MIDDLE EAST TECHNICAL UNIVERSITY

ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE 568 Selected Topics in Electrical Machines

Final Examination 18 June 2020

Suggested Time: 300min

Exam Rules:

You are allowed to	**You are NOT allowed to**
• Use any additional materials, books, etc. • Use your laptops to access internet, download extra materials, run simulations • Use scientific calculators for your calculations • Have a short break, have a coffee etc.	• Use your mobile phones/tablets (not even as a calculator) • Communicate (talk, instant messaging, email etc) within or outside the class. • Sharing photos of the exam paper • Getting closer than 1.5 m to anyone

Student Name:______________________

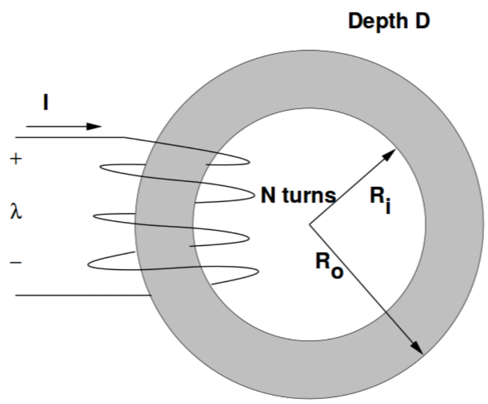
Student ID:____________

Q1	
Q2	
Q3	
Q4	
Total	

Q1 – (20 pts) Inductor Design

Suppose that you have a toroidal core as shown in the figure below. You want to make an inductor of 10mH. Inner radius of the core is 9 cm and the outer radius is 11 cm and the depth(D) is 2 cm.

Assume the relative permeability of the core is 1400 and the core has a maximum flux density value of 1.6 T. Neglect the leakage flux throughout this problem.



Part-I: Assume the flux is homogeneously distributed along the core

a) How many turns are needed?

b) What is the maximum current that the inductor can carry without saturating the core?

c) Considering the fill factor and thermal issues, is that design feasible?

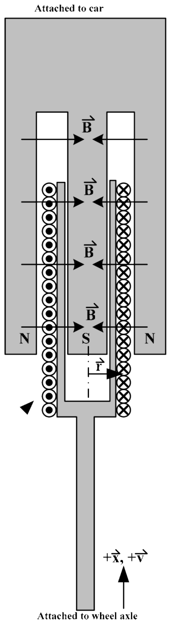
Part-II:

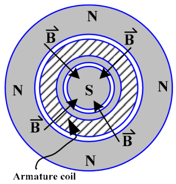
d) Repeat the part(a) and part(b), but now the flux is NOT homogeneously distributed.

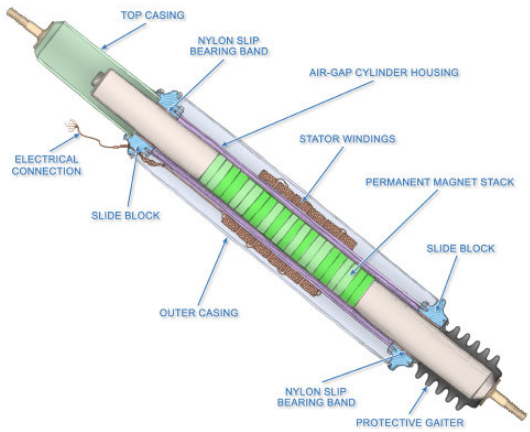
e) Plot the H_{tan} and B_{tan} versus radius under this operating condition.

Q2- (20pts) Linear Actuators

There are novel regenerative shock absorbers that use linear PM motors instead of conventional mechanical shock absorbers (Mercedes Magic Body Control uses a hydraulic version). Assume, a PM linear actuator as shown in the figure with PMs magnetized inwards and flux density is uniform in the coils.







Find the Lorentz force on the coil and vertical displacement of the absorber using the following parameters:

- $r = 10$ cm, $B = 1.5$ T, $N_{coil} = 30$, R= 0.5 Ω, Applied voltage= 12 V
- Total height of the stator = 20 cm
- Spring stiffness: 100 N/cm (The spring is connected in parallel to the PM actuator. Neutral position of the spring is the mid-point of the stator.

Q3-(20 pts) Short Answer Questions

Explain your reasoning as detailed as possible for full credit. Mathematical calculations are not required, but can be used to prove your point.

a) Assume you have two permanent magnets motors with the exact same dimensions and windings. The only difference is one of the motor has magnets of N42H, but the other one is N42UH. Compare these two machines in terms of:

i) Magnetic loading, electrical loading

ii) Insulation class, operating temperature

b) What are real world correspondence of direct and quadrature axis inductances (Ld, Lq) of electric machines? Propose a experimental method to measure Ld and Lq.

c) Assume you have an interior permanent magnet (IPM) machine. Can you generate any torque if all the magnets are demagnetized completely?

d) What are the advantages and disadvantages of fractional pitched windings over integral slot windings?-

Q4- (40 pts) Motor Analysis from Lamination Design

Assume you have the lamination design given as an attachment. The legend for the dimensions are also available. All dimensions are in mm.

- Assume M400-50A laminations are used in the machine (Datasheet is avaiable)
- NdFeB magnets of N40UH are used in the slots.

a) How many poles and slots does the machine have? (Don’t count, just read the legend)

b) Sketch the magnetic equivalent circuit for one pole and rouhgly calculate the peak airgap flux density (please clearly state any assumptions you make). Estimate the peak flux density at the stator teeth and at the back-core.

c) The slot for the magnets are slightly larger than the actual magnets. What is the purpose of the extra air-region next to the magnets?

d) Design a winding diagram for this machine. Draw the winding diagram or show the phasors for the induced voltages to clearly describe the winding diagram. You can simplify your diagrams by using any symmetry in your winding designs. Calculate the winding factor for the fundamental component. Estimate

e) Choose an axial length and rated speed for this machine. Using the standard values (electircal loading, magnetic loading etc.) estimate the power output for this machine.

f) Choose a rated voltage (you can use any standard values), then choose the number of turns per slot and standard wire size for this machine. Clearly state any assumptions such as fill factor, current density etc. Verify the electrical loading value you had chosen in part (c).