Answer on Question 56892, Physics, Mechanics, Relativity

Question:

The outer edge of the grooved area of a long-playing record is at a radial distance $36cm$ from the center; the inner edge is at a radial distance of $15cm$. The record rotates at $6.7\,rev/min$. The needle of the pick-up arm takes 2.3 minutes to move uniformly from the outer edge to the inner edge.

a) What is the radial speed of the needle?

b) What is the speed of the outer edge relative to the needle?

c) What is the speed of the inner edge relative to the needle?

d) Suppose the phonograph is turned off, and the record uniformly stops rotating after $10s$. What is the angular acceleration?

Solution:

a) We can find the radial speed of the needle from the formula:

$$v = \frac{s}{t},$$

here, s is the distance that the needle moves uniformly from the outer edge to the inner edge (in fact, it is the difference between outer and inner radial distances), t is the time.

Substituting s and t into the previous formula we get:

$$v = \frac{s}{t} = \frac{(r_{outer} - r_{inner})}{t} = \frac{(0.36m - 0.15m)}{2.3 \cdot 60s} = \frac{0.21m}{138s} = 0.00152\frac{m}{s} = \\ = 1.52 \cdot 10^{-3}\frac{m}{s}.$$

b) Let's first convert rev/min to rad/s:

$$\omega = \left(6.7\frac{rev}{min}\right) \cdot \left(2\pi\frac{rad}{1rev}\right) \cdot \left(\frac{1min}{60s}\right) = 0.701\frac{rad}{s}.$$

Then, from the relation between linear and angular variables we can find the speed of the outer edge relative to the needle:

$$v_{outer\,edge} = r_{outer}\,\omega = 0.36m \cdot 0.701\frac{rad}{s} = 0.252\frac{m}{s}.$$

c) Similarly, we can find the speed of the inner edge relative to the needle:

$$v_{inner\ edge} = r_{inner}\ \omega = 0.15m \cdot 0.701\frac{rad}{s} = 0.105\frac{m}{s}.$$

d) By the definition, the angular acceleration is the change in the angular velocity, ω, per unit of time, t:

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_f - \omega_i}{\Delta t} = \frac{0\frac{rad}{s} - 0.701\frac{rad}{s}}{10s} = \frac{-0.701\frac{rad}{s}}{10s} = -0.0701\frac{rad}{s^2}.$$

The sign minus indicate that the record is slow down.

Answer:

a) $v = 1.52 \cdot 10^{-3}\frac{m}{s}$.

b) $v_{outer\ edge} = 0.252\frac{m}{s}$.

c) $v_{inner\ edge} = 0.105\frac{m}{s}$.

d) $\alpha = -0.0701\frac{rad}{s^2}$.