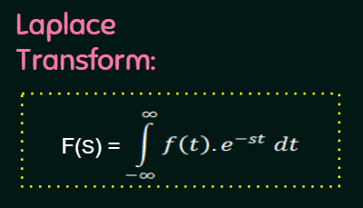
***Online Calculator Link***:

* **Laplace**: <https://www.symbolab.com/solver/calculus-calculator>
* **Inverse Laplace**: <https://www.symbolab.com/solver/inverse-laplace-calculator/inverse%20laplace%20%5Cfrac%7B1%7D%7Bs%5Cleft(s%5E%7B2%7D%2B16%5Cright)%7D%20e%5E%7B-3s%7D?or=input>
* **Integration**: <https://www.symbolab.com/solver/calculus-calculator>
* **Partial Fraction**: <https://www.symbolab.com/solver/partial-fractions-calculator/partial%20fractions%5Cfrac%7B1%7D%7Bs%5Cleft(s%5E%7B2%7D%2B16%5Cright)%7D?or=input>
* **Differentiation**: <https://www.symbolab.com/solver/calculus-calculator>
* **Observability & Controllability:** <https://www.wolframalpha.com/input?i=controllability+of+the+control+system+given+by+state%3A+%7B%7B0%2C1%2C0%7D%2C%7B0%2C-2%2C1%7D%2C%7B1%2C-1%2C0%7D%7D+input%3A+%7B%7B0%7D%2C%7B0%7D%2C%7B1%7D%7D+output%3A+%7B%7B0%2C1%2C0%7D%7D>

***Formulae –***



A picture containing text, screenshot, font, number

Description automatically generated

A black background with white text

Description automatically generated with low confidence

A picture containing text, font, screenshot, number

Description automatically generatedA picture containing font, text, handwriting, screenshot

Description automatically generated

A picture containing text, font, screenshot, handwriting

Description automatically generatedA picture containing text, font, handwriting, screenshot

Description automatically generated

A picture containing text, font, screenshot

Description automatically generated

A picture containing text, font, screenshot, typography

Description automatically generated

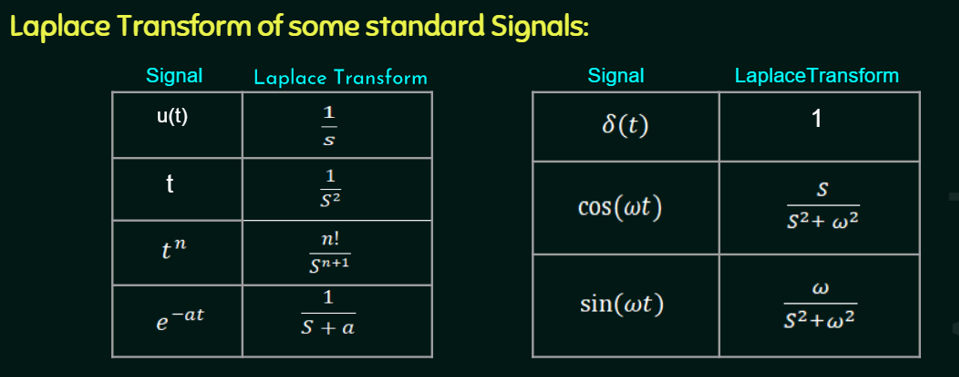
A diagram of a system

Description automatically generated with medium confidence

A picture containing text, menu, number, document

Description automatically generated

***Laplace Transform of different Input standard signal:***



***Steps of calculating Transfer Function from differential equation: Problem given in assignment 1***

* Identify input and output of the system.
* Take Laplace transformation on both side of the differential equation.
* Calculate the ratio of input and output.

A picture containing text, screenshot, font

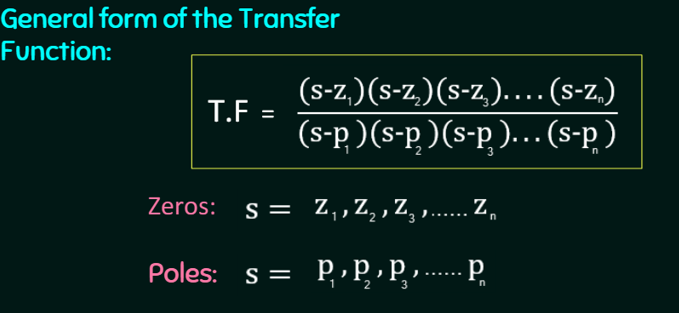
Description automatically generated

***For particular solution:***

***RLC circuit equation:***

* ***Resistor: V = IR or I = V/R***
* ***Capacitor: I=C\*dV/dt or V = (1/C)\** ∫I\*dt**
* ***Inductor: V = L\*dI/dt or I = (1/L)\**** **∫V\*dt**

***Poles & Zeros:***



***Open & Closed loop transfer function:***

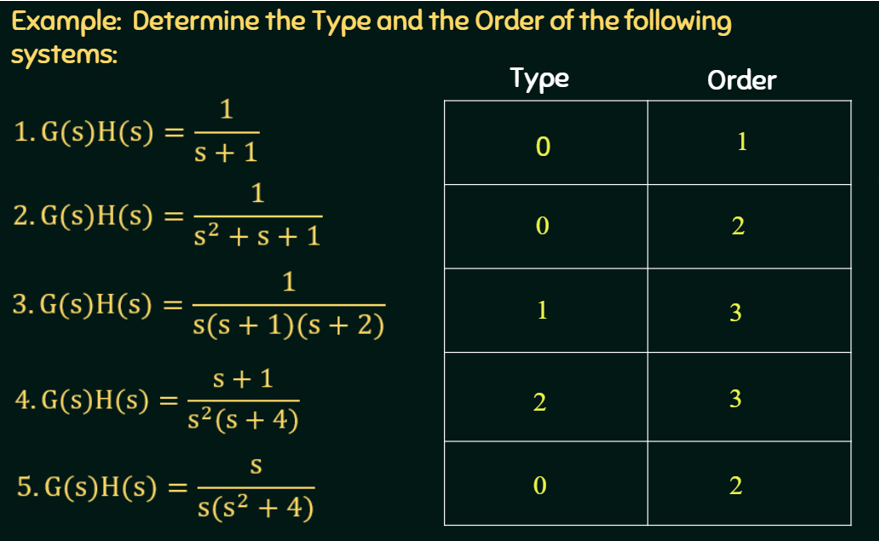
A picture containing text, font, screenshot, number

Description automatically generated

A picture containing font, text, screenshot, number

Description automatically generated

***Type (Number of poles at origin) & Order(Max power of S at denominator) of any control system:***



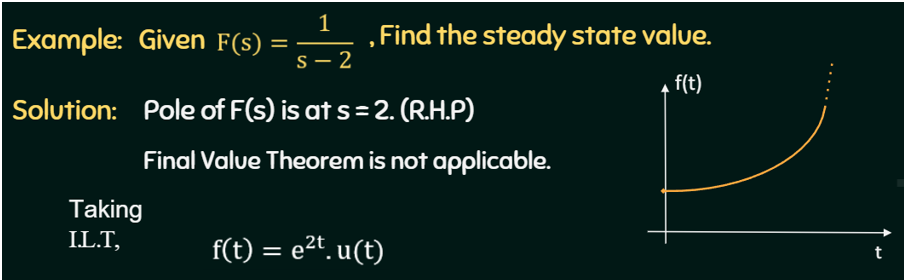
A picture containing text, font, screenshot, design

Description automatically generated

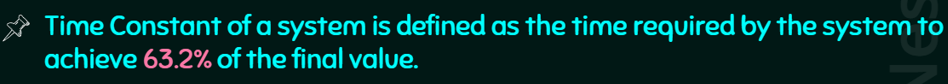
A picture containing text, font, screenshot, graphics

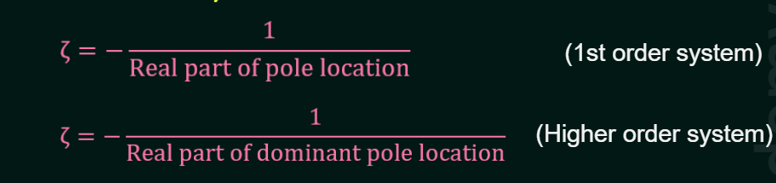
Description automatically generated

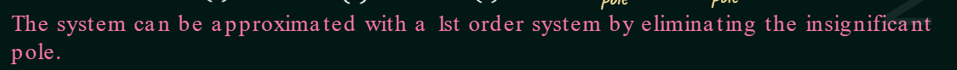
***Note: If any pole of control system is on the RHS side of S plan then final value will be infinite as the system is unstable.***



***Time Constant:*** 







A picture containing text, screenshot, font

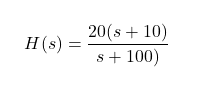
Description automatically generated

A picture containing text, font, screenshot

Description automatically generated

***Corner Frequency:*** Cut-off /Corner frequency (also known as corner frequency or break frequency) is defined as a boundary in a system’s frequency response at which energy flowing through the system begins to be attenuated (reflected or reduced) rather than passing through.

For Example:

*=>*A picture containing font, white, text, typography

Description automatically generated*=>* A picture containing font, text, white, line

Description automatically generated

A picture containing text, font, screenshot, line

Description automatically generated

<https://www.electrical4u.com/cutoff-frequency/#Cutoff-Frequency-from-Transfer-Function>

***DC Gain: Gain of a system at frequency is zero***

***Formula:*** A picture containing text, font, graphics, screenshot

Description automatically generated

***Power of S will be the type of system***

***Note: G(S) is not a transfer function it is open loop gain***

A picture containing text, screenshot, font, number

Description automatically generated

***Sensitivity:***

A picture containing text, font, screenshot, number

Description automatically generated ***with respect to parameter K***

A picture containing text, font, screenshot

Description automatically generated

***Relationship between step, impulse and ramp signal:***

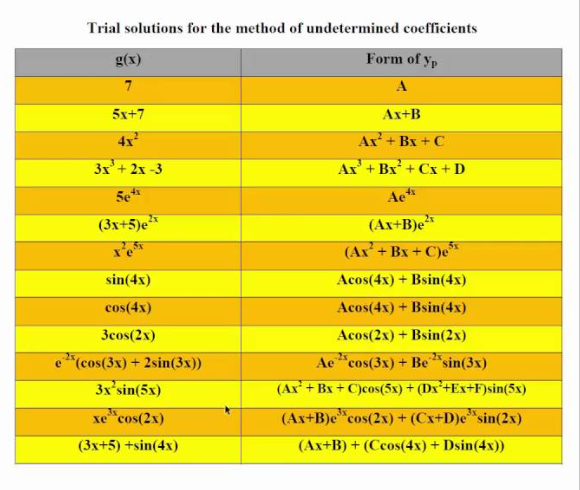
A picture containing text, screenshot, font, line

Description automatically generated

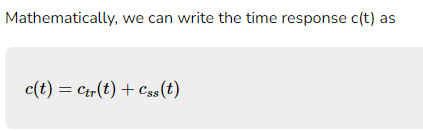
***General Solution and Particular Solution: Homogeneous and Non-Homogeneous equation solver:***

Final Solution = Complementary Solution + Particular-Solution

* **Complementary solution** can be calculated considering system as homogenous equation. Take Laplace from both end and find a solution for Y(S) and final do Laplace inverse to get y(t)
* **Particular-Solution** can be calculated by considering below table. Based on the right side of the equation general solution can be chosen and then solve for the final answer.



***Time response:***

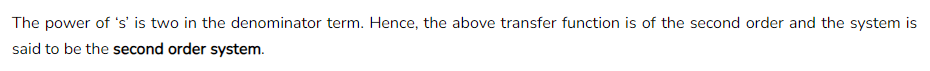
A picture containing text, font, screenshot, white

Description automatically generated

***Second order control system:***

A picture containing text, font, diagram, line

Description automatically generated



A picture containing text, screenshot, font, line

Description automatically generated

A picture containing text, screenshot, font, number

Description automatically generated

***Graphical representation of transient and steady state response of control system:***

A picture containing line, diagram, plot, parallel

Description automatically generated

<https://www.tutorialspoint.com/control_systems/control_systems_time_domain_specifications.htm>

***Delay Time:***  It is the time required for the response to reach **half of its final value** from the zero instant. It is denoted by **td**

***Rise Time:*** It is the time required for the response to rise from 0% to 100% of its final value. This is applicable for the under-damped systems. It is denoted by **tr**

***Peak Time:*** It is the time required for the response to reach the peak value for the first time. It is denoted by **tp**

***Peak overshoot:*** Peak overshoot Mp is defined as the deviation of the response at peak time from the final value of response. It is also called the maximum overshoot.

***SettlingTime:*** It is the time required for the response to reach the steady state and stay within the specified tolerance bands around the final value. In general, the tolerance bands are 2% and 5%. The settling time is denoted by ts.

A screenshot of a computer

Description automatically generated with medium confidenceA picture containing text, screenshot, font, number

Description automatically generated

damped frequency ωd, damping ratio δ, natural frequency ωn

***Steady state error:*** The deviation of the output of control system from desired response during steady state is known as steady state error.

A picture containing text, font, white, graphics

Description automatically generated

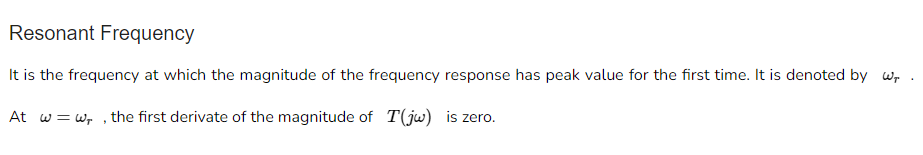
A screenshot of a graph

Description automatically generated with low confidence

A screenshot of a computer program

Description automatically generated with low confidence

***Frequency Domain Specification***:



A picture containing font, text, white, graphics

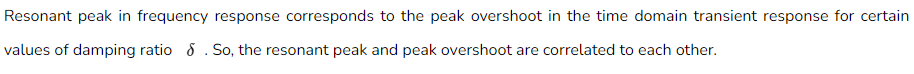
Description automatically generated

A picture containing text, font, screenshot, line

Description automatically generated

A picture containing font, diagram, text, white

Description automatically generated



A picture containing text, screenshot, line, font

Description automatically generated

A picture containing text, font, handwriting, line

Description automatically generated

***State Space Modelling:***

A screenshot of a computer

Description automatically generated with low confidence

1. Differential Equation to State Space
2. Differential Equation to Transfer Function
3. Transfer Function to State Space
4. State Space to transfer Function
5. State Transition Matrix

<https://lpsa.swarthmore.edu/Representations/SysRepTransformations/SysRepTransformations.html>

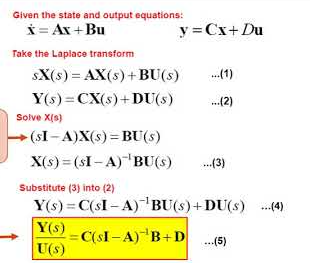
Refer to solution of assignment 3

1. **Differential Equation to State Space**

* Make the differential equation transform to state equation format to compare for A and B matrix
* Make the differential equation transform to output equation format to compare for C and D matrix

1. **Differential Equation to Transfer Function**
   * Take Laplace transformation on both side of differential equation.
   * Then find the ratio of output in S domain and input in S domain
2. **Transfer Function to State Space** 
   * Convert transfer function to differential equation format.
   * Make the differential equation transform to state equation format to compare for A and B matrix
   * Make the differential equation transform to output equation format to compare for C and D matrix
3. **State Space to transfer Function**
   * Find the A, B, C, D matrix by comparing the state and output equation.
   * Apply below formulae,



* + Derivation of the formulae,

1. **State Transition Matrix**

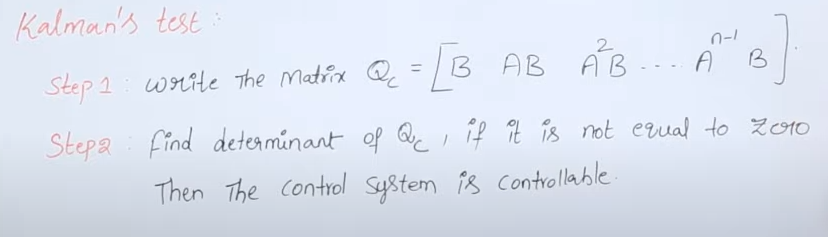
If A is the given matrix then,

* + Find (SI-A)
  + Calculate inverse of (SI-A) = Φ(s) = Adj(sI-A)/det(sI-A)
  + Take inverse Laplace to find Φ(t) => (Φ(s))

**Observability & Controllability:**

**Controllability**: A control system is said to be controllable if the initial states of the control system are changed to some other desired states by a controlled input in finite time duration.

A white surface with red letters

Description automatically generated

A white board with red writing on it

Description automatically generated

**Example :**

A white board with writing on it

Description automatically generated

A white board with writing on it

Description automatically generatedA whiteboard with black writing

Description automatically generated

A white board with writing on it

Description automatically generated

**Example:**

A white board with black text

Description automatically generated

A white board with math equations

Description automatically generated

A hand writing on a white board

Description automatically generated

**Observability: A control system is said to be observable if it can determine the states of the control system by observing the output in finite duration.**

**Coding:**

A screenshot of a computer program

Description automatically generated with medium confidence

A picture containing text, screenshot, font, display

Description automatically generated

A screenshot of a computer code

Description automatically generated with medium confidence

A screen shot of a graph

Description automatically generated with medium confidence

A screenshot of a computer

Description automatically generated with medium confidence

A screen shot of a computer program

Description automatically generated with low confidence

A screenshot of a computer program

Description automatically generated with low confidence

A screenshot of a computer screen

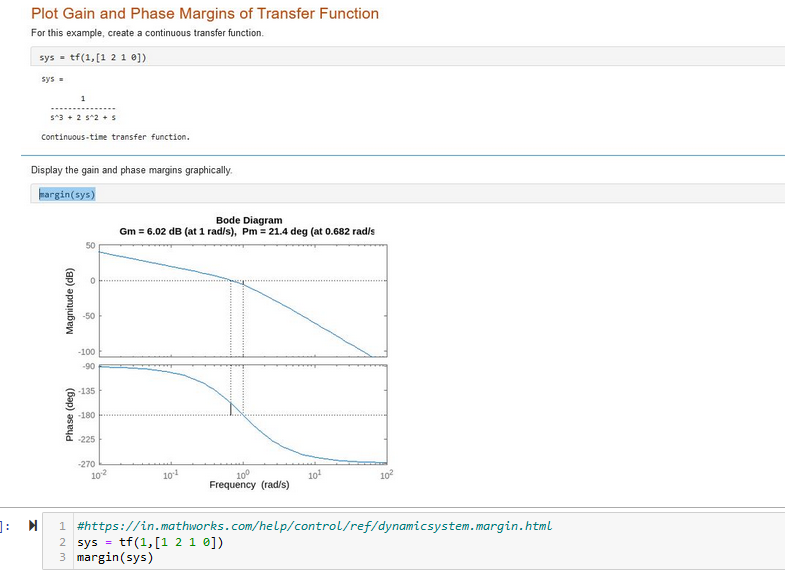
Description automatically generated with low confidence

A screenshot of a computer program

Description automatically generated with medium confidence

A picture containing line, text, diagram, plot

Description automatically generated



A screenshot of a computer program

Description automatically generated with low confidence

A picture containing text, screenshot, font, number

Description automatically generated