

EEE 491 - Biomedical Engineering

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# 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)

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**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)

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

- (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 =  $\frac{12}{4.1357 \times 10^{-15}} \approx 2.3 \times 10^{15}$ .

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

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

**5. A** (a)

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**6. 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

**6. A** (b)

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

- Ⓐ Skin burns
- Ⓑ Loss of appetite
- Ⓒ DNA damage leading to cancer
- Ⓓ Headache

**7. A** (c)

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

- Ⓐ It decreases with increasing dose
- Ⓑ It remains constant regardless of dose
- Ⓒ It increases with increasing dose
- Ⓓ It is not affected by dose

**8. A** (c)

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

- Ⓐ They may arise from any dose.
- Ⓑ They have no known threshold.
- Ⓒ They appear early and/or late.
- Ⓓ Their severity does not depend on the dose.

**9. A** (c)

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**10. 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.

**10. A** (d)

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**11. 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

**11. A** (b)

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

- (a) true
- (b) false

**12. A** (b)

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**13. Q** What is radiation dose?

- Ⓐ The energy deposited by radiation in tissue
- Ⓑ The energy of the emitted radiation
- Ⓒ The energy loss due after a photon hits the outer shell of an atom
- Ⓓ All of the above

**13. A** (a)

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

- Ⓐ Alpha radiation
- Ⓑ Beta radiation
- Ⓒ Gamma radiation
- Ⓓ Neutron radiation

**14. A** (a)

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**15. Q** What is the committed effective dose?

- Ⓐ The dose of gamma radiation absorbed by tissues
- Ⓑ The dose of radiation absorbed by tissues from internal sources over a long period of time
- Ⓒ The dose of radiation absorbed by tissues from external sources over a long period of time
- Ⓓ The dose of gamma radiation absorbed by tissues from internal sources

**15. A** (b)

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**16. 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

**16. A** (d)

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**17. Q** What is Polonium-210?

- (a) A beta-gamma emitter
- (b) A gamma emitter
- (c) An alpha emitter
- (d) A neutron emitter

**17. A** (c)

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**18. 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

**18. A** (b)

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**19. Q** 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

**19. A** (b)

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**20. 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

**20. A** (c)

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**21. 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

**21. A** (a)



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**22. 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

**22. A** (b)

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**23. 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

**23. A** (b)

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## Radiated power density from the cell tower

Radiated power density from the cell tower

$$W = \frac{P_t G_t}{4\pi R^2} \quad (1)$$

Where

$P_t$  : Transmitter power in Watts

$G_t$  : Gain of transmitting antenna.

$R$  : Distance from the antenna in meters

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**24. 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)  $39.75 \mu\text{W}/\text{m}^2$
- (b)  $79.5 \mu\text{W}/\text{m}^2$
- (c)  $159 \mu\text{W}/\text{m}^2$
- (d)  $318 \mu\text{W}/\text{m}^2$

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

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

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**24. A** (d)

**25. Q** 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)  $5.88 \text{ W}/\text{m}^2$
- (b)  $11.76 \text{ W}/\text{m}^2$
- (c)  $23.52 \text{ W}/\text{m}^2$
- (d)  $47.04 \text{ W}/\text{m}^2$

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**25. A** (a)

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

## Impedance of the human

The impedance of the human head tissues ( $\eta$ ) can be determined by the formula:

$$\eta = \sqrt{\frac{\mu_o \mu_r}{\epsilon_o \epsilon_r}} = \eta_o \sqrt{\frac{\mu_r}{\epsilon_r}} \quad (2)$$

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**26. Q** Calculate the impedance of the human head tissues given that  $\sqrt{\frac{\mu_o}{\epsilon_o}} = 377$  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

$$\begin{aligned} \eta &= \eta_o \frac{\mu_r}{\epsilon_r} \\ &= 377 \times \sqrt{\frac{1}{41.676}} \\ &= 58.39 \, \Omega \end{aligned}$$

**26. A** (c)

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## Maximum Power Density

$$W_{\max} = \frac{E^2}{2\eta} \quad (3)$$

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**27. Q** 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

$$\begin{aligned}\text{Electric field, } E &= \sqrt{W_{\max} \times 2\eta} \\ &= \sqrt{5.88 \times 2 \times 58.39} \\ &= 26.22 \text{ V/m}\end{aligned}$$

**27. A** (c)

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### 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.

$$\text{SAR} = \frac{\sigma E_{\text{rms}}^2}{\rho} \quad (4)$$

$$\text{(or) SAR} = \frac{\sigma E_{\text{max}}^2}{2\rho} \quad (5)$$

$E$  : electric field strength (V/m)

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

$\rho$  : mass density of the tissue (kg/m<sup>3</sup>)

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**28. Q** What does SAR stand for?

- (a) Signal Absorption Range
- (b) Specific Absorption Rate
- (c) Signal Amplification Ratio
- (d) Specific Attenuation Rate

**28. A** (b)

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**29. Q** What is the unit of measurement for SAR?

- (a)  $W^2/kg$
- (b)  $W/kg^2$
- (c)  $W\ kg$
- (d)  $W/kg$

**29. A** (d)

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**30. 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, 6 min
- (d) 2 W/kg, 10 gm, 30 min

**30. A** (b)

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**31. Q** 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.

**31. A** (b)

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**32. 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.

**32. A** (b)

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**33. Q** 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

**33. A** (d)

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**34. 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

**34. A** (b)

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**35. 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

**35. A** (a)

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**36. Q** 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

**36. A** (c)

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**37. 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

**37. A** (c)

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

- (a) Yes
- (b) No

**38. A** (b)

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**39. 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

**39. A** (d)



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**40. 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

**40. A** (c)

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**41. 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.

**41. A** (b)

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**42. 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

**42. A** (c)

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**43. 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

**43. A** (a)

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**44. 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

**44. A** (c)

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**45. Q** 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

**45. A** (c)

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**46. 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

**46. A** (b)

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

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**47. 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 resonates

**47. A** (d)

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**48. 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

**48. A** (b)

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**49. 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

**49. A** (c)

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**50. Q** 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

**50. A** (b)

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**51. 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

**51. A** (c)

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**52. 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

**52. A** (a)

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**53. Q** 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

**53. A** (d)

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**54. 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

**54. A** (d)

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**55. 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

**55. A** (c)

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**56. 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

**56. A** (b)

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**57. 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

**57. A** (d)

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

- Ⓐ At the top
- Ⓑ At the middle
- Ⓒ At the bottom
- Ⓓ It does not matter

**58. A** (c)

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

- Ⓐ It reduces the radiation emitted
- Ⓑ It increases the radiation emitted
- Ⓒ It has no effect on radiation emitted
- Ⓓ It varies from phone to phone

**59. A** (b)

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

- Ⓐ 50 meters
- Ⓑ 100 meters
- Ⓒ 300 meters
- Ⓓ 500 meters

**60. A** (c)

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**61. Q** Who developed the guidelines for EMF exposure?

- Ⓐ Appointed experts
- Ⓑ Industry members
- Ⓒ Both industry members and appointed experts
- Ⓓ Government officials

**61. A** (a)

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

- Ⓐ Cancer
- Ⓑ Depression
- Ⓒ Fatigue
- Ⓓ Thermal effect

**62. A** (d)

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

- Ⓐ Yes
- Ⓑ No
- Ⓒ Only for certain populations
- Ⓓ It is unclear

**63. A** (b)



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**64. 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

**64. A** (c)

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**65. 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

**65. A** (c)

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**66. Q** 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

**66. A** (b)

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**67. Q** 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

**67. A** (a)

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**68. Q** 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

**68. A** (a)

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**69. 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

**69. A** (c)