# Introduction to Aerospace Engineering

## Exams

**Name (Naam):** **Student nr.:**

**Exam "Introduction to Aerospace Engineering II" AE1102**

**Date 31-Jan-2012**

# READ THIS FIRST (NEDERLANDS vanaf pg. 9)

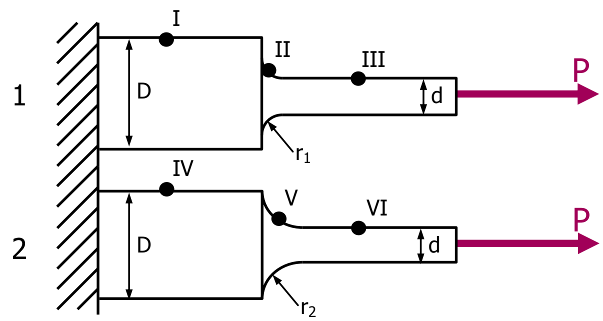
- **This is a multiple-choice exam.**
- **Put your name and student ID on EACH multiple-choice FORM and ANY OTHER SUPPORTING DOCUMENT.**
- **Indicate the correct answer by putting a "cross" in the appropriate boxes or open circles on the forms**
- **Only ONE answer per sub-question is allowed (otherwise the answer will be graded ZERO). So, crossed out and "repaired" results will NOT be accepted.**
- **Only answers with INK PEN are allowed (so answers with lead pencils will NOT be accepted)**
- **Do NOT make any notes on the multiple choice forms! They will be disregarded.**
- **The "structures" part will provide 40 percent of the grade and the "space" part 60 percent.**
- **Submit all multiple-choice forms (and contingent supporting documents) as ONE set to the examination monitors when you leave.**
- **Only submit EITHER a DUTCH or an ENGLISH set of forms.**

**In addition, for the "space" part:**

- **Supporting illustrations, used formulas, derivations and intermediate calculations MUST be provided on separate sheets of regular exam paper (with your name, student ID and number of the question).**
- **"Gambled" answers without supporting notes on regular exam paper will be graded ZERO.**
- **The sub-questions are NOT inter-related. In principle, you should be able to answer them even if you don't know the result of the previous questions.**

**Name (Naam):** **Student nr.:**

**"Structures" Question A:**




With D>d and $r_1$<$r_2$ mark for the following statements the correct answer:

| | | less than | equal to | greater than |
|---|---|---|---|---|
| a) | The stress in location III is … the stress in location VI | | X | |
| b) | The stress in location IV is … the stress in location VI | X | | |
| c) | The stress in location V is … the stress in location II | X | | |
| d) | The stress in location III is … the stress in location II | X | | |
| e) | Under tensile load P diameter D is … diameter D in unloaded condition | X | | |
| f) | The load P at which location VI deforms plastically is … the load P at which location IV deforms plastically | X | | |
| g) | The fatigue life of bar 1 is … the fatigue life of bar 2 | X | | |
| h) | The stress concentration in bar 1 is … that in bar 2 | | | X |

State whether the following statements are true or false:

| | | true | false |
|---|---|---|---|
| i) | Fail-safe is the number of flights, landings or flight hours during which there is a low probability that the structure will degrade below its design strength | | X |
| j) | Composites do not corrode and therefore do not suffer from environmental conditions | | X |
| k) | To provide the load transfer through the spacecraft structure two categories of structures can be distinguished: truss structures and stage structures | | X |
| l) | A sheet provides a diagonal function when loaded in shear | X | |
| m) | Structural safety is solely the responsibility of the aircraft manufacturer and the operator | | X |
| n) | Tension joints can be obtained with mechanical fastening (bolting) and with welding | X | |
| o) | A hole in an infinite plate has a stress concentration $K_t$ = 3 indifferent whether the hole is open or filled | | X |
| p) | Expansion and contraction during respectively temperature increase and decrease is described by the Poisson's ratio | | X |
| q) | During curing of thermoplastic polymers irreversible chain linking occurs | | X |
| r) | The E-modulus of aluminium can be significantly changed by alloying | | X |
| s) | A disadvantage of ceramics is the high ductility | | X |
| t) | Milling is a process that removes "chips" from the material | X | |
| u) | Filament winding is a process that can be applied in dry and wet condition to short fibres only | | X |
| v) | The selection of a rib type depends on 4 aspects: strength, design philosophy, available equipment, and costs | | X |
| w) | The selection of materials for a wing skin application depends on whether it is the upper or lower wing skin. | X | |

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**"Structures" Question B:**

An Airbus A340-600 with a fuselage diameter of 5.64 m is cruising at an altitude of 3000 meters. Gust applies a load that can be represented by a single load of 1500 N acting on the vertical tail at a distance of 6.5 m from the fuselage centre.

What is the torsion moment acting on the rear fuselage?

O 9750 N/m
O 5520 Nm
O 13980 N/m
● 9750 Nm
O 5520 N/m
O 13980 Nm

Assume an average fuselage skin thickness of t = 2 mm and a torsion moment acting on the fuselage of 8000 Nm. What is the shear stress in the fuselage skin ($M_T = 2qA$)?

O 8000 Nm
O 0.04 $N/mm^2$
O 160 N/m
● 80000 $N/m^2$
O 0.16 $N/mm^2$
O 40 N/m

If equilibrium is provided by reaction forces on both wings; for the moment in the previous question, what is the magnitude of each reaction force if these forces act 20 m away from the fuselage centre?

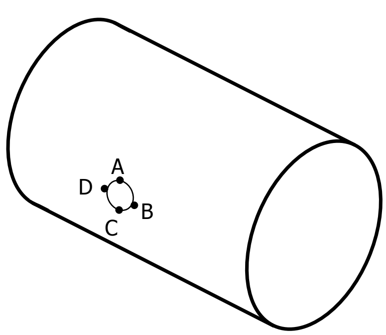
O 400 N
O 800 N/m
● 200 N
O 800 N
O 200 kN
O 400 $N/mm^2$

To limit wing bending, which solution should be applied?

O A high strength material as skin material of the wing
O A high strength material as web plate material for the spars
● A high stiffness material as skin material of the wing
O A high stiffness material as web material for the ribs

If a circular cut-out is created in the skin of the fuselage, which is subsequently sealed air-tight by an unloaded window, see illustration below. Which locations face the highest stress concentration?

O Locations A and C
● Locations D and B
O Locations B and C
O Locations A and D



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## Spaceflight formula sheet

**Basic orbit formulas:**

Ellipse equation $$r = \frac{a\,(1-e^2)}{1+e\cos(\theta)}$$

Vis Viva equation $$V^2 = \mu\left(\frac{2}{r}-\frac{1}{a}\right)$$

Definition of mean motion $$n = \sqrt{\frac{\mu}{a^3}}$$

NB. If you don't know them by heart the equations for the circular velocity, orbital period and escape velocity can be easily derived from the above equations.

**Basic rocket formulas:**

Tsiolkowski (NB. c is the exhaust velocity): $$\Delta V = c\ln\frac{M_{begin}}{M_{end}} = I_{sp}\;g_0\ln\Lambda$$

Equation of motion for vertical flight: $$M\,\frac{dV}{dt} = T - M\,g$$

Mass flow: $$m = -\frac{dM}{dt}$$

Thrust: $$T\ =\ mc$$

Integral of ln(x): ∫ ln x dx = x ln x – x

**Communication:**

Diameter of antenna dish: $$D\ =\ \frac{k\,d}{f}\sqrt{\frac{b}{p}}$$

Where:
- k = constant = 6000
- d = distance (km)
- f = frequency (Hz)
- b = bit-rate (bits/s)
- p = power (W)
- D = dish diameter (m)

**Basic constants:**

| | | |
|---|---|---|
| Mu_Earth | 398601.3 km^3/s^2 | gravitational constant of the Earth |
| Re | 6378 km | Earth radius |
| g0 | 9.81 m/s^2 | gravitational acceleration at Earth surface |

**"SPACE" Question C:**

A spacecraft is in a circular orbit around the Earth at 519 km altitude and an inclination of 30 degrees.

1. **(4 pts)** What is the maximum time per orbit that the spacecraft spends in the Earth's shadow expressed as a percentage of the orbital period? Assume the Sun is at infinite distance.
    a. 18.8 percent O
    b. 37.6 percent ●
    c. 62.4 percent O
    d. 50.0 percent O
2. **(4 pts)** What is the maximum contact time between a ground station and this satellite expressed as a percentage of the orbital period? Assume the Earth does not rotate.
    a. 2.6 percent O
    b. 12.4 percent ●
    c. 18.6 percent O
    d. 6.2 percent O
3. **(6 pts)** Same as question 2, but now with a minimum (cut-off) elevation of 20 degrees (Hint: use sine rule).
    a. 5.4 percent ●
    b. 2.7 percent O
    c. 12.4 percent O
    d. 6.2 percent O
4. **(4 pts)** What is the minimum distance to the spacecraft from a ground station at 35 degrees North latitude (Hint: use cosine rule)?
    a. 519 km O
    b. 666 km O
    c. 777 km ●
    d. 888 km O
5. **(3 pts)** What is the orbital period of the spacecraft?
    a. 8050 seconds O
    b. 23 hours 56 minutes O
    c. 100.5 minutes O
    d. 1 hour 35 minutes ●
6. **(3 pts)** What is the orbital altitude of a geostationary satellite? Note: the time of rotation of the Earth about its axis is 23 hour 56 minutes.
    a. 42241 km O
    b. 35836 km O
    c. 42163 km O
    d. 35785 km ●

7. **(4 pts)** What is the velocity change (Delta-V) of the spacecraft required to enter a Hohman transfer orbit with an apogee at geostationary altitude? Assume Hgeo = 40000 km if you could not answer the previous question.
   a. 9.97 km/s O
   b. 2.36 km/s ●
   c. 7.60 km/s O
   d. 2.43 km/s O 🡐 alternative answer

8. **(5 pts)** At apogee the spacecraft performs a SINGLE maneuver to change the inclination from 30 degrees to zero degrees and to circularize the orbit. It arrives at apogee with a velocity in the inclined orbit of 1.630 km/s and changes to the circular velocity of 3.075 km/s at zero inclination. What is the TOTAL required velocity change (delta-V) for this SINGLE maneuver?
   a. 1.852 km/s ●
   b. 1.445 km/s O
   c. 0.844 km/s O
   d. 2.288 km/s O

9. **(3 pts)** This spacecraft communicates with a ground station at a distance of 40,000 km, using a 64 W radio transmitter at a frequency of 3 GHz. The ground station has a 1 m diameter antenna dish. What is the maximum data rate of the communication?
   a. 1 kbits/s O
   b. 10 kbits/s ●
   c. 1 Mbits/s O
   d. 10 Mbits/s O

**"SPACE" Question D:**

A spacecraft with a starting mass of 1000 kg is launched from the surface of Mars on a vertical trajectory. Assume a homogeneous (constant) gravity field with a gravitational acceleration at the surface of Mars of 3.70 m/s^2. The initial thrust-to-weight ratio of the spacecraft is 1.5. Specific impulse (Isp) of the rocket engine is 300 s.

1. **(3 pts)** What is the trust of the rocket engine?
   a. 1.5 kN O
   b. 14.7 kN O
   c. 5.5 kN ●
   d. 3.7 kN O

2. **(3 pts)** The spacecraft has to achieve an "ideal" (tsiolkowksi) end-velocity of 3.5 km/s. What is the end-mass of the spacecraft?
   a. 304.4 kg ●
   b. 42.8 kg O
   c. 200.9 kg O
   d. 536.1 kg O

3. **(3 pts)** What is the burn-time of the rocket engine? Assume the end-mass to be 400 kg if you could not answer the previous question. (These answers were wrong)

a. 318.0 s O ← alternative answer
b. 52.5 s O
c. 368.7 s ●
d. 70.9 s O

4. **(3 pts)** What is the delta-V "gravity-loss" of the spacecraft during its vertical ascent? Assume the burn-time tb to be 60 s if you could not answer the previous question.
   a. 167 m/s O
   b. 1365 m/s ●
   c. 553 m/s O
   d. 222 m/s O ← alternative answer

5. **(3 pts)** What is the burn-out velocity of the spacecraft?
   a. 2135 m/s ●
   b. 3500 m/s O
   c. 3278 m/s O ← alternative answer
   d. 11226 m/s O

6. **(3 pts)** What is the burn-out altitude of the spacecraft? (Hint: first integrate the velocity equation)
   a. 520.2 km ●
   b. 196.3 km O
   c. 98.6 km O
   d. 5881.3 km O

7. **(3 pts)** What is the maximum altitude of the spacecraft? Assume burn-out altitude to be 150 km and burn-out velocity to be 3000 m/s if you could not answer the previous questions.
   a. 712 km O
   b. 1136 km ●
   c. 1366 km O ← alternative answer
   d. 905 km O

8. **(3 pts)** What is the impact velocity of the spacecraft after it falls down from its maximum altitude to the surface of Mars? Assume Hmax = 1000 km if you could not answer the previous question.
   a. 2900 m/s ●
   b. 8956 m/s O
   c. 2426 m/s O
   d. 2721 m/s O ← alternative answer