



Handed out: 16 February 06  
Due: 2 March 06

## 16.423J/HST515J/ESD.65 Space Biomedical Engineering and Life Support Systems Bone Homework Assignment #2

### Bone:

The goal of this assignment is to further investigate the changes that age and environmental loading (1G, microgravity, etc.) have on geometry and bone mineral density of bone (modeled as a tubular structure). You are to perform simulations using a computer spreadsheet or Matlab. Credit will be given for discussion, professional work, the process articulated, **illustrations**, and number answers.

Assumption: Long bones can be simulated as hollow tubes, which are subjected in life mainly to bending stresses. Generally, the moment arms do not change with age although load magnitudes do change.

Starting conditions for young adult femur shafts.

Female outer radius,  $r_o = 1.40$  cm      Male outer radius,  $r_o = 1.70$  cm  
Female inner radius,  $r_i = 0.90$  cm      Male inner radius,  $r_i = 1.20$  cm

Assume that remodeling normally increases inner radius at the rate of 0.004 cm/year (from measured data in males). The geometry of a hollow tube with effective mineral density of solid bone  $\rho_m = 1.05$  gm/cm<sup>3</sup>.

$$I = \frac{\pi}{4} (r_o^4 - r_i^4)$$

$$Z = \frac{I}{r_o} \quad \text{where } I \text{ is cross-sectional Moment of Inertia and } Z \text{ is Section Modulus}$$

$$A = \pi (r_o^2 - r_i^2)$$

$$BMD = \frac{A \rho_m}{2 r_o}$$

Problems to Solve:

1. (2 points) Find the section modulus of young adult femoral shafts. Assume that this is maintained through life (assuming constant skeletal loading). A) Derive an expression for  $r_o$  as a function of changing  $r_i$  (this is messy). B) Show how the section modulus can be maintained through age 80. C) What happens to the BMD?
2. (2 points) We are interested in spaceflight where skeletal loading is significantly altered. We would like to investigate the influence of higher remodeling rates. A) What happens to BMD (and other parameters) if remodeling rates (increase in  $r_i$ ) double? B) If remodeling rates quadruple? Assume constant section modulus.
3. (2 points) Lets be more realistic and admit that the assumption of constant skeletal loading is unrealistic. Investigate a loading profile that is reduced by 30% at age 60, remaining constant thereafter. Explicitly explain/justify your loading profile(s). Assume a linear effect on section modulus. Describe and show the results for BMD and other parameters?
4. (2 points) Write one paragraph on something you learned from lecture or readings about bone adaptation/physiology that you didn't previously know. Be concise in your answer and feel free to illustrate your answer.
5. (2 points) Write you own bone homework question on a possible skeletal countermeasure for the microgravity environment. Provide your question AND a short, concise (illustrated) answer.