FORMULA STUDENT ALPE ADRIA
2023 REGISTRATION QUIZ ANSWERS

Question 1
(5 points)

Your team put a 1-axis accelerometer in the middle of a rear wing, which is supported on each side, and did a test drive. The output of the sensor is a series of measurements in mV saved as ACC_data.txt. What is the first resonance frequency of the wing as measured by the sensor? The sampling rate was 2 kHz. The sensor is calibrated at 20,23 mV/g. Round the answer to the nearest 5 Hz. (e.g.5, 10, 15, 20…)

Link to the file ACC_data.txt: https://drive.google.com/file/d/1x95jACbs-iF0ax-aVgxw-QWq83yxO0ub/view?usp=share_link

SOLUTION: 40 Hz

EXPLANATION:

Step 1: Translate data (notepad++)

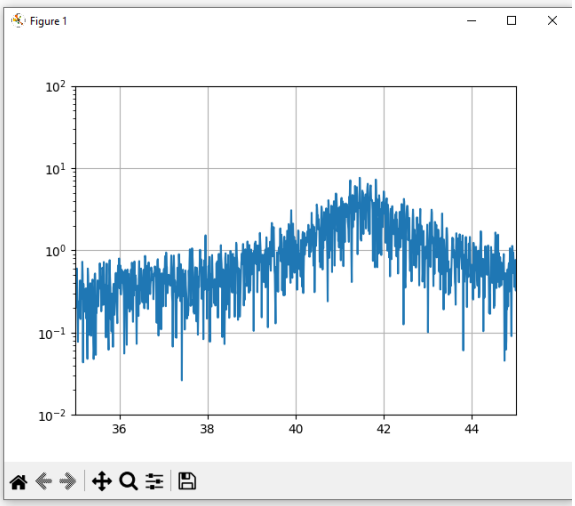
Change blank space to TAB

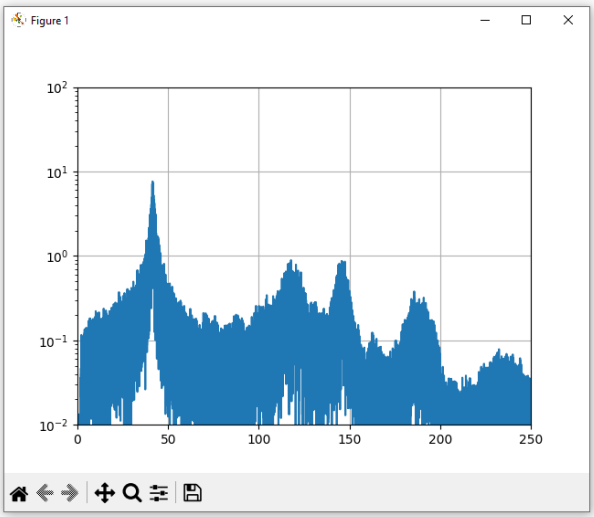
Change ',' to '.'

Step 2: Example: Python

Use fft analysis script (Numpy)

Sample rate: 2kHz = 2000Hz





Question 2

(5 points)

Make a technical drawing of a steel shaft of your design. The shaft must feature at least one parallel key slot, a gear, and secure placement for two bearings. The shaft must have at least 3 different diameters along its length.

The drawing must be drawn by hand. It must feature a cross-section view and show examples of surface roughness markings, dimensional tolerances, hole/shaft tolerances, and geometrical tolerances. Use ISO 7200 title block or equivalent.

The drawing must be scanned (can be done with a phone), titled Drawing_UniversityName.pdf (max 10 MB). Ensure that the quality of the scan is sufficient. The drawing will be judged by accuracy and aesthetics.

CRITERIA:

Cross section view correct	1 point
Surface roughness	1 point
Tolerances – correct examples	1 point
Title Block	1 point
Esthetics and general look Model correctness	1 point

If a drawing is not made by hand (made in CAD software), the team receives 0 points.

Use of pre-made title block is acceptable.

Question 3
(3 points)

You are the last car to start in the Endurance event. So far, the overall fastest time on the time board is 1300 seconds. While watching the event you also saw another team finish endurance in respectable time. You know that team has an Energy Storage that holds only 4,2 kWh.

From simulations, you know your power consumption depends on the average speed in one lap. The faster the lap, the more energy it consumes.

EN= P*v^4

Where:
EN is the energy consumed for the whole of Endurance
v is the average speed in km/h
P= 0,0005 [Wh^5/km^4]

Your Energy Storage holds 6 kWh of energy, and your driver is capable of driving it as fast as possible. BUT! You want to get as many overall points as possible. That means you want to maximize the sum of Endurance event AND Efficiency event points!

What lap times shall the drivers drive to maximize the points total for both events? The Endurance lap is 1 km long and there are 22 laps in total. Write the answer in seconds with 2 decimal points.

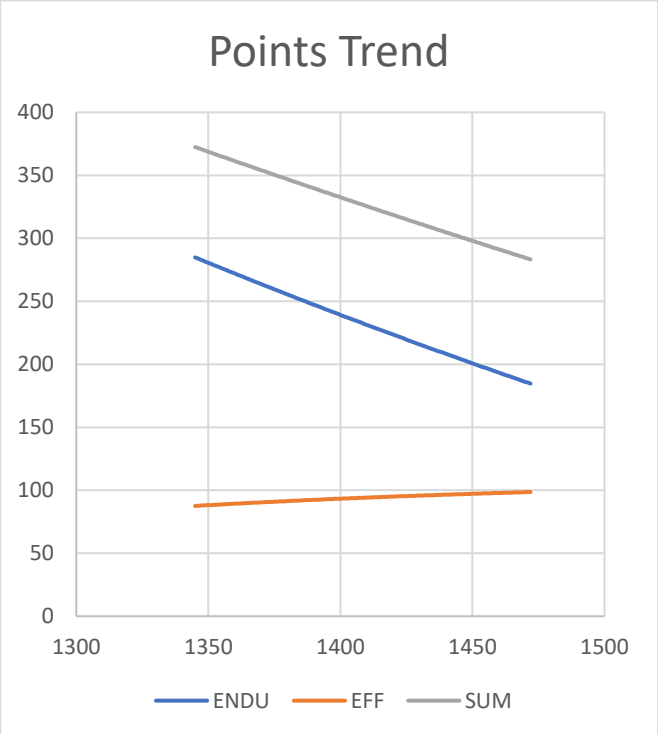
There is no regeneration of energy. No cones are hit.

SOLUTION: 61,17 s (drive as fast as possible)

EXPLANATION:

Relevant times:

1345,64 s (fastest possible) – 1472,94 (100 points difference in endurance from max points)



Question 4
(5 points)

Your team has a potential new sponsor in mind. He has offered to invite you to a meeting if you send him a summary/handout (A4) of a management presentation within 24 hours which your contact person at the company can send to the management. Like all sponsors in Formula Student, this company is not a charity but is after good engineers and managers. Convince the company that your team deserves to get big money (or maybe other support) from them. Upload this document as a Handout_UniversityName.pdf file (10 MB max file size).

Details:

The same handout will be used at your on-site meeting.

The fictitious company has extensive expertise in the automotive field, especially regarding all powertrain components and electrification.

The fictitious company is willing to enter into a longer-term partnership if topics can be found that are profitable for both sides.

EXPLANATION:

Does the Handout contain the following:

Team Structure and Management:

- Contact to Team, Persons present at the “Meeting"
- Project Structure of The Team, Organizational Chart
- Team Structure: Number of active members, Alumni
- Project plan: Gantt chart
- Future plans

Technical / Marketing:

- Unique selling points
- Challenges / solutions / progress
- Sponsorship, Social Media
- Offering of joint ventures or showcasing special technical features
- Short and concise
- Summarized

Aesthetics:

- More than plain text only

Question 5

(5 points)

Dimension a bolt-like part named “DESIGN PART” (required dimensions are D1, D2 and L) which is a part of the assembly provided in drawing “tolerance_stackup_analysis_drawing.pdf”.

Requirements for the part are:

- must protrude a minimum of 7 mm from an assembly
- must have minimum clearance possible to the holes through which it passes (it must not be interference fit)
- contact area of the head to surface D needs to be minimum of 130 mm2
- all of the requirements above need to be satisfied in worst case scenario of 1D tolerance stackup for each axis

NOTE: for dimensioning use worst-case scenario criteria of 1D tolerance stackup analysis. Do a 1D tolerance stackup analysis for each axis separately and then consider the worst case of those for each dimension.

Round all dimensions to 3 decimal points (e.g.,0,123). Write the dimensions and separate them by a semicolon (X,XXX; Y,YYY; Z,ZZZ).

EXPLANATION:

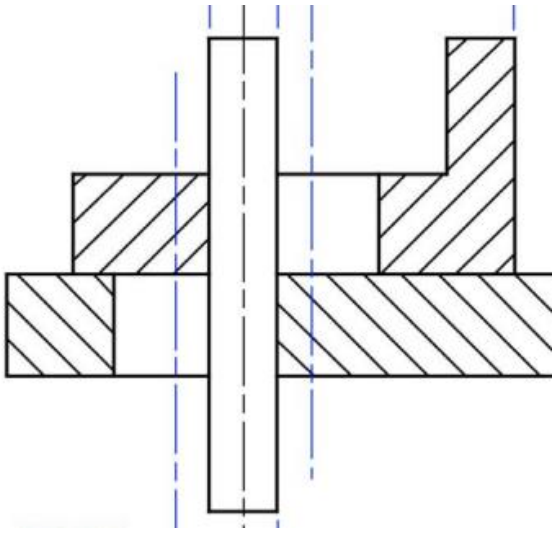
D1 (3 points):

To meet requirement “must have minimum clearance possible to the holes through which it passes (it must not be interference fit)” and “all of the requirements above needs to be satisfied in worst case scenario of 1D tolerance stackup for each axis“ dimension D1 needs to be 5,8 mm.

For calculation of the dimension both hole/slot dimensions+tolerances needed to be considered AND positional tolerances of each hole.

For WCS min. hole/slot dimensions should be used (e.g. if hole is 7,2 $\pm$ 0,05 you should consider hole to be 7,15).

Holes will have impact to D1 not only due to its size but also due to its positions. Since there are 4 parts through which „bolt“ needs to pass there is worst case where one hole position is in minus tolerance and some other hole positions is in plus tolerance creating effective hole diameter which is lower than any of those holes.



In this particular case, WCS was on X axis for holes/slots in stacking part 2 and 3

HOLE 2			
Base A to wall on base part	5	-0.05	0.05
Stacking part 1 width	40	-0.1	0.1
Stacking part 1 wall back to hole	20	-0.2	0.2
HOLE CENTER OVERALL	**25**	**-0.35**	**0.35**
Hole RADII dimension	3.3	-0.05	0.05
HOLE RADII SMALLEST	**3.25**		
LEFT SIDE OF HOLE	**21.75**	**-0.35**	**0.35**
OPTION 1 - Left/Right side of hole when positioned on left	21.4	27.9	
RIGHT SIDE OF HOLE	**28.25**	**-0.35**	**0.35**
OPTION 2 - - Left/Right side of hole when positioned on right	22.1	28.6	
HOLE 3			
Base A to wall on base part	5	-0.05	0.05
Stacking part 3 from wall to stacking part 2	10	-0.1	0.1
Stacking part 2 width	35	-0.3	0.3
Stacking part 2 back to hole	25	-0.2	0.2
Slot CENTER OVERALL	**25**	**-0.65**	**0.65**
Slot RADII dimension * 2	6.6	-0.1	0.1
Slot center distances	0.5	0.1	0.5
HOLE SMALLEST	**7.1**		
LEFT SIDE OF HOLE*	**21.45**	**-0.65**	**0.65**
OPTION 1 - Left/Right side of hole when positioned on left	20.8	27.9	
RIGHT SIDE OF HOLE*	**28.55**	**-0.65**	**0.65**
OPTION 2 - - Left/Right side of hole when positioned on right	22.1	29.2	

	LEFT SIDE OF HOLE*		RIGHT SIDE OF HOLE*	
	LEFT POSITION*	RIGHT POSITION*	LEFT POSITION*	RIGHT POSITION*
HOLE 2 LEFT/RIGHT POSITION	21.4	22.1	27.9	28.6
HOLE 3 LEFT/RIGHT POSITION	20.8	22.1	27.9	29.2

If hole 2 is in plus (right) tolerance position its left side of hole is on coordinate 22,1 mm and if hole 3 is in it minus (left) tolerance positions its right side of hole is on coordinate 27,9 mm. Subtracting 22,1 mm from 27,9 mm it is received 5,8 mm what is value for D1.

	MAX LEFT SIDE	MIN RIGHT SIDE	R-L SIDE COORDINATE
FINAL HOLE = D1	22.1	27.9	**5.8**

*NOTE: Left and right is if viewed normal to XZ plane or XY plane as parked on drawing. Left would be more to origin of axis x and right more to plus value of x, if origin of x would be consided on base A and going in deriction as on drawing.

D2 (1 point):

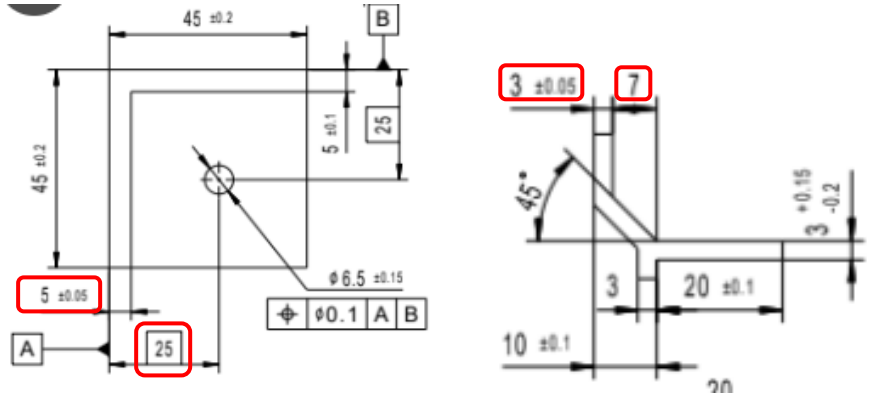
To meet requirement “contact area of the head to surface D needs to be minimum of 130 mm2” and “all of the requirements above needs to be satisfied in worst case scenario of 1D tolerance stackup for each axis“ dimension D2 needs to be bigger than 14,768 mm but smaller than 19,4 mm

(D2 >= 14,768 & <= 19,4).

Lower limit is due to need of minimum 130 mm2 of contact area and upper limit is due to edge on stacking part 3 which doesn’t allow contact to surface D if diameter D2 is bigger than limit.

MIN PRESSURE AREA - A	**130**
HOLE ON UPPER PART (on surface D WCS) - d1	**7.25**
d1 = 7,2 hole + 0,05 tolerance (WCS is when hole is the biggest)	
D2 = sqrt(4*A/pi + d1^2)	
D2	**14.768**

Base A to wall on base part	5	0.05	
Wall thickness on part 3	3	0.05	
Wall to edge of surface D (part 3)	7	0.2	ISO 2768
SUM OF DIMENSIONS AND WCS TOLERANCES	**15**	**0.30**	
Dimension from base A to center of "bolt" part	25		
Distance from center of "bolt" to edge on part 3	**9.70**		
D2 MAX. (= 9,7*2)	**19.4**		



L (1 point):

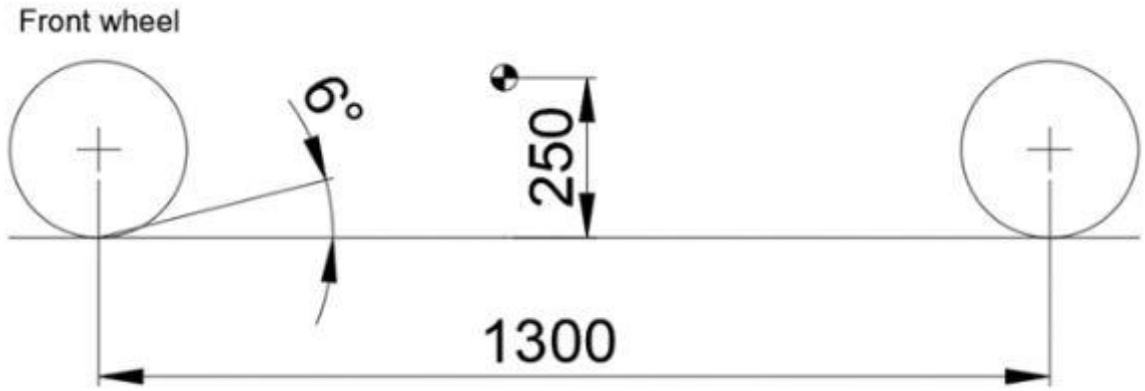
To meet requirement “must protrude a minimum of 7 mm from an assembly” and “all of the requirements above needs to be satisfied in worst case scenario of 1D tolerance stackup for each axis“ dimension L needs to be bigger or equal to 30,75 mm.

(L >= 30,75).

DESCRIPTION	NOMINAL	TOL -	TOL +	
Base part height	10	0	0.3	
Stacking part 1 height	5	-0.1	0.1	ISO 2768
Stacking part 2 height	5	-0.05	0.2	
Stacking part 3 height	3	-0.2	0.15	
Minimal dimension of portruding	7	0	0	
OVERALL HEIGHT (SUM)	**30**	**-0.35**	**0.75**	
MIN WCS HEIGHT	29.65			
MAX WCS HEIGHT	**30.75**			
L	**30.75**			

Question 6
(3 points)

The following side sketch represents the side of a car equipped with outboard brakes that provides 65 % of braking on front brakes. In the side view, the swing arm is inclined for 6°. Calculate the anti-dive percentage (round up to the first decimal place).



SOLUTION: 35,5% (and 35,6%)*

EXPLANATION:

$$AD = FB \cdot \tan\Phi \cdot \frac{l}{h} = 65\% \cdot \tan 6° \cdot \frac{1300}{250} = 35.5\%$$

AD = antidive [%],

FB – front braking [%],

Φ - inclination of the swingarm in side view [°],

l- wheelbase,

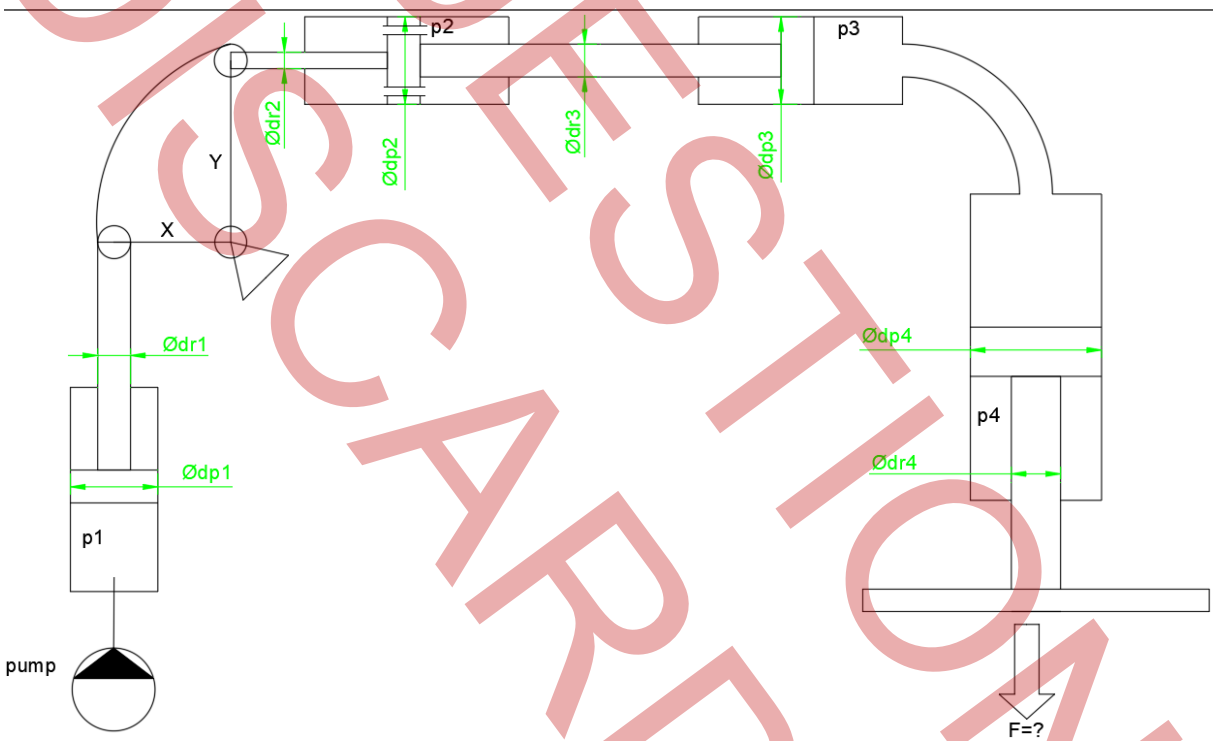
h – height of CoG

*added 35,6% as a correct answer, because of the wording in the question

Question 7
(3 points)

Calculate the force (F) from the picture if the pump gives a pressure of 5 MPa. Round it to the second decimal:
- dp1 = dp2 = dp3 = 30 mm
- dr1 = dr3 = 15 mm
- Y = 1,6 X
- dr2 = 10 mm
- dp4 = 50 mm
- dr4 = 20 mm
- p4 = 3,5 MPa

Write the number in N.



SOLUTION: 314,16 N

EXPLANATION:

$$F_1 = p_1 \cdot \frac{d_{p1}^2 \cdot \pi}{4} = 3534{,}3\ N$$

$$F_2 = \frac{F_1 \cdot X}{Y} = 2208{,}9\ N$$

$$p_3 = \frac{F_2}{\frac{dp_3^2 \cdot \pi}{4}} = 3{,}1\ MPa$$

$$F = p_3 \cdot \frac{d_{p4}^2 \cdot \pi}{4} - p_4 \cdot \left(\frac{d_{p4}^2 \cdot \pi}{4} - \frac{d_{r4}^2 \cdot \pi}{4}\right) = 314{,}16\ N$$

Question 8
(3 points)

Suppose a current F1 with a power of 800 CV and a Coefficient of Resistance Aerodynamic SCx (multiplied by its frontal section) of 1,3 and a mechanical efficiency of 0,95. In an overtaking maneuver, it opens its DRS, which provides the top speed gain of 22 km/h. What is your new SCx? (Assume a Standard Atmosphere with ρ = 1,225 kg/m^3)

a) Remains Invariable
b) 1,365
c) 1,065
d) None of the above

SOLUTION: c)

EXPLANATION:

Speed without the DRS:

$$V_{wo\ DRS} = 88{,}8755\ m/s$$

New car speed (considering the speed delta):

$$V_{w\ DRS} = 94{,}9866\ m/s$$

New SCx:

$$SC_x = \frac{2 \cdot K \cdot P}{\rho \cdot V_{w\ DRS}^3} = \frac{2 \cdot 0{,}95 \cdot 800 \cdot 735{,}5}{1.225 \cdot 94{,}9866^3} = 1{,}065\ N$$

Question 9
(3 points)

Based on question 8, what is the new Aerodynamic Balance of a car, after opening the DRS, if the initial balance was 46% (front) and if we assume that the car always acts in the linear segment of its polar SCz/SCx, whose slope has a value of 4,5.

SCzF constant: assumption (no FRH - Front Ride Height variation)

a) Remains Invariable
b) 42%
c) 56%
d) 60%

SOLUTION: c)

EXPLANATION:

While the DRS is closed, we have:

$$\frac{SC_{z,front}}{SC_{z,tot}} = 0{,}46 \qquad \frac{SC_{z,tot}}{SC_x} = 4{,}5$$

$SC_{z,front}$ does not change when the DRS is opened, so with the SCx = 1,3 we have:

$$SC_{z,front} = 0{,}46 \cdot 4{,}5 \cdot 1{,}3 = 2{,}692$$

Because the car always acts in the linear segment of its polar SCz/SCx, we also have, when the DRS is open:

$$\frac{SC_{z,tot,DRS}}{SC_{x,DRS}} = 4{,}5$$

When the DRS is opened, we have $SC_{x,drs}$ = 1,065, so $SC_{z,tot,DRS}$ = 4,7925.

Finally we can extract the aerodynamic balance value with the DRS:

$$Abal = \frac{SC_{z,front}}{SC_{z,tot,DRS}} = \frac{2{,}692}{4{,}7925} = 0{,}56$$

Question 10
(3 points)

Calculate the load in high-speed corners at 200 km/h of a car having a SCz of 3 at Mexico (air density 0,945 kg/m3). What is the loss compared to the sea level?

a) 5%
b) 14%
c) 23%
d) 32%

SOLUTION: c)

EXPLANATION:

The load in high-speed corner at Mexico is:

$$F_z = \frac{1}{2} \cdot \rho \cdot SC_z \cdot V^2 = \frac{1}{2} \cdot 0{,}945 \cdot 3 \cdot \left(\frac{200}{3{,}6}\right)^2 = 4375\ N$$

At the sea level, we have $\rho = 1{,}225\ {}^{kg}/_{m^{-3}}$, so:

$$F_{z,sea} = 5671{,}3\ N$$

Then, the loss of downforce between those two places is 22,9%.

Question 11
(1 point)

You want to calculate the laminate of your front bulkhead when designing your monocoque. What is the minimum shear strength required?

Re= 235 MPa; Rm= 350 MPa; τ= 280

Write the answer in N. Round to the nearest whole number.

SOLUTION: 32987 N

EXPLANATION:

Steel plate thickness is 1,5 mm:

T 3.13.1 Any alternative material used for the front bulkhead must have a perimeter shear strength equivalent to a 1.5 mm thick steel plate.

Stamp diameter is 25 mm:

T 3.5.9 Perimeter shear tests must be completed which measure the force required to push or pull a 25 mm diameter flat punch through a flat laminate sample. The sample must be at least 100 mm × 100 mm. Core and skin thicknesses must be identical to those used in the actual primary structure and be manufactured using the same materials and processes.

Shear surface:

$$S = \pi \cdot d \cdot s = \pi \cdot 25\ mm \cdot 1{,}5\ mm = 117{,}81\ mm^2$$

Minimum shear strength is calculated using τ:

$$F_{max} = S \cdot \tau = 117{,}81 \cdot 280 = 32987\ N$$

Question 12
(1 point)

An F1 car and a bus have nearly the same track (assume it's the same). At the same longitudinal acceleration, which one will have more longitudinal load transfer?

a) F1 car since it has lower CoG
b) It depends on the wheelbase
c) It depends on the wheelbase and CoG position

SOLUTION: c)

EXPLANATION:

Since the both vehicles have the same track, lateral transfer is the same. Longitudinal transfer in this case is the function of CoG height and the wheelbase as it is shown in the following equation:

$$Long.transfer = \frac{CoG\ height}{wheelbase} \cdot veh.weight \cdot acc$$

Question 13
(1 point)

A Formula Student car weighs 120 kg, has a wheelbase of 1475 mm, uses 10” tires with magnesium wheels, the front track is 1200 mm, the rear track is 850 mm, and it has a Honda CBR 650r engine. What is true?

a) everything is according to the rules
b) engine displacement is too big
c) bigger track should be at least 75% of the wheelbase
d) wheelbase and tracks are not according to the rulebook
e) weight is under the lower limit

SOLUTION: d)

EXPLANATION:

T 2.8 Wheelbase

T 2.8.1 The vehicle must have a wheelbase of at least 1525 mm.

T 2.9 Track and Rollover Stability

T 2.9.1 The smaller track of the vehicle (front or rear) must be no less than 75 % of the larger track.

T 2.9.2 The track and center of gravity of the vehicle must combine to provide adequate rollover stability.

Question 14
(1 point)

By the Formula 1 2022 Rulebook, if the race from Novi Marof Karting to Spar Novi Marof (there and back would be one lap, round to one decimal place) would be a Grand Prix, how many laps would the race have to be (consider minimum race length)?

Karting track Novi Marof: Karting staza Novi Marof - Google Maps

Spar Novi Marof: SPAR Novi Marof - Google Maps

SOLUTION: 118, 122

EXPLANATION:

Distance from Novi Marof Karting to Spar Novi Marof is 1,3 km. We need to calculate the one lap distance, which would be:

$$1\ lap = 1{,}3\ km \cdot 2 = 2{,}6\ km$$

Formula 1 rules dictate, that a full race distance must be a minimum of 305 km:

$$Number\ of\ laps = \frac{305\ km}{2{,}6\ km} = 117{,}3$$

Because of those pesky rules, we must have a full number of laps, so the correct answer is 118.

Because of a different distance acquisition, we also accepted 122 laps.