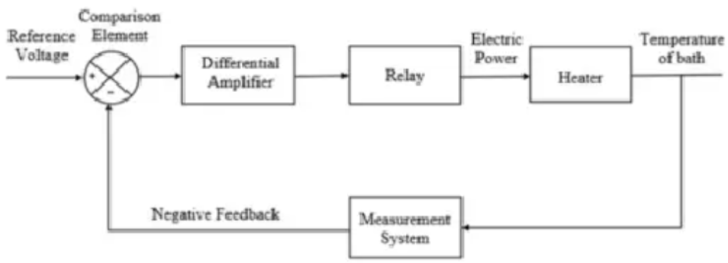
EMTR-2019 Assignment #1
Reference solutions

Q1: Problem 1.4

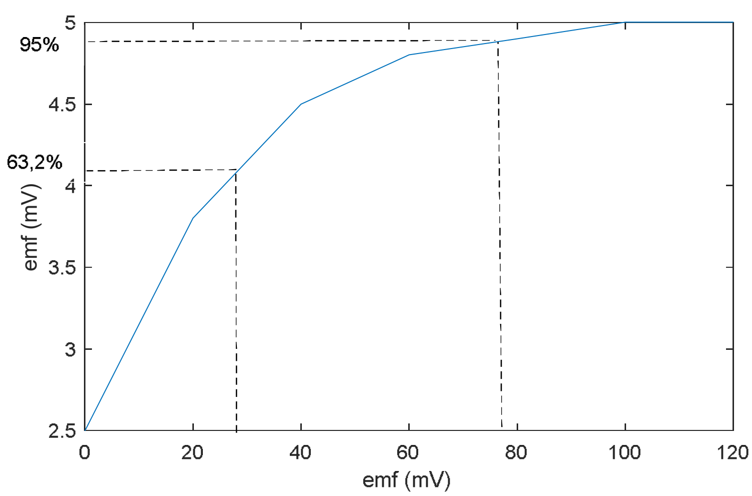


The reference voltage corresponds to the desired temperature of the bath. The actual temperature of the bath is measured by the measurement system and sent as a voltage signal to the Comparison element which in this case is the Differential Amplifier. The signal sent by the measurement system is also called Negative feedback. The comparison element adds the reference voltage signal and the measurement system voltage signal and produces an error signal. In this case, the Reference voltage is positive and the Measurement system voltage signal is negative. The error signal can thus be written as,

Error Signal = Reference Voltage Signal – Measurement System Voltage Signal

Q2: Problem 2.3

As approximately represented in the following graph



95% response time: 2.5+(5-2.5)*0.95 = 4.875: Approximate response time: 78 sec.
Time constant, or 63.2% of response time: Approximately 29 sec.

Q3: Problem 2.17

A reference solution:

You can use resistance sensors for measurement, as illustrated in the lecture. Each container uses a float, link and lever (depending on the contain structure). The level can be directly proportional to a force, which is then measured by using a strain gauge. The outputs from two strain gauges can be transmitted to voltage signals (using batteries). Then the voltage differences can be related to level and level differences for system monitoring and control applications.

Q4:

Reference solution:

(a) Suppose the displacement signal is:

$$x(t) = 2\cos(\omega t) = 2\cos(2\pi 100t) = 2\cos(200\pi t)$$, in mm.

Velocity $v(t) = \frac{dx}{dt} = -400\pi \sin(200\pi t) = 400\pi \cos(200\pi t + \pi/2)$, in mm/sec

Acceleration:

$a(t) = \frac{dv}{dt} = -(400\pi)^2 \sin(200\pi t) = (400\pi)^2 \cos(200\pi t + \pi/2) = (400\pi)^2 \cos(200\pi t + \pi)$, in mm/sec^2

(b) It is seen that the velocity has an offset of $\pi/2$ over the displacement, and the acceleration has an offset of $\pi/2$ over the velocity and π over the displacement.

Q5:

Reference solution:

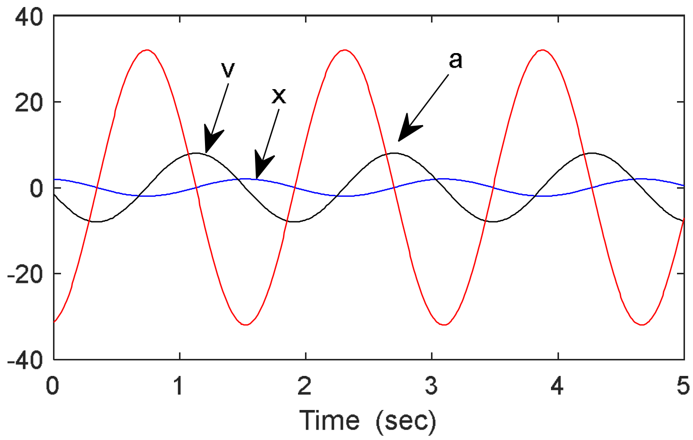
(a) Velocity

$$v(t) = \frac{dx}{dt} = -8\sin(4t + 0.2) = 8\cos(4t + 0.2 + \pi/2) = 8\cos(4t + 1.771)$$

Acceleration:

$$a(t) = \frac{dv}{dt} = -32\sin(4t + 1.771) = 32\cos(4t + 3.341)$$

(b) The Matlab graph is shown below:



(c) It is seen that the velocity has an offset of $\pi/2$ over the displacement, and the acceleration has an offset of $\pi/2$ over the velocity and π over the displacement.

Q6: Problem 7.11

Reference solution:

$Q_{\min} = 0.2\ m^3/s$, $Q_{\max} = 0.4\ m^3/s$, $s_{\min} = 0\ \text{mm}$, $s_{\max} = 40\ \text{mm}$

$$\frac{Q}{Q_{\min}} = \left(\frac{Q_{\max}}{Q_{\min}}\right)^{(s-s_{\min})/(s_{\max}-s_{\min})}$$

(a) When $s = 10\ \text{mm}$, $Q = 0.423\ m^3/s$

(b) When $s = 20\ \text{mm}$, $Q = 0.894\ m^3/s$