**During the exam it is not possible to look at any study material, notes, slides, textbook, etc.**

**You can only make use of a normal calculator and the formula sheet provided in class.**

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You are an engineer at AeroIndustries, conceptual development group.
Together with your colleagues, you are currently busy developing a new 200 passenger jet aircraft, which must be able to cover a cruise range of 10000 Km with maximum payload.
<u>Your first task</u> is to compute the **cruise fuel fraction** (i.e. the ratio between the aircraft weight at the end of the cruise segment and its weight at the beginning of the cruise).
These are the data you have available so far (some have been estimated by your colleagues, some are requirements from the customer):

Passengers: 200 in single class (90 Kg per pax including luggage)
Cruise speed: 250 m/s at an altitude of 10000m
Loiter time: 45 minutes
Engines specific fuel consumption Cj : 0.00001415 Kg/Ns
Cruise aerodynamic efficiency: 15
Maximum landing/takeoff weight ratio: 0.85
Take off and landing distance: 2000m at sea level

<u>Your second task</u> is to investigate the potential benefit in term of **weight reduction** of some technology improvements. In particular you have to evaluate whether it is more convenient to **improve the aerodynamic efficiency** of your aircraft by **10%** or try to obtain from the engine manufacturer a propulsive system with a **5% lower specific fuel**. Of course you will have to substantiate your evaluation with some calculation.

The Aeroindustries company is currently also dealing with the development of a successor to the European Vega rocket. This rocket must be capable of delivering a 2.5 ton payload into a Low Earth Orbit (LEO).

*Task 1*

To start with the design you have made a study of the Vega rocket you would like to replace. This rocket, see figure, is a single-body launcher (no strap-on boosters) with three solid rocket stages, the P80 first stage, the Zefiro 23 second stage, the Zefiro 9 third stage, and a liquid rocket upper module called AVUM. Typical data of the stages, payload and fairing are provided in the next table.

| | Stage 1 | Stage 2 | Stage 3 | Stage 4 | Fairing | Payload |
|---|---|---|---|---|---|---|
| Mass at lift off [ton] | 95.796 | 25.751 | 10.948 | 0.968 | 0.49 | 1.50 |
| Propellant mass [ton] | 88.365 | 23.906 | 10.115 | 0.55 | | |
| Effective exhaust velocity $(V_e)_{eff}$ [m/s] | 2550 | 2834 | 2893 | 3094 | | |

Vega rocket

To understand what we need to design for, you are asked to determine for the Vega rocket:

1. Payload, propellant and structure mass fraction for the 2$^{nd}$ sub-rocket
2. The total ΔV delivered by the rocket.

**Assumptions and approximations must be clearly indicated and motivated**

*Task 2*

Based on their study of the Vega rocket, the Aeroindustries company is opting for a two stage rocket capable of delivering a 2.5 ton payload an ideal velocity increment ΔV of 10.5 km/s. For this rocket we have available a rocket propulsion system capable of delivering a constant effective exhaust velocity of 3750 m/s. Given a constant structural mass ratio of 7.5%, determine the minimum launch mass needed to bring this payload into orbit.

**Assumptions and approximations must be clearly indicated and motivated**

Based on the table below from CS25, define the **type and minimum amount** of emergency exits for a 300 passenger aircraft.

| No. Pass. | Type I | Type II | Type III | Type IV |
|---|---|---|---|---|
| 1–9 | | | | 1 |
| 10–19 | | | 1 | |
| 20–39 | | 1 | 1 | |
| 40–79 | 1 | | 1 | |
| 80–109 | 1 | | 2 | |
| 110–139 | 2 | | 1 | |
| 140–179 | 2 | | 2 | |
| 180–299 | Add exits so that 179 plus "seat credits" ≥ passenger number. | | | |

| | Seat Credit | Exit Type |
|---|---|---|
| | 12 | Single Ventral |
| | 15 | Single Tailcone |
| | 35 | Pair Type III |
| | 40 | Pair Type II |
| | 45 | Pair Type I |
| | 110 | Pair Type A |
| ≥ 300 | Use pairs of Type A or Type I with the sum of "seat credits" ≥ passenger number. | |

Which of the following are the main ingredients required to build a **trade off table**?

1. Trade off criteria, weights, aircraft functions, scores
2. Trade off functions, scores, concepts, top level requirements
3. Weights, trade off criteria, scoring system, list of concepts to be traded off
4. Concept drawings, functional analysis results, trade off requirements
5. None of the groups above is either correct or complete. The correct ingredients are actually the followings: ……………………….

Which of the statement below is wrong?

1. The required overnose angle is related to the approach speed of the aircraft
2. The tail cone angle of the fuselage (also called divergence angle) should be smaller than 24 degrees to allow good aerodynamic performance
3. The so-called aircraft rotation angle depends on the position of the aircraft main landing gear
4. The overside angle determines the side stability of the aircraft on the ground
5. The grazing angle depends on the inclination of cockpit windshield

Why it is not possible for a given aircraft to fulfill <u>at the same time</u> the requirements of maximum payload and maximum range?

1. Actually it is technically possible, but airworthiness regulations do not allow
2. Actually it would be possible, but the fuel consumption would become too high when exceeding the harmonic range
3. Actually it is possible for ferry operations
4. It is not possible because the limits on maximum take off weight require trading off payload and fuel
5. It is not possible because the limits on maximum take off weight require trading off fuel weight and harmonic range

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In the sizing process of a propeller aircraft it is generally convenient to have:
1. The highest value of power loading (W/P) and lowest value of wing loading (W/S)
2. The lowest value of power loading (W/P) and the lowest value of wing loading (W/S)
3. The highest value of power loading (W/P) and the highest value of wing loading (W/S)
4. A linear relation between the power loading and the wing loading
5. Wing loading and power loading values close to the values stipulated by airworthiness regulations

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During the preliminary sizing of an aircraft (i.e. when defining the wing loading vs. thrust loading diagram), we should keep in mind that:
1. The aspect ratio has influence on the climb rate performance of an aircraft
2. The aspect ratio has influence on the landing performance of an aircraft
3. The engine power has influence on the landing performance of the aircraft
4. The maximum lift coefficient of the aircraft has no influence on the wing loading
5. The TOP parameter needs to be computed for the top climb gradient estimation

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There are several factors and design choices that directly influence the drag performance of an aircraft. Which of the following would help lowering drag?
1. Lower the Oswald factor
2. Decrease the ratio S/Swet (where S is the reference lifting surface area and Swet is the wetted surface of the aircraft)
3. Increase the cruise lift coefficient (without affecting the lifting surface area)
4. Lower the equivalent skin friction coefficient by using special paint
5. Lower the wing aspect ratio to get a shorter wing

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What is the main advantage of an elliptical lift distribution?
1. Ease of manufacturing
2. Minimizing the wing bending loads
3. Minimize the wing loading
4. Facilitate engine integration
5. None of the first 4 statements

6. All of the first 4 statements

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Some of the statements below are wrong:

1. There is generally a good (almost linear) correlation between aircraft payload weight and range
2. There is generally a good (almost linear) correlation between the aircraft empty weight and take off weight
3. When performing a regression analysis of statistical data, values of Q squared very close to one indicate low scatter values
4. For a given class of aircraft, the ratio of empty weight and maximum take off weight strongly depends on the range
5. The first 4 statements are all wrong
6. The first 4 statements are all correct

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Which of the following options describes the function of a ram air turbine?

1. Provides additional thrust in case of engine failure
2. Converts chemical energy into electrical energy in case of engine failure
3. Generates energy from the airstream in case of an emergency
4. Is used during emergencies to accurately measure the airspeed
5. None of the above

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Which of the following statements is true?

1. The drag strut carries lateral loads on the landing gear
2. The tire absorbs all the impact energy during touchdown
3. The shock absorber absorbs all the impact energy during touchdown
4. The side brace carries the longitudinal loads on the landing gear
5. The braking forces are carried by the drag strut on the landing gear

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A: The acronym SMART stands for specific, measurable, achievable, realistic, time-bound
B: The specific impulse of a rocket motor is independent of flight altitude in Earth's atmosphere

1. Statement A and B are both False
2. Statement A and B are both True
3. Statement A is False and B is True
4. Statement A is True and B is False

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You are designing an Earth Observation satellite. You have collected the following mass values for a range of EO satellites:

| ID | Satellite payload mass (kg) | Total mass (kg) |
|---|---|---|
| 1 | 410.1 | 1000.2 |
| 2 | 184.5 | 500.3 |
| 3 | 91.5 | 300 |
| 4 | 358.8 | 1200 |

Determine the average payload mass % and the sample standard deviation

(average ; SSD).

1. 34.6% ; 5.4%
2. 30% ; 5.4%
3. 34.6% ; 6.5%
4. 30% ; 5.7%
5. 34.8% ; 5.7%
6. 34.8% ; 6.5%

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A S/C with a mass of 1000 kg is connected to the launch vehicle via a cylindrical shaped thin shell adapter. This adapter is made out of aluminum with a modulus of elasticity of 70 GPa. Its length is 0.5 m, diameter is 0.4 m and wall thickness is 1 mm. Maximum acceleration load is 5g. Calculate the Euler buckling load for this structure.

1. 7040 MN
2. 1408 MN
3. 176 MN
4. 22 MN
5. 49.1 kN

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You are designing the EPS of a S/C in LEO that must deliver an electrical power output of 1000 W. You have selected Si as the cell material. Given a solar intensity of 1400 W/m$^2$, a power conversion efficiency of 12% a cell size of 5 cm square, and an inherent degradation factor of 0.8, calculate the required solar array surface area (in m$^2$; accurate up to 2 decimals) to provide the required power output given that the solar radiation is perpendicular to the solar panel. Note: Life degradation is considered negligible.

1. 0.71m$^2$
2. 5.95m$^2$
3. 6.03m$^2$
4. 7.44m$^2$
5. 9.36m$^2$

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A 1000 kg, 3-axis stabilized, cubical S/C in LEO experiences a worst case disturbance torque of 0.01 Nm about the pitch axis. MMOI about the pitch axis is 1000 kg-m$^2$. Given that the vehicle initially is at stand still, calculate the angle over which the S/C rotates about the pitch axis in 5 minutes?

1. 0.13deg
2. 2.45deg
3. 12.4deg
4. 25.8deg
5. 263deg

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A satellite has a transmission power of 10 W and an antenna gain of 20. In case line loss is a factor 0.9, calculate the EIRP.

1. 9 Watt
2. 3.3Picowatt
3. 222 Watt
4. 10 Watt
5. 180 Watt

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For a spacecraft are given:

- 739 Mbits/sec (Mbps) of payload data generated on average (during daylight)
- Payload not operative during eclipse periods (no data generated)
- 10 Mbps Telemetry (TM) data generated continuously
- Orbital period is 90 minutes
- Eclipse period is <u>maximum</u> 40 minutes (some orbits have no eclipse period)
- Ground contact time is minimum 7 minutes/orbit

Determine for this spacecraft the required recorder data storage size.

1. 2217 GByte
2. 277.1 GByte
3. 282.5 GByte
4. 498.9 GByte
5. 504.3 GByte

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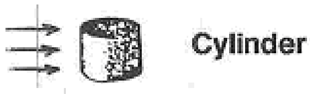
A rocket stage in the vicinity of Earth (1 AU) uses the cryogenic propellant combination liquid hydrogen and liquid oxygen as the propellant tank. The hydrogen tank positioned on top of the oxygen tank is of a cylindrical shape with spherical end caps. Maximum height of the cylindrical part enclosing the tank is 26.7m and diameter is 5m). This stage is irradiated upon by the Sun, see figure below. Calculate for this stage the equilibrium temperature reached given that the stage is in full sunlight, that effects of albedo and Earth IR can be neglected, tank wall absorptivity is 0.05 and emissivity is 0.9 and in case only the cylinder wall acts as a radiatior.




1. 95K
2. 145K
3. 230K
4. 293K
5. 432K

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Consider a 2 m diameter spherical spacecraft covered with thermal protection material with a reflectivity (r) of 0.8 at a distance of 0.5 AU. Calculate for this spacecraft the force due to solar radiation pressure.

1. 26.3µN
2. 52.6 µN
3. 103µN
4. 26.3 mN
5. 52.6 mN

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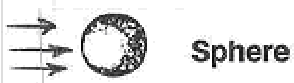
A sphere in cold space is illuminated by the Sun in a direction perpendicular to its longitudinal axis, see figure. Distance to the Sun is 1 AU.




Calculate for this sphere the equilibrium temperature given that the cylinder is covered with white paint with a solar absorbtion factor of 0.15 and an IR emissivity of 0.9.

1. 178K
2. 212K
3. 283K
4. 367K
5. 436K