Note: you have 3h 50 min to do the exam. Read the instructions on this page. Questions are in the correct order in this document (1…5)

Exam 12.12.

Exam info and rules:

1. **Any material is allowed.** This includes books, lecture slides/notes, internet sources, USB sticks, model answers for the weekly exercises etc. If you bring your own Matlab models, check that they are compatible with the Matlab version in the class room computers. **Exception to this rule is using someone else's exam answers from previous exams.**

2. **No communication with other persons than course staff is allowed.** Using any form of communication methods i.e. chats, facebook, email, pastebin etc. is forbidden and so is using Google Docs or similar services with the possibility for sharing documents. Communication leads automatically to a failed exam. You are **not** allowed to use your own cell phones, laptops, tablets etc. You are allowed to use a calculator but remember that Matlab is a far superior computing tool.

3. **Computers are monitored remotely during the exam with a dedicated software which shows your screen to the person supervising the exam as well as stores your internet communication history.**

4. If necessary, the course staff will help you with any technical problems related to Matlab or Simulink and in preparing the files to be submitted. The staff will not comment on understanding the exercises or completing them, unless there is error in the exercise which needs to be announced to all participants of the exam.

5. **Exam starts at 12:10 and ends at 16:00. You are not allowed to leave the exam before 13:00. You can arrive late to the exam but not after 13:00 and not 12:10-12:25.** It is advised to arrive to the computer classes well in time in order to login and open any necessary programs before the exercises open.

6. **Exam is arranged in Maari C-D (surnames starting with Li-Y) and candidate building's computer classes U256 (surnames starting with Jo-La) and U257 (surnames starting with A-Ja).**

7. **You must report to course staff with your student identification card in the computer class when leaving the exam. If you fail to do this, your exam will not be graded.**

8. **Essays are submitted to Turnitin and are subject to originality check**, similarly as in weekly exercises. The other exercises are either quizzes or are returned as .pdf files into the download boxes of "Assignment" type exercises in MyCourses. Make sure before the exam that you know how to make a .pdf file for example from Word or whichever typing program you want to use. Add your name inside the .pdf documents and also in their filename.

9. **In the exam, you have to return answers for three exercises.** There are five exercises available. If you for some reason return more than three exercises, your exam grade will be calculated from the ones with the worst grades. Therefore, if you submit more than three exercises, make sure to mark clearly the exercises that you do not want to be graded. The assignments have unlimited attempts so you can revise an already submitted assignment by returning it again. **Be 100 % sure that you have properly submitted the answers before leaving the exam.**

10. The questions can be answered **either in English, Finnish or Swedish**.

11. **40 % of maximum points are required to pass the exam. The maximum grade for each exercise is 10 points.**

12. Bathroom breaks are OK **after asking for a permission**. One student at a time.

Tips: **Be sure to you use SI units in simulations and calculations and use the correct scale.** If you start doing a model or calculations but think they are probably wrong, it is still better to submit them than to submit nothing. They might be at least partially correct.

Gatekeeper 12.12.2019

First complete this quiz to gain access to the exam questions. The password is given in the examination class.

Complete **either Q1 or Q2**. Not both.

Question 1

Question 2

Complete two from Q3, Q4 and Q5.

Question 3

Question 4

Question 5

◀ Related advanced courses

My Submissions

Part 1

Title	Start Date	Due Date	Assessment available	Maximum Mark
Question 1 - Part 1	12 Dec 2019 - 12:10	12 Dec 2019 - 16:01	14 Jan 2020 - 15:21	10

Description:

Bottling line

A factory needs an automation system for a bottling line.

Empty white plastic bottles are brought by the workers next to a conveyor line in cardboard boxes. The bottles are in upright orientation inside the boxes. The automation system should pick up the bottles from the boxes and lift them on the conveyor line. The lids of the boxes are already opened and the boxes are less than a meter away from the conveyor line. The bottles are transferred along the conveyor line to a spot where a liquid is injected into them. After that, a screw top is twisted on the bottles.

What kind of sensors and actuators does a production line such as this require? Choose appropriate actuators for gripping and moving the bottles from the boxes onto the conveyor, for driving the conveyor, and for mounting the screw top. Choose also suitable methods for guiding the actuators to the correct gripping and mounting positions and for checking that the operations were correctly executed. Justify your choices.

It is not required, but you can use for example Powerpoint or even Paint to draw a schematic of the bottling line. Return your answer as .pdf file into the box below. Maximum length 800 words in English.

Bottles

Pullotuslinja

Suunnittele automaatiojärjestelmä tehtaan pullotuslinjalle.

Tehtaan työntekijät tuovat tyhjät valkoiset muovipullot liukuhihnan vierelle pahvilaatikoissa. Pullot ovat pahvilaatikoissa pystyasennossa. Automaatiojärjestelmän tulee poimia pullot laatikoista ja nostaa ne liukuhihnalle. Laatikoiden kannet on avattu etukäteen ja laatikot ovat alle metrin päässä liukuhihnasta. Pullot kulkevat liukuhihnaa pitkin kohtaan, jossa niihin ruiskutetaan nestettä. Tämän jälkeen niihin tulee kiertää kierrekorkki.

Minkälaisia toimilaitteita ja antureita tämänkaltainen pullotuslinja tarvitsee? Valitse sopivat toimilaitteet pulloihin tarttumiseen, niiden nostamiseen laatikoista liukuhihnalle, liukuhihnan liikuttamiselle sekä kierrekorkin asentamiseen. Valitse myös menetelmät toimilaitteiden ohjaamiseen oikeaan paikkaan niiden tarttuessa pulloihin ja niitä siirrettäessä sekä kierrekorkkia asennettaessa ja myös sen varmistamiseksi, että toiminnot suoritettiin oikein. Perustele valintasi.

Voit käyttää Powerpointia tai jopa Paintia piirtääksesi pullotuslinjasta kuvan, mutta se ei ole vaatimuksena. Palauta vastauksesi .pdf-tiedostona alla olevaan laatikkoon. Maksimipituus 600 sanaa suomeksi.

My Submissions

Part 1

Title	Start Date	Due Date	Assessment available	Maximum Mark
Question 2 - Part 1	12 Dec 2019 - 12:10	12 Dec 2019 - 16:01	14 Jan 2020 - 15:40	10

Description:
Pick suitable sensors to be used in an autonomous car. Concentrate on analyzing the suitability of the sensors introduced on the lectures.
The car must:

1. Be able to position itself on the road and to measure the traveling speed.
2. Be able to avoid other cars, pedestrians, animals, holes and any unexpected obstacles on the road.
3. Know the orientation of its own wheels and steering wheel as well as the angular velocity of its tires.
4. Detect if any of the doors or the trunk is open.
5. Detect if there are passengers on the seats and if they are using seat belts.

Choose suitable sensors for the previous tasks and justify your selections.
Return your answer as a .pdf file. Maximum 600 words in Finnish, 800 words in English. Max 10 exam points.

Valitse sopivat anturit autonomiseen autoon. Keskity analysoimaan luennoilla esiteltyjen antureiden sopivuutta sovellukseen.
Auton tulee pystyä...

1. paikantamaan itsensä tiellä sekä mittaamaan kulkunopeutensa
2. väistämään muita tiellä olevia autoja, jalankulkijoita, eläimiä, kuoppia tai muita odottamattomia esteitä.
3. tunnistamaan renkaidensa ja ratin asento sekä pyörimisnopeudet.
4. tunnistamaan onko jonkin ovista tai takaluukku auki.
5. tunnistamaan onko istuimilla matkustajia ja käyttävätkö he turvavöitä.

Valitse opivat anturit, jotta em. edellytykset täyttyvät. Perustele valintasi.
Palauta vastauksesi .pdf-tiedostona. Maksimipituus 600 sanaa suomeksi, 800 englanniksi. Maksimipisteet 10 tenttipistettä.

Question 1

Flag question Marked out of 1.00 Not yet answered

An AD converter has a lower reference voltage of 2 volts and an upper reference voltage of 4 volts. The resolution of the AD converter is 12 bits.
What is the resolution of the AD conversion in millivolts.

Select one:

- a. 0.49 mV
- b. 15.63 mV
- c. No answer (0 points)
- d. 0.98 mV
- e. 7.81 mV
- f. 4.12 mV
- g. 1.23 mV

Question 2

Flag question Marked out of 1.00 Not yet answered

An encoder which has a code disc like the one shown in the following picture is a/an "insert answer here" encoder.

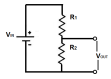
Select one:

- a. differential
- b. incremental
- c. absolute
- d. analog
- e. none of the previous options.
- f. No answer (0 points)

Question 3

Flag question Marked out of 1.00 Not yet answered

An AD converter input range is 0...5 V. The resolution of the AD converter is 8 bits. A signal varying between 0...12 volts (VIN) is first converted to an appropriate range with a voltage divider (R1 = 2 kΩ and R2 = 1 kΩ) and then the resulting VOUT value is digitized (VOUT is connected to AD converter input). What is the decimal digital value corresponding to a 7 V analog input signal value? 0 in analog values is 0 also in digital values.



Select one:

- a. 768
- b. 197
- c. 149
- d. 75
- e. 113
- f. No answer (0 points)
- g. 299
- h. 358

Question 4

Flag question Marked out of 1.00 Not yet answered

A vibration measurement system consists of three accelerometers (sensitivity 1.5V/m/s^2), a three channel amplifier (gain 5.2) with analog low-pass filters for each channel and a data-acquisition card (maximum sampling rate 250 kHz) and a computer. The data-acquisition card is multiplexing, i.e., all the measurement channels use the same AD-converter.
The largest frequency component of the measured vibration is estimated to be between 0.5 and 1 kHz. What is the highest possible cutoff frequency that can be used in the low-pass filters of the amplifier in order to prevent any aliasing of the three measured signals.
The maximum sampling rate of the data-acquisition card is used. The low pass filters can be assumed to be ideal i.e. gain for pass band is one and gain for stop band is zero.

Select one:

- a. 8.5 kHz
- b. 125 kHz
- c. 4 kHz
- d. 83 kHz
- e. 1 kHz
- f. 2 kHz
- g. 250 kHz
- h. 41 kHz
- i. No answer (0 points)

Question 5

Flag question Marked out of 1.00 Not yet answered

A microcontroller usually does **not** contain...

Select one:

- a. analog to digital converter.
- b. microprocessor.
- c. No answer (0 points)
- d. general purpose input output pins.
- e. program memory.
- f. PWM output.
- g. timers.
- h. random access memory.
- i. graphics processing unit.

Question 6

Flag question Marked out of 1.00 Not yet answered

What are the purposes of P, I and D parts of the PID controller?

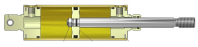
Select one:

- a. P part controls the process proportionally to the difference between set and measured value, I removes the steady state error and D is proportional to the rate of change of the error.
- b. They affect different frequency ranges of the signal. P is the constant part, I to the slow frequencies and D to high frequencies.
- c. P amplifies the reference signal, I amplifies the error signal and D enhances high frequency operation.
- d. Both a and b.
- e. All are correct.
- f. None is correct.
- g. P amplifies the error signal with a constant gain, I amplifies the integrated error signal and D amplifies the differentiated signal.
- h. Both e and g.
- i. No answer (0 points)

Question 7

Flag question Marked out of 1.00 Not yet answered

Both chambers of a pneumatic cylinder are connected to an air source with a 5 bar gauge pressure level. The piston diameter is 50 mm and the rod diameter is 20 mm. What kind of a force does the cylinder produce? The cylinder is erected as in the following image.



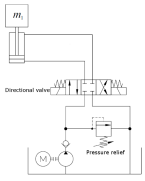
Select one:

- a. No answer (0 points)
- b. 824 N towards left.
- c. 353 N towards right.
- d. 824 N towards right.
- e. 1651 N towards right.
- f. 1651 N towards left.
- g. 353 N towards left.
- h. 157 N towards right.
- i. 157 N towards left.
- j. It does not produce any force.

Question 8

Flag question Marked out of 1.00 Not yet answered

A hydraulic cylinder is used to lift a mass. The cylinder movement is controlled with a hydraulic valve and the circuit has also a pressure relief valve.
Which of the following factors affect the pressure in the cylinder chambers when the cylinder lifts the mass at constant speed?
You can choose multiple answers. Each correct answer gives 0.25 points, each incorrect reduces 0.25 points.



Select one or more:

- a. hydromechanical efficiency of the pump
- b. pressure losses in the valve and piping
- c. the weight of the mass
- d. the dimensions of the cylinder
- e. dimensions of the pump
- f. the cracking pressure of the pressure relief valve
- g. the hydromechanical efficiency of the cylinder

Question 9

Flag question Marked out of 1.00 Not yet answered

Choose the **wrong** option.

Select one:

- a. PLC can be used to implement a real time system.
- b. A real time systems may have a response time of over minute
- c. Real time operating systems are used in modern CNC machines
- d. A real time system outputs a response in specified time frame
- e. Real time systems are useful in control applications
- f. Real time systems are useful in measurement applications
- g. No answer (0 points)
- h. Microcontroller interrupt can be used to implement a simple real time system
- i. Real time systems require a lot of computational power

Question 10

Flag question Marked out of 1.00 Not yet answered

A stepper motor has rotated 210 revolutions in 30 seconds with full stepping and a 2.8 kHz step pulse frequency. How many degrees does one step correspond to?

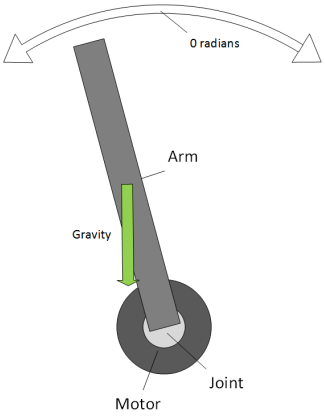
Select one:

- a. No answer (0 points)
- b. 2.5 degrees
- c. 1.8 degrees
- d. 2.7 degrees
- e. 7.5 degrees
- f. 1.75 degrees
- g. 0.9 degrees

Question 4

Modeling a simple robot arm

Model a highly simplified one-degree-of-freedom robot arm. The arm consists of a 0.6 meters long rod of uniform density which rotates around a joint in a vertical plane. The arm is directly actuated by a DC motor which is controlled by an H-bridge and PWM from 24 V voltage source. The position of the joint does not change.



The arm has to follow an angle reference produced by the simulink model given as an attachment at the bottom of this page. The angle relative to vertical axis varies between -1 and 1 radians. Use a PID controller built from separate Simulink blocks to control the position of the arm. The output from the PID controller represents the voltage from the H-bridge. Tune the PID controller so that the arm as well as the output of the controller are stable i.e. there are no significant oscillations the outputs. You can use the DC motor model from the weekly exercises as the basis for your model.

- Mass of the arm is 10 kg
- Gravitational acceleration is 9.82 m/s^2
- Length of the arm is 0.6 meters
- No gearing between the arm and the motor
- 10 ms transport delay between the measurement and the error value calculation
- Motor specifications
  - Winding resistance R = 0.41 ohms
  - Winding inductance L = 3.7 mH
  - Torque coefficient Kt = 1 Nm/A
  - Back-EMF coefficient Ke = 1 V/rad/s
  - Damping coefficient b = $1*10^{-2}$ kgm^2/s.
  - Rotor inertia $17*10^{-3}$ kgm^2

Return a report as a .pdf as well as the model and script files you used.

In the report:

- Include an image of your model.
- Include also equations describing how you calculated the total moment of inertia of the system and any external moments acting on the arm.
- Include also the PID gains you used and a time integral of the absolute value of the angle error over the 10 second simulation. This integral describes the performance of your controller and is used as a (small) part of the grading.
- Include the following plots
  - Angular position of the arm with the reference angle in the same plot.
  - Electromagnetic torque produced by the motor.
  - PID controller output with plots of all the separate parts of the controller in the same graph.
- Answer also the following questions.
  - Why is the derivative part of the PID controller important in this kind of application?
  - Why is the integral part of the PID controller important in this kind of application?

Tips:
Start by making a model which represents the arm rotating in a horizontal plane, when it works include the modifications required to represent the motion in vertical plane.
You can use for example the following Simulink blocks: Transport delay, Trigonometric function, Derivative and Abs.
Check that your Simulation time step is sufficiently small.
List of moments of inertia in Wikipedia

Yksinkertaisen robottikäsivarren mallinnus

Mallinna yksinkertaistettu yhden vapausasteen robottikäsivarsi. Käsivarsi koostuu 0,6 metriä pitkästä tiheydeltään tasaisesta varresta, joka pyörii nivelen ympäri pystysuorassa tasossa. Varsi on liitetty DC moottoriin, jota ohjataan H-sillan ja PWM:n avulla. H-sillan syöttöjännite on 24 volttia. Nivelen paikka ei muutu.

Käsivarren tulee seurata kulmaohjetta, joka on annettu Simulink-mallissa tämän sivun alareunassa. Kulma suhteessa pystysuoraan akseliin vaihtelee -1 ja 1 radiaanin välillä. Käytä varren paikan säätämiseen erillisistä lohkoista rakennettua PID-säädintä. PID-säätimen ulostulo kuvaa H-sillan ulostulojännitettä. Viritä PID-säädin siten että käsivarsi sekä säätimen ulostulo ovat stabiileja eli niiden ulostuloissa ei ole merkittävää värähtelyä. Voit käyttää mallisi pohjana viikkoharjoitusten DC-moottorin mallia.

- Käsivarren massa on 10 kg
- Normaalikiihtyvys on 9,82 m/s^2
- Käsivarren pituus on 0,6 m
- Moottorin ja käsivarren välissä ei ole vaihteistoa
- Mittauksen ja erosuureen laskemisen välillä on 10 ms siirtoviive
- Moottorin parametrit
  - Käämityksen vastus R = 0,41 ohmia
  - Käämityksen induktanssi L = 3,7 mH
  - Vääntövakio Kt = 1 Nm/A
  - Vastasähkömotorisen voiman vakio Ke = 1 V/rad/s
  - Vaimennuskerroin b = $1*10^{-2}$ kgm2/s.
  - Roottorin hitausmomentti $17*10^{-3}$ kgm^2

Palauta pdf raportti sekä käyttämäsi malli- ja skriptitiedostot.
Raportin tulee sisältää seuraavat kohdat

- Kuva simulointimallistasi
- Kaavat joita käytit järjestelmän hitausmomentin sekä käsivarteen vaikuttavien ulkoisten momenttien laskemiseen
- PID säätimen vahvistukset sekä aikaintegraali kulmavirheen absoluuttiarvosta koko 10 sekunnin simulaation ajalta. Integraali kuvaa säätimesi suorituskykyä ja toimii (pienenä) osana tehtävän arvostelua.
- Seuraavat kuvaajat
  - Robottikäsivarren paikka sekä referenssikulmasignaali samassa kuvaajassa
  - Moottorin tuottama sähkömagneettinen vääntömomentti
  - PID säätimen ulostulo sekä kaikkien sen osien osuudet samassa kuvaajassa
- Vastaa myös seuraaviin kysymyksiin
  - Miksi PID-säätimen derivoiva osa on tärkeä tämänkaltaisessa sovelluksessa?
  - Miksi PID-säätimen integroiva osa on tärkeä tämänkaltaisessa sovelluksessa?

Vinkkejä:
Aloita tekemällä malli, joka kuvaa robottikäsivarren liikettä vaakasuorassa tasossa. Kun malli toimii, tee muutokset, joita tarvitaan pystysuorassa tasossa liikkumisen mallintamiseksi.
Voit käyttää esimerkiksi seuraavia Simulink-lohkoja: Transport delay, Trigonometric function, Derivative and Abs.
Tarkista että käyttämäsi simuloinnin aika-askel on riittävän pieni.
List of moments of inertia in Wikipedia

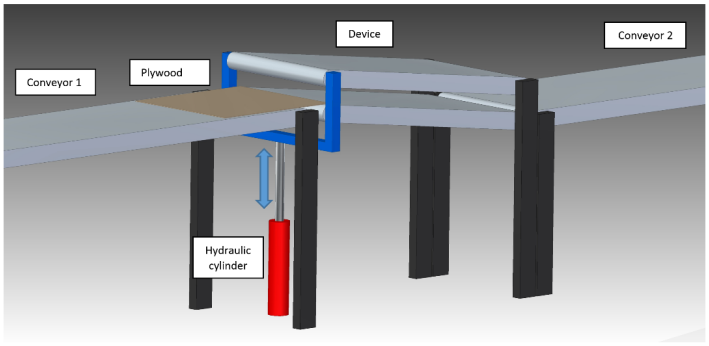
Question 5

A plywood factory has a device consisting of two conveyors on top of each other and a hydraulic cylinder moving them. The device is used to stack plywood boards on top of each other. When the device is in its lower position, conveyor 1 feeds a plywood board on the upper conveyor of the device. After that the hydraulic cylinder lifts the device to its upper position and conveyor 1 feeds a plywood board to the lower conveyor of the device. Then both plywood boards are transported on top of each other to conveyor 2 and the device returns at the same to its original position to receive a new board.

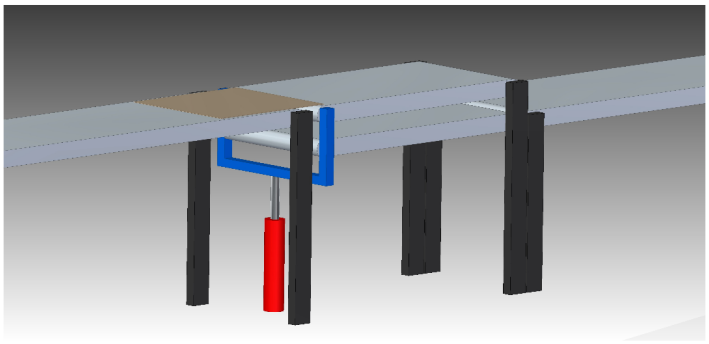
- Diameter of the hydraulic cylinder piston 100 mm
- Diameter of the hydraulic cylinder rod 40 mm
- Mass of the part joining the end of the conveyors and the hydraulic cylinder (blue in the image) 150 kg. Distance of its center of mass from the rotating joint of the device 1,3 meters.
- Weight of the device's conveyors is 200 kg. The distance between their center of mass and to rotating joint is 0.65 meters.
- Weight of he hydraulic cylinder's rod is neglected.
- Rotation angle around the rotating joint is small and thus moment of inertia can be neglected.
- Cylinder stroke when changing device position is 0,2 meters.
- Total efficiency of the hydraulic pump feeding fluid into the cylinder is 0.85.
- Volumetric efficiency of the hydraulic cylinder is 0.99.
- Hydromechanic efficiency of the hydraulic cylinder is 0.96.

1. Conveyor 1 feeds plywood boards at a speed of 4 m/s. The distance between two boards on the conveyor is 1 meter. The device changes its position immediately when a board is completely on its conveyor. How fast (in seconds) does the device have to change its position after receiving a board to be ready to accept a new board in time. (1 point).
2. How large a force does the hydraulic cylinder have to produce in order to change the position of the device from lower position to upper position fast enough? What about from upper to lower position? The cylinder starts moving from stand still with a constant acceleration and decelerates also with a constant acceleration of the same magnitude as the acceleration. (3 points)
3. How large a pressure difference is required over the piston of the cylinder in order to produce the forces during the movement in both directions. (2 points)?
4. What is the largest momentarily fluid flow rate into the cylinder? What is the largest momentarily mechanical input power to the hydraulic pump providing fluid to the cylinder? (1,5 pistettä)?
5.The position of the cylinder is measured with a LVDT sensor. The integrated signal conditioning electronics of the sensor provide a 0-10 VDC output on the 0-300 mm stroke of the sensor. When the device is in its lower position, the sensor is on the lower end of its stroke. What is the output voltage from the sensor when the device is in its upper position. (1 point)?
6. The voltage produced by the sensor is measured with an AD converted which has a reference voltage of 12 volts and a resolution of 12 bits. How far from the lower position the device is when the output of the AD converter is 2141 (1,5 points)?

Return your answer as .pdf file. If you use Matlab scripts, return also them.



The device in its upper position. Laite yläasemassaan.



The device in its lower position. Laite ala-asemassaan.

Vaneritehtaalla on kahdesta päällekkäisestä liikuteltavasta liukuhihnasta ja niitä liikuttavasta hydraulisylinteristä koostuva laite, joka kerää vanerilevyjä päällekkäin. Laitteen ollessa ala-asennossa, liukuhihna 1 syöttää vanerilevyn laitteen ylemmälle tasolle, jonka jälkeen hydraulisylinteri nostaa laitteen alemman tason liukuhihnan kohdalle ja liukuhihna 1 syöttää vanerilevyn alemmalle tasolle. Tämän jälkeen laitteen eri tasoilla olevat vanerilevyt kuljetetaan päällekkäin liukuhihnalle 2 ja laite palaa samalla alkuperäiseen asemaansa vastaanottamaan uutta levyä.

- Hydraulisylinterin männän halkaisija 100 mm
- Hydraulisylinterin varren halkaisija 40 mm
- Hydraulisylinterin ja laitteen liukuhihnojen päät yhdistävän osan (kuvassa sininen) massa 150 kg ja etäisyys nivelpisteestä 1,3 metriä.
- Laitteen liukuhihnojen massa yhteensä 200 kg. Massakeskipisteen vaakasuuntainen etäisyys nivelpisteestä 0,65 metriä.
- Hydraulisylinterin varren massa oletetaan merkityksettömän pieneksi.
- Voit olettaan laitteen pyörimisen nivelpisteen ympäri merkityksettömän pieneksi, joten hitausmomentteja ei tarvitse ottaa huomioon.
- Sylinterin iskunpituus asemaa vaihdettaessa 0,2 metriä.
- Hydraulisylinteriin nestettä syöttävän hydraulipumpun kokonaishyötysuhde 0,85.
- Hydraulisylinterin volumetrinen hyötysuhde 0.99.
- Hydraulisylinterin hydromekaaninen hyötysuhde 0.96.

1. Liukuhihna 1 syöttää vanerilevyjä jatkuvasti nopeudella 4 m/s. Levyjen välinen etäisyys hihnalla on 1 metri. Laite vaihtaa asemaansa välittömästi kun levy on kokonaan sen liukuhihnalla. Kuinka nopeasti (sekunneissa) laitteen on vaihdettava asemaansa vastaanotettuaan edellisen levyn, jotta se on valmis ottamaan seuraavan levyn toiselle tasolle (1 piste).
2. Kuinka suuri voima hydraulisylinterin tulee tuottaa, jotta laite ehtii vaihtaa asemaansa riittävän nopeasti alhaalta ylös? Entä ylhäältä alas. Sylinteri lähtee liikkeelle paikaltaan vakiokiihtyvyydellä ja jarruttaa paikalleen yhtä suurella vakiokiihtyvyydellä (3 pistettä).
3. Kuinka suuri paine-ero hydraulisylinterin männän yli tarvitaan em. voimien tuottamiseksi ylös- ja alaspäin liikkeen aikana (2 pistettä)?

4. Mikä on suurin hetkellinen nesteen virtausnopeus hydraulisylinteriin ja mikä on suurin hydraulipumpun vaatima hetkellinen teho (1,5 pistettä)?
5. Sylinterin paikkaa mitataan LVDT-anturilla, jonka sisäänrakennettu elektroniikka tuottaa anturin 0-300 mm liikealueella 0-10 V tasajännitteen. Laitteen ollessa ala-asemassa, on anturi liikealueensa alapäässä. Mikä on anturin tuottama jännite, kun laite on yläasemassaan (1 piste)?
6. Anturin tuottamaa jännitettä mitataan AD-muuntimella, jonka referenssijännite on 12 volttia ja muuntimen tarkkuus on 12 bittiä. Kuinka kaukana ala-asemasta laite on, kun AD-muuntimen ulostulo on 2141 (1,5 pistettä)?

Palauta vastauksesi .pdf-tiedostona. Jos käytät Matlab skriptejä, palauta myös ne. Näytä .pdf-tiedostossa käyttämäsi kaavat. Perustele vastauksesi.