Practice Midterm 1 – Solutions

written response

1. Briefly explain why the Doppler formula can not be correct in general. Why do we learn incorrect equations?

Think of $f_o = f_s/(1 - v_s/v)$. This goes to infinity at $v = v_s$ which doesn't make any sense. What happens in fact is that a shock wave is created. We use this equation anyway because it is accurate for v_s much less than v which is a common situation.

partial credit questions

2. A string is kept under tension by attaching a weight of mass M to one end and hanging it over a massless pulley. If the mass M is doubled what happens to the fundamental frequency of oscillation of the string? What happens to it if 1/2 of the mass is immersed in syrup. Assume that the density of the syrup is 30

If the mass is doubled the tension on the string doubles and because $v = \sqrt{TL/m}$ the speed of sound in the string goes up by $\sqrt{2}$ and because $f_1 = v/2L$, the fundamental frequency goes up by $\sqrt{2}$ as well.

If 1/2 of the mass is dipped in syrup, there is an additional bouyancy force of magnitude $B = 1/2V(\rho_{mass} - \rho_{syrup})g = 1/2V\rho_{mass}0.7 = 0.35Mg$. Thus the new tension is $T = Mg - 0.35Mg = 0.65Mg = 0.65T_{old}$. Finally the fundamental frequency goes down to $\sqrt{0.65}$ = 0.81 % of its former value.

3. Two charges with $q = +4\mu C$ are placed at $\pm 2cm$ from the y-axis. A third charge with $q = -6nC$ is placed 6 cm up the positive y-axis. Determine the magnitude and direction of the total force on the third charge.

Call on of the $4\mu C$ charges 1. The magnitude of force of 1 on 3 is given by Coulomb's Law and is 0.0539 N acting down and to the left (or right). The angle this force vector makes with respect to the vertical is given by $\tan\theta = 2/6$ and the total force vector is directed downwards ($-\hat{y}$) with magnitude $2\cos\theta 0.0539 = 0.102$ N.

multiple choice questions

4. You hear a sound with a wavelength of 30 cm. Assuming that the speed of sound is 343 m/s, what is the frequency of the sound wave?

a. 10300 Hz
b. 114300 Hz
c. 103 Hz
d. 1143 Hz *Use $v = \lambda f$ and convert 30 cm to 0.3 m.*

5. If the air temperature is doubled in the above example what happens to the wavelength and the frequency? Assume that air is an ideal gas.

a. wavelength doubles, frequency stays the same
b. wavelength goes up by $\sqrt{2}$, frequency stays the same *The formula $v = \sqrt{\gamma kT/m}$ implies that v goes up by $\sqrt{2}$. This implies that λf goes up by $\sqrt{2}$. But our discussion on diffraction implies that f cannot change, so λ goes up by $\sqrt{2}$.*
c. wavelength goes up by $\sqrt{2}$, frequency goes up by $\sqrt{2}$
d. wavelength stays the same, frequency goes up by 2
e. wavelength stays the same, frequency goes up by $\sqrt{2}$

6. Use Gauss's Law to determine the electric field at a radius r from the axis of a hollow conductor of charge λ C/m. The tube has radius a and you should take $r > a$.

a.

$$\frac{\lambda}{4\pi\epsilon_0 r^2}$$

b.

$$\frac{\lambda}{2\pi\epsilon_0 r}$$

Place a cylindrical Gaussian surface around the tube a distance r from its axis. The flux through this tube (ignoring end caps) is $\Phi_E = E(r)\cdot\cos(180)A = E(r)2\pi rL$ where L is the length of the tube. This equals $\lambda L/\epsilon_0$ and solving for E gives (b).

c.

$$\frac{\lambda}{\epsilon_0}$$

d.

$$\frac{\lambda a^2}{4\pi r^3}$$

7. Two microphones pick up a sound wave and transmit the sound to a speaker in the lab. One of the microphones is thrown towards to the sound source at 10 m/s. If the speed of sound is 343 m/s and the source frequency is 1200 Hz, what beat frequency is heard in the lab?
a. 25 Hz
b. 1235 Hz
c. 50 Hz
d. 35 Hz *The moving mike picks up a Doppler shifted sound at frequency* $f_o = f_s(1 + v_o/v)$. *The beat frequency is then* $f_b = f_s - f_o = 35$ *Hz.*

8. A 5000 Hz tone is produced by a speaker which is moving towards a wall at 43 m/s. The wall has a hole of diameter 10 cm in it. What is the diffraction angle of the wave as it passes through the hole? Use $v = 343$ m/s for the speed of sound.
a. 11 deg
b. 23 deg
c. 47 deg *We know* $\sin\theta = 1.22\lambda/D = 1.22v/(fD)$. *Use the Doppler shift formula* $f_o = f_s/(1 - v_s/v)$ *to get* $\sin\theta = 1.22(v - v_s)/(f_s D) = 0.732$.
d. 57 deg

equations

$v = \lambda f \qquad v = \sqrt{TL/m} \qquad v = \sqrt{B_{ad}/\rho} \qquad v = \sqrt{Y/\rho}$

$y = A\sin(2\pi f t \pm 2\pi x/\lambda) \qquad I = P/A \qquad \beta = (10db)\log(I/I_0)$

$f_o = f_s \frac{v \pm v_o}{\mp v_s} \qquad \sin\theta = \lambda/D \qquad \sin\theta = 1.22\lambda/D \qquad f_n = \frac{nv}{2L}$

$F = \frac{|q_1||q_2|}{4\pi\epsilon_0 r^2} \qquad \epsilon_0 = 8.85\cdot 10^{-12} \qquad |q_e| = 1.6\cdot 10^{-19}C$

$E = F/q_0 \qquad E = \sigma/\epsilon_0 \qquad \Phi_E = \int E\cos\phi dA = Q/\epsilon_0$