Date Question Set 1b

Investigating Magnetic Braking

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1 Magnetic braking of a long wide strip

1.1 introduction

We now consider a simple model of magnetic braking of a long wide metallic strip moving in a uniform magnetic field. We shall tackle this problem by making an electrical analog a battery of certain emf, internal resistance r, external load resistance R. However, we assume that the speed of the strip is sufficiently small that the magnetic field due to induced currents is negligible in comparison with applied field B_0.

A) This will occur if strip speed is much smaller than some characteristic eddy-current-related speed(v_c) for the metal composing the strip. Assume that it depends on conductivity σ, permeability μ_0, the thickness of the strip δ, find the expression for v_c using dimensional analysis. [0.5]

Consider a long wide metallic strip with length L, width w($w << l$), thickness δ as part of a bigger metallic piece as shown in the figure below. Assume that there exists a uniform magnetic field $B_0\hat{k}$, perpendicular to the strip and only in the region of strip.(Ignore edge effects, if any). Let the velocity of the strip be $\mathbf{v} = v\hat{j}$.

B) Make an electric analog of the situation as indicated above and show that

$$I = \alpha\sigma B_0 L\delta v$$

$$\mathbf{F} = -\alpha\sigma L\delta w {B_0}^2 v\hat{\mathbf{j}}$$

where,

$$\alpha = \frac{1}{1+\frac{R}{r}}$$

[2.5] Clearly state your assumptions.

1.2 Experimental Setup

A circular disk of large radius is rotated at an angular speed ω. This system will produce results which are identical to those of a long wide strip if the magnet is positioned sufficiently far off from the center so that the velocity of the disk under the pole pieces is practically uniform. The outer edge of the disk is also assumed to be far off from this region. Under these conditions, we can view the spinning disk braking problem as that of braking a long wide strip. Let D be the distance from the center of rotation to the center of the region under magnetic poles.

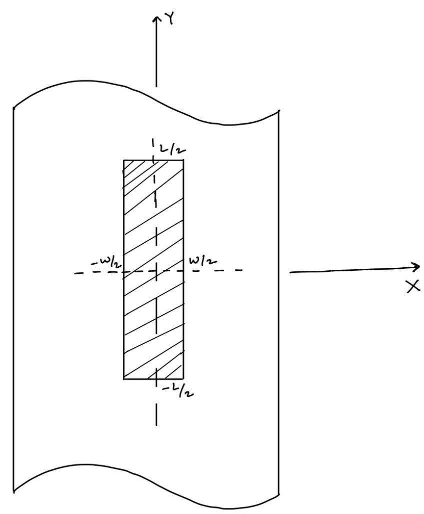

Figure 1

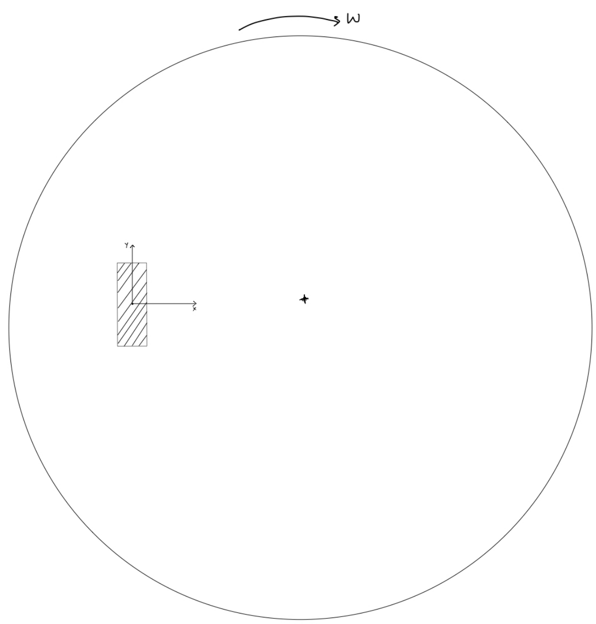

Figure 2

1.3 Questions

C) Let the moment of inertia of the setup be K. Assume the air drag to be linearly related to angular speed. Obtain an expression for angular speed as a function of time.
Show that the time constant

$$\tau = \frac{\tau_0}{1 + \tau_0 m B_0^2}$$

τ_0 is the parameter associated with air damping alone.
Deduce an expression for m in terms of parameters given above. [3]

Consider the following measurements,
$D = 162.5mm$, $K = 1.18 \times 10^{-2} kgm^2$, ρ(electrical resistivity)$= 4.2 \times 10^{-8} \Omega m$, $\delta = 1.17mm, L = 55mm, w = 2.9mm$

D) Using the data in file Dataset3, calculate the value of α by plotting an appropriate **Linear fit** ONLY. Also, find the parameter τ_0 associated with air damping alone. [2.5]

E)Using data in the file Dataset4, calculate at which magnetic field the experiment was carried out by plotting an appropriate **Linear fit** ONLY. You may use the results obtained in Question D. [1.5]