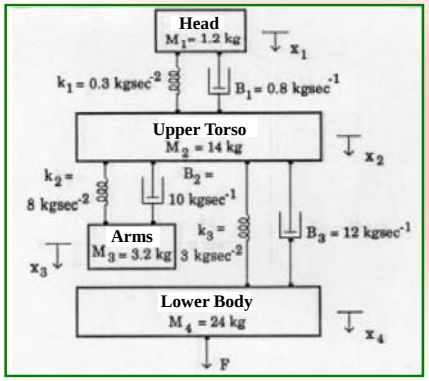
2nd Homework Problem

- In this homework problem, we wish to model a mechanical system.
- The problem deals with a simple, purely mechanistic model of some aspects of motion of a human body.

Description

- Some people suffer from a so-called ***cervical syndrome***. Their neck is not sufficiently stiff to connect their head solidly with their upper torso. Therefore, if their torso is exposed to vibrations, such as when riding in a car, these people often react with severe headaches.
- A car manufacturer wants to design a new car in which these problems are minimized. Resonance phenomena are to be studied with the purpose of avoiding resonance frequencies of the human body to appear as eigen-frequencies of the car.

Mechanical Model of the Human Body



The figure to the left shows a mechanical model of a sitting human body. The legs were left out since they do not contribute to potential oscillations of the upper body. The numerical data are average data for a human adult.

1st Sub-problem

1. Derive a state-space model for this system. Since this is a linear time-invariant system, put it in linear state-space form and simulate the system in ***Matlab***.
2. Simulate the system during ***15 seconds***. Use a sinusoidal force ***(F)*** with a frequency of ***1.5 Hz***. As the system is linear, the amplitude of the input signal is irrelevant. 1.0 represents an excellent value. The output is the distance between the head and the shoulder. The initial conditions of all state variables may be assumed as 0.0. This is acceptable, since only the deviation of the output from the stationary position is of relevance.

2nd Sub-problem

3. In order to be able to better analyze the ***resonance phenomena***, we wish to obtain a ***Bode diagram*** of the system. To this end, we generate a logarithmic base of frequency values in the range from 0.01 Hz to 100 Hz by means of Matlab's ***logspace*** function. The ***Bode*** function may now be used to compute the Bode diagram. The amplitude needs to be converted to decibels. Using the functions ***subplot***, ***semilogx***, ***grid***, ***title***, ***xlabel***, and ***ylabel***, the Bode diagram shall now be displayed on two separate graphs on the same page.

3rd Sub-problem

4. Finally, we wish to perform a ***sensitivity analysis***. We want to study the variability of the spring constant and the damper between head and upper torso. For this purpose, we assume a variability of these two parameters of ±50%.
5. Repeat the frequency analysis for the four worst-case combinations of the two parameters.
6. Plot the maxima and minima of the amplitude and phase curves as a sensitivity Bode diagram.