THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
FINAL EXAMINATION 2009/2010
MEX4271 – SENSORS AND ACTUATORS
DATE : 2nd MARCH 2010
TIME : 0930HRS TO 1230HRS
DURATION : THREE HOURS [3 hrs]

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THE QUESTION PAPER

- This question paper has eight questions.
- Answer five questions only.

Question 01

i) Discuss the main differences between the following two types of electronic temperature sensors:
   a) Linear electronic temperature sensors
   b) Thermistors

ii) A solar water heater has a mains-powered electric pump which circulates water through the solar panel and the collection tank. To avoid losing heat when the sun is not shining, and to save pump power, the pump has a controller which switches it on only when the solar panel is hotter than the collection tank. Draw a circuit which uses two linear electronic temperature sensors to compare the temperature of the panel and the tank, and switches the pump on when the panel is hotter than the tank. Suggest a suitable means of switching AC mains using your circuit.

Question 02

i) A temperature difference measuring system is being designed, using chromel-alumel thermocouples with an output of 40 μV / ^{O}C (40 microvolts per degree Celsius). The two temperatures can vary over the range 200 ^{O}C to 300 ^{O}C, with either of them being hotter than the other. The analogue signal is taken to the input of an analogue-to-digital converter with an input of 0 to 1 volt (positive only). Design a suitable amplifier, giving suggested values of passive components, and suggested voltages. You may take the thermocouples as ideal voltage sources, with no resistance.

ii) The resolution required from the measuring system in (i) above is 0.1 ^{O}C. What is the required number of bits for the analogue-to-digital converter?

iii) The environment in which the measuring system works is electrically noisy, with a significant amount of 50Hz noise. Explain how would you minimize the problem of noise?

Question 03

i) Distinguish between incremental encoding and absolute position measurement.

ii) What is a Linear Variable Differential Transformer (LVDT)? Describe briefly how it works. Is output analogue or digital?

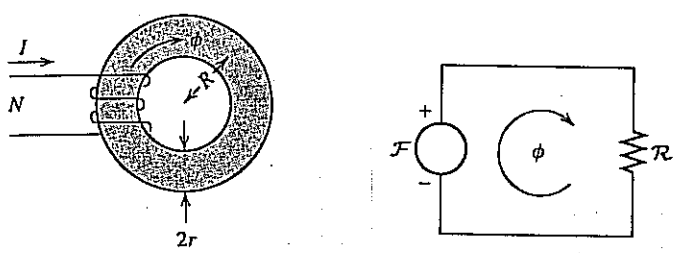
iii) A linear variable differential transformer has a moving core, and a primary winding excited by a wave current i = I sinωt. The coupling coefficients to the two secondary coils are k_1 an respectively. Derive an expression for the output voltage Vo. What happens as the core moves thr the central position between the two secondaries? Draw a sketch graph showing the relation between output voltage (y-axis) and linear position of the moving core (x-axis). How can a syste set up to distinguish between positions on the two sides of the central position? How can your g be modified to take this into account?

Question 04

i) State the right hand rule as it applies to
   a) A current carrying conductor.
   b) A current carrying coil.

ii) Explain what is the magnetic circuit concept?

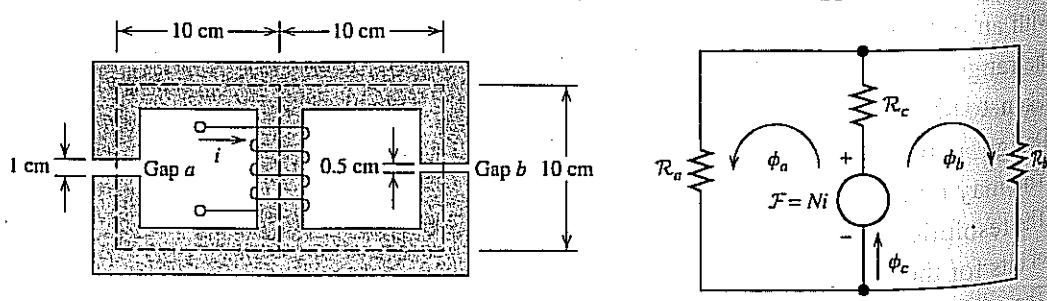
iii) Using magnetic circuit concepts, analyze the toroidal coil shown in Figure Q4-1 to find an expres for the flux.



(a) Coil on a toriodal iron core (b) Magnetic circuit

Figure Q4-1

iv) The iron core shown in Figure Q4-2 has a cross section of 2cm by 2cm and a relative permeability 1000. The coil has 500 turns and carries a current of $i = 2A$. Find the flux density in each air gap.



(a) Core (b) Magnetic circuit

Figure Q4-2

Question 5

i) The ideal transformer shown in Figure Q5-1 has turns ratio $N_1:N_2$ and $Z_L$load connected to secondary side. Show that the load impendence is reflected to the primary side by square of the turns ratio.

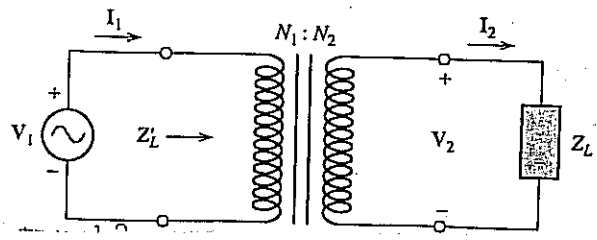


Figure Q5-1

ii) The transformer shown in Figure Q5-2 has turns ratio $N_1:N_2 = 10:1$and output load is $Z_L = 10 + j20$. Find the phasor currents and voltages. Also, find the power delivered to the laod.

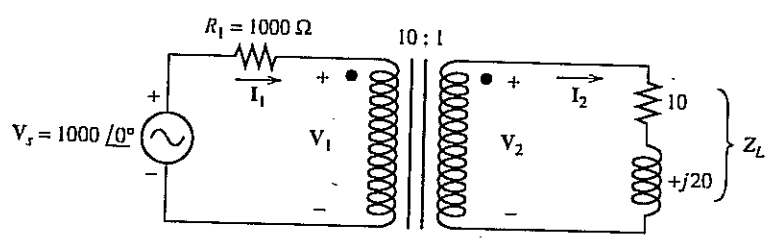


Figure Q5-2

Question 06

A 3-phase induction motor having a synchronous speed of 1200r/min draws 80kW from a 3-phase feeder. The copper losses and iron losses in the stator amount to 5kW. If the motor runs at 1152rpm, calculate the following:

i) The active power transmitted to the rotor.
ii) The rotor I^2R losses.
iii) The mechanical power delivered.
iv) the mechanical power delivered to the load, knowing that the windage and friction losses are equal to 2kW.
v) The efficiency of the motor.

Question 07

i) What are two types of windings are used in electrical machines? Which type is not used in permanen magnet? Why not?

ii) In what application dc motors be more advantageous than ac motors?

iii) A 50-hp shunt-connected dc motor has the magnetization curve shown in Figure Q7-1 and equivale circuit is shown in Figure Q7-2. The dc supply voltage is $V_T = 240V$, the armature resistance $R_F = 10\Omega$, and the adjustable resistance is $R_{adj} = 14\Omega$. at a speed of 1200 rpm, the rotational loss $P_{rot} = 1450W$. If this motor drives a hoist that demands a torque of $T_{out} = 250Nm$ independent speed, determine the motor speed and efficiency.

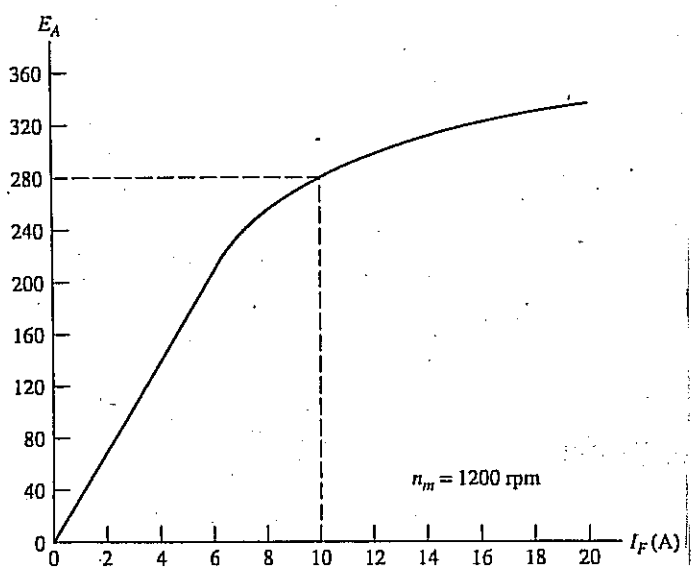


Figure Q7-1

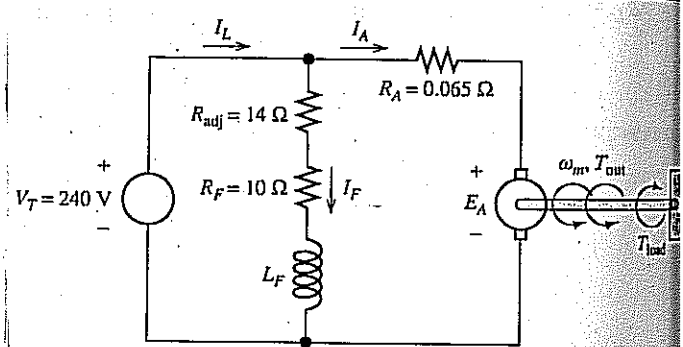


Figure Q7-2

Question 08

i. What is the main use of stepper motor?
ii. What is the difference between a reluctance and a permanent magnet stepper motor?
iii. Describe the construction of a hybrid stepper motor.
iv. A stepper motor advances 2.5° per step. How many pulses are needed to complete 8 revolutions?
v. State the limitations and disadvantages of potentiometer, when it is us as displacement measuring devices.
vi. A mobile robot uses a potentiometer attached to the drive wheel to record its travel during the "teach" mode. The required resolution for robot motion is 1mm, and the diameter of the drive wheel of the robot is 20cm. examine the design considerations for a standard (single-coil) rotary potentiometer to be used in this application.

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