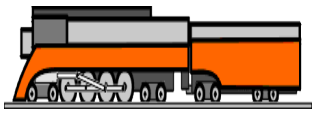
Umm Al-Qura University

**College of Engineering & Islamic Architecture**

**Mechanical Engineering Department**

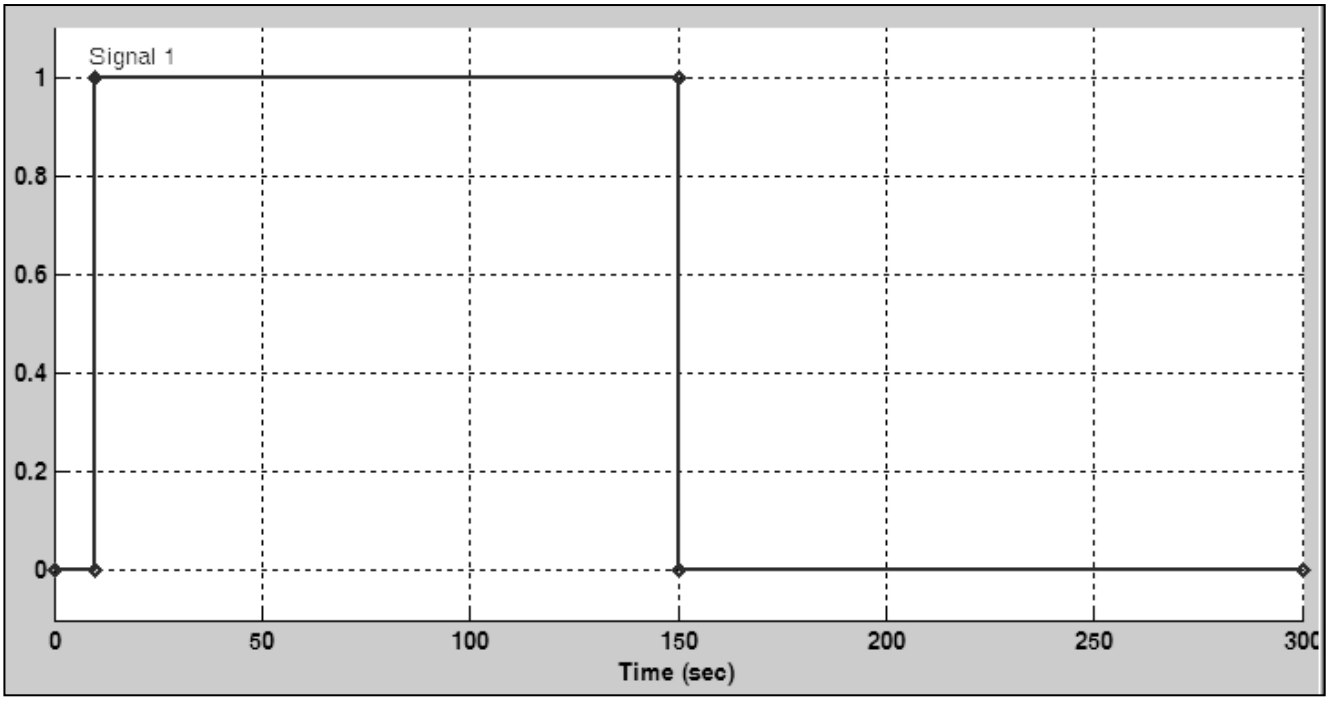
# Course #: 804465–Automatic Control Lab # 4 - Assignment

**Student's name:**_____**ID #:**_____ **Group #:**___

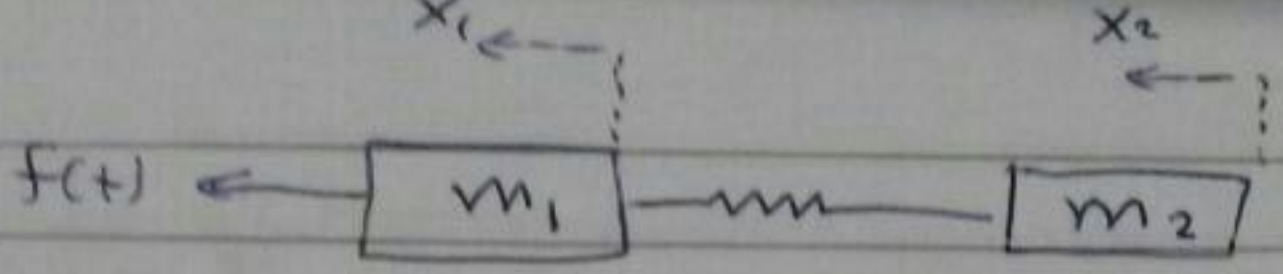


Consider a toy train consisting of an engine and a car. Assume that the train only travels in one dimension (along the track). The mass of the engine and the car will be represented by $M_1$ and $M_2$, respectively and Engine is moving with a Force $F_1$ and Car $F_2$ respectively. Furthermore, the engine and car are connected via a spring with stiffness*k*. Determine the following:

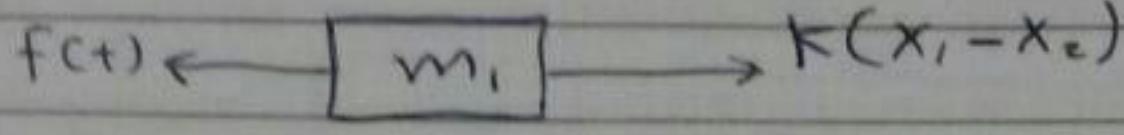
a. Build a Simulink Model of the system discussed in Lab 3 using PID controller.
b. Assuming that the train only travels in one dimension (along the track), apply control to the train engine so that it starts and comes to rest smoothly, and so that it can track a constant speed command with minimal error in steady state.
c. To represent the velocity commanded to the train, use the following function,




Note: Use following System parameters,
M1 = 1 kg
M2 = 0.5 Kg
F = 1N
K = 1 N/m




For $m_1$:




$$\Sigma F = ma$$

$$\Rightarrow f(t) - K(x_1-x_2) = m_1 \frac{d^2x_1}{dt^2}$$

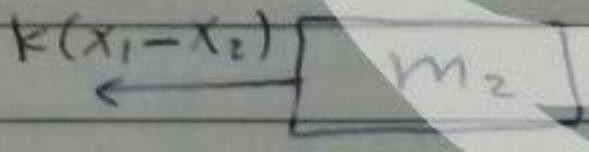
$$\mathcal{L} \Rightarrow F(s) - K(X_1-X_2) = m_1 s^2 X_1$$

$$\Rightarrow m_1 s^2 X_1 + K X_1 - K X_2 = F(s)$$

$$\Rightarrow X_1(m_1 s^2 + K) = K X_2 + F(s)$$

$$\Rightarrow \boxed{X_1 = \frac{1}{m_1 s^2 + K} F(s) + \frac{1}{m_1 s^2 + K} X_2}$$

For $m_2$:




$$\Sigma F = ma$$

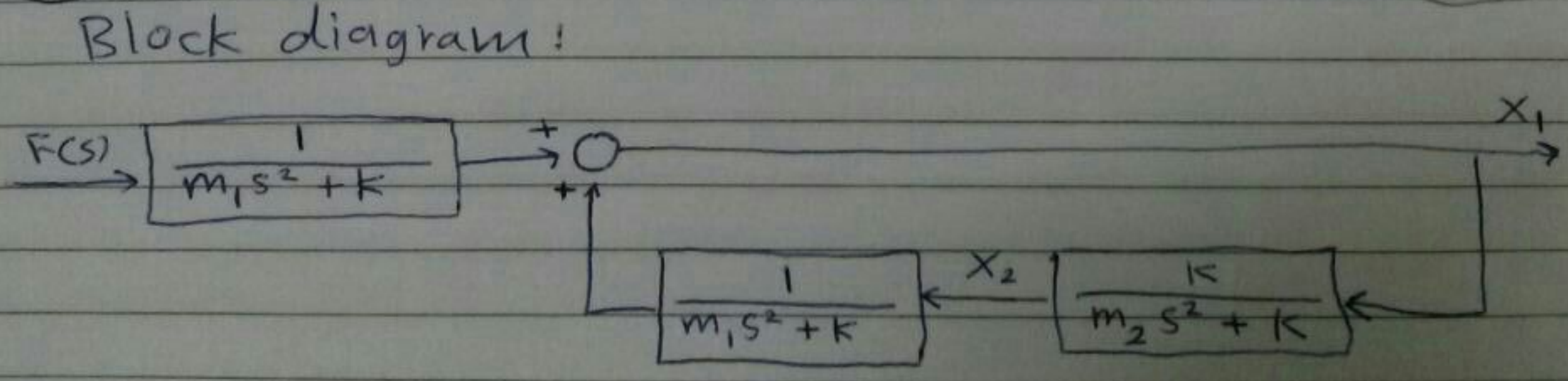
$$\Rightarrow K(x_1-x_2) = m_2 \frac{d^2x_2}{dt^2}$$

$$\mathcal{L} \Rightarrow K X_1 - K X_2 = m_2 s^2 X_2$$

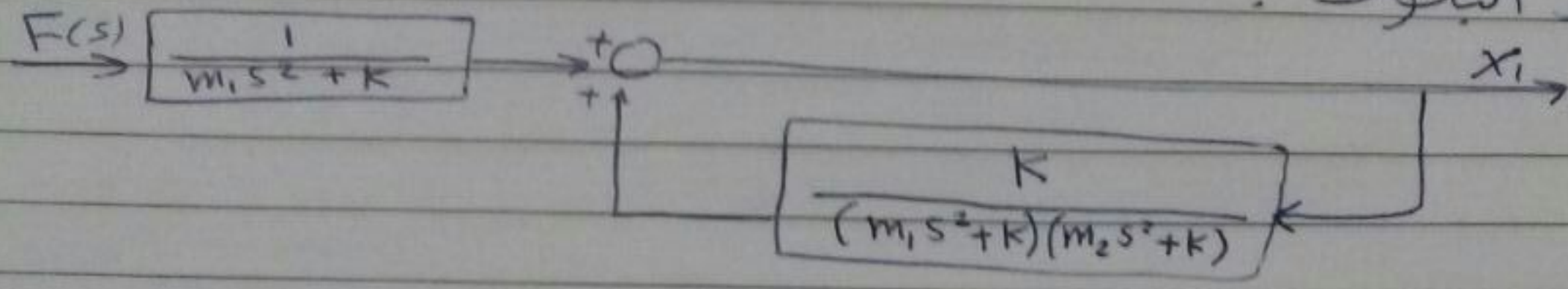
$$\Rightarrow X_2(m_2 s^2 + K) = K X_1$$

$$\Rightarrow \boxed{X_2 = \frac{K}{m_2 s^2 + K} X_1}$$

Block diagram:



نبسط البلوك :




$$\Rightarrow \quad F(s) \longrightarrow \boxed{\frac{1}{m_1 s^2 + k}} \longrightarrow \boxed{\frac{1}{1 - \frac{K}{(m_1 s^2+k)(m_2 s^2+k)}}} \longrightarrow x_1$$

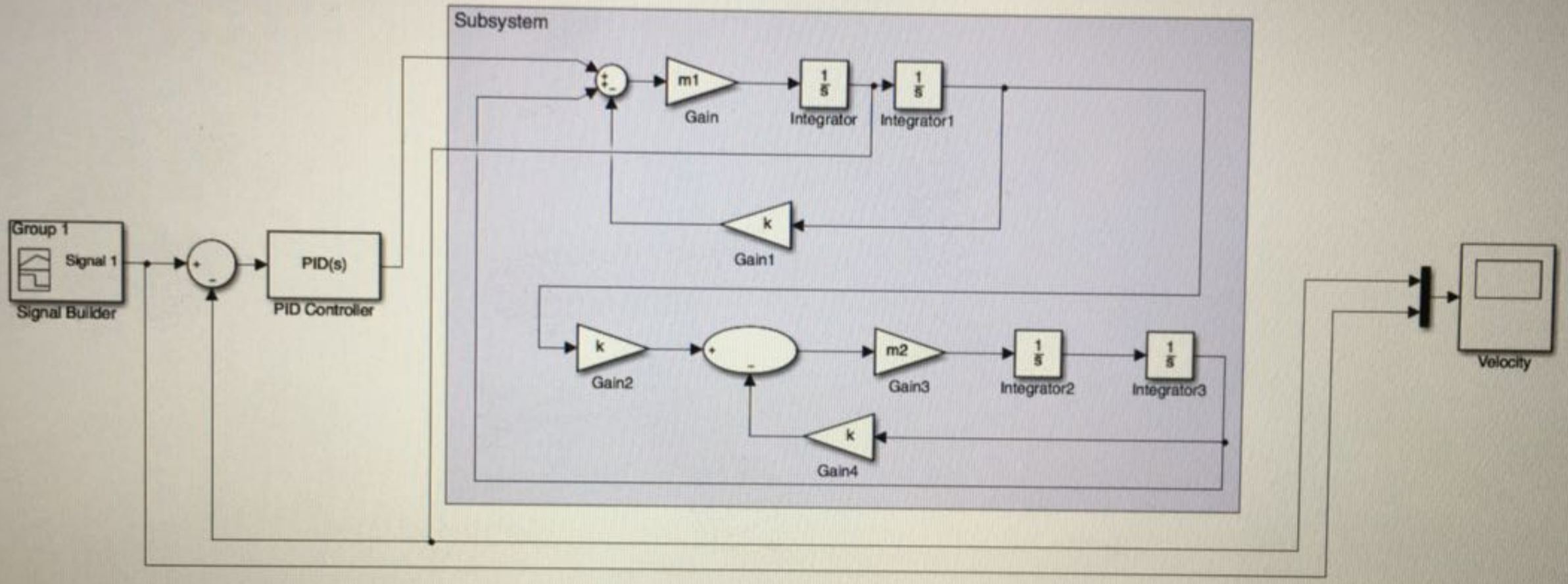
نبسط الكسر :

$$\frac{1}{\frac{(m_1 s^2+k)(m_2 s^2+k) - K}{(m_1 s^2+k)(m_2 s^2+k)}} = \frac{(m_1 s^2+k)(m_2 s^2+k)}{(m_1 s^2+k)(m_2 s^2+k) - K}$$

$$\Rightarrow \quad F(s) \longrightarrow \boxed{\frac{1}{m_1 s^2 + k}} \longrightarrow \boxed{\frac{(m_1 s^2+k)(m_2 s^2+k)}{(m_1 s^2+k)(m_2 s^2+k) - K}} \longrightarrow x_2$$

$$\Rightarrow \quad F(s) \longrightarrow \boxed{\frac{m_2 s^2 + k}{(m_1 s^2+k)(m_2 s^2+k) - K}} \longrightarrow x_2$$

$$\Rightarrow \text{Transfer function} : \quad \frac{X_2(s)}{F(s)} = \frac{m_2 s^2 + k}{(m_1 s^2+k)(m_2 s^2+k) - K}$$


Subsystem
Group 1
Signal 1
Signal Builder
PID(s)
PID Controller
m1
Gain
1/s
Integrator
1/s
Integrator1
k
Gain1
k
Gain2
m2
Gain3
1/s
Integrator2
1/s
Integrator3
k
Gain4
Velocity