Part I. [29 points] The transverse displacement of a traveling harmonic wave on a stretched rope is \( D(x,t) = 0.03 \cos(3.4x - 6.8t) \), where \( x \) and \( y=D(x,t) \) are in meters and \( t \) is in seconds.

1. [3 points] What is the amplitude of this wave?
   A. 0.03 m
   B. 0.06 m
   C. 3.4 m
   D. 6.8 m
   E. 6.8 m

2. [3 points] What is the wavelength of this wave?
   A. 0.29 m
   B. 0.92 m
   C. 1.9 m
   D. 105 m
   E. 209 m

3. [3 points] What is the speed with which this wave travels?
   A. 0.32 m/s
   B. 1.0 m/s
   C. 2.0 m/s
   D. 113 m/s
   E. 227 m/s

4. [3 points] In what direction is this wave propagating?
   A. \(+x\)
   B. \(-x\)
   C. \(+y\)
   D. \(-y\)
   E. None of the above

5. [3 points] What is the frequency (NOT the angular frequency) of this wave?
   A. 0.00475 Hz
   B. 0.0095 Hz
   C. 0.54 Hz
   D. 1.1 Hz
   E. 6.8 Hz
6. [3 points] Consider the piece of rope located at x = 2 m. What is the velocity \( v \) of this piece of rope at the time \( t = 3 \) s in the \( x \) direction?
   
   A. \(-0.18\) m/s  
   B. \(-0.03\) m/s  
   C. \(0.0\) m/s  
   D. \(0.015\) m/s  
   E. \(0.20\) m/s  

7. [4 points] And in the \( y \) direction?
   
   A. \(-0.18\) m/s  
   B. \(-0.03\) m/s  
   C. \(0.0\) m/s  
   D. \(0.015\) m/s  
   E. \(0.20\) m/s  

8. [4 points] Consider the piece of rope located at x = 2 m. What is the acceleration of this piece of rope at the time \( t = 3 \) s?
   
   A. \(-0.71\) m/s\(^2\)  
   B. \(-0.18\) m/s\(^2\)  
   C. \(0.0\) m/s\(^2\)  
   D. \(0.016\) m/s\(^2\)  
   E. \(0.71\) m/s\(^2\)  

9. [3 points] If the tension in the rope were increased by a factor of 3, how would the wave speed change?
   
   A. The wave speed would increase by a factor of 3.  
   B. The wave speed would decrease by a factor of 3.  
   C. The wave speed would increase by a factor of \( \sqrt{3} \)  
   D. The wave speed would decrease by a factor of \( \sqrt{3} \)  
   E. The wave speed would not change.
Part II. [21 points] Consider a guitar string, 50 cm long. Its left most end is at $x=0\ m$.

10. [3 points] What is the wavelength of the first excited mode (natural mode)?
   A. 25 cm
   B. 50 cm
   C. 100 cm
   D. 125 cm
   E. 150 m

11. [3 points] What is the wavelength of the second excited mode?
   A. 25 cm
   B. 50 cm
   C. 100 cm
   D. 125 cm
   E. 150 m

The string is under 75 N of tension, and has a mass per unit length of 20 g/m.

12. [4 points] What is the natural frequency, $f_1$?
    A. 1.94 Hz
    B. 3.87 Hz
    C. 40.8 Hz
    D. 61.2 Hz
    E. 122 Hz

13. [3 points] What is the second natural frequency, $f_2$?
    A. 1.94 Hz
    B. 3.87 Hz
    C. 40.8 Hz
    D. 61.2 Hz
    E. 122 Hz

14. [4 points] Which of the following is the most accurate mathematical description of the guitar string’s oscillation in the second excited mode (assume $D_M$, $k$, and $\omega$ are set to the correct values)?
    A. $D(x,t) = D_M \sin(kx + \omega t)$
    B. $D(x,t) = D_M \sin(kx - \omega t)$
    C. $D(x,t) = D_M \cos(kx - \omega t)$
    D. $D(x,t) = D_M \sin(kx)\cos(\omega t)$
    E. $D(x,t) = D_M \cos(kx)\sin(\omega t)$
Two guitar strings are placed next to each other. The first one resonates at 2010 Hz, and the second one at 2020 Hz.

15. [3 points] What is the beat frequency?
   A. 5 Hz
   B. 10 Hz
   C. 2010 Hz
   D. 2015 Hz
   E. 4030 Hz

16. [3 points] The frequency that best represents the tone you would hear?
   A. 5 Hz
   B. 10 Hz
   C. 2010 Hz
   D. 2015 Hz
   E. 4030 Hz

17. [4 points] Consider an open tube 100 cm long. Pick the picture that best represents the displacement of the air particles in a tube oscillating in its second harmonic mode.

   A)  
   B)  
   C)  
   D)  
   E)  

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Part III. [25 points] The two speakers emit a sound with pitch $f$ (units Hz). The two speakers are in phase. The speakers are placed at $+d$ and $-d$. The speed of sound is $v$.

18. [5 points] Closest point to $x=0$, on the $x$-axis, that you can stand and get constructive interference? Destructive interference? Express your answers in terms of the quantities given.

19. [10 points] The sound level at $x=0$ is measured to be 10 db due to the two speakers. At a nearby point, $x=x_m$, the sound level due to the two speakers is measured to be 0 db. Calculate the ratio of amplitudes of the interfering sound wave at $x=0$ and the point $x_m$, $D_0/D_{x_m}$.

20. [10 points] Determine an expression for $x_m$ in terms of the quantities given.