# Wi-Fi Lab – EXAM

## 2022 UMD Invitational

Team Number: _____

Team/School Name: _____

No abbreviations / PRINT LEGIBLY

Student Names (First & Last): PRINT LEGIBLY

1. _____

2. _____

Total Points Possible (written test): **129**

Total Points Earned:_____

Team Number: _____ School Name: _____

## Multiple Choice (66 points)

1. The main way electromagnetic (EM) waves are identified is by their wavelength. Which of the following types of EM waves have the longest wavelength? (2)
    a. Microwave
    **b. Radio**
    c. Ultraviolet
    d. Gamma

2. What property of radio waves are usually used to distinguish between them? (2) **(TB #4)**
    a. Wavelength
    b. Velocity
    c. Polarization
    **d. Frequency**

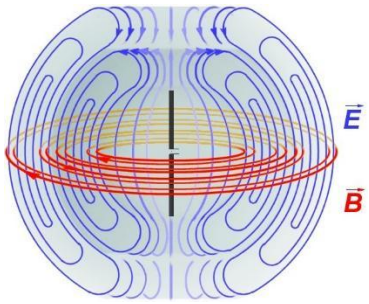
3. Electromagnetic waves have both an electric field and magnetic field component. These travel at what angle with respect to each other? (2)
    a. 45°
    **b. 90°**
    c. 135°
    d. 180°

4. For EM waves, what is the relationship between frequency and wavelength? (2)
    **a. They are inversely proportional**
    b. They are directly proportional
    c. They are related but cannot be found without a third variable
    d. They are independent

5. Who created the first functional antenna? (2)
    **a. Heinrich Hertz**
    b. Guglielmo Marconi
    c. James Clerk Maxwell
    d. Albert Einstein

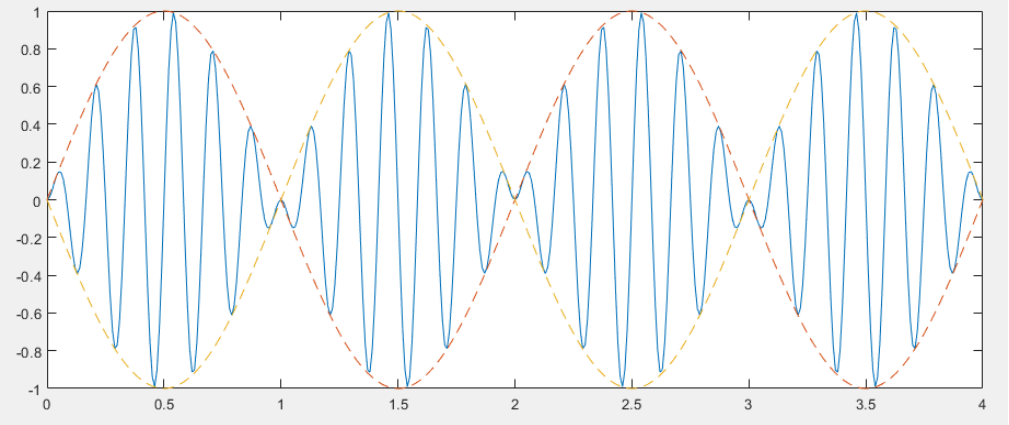
6. Which of the following is not a possible polarization of an electromagnetic wave? (2)
    a. Unpolarized
    b. Linearly polarized
    c. Circularly polarized
    **d. Rectangularly polarized**

7. What form of antenna would generate an electric and magnetic field like that shown to the side? (2)
   a. Beam antenna
   b. Whip antenna
   **c. Dipole antenna**
   d. Horn antenna




8. The first antenna created was of what design? (2)
   a. Loop
   b. Monopole
   **c. Dipole**
   d. Array

9. Waves can travel in packets shown below:




What are the velocities of the smaller wavelength wave and large wavelength wave referred to as? (2) **(TB #3)**
   a. Inner velocity, packet velocity
   b. Inner velocity, group velocity
   c. Phase velocity, packet velocity
   **d. Phase velocity, group velocity**

10. In addition, what must occur in a medium to create a wave like in the previous image? (2)
   **a. Dispersion**
   b. Reflection
   c. Refraction
   d. Transmission

11. An antenna capable of transmitting equal power in all horizontal directions is referred to as a (2)

a. Unidirectional antenna
b. Polydirectional antenna
c. Isotropic antenna
**d. Omnidirectional antenna**

12. Which of the following portions of the EM spectrum does our Sun emit at? (2)
    a. X-ray
    b. Visible
    c. Radio
    **d. All the above**

13. What is the kind of antenna that can be found on radios such as that shown to the side? (2)

    a. Rubber ducky
    b. Mast radiator
    **c. Whip**
    d. Turnstile

14. What form of modulation do the most recent generations of Wi-Fi (4, 5, and 6) use? (2)
    a. FSK
    **b. OFDM**
    c. AM
    d. FM

15. Which radio frequency band does Wi-Fi fall in? (2)
    a. VHF
    **b. SHF**
    c. EHF
    d. THF

16. Antenna can be used for what purpose when it comes to EM waves? (2)
    **a. Transmission and reception**
    b. Transmission
    c. Reception
    d. Dispersion

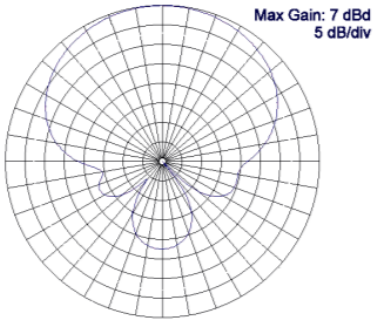
17. Which of Maxwell's Equations implies that changes in electric fields may create a magnetic field, and vice versa? (2)
    a. Gauss' law for electricity
    b. Gauss' law for magnetism

**c. Faraday's law of induction**
d. Ampere's law

18. Wire antenna includes antenna of all the following types EXCEPT (2)
    a. Dipole antenna
    b. Monopole antenna
    c. Loop antenna
    **d. Yagi-Uda antenna**

19. Which of the following is an advantage of antenna arrays? (2)
    a. Easy maintenance
    **b. High signal strength**
    c. Efficient use of space
    d. More complex information encoding

20. What type of antenna would most commonly be used for communication with a ship at sea? (2)
    **a. Wire antenna**
    b. Antenna array
    c. Parabolic reflector
    d. Horn antenna

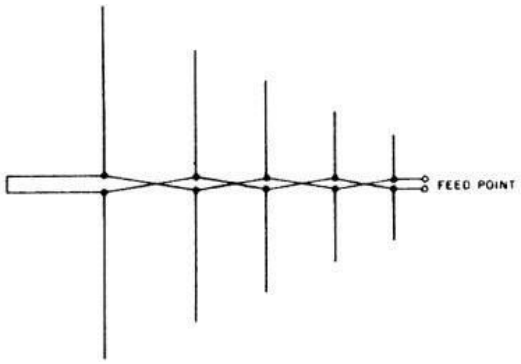



21. The radiation pattern of which of the following antennas matches with the diagram above? (2)
    a. Isotropic Antenna
    b. Aperture Array Antenna
    **c. Yagi-Uda Antenna**
    d. Dipole Antenna

22. Which of the following units is sometimes used to measure antenna efficiency? (2)
    a. Gigahertz (GHz)
    **b. Decibels (db)**
    c. Watts (W)
    d. No units are used as it is a ratio

23. Calculate the total efficiency of an antenna if its loss due to impedance mismatch is 0.35 and its radiation efficiency is 0.6 (2)
    a. 0.05
    **b. 0.21**
    c. 0.95

d. 0.25
e. 0.36




24. Identify the type of antenna depicted in the diagram above: (2)
    **a. Log-Periodic Antenna**
    b. Horn Antenna
    c. Dipole Antenna
    d. Dual-Plane Antenna

25. What range in the electromagnetic spectrum is primarily used for communication and why? (2)
    **a. Radio Waves, due to their desirable propagation properties and large wavelengths**
    b. Radio Waves, due to their tendency to be absorbed by objects larger than their wavelength
    c. Infrared Waves, due to their ability to be used in long-range communication among computer and technological peripherals
    d. Infrared Waves, due to their ability to directly beam information from one device to another
    e. Microwaves, due to their optimal wavelength which enhances the performance of highly directional antennas used for communication

26. Which of the following describes the behavior of a circularly polarized wave? (2)
    a. The wave's electric field (at any point) rotates about the wave's magnetic field
    b. The wave's magnetic field (at any point) rotates about the wave's direction of motion
    c. The wave's magnetic field (at any point) rotates about the wave's electric field
    **d. The wave's electric field (at any point) rotates about the wave's direction of motion**

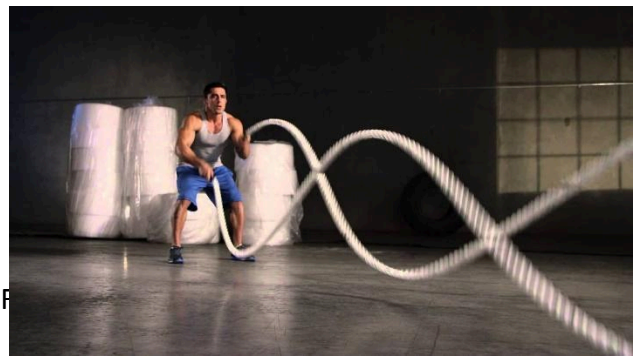
27. What is the frequency range for microwaves? (2)
    a. 0.3 MHz to 300 GHz
    b. 3 MHz to 300 MHz

**c. 0.3 GHz to 300 GHz**
d. 0.3 GHz to 30 GHz
e. 3 GHz to 300 GHz

28. Which region of the electromagnetic spectrum contains the “fingerprint region”, a region used to identify compounds? (2)
    a. Radio
    b. Microwaves
    **c. Infrared**
    d. Ultraviolet
    e. Gamma

29. Which of the following explains why AM radio waves have a greater range than FM waves? (2)
    a. FM waves use weaker transmitters to preserve audio quality
    b. The propagation of AM waves through atmosphere is much more efficient than FM waves
    c. FM waves are denser and contain more packets of information compared to their AM counterparts. To limit loss and maximize the amount of usable information, the range is purposefully reduced
    **d. AM waves have longer wavelengths which allow them to travel as ground waves and reflect off the ionosphere to increase range**

30. The wavelength of wave A is 3x longer than the wavelength of wave B. The velocity of wave B is 9x faster than the velocity of wave A. What is the frequency of wave A compared to wave B? (2)
    a. The frequency of wave A is 27x the frequency of wave B
    b. The frequency of wave A is 9x the frequency of wave B
    c. The frequency of wave A is 3x the frequency of wave B
    d. The frequency of wave A is 1/3$^{rd}$ the frequency of wave B
    e. The frequency of wave A is 1/9$^{th}$ the frequency of wave B
    **f. The frequency of wave A is 1/27$^{th}$ the frequency of wave B**



Wi-F

31. A man arrives at the gym to start his ropes workout (the ropes are tied to a machine and are of fixed length). To warm up, he practices the motion depicted above, albeit slowly. Over time, he begins to speed up and move the ropes faster in succession. Imagine the ropes as waves. Throughout his session, what aspects increased? (2)
    a. Wavelength only
    b. Frequency only
    c. Velocity only
    d. Wavelength and frequency
    **e. Frequency and velocity**

32. Monochromatic waves maintain the same _____ when passing from one medium to another (2)
    **a. Frequency**
    b. Wavelength
    c. Speed
    d. Amplitude

33. All matter exhibits both wave and particle like behavior, an example of the wave-particle duality. What is the name of the wavelength associated with a massive particle? (2)

    a. Snell's wavelength
    b. Planck's wavelength
    **c. de Broglie's wavelength**
    d. Young's wavelength

Team Number: _____ School Name: _____

## True False (10 points)

34. Radio waves are the only form of EM waves used for wireless communication. T/**F** (1)

35. Radio waves can be transmitted over great distances by reflecting them off the ionosphere. **T**/F (1)

36. Attenuation of EM waves is mainly a result of the imperfect construction of antenna. T/**F** (1)

37. In general, newer generations of Wi-Fi have seen its frequency decrease. T/**F** (1)

38. Electromagnetic waves require a medium to propagate in. T/**F** (1)

39. A phone wirelessly charging would be an example of a use for antennas. **T**/F (1)

40. All antennas are constructed with the aim of linearly polarizing emitted EM waves. T/**F** (1)

41. It is not possible for a real antenna to radiate equal power in all three dimensions. **T**/F (1)

42. Since the velocities of light packets can have speeds exceeding *c*, it is possible to convey information superluminally. T/**F** (1)

43. Light waves can travel slower than *c* if in a medium other than vacuum, such as glass. **T**/F (1)

## Completion (18 points)

44. Satellite dishes are a type of antenna commonly in the shape of a parabola (2) designed to reflect incident waves to the focus (1) of the antenna.

45. Electromagnetic waves transport energy (2) through space/vacuum (1).

46. There are 12 (1) radio bands defined by the ITU, ranging from on the low end ELF (1) to THF (1).

47. The well-known modes of radio communication AM and FM are short for amplitude (1) modulation (1) and frequency (1) module.

48. The three common prefixes for radio frequencies are kilo (1), mega (1), and giga (1).

49. When two waves are out phase, they create destructive (1) interference.

50. Two disadvantages of a helical antenna are that they costly (1) and take up extra space (1).

## Math (35 points)

For each of the following problems, make sure to write the equations used in your calculations and give units.

51. A magnetic field is enclosed by a sphere with a radius of 2 m centered at the origin is described by **B** = x**i** + xy**j** + y**k**. (7)
    a. What is the net magnetic flux out of this sphere? [Hint: start with the relevant equation] (4)
    $\nabla \bullet B = 0$ (2)
    0 (2)

    b. In what case would you find a different value for the question above? (3)
    Some mention of a non-closed surface, magnetic monopole, or other case where magnetic flux would be non-zero. (3)

52. An electromagnetic wave is described by the function $f(t) = C \sin sin\, kt$ , where *C* = 13.87 m and *k* = 435.31 MHZ. (7)
    a. What is the amplitude of this wave? (2)
    13.87 (1) m (1)

    b. What is the frequency of this wave? (2)
    69.282 (1) MHZ (1) or equivalent

    c. What portion of the EM spectrum is this? (2)
    Radio (2)

    d. Could this possibly describe a radio signal? (1)
    Yes (1)

53. An electric field is described by the function **E**(*x,y*). (7)
    a. Find the charged enclosed within the closed region *C* if $\oint E \cdot dA = 3.171 \times 10^{-3}$.

    (3)

$\oint E \cdot dA = \frac{q}{\epsilon_0}$ (1)

2.808e-14 (1) C (1)

b. Assume that the field is generated by a point at the center of the region. What will be the magnitude of the field at a distance of 12 m from the point? (4)

$E = \frac{kq}{r^2}$ (2)

1.753e-6 (1) N/C or V/m (1)

54. An electromagnetic wave is found to have a frequency of 4.31 kHz. (7)

a. What is the wavelength of this wave? (2)

v = fλ (1)

6.961e4 m (1)

b. What portion of the EM spectrum is this? (2)

Radio (2)

c. What is the energy of a photon with this frequency and wavelength? (3)

E = hf (1)

2.856e-30 (1) J (1) or equivalent

55. The Poynting vector describes the rate of energy transport of an electromagnetic wave. It can be simplified to the form of $S = \frac{1}{\mu_0} EB$. (7)

a. Find *S* if $E = 4.381 \times 10^2$ N/C and $B = 3.976 \times 10^4$ T. (3)

1.386e13 (1) W (2) or equivalent

b. Over the course of 4 hr, how much energy will be conveyed if these fields maintain their magnitudes? (2)

1.996e17 (1) J (1) or equivalent

c. The value of *S* remains constant, but now the magnetic field $B = 9.781 \times 10^1$ T. What is the magnitude of *E*? (2)

1.781e5 (1) N/C or V/m (1) or equivalent

## Extra Tiebreakers

The wave equation for plane electromagnetic waves in one direction is given as:

$$\frac{\partial^2 E}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 E}{\partial t^2}$$

56. What form does a solution to this equation take? **(TB #1)**
    a. $E = Ae^{kx-\omega t}$
    b. $E = A(kx - \omega t)^2$
    **c.** $E = A \sin sin\,(kx - \omega t)$
    d. $E = A\sqrt{kx - \omega t}$

57. The impedance of an electromagnetic wave is somewhat similar to what property of electrical systems? **(TB #2)**
    **a. Resistance**
    b. Current
    c. Voltage
    d. Inductance