1) Consider the following discrete time system

$$G(z^{-1}) = \frac{z^{-1}(2+0.8z^{-1})}{1-1.7z^{-1}+0.7z^{-2}}$$

Let the reference model be given by

$$G_m(z^{-1}) = \frac{z^{-1}\,3.56}{1-1.2z^{-1}+0.36z^{-2}}$$

Assume that G (q^{-1}) is unknown. Design an adaptive model reference controller. Use

a) normalized gradient algorithm
b) recursive least square algorithm

Take the following command signals

a) r (k) = 10, k > 0.
b) r (k) = square wave signal with a period of 25 samples, and the amplitude of +10 units.

2. Disturbance canceling: Consider following system

$$y(k+1) = \frac{B(q^{-1})}{A(q^{-1})} u(k) + n(k+1), \quad k \geq 0$$

where $n(k) = 5\sin\left((2\pi/600)k\right), \quad k \geq 0$

1. $$\frac{B(q^{-1})}{A(q^{-1})} = \frac{b_0 + b_1 q^{-1}}{1+a_1 q^{-1}}, \quad \theta_0 = \begin{pmatrix} b_0 \\ b_1 \\ a_1 \end{pmatrix} = \begin{pmatrix} 2 \\ -1.8 \\ 0.4 \end{pmatrix}$$

or

2. $$\frac{B(q^{-1})}{A(q^{-1})} = \frac{2-1.8q^{-1}+0.6q^{-2}}{1}.$$

The control signal is given by

$$u(k) = -\frac{\hat{A}(q^{-1})}{\hat{B}(q^{-1})} \varepsilon(k), \quad \varepsilon(k) = y(k) - \hat{y}(k)$$

$$\hat{y}(k) = \frac{\hat{B}(q^{-1})}{\hat{A}(q^{-1})} u(k-1).$$

Simulate NLMS and RLS algorithms (see notes on disturbance canceling). Plot

1) $\frac{1}{N}\sum_{k=1}^{N} \varepsilon(k)^2$

2) $\frac{1}{N}\sum_{k=1}^{N} y(k+1)^2$

3) parameter estimates.

3. Describe the continuous time model reference adaptive control for a first order systems.
Describe the continuous time universal stabilizers for a first order systems.

Write report containing:
this **problem statement**,
theoretical background- present necessary theoretical background of the algorithms and control method, and
simulation results. Describe your observations and comment on each simulation result. For example, whether parameter estimates converge, and if they do, whether result converge to the true values, the effect of different r (k), relation between parameter convergence and the matrix p (k), etc.
Graphical data- run sufficient number of iterations, such that the "steady state" is observed. Plot the following data:

Tracking error, e (k)= $y(k) - y_m(k)$

Parameter estimates $\hat{\theta}(k)$

For NGA: $\|\hat{\theta}(k)-\theta_0\|$

For RLS: $\lambda_{max} P(k),\ k \geq 0.$

Simulation code is placed in the appendix.