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<th>Provkod</th>
<th>Tentamensdatum</th>
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<tbody>
<tr>
<td>ET086G</td>
<td>T101</td>
<td>2019-04-23</td>
</tr>
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<td>Kursnamn</td>
<td>Elektroteknik GR (B), Styr- och reglerteknik</td>
<td></td>
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Instructions for submitted solutions:
• Rationale and justifications may not be so scarce that they become difficult to follow.
• The reasoning behind used equations should be explained.
• The calculations shall be sufficiently complete to show how the final result was obtained.
• Each task must be concluded with a clearly written answer.
• Answer all questions.
• Do not write any answer on question paper.
• Answers can be written in English or in Swedish.

1. Choose the suitable answer.
Note: There will be no negative points for wrong answer.

1.1. Large proportional band makes the controller______ (1p)
   a. More sensitive
   b. Low cost
   c. Multivariable
   d. Less sensitive

1.2. The controller compares the CURRENT Value (PV) and SET Value (SP) and calculate______ (1p)
   a. Gain
   b. Error
   c. Control signal
   d. Proportional band

1.3. To minimize the Oscillations in the process the controller need to be____ (1p)
   a. Switched off
   b. Connected through Profinet
   c. Optimized
   d. Slow
1.4. Why the controller should be optimized? (1p)

a. Because improperly optimized controller introduce low quality in the process.
b. Because it is good for PLC controller
c. Because of high flow rate.
d. Because to observe the complete process chain.

1.5. A control application where the load varies, which type of control structure can be suitable for such scenario? (1p)

a. Ratio Control
b. Feed-Forward Control
c. Cascaded Control
d. Both the Ratio and Cascaded Control

1.6. If the control Error E is more positive when the control signal increases, the action of the controller is said to be: (1p)

a. Reverse Acting
b. Direct Acting
c. D Action
d. Dynamic error

1.7. You have a bike that worked well in the past but recently got one error after another, and the errors are frequent. You subconsciously start thinking to switch to a newer bike. What function makes you think like that? (1p)

a. Integrator function
b. Proportional function
c. Proportional band
d. Derivative function

1.8. Figure01 is a symbol of. (1p)

Note: In APPENDIX1, table T-2 and table T-3 contain some symbolic names.

Figure01

a. Flow indicating and conductivity
b. Flow indicating and controlling
c. Controlling and indicating unit for Fire
d. Operating object that indicate and control
1.9. A car’s cruise control mechanism is to maintain the Set-Point speed. Cruise control is very effective to reduce the effect of: (1p)

a. Integral time that could add a delay in car’s response.
b. Disturbances, which influence the process and alter the process variable (i.e. speed).
c. Derivative time, which creates a negative manipulating signal.
d. Proportional gain which induces a steady state error

1.10. In a controller with PID or PD mode, if the Control Variable (CV) increases because of disturbance in the process (for example a heating process) then the D component forms a____________. (1p)

a. Positive manipulating variable to support the increase in Control Variable.
b. Stationary error to avoid oscillation
c. High gain to increase the control variable as much as possible
d. Negative manipulating variable to counteract the increase in Control Variable

1.11. Imagine that an unexpected cold breeze sweeping through a residential area that is heated by district heating system. Sudden load increases sharply and the boiler has to produce more heat. Even if boiler is rapidly increasing its power, still it will take a long time to have hot water from the heating plant to the consumer. This time is called: (1p)

a. Time Constant  
b. Integrating time

c. Dead Time
d. P-time
e. Derivation time

1.12. One goal of having a control system in a process is to keep the error value as close to zero as possible. But almost all systems have some kind of allowable fluctuation in error, meaning that the error can vary from zero by a certain amount without holding back the final product. The term use for this fluctuation allowance is commonly known as: (1p)

a. Proportional band
b. Error Dead band
c. Direct acting controller
d. Transfer function

1.13. An equation that describes a process in terms of response over time, as well as calculates the outcome of the process variable (PV) is called: (1p)

a. Laplace transform
b. Process dynamics
c. Transfer function
d. Step response
1.14. In a process if the change in control variable from 55% to 75% creates a change in temperature (PV) from 65 °C to 81 °C what will be the process gain? (1p)

a. 0.8 °C/%
b. 1 °C
c. 0.8 °C
d. 1 °C / %

1.15. In a process if there is a step change in input and the process variable gives an oscillating response before reaching to steady state as shown in this figure. What type of response is this? (1p)

![Figure 02](image)

a. First order lag or First order response
b. Second order lag or Second order response
c. Step response.
d. Cascaded control

1.16. Which of these option represent controller's open loop transfer function: (1p)

a. $H_c = \frac{CV}{E}$
b. $H_c = \frac{PV}{CV}$
c. $H_c = Hp$
d. $H_c = \frac{E}{PV}$

1.17. If a process is using a discrete mode controller then the response is usually: (1p)

a. Conditionally stable
b. Stable
c. Unstable
d. Transient
1.18. In a process control it is the responsibility of the controller to create stability in the control system. There are three typical stability responses, among them one of the response is shown in figure03. What kind of stability response is this? 

![Response](image)

Figure03

1p)

a. Stable  
b. Unstable  
c. Conditionally stable

1.19. If one has to use Discrete mode controller in a process then in order to reduce the cycling behaviour of the process variable:

1p)

a. Direct acting controller will be the best choice  
b. Two position controller will be the best choice  
c. Three position controller will be the best choice  
d. Analog controller will be the best choice

1.20. A closed loop system’s response to a proportional controller creates an error that cannot be eliminated this error is called:

1p)

a. Error Dead-band  
b. Offset  
c. Reset time  
d. %error.
2. A process with a temperature SET Value (SP) of 150°C has a CURRENT Value (PV) of 160°C (see Figure 04). Express the error as a percentage of range given that the CURRENT Value(PV) has a range of:
   a) 100°C to 200°C (6p)
   b) 50°C to 350°C. (6p)
   c) Explain what differences you find after calculating the percentage error E for both (a) and (b) (4p)

Figure04, Process control loop (a) a 100 to 200 °C Current value (PV) range and (b) a 50-350 °C range

3. Using Lambda (λ) factor size, speed of the process can be controlled. Now with the help of following parameters (see table T-1).
   a) Calculate Kc when Lambda (λ) factor is 3. (6p)
   b) Calculate Kc when Lambda (λ) factor is 1.5. (6p)
   c) Based on results from task a and task b which process will give fast response? And why? (3p)

<table>
<thead>
<tr>
<th>T=20</th>
<th>The time constant of the open loop control system</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_p=1.3</td>
<td>Process Gain</td>
</tr>
<tr>
<td>L=15</td>
<td>Dead time</td>
</tr>
<tr>
<td>T_i added to T (20sec)</td>
<td>T_i is equal to integration time</td>
</tr>
<tr>
<td>Kc</td>
<td>?</td>
</tr>
</tbody>
</table>

Table T-1

4. For a proportional process controller:
   a) What value of Proportional band corresponds to a Gain (Kc) of 0.4? (5p)
   b) What value of Gain (Kc) corresponds to a Proportional band of 400? (5p)
5. If a closed-loop system with a proportional gain has a first-order Process ($H_p$) with a gain of 2.8 and a time constant of $\tau = 25$ seconds. The controller ($H_c$) is using PI mode with parallel configuration as shown in figure05 and has a proportional gain of 7 with an integral time of 10 seconds. Your task is to find:
   a) The integral gain $K_i$ for the PI controller (5p)
   b) The closed-loop transfer function of the system (10p)
   c) The steady state value of the response to a unit step change in Set-Point. (6p)
   d) The value of Error at steady state. (3p)

![Figure05, Close loop system with parallel PI controller](image)

6. Identify and write the names of the Symbolic notations shown in this process (see figure06). (15p)

Note: In APPENDIX 1, table T-1 and table T-2 contain some symbolic names.

![Figure06](image)
APPENDIX 1.

Symbolic Names:

<table>
<thead>
<tr>
<th>Notations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Analysis</td>
</tr>
<tr>
<td>C</td>
<td>Conductivity</td>
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<tr>
<td>D</td>
<td>Density</td>
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<tr>
<td>E</td>
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</tr>
<tr>
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<td>Flow</td>
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</tr>
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<td>W</td>
<td>Weight</td>
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<td>X</td>
<td>Auxiliary</td>
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T-2 shows how a quantity is designated
<table>
<thead>
<tr>
<th>Notations</th>
<th>Description</th>
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<tbody>
<tr>
<td>E</td>
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<td>R</td>
<td>Recording</td>
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<td>C</td>
<td>Controlling</td>
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<td>T</td>
<td>Transmitting</td>
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<tr>
<td>Q</td>
<td>Integrating</td>
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<td>Transforming</td>
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<td>A</td>
<td>Alarming</td>
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<tr>
<td>V</td>
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</table>

T-3 indicates the functions
### APPENDIX 2.

**Table shows the Laplace and inverse Laplace of functions**

<table>
<thead>
<tr>
<th>Description of the function</th>
<th>Time function</th>
<th>Laplace transform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any Function ( f(t) )</td>
<td>( f(t) )</td>
<td>( F(s) )</td>
</tr>
<tr>
<td>Unit step input</td>
<td>( U(t) )</td>
<td>( \frac{1}{s} )</td>
</tr>
<tr>
<td>Step input</td>
<td>( A(t) )</td>
<td>( A )</td>
</tr>
<tr>
<td>Dead time to a step input</td>
<td>( A(t-t_d) )</td>
<td>( Ae^{-ts_d} )</td>
</tr>
<tr>
<td>First Derivative</td>
<td>( \frac{dx}{dt} )</td>
<td>( sX(s)-X(t=0) )</td>
</tr>
<tr>
<td>Second Derivative</td>
<td>( \frac{d^2x}{dt^2} )</td>
<td>( s^2X(s)-s\frac{dx(t=0)}{dt}-x(t=0) )</td>
</tr>
</tbody>
</table>

**First Order Equations**

- First order response: \( Ae^{-at} \)
  - First-order response with Lag: \( \frac{A}{s+a} \)
  - First order response plus dead time: \( A_1A_2e^{-at} \) for \( t \geq t_d \)
  - First order response with lag plus dead time: \( \frac{A_1A_2}{\tau s+1} \)
  - First order Response to step input(\( \frac{A_1}{s} \)) with lag: \( \frac{A_1A_2(1-e^{-\frac{t}{\tau}})}{s(\tau s+1)} \)
  - First order Response to step input(\( \frac{A_1}{s} \)) with lag plus dead time: \( \frac{A_1A_2A_3(1-e^{-\frac{t}{\tau}})}{s(\tau s+1)} \)

**Second-Order Equations**

- Second order transfer function(\( H_p(s) \)) for \( \zeta < 1 \) (underdamped): \( \frac{A\omega_n e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin(\omega_n \sqrt{1-\zeta^2} t) \)  
  \[ \frac{A\omega_n^2}{s^2 + 2\zeta \omega_n s + \omega_n^2} \]
- Second order transfer function(\( H_p(s) \)) for \( \zeta = 1 \) (Critically Damped): \( At \) e^{-\frac{t}{\tau}} \)  
  \[ \frac{A}{(\tau s + 1)^2} \]
- Second order transfer function(\( H_p(s) \)) for \( \zeta > 1 \) (Overdamped): \( \frac{A}{\tau_1 - \tau_2} \) e^{-\frac{t}{\tau_1}} - \frac{A}{\tau_2} e^{-\frac{t}{\tau_2}} \)  
  \[ \frac{A}{(\tau_1 s + 1)(\tau_2 s + 1)} \]
- Second order step response(\( \frac{A_1}{s} \)) for \( \zeta < 1 \) (underdamped): \( A_1A_2 \left[ 1 + \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin(\omega_n \sqrt{1-\zeta^2} t - \psi) \right] \)  
  \[ \frac{A_1A_2\omega_n^2}{s^2 + 2\zeta \omega_n s + \omega_n^2} \]
  Where \( \psi = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{-\zeta} \) (0 < \( \varphi < \pi \))
- Second order Step response(\( \frac{A_1}{s} \)) for \( \zeta = 1 \) (Critically Damped): \( A_1A_2 \left[ 1 - \frac{t}{\tau} e^{\frac{-t}{\tau}} \right] \)  
  \[ \frac{A_1A_2}{s(\tau s + 1)^2} \]
- Second order Step response(\( \frac{A_1}{s} \)) for \( \zeta > 1 \) (Overdamped): \( A_1A_2 \left[ 1 + \frac{\tau_1 \tau_2 e^{\frac{-t}{\tau_1}}}{\tau_2 - \tau_1} \right] \)  
  \[ \frac{A_1A_2}{s(\tau_1 s + 1)(\tau_2 s + 1)} \]

T-4: Table shows the Laplace and inverse Laplace of function