

Problem 30 Turntable

A turntable is a uniform disc of mass 1.2 kg and radius $1.3 \times 10^{-1}\text{ m}$. The turntable is spinning at an initial constant frequency of $f_0 = 33\text{ cycles/min}$. The motor is turned off and the turntable slows to a stop in 8.0 s due to frictional torque. Assume that the angular acceleration is constant. What is the magnitude of the frictional torque acting on the disc?

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Answer: Initially, the disc is spinning with a frequency

$$f_0 = (33 \frac{\text{cycles}}{\text{min}})(\frac{1 \text{ min}}{60 \text{ s}}) = 0.55 \frac{\text{cycles}}{\text{s}} = 0.55 \text{ Hz}.$$

So the initial angular velocity is

$$\omega_0 = 2\pi f_0 = (2\pi \frac{\text{rad}}{\text{cycle}})(0.55 \frac{\text{cycles}}{\text{s}}) = 3.5 \frac{\text{rad}}{\text{s}}.$$

The final angular velocity is zero, so the angular acceleration is

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_f - \omega_0}{t_f - t_0} = \frac{-3.5 \text{ rad/s}}{0.8 \text{ s}} = -4.3 \text{ rad/s}^2.$$

Since the angular acceleration is negative, we confirm that the disc is slowing down.

The moment of inertia of the turntable about an axis passing perpendicular to the disc and through the center of mass is

$$I_{cm} = \frac{1}{2} m R^2 = \frac{1}{2} (1.2 \text{ kg})(1.3 \times 10^{-1} \text{ m})^2 = 1.01 \times 10^{-2} \text{ kg} \cdot \text{m}^2$$

So the magnitude of the frictional torque is

$$|\tau_{fric}^{total}| = I_s |\alpha| = (1.01 \times 10^{-2} \text{ kg} \cdot \text{m}^2)(4.3 \text{ rad/s}^2) = 4.3 \times 10^{-2} \text{ N} \cdot \text{m}.$$