Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2010-2011 (2 hours)

EEE202 Electromechanical Energy Conversion 2

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. Explain what is meant by the term 4-quadrant operation of a drive system. Show that whilst moving an inertial load from standstill at an initial position, to standstill at a final position, only requires a dc motor to operate in two quadrants whilst the motor drive electronics may have to operate in three quadrants. **(7)**

b. Draw the equivalent circuit and derive the operational characteristics of a series connected, wound field dc motor. Given the motor and load parameters below, calculate the operating speed and current of a series connected wound field motor when supplied from a 12V dc supply, driving a fan load. (Where $T_{Load} = B_f.\omega^2$) **(9)**

c. Would it be possible to run the system from an a.c. supply? Would the voltage need to be increased or decreased? Justify your answer. **(4)**

DC Motor Parameters: $R_f = 1\Omega$, $R_a = 0.2\Omega$, $M = 1\ V.rad^{-1}.s^{-1}$

Fan Constant: $B_f = 0.01Nm.rad^{-2}.s^{-2}$

2. **a.** Show that for a simple solenoid actuator with a linear soft iron core, the force exerted on the core is given by the expression:

$$F = \frac{1}{2} I^2 \frac{dL}{dx}$$ **(7)**

b. Figure 1 shows the cross section of a 10cm long solenoid, which is to be used to accelerate a small soft iron projectile having a mass of 25 grams. The variation of the solenoid inductance with projectile position is also given within the figure.

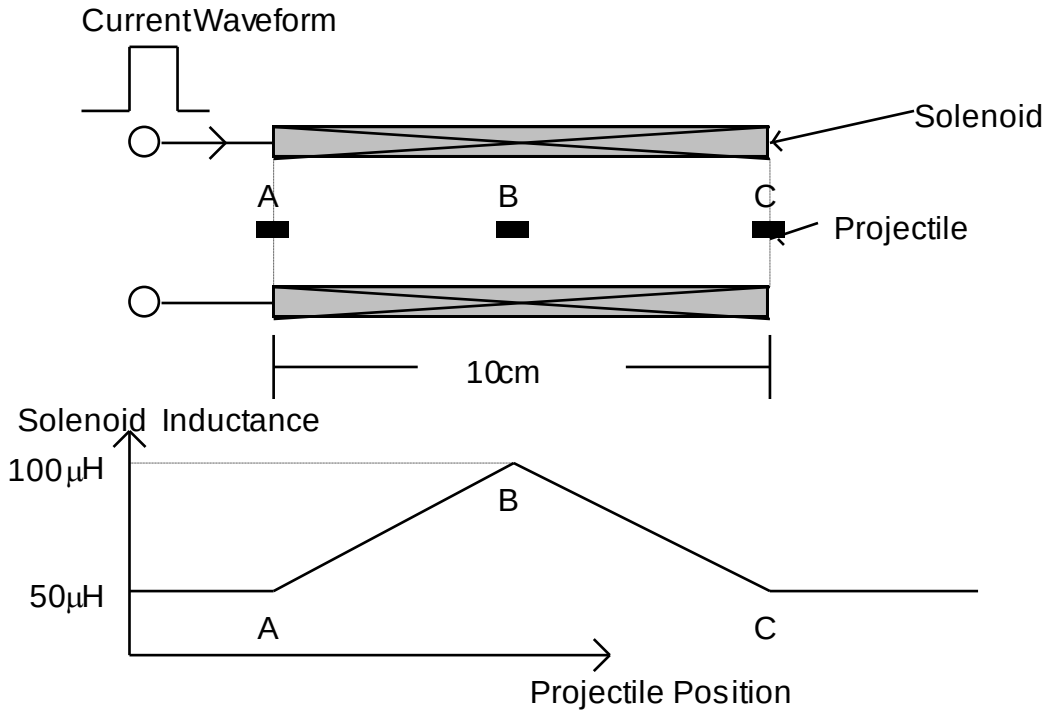

Figure 1

Neglecting air friction on the projectile, calculate the amplitude and duration of a rectangular current pulse which is required to accelerate the projectile from rest at an initial position 'A' in the figure to an exit velocity of 100ms^{-1} at position 'C'. (Position B is at the centre of the solenoid). **(7)**

c. Calculate the maximum energy stored in the magnetic circuit, and the total energy lost in the coil given a coil resistance of 1mΩ **(6)**

3. **a.** Draw a full equivalent circuit for a 3 phase induction motor and briefly describe the origins of each component. From the equivalent circuit derive an expression for the motor output torque. **(8)**

b. The following readings were taken during a locked rotor test performed on a 6-pole, 415V, 3-phase, 50Hz star connected induction motor.

Line Voltage = 96V, Line current = 36A, Input power = 2.33kW

The stator resistance was measured at 0.3Ω per phase

In a particular installation, the 50Hz supply to the motor is prone to voltage drops of up to 30%. Find the maximum mechanical load torque which it is safe for it to drive, such that the motor will not stall under the worst supply conditions. **(12)**

4. **a.** Given that the equivalent circuit model of a voice-coil actuator is dominated by its mechanical inertia and winding resistance, show how the actuator may be included in a closed loop control system to improve the apparent time constant of the actuator response from τ to $\tau/(1+A)$, where A is the gain of the servo amplifier. Include a suitable system diagram in your answer and list any assumptions made. **(10)**

b. The system above is used to electrically actuate the valves in a car engine. Given the actuator parameters below, calculate

The capacitance in the equivalent circuit. **(2)**

The open loop system time constant. **(2)**

The required amplifier gain to make the system time constant less than 20ms. **(2)**

c. Given that the main system power supply is from a 'next generation' car battery, which limits the available source voltage to 42V, under what circumstances might this effect system performance. **(4)**

ACTUATOR DATA:

Actuator resistance = 0.1Ω

Mass of system = 100g

Force constant of actuator = 0.12 Nm/A

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