Exercise sheet 12: Transformer, waves

4/12/2024

We indicate the challenges of the problems by categories I ("warming-up"), II ("exam-level"), III ("advanced"). For your orientation: problems attributed to category II have been or could have been considered for an exam (assuming a specific duration for finding the solution; see comments in the solutions). The exact problem setting cannot be repeated in an exam however.

Exercise 1.

(Transformer/Category I)

A transformer (battery charger) is used to charge ten nickel-cadmium batteries connected in series (total emf of 12.5 V DC). The transformer needs to have a voltage difference $\Delta V_2 = V_{\text{rms},2} = 15.0$ V at its output (secondary coil) to charge these batteries. It uses a step-down transformer with a 200-loop primary coil and $\Delta V_1 = V_{\text{rms},1} = 120$ V in the input.

a) How many loops should there be in the secondary coil?

b) If the charging current is $I_{\text{rms},2} = 16.0$ A, what is the input current $I_{\text{rms},1}$ in the primary coil?

Exercise 2.

(Electromagnetic wave/Category I)

The electric field of an electromagnetic wave is given by $E_x = E_0 \cos(kz + \omega t)$, $E_y = E_z = 0$ in Cartesian coordinates. Determine (a) the direction of propagation and (b) the direction of $\vec{B}$. Hint: for an electromagnetic wave the vectors $\vec{E}$, $\vec{B}$ and propagation vector $\vec{k}$ *must* all be orthogonal to each other, following the right hand rule: $\vec{E}$ - thumb, $\vec{B}$ - pointer finger, $\vec{k}$ - middle finger.

Exercise 3.

(String under tension/Category I)

The wave function for a travelling transverse wave on a string under tension is given in SI units (t in seconds, x in meters, ω in rad/s) as follows: $\vec{\xi}(x,t) = 0.450 \sin(10\pi t - 3\pi x + \frac{\pi}{4})\hat{y}$.

a) What is the speed v of the wave collinear with the x-axis?

b) In which direction does the wave travel?

c) What is the wavelength?

d) What is the frequency?

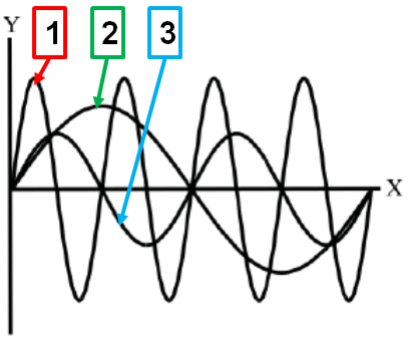
e) What is the vertical position of a mass element dm of the string at $t = 0$ s and $x = 0.100$ m?

f) What is the maximum transverse speed v_y of an element of the string in y-direction?

Exercise 4.

(Waves on different strings/Catgeory I)

The figure shows a snapshot (a photo taken at a given time) of three waves propagating along some strings. The waves come from $-\infty$ and go to $+\infty$. Associate each wave with one of the following expressions:



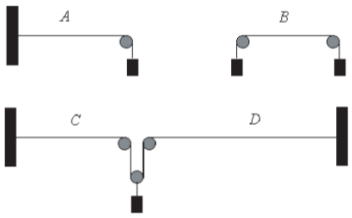
a) $y(x,t) = y_a \sin(2x - 4t)$

b) $y(x,t) = y_b \sin(4x - 8t)$

c) $y(x,t) = y_c \sin(8x - 16t)$

What property do those waves have in common?

Exercise 5.
(Waves on four strings/Catgeory I)



The figure shows four strings A to D. Tension T is applied to them using one or two weights of mass m. Each weight has the same mass m. Strings A,B, and C have the same linear mass density σ_s; string D has a larger mass density σ_l. Order the strings according to the phase velocity v of the waves that propagate along them. Start with the largest velocity.