WiFi Lab C

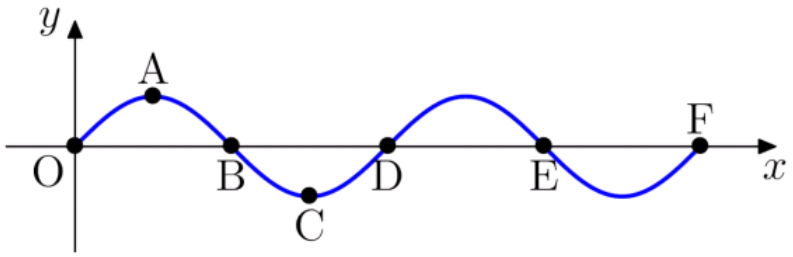
BirdSO 2022 Mini

December 11th-18th, 2021

Directions:

- Make sure you express your answers in the correct units.
- For fill in the blank questions, do not include units or any commas/spaces in your answer.
- Do not round intermediate results as that might change your final answer.
- Use the exact speed of light in your calculations.

Use the following diagram of a wave for the next 3 questions.



1. (3 points) The vertical distance between which of the following pairs of points is the amplitude of the wave?

   √ **O and A**

   ◯ O and B

   √ **O and C**

   ◯ A and C

   √ **B and C**

   ◯ B and D

2. (3 points) The horizontal distance between which of the following pairs of points is the wavelength of the wave?

   ◯ O and A

   ◯ O and B

   ◯ O and C

   √ **O and D**

   ◯ A and C

   √ **B and E**

3. (3 points) If we interpret the x-axis of the diagram as time instead of distance, what property of the wave is represented by the interval between points D and F? Your answer should be a single word.

   period

4. (3 points) What is the difference between the speed of light in a vacuum and the speed of light in air? Assume that the index of refraction of air is 1.000273. Express your answer in m/s to the nearest whole number.

   81821

5. (2 points) If the period of a wave is 2 s, what is its frequency in Hertz?

   A. 0 Hz

   B. 0.25 Hz

   C. 0.5 Hz

   D. 1 Hz

   E. 2 Hz

   F. 4 Hz

6. (3 points) What is the wavelength of a 98.6 MHz radio wave travelling in a vacuum? Express your answer in cm to the nearest whole number.

   304

7. (3 points) A radio wave is produced by an oscillator with a period of 0.3 s. What is the wavelength of the resulting wave? Express your answer in kilometers to the nearest whole number.

89938

8. (2 points) What is the relative phase of the magnetic field with respect to the electric field in a radio wave?

A. 180° behind

B. 90° behind

C. 0°

D. 45° ahead

E. 90° ahead

F. 180° ahead

9. (2 points) What is the angle between the oscillations of the electric field and the magnetic field in an electromagnetic wave?

A. 0°

B. 45°

C. 90°

D. 135°

E. 180°

F. It can vary depending on the wave

10. (4 points) Describe how circularly polarized radiation can be created using only dipole antennae.

Solution: Two identical perpendicular dipoles fed 90° apart.

11. (3 points) Which of the following characteristics of an antenna made from linear, reciprocal materials are the same whether the antenna is transmitting or receiving?

√ **gain**

√ **radiation pattern**

√ **bandwidth**

√ **resonant frequency**

√ **directivity**

√ **impedance**

12. (3 points) What is the real impedance of an ideal half-wave dipole? Express your answer in ohms to the nearest whole number.

73

13. (4 points) Express the intrinsic impedance of free space in terms of the constants of vacuum permittivity and vacuum permeability.

Solution:

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}}$$

14. (3 points) What is the gain of a short dipole? Express your answer in dBd to the nearest hundredth.

-0.39

15. (4 points) Suppose that an antenna were constructed that emits its power at constant intensity over a solid angle of 2.094 sr. What is the directivity of the antenna? Express your answer in dBd.

Solution: $4\pi/2.094 = 6$, $10 \log 6 - 2.15 = 5.63$ dBd.

16. (4 points) Suppose the antenna in the previous question were constructed by taking an isotropic antenna and surrounding it with perfectly absorbent material on all sides except for a circular cutout of 2.094 sr. What would the gain of this antenna be? Express your answer in dBd.

Solution: -2.15 dBd

17. (3 points) Suppose that an alphabet with 64 characters was used to construct 23-character messages. Assuming that all messages appear with equal probability, how many bits of information are in each message? Express your answer in bits to the nearest whole number.

138

18. (3 points) Which of the following types of antenna are monopole antenna?

- ◯ Yagi-Uda
- ◯ Turnstile
- √ **Inverted F**
- ◯ Microstrip
- √ **Umbrella**
- √ **Whip**

19. (4 points) What allows low frequency waves to function well as ground waves?

Solution: Ground propagation works because lower-frequency waves are more strongly diffracted around obstacles due to their long wavelengths, allowing them to follow the Earth's curvature.

20. (3 points) What is the name of the region in Earth's atmosphere where skywaves are reflected?

ionosphere

21. (2 points) What type of antenna is shown in this image?

A. Yagi-Uda

B. Mast radiator

C. Reflective Array

D. Turnstile

E. Sector

F. Corner reflector

22. (1 point) True or false: An omnidirectional antenna is synonymous with an isotropic antenna.

A. True

B. False

23. (2 points) To what class of the electromagnetic spectrum does a wave with a wavelength of 0.5 mm belong to?

A. Visible

B. Radio

C. Gamma

D. Ultraviolet

E. Microwave

F. Infrared

24. (3 points) What is the energy of a single photon with a wavelength of 10 cm? Express your answer in μeV to the nearest whole number.

12

25. (4 points) Explain a disadvantage of the high-band millimeter waves that can be used in 5G.

Solution: mmWave has a limited range and is readily impeded by materials commonly present in buildings. Thus, they require many small cells and are only currently feasible in dense urban environments.

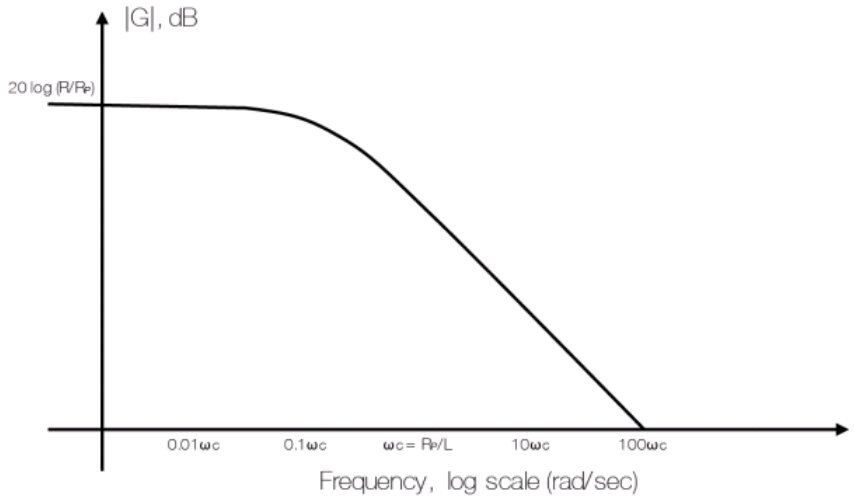
26. (4 points) Why is directly connecting a coaxial cable to a dipole antenna not advisable?

Solution: Coaxial cables are unbalanced lines, as the shield connector is grounded. Dipoles require balanced lines, as otherwise the currents along the two conductors of the dipole will not be equal and opposite. Furthermore, the cable can begin to operate as an antenna, which can greatly affect the radiation pattern and alter the impedance.

27. (3 points) What is the name of the electrical device that can be used to remedy the problem from the previous question? Your answer should be a single word.

balun

The following four questions reference the gain plot shown below.



28. (3 points) Which of the following statements about the figure above are true? Select all that are true.

- ◯ The gain plot shows no filtering characteristics.
- √ **The frequency response shown could be used for low-pass filtering.**
- ◯ The gain plot shows ideal response around its cutoff frequency.
- √ **This could be used for high-frequency noise reduction.**

29. (2 points) For the frequency response shown in the graph above, what is the bandwidth? Answer in terms of ω_c, the cutoff frequency.

A. $0.01\omega_c$

B. $0.1\omega_c$

C. ω_c

D. $10\omega_c$

E. $100\omega_c$

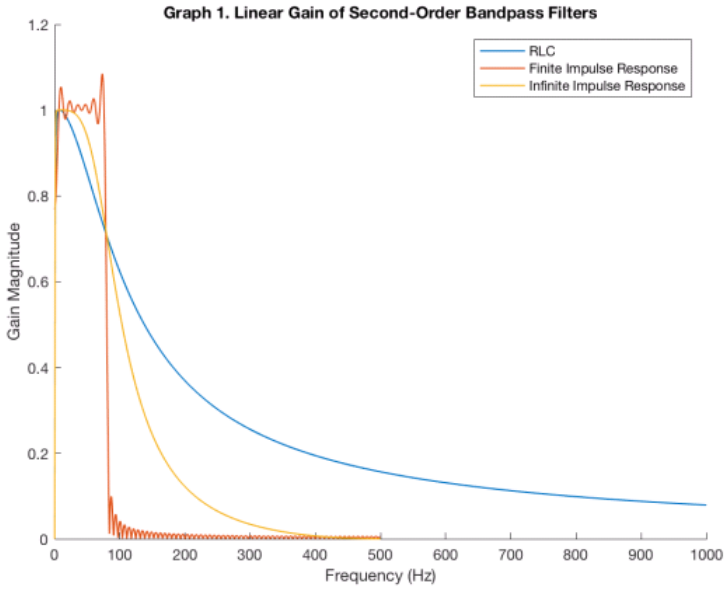
30. (4 points) The gain equation for the plot above is given by $|G| = 20\log(R/R_p)$. What is the significance of the value -3 dB? At what frequency is this observed?

Solution: Gain of -3 dB indicates signal is attenuated by factor of 2 (i.e. halved). This occurs at the cutoff frequency, ω_c.

31. (4 points) What is the significance of the figure -20 dB per decade?

- ◯ It is the expected loss in signal experienced by radio antennas as they age
- √ **It is the roll off beyond the cutoff frequency**
- √ **It is the slope of the linear portion of the gain plot when plotted on a logarithmic scale**
- ◯ It is the expected gain for filtered frequencies
- ◯ It corresponds to the threshold of pain for acoustic frequencies

The following two questions reference the gain plot for three filters, one analog (RLC) and two digital (FIR and IIR) modeled in MATLAB.



32. (3 points) Which of the following is/are the bandwidth for these filters? Select all that are correct.

- ◯ 0.12 dB
- ◯ 1.00 dB
- ◯ 1.00 dB
- √ **79.2 Hz**
- ◯ 500 Hz

33. (4 points) Briefly discuss the trade-offs of using an analog filter (in the RLC case) and using a digital filter (in the FIR and IIR cases). Keep your answer very brief, you are welcome to use bullet points, but be sure to mention both analog and digital.

Solution: Analog: fast (being done by hardware), typically greater dynamic range and frequency range, easy to design, but requires physical space and physical components that cannot be altered with just digital changes (need to replace components). Digital: can be advanced and specialized, requires less hardware, significantly slower than analg and cannot handle large frequency ranges.

34. (3 points) Which of the following is/are effective ways for increasing a signal-to-noise ratio?

- ◯ Linearly amplifying the received signal
- √ **Applying an analog frequency-based filter**
- √ **Digitally processing a signal after it is received**
- √ **Changing the physical components use to receive the signal**
- √ **Changing the environment in which a signal is received**
- ◯ Narrowing the measurement range for the receiver

35. (4 points) Give two examples of materials or components that will cause the reciprocal property of an antenna to not hold.

Solution: Non-reciprocal materials such as ferrite are used in some antennas as isolators and circulators.

36. (4 points) Suppose a weighted coin has a 2/3 chance of landing on heads and a 1/3 chance of landing on tails when flipped. What is the entropy in each coin flip?

Solution: 0.918 bits

37. (3 points) How long does it take a radio wave to travel 1000 km? Express your answer in µs to the nearest whole number.

3336

38. (3 points) Suppose you want to construct a half-wave dipole antenna to transmit at 93 MHz. What should the length of each arm of the antenna be? Express your answer in cm to the nearest whole number.

81

39. (2 points) In a Yagi-Uda antenna, how many of the arms are driven by a current?

A. 0

B. 1

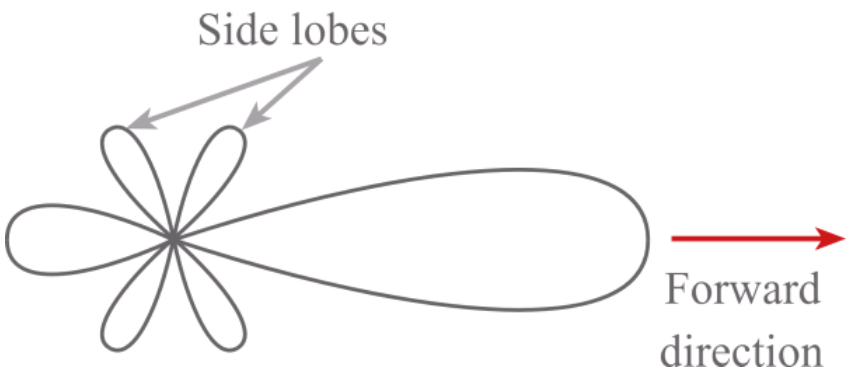
C. 2

D. 3

E. Half of them

F. All of them

40. (3 points) The following diagram shows the radiation pattern of a Yagi-Uda antenna. What physical phenomenon leads to the decrease in the radiation intensity in the backwards direction? Your answer should consist of two words.



destructive interference

41. (4 points) For an antenna whos frequency must be adjustable, is a narrower or a wider bandwidth preferred? Explain your answer.

Solution: Wider, as it will still operate at high gains off the peak frequency.

42. (2 points) The electric field in the far field of a radiator is proportional to which of the following? r represents the distance from the radiator.

A. $1/r^3$

B. $1/r^2$

C. $1/r$

D. 1

E. r

F. r^2

43. (3 points) What is the impedance of free space? Express your answer in ohms to the nearest whole number.

377

44. (3 points) What is the magnitude of the impedance of an ideal half-wave dipole? Express your answer in ohms to the nearest whole number.

85

45. (4 points) In especially noisy communication channels, when receiving information, bits can be misinterpreted, resulting in errors. Consider a message of length m bits. After being transmitted, each bit has a probability p in being misinterpreted as the wrong bit (0 to 1, 1 to 0). To increase redundancy, the same message can be sent three times. How can these three messages be interpreted to produce the original message.

Solution: Take the most common bit in each index of the three messages. (This assumes that $p < 0.5$)

46. (4 points) Given the strategy in the previous question, what is the probability that the message is interpreted correctly in terms of m and p?

Solution: $((1-p)^3 + 3p(1-p)^2)^m$

47. (3 points) What is the code rate of the error-correcting strategy above?

Solution: 1/3

48. (4 points) Interleaving is often used to improve error correcting codes, like the one above. When this is implemented, what assumptions must be made about the nature of the errors?

Solution: The errors are made in bursts, rather than individual bits. That is, the probability that adjacently transmitted bits are misinterpreted are not independent.

49. (3 points) What is the adjustment factor for a half-wave dipole antenna if the diameter of the conductor is 1/1000 times the wavelength? Express your answer to the nearest hundredth.

0.96