1. A sound wave traveling in air \((v_{\text{sound}} = 344 \text{ m/sec})\) refracts into a solid wall \((v_{\text{sound}} = 1000 \text{ m/sec})\). Which of the following is true about the refracted wave, compared to the original wave?

A) longer wavelength and lower frequency  
B) longer wavelength and same frequency  
C) shorter wavelength and higher frequency  
D) same wavelength and same frequency

2. In a sound wave traveling in air, what is the distance between a point of maximum pressure and a point of maximum particle displacement?

A) \(\frac{1}{4}\) wavelength  
B) \(\frac{1}{2}\) wavelength  
C) 1 wavelength  
D) zero

3. Why is the total electric field zero inside a conducting material? (choose the best description)

A) There are no free electrons to move around.  
B) The electric potential has a large gradient.  
C) The induced electric field is equal in magnitude to the external electric field.  
D) The potential energy is maximized when the electric field is zero.

PROBLEMS 4-6 REFER TO THE SITUATION DRAWN BELOW.

Speaker 1 and speaker 2 are separated by 2.00 meters. They emit identical sound wave signals at a frequency of 344 Hz. A listener at point P is 1.50 meters in front of speaker 2. Use \(v_{\text{sound}} = 344 \text{ m/sec}\)

4. How many decibels louder does the listener hear speaker 2 compared to speaker 1?

A) 1.20 dB  
B) 4.55 dB  
C) 7.36 dB  
D) 9.84 dB

5. The listener slowly walks 10 meters directly away from the speakers, then back to point P. Which of the following describes what is heard during the walk?

A) always constructive interference  
B) always destructive interference  
C) alternating regions of constructive and destructive interference  
D) a beat frequency of 688 Hz

6. With the listener standing still at point P, speaker 1 now moves directly away from the listener at a speed of 10 m/sec. Speaker 2 is standing still. What is the beat frequency heard by the listener?

A) 2.6 Hz  
B) 5.3 Hz  
C) 7.2 Hz  
D) 9.7 Hz
PROBLEMS 7-9 REFER TO THE SITUATION DRAWN BELOW.

Three point charges (two \(+1\, C\) and one \(-1\, C\)) are arranged in an equilateral triangle such that each charge is 1 meter from the other two. Point P lies at the midpoint between the two positive charges.

7. What is the net force on the positive charge which is NOT at the origin?

A) \((4.5\hat{i} + 7.8\hat{j}) \times 10^9\, N\)  
B) \((2.2\hat{i} + 6.4\hat{j}) \times 10^9\, N\)  
C) \((3.3\hat{i} - 5.8\hat{j}) \times 10^9\, N\)  
D) \((6.0\hat{i} + 3.2\hat{j}) \times 10^9\, N\)

8. What is the total potential energy of the system of charges? (assume \(U=0\) at infinite charge separation, as usual)

A) \(2.7 \times 10^{10}\, J\)  
B) \(9.0 \times 10^9\, J\)  
C) \(-9.0 \times 10^9\, J\)  
D) \(-2.7 \times 10^{10}\, J\)

9. What is the electric field at point P due to all 3 charges?

A) \(5.0\hat{j} \times 10^9\, N/C\)  
B) \(1.2\hat{j} \times 10^{10}\, N/C\)  
C) \(3.6\hat{i} \times 10^9\, N/C\)  
D) \(4.5\hat{i} \times 10^{10}\, N/C\)

PROBLEMS 10-12 REFER TO THE SITUATION DESCRIBED BELOW.

A guitar string has a mass of 10 grams and length 60 centimeters. It is stretched to a tension of 500 N.

10. What is the fundamental frequency of this guitar string?

A) 82 Hz  
B) 144 Hz  
C) 163 Hz  
D) 203 Hz

11. Which of the following equations describes a standing wave on the guitar string?

A) \(y(x,t) = A [\sin(kx) + \sin(\omega t)]\)  
B) \(y(x,t) = A \sin(kx - \omega t)\)  
C) \(y(x,t) = A \sin(kx+\omega t)\)  
D) \(y(x,t) = A \sin(kx) \sin(\omega t)\)

12. A guitar player wants to tune another (identical) string to a note which has double the frequency of the first string. How much tension is required in the new string?

A) 250 N  
B) 707 N  
C) 1414 N  
D) 2000 N
PROBLEMS 13-14 REFER TO THE SITUATION DESCRIBED BELOW.

A point charge \((+1 \text{C})\) lies at the center of a hollow spherical shell. The spherical shell has an inner radius of \(1.0 \text{ meters}\) and an outer radius of \(2.0 \text{ meters}\), has a net charge of \(+3 \text{C}\) and is made of conducting material.

13. What is the surface charge density of the outer surface of the spherical shell?
   A) 0.060 C/m\(^2\)   B) 0.080 C/m\(^2\)   C) 0.100 C/m\(^2\)   D) 0.120 C/m\(^2\)

14. What is the voltage difference between the inside and outside surfaces of the spherical shell?
   A) 0.0 V   B) 1.0 V   C) \(4.5 \times 10^9 V\)   D) \(9.0 \times 10^9 V\)

PLEASE HAVE YOUR PICTURE I.D. READY WHEN YOU TURN IN THE EXAM.

FORMULA

\[
v = \lambda f \quad I \propto \frac{1}{r^2} \quad \beta = 10 \log_{10} \left( \frac{I}{I_0} \right) \quad f_L = \left( \frac{v + v_L}{v + v_S} \right) f_S
\]

\[
f_{\text{beam}} = |f_1 - f_2| \quad \lambda_n = \frac{2L}{n} \quad \mu = \sqrt{\frac{F}{\mu}}
\]

\[
k = \frac{1}{4 \pi \varepsilon_0} \approx 9.0 \times 10^9 \frac{N \cdot m^2}{C^2} \quad \vec{E} = k \frac{q}{r^2} \hat{r} \quad \vec{V} = k \frac{q}{r}
\]

\[
\vec{E} = -\nabla V \quad \vec{F} = k \frac{q_1 q_2}{r^2} \hat{r} \quad U = k \frac{q_1 q_2}{r}
\]

\[
\Phi_E = \frac{q_{\text{enclosed}}}{\varepsilon_0} \quad \Phi_E = \oint \vec{E} \cdot d\vec{A}
\]