HW#1 SOLUTIONS
MAE 143B

(1.1c) The block diagram shows a open-loop system with a water input and a position input into the faucet and a water output from the shower. There are no disturbances.

As we only have a single water input, we can assume that the water is pre-mixed and the position input controls the ~~flow pressure~~ flow rate of water into the shower.

So, the ~~pos~~ input position could take some value between 0 and 1 (i.e. $\alpha \in [0,1]$), where 0 indicates no flow and 1 indicates max flow.

In this case we could model the output flow of the faucet as

$$F_o(t) = \alpha F_i(t)$$

where $F_o(t)$ is the output flow from the faucet and $F_i(t)$ is the input flow. This is a static block.

The shower could be modeled as a dynamic component to account for the delay experienced under a shower, such as:

$$W_{out}(t) = F_o(t-\tau)$$

for some $\tau > 0$, where $W_{out}(t)$ is the water output from the shower.

(1.1f)

The block diagram shows an open loop system with a signal input into the radio and a disturbance noise input. The music output from the amplifier is the only output of the system.

The amplifier block can either be static or dynamic. A static amplifier will amplify all frequencies by some constant gain K. This could be problematic if we have undesirable high frequency noise.

To ensure high frequency noise is not amplified, we could use a dynamic amp which perhaps has a low pass response, i.e.

$$H(s) = \frac{1}{\tau s + 1},$$

where τ is related to the cutoff frequency of the amplifier.

The radio block will have a modulated waveform as a input, and would demodulate it and output it to the amplifier. If we use Frequency Modulation (FM), then the frequency of the input signal to the radio changes in response to changes in the audio signal we are transmitting.

In order to be able to convert the frequency variations into voltage variations which will be inputted into the amplifier, the radio block must have a frequency dependence, which suggests it would be a dynamic block.

(1.1h).

Here we have a open-loop block diagram where the input is the music signal into the amplifier and the output is the music output from the speaker.
We also have ambient noise entering into our system which is a disturbance.

As in (1.1f), the amplifier can either be static or dynamic. In most cases, we want to ensure the amplifier only amplifies the actual music signal, in which case it will be dynamic with either a low pass or bandpass response.

The speaker will be dynamic as well. The speaker will likely act as a filter as well depending on how it is made. Some speakers will have a low pass response and will be better at playing low frequencies (i.e. a sub-woofer), whereas other speakers will be better with high frequencies (i.e. a tweeter). We indicated what a low pass response was in the ~~the~~ previous question. A high pass response will be like:

$$H(s) = \frac{s\tau}{s\tau + 1}$$

(MODIFIED FROM WIKIPEDIA ARTICLE ON THERMOREGULATION)

(1.3)

Thermoregulation is the ability of a organism to keep its body temperature within certain thresholds, regardless of the surrounding temperature. Thermo regulation is a closed loop control process where the mamal will modify its behavior to maintain a desirable temperature.

Thermoconforming organisms, simply adopt to the surrounding temperature. This is an extreme case of a open loop system where the organism simply does nothing in response to the surrounding temperature. In humans and other mammals, our body temperatures are required to lie in a certain range otherwise we would die. So this type of open loop control will not work.

Actuation:

In cold environments, mammals can do the following to reduce heat loss:

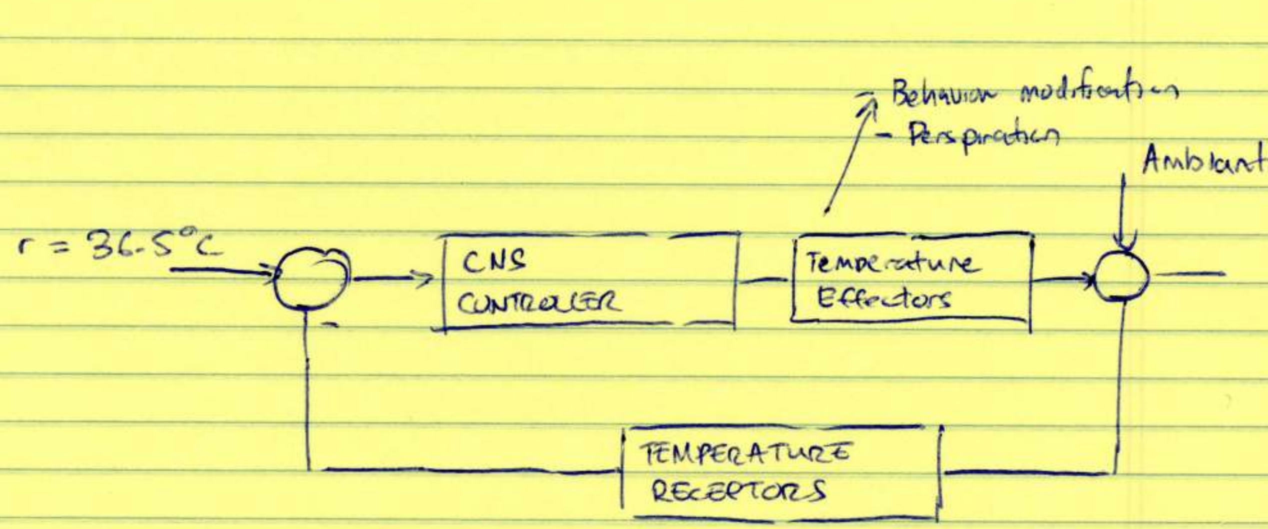
- goosebumps: slow the movement of air along skin to reduce heat loss
- concurrent blood flow: where warm blood flowing to the limb passes cooler blood flowing from the limb.

Maximize heat loss in hot environments:

- Changing of behavior: living in burrows during the day
- Elongation of body
- Perspiration.

SENSING

- Humans use specialized sensory neurons to detect temperature. These neurons are located in the spinal column and connected to the skin and organs through long extensions known as axons.

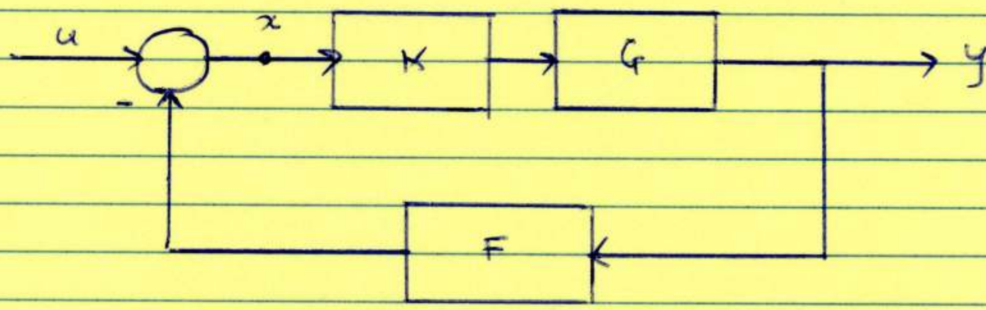


Behavior modification
- Perspiration
Ambient
r = 36.5°C
CNS CONTROLLER
Temperature Effectors
TEMPERATURE RECEPTORS

(1.9b)

$$y = u(G_1 + G_2) \quad \Rightarrow \quad \frac{y}{u} = G_1 + G_2$$

(1.9c)



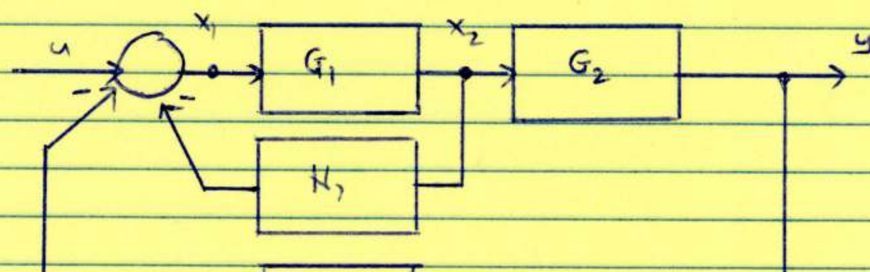
$$y = KGx$$
$$x = u - Fy$$

$$\Rightarrow \quad y = KG(u - Fy)$$

$$\Rightarrow \quad (1 + KGF)y = KGu$$

$$\Rightarrow \quad \frac{y}{u} = \frac{KG}{1 + KGF}$$

(1.9d)



$$x_2 = G_1(u - H_1 x_2 - H_2 y)$$

$$\Rightarrow \quad x_2 = \frac{G_1}{1 + G_1 H_1}(u - H_2 y)$$

we have that $y = G_2 x_2$, so

$$y = \frac{G_2 G_1}{1 + G_1 H_1}(u - H_2 y)$$

which implies that

$$\frac{y}{u} = \frac{G_1 \cdot G_2}{1 + G_1 H_1 + G_2 G_1 H_2}$$

(2.11)

From our assumptions, we know that the velocity at any two points of the belt must be the same. Therefore:

$$\omega_1 r_1 = \omega_2 r_2,$$

from which we get that:

$$\omega_2 = \left(\frac{r_1}{r_2}\right)\omega_1 .$$

Substitute this into the ODE for J_2 to get:

$$J_2\left(\frac{r_1}{r_2}\right)\dot{\omega}_1 = r_2\left(\frac{J_1\dot{\omega}_1 - \tau}{-r_1}\right)$$

which implies that:

$$(J_1 r_2^2 + J_2 r_1^2)\dot{\omega}_1 = r_2^2 \tau$$

(2.12) If $f_1 = f_2$, we would have:

$$J_2\dot{\omega}_2 = 0, \qquad J_1\dot{\omega}_1 = \tau$$

But we know that $\dot{\omega}_2 = \left(\frac{r_1}{r_2}\right)\dot{\omega}_1$,

so in order to have $f_1 = f_2$, it must be the case that $\underline{\tau = 0}$, in which case there would be no angular acceleration, $\underline{\dot{\omega}_1 = \dot{\omega}_2} = 0$.

(2.13) Applying similar steps as in (2.11) we get

$$(J_1 r_2^2 + J_2 r_1^2)\dot{\omega}_1 + (b_1 r_2^2 + b_2 r_1^2)\omega_1 = r_2^2 \tau$$