NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2017-2018

MA2011 - MECHATRONICS SYSTEM INTERFACING

April/May 2018 Time Allowed: 2½ hours

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **FOUR (4)** pages.
2. Answer **ALL** questions.
3. All questions carry equal marks.
4. This is a **RESTRICTED OPEN-BOOK** examination. One double sided A4 reference sheet is allowed.

1(a) Give five different definitions of "Mechatronics".

(10 marks)

(b) Based on Figure 1, describe in detail what is a typical mechatronics system.

(15 marks)

Figure 1: A Mechatronics System.

2. Figure 2 shows a periodic waveform.

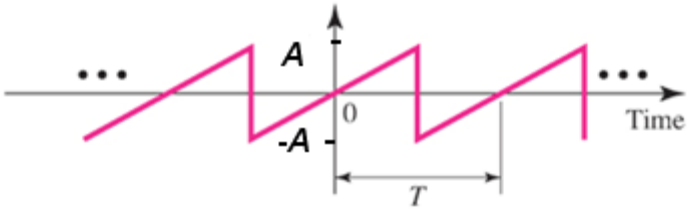

Figure 2: A waveform.

(a) Define the function *f(t)* over the period *T*.

(5 marks)

(b) Calculate the coefficients A_n and B_n in the Fourier series of the waveform.

(10 marks)

(c) Using the Frequency-Domain representation of the Fourier Series, show the spike diagram of the frequency spectrum.

(10 marks)

3. A solid disk, with its height along the z-direction, has to remain centered at the origin of the X-Y plane, as shown in the cross-sectional view in Figure 3(a). To monitor variations from the centered position, a pair of inductive sensors is used for each axis. Specifically for the x-axis, two inductive sensors L_1 and L_2, are arranged symmetrically, with respect to the disk, as shown in Figure 3(a), and electrically connected to a Wheatstone bridge, as shown in Figure 3(b).

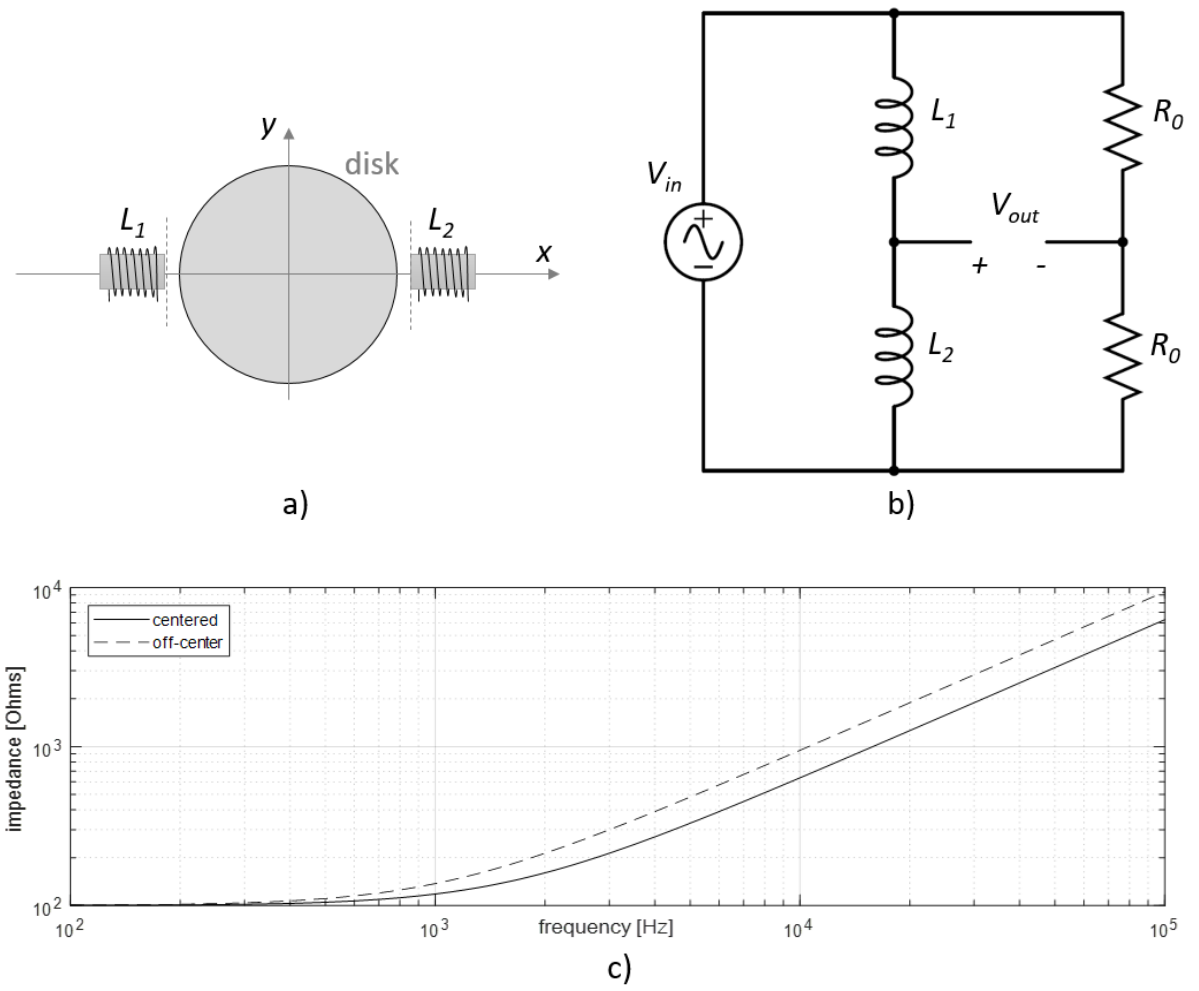

Figure 3

(a) When the disk is perfectly centered along the x-axis, each inductive sensor is characterized by intrinsic resistance r_0 and inductance L_0. However, an inductance change of $L_0+\Delta L$ is observed when the distance from the disk is off-center. Based on the values of the amplitude response in Figure 3(c), determine

(i) an approximate value for r_0,
(ii) an approximate value for L_0
(iii) an approximate value for ΔL.

(10 marks)

Note: Question 3 continues on page 4.

(b) Consider the Wheatstone bridge in Figure 3(b), with an AC driving input and with similar bridge resistances (R_0).

(i) Derive **a symbolic expression** of the bridge output V_{out} as a function of r_0, L_0, ΔL and input frequency, assuming that inductance varies linearly with the distance.

(Note: if the inductance of L_2 changes $L_0+\Delta L$, the inductance for L_1 will change as $L_0-\Delta L$)

(5 marks)

(ii) Sketch the frequency response of the amplitude $|V_{out}/V_{in}|$ between 100-100,000 Hz.

(5 marks)

(c) Considering the bridge as a filter, with input V_{in} and output V_{out}, determine whether it is a low-pass or high-pass filter and its cut-off frequency in the case of off-centered disk.

(5 marks)

4. A DC motor driven at a nominal voltage V_0 = 10V, is designed to provide a rated torque 0.5 Kg.cm, at a rated speed of 6,500 rpm, drawing a rated current of 4,000 mA. At no load, the motor requires 500 mA of current and its speed reaches 9000 rpm.

(a) On your answer book, draw on the same graph the Speed vs. Torque, Current vs. Torque and output Power vs. Torque responses.

NOTE: The rated values refer to one possible (suggested) operating point, not the stall point. You can assume linearity.

(8 marks)

(b) Determine, at the nominal voltage, the maximum power (in Watts) which can be delivered to a mechanical load as well as the torque, speed and efficiency at such optimal operating point.

(5 marks)

(c) Based on previous calculations and the information reported above, determine the friction coefficient of the bearings (assuming a linear model) and the amount of friction torque in the no-load conditions.

(7 marks)

(d) Compute the *efficiency* of the motor when operating at the rated speed and when operating at maximum power transfer conditions.

(5 marks)

END OF PAPER