Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.685 Electric Machines

Problem Set 8 — Issued October 30, 2005
Due November 9, 2005

Problem 1: DC Generator

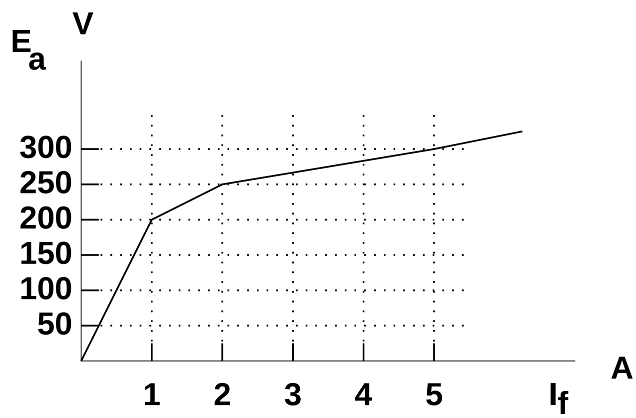

Figure 1: DC Generator Test Curve at 2000 RPM

A DC generator has the following characteristics:

Field Resistance	R_f	74 Ω
Armature Resistance	R_a	1 Ω
Field Inductance	L_f	1 Hy
Number of Field Turns	500	

Operating at a speed of 2000 RPM, the machine exhibits the saturation curve shown in Figure 1.

- This is to be a self-excited machine, so the field winding is connected across the armature terminals. At what speed will this machine self-excite?
- Operating at 2000 RPM, what is the steady state voltage if the machine is otherwise unloaded?
- Calculate the output voltage as a function of load current, with the machine turning at a steady 2000 RPM.
- Now, the machine is to be compounded by use of a series field winding to make it a 'stiffer' voltage source. How many turns should there be to make it 'flat' compounded? (Zero apparent output impedance).
- Now, the machine is operating at 2000 RPM when the field winding is suddenly connected to the armature terminals. We expect it to self-excite. Build a simulation for this case, starting at 6 V.

Problem 2: Compound Motor

This problem concerns a compound-wound DC motor. As mentioned briefly in class, a compound motor has two (or maybe more) field windings, one in series with the armature and one either separately excited or in parallel with the armature. A *short shunt* connection has the 'shunt' field winding directly in parallel with the armature brushes and the series field winding connected between the parallel combination of shunt field and armature, and the machine terminals. A *long shunt* connection has the series field connection between the armature and the shunt field which is therefore right across the machine terminals. Motors with compound windings are normally wound *cumulatively*, or in such a way that motor current in the series field reinforces the flux from the shunt field winding.Here is some data:

Shunt Field Resistance	R_f	300 Ω
Armature Resistance	R_a	0.25 Ω
Series Field Resistance	R_s	2 Ω
Number of turns in Shunt Field	N_f	500
Number of turns in Series Field	N_s	20

The machine has been tested, and with the armature winding open and 2.0 amperes in the shunt field, operating at 1000 RPM, the armature voltage is measured at 600 V. Ignoring any mechanical losses (friction, windage, etc., calculate and plot torque-speed and current-speed curves for this motor operating with a terminal voltage of 600 V:

1. operating with the series field not connected,
2. operating with the series field connected cumulatively in *long shunt*, and
3. operating with the series field connected cumulatively in *short shunt*.

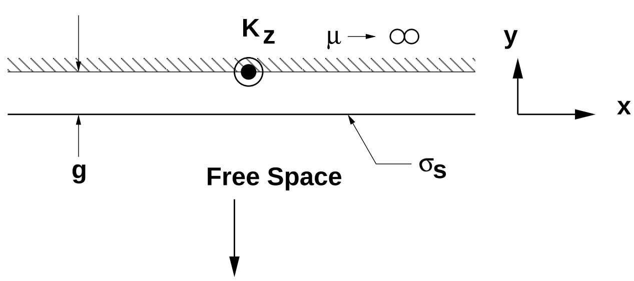

Figure 2: Linear Loss Problem

Problem 3: Losses Shown in Figure 2 is another loss problem for which you should *not* use the normal assumption of narrow gap. Assume that the lower surface is thin and has some surface conductivity. That surface is stationary. Below it is 'free space'. There are two ways of treating the upper surface:

Current Source : The upper surface is backed by ferromagnetic material and carries a surface current in the z- direction:

$$K_z = K_0 \cos kx \cos \omega t$$

Flux Source The surface may be modeled as constraining y-directed magnetic flux density:

$$B_y = B_0 \cos kx \cos \omega t$$

Note that we can treat the magnetic fields as being of a form similar to:

$$\begin{aligned} H_x &= \mathrm{Re}\left\{ \underline{H}_x e^{j(\omega t - kx)} \right\} \\ H_y &= \mathrm{Re}\left\{ \underline{H}_y e^{j(\omega t - kx)} \right\} \end{aligned}$$

where

$$\begin{aligned} \underline{H}_x &= \underline{H}_+ e^{ky} + \underline{H}_- e^{-ky} \\ \underline{H}_y &= j\underline{H}_+ e^{ky} - j\underline{H}_- e^{-ky} \end{aligned}$$

1. To start, note that the component H_- growing in in the direction below the sheet must be zero (why?). You can assign a value to the ratio of y-directed to x- directed field: $\mathcal{S} = \frac{\underline{H}_y}{\underline{H}_x}$.
2. Next, you can use the properties of the conductive sheet to find a value of the same field ratio $\mathcal{S}$ on *top* of the conductive sheet.
3. Then you should find the same field ratio $\mathcal{S}$ right at the surface of the current source (just below the upper surface).
4. Now use this ratio to calculate an equivalent surface impedance and then compute the time and space average dissipation in the conductive sheet (which is just the negative y-going value of the Poynting energy flow) for the two cases:
   (a) Current Source
   (b) Flux Source
5. Find and plot the dissipation in the sheet for the two cases and for a range of electrical conductivity of the sheet from zero to what you would have with one millimeter of copper: $0 < \sigma_s < 6 \times 10^4$S. Assume the following parameters:

Surface Current	K_0	80,000	A/m
Constrained flux	B_0	0.1	T
Wavelength	λ	5	cm
Gap	g	5	mm
Frequency	F	1000	Hz