ONTARIO TECH RACING

2020-2021 Season Passport

First and Last name	
Student ID	
University Email	
Program, Year of Study	
1st Choice Department	
2nd Choice Department	
3rd Choice Department	

Table of Contents

Departments

Please review all of the departments, their questions and select a maximum of 3 departments. You **must** do the challenge questions for every department you plan to join.

Mechanical Departments

1. Aerodynamics
2. Chassis
3. Driver Interface
4. Suspension
5. Drivetrain/Braking

Electrical Departments

1. Telemetry and ECU
2. Safety Systems

Signature: _____

Passport Information

The recruiting process for the Ontario Tech Racing team consists of a passport which will test your knowledge, critical thinking, and problem-solving skills. The passport consists of 20 general questions which will test your ability to quickly research and understand many aspects of the vehicle. **These 20 questions must be completed by everyone interested in joining any Mechanical or Electrical departments of the team.**

The following sections are separated between the Mechanical and Electrical passport questions. Note that you can apply to a **maximum of three departments**. Please navigate to your department(s) of interest and complete the challenge questions outlined in that department. You must complete each of the department's challenge questions that you plan to apply for. Some questions may be exclusive to your year of study so ensure you follow all instructions outlined in the question.

Submission Information

Ensure that the general questions are answered on the passport, and department specific questions are answered on a separate piece of paper and both are submitted online as one pdf document. **The entire passport package must be submitted by Wednesday, September 30th 2020 11:59pm on Ontario Tech Racing's website.** Late submissions will not be accepted unless otherwise approved by a team director due to certain circumstances. After submission, you will be contacted by email for a short interview if your passport moves on to the next stage.

Tips

1. Answer each question fully to the best of your abilities, we are not solely looking for the correct answers, we want to know how well you can research and effectively solve problems.

2. Attaching a resume and an optional single page portfolio to outline experience will greatly aid your chances of being selected.

3. In your department specific questions, include screenshots or mention any software used to solve or help solve the questions (CAD, Visual Studio, MATLAB, NI Labview, etc.).

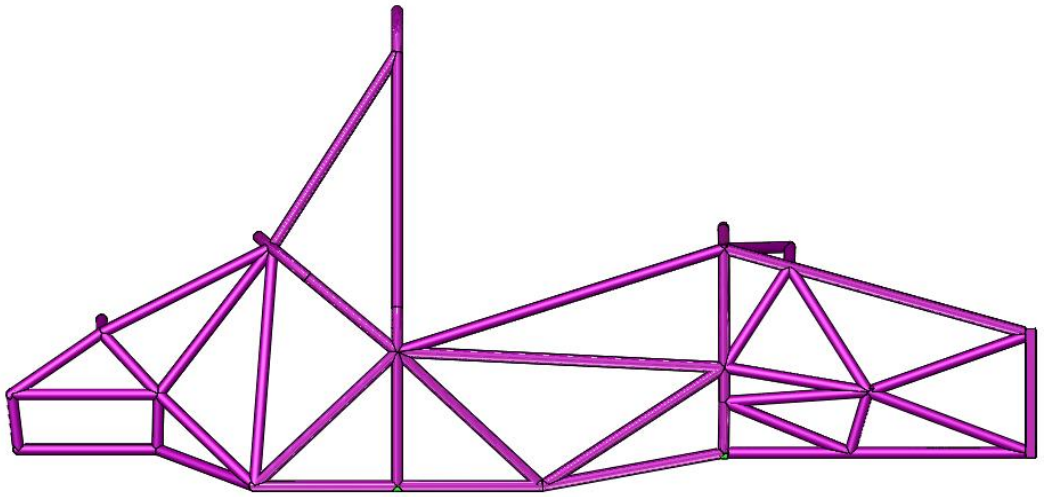
4. Use https://www.fsaeonline.com to refer to FSAE rules and technical documentation.

5. Show your work! Draw pictures and diagrams when attempting to solve challenge questions.

6. Current OTR members are not to help applicants and cheating will not be tolerated. You will be immediately discarded if plagiarism or cheating is discovered.

General Questions

1) In the diagram below, please label the **main hoop, front hoop, side impact structure and front bulkhead**. Specify the minimum wall thickness of each section of the chassis as required by the FSAE rules. Refer to **Formula SAE Rules 2020 V2.1 section F.3.2.1**.



2) What is the function of the “Tractive System Active Light” on the car?

3) Find the university's **Harassment and Discrimination Policy (LCG 1105)** on the ontariotechu.ca website, list the 5 forms of harassment/discrimination defined within the policy and **briefly** define it **in your own words.**

4) What is the term for a wing where the airflow has separated and is no longer providing lift?

5) Explain why triangulating a steel tube frame chassis is important.

6) What is double shear and single shear? Why is it more desirable to mount brackets in double shear than single shear?

7) What does the term **pedal ratio** mean?

8) Briefly explain the differences between **analog** and **digital** communication (include examples where each communication might be used)

9) Using 2 wires for CAN communication, how can you achieve a ‘dominant’ state?
   a) When the CAN high wire carries a greater voltage than the CAN low wire.
   b) When the CAN low wire carries a greater voltage than the CAN high wire.
   c) When the CAN high wire has a voltage equal to the CAN high wires voltage.
   d) None of the above.

10) Name and describe **4 types of welding**. What type of welding is most beneficial for a steel tube chassis? Why?

11) What is the function of an Anti-Roll Bar on a racecar?

12) What is brake bias? Is a front bias or a rear bias favoured and why?

13) Explain what is understeer and oversteer. Explain the significance of having an understeering or oversteering car on the driver's ability to operate the vehicle.

14) Find the university's **Policy Against Violence, Harassment and Discrimination in the Workplace (LCG 1137)** policy on the ontariotechu.ca website, list 5 roles and responsibilities that **employees** are expected to follow in your own words. *Note: these responsibilities are expected from members of the team as well!*

15) Why is a diffuser/undertray better than a rear wing?

16) What should you do if you spot someone being electrocuted?

17) The forces that the Tyres on a racing car generates to turn the car act through the _____ of the Tyre.

18) Draw a front view diagram of a **double wishbone pushrod suspension system.** Label the push rod, wishbones (upper and lower), bellcrank (rocker), and spring-damper.

19) What is the function of the brake balance bar, and where is it assembled on the vehicle? Modifying the length ratio does what to the braking system?

20) Which is **not** something a MOSFET should do?
    a) Voltage Isolation
    b) DC to AC conversion
    c) Switching
    d) Amplification

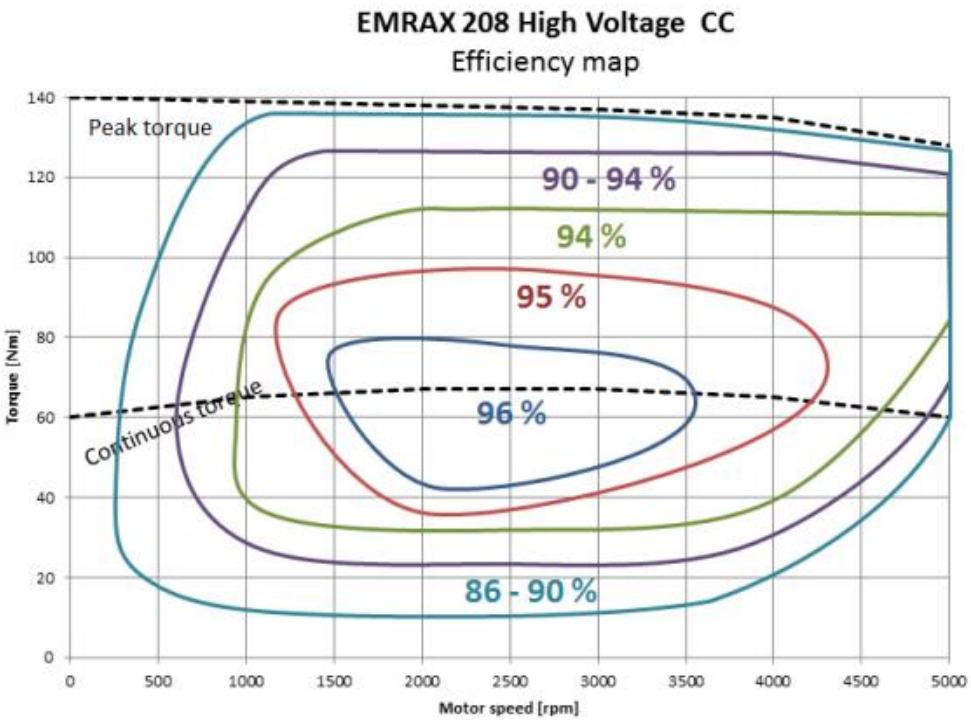
Challenge Questions

Aerodynamics

Answer the following questions to the best of your ability and be sure to show your work. **First year students are only required to answer question 1**, other students are required to answer all questions.

1) An electric drivetrain system consists of an electric motor and a motor controller. If the power drawn from the powertrain at **peak torque is 32kW**, and the motor controller is **97% efficient**, calculate what is the power required to be dissipated by the cooling system? Use the figure below.

(HINT for first years: Research how to estimate amount of heat produced from a power supply, your first step should be to determine the total efficiency of the drivetrain system given that the motor controller is 97% efficient and the graph below contains the efficiency of the motor)



2) Create a **2D** Simulation of a front wing setup (no other parts of the car) using ANSYS Fluent Student 2019 R2 (https://www.ansys.com/academic/free-student-products). Launch workbench and select the Fluent (with meshing) block to start.

What you must include:

- Simulate with the air flow at 50 km/h.
- Wing design must fit in a 625 mm by 250 mm area (length by height).

Everything else is up to you:

- Meshing, design domain, and boundary condition setup.
- Airfoil selection.
- Airfoil configuration.
- Be realistic in your simulation, but creative in your design.

Design Goal:

- Generate maximum downforce with minimum drag.

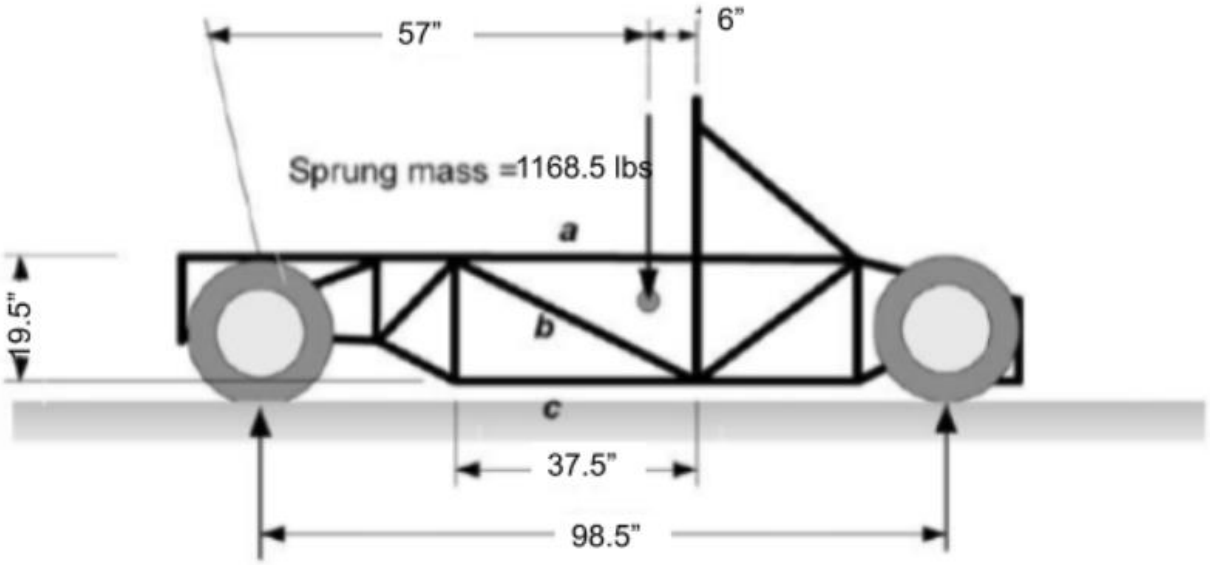
Create a <u>brief</u> report of your results and include:

- Draft of your final 2D design as well as any iterations showing your design process.
- Mesh resolution selected including reasoning behind the choice.
- Design domain size selected including reasoning behind the choice.
- Solver model chosen and parameters selected including reasoning behind the choice.
- Screenshots of total pressure plots and anything else you deem necessary.
- Drag and lift force results.
    - Explain each decision you made and the limitations of your simulation.

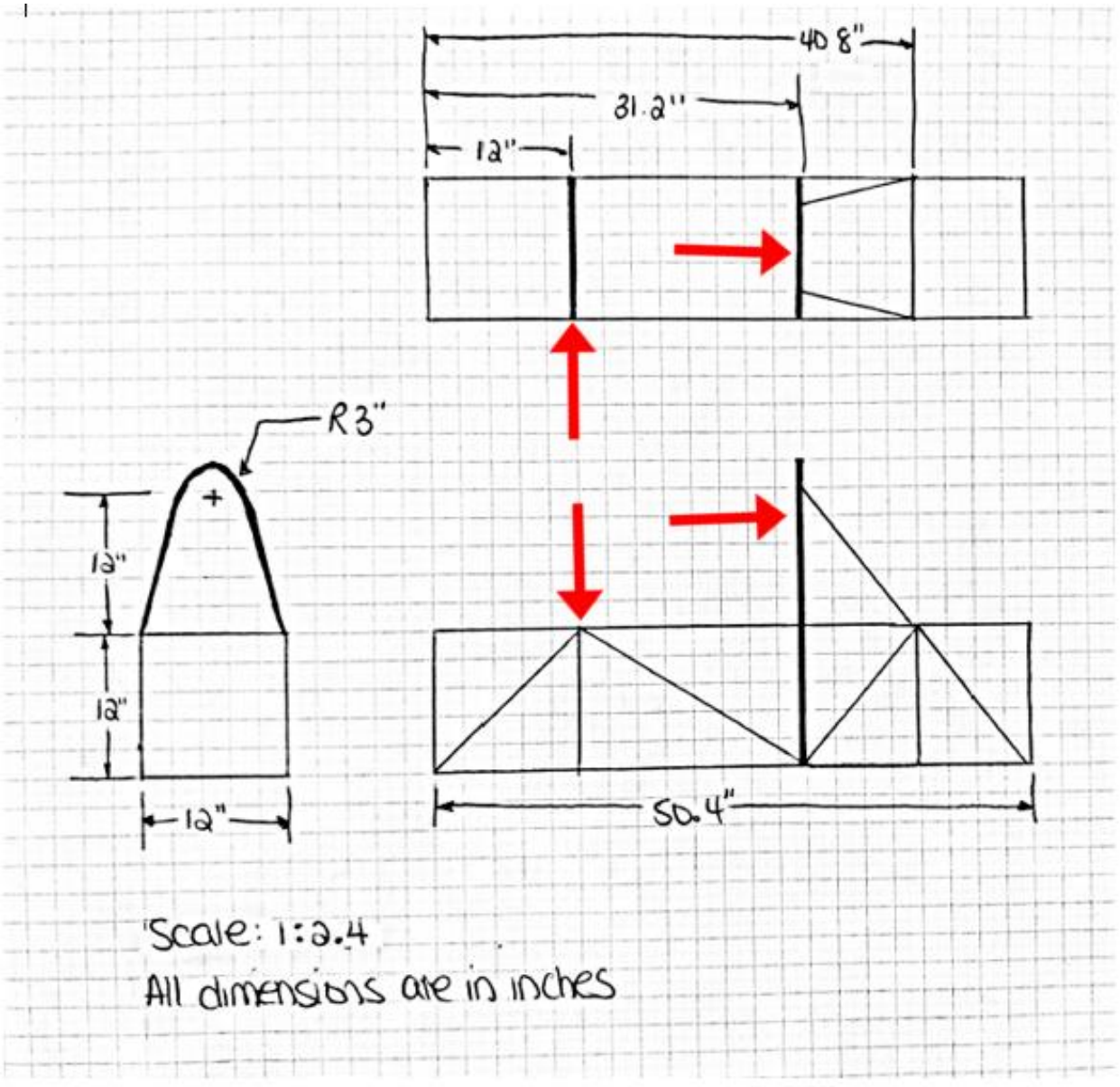
Chassis

Answer the following questions to the best of your ability and be sure to show your work. **First year students are only required to answer question 1**, other students are required to answer all questions.

1) A steel tube frame chassis for a vehicle is shown below, the sprung mass is 1168.5 lbs and location of the center of gravity is shown.
   a) Using the **Method of Sections,** determine the forces acting on members **a, b, and c.**
   b) BONUS: Determine the suitability of using a 1" diameter, 0.047" thick steel tube given the properties listed below. *(Hint: research Euler buckling theory)*
   - Cross section 0.1716in^2
   - Second Moment of area: 0.018 in^2
   - Yield Stress: 40 000psi
   - Elastic Modulus: 29 000 000 psi



2) Model the chassis sketched below using Solidworks or Siemens NX. All tubes have a diameter of 1”, the roll hoops marked with an arrow have a thickness of 0.095” while all other tubes are 0.065”. Paste an image of your CAD model in isometric view



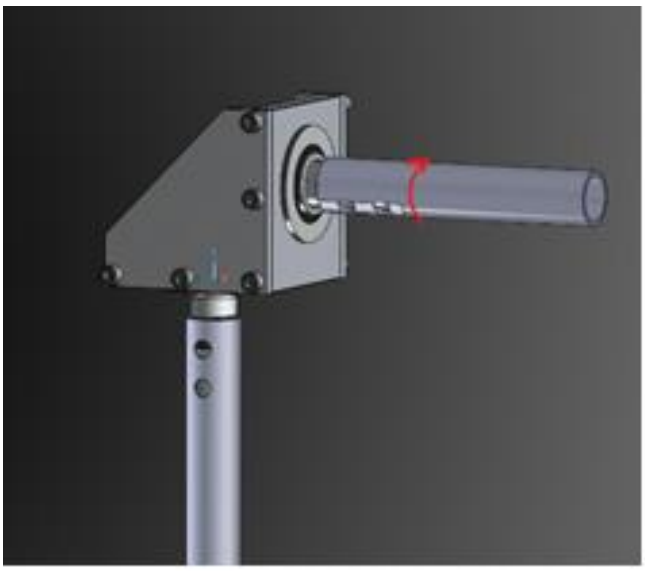
b) Import your CAD file into ANSYS and create a static structural analysis. Perform a front impact analysis with a 5g acceleration. (Hint: Fix the rear bulkhead and apply the force on the front bulkhead). Does the chassis fail under this loading scenario? Paste an image of your simulated chassis in isometric view

Driver Interface

1) If a moment of 135 N, is applied on the steering shaft as shown by the red arrow in the diagram, calculate the:
   a) Define what a moment is?
   b) Maximum tangential force applied on the gear tooth faces?
   c) What is the maximum axial force (thrust) the gear experiences?
   d) What feature can be changed on the gearbox to reduce the maximum amount of force on a single tooth? What addition to the gearbox could help reduce axial load (thrust) on the inner bearing races?

Gear Specifications:

m = 2.33 (module)
d = 35mm (outer diameter)
z = 15 (number of teeth)
D_m = Center reference diameter
T_i = 135 Nm
b = 6.9mm (face width)
δ= 45° (reference cone angle)



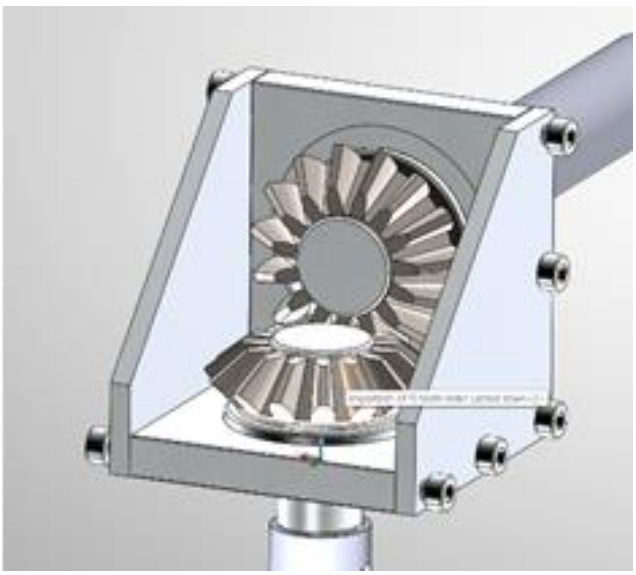


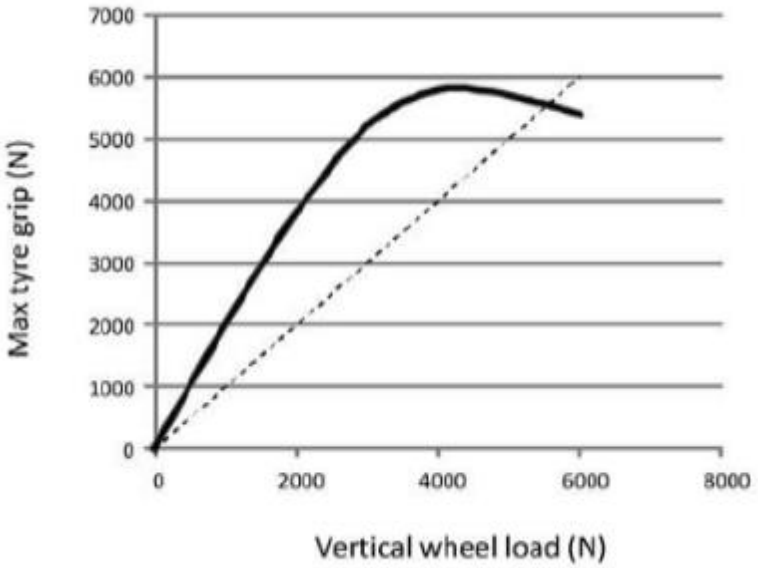
Table 12.4 Calculation Examples (Straight Bevel Gear)

No.	Specifications	Symbol	Unit	Formula	Straight Bevel Gear	
					Pinion	Gear
1	Shaft angle	Σ	Degree	Set Value	90°	
2	Module	m_t	mm		2	
3	Pressure angle	α	Degree		20°	
4	No. of teeth	z	—		20	40
5	Spiral angle	β	Degree		0°	
6	Facewidth	b	mm		15	
7	Input torque	T_1	N·m		1.6646	—
8	Reference diameter	d	mm	zm	40	80
9	Reference cone angle	$\delta_1 \bullet \delta_2$	degree	$\tan^{-1}\left(\frac{z_1}{z_2}\right) \quad \Sigma - \delta_1$	26.56505	63.43495
10	Center reference diameter	d_m	mm	$d - b \sin \delta$	33.292	66.584
11	Tangential force	F_t	N	$\frac{2000T}{d_m}$	100.0	
12	Axial force	F_x		$F_t \tan \alpha \sin \delta$	16.3	32.6
13	Radial force	F_r		$F_t \tan \alpha \cos \delta$	32.6	16.3
14	Output torque	T_2	N·m	$\frac{F_t d_{m2}}{2000}$	—	3.329

Suspension

Answer the following questions to the best of your ability and be sure to show your work. **First year students are only required to answer question 1**, other students are required to answer all questions.

1) Answer the following questions about the graph below
   a) Describe the relation shown in the graph, what is the importance/significance of analyzing a graph like this
   b) What can the slope of an instantaneous point on this graph give you?
   c) What would the difference in max tire grip be for a car with aerodynamics and for a car without aerodynamics
   d) How would the max tire grip differ between left and right wheels if a car was cornering



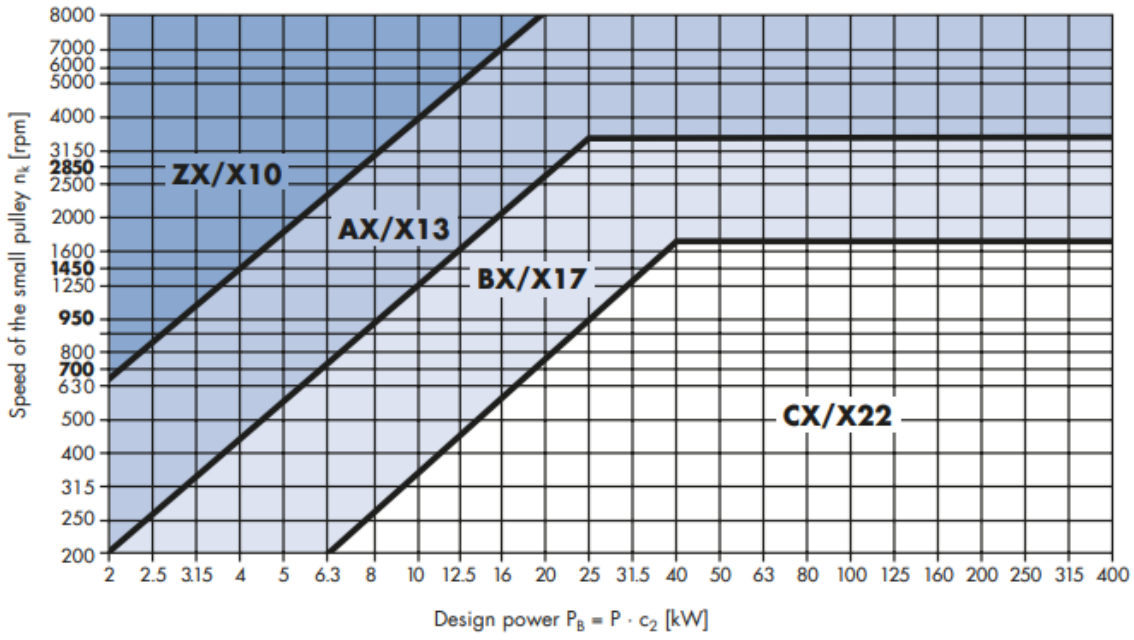
2) The suspension department of a Formula SAE team is looking to increase the wheel center rate of 30N/mm by 50% in order to reduce roll. They plan on utilizing a U-shaped anti-roll bar system coupled to their existing pushrod suspension. The wheel movement in bump and rebound is 25.4mm and the effective motion ratio is 1. Using a solid circular ½" diameter spring steel (E = 207,000 N/mm^2, G = 79,300 N/mm^2) shaft with a half-length of 125mm, and assuming the ARB arm (cantilever arm) is made of a different infinitely stiff material, calculate the following.
   a) The target ARB stiffness to achieve the desired wheel center rate
   b) The ARB arm (cantilever arm) length
   c) The shear stress in the U-bar

Drivetrain and Braking

Answer the following questions to the best of your ability and be sure to show your work or explanation of your responses. **All students must answer question 1**. Additionally, **first-year students only need to answer (a) for question 2**, and upper-year students are required to answer **(b) for question 2**. Bonus points may be awarded for completing questions you are not required to do.

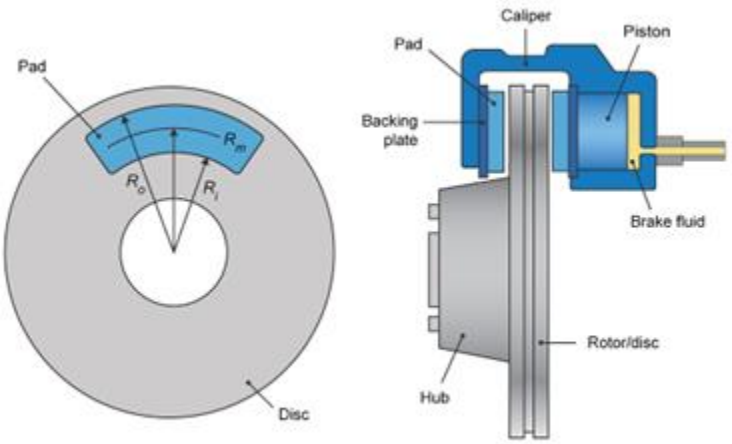
1) Please reference the below diagram when answering the following questions based on V-belt selection for a belt drive. Design power, P_B, is a product of required power, P, and load factor, c_2.

   a) If the driving pulley is rotated at a peak speed of 6000rpm, what would be the belt profile selected if required power is 64kW and load factor is 1.2?
   b) Which belt profile between AX/X13 and BX/X17 would be smallest (i.e. smallest cross-section of the two)?
   c) Are smaller belt profile sizes used for higher or lower operating speeds? Why?



2) A testing rig rotates a 6.3in brake rotor to angular velocity, Ω, to a magnitude of 50 rad/s when a hydraulic dual-piston caliper actuates with an effective piston area of 0.79in per piston to stop the rotor from spinning. The braking assembly positioned in such a way mean-radius of the pad is 2.75in, where this distance is the moment arm for braking torque. There are a total of two brake pads used during actuation. The coefficient of kinetic friction is 0.5.

   a) **For first-year students**, find the line pressure if the Ω = 0, at the moment of actuation due to an applied brake torque of 266Nm.
   b) **For upper-year students**, find the line pressure if Ω ≠ 0, where the brake rotor has rotated 0.25 times before stopping. The moment of inertia of the rotor relative to the axis of the testing rig is 0.004801kg*m2. Additionally, model the braking calculation using Simulink, where brake pressure is an input signal, and brake torque is an output signal.



Telemetry and ECU

Answer the following questions to the best of your ability. **First year students are only required to answer question 1**, all other students are **only required to answer questions 2 and 3**. Bonus points will be awarded for successfully completing the questions you are not required to do

1) Using Python, create a tkinter application. The page should display a picture of the OntarioTech University logo, a button that's titled "OntarioTech Racing", and a checkbox labeled "Done". Your name should be placed in the bottom right corner of your window in the form of a label. Include a screenshot of your window and code as well as an explanation of your process.

2) You are receiving data from a temperature sensor that receives multiple temperature readings per second. The control system you are working with triggers a fault when the temperature received is above 35 deg C. However, this temperature sensor's data has a lot of noise and regularly has spikes in its data. Using Simulink in MATLAB, create a system that would trigger a fault **after** the sensor receives 4 values above 35 deg C in the span of 1 second (use an input block for the sensor's data). Include a screenshot of your simulink model with a written explanation of how your model works.

3) Your job on the team is to analyze the car's performance. You are tasked with providing some characteristics of the OTR-21's suspension before it is put on ACE's 4 post shaker. Using a quarter car model, determine the natural frequency and damping ratio if you know that the Spring rate is 190000 N/m, the damping rate is 20000 N/m on the low side and 1000 N/m on the high side, the quarter-car and tire mass is 150kg and 10kg respectively, and the tire spring rate is 300000 N/m. Assume the motion ratio is 1. Also determine the frequency response from a step input using Simulink. Provide a picture of the response and your model. Hint: there should be two answers for Natural frequency, damping ratio and response.

Safety and Circuits

Answer the following questions to the best of your ability and be sure to show your work.

1) Create a high-level schematic diagram for an electric vehicle with a battery pack and a single rear electric motor, include safety systems and devices that are applicable for electric vehicles. The safety components should be able to sense an abnormality, control the system, or actuate a safety measure in some way. Also explain your design choices and how it complies with the FSAE rulebook. Be sure to follow the standards listed below

    a) High voltage lines (>60V) should be solid, orange and bolded
    b) Low voltage power lines must be red
    c) Communication lines must blue
    d) Please create a legend

2) Design a circuit that assists in stepping down a 400V **high voltage** DC signal to a 10V and 1A output, an external 15V supply is provided for powering the circuit. Please include any circuit protection or control that would be suitable for this system. Include all work, calculation, simulations, design decisions, diagrams as needed.