1. **Why is the joint reaction forces are usually lower than the actual joint contact forces? (00.01.2018)**

   Why is it that the joint reaction forces are usually lower than the actual joint contact forces? (28.01.2021)

   Why is that the joint reaction forces are usually lower than the actual joint contact forces? Which of those two forces can be determined using inverse dynamics?(28.01.2022)

2. **What is inverse dynamics? Explain it with an athlete as example. (27.04.2016)**

   Explain what is meant by inverse dynamics. Using the example problem of a running athlete: what are the inputs required to enable the solution of this inverse dynamics problem and what are the outputs? (00.01.2018)

   Explain what is meant by inverse dynamics. Using the example problem of a running athlete: what are the inputs required to enable the solution of this inverse dynamics problem and what are the outputs? (28.01.2021)

3. **Name and explain two input parameters for solving an inverse dynamics model. (15.03.2021)**

4. **What is meant by positive and negative work for a movement? (15.03.2021)**

5. **The linked segment model is used to describe locomotion. Name the crucial assumptions in this model. (15.03.2022)**

6. **How many gauge rosettes are necessary to determine a 2D strain state and how would they need to be arranged? (27.04.2016)**

   A strain gauge rosette can be used to measure the strain on a selected location of a bone surface. How many strain gauges are required to determine the surface strain state of a location of interest on a bone surface and how would these gauges be arranged within the rosette? (00.01.218)

   A strain gauge rosette can be used to measured the strain on a selected location of a bone surface. How many strain gauges are required to determine the strain state at a location of interest on a bone surface, and give an example how these gauges can be arranged within te rosette? (27.01.2022)

7. **What kind of variable (scalar, vector, etc.) is strain? Write down the transformation equation for strain under a rotation R. (15.03.2022)**

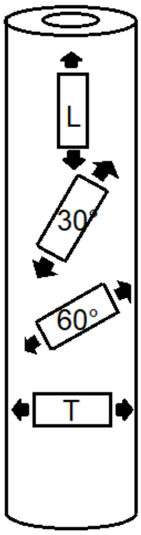
8. **What is the material law for solids. State also the equivalent relation of fluids. (27.04.2016)**

9. **Give bone properties (shear-modulus, Young modulus, max. strain,...) (00.03.2018)**

10. **Tensile experiment: Two gauges are places (certain angle) on a rod. Draw the measured stress/strain curve for each gauge. Exactly like the following figure. (00.03.2018)**

Figure 1 shows a schematic of samples machined form the cortical bone of a long bone in different orientations. The arrows indicate the orientation of a tensile test performed on each sample. Sketch the mechanical behaviour (i.e. stress-strain curve) of each sample in the same diagram. (15.03.2021)

Figure 1 shows a schematic of samples machined from the cortical bone of a long bone in different orientations. The arrows indicate the orientation of a tensile test performed on each sample. Sketch the mechanical behaviour (i.e. stress-strain curve) of each of the four samples in the same diagram. (28.01.2022)



11. **Give the definition of Hematocrit (H). What is the average physiological value of H? Describe what is meant by Rouleaus foramtion. (15.03.2021)**

12. **Name for components that make up blood? (28.01.2022)**

13. **Make a sketch of shear stress vs shear rate for a Casson fluid and a Nowtonian fluid. For fluid flow in a cylindrical tube, sketch the flow profile for a Newtonian fluid and for a Casson fluid. (15.03.2022)**

14. **What is the Fahreus-Lindqvist effect? Give both observations that lead to the discovery. (27.04.2016)**

    Fahreus Lindqvist Effect and inverse Fahreus Lindqvist effect. Describe both + the phenomena's which lead to the discovery in the first place. (00.03.2018)

    Explain what is meant ba the Fahreus-Lindqvist effect and what the two observations were that lead to the discovery of this effect. What is the inverse Fahreus-Lindqvist effect? (28.01.2021)

15. **Describe the course of the ventricular and aortic pressure. When and why do you hear heart sounds (Sketch and mark the different phases)? (27.04.2016)**

16. **Given a reason why the cardiovascular system consists of two circuits - or in other words: why would it problematic if the heart was pumping blood into only one common circuit? (00.01.2018)**

17. **Name the two circuits through which blood is pumped in the body and describe their function. What is the difference between the two circuits? (15.03.2021)**

18. **What is meant by diastolic pressure and systolic pressure? Briefly describe hot wo measure the pressure using a pressure cuff (sphygmomanometer) and a stethoscope. (00.01.2018)**

    During the heart cycle what is systole and what is diastole? Considering either the right and left ventricle: which condition has to be met such that the aortic valve opens? (28.01.2022)

19. **Where in the heart are semilunar valves? What make them open and close? During which phase of the heart cycle are they open? (15.03.2022)**

20. Describe the Windkessel effect with the corresponding model. What are the limitations of the model etc. (00.03.2018)

How can the arterial system be modelled with a Windkessel model. Which effects can be mimicked. State one limitation. (28.01.2021)

21. **Capillary filtration: Describe the fluid pathways in capillaries and the surrounding tissue - what are the driving forces that cause filtration and resorption? (15.03.2021)**

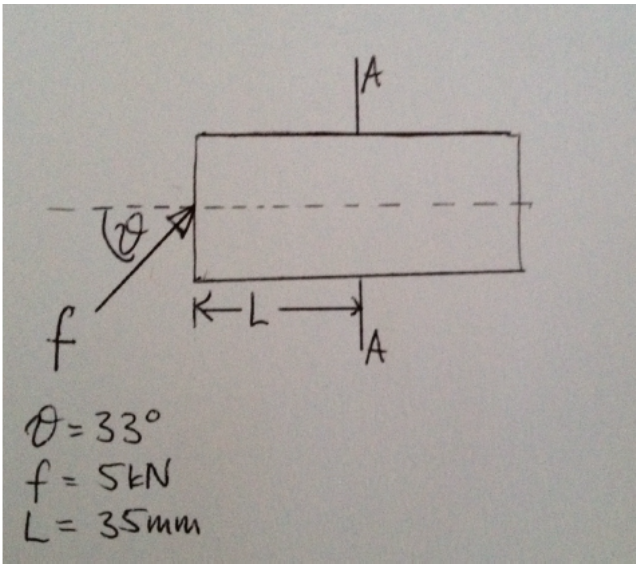
22. **What causes fluid flow in and out of the capillary in the cardiovascular system? (15.03.2022)**

1. **Given is a bone hollow shaft Figure 1. (27.01.2016)**

   a) **Derive an expression for depending on the distance form neutral surface.**

   b) **Calculate the maximum stress. For out diameter 32 mm and inner diameter 27 mm.**

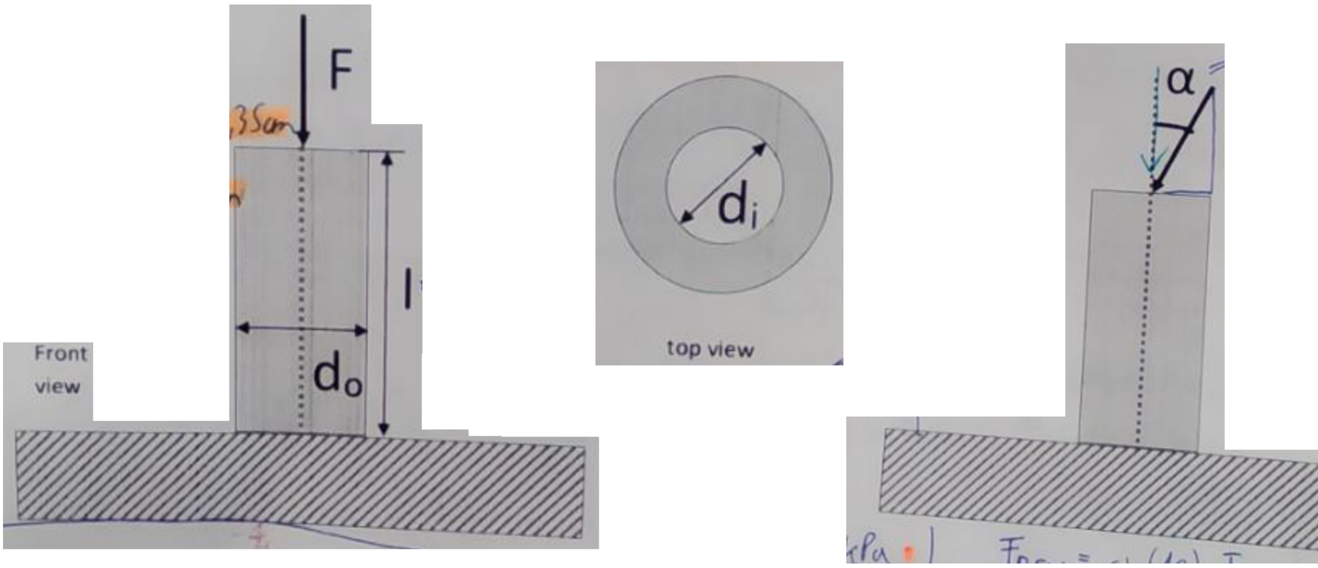
   c) **Calculate the risk factor change for an older bone with outer diameter 33 mm, inner diameter 29 mm and yield stress 80 MPa.**



2. **The diaphysis of a femoral bone is embedded and fixated to be tested in a material-testing-machine (see sketch below). Let's assume the bone to be a perfect cylinder. The length / of the bone is 98 mm, the outer diameter d_o 47 mm and the inner diameter d_i is 21 mm. (00.01.2018)**

   a) **If the force F, generated by the material-testing-machine is 100 kN, how high is the stress at the transition from femur to embedding?**

   b) **If the femur is not perfectly aligned, the central axis of the femur is tilted by an angle α, so that a bending moment arise. Calculate if the bone will break at a maximum angel α_{max} of 10° due to the combined stress state arising from compression and bending. To simplify the model we assume that the force-vector is tilting and not the bone. The Yongs-modulus of the femur is 17 GPa with the ultimate strain is at 1.5%.**

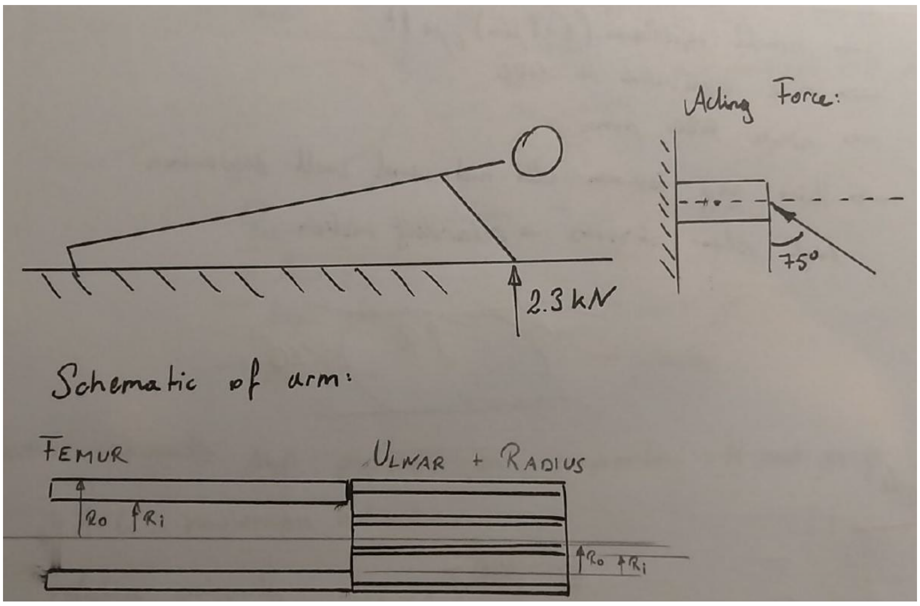


3. **A person trips and falls. He was able to stretch out his arms. The arm consist of the upper arm (femur) and the lower arm (ulnar and radius - both have the same dimensions and are parallel). The arm joints are neglected and between the upper and lower arm is a rigid connection. Calculate if the bones will fracture and the precise fracture location. (00.03.2018)**

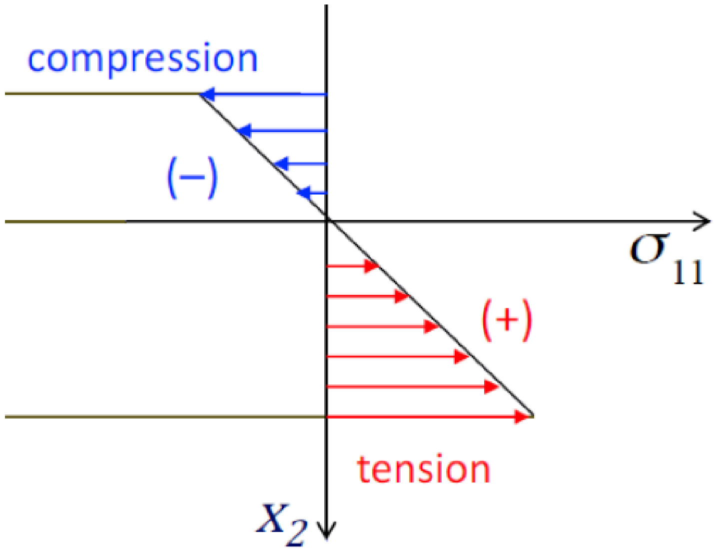
   a) **Inner diameters, outer diameters and length of upper and lower arm were given.**

   b) **Angle and acting forces was given.**

   c) **Young modulus of bone and critical strain was given.**



Note: The arrangement of ulnar and radius was not important - just divide the acting forces by two. Be careful as the neutral line is between the bones (lower arm). You could derive from a figure (strain is linear over the distance) where the fracture occurs, like this:



4. **Bone fracture can occur due to a fall (A). Falling onto the hip is simplified in a loading situation as shown in Figure 1 and in the derived free body diagram (C). For simplicity, the femoral neck can be modelled as a hollow circular rod with constant cross-sectional area. Answer the following: (15.03.2021)**

   - D_o = 35 mm - outer diameter
   - D_i = 25 mm - inner diameter
   - F = 12 kN - experienced falling Force,
   - θ = 31° - the angle between falling force and longitudinal axis (e_1),
   - $\sigma_{max\ tensile}$ = 150 MPa
   - $\sigma_{max\ comp}$ = 200 MPa

   a) **Derive an expression for the total normal stress σ_{xx} as a function of the distance from the neutral axis (y) and the distance force insertion point (x).**

   b) **Considering fracture to initiate at section A-A: does the fracture occur due to tensile or compressive stress?**

      Hint: Independent from L!

   c) **Determine the closest distance (L) to the force insertion point where fracture can occur under the given loading state.**

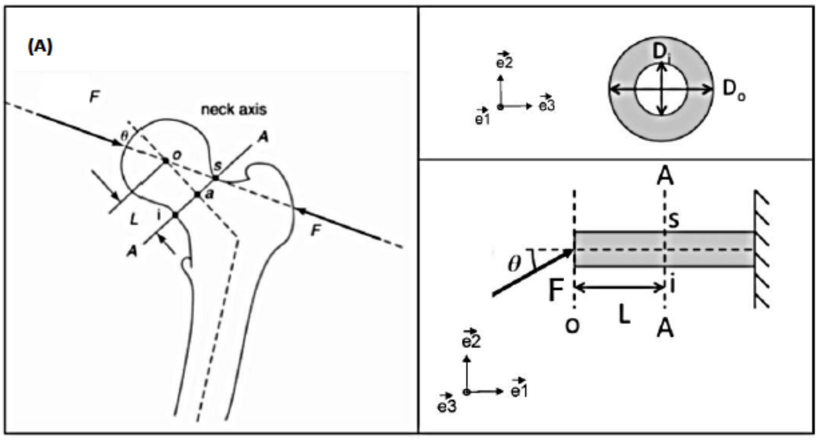


Figure 2: Femur geometry and simplified free body diagram – o…point where the impact force vector coincides with the longitudinal axis; s… superior end of section AA; i…inferior end of section AA

5. **For a new model of an ankle prosthesis (Fig 2A), you should calculate the mechanical characteristics of the foot-plate under load. Fig 2C shows the loading situation for the prosthesis and the corresponding loading diagram. We assume that weakest section is section A-A Assume the prosthesis foot-plate to be rectangular with: Answer the following: (15.03.2021)**

   - l = 24 cm, b = 10 cm h = 2 cm
   - E = 18 GPa - Young's modulus of the material
   - F = 2 kN - acting force
   - θ = 30° - the angle between the acting force and vertical axis (ex)
   - l_A = 12 cm - distance between point of force application and section of interest

   Hint: just consider section AA for the stress determinations

   a) **Calculate the internal force and bending moment along the length of the prosthesis as a function of x and draw the corresponding diagrams.**

   b) **Derive an expression for the total normal stress σ_{xx} at section AA as a function of distance from the neutral axis.**

   c) **Where does the maximum stress at section AA occur?**

   d) **What is the risk factor of experiencing a fracture at section AA assuming the yield strength (σ_{yield}) to be 100 MPa? Taking the calculated risk factor, will fracture occur?**

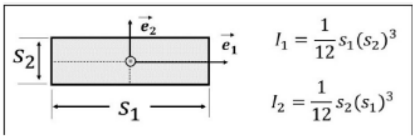
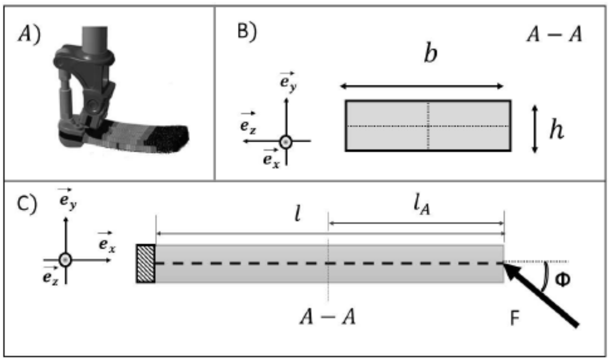


Table1: Second moment of area for a rectangular



6. **A common scenario leading to compression fractures of a vertebra is during lifting of a weight in a tilted position (A). The loading situation is simplified as shown in the free body diagram (C). Model the vertebra as a hollow cylinder with constant cross-sectional area and an inner radius ri and outer radius ro (B). Answer the following: (27.01.2022)**

- r_o = 16 mm - outer radius
- r_i = 14 mm - inner radius
- F = 10 kN - loading force
- θ = 33° - the angle between loading force and longitudinal axis (ex),
- $|\sigma_{max\ tensile}|$ = 150 MPa
- $|\sigma_{max\ comp}|$ = 200 MPa

a) **Derive an expression for the total normal stress σ_{xx} as a function of the distance from the neutral axis (z) and the distance from the force insertion point at the top surface (x).**

b) **Considering fracture to initiate at section A-A: does the fracture occur due to tensile or compressive stress? Give reasons for your conclusion!**

c) **Considering fracture to initiate at section A-A: does the fracture occur due to tensile or compressive stress? Give reasons for your conclusion!**

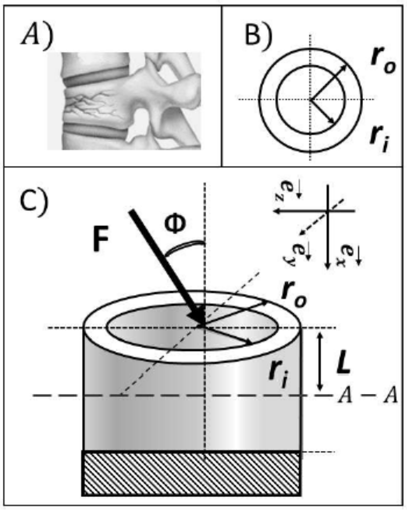


Figure 2: Loading state of a vertebra simplified and shown as a free body diagram

7. **A skier hits an obstacle with his leg. This results in a force F1 acting on the upper end of the tibia. In addition, the tibia is loaded with a force F2 = 300 N caused by the body weight of the skier (see Figure 2. A). The foot of the skier is fixed in the boot, so the loading scenario on the tibia can be modeled as shown in Figure 2. C. The force F2 acts at the center of the tibias cross-section. The tibia can be approximated as a hollow cylinder with a constant inner radius ri and a constant outer radius ro (see Figure 2. B)**

   - r_o = 14 mm - outer radius of the tibia
   - r_i = 6 mm - inner radius of the tibia
   - l_1 = 25 cm - distance between the edge of the skiing boot and the insertion point of the forces F1 and F2
   - F2 = 300 N
   - θ = 60° - angle at which F2 acts
   - $|\sigma_{max\ tensile}|$ = 150 MPa – ultimate tensile strength

   a) **Derive an expression for the total normal stress σ_{xx} in the tibia, as a function of the distance from the neutral axis (z) and the distance from the force insertion point at the top surface (x).**

   b) **Derive an expression for the total normal stress σ_{xx} in the tibia, as a function of the distance from the neutral axis (z) and the distance from the force insertion point at the top surface (x).**

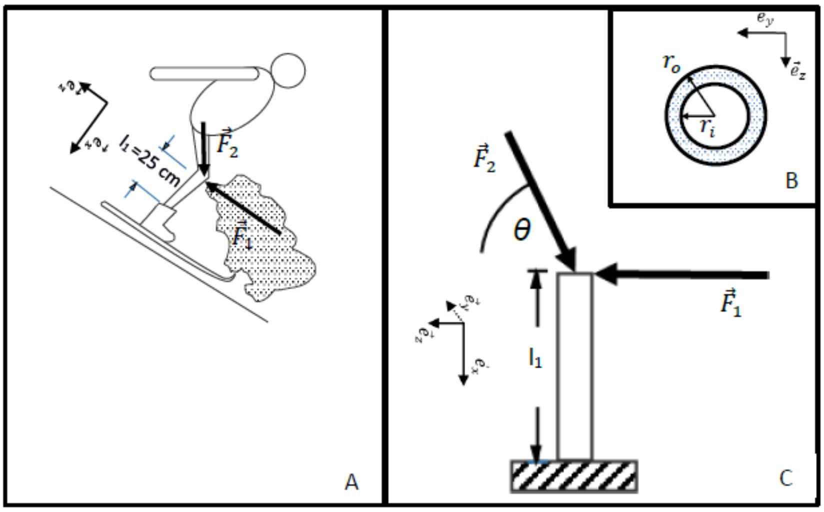


Figure 2: Forces acting on the skier's tibia, with the respective free body diagram

8. **The yield stress of two people is given: one (A) with 0.14 dyne/cm^2, the other (B) with 0.06 dyne/cm^2. The values are measured for a tube of 10 cm length, 6 mm diameter and a pressure difference of 50 dynes/cm^2. Predict Q_A/Q_B. (The formulas of ξ and F(ξ) are given). (27.01.2016)**

9. **In the diagram given in figure 1, you can see the PV-loop of a healthy human heart, compared to a heart from a person suffering from dilated cardiomyopathy. This disease leads to an enlarged heart, which can lead to heart failure. (28.01.2021)**

   a) **Estimate the work of the heart for both loops, assuming they are rectangles, and compare them.**

      Note that 1 mmHg = 133 Pa

   b) **The aorta is assumed to be a tube with a length of 30 cm and a diameter of 3 cm. Assuming the viscosity of blood to be 4 cp, a yield stress of τ_y = 0.05 dyn/cm^2 and the pressure drop in the aorta to be 50% of the maximum pressure taken from the respective PV-loop. How high is the flow rate in the aorta for a patient with dilated cardiomyopathy in comparison to a healthy human?**

Note: Assume that the blood form both patients follows identical Casson rheology.

Note the following equation: $F(\xi) = 1 - \frac{16}{7}\sqrt{\xi} + \frac{4}{3}\xi - \frac{1}{21}\xi^4$

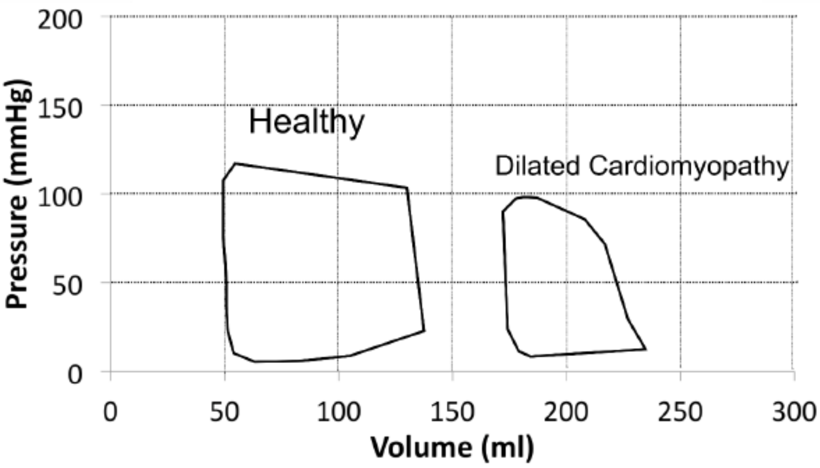


Figure 1: PV-loop of a healthy human heart next to the heart of a person suffering from dilated cardiomyopathy.

10. **You have blood with a velocity profile. On the outer side, there is only plasma, in the plug region there is blood with 45% Haematocrit. Calculate the haematocrit of this fluid. (27.01.2016)**

$$u = -\frac{R^2(?)}{4\mu}\left[1 - \frac{r - R_e}{R - R_e}\right]$$

11. **Blood flow in the ascending aorta can be modelled as a Casson fluid, with the following rheological parameters: viscosity μ = 4 cP and yield shear stress τ_y = 0.005 Pa. If we assume the radius R of the aorta is 2 cm and the pressure drop $\triangle$p/$\triangle$x = 0.05 Pa/cm calculate the following: (15.03.2021)**

    a) **Calculate the Casson radius Rc (the radius where we have plug flow)**

    b) **Calculate the flow rate Q in the ascending aorta.**

    c) **With the flow rate Q, you know the volume of blood per unit of time flowing from the heart through the ascending aorta. Assuming 50 heartbeats per minute calculate the volume flowing out for each heart cycle. With this calculate the work done by the heart during one cycle, if it has a volume change equal to the ejected blood volume and it has to overcome a pressure difference of 100 mmHg.**

Hint: 1 mmHg = 133.3 Pa

Note the following equation: $F(\xi) = 1 - \frac{16}{7}\sqrt{\xi} + \frac{4}{3}\xi - \frac{1}{21}\xi^4$

12. **A reservoir has to be filled with 0.8 liters of different fluids. The fluid is pumped through a 100 cm long tube of radius 3 cm. Over the entire length of the tube a pressure drop of 1 Pa is measured in case of all fluids. (00.01.2018)**

a) **First, the reservoir is filled with a Newtonian fluid with viscosity μ = 4 cP. How long does it take to fill the reservoir?**

$[P] = 0,1\,Pa \cdot s$

b) **Second, the reservoir is filled with blood. Blood usually has yield stress τ_y = 0.05 dyn/cm^2 and viscosity μ = 3.5 cP. Blood is pumped using the same tubes, white also the pressure drop is the same. How long does it takes to fill the reservoir with blood?**

$[dyn] = 10^{-5}\,N$

Hint: $F = 1 - \frac{16}{7}\sqrt{\xi} + \frac{4}{3}\xi - \frac{1}{21}\xi^4$

13. **A tube with certain diameter, length and pressure drop was given. (00.03.2018)**

Note: viscosity and Ty were given in CGS units, the pressure difference in Pa.

a) **Calculate the flow for plasma - viscosity was given (Newtonian fluid).**

b) **Calcualte the flow of blood for the same tube - F(ξ) and Ty was given (just derive for ξ) and the calculated F(ξ) and the flow with** $Q = \frac{R^4\pi}{8\mu}\frac{dp}{dx}F(\xi)$

c) **Some alteration with Rc - can't remember precisely.**

14. **A healthy heart pumps about 5 liters of blood per minute through the body. To do so, the heart pumps with a frequency of 70 beats over the same period. Normally, the left ventricle has a systolic to diastolic blood pressure of 120/10 mmHg during one cycle. (27.01.2022)**

Hint: 1 mmHg = 133 Pa

a) **What is the power of the described healthy hear**

b) **In a case of early stage hypertension the systolic pressure is increased by 20 mmHg. What is the change in pumping power of the heart?**

15. **Blood flows from a beaker through a 99 μm diameter glass capillary that is 0.1 cm long. The pressure difference across the capillary tube is maintained at 60 kdynes/cm^2 and the effective viscosity of the flowing blood is 2.3 cP. How long does it take to fill a reservoir with a volume of 1l? (27.01.2022)**

$[P] = 0.1\,Pa \cdot s$ and $[dyn] = 10^{-5}\,N$

16. **A rat's heart beats at 420 beats per minute. The pumping power of the left ventricle is 0.012 W, the systolic to diastolic blood pressure in the left ventricle is 140/10 mmHg (1 mmHg = 133 Pa). (15.03.2022)**

a) Estimate the blood volume, which the rat's left ventricle ejects with each heartbeat.

b) In some aged rats, the systolic blood pressure decreases to 100 mmHg. What is the pumping power of the left ventricle for an aged rat, assuming that the ejected blood volume and the heart rate stay the same?

17. In a dialysis machine, blood flows from reservoir A to reservoir B, through a horizontal capillary with a length l = 20 cm and a diameter d = 2 mm (see Figure 1). The filling height of reservoir A, h_1 = 15 cm and the filling height of reservoir B, h_2 = 10 cm. Blood has the following properties: (15.03.2022)

μ = 3.5 cP, τ_y = 0.05 dynes/cm^2, ρ = 1.06 g/cm^3 $([P] = 0.1\,Pa \cdot s,\,[dyn] = 10 - 5\,N$

a) What is the pressure difference between the two ends of the capillary?

b) Calculate the flow rate through the capillary for the pressure difference calculated in a).

Hint 1: $F(\xi) = 1 - \frac{16}{7}\sqrt{\xi} + \frac{4}{3}\xi - \frac{1}{21}\xi^4$ Hint 2: If you could not complete a) assume a pressure difference Δp = 200 Pa

c) When blood flows from reservoir A to reservoir B, the filling height of reservoir A will decrease. At what pressure difference between the ends of the capillary will blood stop to flow?

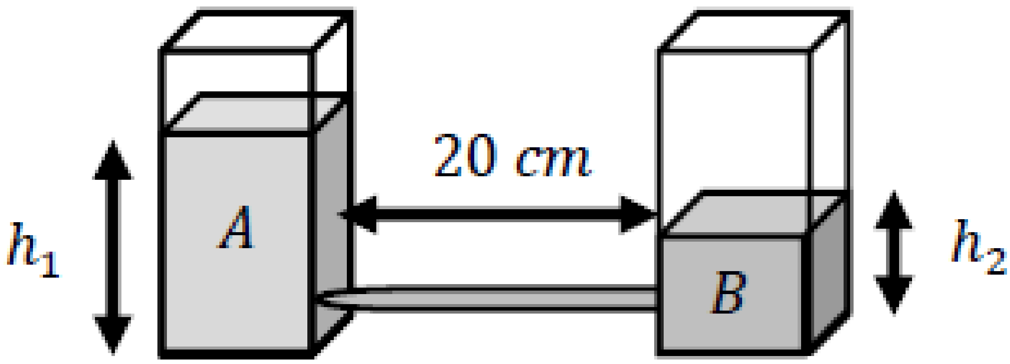


Figure 1: Blood flows between two reservoirs