PROBLEMS

Physical constants and numerical data are listed in chapter 30. APPENDIX.

1. Find the velocities of the oxygen and nitrogen molecules of air in normal state (t = 0 ºC, p = 101 kPa), assuming that all the molecules have equal (translational) kinetic energy. (oxygen: ≈ 460 m/s, nitrogen: ≈ 490 m/s)

2. At what temperature will the number of thermal defects double (compared to that at body temperature) in the H-bonds of a protein molecule, if the bond energy is 18.8 kJ/mol? (342.9 K)

3. Calculate the number of thermal defects in a protein molecule containing 1400 hydrogen bonds at 37 ºC, if the bond energy is 18.8 kJ/mol. (≈ 1)

4. What percentage of the chemical bonds is broken at body temperature? Calculate it for two different bond energies, 200 kJ/mol and 0.5 kJ/mol. ($2\cdot10^{-32}$ % and 45 % respectively)

5. Calculate the bond energy that is needed to keep 99.9 % of the chemical bonds intact at body temperature? (17.8 kJ/mol, $2.97.10^{-20}$ J/bond)

6. The flame temperature in a photometer is 800 ºC. What percentage of the sodium atoms sprayed into the flame becomes excited, if the wavelength of the emitted yellow light is 590 nm? ($1.5\cdot10^{-8}$ %)

7. Assuming a quiet atmosphere at 5 ºC, at what altitude would the oxygen concentration decrease by half? And by the factor of e? (5 km, 7.1 km)

8. Within the optical region of the electromagnetic spectrum, wavelengths of visible light span from 400 to 800 nm. Find the corresponding photon energy interval in eV units. (3.1 - 1.55 eV)

9. What wavelength of light causes photochemical effect, if the required energy is 240 kJ/mol? (495 nm)

10. The human eye is most sensitive to the yellow-green light, and as low as 2.10^{-12} W/m^2 intensity induces light sensation. Calculate the lowest number of photons in a second needed to light perception? The diameter of the pupil is 5 mm. (109 photon/s)

11. Based on your physical optics knowledge, calculate the smallest distance between two points at 1m distance from the eye, which are just seen separately. What is the angle of view in this situation? (0.3 mm, 1 minute of arc)

12. A single photon of 5.10^{-7} m wavelength that reaches the retina induces light perception. There is 100 Ω resistance between the two points along the visual nerve, and a 10^{-4}s long, 10^{-5}V potential difference is induced as a result of the photon.
a) What is the energy of the photon? ($3.96.10^{-19}$ J)
b) How many times greater is the energy of the electric signal generated on the nerve cell, compared to the photon energy? (250 times)

13. Infrared light of a CO_2 laser with 20 W power is focused onto a spot of 0.1 mm in diameter. Find the power density (intensity) of the radiation. ($2.5\cdot10^{9}$ W/m^2)

14. The attenuation coefficient of muscle tissue is 800 cm^{-1} at the wavelength of the CO_2 laser (10.6 μm), and it is 5.7 cm^{-1} at the wavelength of the Nd-YAG laser (1.06 μm). Calculate the thickness of the muscle tissue layer that absorbs 90 % of the light energy of these lasers. (0.03 mm, and 4 mm respectively)

15. At the wavelength of the argon-ion laser (488 nm), the optical media of the eye can be characterized by an attenuation coefficient of 10^{-4} cm^{-1} , which is similar to that of water. The attenuation coefficient of blood at the same wavelength is 330 cm^{-1}.

a) Calculate the energy loss of the 488 nm laser light after reaching the fundus in %, if the path length in the eye is 2.5 cm! (0.025 %)

b) A capillary is irradiated by this laser beam in the fundus to be coagulate. What is the thickness of blood layer that reduces light intensity by half? (0.02 mm)

16. An object is placed 12 cm from a convex lens. The image is located 36 cm behind the lens. Find the focal distance, the power (in diopters), and the magnification of the lens. (9 cm, 11.1 dpt, M = 3)

17. What is the smallest distance between two object points which a microscope can just resolve, if the aperture angle of the objective is 140º, cedar oil immersion is used (n = 1.5), and the illuminating light is yellow-green (λ = 520 nm)? ($2.25\cdot10^{-5}$ cm)

18. Distilled water (index of refraction: 1.333) is dropped between the prisms (index of refraction: 1.739) of the Abbe refractometer.

a) Calculate the critical angle. (50º)

b) How does the critical angle (and the position of the shadowline) change, if we drop blood serum of a healthy person (of 70 g/l protein concentration) between the prisms? Obtain the index of refraction of the blood plasma from the calibration curve at the Fig 14 of the 4. REFRACTOMETER manual. (50.85º)

c) By what percentage is the speed of light decreased in the prism compared to distilled water? (23.4 %) Calculate the decrease for the air *versus* prism relation, too. Assume that the index of refraction of air is 1. (42.5 %)

19. Calculate the net energy loss due to thermal radiation in 1 hour for a person with a body surface area of 0.8 m^2 if the ambient temperature is 20 ºC. The temperature of the skin surface is 27 ºC. (120 kJ)

20. What is the temperature of the environment, which radiates back half of the energy that the skin radiates out at 28 °C? (-20 °C)

21. An X-ray tube operates at 80 kV anode voltage and 6 mA anode current.

a) What is the maximum energy of the X-ray photons generated? (80 keV=$1.28\cdot10^{-14}$ J)

b) What is the minimum wavelength? (15 pm)

c) What is the emitted power if the anode material is tungsten (Z = 74)? (3.125 W)

d) What is the efficiency of this tube? (0.65 %)

e) How much heat is generated in one minute? (28.6 kJ)

f) What is the velocity of the electrons reaching the anode? (Assume that relativistic mass increase is negligible.) ($1.68\cdot10^{8}$ m/s)

g) Calculate the number of electrons that arrive at the anode in one second. ($3.75\cdot10^{16}$)

22. What is the intensity of the X-ray at 1 m from the focus of the X-ray tube, if the anode voltage is 50 kV, the anode current is 5 mA and the efficiency of the tube is 0.37 %? Assume that the radiation emerges from a point-like focus, and it is distributed uniformly in a 2π spherical angle (in a hemisphere). (0.147 W/m^2)

23. Calculate the thickness of the aluminum plate that absorbs 90 % of the incident radiation, if the mass attenuation coefficient of aluminum is 0.171 cm^2/g for this radiation. (5 cm)

24. The half-value thickness of lead for gamma radiation is 3 mm. What thickness of lead is required to reduce the intensity by a factor of 10? Calculate the attenuation coefficient of lead for this radiation. (1 cm, 2.31 cm^{-1})

25. How many times the half-value layer thickness attenuates radiation by 95 %? (4.33)

26. To what percent does a layer of 3.33 times the half-value layer thickness attenuate ratiation? (10 %)

27. An aluminum plate attenuates the intensity of beta radiation by 29.2 %. How many of these plates would give the half-value layer thickness? (two)

28. Incident gamma photon of 0.66 MeV dissipates its energy by Compton scattering. Work function (activation energy) is 50 eV. Find the energy and wavelength of the scattered photon, if the velocity of the released electron is $6\cdot10^{7}$ m/s. Assume that relativistic mass increase is negligible. (649.7 keV ≈ $1.04\cdot10^{-13}$ J, 1.9 pm)

29. Calculate the largest possible energy of the β^- particle, produced in a neutron decay, if we suppose that the neutron did not move? ($9.8.10^{-14}$ J = 0.61 MeV)

30. An isotope test requires 2 MBq of ^{24}Na isotope for every patient. 5 patients are scheduled for both the Tuesday and the Thursday 8 AM examinations. Calculate the activity of the isotope that needs to be ordered, if its delivery time is Monday, 4 PM. (0.213 GBq)

31. Two different radioisotopes are present in a preparation. At the beginning of the observation they had the same activity. The halflife of the first isotope is 15 hours and the lifetime of the of the second is 2.5 days. Calculate the ratio of the activities of the isotopes after 3 and 12 days. (12.1:1 and 4096: respectively)

32. When will the activity of the 2 MBq ^{32}P preparation decrease to 0.1 kBq? (approximately 205 days)

33. 0.5 GBq of ^{24}Na-isotope arrived 30 hours ago. We use 50 MBq now. By what time, from the arrival, will the activity of the rest of the isotope decay to 50 MBq? (38.8 h)

34. What is the activity of 1 μg of pure ^{131}I ? (4.636 GBq)

35. Calculate the number of moles of radioactive iodine molecules (I_2) in a ^{131}I preparation of 0.5 MBq activity. ($8.3\cdot10^{-13}$ mol)

36. How many radioactive iodine nuclei are there in the ^{131}I preparation of 2.4 MBq activity? ($2.4\cdot10^{12}$)

37. What is the biological half-life for the decay of sulphur in the skin, if the initial activity of ^{35}S in the skin was 6 kBq/g, and after 2 weeks it was reduced further to 3.45 kBq/g. (T_{eff} = 17.4 days, T_{biol} = 22 days)

38. Before starting the radioiodine therapy of the thyroid cancer, the iodine uptake and storage capacity of the thyroid gland has to be measured. In this examination, radioactive ^{131}I isotope is administered to the patient, and the activity in the thyroid gland is determined from the descending part of the istope accumulation curve. Calculate the biological halflife of iodine in the examined thyroid gland in hour units! (T_{biol} = 60.7 hours)

39. Consider an α-emitting isotope of 5 MBq activity. The energy of the emitted α particles is 6.2 MeV. The total emitted energy is absorbed in 0.1 kg water. Calculate the temperature change of water after half an hour of irradiation. Assume that the change in the activity of the radioactive sample during the experiment is negligible. ($2.1\cdot10^{-5}$ ºC)

40. Radioactive ^{131}I isotope of 0.2 GBq initial activity decays with 7.5 days effective halflife in a thyroid gland of 80 g mass. Calculate the total dose that was absorbed by the thyroid gland during complete decay, if the mean energy of the emitted particle is 0.18 MeV. (67.5 Gy)

41. What is the absorbed dose for the hands, if a test tube of 680 MBq ^{24}Na solution was held for 30 seconds? Assume that the distance of the hand from the test tube was 1 cm. Calculate the absorbed dose if the same test tube was held with a 20-cm-long clamp. What conclusions can you draw? (25 mGy_{air}, 62.5 μGy_{air})

42. Calculate the total absorbed dose received by the patient during a 1 minute X-ray examination of 0.5 W/m^2 intensity. Thickness of the projected body was 20 cm. Mean mass attenuation coefficient of the tissues of the body is 0.166 cm^2/g. (approximately 0.14 Gy)

43. Skin surface of 0.4 m^2 area of a person of 70 kg mass absorbed, on average 4.2 J energy per minute per cm^2 from the Sun. How much time is needed to absorb the energy that equals the lethal dose for gamma radiation (6 Gy)? (1.5 s)

44. The human lethal dose in the case of whole-body exposure to gamma radiation is 6 Gy. Calculate the temperature change of the body due to this dose (the specific heat of the body is 4 kJ/kg·K). ($1.5\cdot10^{-3}$ °C)

45. Calculate the dose rate at 30 cm from a ^{24}Na isotope of 0.6 GBq activity in the air. (2.96 mGy_{air}/h)

46. Two scintilation detectors are used to measure the radiation emitted by two ^{24}Na preparations of identical activity placed in lead towers of the same size. Both preparations are at 10 cm distance from the detector head. The distance of the detectors is 30 cm. What is the thickness of the lead wall that causes less than 1 % error in the measurement of the other preparation? (Draw a scheme of the arrangement.) (4.07 cm)

47. During a measurement, ^{24}Na isotope preparation of 20 MBq is at 40 cm distance from us. Calculate the thickness of the lead shielding that reduces the dose rate below 20 μGy_{air}/h. (1.8 cm)

48. What distance should be kept from an ^{131}I isotope of 0.56 GBq so that the dose rate is below 20 μGy_{air}/h? (123 cm)

49. A ^{24}Na isotope preparation of 0.5 GBq was placed behind a 2 cm thick lead wall. What is the dose rate at a distance of 30 cm from the isotope? (0.8 mGy_{air}/h)

50. How long can one stay at a 30 cm distance form the 0.75 GBq ^{59}Fe preparation to keep the exposure below the weekly limit of 1 mSv? (45 minutes)

51. A person works at 30 cm distance from a ^{24}Na isotope preparation of 75 MBq. Calculate the thickness of the lead shielding that reduces the dose rate to 15 μGy_{air}/h at the working place. (≈ 5.6 cm)

52. Consider, that we work at 30 cm distance from a ^{24}Na isotope of 75 MBq activity. How thick lead wall would decrease the dose rate to 15 Gy_{air}/h at the work area? (5.6 cm)

53. A scintillation detector crystal with 5 cm diameter is at a large distance from the preparation of 50 kBq activity (incident rays can be considered parallel). Thickness of the crystal is 4 cm, and its attenuation coefficient is 9.10^{-2} cm^{-1} for the given radiation. Calculate the detection efficiency for the given radiation in percents? (Detection efficiency is defined as the ratio of detected and incident photons.) (30.3 %)

54. What is the velocity of an electron accelerated by 5 kV voltage? What is the wavelength of the corresponding matter wave? Assume that relativistic mass increase is negligible. ($v = 4.2\cdot10^7$ m/s, λ = 17.3 pm)

55. An electron microscope operates with 5-keV electrons. Calculate the resolving power, if the aperture angle of the magnetic objective lens is 6º. (5 nm^{-1})

56. The heart pumps 5.6 l blood through the aorta of 1 cm radius in one minute. What is the average flow velocity of blood in the aorta? (30 cm/s)

57. During blood transfusion the blood bottle is placed 1.3 m above the needle. The inner diameter of the needle is 0.36 mm, its length is 3 cm. 4.5 cm^3 blood flows through the needle in one minute. What is the blood viscosity? (2.5 mPas)

58. Calculate:
a) What force is necessary to maintain 0.5 cm/s flow velocity of blood in a 20-cm-long segment of aorta, assuming that the force is necessary only to overcome internal friction. (11.3 mN)
b) What percentage of the total pressure of $1.6 \cdot 10^4$ Pa maintaining the blood circulation falls in this aorta segment if the average cross-sectional area is 2 cm^2? (0.35 %)
c) What percentage of increase in flow intensity would cause turbulence? Suppose that the flow is stationary. (24 %)

59. In an artery of 4 mm inner diameter the flow velocity of blood is half of the critical velocity. The diameter of the artery decreases by half at some part. Assuming stationary flow, calculate the average and critical velocities in both regions. (v_1 = 1.24 m/s, $v_{crit,1}$ = 2.49 m/s; v_2 = 4.97 m/s, $v_{crit,2}$ = 4.97 m/s, thus it becomes turbulent)

60. An artery branches into 5 sections of the same diameter. The velocity is decreased to the eight tenth of original value in each of these branches, and exactly the third of the critical velocity. At which section would the flow become turbulent, if the flow intensity were increased, and at what % of increment would it happen? (Consider the flow stationary.) (20 %)

61. An artery of 9 mm inner diameter is examined with Doppler ultrasound. The frequency of the ultrasound is 8 MHz. The average frequency audible to the examiner is 1200 Hz. Calculate the average velocity of blood in the artery. The velocity of the ultrasound in the body is 1500 m/s, and we assume that it propagates in parallel with the axis of the blood vessel. (11.25 cm/s)

62. How does the internal energy of one mole of oxygen gas change in normal state if its temperature is changed
a) at constant volume by 25 ºC?
b) at constant pressure by 25 ºC?
(the answer for both questions is practically the same: 520 J)

63. 1 kg each of freezing (0ºC) and boiling (100ºC) water are mixed together. What is the entropy change (increase or decrease) of the system? (increase: 100 J/K)

64. We put 0,5 kg of 0 °C ice into 4 kg of 55 °C water. Calculate the entropy change until the equillibrium is established. (117 J/K)

65. 1 mL water is injected into the bloodstream via a vein that spreads in the total 5 L blood volume. How many times larger is the thermodynamic probability of the evenly distributed case, than the 1 mL water staying separated. (Consider the process isothermic and reversible, and express the ratio as the powers of ten.) (W_1/W_2=10^(1.24 10^23))

66. Energy is provided to a thermodynamic system of 350 K temperature. How much is the given energy, if the ratio of the number of macrostates before and after the process is 10^10^10? The temperature of the system is unchanged. (483 mJ)

67. 100 g water evaporates at 100 ºC and 101 kPa (at its normal boiling point). Calculate the change in entropy, enthalpy and internal energy. (Do not take into account the volume of the water.) (ΔS = 0.61 kJ/K, ΔH = 225.7 kJ, ΔU = 209 kJ)

68. 0.5 mol of ideal gas at 100 ºC temperature is confined in a cylinder with a movable piston. The work done by the gas during isothermal, reversible expansion is 1554 J. What is the distance traveled by the piston if its initial distance from the end of the cylinder was 40 cm? (68.4 cm)

69. One needs to blow 0.25 mol of air into a balloon with the mouth at a pressure causing 30 % decrease of the volume. Calculate the work done on the air in this isothermal process. Assume that the process is reversible and air is an ideal gas. (236.8 J)

70. a) Find the Gibbs free energy of 200 ml glucose solution of 0.02 mol/l concentration at 25 ºC. (-3.65 kJ)
b) What percentage of this comes from the mixing term? (1.06 %)

71. How much work is done by the tubular cells of the kidney in the body (37 ºC) when concentrating 1 mol of glucose 100 times (from the filtrated primary urine towards the blood)? The renal tubule reabsorbs this quantity in 2000 minutes. With what power do these cells work? ($12 \cdot 10^3$ J, 0.1 W)

72. The reaction heat of the Cu^{++} + Zn → Cu + Zn^{++} process is 231 kJ/mol. The Daniell cell battery of 1.09 V electromotive force is based on this reaction. Calculate the energy that must be released as heat during the precipitation of 1 mol copper? ($W_{max(rev)}$ = 210 kJ, Q_{min} = 21 kJ)

73. Resting potential of a frog muscle is 92 mV according to the measurement. How different (in %) is the resting potential calculated from the Hodgkin-Huxley-Katz model, if only the two most mobile ions were taken into account (at 25 °C)? (Calculate with the concentration data of the table III. 7. in the Textbook. Permeability of the ion K^+ was taken as 1. Relative permeability of Cl^- is 2 and that of Na^+ is 0.01 in the frog muscle.) (1.1 %)

74. Radiotracing experiments showed that the cell membrane is permeable to K^+ ions. The concentration of the K^+ ion in the intracellular and extracellular fluids of a mammalian muscle cell is 155 and 4 mmol/l, respectively. The difference is due to the immobile negative protein ions present in the intracellular fluid. What electromotive force is generated by this concentration difference at body temperature (37 ºC)? (98 mV)

75. What change of power gain level corresponds to a decrease of signal voltage by half? (– 6 dB)

76. A person has a hearing loss of 40 dB at a particular frequency.

a) What is the intensity of the sound perceived, if the auditory threshold at the applied frequency is $5\cdot10^{-12}$ W/m^2? ($5\cdot10^{-8}$ W/m^2)

b) If $5\cdot10^{-12}$ W/m^2 of the intensity calculated above can pass through a wall, then the sound-proof capacity of the wall is said to be 40 dB. How many times the half-value layer thickness is this wall? (13.3 times)

c) Calculate the half-value layer thickness and attenuation coefficient of the wall for this sound frequency if you know that the wall was 12 cm thick. (0.9 cm, 0.78 cm^{-1})

77. Mr. Deaf, who has 30 dB hearing loss is bothered with the loud party in the neighbourhood, despite of the wall of 15 times the half value thickness. He has to wear 45 dB earplug in order to not hear the noise. What is the sound intensity on the other side of the wall? (To simplify, calculate with 1 kHz sound.) (1 W/m^2)

78. What is the intensity of a 300 Hz sound that a person with 25 dB hearing loss can hear at this frequency? The average hearing threshold at this frequency is $3\cdot10^{-11}$ W/m^2. ($9.5\cdot10^{-9}$ W/m^2)

79. 45 dB hearing loss of a person was compensated by a hearing aid in which the efficiency of the microphone is 5 %, and that of the speaker is 8 %. Determine the gain level of the ampifier in dB. (69 dB)

80. John sits at 2 m from a pointlike speaker of 40 W power, which has 8 % efficiency. The speaker emits 1000 Hz sound. What is the loudness of the sound in phon units? (108 phon)

81. The power gain level of an amplifier is 13 dB. Due to negative feedback, the gain was decreased to 10 dB. What portion of the output power was fed back into the input? (1/20, or 0.05 times the incident value)

82. Find the capacity that can be used with a 10 MΩ resistance to construct an RC circuit with a time constant of 1 s. Calculate the percentage of the initial voltage remaining in this RC circuit after discharging for 2 s. (0.1 μF, 13.5 %)

83. The time constant of an RC circuit is 0.6 s. What voltage will the capacitor be charged to after 1 s, if the source voltage is 100 V? How long will it take for the capacitor to discharge from the calculated voltage by half? (81.2 V, 0.45 s)

84. In the skin impedance measurement we got the following values: the specific resistance of the skin is 2 Ωm^2, and the specific capacity is 0.3 μF/cm^2.

a) What is the time constant of the skin as an RC circuit? (6 ms)

b) At which frequency will the ohmic and the capacitive resistances be the same? (26.5 Hz)

85. An ultrasound echogram is viewed on an oscilloscope screen. The frequency of the sawtooth wave is 5 kHz, and the width of the image on the screen is 8 cm. Signal reflected from the outer surface of the body and a signal coming from an inner surface are at 3 cm distance on the screen. How deep in the body is the inner reflecting surface, if the velocity of the ultrasound in the body is 1500 m/s? (5.62 cm)

86. What wavelengths correspond to the 27 MHz and 2.37 GHz frequencies of the heat-therapy generators? (11 m and 12.6 cm, respectively)

87. Calculate the frequency of the short-wave device used in heat therapy, if its wavelength in air is 11 m. (27.3 MHz)

88. Calculate the wavelength of the ultrasound in water, if its frequency is 800 kHz and its velocity in water is 1500 m/s. (1.87 mm)

89. What is the reflectivity of the muscle-bone boundary based on the following data? (33 %)

	In muscle	In bone
Sound velocity (m /s)	1600	3600
Density (kg /m^3)	1040	1700

90. Muscle was treated by capacitive field diatermy. (Frequency: 30 MHz, electric conductivity of the muscle tissue at 30 MHz frequency: 0,8 $\Omega^{-1}.m^{-1}$, duration of the treatment: 3 minutes, volume of the muscle: 600 cm^3, electric field strength: 100 V/m.) Calculate the temperature change of the muscle tissue, if the blood circulation removes 70 % of the produced heat? (0.11 °C)

91. Calculate the warming of muscle during 10 minutes of heat therapy, if the electric field is 100 V/m, and blood circulation removes 30 % of the produced heat. The specific heat of muscle is 3.76 kJ/(kg·K), its conductivity at the applied frequency is 0.8 $\Omega^{-1}\cdot m^{-1}$, and its density is 1.04 g/cm^3. ($\Delta T \approx$ 0.86 K)

92. To what voltage should the 20 μF condenser of the defibrillator be charged, to get a pulse of 160 J energy? (4 kV)

93. The voltage amplitude of the 1-ms-long square pulse of a pacemaker is 4 V. Find the energy of one pulse, if the resistance of the stimulated area between the electrodes is 800 Ω. (20 μJ)

94. Transport of how many moles of monovalent ion results in the threshold charge, if the rheobase is 4 mA, and chronaxie is 0.4 ms? ($1.66.10^{-11}$ mol)

95. How many different insulin-size (51 amino acids) polypeptide chains can be built from 20 different amino acids? ($2.25\cdot10^{66}$)

96. How many different nucleic acid sequences of the size of the MS2 bacteriophage (3600 base pairs) can be built from 4 nucleotide bases? ($2.6\cdot10^{2167}$)

97. A biting force of 700 N was measured in a study, and the total contact area between the upper and lower teeth was 0,8 cm^2. Calculate the average pressure. (8.75 MPa)

98. The tooth enamel can withstand a stress of about 400 MPa before breaking. How large force at 1 mm^2 area can it withstand before breaking? (400 N)

99. The maximum load of the Achilles tendon (2 cm in diameter) is 20 000 N. Calculate the maximum strain to failure. (100 MPa)

100. A collagen fiber is stressed with 12 N force. The cross-sectional area of the fiber is 3 mm^2, and its Young's modulus is 500 MPa. Give the percentage of relative extension. (0.8 %)

101. What force is needed to extend an elastic fiber with 0.2 mm^2 cross-sectional area by 100%? (Young's modulus of the fiber is 200 kPa.) (0,04 N)

102. 700–700 N perpendicular compression force is applied to both ends of a cylindical piece that was cut from a bone. Originally, the length of cylinder was 9 cm, and its diameter was 2 cm. Young's modulus of the bone is 10 GPa. Calculate the compression of the piece in mm. Calculate shortening in % as well.(0.02 mm, 0.022 %)

103. Calculate the shortening of the shin in a standing person, if the relaxed length of the bone was 30 cm. Mass of the person is 80 kg, and we consider the bone as a simple rod with a cannon in the middle with inner and outer radii of 2,5 cm and 3,5 cm, respectively. Young's modulus of the bone is 20 GPa. What would be the absolute and relative shortening of the bone just before the fracture if the of the shin is 140 MPa? (0.013 mm; 2.1 mm, that is 0.7 %)

104. The length of an elastic thread used in orthodontics is 6 cm, its cross-sectional area is 1 mm^2, its Young's modulus is 5 MPa. We extend the thread by 40 %. How large is the retracting force, and what is the amount of elastic energy stored in the thread? (2 N, 24 mJ)

105. A 7,5-cm-long elastic thread of rectangular cross-section (1 mm 2 mm), used in orthodontics was slightly bent perpendicularly to the longer side of its cross-section. The elastic modulus of the thread material is 148 GPa. What force and work are needed to bent the thread by 2 cm? (3.5 N, 35 mJ)

106. A solid and a hollow rod of the same length, mass and material are bent with the same force. The outer and inner radii of the hollow rod are 24 mm, and 12 mm respectively. How much larger is the relative bending of the solid rod than that of the hollow one? (66.7%)