T1 - Steering by wire

Prototype of a racing car will have "by-wire" steering system presented in Figures T1a and T1b installed. Calculate main parameters of this steering system, as described below, based on a hydraulic actuator for a car with weight on a steering axle of 1200 kg and tyres 205/55R16. Assume ratio of E/B=0.4, circular shape of tyre patch and wheel steering angle of +/-35º. Use arm radius equal to radius of the wheel.

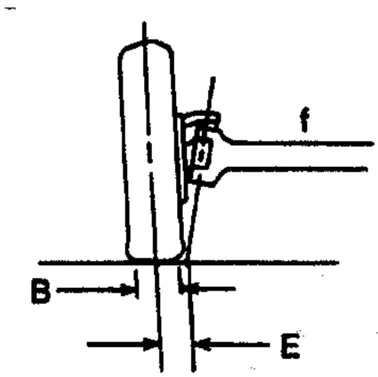


Figure T1a: Kingpin offset and tyre patch width.

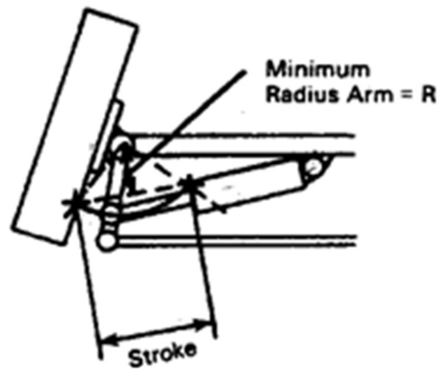


Figure T1b: Configuration of hydraulic actuator.

Calculate:

a. Calculate kingpin torque (T_k) assuming coefficient of friction μ=0.44 [566.9 Nm]

b. Determine minimum cylinder force (F_c) necessary to turn the wheel when vehicle is stationary [3405.6 N]

c. Calculate minimum cylinder area (A_c) if the hydraulic pump can deliver pressure of 5 MPa [0.000 681 m^2]

d. Determine cylinder stroke (S) required to achieve steering angle of +/-35º [0.2331 m]

e. Calculate swept volume of hydraulic oil required to turn wheels from -35º to +35º [0.000 158 769 m^3]

T2 - LIDAR Processing Speed

A LIDAR sensor has a field of view of 180 degrees horizontally and 30 degrees vertically, and its horizontal angular resolution is 0.2 degrees and vertical angular resolution of 1.0 degree. The maximum frame rate is 20 Hz. Calculate how many points can be updated per second.
[540000 points/second]

T3 - Camera Processing Speed

Image data obtained from the camera with resolution of 1920x1080 pixels and frame rate of 30 fps will be processed by the on-board computer with a single processor with 4 cores; each data point will take 100 processor cycles (ticks) to process, and other functions will take another 600,000 cycles, what should be the minimum processor speed in MHz. [1555.35 MHz]

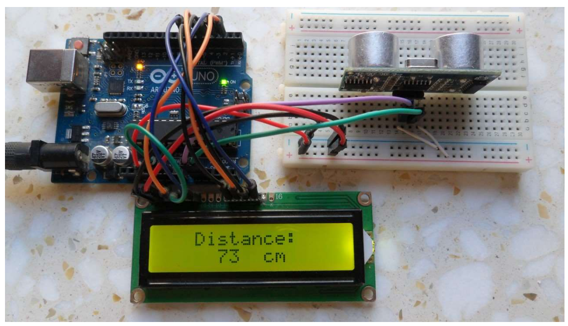
T4 - Ultrasound sensor

Calculate the minimum and maximum frequency of signal updates that can be obtained from the ultrasound sensors working with the following parameters:

Range of the detection: d_{US} from 0.3m to 8m

Speed of sound: c_s=343 m/s

Experimental tests with an ultrasound sensor connected to the Arduino Uno suggest that the maximum frequency for 0.3 m is 10% lower than the theoretical value. Please explain why the theoretical speed is not possible to achieve in real-life applications.
[min 21 Hz, max 571 Hz]



T5 - Encoders

Formula Student autonomous vehicle has encoders installed on the wheels and is driving along left-hand turn of the track.

Number of teeth on the encoders:	200 teeth per revolution
Wheel rolling radius:	0.4 m
Vehicle track:	1.5 m
Left wheel encoder signal pulses	20 pulses per 80ms
Right wheel encoder signal pulses	24 pulses per 80ms

Calculate the radius of the turn [8.25 m]

T6 – Vehicle position

The autonomous vehicle is using wheel **Encoders** and **GPS** signal to estimate the position. Encoders provides position measurement at 20Hz with standard deviation of 0.2m.
GPS data is received at a frequency of 1Hz with a standard deviation of 3m.
Vehicle drives at the velocity of 20m/s.

a. Calculate the predicted position of the vehicle after 5s using **Encoders** data and estimate the error [100m +/- 2 m]
b. Calculate the predicted position of the vehicle after 5s using **GPS** data and estimate the error [100m +/- 3 m]
c. After 5s GPS reported new position at 104m from initial position. Calculate the predicted position of the vehicle after another 5s (at t=10s) using above signals fussed by Kalman filter [201.23m +/-2.6m]