Director*.
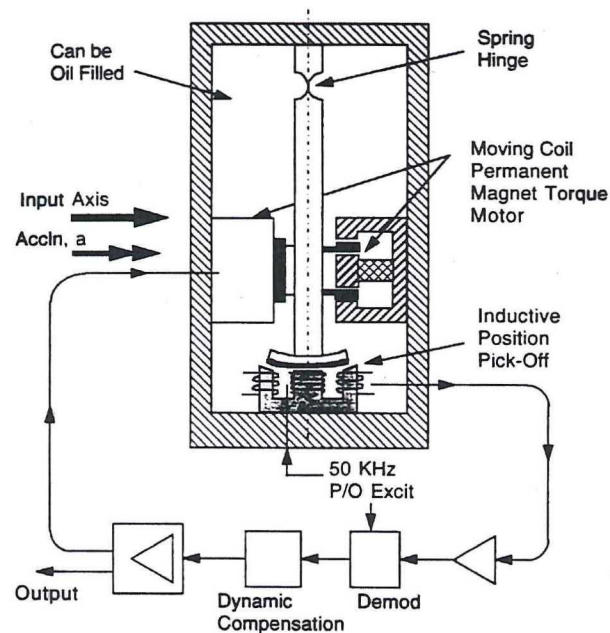
Figure 1: Torque balance pendulous accelerometer.

1. What are the fundamental differences between both solutions?

2. What will be the remaining pilot's task(s) when the *Auto Pilot* solution is implemented? How is the Auto Pilot used?

3. What will be the remaining pilot's task(s) when the *Flight Director* solution is implemented? How is the Flight Director used?

(7 points)

5. TERRESTRIAL RADIO NAVIGATION (15 points)

[a] Describe the main working principle of the VHF Omni-directional Radio Range (VOR) beacon. Include in your answer the signal(s) used for navigation, the airborne receiver, and how the VOR information is presented to the pilot. (5 points)

[b] What other types of information does the VOR carry? (1 point)

[c] Consider a Doppler VOR (DVOR) beacon.

- What type(s) of modulation is/are used for the navigation signal(s) and how is/are they created? (3 points)

- A DVOR is subject to a so-called switching frequency. Explain how the switching frequency is caused, why it is considered a handicap for VOR receivers, and how it is mitigated. (3 points)

[d] Suppose the DVOR beacon is co-located with a DME beacon to result in a so-called $\rho - \theta$-system.

- What is GDOP? (1 point)

- Explain the concept of GDOP for a $\rho - \theta$-system and describe how the GDOP changes when moving away from the beacon. (2 points)

6. THE FUTURE AIR NAVIGATION SYSTEM (20 points)

[a] Describe the *general* shortcomings of the current Air Navigation System (ANS) in the <u>en-route</u> environment. (5 points)

[b] What are the names of the two largest research programs in the world that investigate the modernization of the current ANS? (2 points)

[c] To make optimum use of the available airspace and aircraft capabilities, above-mentioned research programs consider Trajectory-Based Operations. Briefly explain what this means. (3 points)

[d] To facilitate Trajectory-Based Operations an updated CNS system is required. Describe the future of Navigation (the 'N' in CNS) in FANS. In your answer, include the roles of GNSS, RAIM, LAAS/RAAS, RNAV and the concept of RNP. (10 points)