EEE 491 - Biomedical Engineering

Biological Effects of Electromagnetic Radiation

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MCQ Questions

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1. Q What is the main difference between ionizing and non-ionizing radiation?

(a) Ionizing radiation has a lower frequency than non-ionizing radiation.

(b) Ionizing radiation can make changes in the atoms of matter it strikes, while non-ionizing radiation cannot.

(c) Non-ionizing radiation is more powerful than ionizing radiation.

(d) Non-ionizing radiation can cause ionization, while ionizing radiation cannot.

1. A (b)

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2. Q Which type of electromagnetic radiation is considered ionizing?

(a) Radio waves

(b) Microwaves

(c) Infrared radiation

(d) X-rays

2. A (d)

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3. Q What is non-ionizing radiation?

(a) Radiation that is powerful enough to ionize atoms and molecules

(b) Radiation that lacks the energy to ionize atoms and molecules

(c) Radiation that can cause chemical changes in matter

(d) Radiation that only affects DNA

3. A (b)

4. Q What is the minimum quantum energy of radiation required for ionization?

(a) 3 electron volt (eV)

(b) 6 electron volts (eV)

(c) 12 electron volts (eV)

(d) 24 electron volts (eV)

4. A (c)

5. Q Calculate the minimum ionization wavelength, given that $h = 4.1357 \times 10^{-15}$ eV.s, then calculate the energy

(a) 103.4 nm

(b) 206.8 nm

(c) 6521.7 m

(d) 652.17 m

For minimum ionization energy of 12 electron volts (eV).

Therefore the minimum frequency $= \dfrac{12}{4.1357 \times 10^{-15}} \approx 2.3 \times 10^{15}$.

(Note that the Planck constant is given in eV.s not in J.s)

Therefore $\lambda = \dfrac{c}{f} = 1.034 \times 10^{-7}$ m or 103.4 nm.

5. A (a)

6. Calculate the energy of 100 nm photon, given that $h = 6.62 \times 10^{-34}$ j.s,

(a) 1.986×10^{-18} j

(b) 2.936×10^{-18} j

(c) 3.581×10^{-18} j

(d) 4.178×10^{-18} j

$$E = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{100 \times 10^{-9}} = 1.986 \times 10^{-18} \text{ j}$$

6. A (a)

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7. Q What is ionization?

(a) The process by which an atom gains or loses protons

(b) The process by which an atom gains or loses electrons

(c) The process by which an atom changes its atomic number

(d) None of the above

7. A (b)

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8. Q What is the potential long-term health effect of low doses of ionizing radiation?

(a) Skin burns

(b) Loss of appetite

(c) DNA damage leading to cancer

(d) Headache

8. A (c)

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9. Q How does the probability of stochastic effects of ionizing radiation relate to dose?

(a) It decreases with increasing dose

(b) It remains constant regardless of dose

(c) It increases with increasing dose

(d) It is not affected by dose

9. A (c)

10. Q **Which of the following statements is true regarding deterministic effects of ionizing radiation?**

(a) They may arise from any dose.

(b) They have no known threshold.

(c) They appear early and/or late.

(d) Their severity does not depend on the dose.

10. A (c)

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11. Q **Which of the following statements is true regarding stochastic effects of ionizing radiation?**

(a) They have a threshold before they appear.

(b) They have a severity depending on the dose.

(c) They almost certainly occur above a threshold dose.

(d) They have a long latency period.

11. A (d)

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12. Q **Why is it challenging to determine if a cancer or hereditary effect is caused by exposure to ionizing radiation?**

(a) There is no known threshold for deterministic effects

(b) The adverse outcome may be due to some other agent

(c) Deterministic effects have a long latency period

(d) The risk of stochastic effects independent of dose

12. A (b)

13. Q There is likely to have been a immediate occurrence the adverse outcome due to the radiation exposure in case of stochastic effects .

(a) true

(b) false

13. A (b)

14. Q What is radiation dose?

(a) The energy deposited by radiation in tissue

(b) The energy of the emitted radiation

(c) The energy loss due after a photon hits the outer shell of an atom

(d) All of the above

14. A (a)

15. Q Which type of radiation is mainly a hazard if it is ingested or inhaled?

(a) Alpha radiation

(b) Beta radiation

(c) Gamma radiation

(d) Neutron radiation

15. A (a)

16. What is the committed effective dose?

(a) The dose of gamma radiation absorbed by tissues

(b) The dose of radiation absorbed by tissues from internal sources over a long period of time

(c) The dose of radiation absorbed by tissues from external sources over a long period of time

(d) The dose of gamma radiation absorbed by tissues from internal sources

16. A (b)

17. Q What radionuclide behaves chemically like calcium and is incorporated into bones and teeth where it decays slowly?

(a) Uranium

(b) Iodine

(c) Thorium

(d) Radium

17. A (d)

18. Q What is Polonium-210?

(a) A beta-gamma emitter

(b) A gamma emitter

(c) An alpha emitter

(d) A neutron emitter

18. A (c)

19. Q Which of the following is a principle by which radiation dose can be minimized?

(a) Reduce the wavelength of radiation absorbed by the body

(b) Increase the distance between the radiation source and the body

(c) Increase the time of exposure to the radiation

(d) Use material to enhance the radiation effect

19. A (b)

20. What is the difference between a biological effect and an adverse health effect?

(a) There is no difference between the two

(b) A biological effect is noticeable or detectable physiological change, while an adverse health effect leads to a detrimental health condition

(c) An adverse health effect is noticeable or detectable physiological change, while a biological effect leads to a detrimental health condition

(d) A biological effect and an adverse health effect both lead to a detrimental health condition

20. A (b)

21. Q What is the frequency range of RF waves?

(a) 300 MHz to 300 GHz

(b) 800 MHz to 2200 MHz

(c) 3 KHz to 300 MHz

(d) None of the above

21. A (c)

22. Q What is the frequency range of microwaves?

(a) 300 MHz to 300 GHz

(b) 800 MHz to 2200 MHz

(c) 3 KHz to 300 MHz

(d) None of the above

22. A (a)

23. Q What is the average transmission power of a CDMA - GSM digital phone respectively?

(a) 250 mW - 200 mW

(b) 200 mW - 250 mW

(c) 700 mW - 500 mW

(d) 500 mW - 700 mW

23. A (b)

24. Q Does a large number of antennas on a cell phone tower mean greater RF exposure?

(a) Yes, the more antennas, the more RF exposure

(b) No, the maximum power is transmitted only when all users are operating at the same time

(c) It depends on the height of the tower

(d) It depends on the frequency being used

24. A (b)

Radiated power density from the cell tower

Radiated power density from the cell tower

$$W = \frac{P_t G_t}{4\pi R^2} \tag{1}$$

Where

P_t : **Transmitter power in Watts**

G_t : **Gain of transmitting antenna.**

R : **Distance from the antenna in meters**

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25. Q **A cell tower transmitting a 20 W signal with gain equals 50 , calculate the radiated power density at 500 meters far from the tower**

(a) $39.75\ \mu\text{W/m}^2$

(b) $79.5\ \mu\text{W/m}^2$

(c) $159\ \mu\text{W/m}^2$

(d) $318\ \mu\text{W/m}^2$

$$\because W = \frac{P_t G_t}{4\pi R^2}$$

$$\therefore W = \frac{20 \times 50}{4\pi \times 500^2} = 3.18 \times 10^{-4}\ \text{W/m}^2 = 318\ \mu\text{W/m}^2$$

25. A (d)

26. Calculate the power density produced by the mobile phone at the maximum penetration depth 41.198 mm if the radiated power is 0.125 W and the antenna gain is 1 and the separation between the head and the antenna is nearly equals zero

(a) $5.88\ \mathrm{W/m^2}$

(b) $11.76\ \mathrm{W/m^2}$

(c) $23.52\ \mathrm{W/m^2}$

(d) $47.04\ \mathrm{W/m^2}$

26. A (a)

$$W_{\max} = \frac{P_t G_t}{4\pi d^2}$$
$$= \frac{0.125 \times 1}{4\pi(0 + 0.0411)^2}$$
$$= 5.88\ \mathrm{W/m^2}$$

Impedance of the human

The impedance of the human head tissues (η) can be determined by the formula:

$$\eta = \sqrt{\frac{\mu_o}{\varepsilon_o}\frac{\mu_r}{\varepsilon_r}} = \eta_o\sqrt{\frac{\mu_r}{\varepsilon_r}} \tag{2}$$

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27. Calculate the impedance of the human head tissues given that $\sqrt{\frac{\mu_o}{\varepsilon_o}} = 377$ and the relative permittivity of skin = 41.434 and the relative permeability = 1

(a) 14.59

(b) 29.19

(c) 58.39

(d) 116.78

$$\eta = \eta_0 \frac{\mu_r}{\varepsilon_r}$$
$$= 377 \times \sqrt{\frac{1}{41.676}}$$
$$= 58.39\ \Omega$$

27. A (c)

Maximum Power Density

$$W_{\max} = \frac{E^2}{2\eta} \tag{3}$$

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28. In the previous question, given that the maximum power density is 5.88 W, calculate the electric field

(a) 6.22 V/m

(b) 16.22 V/m

(c) 26.22 V/m

(d) 36.22 V/m

Electric field, $E = \sqrt{W_{\max} \times 2\eta}$
$= \sqrt{5.88 \times 2 \times 58.39}$
$= 26.22$ V/m
28. A (c)

Specific Absorption Rate (SAR)

SAR stands for Specific Absorption Rate, which is the unit of measurement for the amount of RF energy absorbed by the body when using a mobile phone in units of watts per kg(W/kg) of tissue.

$$\mathbf{SAR} = \frac{\boldsymbol{\sigma} \boldsymbol{E}_{\mathbf{rms}}^{\mathbf{2}}}{\boldsymbol{\rho}} \tag{4}$$

$$\mathbf{(or)\ SAR} = \frac{\boldsymbol{\sigma} \boldsymbol{E}_{\mathbf{max}}^{\mathbf{2}}}{\mathbf{2}\boldsymbol{\rho}} \tag{5}$$

$\boldsymbol{E}$: electric field strength (V/m)

$\boldsymbol{\sigma}$: conductivity of the tissue (S/m)

$\boldsymbol{\rho}$: mass density of the tissue (kg/m^3)

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29. Q What does SAR stand for?

(a) Signal Absorption Range

(b) Specific Absorption Rate

(c) Signal Amplification Ratio

(d) Specific Attenuation Rate

29. A (b)

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30. What is the unit of measurement for SAR?

(a) W^2/kg

(b) W/kg^2

(c) W kg

(d) W/kg

30. A (d)

31. Q What is the SAR value in Europe and what is the averaging mass and averaging time used for the measurement?

(a) 1.6 W/kg, 1 gm, 30 min

(b) 2 W/kg, 1 gm, 6 min

(c) 1.6 W/kg, 10 gm, 30 min

(d) 2 W/kg, 10 gm, 6 min

31. A (d)

32. What is SAR?

(a) The unit of measurement for the amount of RF energy emitted by a mobile phone.

(b) The the power absorbed by the unit mass of tissue from an RF source.

(c) The unit of measurement for the amount of RF energy absorbed by the unit area of the skin

(d) The rate of penetration of EM energy in tissue.

32. A (b)

33. Q Why is SAR the most appropriate metric for determining EM exposure effects in the very near field of an RF source?

(a) Because it is the only metric available.

(b) Because it takes into account the nonuniform exposure during the operation of RF sources.

(c) Because it is easy to calculate.

(d) Because it is based on the power absorbed by the unit volume of tissue.

33. A (b)

34. What of the following is not a factor that SAR depends on?

(a) Incident field parameters

(b) Characteristics of the exposed body

(c) Ground effects and reflector effects of the objects in the field near the exposed body

(d) None of the above

34. A (d)

35. Q When the frequency of the incident field increases, the conductivity of the tissue ..... and the penetration depth .....

(a) increases, increases

(b) increases, decreases

(c) decreases, increases

(d) decreases, decreases

35. A (b)

36. Q What is the maximum SAR limit set by the FCC for acceptable power radiation for cell phones in the USA?

(a) 1.6 W/Kg

(b) 2 W/Kg

(c) 0.6 W/Kg

(d) 1 W/Kg

36. A (a)

37. What is the relationship between SAR and potential health hazards?

(a) Higher SAR means better phone

(b) There is no relationship between SAR and potential health hazards

(c) Lower SAR means better phone

(d) SAR has no effect on potential health hazards

37. A (c)

38. Q Why is the compliance test not effective in most African countries for SAR enforcement?

(a) Strong legal systems prevent illegal importation of non-compliant phones

(b) The SAR value indicated on phones is always accurate

(c) Counterfeit phones are a growing problem and may have fake SAR values

(d) African countries do not have SAR standards for mobile phones

38. A (c)

39. Q Does the SAR value of counterfeit phones always exceed the safety limits?

(a) Yes

(b) No

39. A (b)

40. Q What is the purpose of providing measured SAR of phones in markets with counterfeit phones annually?

(a) To ensure that all phones in the market comply with the SAR standards

(b) To compare the SAR values in the phone manual and measured ones

(c) To inform the public of the SAR values of different phones in the market

(d) All of the above

40. A (d)

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41. Q What is the basis for determining health hazard from RF exposure?

(a) Frequency of the RF radiation

(b) Amplitude of the RF radiation

(c) Thermal effect caused by RFR absorption

(d) ionizing effect caused by RFR absorption

41. A (c)

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42. Q How does the user's head affect the interaction of RFR with tissues?

(a) It has no effect on the interaction of RFR with tissues.

(b) It alters the manner in which RFR interacts with tissues.

(c) It enhances the absorption of RF energy.

(d) It increases the penetration of RFR into tissues.

42. A (b)

43. Q How does microwave radiation cause heating in living tissue?

(a) By inducing nuclear reactions

(b) By causing chemical reactions

(c) By rotations of polar molecules induced by the electromagnetic field

(d) By ionizing living tissue

43. A (c)

44. Q Where does most of the heating effect occur in a person using a cell phone?

(a) At the surface of the head

(b) In the legs

(c) In the fingers

(d) In the stomach

44. A (a)

45. Q How does the brain dispose of excess heat caused by microwave radiation from a cell phone?

(a) By sweating

(b) By decreasing local blood flow

(c) By increasing local blood flow

(d) By evaporating excess water

45. A (c)

46. In the case of a person using a cell phone, the temperature of the surface increases by ..... degree(s)

(a) from 1 to 2 degrees

(b) from 2 to 3 degrees

(c) a fraction of a degree

(d) no increase in the temperature of the surface of the head has been reported

46. A (c)

47. Q Which body parts are more susceptible to microwave absorption effects?

(a) Bones and muscles

(b) Brain and eyes

(c) Skin and hair

(d) Lungs and teeth

47. A (b)

becuase it contains more fluid and the movement of the fluid is less

48. Q What is the reason for localized heating inside the body due to multiple resonances?

(a) The body absorbs more radiation from the environment

(b) The body creates an electromagnetic field that interacts with the environment

(c) The body reflects the radiation back to the environment

(d) human height is greater than the wavelength of the transmitted signal so the body reson

48. A (d)

49. Q What is the effect of exposing the cornea of the eye to radiation for 2-3 hours?

(a) It can cause skin burns

(b) It can result in the formation of cataracts

(c) It can cause hair loss

(d) It can lead to bone fractures

49. A (b)

50. Q In which age group does radiation penetrate the skull the deepest?

(a) Adults

(b) 10-year-olds

(c) 5-year-olds

(d) Radiation penetrates the skull equally in all age groups

50. A (c)

51. 🟦 Why do younger children have a higher risk of cancer from radio frequencies?

(a) They have more hair on their head

(b) Their brains contain more fluid and their skulls are thinner

(c) They have thicker skin

(d) They have a higher resistance to radiation

51. A (b)

52. Q Which of the following is true regarding the rate of cell division in children?

(a) Children have a lower rate of cell division compared to adults

(b) Children have a similar rate of cell division as adults

(c) Children have a higher rate of cell division compared to adults

(d) Rate of cell division is not affected by age

52. A (c)

53. Q What is the blood-brain barrier (BBB)?

(a) Tight junctions between capillary walls that selectively let nutrients pass through to the brain

(b) A layer of cells that prevents nutrients from reaching the brain

(c) a substance in the gray matter in the brain

(d) A protein that causes damage to the brain

53. A (a)

54. How does RF from mobile phones affect the BBB?

(a) It strengthens the barrier and prevents toxic substances from entering the brain

(b) It has no effect on the BBB

(c) It causes the BBB to disappear completely

(d) It causes leakage of albumin from blood vessels in the brain

54. A (d)

55. Q Why is the presence of albumin in brain tissue a cause for concern?

(a) It indicates that the brain has lost some of its protection

(b) It is a sign that blood vessels have been damaged

(c) It can lead to serious health problems

(d) All of the above

55. A (d)

56. Q How does radiation from mobile phones affect the inner ear?

(a) It strengthens the delicate workings of the inner ear

(b) It has no effect on the inner ear

(c) It damages the delicate workings of the inner ear

(d) It improves hearing loss in the inner ear

56. A (c)

57. Q How does the use of mobile phones before bed affect sleep?

(a) It helps in improving sleep

(b) It delays and reduces sleep

(c) It has no effect on sleep

(d) It leads to deeper and longer sleep

57. A (b)

58. Q How can you minimize cell phone radiation exposure to your body?

(a) Move towards the base station

(b) Hold the phone close to your body

(c) Use your cell phone in places with weak signals

(d) Use a wired headset

58. A (d)

59. Q What is the recommended position to hold a mobile phone?

(a) At the top

(b) At the middle

(c) At the bottom

(d) It does not matter

59. A (c)

60. Q How does a weak signal affect mobile phone radiation?

(a) It reduces the radiation emitted

(b) It increases the radiation emitted

(c) It has no effect on radiation emitted

(d) It varies from phone to phone

60. A (b)

61. Q What is the recommended minimum distance for mobile phone base stations from populations, according to the study by Santini et al. in 2002?

(a) 50 meters

(b) 100 meters

(c) 300 meters

(d) 500 meters

61. A (c)

62. Who developed the guidelines for EMF exposure?

(a) Appointed experts

(b) Industry members

(c) Both industry members and appointed experts

(d) Government officials

62. A (a)

63. Q What is the only established adverse health effect of RF energy in the human body according to international guidelines?

(a) Cancer

(b) Depression

(c) Fatigue

(d) Thermal effect

63. A (d)

64. Q Is there credible evidence that RF exposure within internationally accepted limits causes adverse health effects?

(a) Yes

(b) No

(c) Only for certain populations

(d) It is unclear

64. A (b)

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65. Q How do electromagnetic waves cause heating of biological tissues in the brain?

(a) By creating electric fields in the tissues

(b) By causing vibrations in the tissues

(c) By inducing internal frictions in water molecules in the tissues

(d) By causing ionization of atoms in the tissues

65. A (c)

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66. Q Can electromagnetic waves cause non-thermal effects in biological tissues?

(a) No, only thermal effects are possible

(b) Yes, only in tissues that are rich in water content

(c) Yes, in all types of biological tissues

(d) No, electromagnetic waves have no effect on biological tissues

66. A (c)

67. According to the numerical simulation of electromagnetic power vs f different radiation frequencies, how does cerebral heating change with respect to radiation frequency?

(a) It increases as radiation frequency increases

(b) It decreases as radiation frequency increases

(c) It remains constant for all radiation frequencies

(d) It is not affected by radiation frequency

67. A (b)

68. At what frequency range do thermal effects dominate in biological systems according to the information given?

(a) Low frequencies, less than tens of Mega Hertz

(b) High frequencies, tens of Mega Hertz and more

(c) Mid-range frequencies, between tens of Hertz and tens of Mega Hertz

(d) All frequencies have equal thermal effects

68. A (a)

69. According to the curves in the figures, which generation of mobile phones causes less heat in the brain?

(a) 3G

(b) GSM

(c) 2G

(d) No matter the generation used

69. A (a)

70. Q **What is the origin of thermal effects in the brain caused by electromagnetic waves?**

(a) **Reflection of radiation energy from the brain tissues**

(b) **Conversion of radiation energy into chemical energy**

(c) **dissipation in the form of heat from the radiation energy reaching the tissues**

(d) **Scattering of radiation energy by the brain cells**

70. A (c)