Phys 3 Midterm Solutions (TTh)

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Question 1

In order to find the speed, we look at the arguments of the sine/cosine functions. Consider

$$y = \cos(ax + bt),$$

then the speed of the wave is $|b/a|$. In this question, options I and IV have the same speed.

Question 2

Using the same formula as in Question 1, we can see that the speed of the wave is 38/14 m/s. In order to keep the argument of the cosine function fixed, x must increase as t increases. Hence the wave is travelling in the $+x$-direction.

Question 3

Using $f = 1/T = c/\lambda$, where f is the frequency, T is the period, c is the wave speed, and λ is the wavelength, we find

$$\lambda = 750\text{km/hr} * 12\text{hr} = 9000\text{km}$$

Question 4

First, we want to find the equation of the wave, which can be written as

$$y = A \sin \frac{2\pi(x - ct)}{\lambda},$$

where A is the amplitude, λ is the wavelength, and c is the wave speed. With this, we can differentiate twice with respect to t and find the acceleration. Here λ is given to be 0.7m, and A is given to be $6.7 * 10^{-3}$m. We can find the wave speed using $f = c/\lambda$, which gives $c = 525$m/s.

Putting it all together, we have

$$y = 6.7 * 10^{-3} \sin \frac{2\pi(x - 525t)}{0.7}$$

Then the acceleration is

$$y'' = -6.7 * 10^{-3} * (2\pi * 525/0.7)^2 \sin \frac{2\pi(x - 525t)}{0.7}$$

Since the sine function just varies between 1 and -1, the largest acceleration is just the factor in front, about 149000m/s.

Question 5

Since the air and the guitar string have different mass densities, as well as different stiffness, we would not expect either the velocity or the wavelength to be the same in both media. The coupling between the guitar string and the air depends on many things, including the shape of the guitar, so we would not expect the amplitudes to be equal, either.

Question 6

A pipe closed at one end and open at the other would support the longest possible standing wave. A quarter of a wave would resonate inside the pipe. The closed end would be at a crest/trough of the wave and the open end would be at a node of the wave.

Question 7

The sound intensity level L in decibels is given by

$$L = 10\log_{10}(P/P_0),$$

where $P_0 = 10^{-12}$W. Setting $L = 78$db and solving for P gives $P = 63\mu\text{W/m}^2$. The area of the window is 2m^2, which gives 126μW.

Question 8

As mentioned in Question 6, the fundamental frequency of a tube closed at one end and open at the other corresponds to 1/4 of a wave inside the tube. Since the tube is 1.3m long, we have $\lambda = 5.2$m. To get the speed of the wave, we use $f = c/\lambda$, with $f = 80$Hz.

Question 9

The sound intensity level L in decibels is given by

$$L = 10\log_{10}(P/P_0),$$

where $P_0 = 10^{-12}$W.

Question 10

We can answer this question by process of elimination. The charge q_1 must be chosen to cancel off the x-component of the electric field due to charge Q. Therefore q_1 is positive, and somewhat *less* than 400nC, since q_1 is closer to the origin. Hence the net charge of $Q + q_1$ is negative, and significantly smaller than 400nC.

To make the total field zero at the origin, q_2 must cancel the vertical component of the electric field due to the other two charges. Since q_2 is roughly the same distance from the origin as Q and q_1, and since $Q + q_1$ is negative, and significantly smaller than 400nC, we have to choose answer B.

Alternatively, you could use Coulomb's law.

Question 11

The initial kinetic energy of the electron is

$$K_i = \frac{1}{2} m_e v_0^2,$$

where m_e is the mass of the electron. The electric field is $E = 12 * 10^3$N/C $= 12 * 10^3$V/m. Over the 40mm gap, the electron exchanges

$$\Delta K = -e * 12 * 10^3 * 40 * 10^{-3}\text{J}$$

of kinetic energy with the electric field, where e is the charge of the electron. Hence the final velocity of the electron is

$$v_f = \sqrt{2 * (K_i + \Delta K)/m_e}$$

Question 12

All of the charge placed on the inner conducting sphere will be attracted outwards. None of the charge on the inner sphere can move outwards beyond surface B. Hence we expect 0nC on surface A and -200nC on surface B.

Question 14

The electric potential of a proton is

$$V(r) = \frac{1}{4\pi\varepsilon_0} \frac{e}{r}$$

The change in kinetic energy of the electron is

$$\Delta K = \frac{-e^2}{4\pi\varepsilon_0} \left(\frac{1}{0.09} - \frac{1}{0.03}\right)$$

The change in velocity of the electron is

$$\delta v = \sqrt{2\Delta K/m_e}$$

Question 15

We use Gauss' law:

$$F = A * Q_{encl}/\varepsilon_0$$

where F is the total flux and $Q_{encl} = 40nC$. The area of the sphere is $A = 4\pi * (10^{-3})^2$.

Question 16

Since the electric field is parallel to the curved surface of the cylinder, the electric flux just depends on the fields through the ends of the cylinder:

$$F = A * (E_2 - E_1),$$

where $A = \pi * (0.1)^2$.