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 \(\lambda\) is the wavelength, we find

\[ \lambda = 750\text{km/hr} \times 12\text{hr} = 9000\text{km} \]

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

Putting it all together, we have

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

Then the acceleration is

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

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 $P = 63\mu W/m^2$. The area of the
window is $2m^2$, which gives $126\mu W$.

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 $1.3$m 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 \( E = 12 \times 10^3 \text{N/C} = 12 \times 10^3 \text{V/m} \). Over the 40mm gap, the electron exchanges

\[ \Delta K = -e \times 12 \times 10^3 \times 40 \times 10^{-3} \text{J} \]

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

\[ v_f = \sqrt{2 \times (K_i + \Delta K)/m_e} \]

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

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

The change in velocity of the electron is

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

Question 15

We use Gauss’ law:

\[ F = A \times Q_{encl}/\varepsilon_0 \]

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

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:

\[ F = A \times (E_2 - E_1), \]

where \( A = \pi \times (0.1)^2 \).