Midterm Exam 2

April 8, 2008

Rules:

- 25 questions
- 4 points per correct answer, -1 for each incorrect answer, 0 for no answer
- Closed book, closed notes- only pen/ pencil allowed
- One and only one answer is correct- circle the corresponding letter

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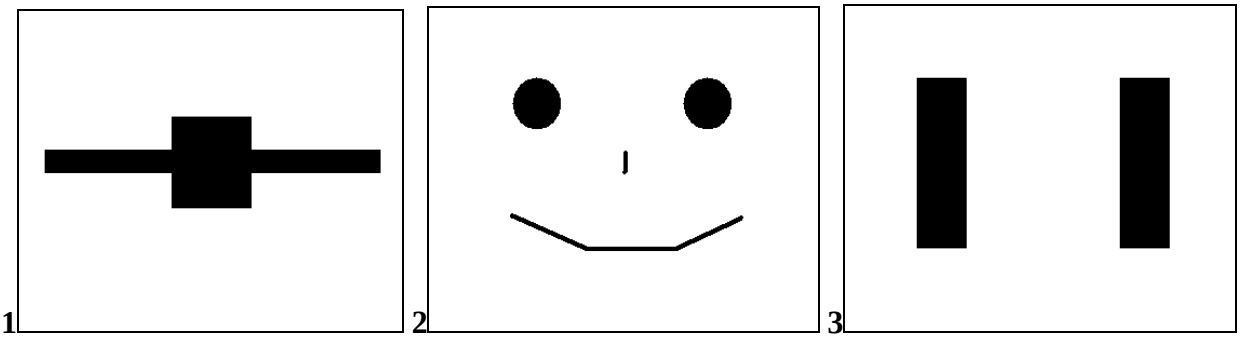
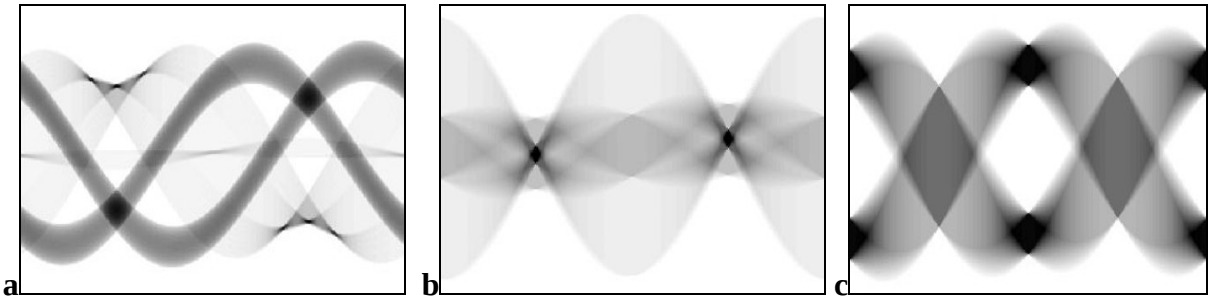
1. **Let us consider 3 images (labeled by 1-3 from left to right) and 3 sinograms (labeled by a-c from left to right):**



1 2 3

And



a b c

The following set matches each image with its coresponding sinogram:

A. 1-a, 2-b, 3-c

B. 1-c, 2-b, 3-a

C. 1-b, 2-a, 3-c

D. 1-b, 2-c, 3-a

2. **The following is true about nuclear imaging:**

A. Maps the concentration of radiopharmaceuticals in the body

B. Has high SNR and low specificity

C. Has low sensitivity and low resolution

D. Uses collimated gamma-ray source

3. **Radioactivity**

A. Is the property of nuclei to emit radiofrequency waves

B. Occurs only in stable nuclei

C. Is the process by which a positron and an electron annihilate

D. Is a spontaneous change in nuclear composition that results in radiation

4. **A particular radioactive decay is characterized by the decay constant λ. The number of nuclei <u>not</u> disintegrated at times t_1 and t_2 are N_1 and N_2, respectively. The following is true:**

A. $N_2/N_1=\exp[\lambda(t_1-t_2)]$

B. $N_2/N_1=\exp[\lambda(t_2-t_1)]$

C. $N_2/N_1=t_2/(t_1+t_2)$

D. $N_2/N_1=t_1/(t_1+t_2)$

5. **In a Technetium generator, the number N_2 of ^{99m}Tc nuclei is governed by $\frac{dN_2}{dt}=\lambda_1 N_1-\lambda_2 N_2$. Then N_2 reaches a maximum when**

A. t=0

B. t=∞

C. $N_2/N_1=\lambda_2/\lambda_1$

D. $N_2/N_1=\lambda_1/\lambda_2$

6. **The ^{99m}Tc population N in the body decreases via two main processes: the intrinsic radioactive decay (decay constant λ_1) and excretion from the body (equivalent decay constant λ_2), i.e. we can write $\frac{dN}{dt}=-\lambda_1 N-\lambda_2 N$. The effective half life time for ^{99m}Tc in the body is**

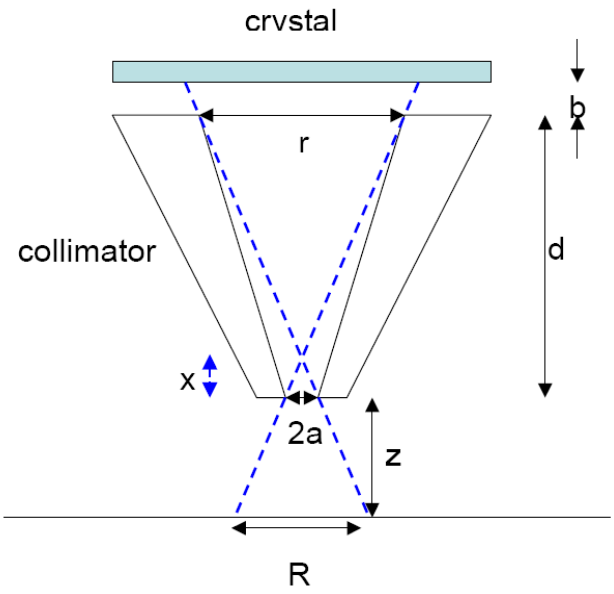
A. $\tau_{1/2}=\ln(2)/(\lambda_1+\lambda_2)$

B. $\tau_{1/2}=\ln(2)/\lambda_1+\ln(2)/\lambda_2$

C. $\tau_{1/2}=2/(\lambda_1+\lambda_2)$

D. $\tau_{1/2}=1/\sqrt{\lambda_1\lambda_2}$

7. **For the γ-ray collimator depicted below, the size R in the sample plane defines the resolution of the system (smaller R gives better resolution).**



Keeping all the other parameters constant, resolution improves (R decreases) if:

A. a increases

B. z decreases

C. d decrease

D. r increases

8. The SNR in nuclear imaging definitely improves if

A. The thickness of the detector crystal increases and the length of the collimator septa increases

B. The depth of interest in the body decreases and exposure increases

C. The thickness of the detector crystal decreases and the specificity of the ligand increases

D. Post-acquisition low-pass filtering is performed and the thickness of the detector crystal decreases

9. The following is true about SPECT as compared to common nuclear imaging

A. Provides increased resolution

B. It requires totally different instrumentation and radiopharmaceuticals

C. Provides lower CNR

D. Is the CT version of nuclear imaging

10. The following properties of a radiopharmaceutical <u>favor</u> its passage through the blood brain barrier (BBB):

A. High electric charge
B. Small molecular weight
C. Low lipophilicity
D. Weak ligand binding

11. The following is true about PET:

A. Maps the absorption coefficient of radiopharmaceuticals in the body
B. Has lower sensitivity than SPECT
C. Relies on detecting pairs of gamma rays at 120^o with respect to each other
D. Maps the distribution of e+ emitting radiopharmaceutical

12. Given the nuclear reaction $^{m}_{z}X + p + \beta \rightarrow {}^{m'}_{z'}Y + \alpha + n + \gamma$, the following conservation laws apply

A. z=z' and m=m'
B. z=z'+1 and m=m'+5
C. z=z'+2 and m=m'+4
D. z=z'+1 and m=m'+4

13. The following is true about resolution in PET

A. It does not depend on the depth of the imaged tissue
B. It improves with the distance traveled by the positron before annihilation
C. It improves with larger deviations from 180^o in the angle between the 2 gamma photons
D. It degrades with decreasing the size of the detector elements

14. To generate shorter US pulses, the transducer operates at

A. Higher amplitudes
B. Lower pressure
C. Larger damping
D. Higher velocity

15. In ultrasound imaging, SNR increases with

A. Increasing transducer focal distance because intensity is higher

B. Increasing transducer focal distance because intensity is lower

C. Decreasing transducer focal distance because intensity is higher

D. Decreasing transducer focal distance because intensity is lower

16. A tissue portion is set in harmonic motion by an ultrasound wave, such that the displacement *w* depends on time *t* as $w(t) = w_0 e^{i\omega t}$, where w_0 is the amplitude and ω is the angular frequency. The associated velocity u_z

A. Has a modulus $|u_z| = \omega w_0$ and is in phase with the displacement

B. Has a modulus $|u_z| = \omega w_0$ and is out of phase with the displacement

C. Has a modulus $|u_z| = \omega / w_0$ and is in phase with the displacement

D. Has a modulus $|u_z| = \omega / w_0$ and is out of phase with the displacement

17. An ultrasound wave of wavelength λ in tissue induces a particle displacement w_0. The ratio between the maximum *particle speed* and *wave speed*, $|u_z| / c$, equals

A. $2\pi w_0 / \lambda$

B. w_0 / λ

C. $2\pi\lambda / w_0$

D. λ / w_0

18. The ultrasound speed in vacuum is:

A. c=0

B. c=infinity

C. c=340 m/s

D. c=1,500 m/s

19. Given an ultrasound wave at the interface between air (wave speed c_a) and tissue (wave speed c_t), how much is the critical angle θ_c and where does it occur?

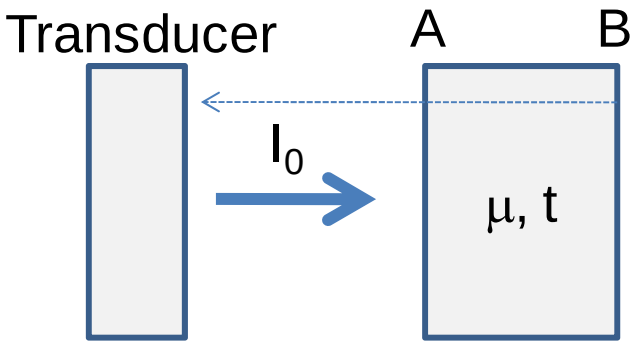
A. $\theta_c = \sin^{-1}(c_a / c_t)$, as the wave passes from air to tissue

B. $\theta_c = \sin^{-1}(c_a / c_t)$, as the wave passes from tissue to air

C. $\theta_c = \sin^{-1}(c_t / c_a)$, as the wave passes from air to tissue

D. $\theta_c = \sin^{-1}(c_t / c_a)$, as the wave passes from tissue to air

20. A tissue slice in air is illuminated by a parallel ultrasound beam from a transducer. The intensity reflection coefficient between tissue and air is R. The tissue slice has thickness t, attenuation coefficient μ, as shown in the figure below.



What portion of the initial intensity I_0 is received by the same transducer from the second surface (B) of the tissue.

A. $R*I_0$

B. $(1-R)*I_0$

C. $R*(1-R)*\exp(-\mu*t)*I_0$

D. $R*(1-R)^2*\exp(-2*\mu*t)*I_0$

21. During propagation through tissue the intensity of an ultrasound beam is attenuated by a factor of 10^{-6}. How much is this attenuation factor in Decibel (dB)?

A. -6dB

B. -16dB

C. -0.6dB

D. -60dB

22. A Rayleigh scattering particle is illuminated with an ultrasound radiation of frequency f. If the frequency is increased to 2f, the scattering cross section changes by a factor of

A. 1/2

B. 16

C. 1/8

D. ¼

23. The following is true about resolution in ultrasound

A. Transverse resolution improves with shorter focal distance and longitudinal resolution improves with shorter pulses

B. Transverse resolution degrades with shorter focal distance and longitudinal resolution improves with shorter pulses

C. Transverse resolution improves with shorter focal distance and longitudinal resolution degrades with shorter pulses

D. Transverse resolution degrades with shorter focal distance and longitudinal resolution degrades

24. The heart of a fetus in the womb works at 120 beats/ minute. If the instrument requires 100 microseconds per A scan and has 150 A-lines per B-scan, how many B-scan images can it stream between two heart beats?

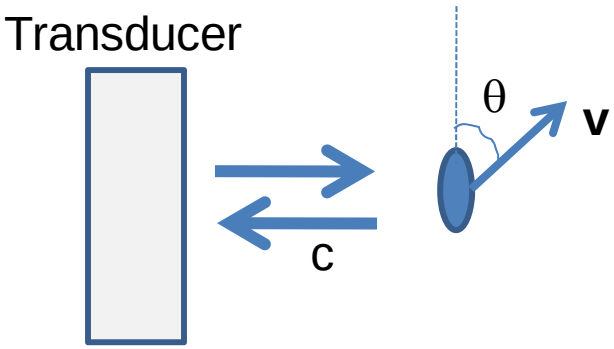
A. 0.5

B. 2

C. 33

D. 300

25. An ultrasound of frequency f and speed c is incident on a red blood cell of velocity v oriented as in the figure below



The transducer will receive a shift in frequency of

A. $\Delta f = 2 f \frac{v}{c} \cos(\theta)$

B. $\Delta f = 2 f \frac{v}{c} \sin(\theta)$

C. $\Delta f = -2 f \frac{v}{c} \cos(\theta)$

D. $\Delta f = -2 f \frac{v}{c} \sin(\theta)$