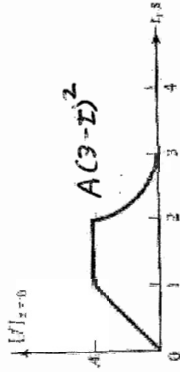
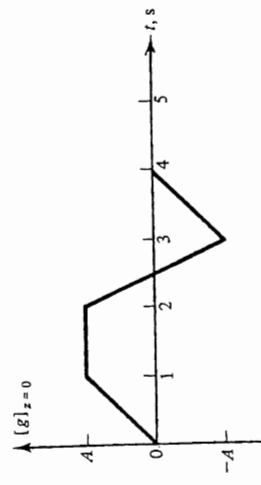


ECE341 EMC Homework #5

- 1) For each of the following traveling wave functions, find the velocity of propagation both in magnitude and direction.
- a) $(t - 0.1y)^2$ (b) $e^{j0.02z + t}$ (c) $[\sin(5x - 1000t)]^2$
 Answers: (10i, m/s, -50i, m/s, 200i, m/s)
- 2) The time variation for $z = 0$ of a traveling wave function $f(z,t)$ representing a traveling wave propagating in the +z direction with a velocity of 200 m/s is shown below. Find the value of the function for each of the following cases:
- a) $z = 300$ m, $t = 1.9$ s b) $z = 400$ m, $t = 1.9$ s c) $z = 300$ m, $t = 2.9$ s
 d) $z = -400$ m, $t = 0.90$ s e) $z = -600$ m, $t = -0.9$ s
- Hint: Consider, for example, Problem (2a). You are given the function vs. t for $z = 0$, so plot the wave function vs. t for $z = 300$ m (Do this by shifting the entire plot to the right by 1.5 s), then read off the value corresponding to $t = 1.9$ s.
 Answers: (0.4A, 0, A, 0.01A, 0.81A)



- 3) The time variation for $z = 0$ of a function $g(z,t)$ representing a traveling wave propagating in the -z direction with velocity magnitude of 300 m/s is shown in the figure below. Find the value of the function for each of the following cases:
- (a) $z = 150$ m, $t = 0.3$ s (b) $z = 150$ m, $t = 2.3$ s
 (d) $z = -300$ m, $t = 2.3$ s (e) $z = -600$ m, $t = 5.3$ s
 Answers: (0.8A, -0.6A, 0, A, -0.7A)



- 4) (a) Plot the "g" wave from Problem 3 as a function of distance at the fixed time $t = 2$ s. Remember this wave is traveling in the -z direction with a velocity magnitude of 300 m/s.
 (Partial answer: your plot should show that $g(2s, 300m) = -4$)
 (b) Now assume the "g" wave is traveling in the +z direction with the same velocity magnitude. Once again plot the wave as a function of distance at the fixed time $t = 2$ s.
 (Partial answer: your plot should show that $g(2s, -300m) = -4$.)
- 5) Fill in the blanks in the Radio Frequency Classification Table below, assuming radio wave propagation in air (free space):

Designation	Frequency Range	Wavelength Range
ELF (Extremely Low Frequency)	30 - 30000 Hz	10,000 - 100 km
VLF (Very Low Frequency)	3 - 30 kHz	
LF (Low Frequency)	30 - 300 kHz	
MF (Medium Frequency)		1000 - 100 m
HF (High Frequency)		100 - 10 m
VHF (Very High Frequency)	30 - 300 MHz	
UHF (Ultra-High Frequency)	300 - 3000 MHz	
Microwaves		
Millimeter Waves		30 - 1 cm
		10 - 1 mm

- 6) A uniform plane electromagnetic wave propagating in free space has the following electric field intensity (note that the axes have been rotated from the orientation used to derive the plane wave in class.)

$$\mathbf{E} = 37.7 \cos(9\pi \times 10^7 t + 0.3\pi y) \mathbf{i}_x \text{ V/m}$$

- Find: (a) the frequency in MHz of the E field observed by a fixed observer in space
 (b) the wavelength (c) the direction of propagation of the wave
 (d) the associated magnetic field intensity \mathbf{H}
 Answers: (45 MHz, 6.667 m, -i direction, $0.1 \cos(9\pi \times 10^7 t + 0.3\pi y) \mathbf{i}_z$ A/m)

- 7) Consider an EM wave traveling in the +z direction with $\mathbf{E} = A \cos(\omega t - \beta z) \mathbf{i}_x$. Show that the frequency observed by an observer moving at speed " v_{obs} " along the z axis in the +z direction is given by $\omega_{observed} = \omega(1 - v_{obs}/v_p)$, where $v_p = \omega/\beta = 1/\sqrt{\mu\epsilon}$ = wave velocity in the medium. The difference between the source frequency ω and the frequency observed by a moving observer is called the Doppler-Shift, $\omega(v_{obs}/v_p)$. (Hint: Recall that frequency is the time rate of change of the argument (phase) of the cosine function in the given E field expression. At a fixed point in space, z is a constant, and so the observed angular frequency is simply ω . But in this case, the observer is moving, so z is no longer a constant, and we must replace z by " $z_0 + v_{obs}t$ ", and differentiate the phase of the cosine function with respect to time.)

- 9) For a police radar gun operating at a frequency of 30.0000000 GHz, find the (Doppler-shifted) frequency received at a speeding car that is traveling directly toward the police radar gun at 30 m/s. Repeat if the speeding car is traveling directly away from the police radar gun at 30 m/s.
 (Answers: 30.0000003 GHz, 29.9999997 GHz)

- 10) Text Problem 3-24 (p. 118) **B6.3 (p. 937)**
 11) Text Problem 3-26 (p. 118) **B6.9 (p. 938)**
 11) Text Problem 3-27 (p. 119) Consider ONLY the following two cases: 1 MHz (AM broadcast frequency) and 100 MHz (FM broadcast frequency). Hint: Since the wave attenuates as $e^{-\alpha z}$, the most accurate formula for skin depth δ is $1/\alpha$, where α is the real part of the propagation constant γ that is calculated directly from its definition, without any approximation being made.

B6.9 (p. 938)