Toorikkonspekt kursuse “Biofüüsika” füüsikalistest küsimustest

7 VÕNKUMISED JA LAINED. HELI. OSCILLATIONS AND WAVES. SOUND.

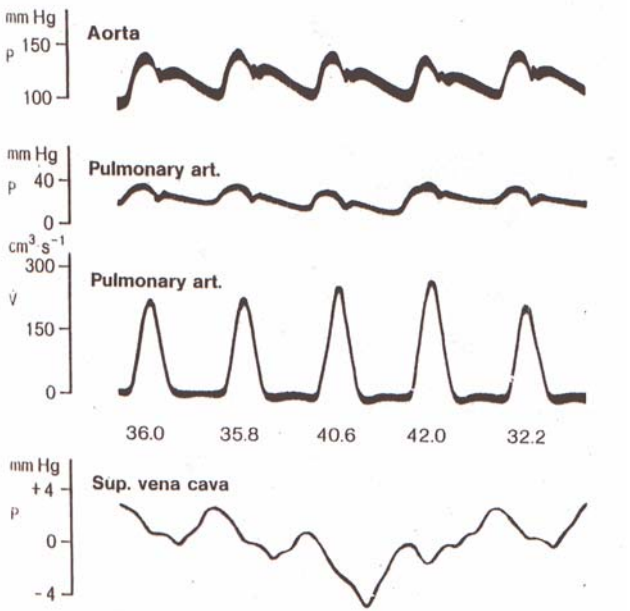
KÄESOLEVAS FAILIS sisaldub konspekti toorik aine “Biofüüsika” **järgmiste osade jaoks:**

Võnkumised. Lained. Heli. Ultraheli meditsiinis.

THE PRESENT FILE contains provision for the course “Biophysics” **corresponding to the following parts of the course:**

Oscillations. Waves. Sound. Ultrasound in medicine.

3.6.1



Kvaasiperioodilised võnkumised
Quasi-periodic oscillations
Квазипериодические колебания

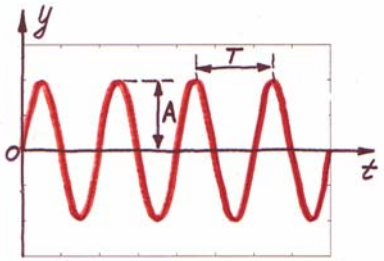
Perioodilisus
Periodicity
Периодичность

$y(t+T) = y(t)$

Periood: Period: Период: T, s

3.6.2

Harmoonilised võnkumised
Harmonic oscillations
Гармонические колебания



$$\begin{cases} y = A \cdot \sin\varphi \\ \varphi = 2\pi \frac{t}{T} \end{cases}$$

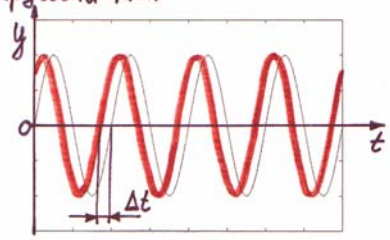
$$y = A \cdot \sin\left(\frac{2\pi}{T} \cdot t\right)$$

Sagedus
Frequency
Частота

$f \triangleq \frac{1}{T}$ $\quad [f] = \frac{1}{s} \equiv 1\,Hz$

Ringsagedus
Cyclic frequency
Круговая част.

$\omega \triangleq 2\pi f$ $\quad [\omega] = \frac{1}{s} = 1\,Hz$



$$y = A \cdot \sin(\omega t + \varphi_0)$$

Algfaas
Initial phase
Начальная фаза

$\varphi_0 = \frac{\Delta t}{T}$

3.6.3

Sinusoidaalsed lained
Sinusoidal waves Синусоидальные волны

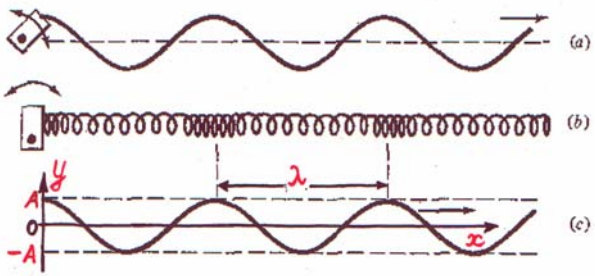


Figure (a) A periodic disturbance produced in a string by an oscillating lever travels toward the right. The dashed line indicates the undisturbed position of the string. (b) A spring is alternately compressed and extended. (c) The same graph can represent either wave.

$$y = A \cdot \sin\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x + \varphi_0\right)$$

λ: Laine-pikkus
Wavelength
Длина волны

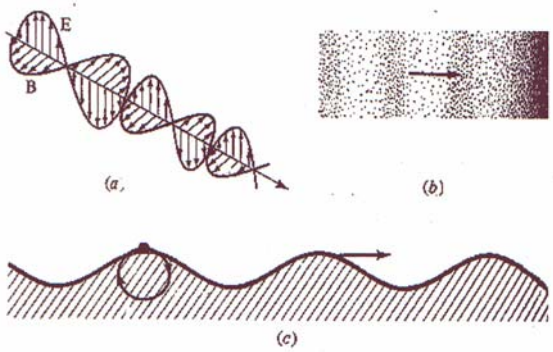


Figure (a) An electromagnetic wave. (b) A sound wave (c) A water wave. All these waves can be represented by the same kind of graphs as used for springs and strings.

3.6.

Lainearv
Wave number
Волновое число

$$\xi \triangleq \frac{2\pi}{\lambda} \qquad [\xi] = \frac{1}{m}$$

$$y = A \cdot \sin(\omega t - \xi x + \varphi_0)$$

Laine levikiirus
Wave propagation velocity
Скорость распространения волны

$$c = \frac{\lambda}{T} = \lambda f$$

	õhus	vees	Valgus vaakumis
Heli	in air	in water	Light in vacuum
Sound	в воздухе	в воде	Свет в вакууме
Звук	$c = 330\frac{m}{s}$	$c = 1500\frac{m}{s}$	$c = 300\,000\frac{km}{s}$

Lainete intensiivsus:
Intensity of waves:
Интенсивность волн:

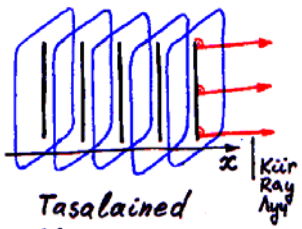
$$I \triangleq \frac{dN}{dS}$$

$$[I] = 1\frac{W}{m^2}$$

Helilaine intensiivsus:
Intensity of sound:
Интенсивность звука:

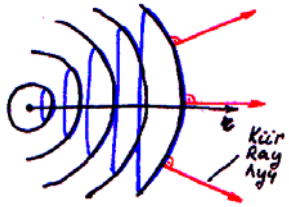
$$I = \frac{1}{2}\frac{\varrho}{c}\omega^2 A^2$$

ϱ - keskkonna tihedus
density of medium
плотность среды



Tasalained
Plane waves
Плоские волны

$I(x) = const$

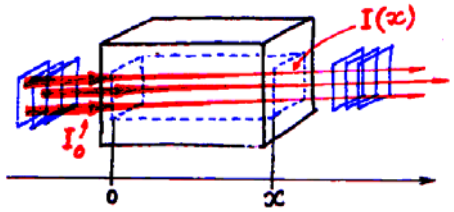


Sfäärilised lained
Spherical waves
Сферические волны

$I(r_1) \cdot 4\pi r_1^2 = I(r_2) \cdot 4\pi r_2^2$

$$\frac{I(r_1)}{I(r_2)} = \frac{r_2^2}{r_1^2}$$

Tasalaine nõrgenemine levimisel aines:
Attenuation of plane wave at propagation in media:
Ослабление плоской волны при распространении в среде:



$$I(x) = I_0 \cdot e^{-\alpha x} = I_0 \cdot e^{-\frac{x}{\tau}} = I_0 \cdot 2^{-\frac{x}{\tau_2}} = I_0 \cdot 10^{-\frac{x}{\tau_{10}}}$$

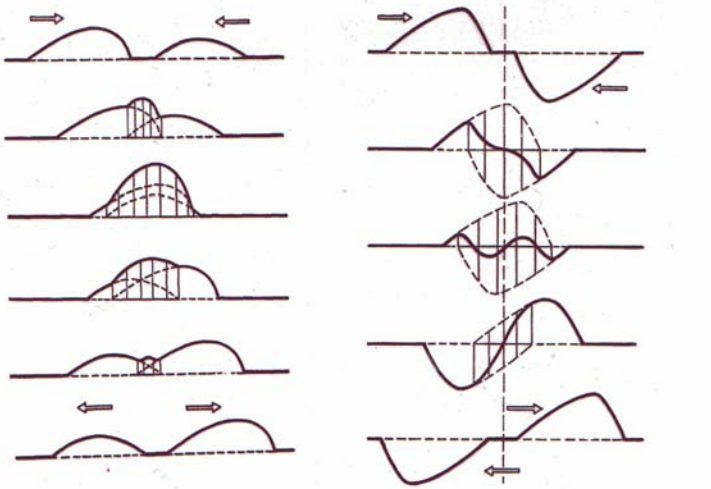
α – nõrgenemistegur, $[\alpha] = \frac{1}{m}$ τ, τ_2, τ_{10} – osanõrgenemis-paksused, $[\tau] = m$

3.7.2

Ühemõõtmelises keskkonnas levivate lainete liitumine
Summation of waves propagating in a one-dimensional medium
Сложение волн, распространяющихся в одномерной среде

Samasuunaliste kõlvete lained
Waves of deflection in same direction
Волны отклонения в одинаковом направлении

Vastassuunaliste kõlvete lained
Waves of deflection in opposite directions
Волны отклонения в противоположных направлениях

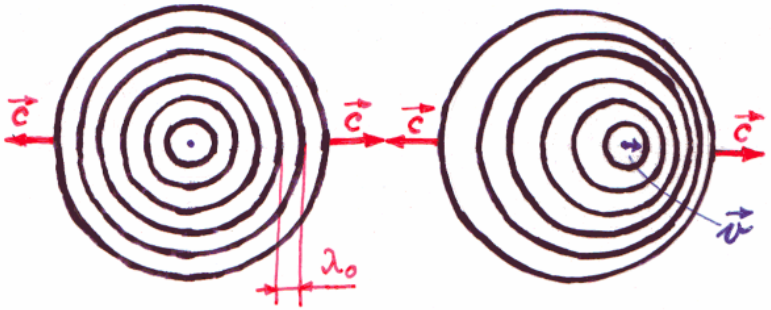


Näiteks For example Например:

Rõhulained arteris
Pressure waves in artery
Волны давления в артерии

Voolamise lained arteris
Flow waves in artery
Волны течения в артерии

Doppleri efekt:
Doppler effect:
Эффект Допплера:



$f = f_0 \;,\; \lambda = \lambda_0$

$\lambda_0 = c \cdot T_0 = \frac{c}{f_0}$

$\lambda = cT_0 \mp vT_0 =$

$= (c \mp v) \cdot \frac{1}{f_0}$

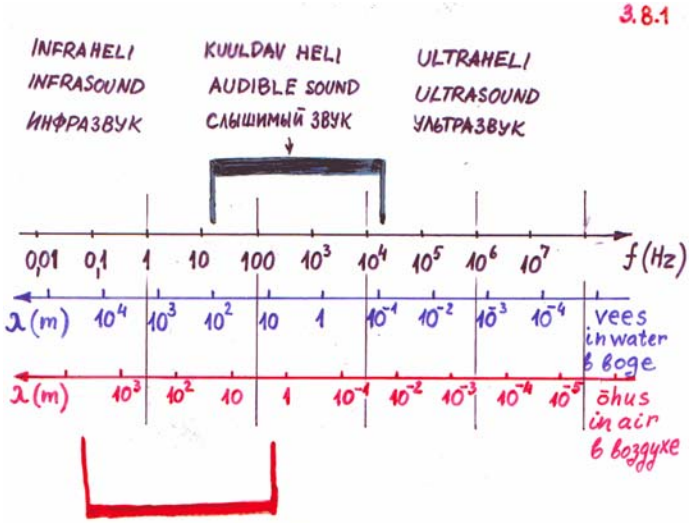
$f = \frac{c}{\lambda} = \frac{c}{c \mp v} \cdot f_0 =$

$= \frac{1}{1 \mp \frac{v}{c}} \cdot f_0 \approx$

$\approx \left(1 \pm \frac{v}{c}\right) \cdot f_0$

$$f = f_0 \cdot \left(1 + \frac{v}{c} \cdot \cos\left(\hat{\vec{v}, \vec{c}}\right)\right)$$

3.8.1



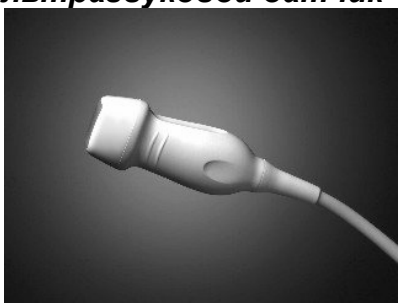
HELI JA MEHAANILISTE VÕNKUMISTE DIAPASOONID INIMESES

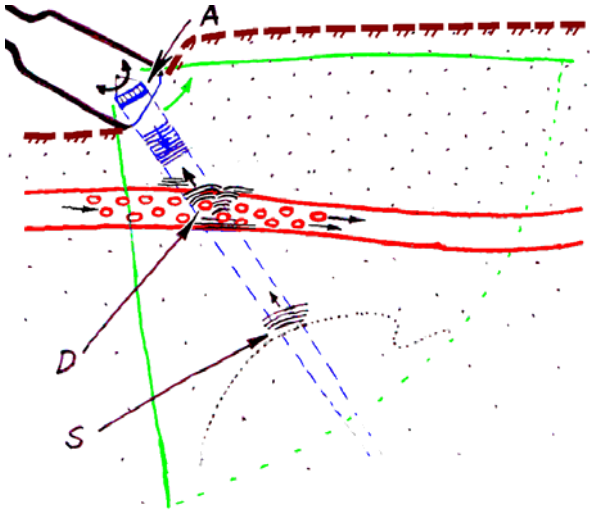
SCALE OF SOUND AND VIBRATIONS

ДИАПАЗОНЫ ЗВУКА И МЕХАНИЧЕСКИХ КОЛЕБАНИЙ В ЧЕЛ.

Ehhokardiograafia
Echo cardiography
Эхо-кардиография

Meditsiiniline ultraheli-andur
Medical ultrasound transducer
Медицинский ультразвуковой датчик





A – piesoelektriline ultraheliandur (saatja ja vastuvõtja)
– piezo-electric ultrasound transducer (sender and receiver)
– пьезоэлектрический ультразвуковой датчик (передатчик и приёмник)

S – staatiline objekt, staatiline kaja
– static object, static echo
– статический объект, статическое эхо

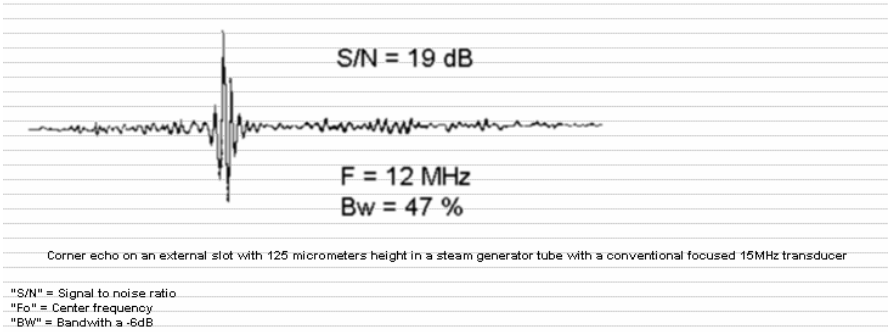
D – kiirelt liikuv veri, doppler-nihkega kaja
– rapidly moving blood, echo with Doppler shift
– быстро текущая кровь, эхо с допплеровским смещением

Kasutusel on ultraheli sagedusega 1-15 MHz, lainepikkus pehmetes kudedes vastavalt 1,5-0,1 mm

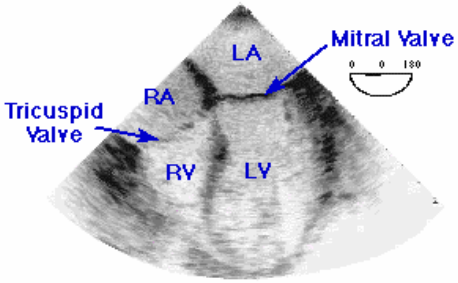
Ultrasound with frequency of 1-15 MHz is used, correspondingly wavelength in human soft tissues is 1.5-0.1 mm

Используется ультразвук с частотой 1-15 МГц, соответствующая длина волны 1,5-0,1 мм

Anduriga registreeritud peegeldunud ultraheliimpulss:



Sektor-2D ehokujutis
Sector 2D echo scan
2-мерное секторное эхо-изображение



Sama koos dopplermeetodil registreeritud voolukiiruse kujutisega
The same, the Doppler flow image superponed
То же, добавлено допплеровское изображение течения