Phys 3 Midterm Solutions (MW)

Jonathan Essen

November 9, 2016

Question 1

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

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

then the period of the wave is $|2\pi/b|$. In this question, options I and III have the same period, as well as options II and IV.

Question 2

The speed of a wave on a string is $v = \sqrt{T/\mu}$, where T is the tension and μ is the mass density. If the weight hanging from the string is doubled, $T \to 2T$, then $v \to \sqrt{2}v$

Question 3

Consider again a wave described by

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

then the speed of the wave is $|b/a|$.

Question 4

The pressure waves making up the sound expand out on spherical shells, with the intensity (W/m^2) inversely proportional to the area of the shell. The area of a sphere is proportional to the square of the radius, hence

$$I \propto \frac{1}{R^2},$$

and therefore

$$\frac{I_0}{I_1} = \frac{R_1^2}{R_0^2}$$

We'll say that I_1 is the sound intensity level at 3m from the source, so that $I_1 = 1.1 * 10^{-7}\mathrm{W/m^2}$ and $R_1 = 3$m. Then $R_0 = 4$m and the sound intensity level at 4m from the source is

$$I_0 = I_1 * \frac{R_1^2}{R_0^2} = 1.1 * 10^{-7} * (3/4)^2$$

Question 5

The sound intensity level in W/m^2 is always positive. The sound intensity level L in decibels is given by

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

where P_0 is some reference sound intensity level in W/m^2. If P is smaller than P_0, then L is negative. Therefore the answer is D.

Question 6

A standing wave in a pipe that is open at both ends would have nodes at both ends of the pipe. Therefore the longest standing wave supported by the pipe has wavelength $2L$. An integer number of half-waves must fit within the pipe, so the answer is E.

Question 7

The speed of sound is given by

$$v = \sqrt{\frac{K}{\rho}}$$

where K is the bulk modulus, and ρ is the volume density. Putting in the numbers, $v = 1209$m/s. The length of the pipe is 20m, so the crossing time is

$$t = 20/1209 = 16.5\text{ms}$$

Question 8

As mentioned in Question 4, the pressure waves making up the sound expand outward on spherical shells, with the intensity (W/m^2) inversely proportional to the area of the shell. The total acoustic output, 63μm is uniformly distributed over a sphere of radius 210m, so the sound intensity is

$$I = \frac{63 * 10^{-6}}{4\pi(210)^2}\frac{\text{W}}{m^2} = 114 * 10^{-12}\frac{\text{W}}{m^2}$$

Question 9

The positively charged rod polarizes the spheres, i.e. the electrons collect on sphere X, so that X becomes negatively charged and Y becomes positively charged.

Question 10

According to Coulomb's law, the force of charge q_1 on charge q_2 is proportional to $q_1 * q_2$. Similarly, the force of q_2 on q_1 is proportional to $q_2 * q_1$, which is the same as before.

Question 11

Coulomb's law is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}.$$

We know that $q_1 = 1$, $F = 1$, and $r = 15$. Solving for q_2,

$$q_2 = 15^2 * 4\pi\varepsilon_0 = 25 * 10^{-9}C$$

Question 12

Since line #2 has twice the charge per unit length as line #1, we need to be closer to line #1 in order to experience the same electric field from both lines. This leads us to answer B.

Question 13

Gauss' law is: The total electric flux through a closed surface is proportional to the amount of charge enclosed within the surface.

Answers A, and E don't make sense because Gauss' law refers to the total flux rather than the electric field. Answer B is also incorrect since Gauss' law does not mention any symmetries. Answer C happens to be true, since the electric field inside a conductor is always zero. Answer D is also true, it is quite similar to the statement of Gauss' law above. Either answer (or both) would be enough to get credit for this question.

Question 14

The tension in thread B is equal to the electric force on q_2 minus the weight of the sphere.

From Coulomb's law (see Question 11), the magnitude of the electric force on q_2 is

$$|F_{el}| = \frac{1}{4\pi\varepsilon_0}\frac{(2.0 * 10^{-6}\mathrm{C})^2}{(0.15\mathrm{m})^2} = 1.6\mathrm{N}$$

The magnitude of the gravitational force on sphere 2 is

$$|F_g| = 9.8\mathrm{m/s}^2 * 40 * 10^{-3}\mathrm{kg} = 0.4\mathrm{N}$$

So the tension in the string is 1.6 - 0.4 = 1.2 N.

Question 15

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

Question 16

According to Gauss' law (see Question 13), the total electric flux depends only on the charges present, therefore we can ignore the external electric field.

The electric field due to charge q points radially outward with magnitude

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

Since E is constant over the surface of a sphere (which has constant r), the total electric flux is

$$F = A * E = 4\pi r^2 * E$$

Simplifying, we find

$$F = q/\varepsilon_0 = 2.26 * 10^5 \frac{\mathrm{N\ m^2}}{\mathrm{C}}$$