# FORMULA STUDENT ALPE ADRIA
# 2025 REGISTRATION QUIZ SOLUTIONS

**Note for all questions: We will consider as a correct answer all the answers that fall within the +/- 1 last decimal number. In another words, all of the answers have a tolerance of +/- 1 on the last decimal number.**

## Question 1

(2,5 points)

Determine white parameter from the figure below for the racetrack so that Nevera's wheels shown in figure below will not have to depend upon friction to prevent the car from sliding up or down the track. Assume that the car has negligible size, a mass *m* (both car and the driver), and travel around the curve of a radius *r* with a constant speed *v*. Round the answer to the nearest degree. Use the average gravitational pull of the Earth rounded to two decimal numbers.

Parameters: $m$=2020 kg, $r$=75 m, $v$=55,67 km/h.


Bonus question: Based on the rounded banking angle and the figure given in the task, which famous current F1 racetrack would the question be about?

SOLUTIONS: 18° (2 points); Zandvoort, Netherlands (0,5 point)

## Question 2

(3 points)

Let us assume a series of gear units connected in series shown in figure below and assume that they are all identical and that they all have the same efficiency of 0,95. Furthermore, let us assume that the gear ratio is 2, the input speed is 1440 rpm, and the input torque is 10 Nm. The gears act as a multi-stage reducer.

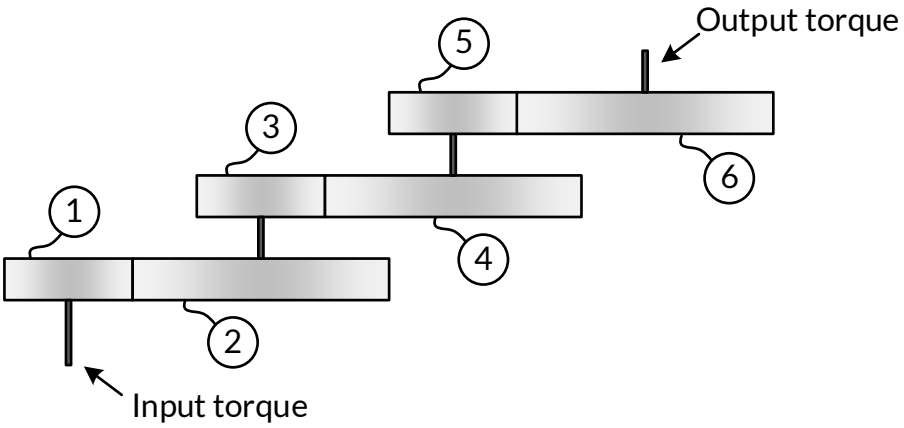
**2.1** At least how many gears must be connected in series to make the total efficiency approximately 0,49?

**2.2** What would be the output torque in that case? Round to a whole number in Nm.

**2.3** How should the dimensions of the gears be determined based on their position and the loads they experience? Explain in one sentence.

**2.4** How is the assumption that all gears have the same degree of efficiency justified and why? Explain in one sentence.

**2.5** How likely is it that all gear pairs will suffer the same damage? Explain in one sentence.




2.1 SOLUTION: 14 (1 point)

2.2 SOLUTION: 80000 Nm (0,5 points) (everything between 78000 and 81000 Nm is correct)

2.3 SOLUTION: According to the last gear in series (0,5 points)

2.4 SOLUTION: Completely unjustified (0,5 points)

2.5 SOLUTION: It is unlikely (0,5 points)

## Question 3
(2 points)

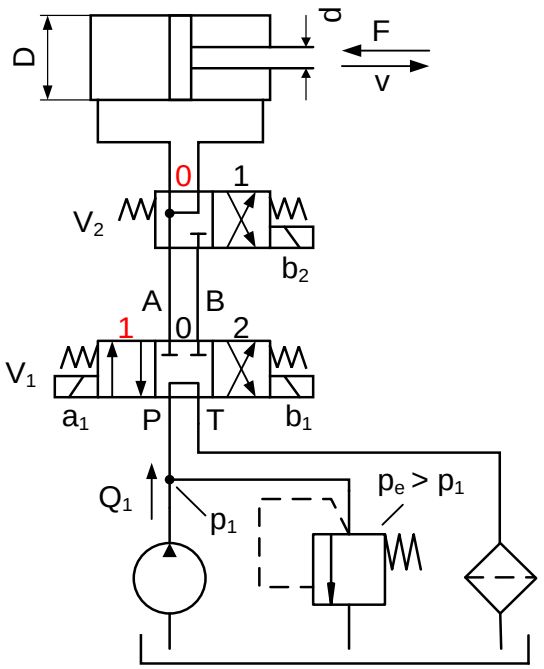
Figure below shows a simplified hydraulic system consisting of a pump, a pressure relief valve, a filter, two solenoid valves and a double acting cylinder. With the given parameters, it is necessary to:

**3.1** Calculate the value of pressure $p_1$ in position 1 of valve $V_1$ and position 0 of valve $V_2$.

**3.2** Calculate the piston speed $v$ in position 1 of valve $V_1$ and position 0 of valve $V_2$.

Write the pressure in bar(s) rounded to a whole number and write the speed $v$ in m/s rounded to two decimal numbers.

Parameters: $D = 100$ mm, $d = 80$ mm, $F = 100$ kN, $Q_1 = 40$ dm$^3$/min.




3.1 SOLUTION :199 bar (1 point)

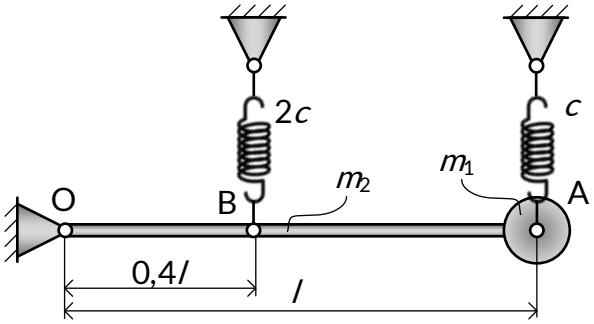
3.2 SOLUTION: 0,13 m/s (1 point)

## Question 4

(3 points)

A rigid lever of mass $m_2$ = 6 kg can vibrate about point O. A sphere of negligible dimensions and mass $m_1$ = 5 kg is attached to the end of the lever of length $l$ = 1 m. The lever is held in a horizontal position, when the system is at rest, only by the spring at point A, while the spring at point B is then unloaded. It is necessary to determine the natural frequency of the system. Round the solution to three decimal numbers, in Hz.

Parameters: $c$=1000 N/m.




SOLUTION: 2,186 Hz (3 points)

## Question 5

(3 points)

Turbo Tony, the lead engineer for Team Apex, has designed a new turbocharger system for their RON98 fuelled Formula Student car. The main focus of the 2025 Formula Student season is Formula Student Alpe Adria. Therefore, Turbo Tony decided to dimension the system based on the environmental conditions of FSAA 2024 (35°C and 1020 mbar). Tony wants to use the maximum air flow that can pass through the restrictor in these conditions. The compressor exit temperature of the turbo is 90°C, and the team's air intake rule compliance requires the intake manifold air temperature not to exceed 50°C. To cool the air, Tony has suggested installing an intercooler. The intercooler is claimed to have a thermal efficiency of 0,8. For simplicity, assume constant specific heat for air ($C_p$ = 1005 J/(kg·K)) and negligible losses in the piping and CAC.

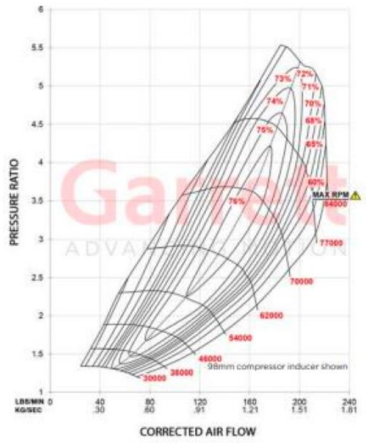
**5.1** What will be the temperature of the air in °C after passing through the intercooler? Round the answer to one decimal number.

**5.2** If the mass flow rate of the air through the system is 0,072 kg/s, how much heat is removed by the intercooler? Write the number in kW, with two decimal numbers.

**5.3** Calculate Total to Total Pressure Ratio required to the Compressor with three decimal numbers.

**5.4** Which is the most appropriate Compressor? Write just one number of the figures below.

1)

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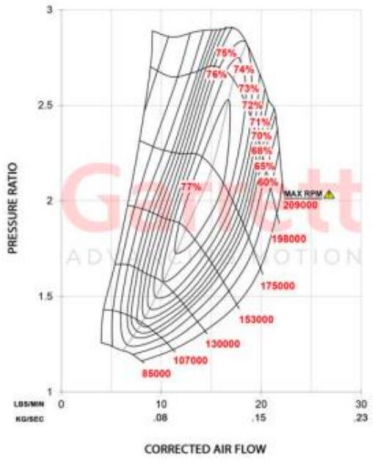
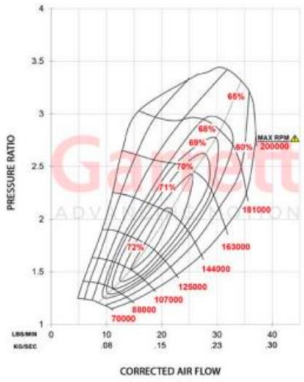



3)




**5.5** Tony wants to cool the car even faster. He suggests spraying 250 mL of demineralised water on the intercooler to absorb more heat. Assume the water has a temperature of 25°C and warms up to 70°C after absorbing heat, calculate how much additional heat energy is absorbed if the water $C_p$ = 4180 J/(kg·K). Use the water density at 4°C. Write the number in kJ, with two decimal numbers.

5.1 SOLUTION: 46,0°C (0,5 point)

5.2 SOLUTION: 3,18 kW (0,5 point)

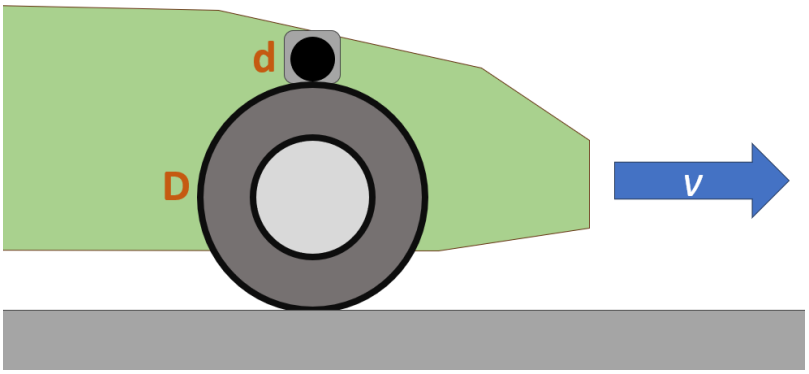
5.3 SOLUTION: 1,777 (1 point)

5.4 SOLUTION: 2 (0,5 point)

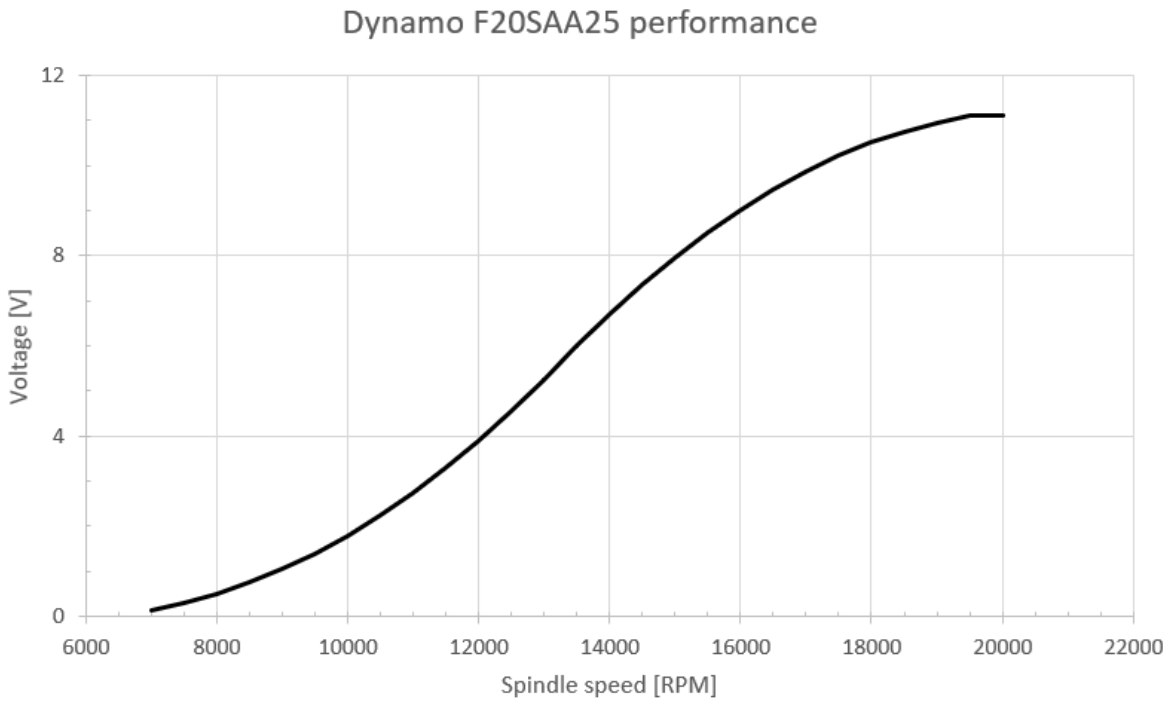
5.5 SOLUTION: 47,03 kJ (0,5 point)

## Question 6
(2 points)

Your team created a speedometer using a bicycle dynamo attached to the car and touching the outer diameter of the wheel. Calculate the speed of your vehicle if the measured voltage is 6 V. The diameter of the dynamo wheel is $d$ = 20 mm.




The voltage response of the dynamo was tested. Results are presented in the graph below:




Note: Write the answer in meters per second with two decimal numbers.

SOLUTION: 14,14 m/s (2 points)

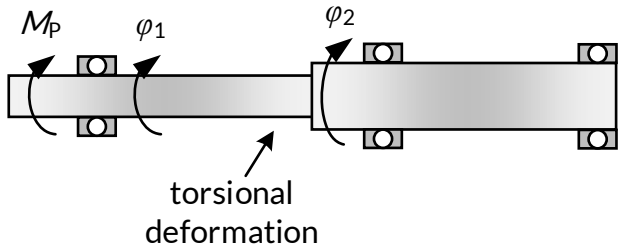
Due to inaccuracies in reading the graph (+/- 250 RPM), all answers between (and including) "13,88" and "14,40" are going to be accepted.

## Question 7

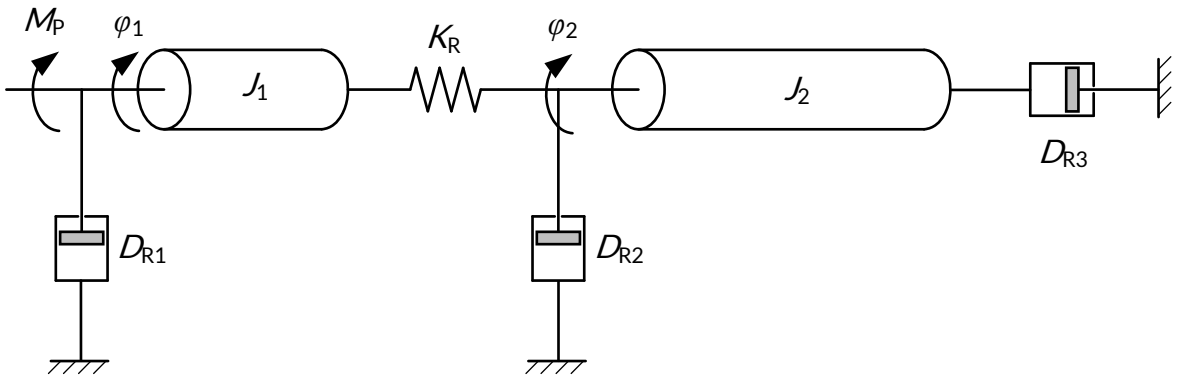
(3 points)

Determine the angular displacements $\varphi_1$ and $\varphi_2$ in rad at $t=1\,\text{s}$ of the mechanical system from the figure in the case of sinusoidal excitation $M_P = 0{,}1 \cdot \sin(t)$ and system parameters:

$J_1 = 0{,}1\,\text{Nms}^2/\text{rad}$, $J_2 = 0{,}2\,\text{Nms}^2/\text{rad}$, $D_{R1} = D_{R2} = D_{R3} = 0{,}1\,\text{Nms/rad}$, $K_R = 1\,\text{Nm/rad}$, initial conditions are all zero.
Write the answer in the following format: X,XXXX; X,XXXX and round it to four decimal places.



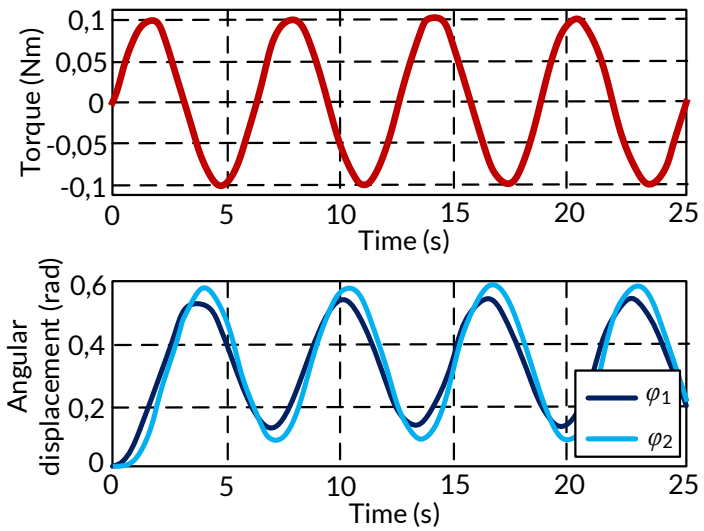

Schematic:




Bonus question: Make time (s) – torque (Nm) and time (s) – angular displacement (rad) diagrams. You are free to use any software. Time (s) axis should be set from 0 to 25 seconds. Upload png, pdf ,jpg or jpeg. Maximum 10 MB. Name your file according to: **TeamName_Question7_FSAA25_Quiz.xxx**

SOLUTIONS: $\varphi_1 = 0{,}1014$ rad; $\varphi_2 = 0{,}1037$ rad (2 points)

BONUS SOLUTION (1 point):



## Question 8
(2 points)

Your Sponsorship department of your Formula Student team has (surprisingly) been able to find a gullible enough sponsor to support your valiant efforts in the sum of 50.000 EUR. You got offered a sponsorship with either a lump-sum amount up front or with structured payments. The lump-sum exceeds the nonsensical limit set by your university and is therefore taxed 15%. On the other hand, monthly payments would be made in 6 instalments, the last one being one month before your first competition and wouldn't be taxed at all. The payment for the one-time payment would be made at the same time as first instalment for the structured payment.

**8.1** What qualitative factors (e.g. Operational cash flow needs, financial flexibility, etc.) would you consider when deciding which payment structure to accept?

**8.2** How would the timing of payments impact your team's financial planning, operational flexibility, and overall performance?

8.1 SOLUTION (1 point):

Qualitative factors and discussion how they influence the decision:

- Operational cash flow needs (lump sum – if it provides sufficient funds to cover early costs it might be beneficial; structured payment could influence cash shortfall),
- Financial flexibility (lump sum – greater flexibility; structured payments – restricting overspending and prioritization of expenses),
- Sponsorship Terms and Risks (lump sum – less risky, funds are readily available without and milestones)
- Impact on team morale and performance (lump sum – less stress; structured payments – more money in the long run),
- Sponsorship relationship and negotiation leverage (accepting structured payments shows long term relationship and willingness to collaborate and work with sponsors; lump sum could show financial instability and limit opportunities for deeper collaboration).

8.2 SOLUTION (1 point):

The answer depends on Your team's financial planning. There is not one answer, but answer should show the understanding of financial planning. For example, pro lump-sum answer should be preferable if the team has high upfront costs or cannot risk delayed funding. Pro structured payment answer would be better if the team has low initial expenses, can negotiate favourable terms for structured payments, and values a higher total amount (even discounted).

## Question 9.1*
(1 point)

Your team got the opportunity from a sponsor to get manufactured continuous steel tubing in any dimension possible. Determine the internal diameter ($d_{internal}$) of the tube to be used for your main loop. The tube is perfectly round. The tube must follow the rulebook and achieve following two goals in that order of priority:

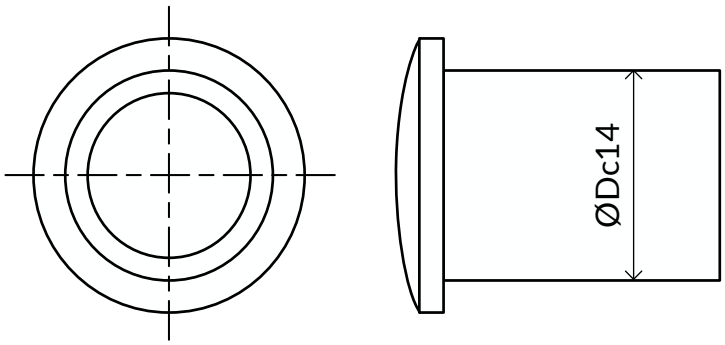
1. The main hoop must be as light as possible
2. The main hoop must have the highest moment of inertia as possible

Note: Calculate the answer for a straight tube with indeterminate length. Write the answer in millimetres, rounded to two decimal numbers.

## Question 9.2*
(1 point)

Your task is to inspect a machined plug designed to fit in the end of the tube. The plug is presented in the bottom drawing. Nominal diameter $D$ of the plug is identical to the internal diameter of the tube calculated in the **Question 9.1***. What is the minimum diameter of the plug still within the prescribed tolerances? Write the answer in millimetres with two decimal places.

$D = d_{internal}$




9.1 SOLUTION: 25,53 mm (1 point)

9.2 SOLUTION: 24,90 mm (1 point)

## Question 10*
(2,5 points)

It is time for IA testing! Suppose you came up with an idea to use a vertical drop setup as an alternative to the required kinetic energy.

Parameters: $C_d = 0{,}8$ ... drag coefficient, $A = 1{,}2\ m^2$ ... frontal area, assume standard air density at sea level and gravitational acceleration as 9,81 $m/s^2$.

**10.1*** Calculate the minimum height from which your FS certified vehicle must be dropped (including air resistance) to ensure the same amount of energy is absorbed by the impact attenuator during the collision. Write the answer in meters with two decimal numbers.

**10.2*** Keeping the maximum average required deceleration in mind, calculate the minimum duration of the collision if the impact attenuator fully stops the vehicle after absorbing the energy. Write the answer in ms, with one decimal number.

**Bonus:** What is the difference in minimum height if we assumed that there is no air resistance? Write the answer in meters with two decimal numbers.

10.1 SOLUTION: 2,52 m (1 point)

10.1 SOLUTION: 35,7 ms (1 point)

Bonus SOLUTION: 0,02 m (0,5 point)

### Question 11
(2,5 points)

The year is 2052 and the first Formula Student Mars was announced. Since you had already tested your car under harsh Arizonian conditions, you think it would be a good fit for the competition.

**11.1** What would be the factor of decrease in drag force compared to the International Standard Atmosphere at sea level on Earth for your car that faithfully resembles a smooth ball (we never said you were good at it) of 0,75 m radius speeding at 30 m/s? Round the answer to two decimal numbers.

**11.2** How would Arizonian dust particles and Martian regolith sticking to the surface of your car affect the drag values? Would the drag increase, decrease or stay the same in each of the cases above?

Assume the Mars atmosphere at 0,015 kg/m$^3$, 1,5 · 10$^{-5}$ Pa.

Write your answer in the following form: [*increase/decrease/stay the same/other*]. [*Explanation in roughly 2-3 sentences*].

11.1 SOLUTION: 28,61 (1 point)

11.2 SOLUTION: either keep it the same or decrease it (0,5 point)

### Question 12*
(3 points)

Suppose that a guy named Mark from FS Team "Carbon Copycats", who is in charge for Business Plan Presentation, stumbled upon unknown data (available on this link) from Engineering Department in his team. Your task is to decode the found data and answer the following questions. The only additional info about the data he found is that:

$y_1 = 1925$, $x_2 = 6{,}64064$, $y_{max} = 12758$, without information about units of measurement.

**12.1** The object that was experimentally tested based on minimum required FS rules has an overall thickness of 23,24 mm, with an inner part of 0,79 mm and outer part of 1,45 mm. What would be a second moment of inertia of that object? Write the answer in mm$^4$ without decimal numbers.

**12.2** For the same object, what would be Young's modulus (write the correct answer in GPa with one decimal number)?

**12.3** For the same object, what would be $\sigma_{UTS}$ (write the correct answer in MPa rounded to a whole number)?

**12.4** What is the energy of the testing object for the first 300 data points? Write the answer in J with one decimal number

**12.5** Based on the data, which official FS document would it belong to?

12.1 SOLUTION: 75416 mm$^4$ (1 point)

12.2 SOLUTION: 36,2 GPa (0,5 points)

12.3 SOLUTION: 197 MPa (0,5 points)

12.4 SOLUTION: 13,1 J (0,5 points)

12.5 SOLUTION: SES (0,5 points)

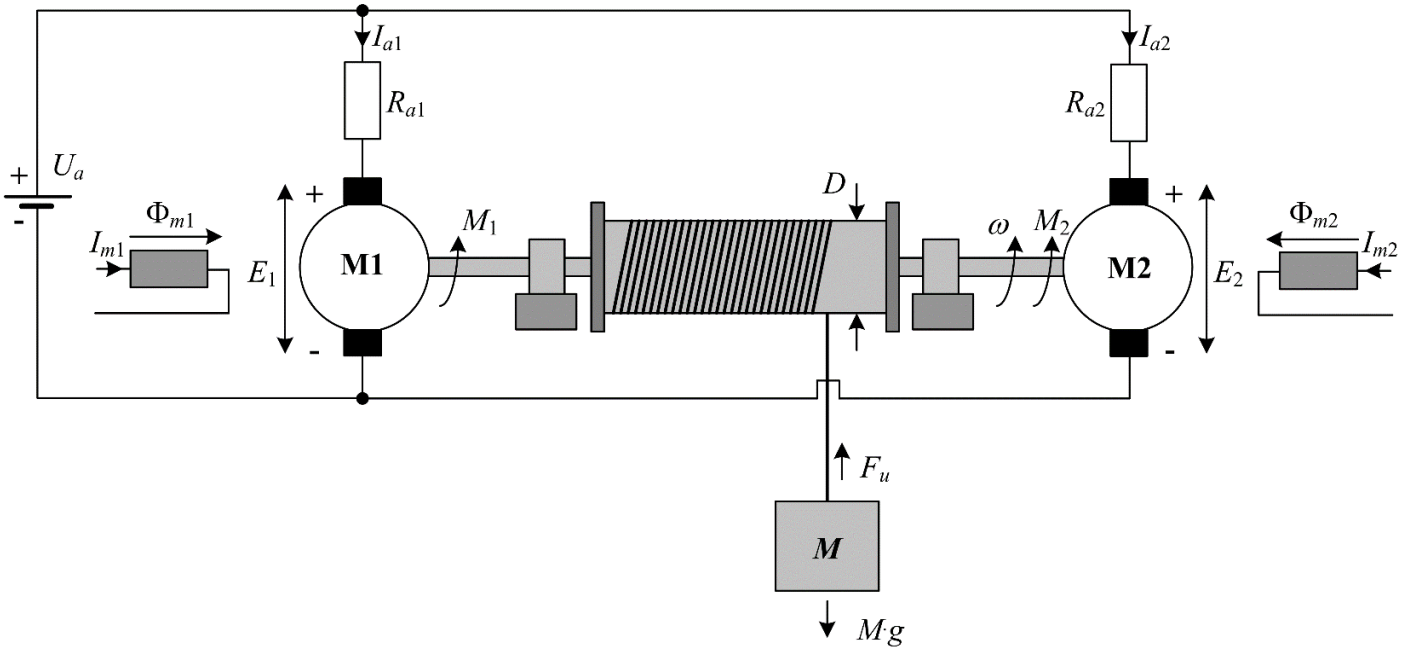
## Question 13
(4 points)

Given the two-motor DC drive in the figure, whose independently excited DC motors have the following nominal parameter values:

- Nominal voltage $U_{an}$ = 750 V
- Nominal current $I_{an}$ = 1050 A
- Nominal speed $n_n$ = 965 rpm
- Nominal armature resistance: $R_{an}$ = 0,018 Ω
- Nominal mechanical power: $P_n$ = 767 kW
- The diameter of the winch drum is $D$ = 2 m, and the mass of the suspended load is M = 1000 kg (gravity acceleration $g$ = 9,81 m/s$^2$)

The basic engine equations are (for the steady state case):

- Armature circuit of motor M1: $U_a = I_{a1}R_{a1} + E_1$
- Armature circuit of motor M2: $U_a = I_{a2}R_{a2} + E_2$
- Relation between induced electromotive force of motor M1, associated field flux $\Phi_{m1}$ and drive angular velocity $\omega$: $E_1 = k_E\Phi_{m1}\omega$
- Relation between induced electromotive force of motor M2, associated field flux $\Phi_{m2}$ and drive angular velocity $\omega$: $E_2 = k_E\Phi_{m2}\omega$
- Relation between torque of motor $M_1$, associated field flux $\Phi_{m1}$ and armature current $I_{a1}$: $M_1 = k_E\Phi_{m1}I_{a1}$
- Relation between torque of motor $M_2$, associated field flux $\Phi_{m2}$ and armature current $I_{a2}$: $M_1 = k_E\Phi_{m2}I_{a2}$




The two-motor drive is connected to the nominal armature voltage $U_{an}$, and the magnetic field fluxes of the motor excitation ($\Phi_{m1}$ and $\Phi_{m2}$) are initially set to the nominal value $\Phi_{mn}$ (by setting the excitation currents $I_{m1}$ and $I_{m2}$ to the nominal values).

**13.1** Determine the motor electromotive force constant and the motor torque constant for the case of the nominal magnetic field flux of the DC motor with independent excitation. Write the answer in Nm/A with three decimal numbers.

**13.2** Determine the load torque on the common shaft of the motor created by the suspended load. Write the answer in Nm rounded to a whole number.

**13.3** Determine the stationary angular velocity of the winch $\omega$ and the armature currents $I_{a1}$ and $I_{a2}$ of both motors with the nominal supply voltage $U_a = U_{an}$ and the nominal values of the armature winding resistance of both motors $R_{a1} = R_{a2}$ = Ran for the case of lifting the load (motor operation mode). Write the answer in rad/s with three decimal places. Write the answer in rad/s rounded three decimal places.

**13.4** Determine the stationary angular velocity of the winch $\omega$ and the armature currents $I_{a1}$ and $I_{a2}$ of both motors with nominal supply voltage $U_a = U_{an}$ and armature winding resistances of both motors $R_{a1} = R_{an}$ and $R_{a2} = 2R_{an}$ for the case of lifting the load (motor operating mode). Write the answer in $min^{-1}$ with one decimal number. Write the answer in rad/s rounded one decimal place.

13.1 SOLUTION: 7,229 Nm/A (1 point) or 7,235 Vs/rad (or both)

13.2 SOLUTION: 9810 Nm (1 point)

13.3 SOLUTION: 101,975 rad/s for both motors (1 point)

13.4 SOLUTION: 101,4 rad/s for both motors (1 point)

## Bonus Question

(2 points)

B.1 In vFSAA II, which group races were the bumper car sessions?

B.2 What is the middle name of Markus Dec?

B.3 Which world famous motorcycle racer joined us for an interview?

B.1 SOLUTION: Group A (0,5 point)

B.2 SOLUTION: xcm (x – any round number between 3 and 7) (1 point)

B.3 SOLUTION: Danilo Petrucci (0,5 point)