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ME772 - Mid Semester QP Set 1
MECHATRONICS
(TOTAL = 60 marks)

Section I : **10 questions x 3 marks/question = 30 marks, -0.5 for every wrong answer**

Section II : **5 questions x 6 marks/question = 30 marks** [*For this Section, you should use the additional papers first for rough work and then neatly write the answers within the given space step by step, without overwriting; no additional paper will be provided*]

Section I [10 Questions] - 3 marks/question

1. Following the definition by the Japan Society for the Promotion of Machine Industry (JSPMI); match the three sets of Mechatronic Systems:

Set 1:

a) Class I
b) Class II
c) Class III
d) Class IV

Set 2:

i) Functionality Mechanical but Internal Mechanism Electronic
ii) Traditionally Mechanical but updated using Electronics
iii) Primarily Mechanical but Electronics improves Functionality
iv) Synergy of Mechanical and Electronic Systems

Set 3:

A) Variable Speed Drive
B) Modern Sewing Machine
C) Automatic Oven
D) Digital Watch

Using the above Sets (Type, Definition and Example) indicate the correct matching of sets:

- 1a – 2 i – 3 A / 1b – 2 ii – 3 B / 1c – 2 iii – 3 D/ 1d – 2 iv 3 C
- 1a – 2 i i – 3 A / 1b – 2 iii – 3 C / 1c – 2 i – 3 D/ 1d – 2 iv 3 B
- 1a – 2 iii – 3 C / 1b – 2 ii – 3 D / 1c – 2 iii – 3 B/ 1d – 2 iv 3 A
- 1a – 2 iii – 3 A / 1b – 2 ii – 3 B / 1c – 2 i – 3 D/ 1d – 2 iv 3 C
- None

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2. A Hardware-in-Loop simulation may refer to:
   - Real Controller –Real Actuator – Process Simulated – Sensor - simulated
   - Simulated Controller –Real Actuator – Process Simulated – Sensor - simulated
   - Real Controller –Simulated Actuator – Process Simulated – Sensor - simulated
   - Simulated Controller – Simulated Actuator – Process Simulated – Sensor - simulated
   - Real Controller – Real Actuator – Process Real – Sensor – simulated
   - All of the above

3. Consider an electro-magnetic transducer, driven by Lorentz Equation. If the transducer is geometrically reduced by four times it will exert a force which will be smaller by?
   - Four times
   - Thirty-two times
   - Eight times
   - Twenty-Eight times
   - None of the above

If a wire is geometrically decreased in size by a factor of N, its resistance will increase by a factor of N. Since the power dissipated in the wire is I^2R, assuming the current remains constant implies that the power dissipated in the geometrically smaller wire will increase by a factor of N. Assuming the maximum power dissipation for a given wire is determined by the surface area of the wire, a wire that is smaller by a factor of N will be able to dissipate a factor of N^2 less power. Constant current is therefore a poor assumption. A better assumption is that maximum current is limited by maximum power dissipation, which is assumed to depend upon surface area of the wire. Since a wire smaller by a factor of N can dissipate a factor of N^2 less power, the current in the smaller conductor would have to be reduced by a factor of $N^{3/2}$. Incorporating this into the scaling of the Lorentz equation, an electromagnetic actuator that is geometrically smaller by a factor of N would exert a force that is smaller by a factor of $N^{5/2}$. Trimmer and Jebens have conducted a similar analysis, and demonstrated that electromagnetic forces scale as N^2 when assuming constant temperature rise in the wire, $N^{5/2}$ when assuming constant heat (power) flow (as previously described), and N^3 when assuming constant current density [23,24]. In any of these cases, the scaling of electromagnetic forces is not nearly as favorable as the scaling of electrostatic forces. Despite this, electromagnetic actuation still offers utility in microactuation, and most likely scales more favorably than does inertial or gravitational forces.

4. The following are a jumbled-up group of Sensor Characteristics and its' implication. Indicate the correct match

Row	Sensor Characteristics	Row	Implication
1	Sensitivity	A	the output that will exist when it should be zero
2	Precision	B	Maximum value that will exist between the actual and the indicated value
3	Resolution	C	Input Parameter change required for standardized output change
4	Accuracy	D	Smallest detectable incremental change of input parameter that can be detected in the output signal
5	Offset	E	Degree of reproducibility of a measurement

- 1 A – 2 B – 3 E – 4 D – 5 C
- 1 C – 2 A – 3 D – 4 B – 5 E
- 1 B – 2 A – 3 D – 4 C – 5 E
- 1 C – 2 A – 3 E – 4 B – 5 D
- 1 C – 2 E – 3 D – 4B – 5 A

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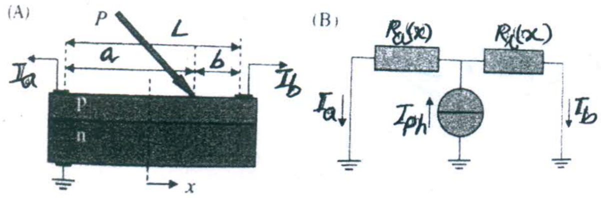
5. Find the correct facts about the transducers:
    - Hall Sensor is denoted as [Ma, El, El]
    - LED is a direct output transducer
    - LCD index is [Ra, Ra, El]
    - Thermocouple is a Direct Output Transducer
    - All LIP ports are not input Ports

6. A fixed electrode Capacitive Liquid Level Sensor is based on the change of
    - Relative Liquid Permittivity
    - Absolute Liquid Permittivity
    - Plate Common Area
    - Separation Distance between the electrodes
    - All of these

7. Consider a one-dimensional Position Sensitive Diode (PSD) of length 24 mm on which a light ray is falling at a point as shown in the figure. Given the ratio of $(\frac{I_a}{I_b}) = 2$ and the measurement origin from the middle of the sensor, find out the position of the light beam.



    - 6mm
    - 4mm
    - 20mm
    - 2mm
    - 22 mm

8. What is/are correct about a Magnetostrictive Torque Sensor in the following?
    - Change in stress causes change in permeability
    - A C-shaped ferromagnetic core is necessary for the measurement
    - The sensor is based on Direct Effect
    - It is a three-port sensor
    - All of the above

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9. Consider the Polymer based MEMS material, their properties and application and indicate the wrong pair /(s)(eg. Pair #, Pair #..):

Row	MEMS Material	Property
Pair 1	PVDF	Electrostrictive Sensor
Pair 2	Silicone	Electrostrictive Actuator
Pair 3	Polyurethane	Electrostrictive Actuator
Pair 4	Fluorosilicone	Electrostrictive Actuator
Pair 5	Polypyrrole	Conductive Polymer – Sensor and Actuator

PVDF - Electrostrictive sensor (Pair 1)
....

10. In State-space form write the A matrix of a SDOF system having states as displacement and velocity, stiffness 10N/m, Damping 0.1 N-s/m and Mass = 1Kg

$$A = \begin{bmatrix} 0 & 1 \\ -10 & -0.1 \end{bmatrix}$$

Section II [5 Questions] - 6 marks/question

11. A missile is instrumented with an optical gyroscope based on Sagnac Effect. The circular gyro has a radius of 10 cm and is based on optical fibre having 10,000 windings. The time delay between clockwise and anticlockwise motion at an instant is found to be 1 Pico second. Assuming (a) the speed of light to be 3 x 10^8 m/s and (b) the light speed to be same in the clockwise and counterclockwise direction, the angular speed of the missile will be close to

- 100 rad/s
- 36 rad/s
- 72 rad/s ✓
- 4900 rad/s

$$\Delta t = \frac{4AN}{c^2}\Omega$$

$\simeq 71.6$ rad/s

$\Delta t = 10^{-12}$ sec

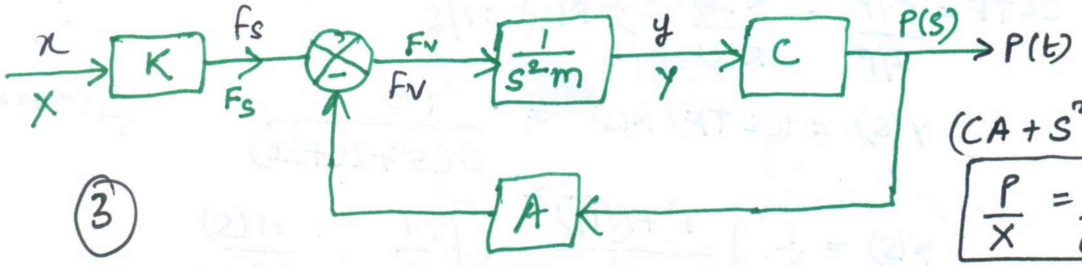
$A = \pi R^2 = \pi \times (10 \times 10^{-2})^2$

$N = 10{,}000$

$c = 3 \times 10^8$ m/s

- none of these

12. Define the following variables: p = output pressure, f_s = spring force = K x, f_D= diaphragm force = A p, and f_v= valve force = $f_s - f_D$. The motion of the valve is described by $\ddot{y} = \frac{f_v}{m}$ where m is the valve mass. The output pressure is proportional to the valve displacement, thus $p = cy$, where c is the constant of proportionality. Draw a Block diagram and find the transfer function of the system.



3

$$c\left(\frac{KX - AP(s)}{s^2 m}\right) = P(s)$$

$$s^2 m P = cKX - cAP$$

$$(CA + s^2 m)P = CKX$$

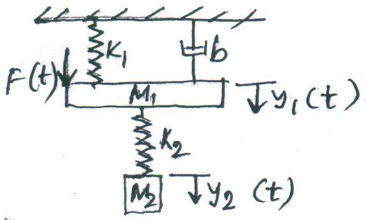
$$\boxed{\frac{P}{X} = \frac{CK}{CA + s^2 m}}$$ 3

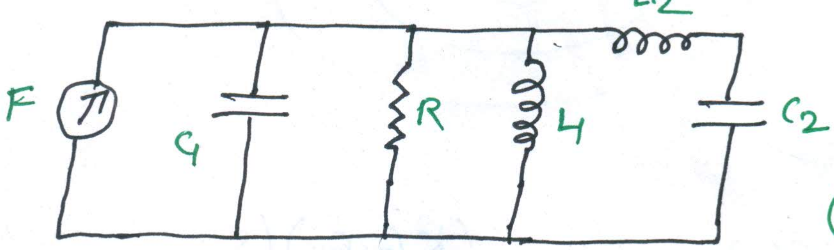
$$\ddot{y} = \frac{f_v}{m}$$

$$s^2 Y = F_v / m$$

$$Y = F_v / m s^2$$

13. A Dynamic Vibration Absorber is shown below. The primary mass M_1 is subjected to a harmonic force $F(t)$ =A sin $\omega_0 t$; while the secondary mass and stiffness are chosen to nullify the effect. Draw the analogous electric circuit based on Force-Current Analogy. Obtain the Differential Equations of the system.

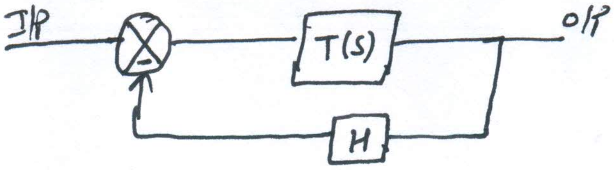




3

$$L_1 = 1/K_1 \,,\; L_2 = 1/K_2 \,,\; R = 1/b \,,\; C_i = M_i$$

$$\boxed{\begin{aligned} M_1 \ddot{y}_1 + K_2(y_1 - y_2) + b\dot{y}_1 + K_1 y_1 &= F(t) \\ M_2 \ddot{y}_2 + K_2(y_2 - y_1) &= 0 \end{aligned}}$$ 3

Name: 

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14. A second order plant has a transfer function $T(s) = 10/(s^2 + 2s + 10)$; considering unity feedback, develop the closed loop transfer function for the plant and find out the step response of the system.

$$T(s) = \frac{10}{s^2+2s+10} \; ; \quad \text{closed loop T/F} = \frac{T(s)}{1+T(s)H(s)} = \frac{10}{s^2+2s+20}$$

$$CLTF = \frac{O/P}{I/P} = \frac{Y(s)}{R(s)} \; ; \; R(s) = 1/s$$

$$\therefore Y(s) = (CLTF)\,R(s) = \frac{10}{s(s^2+2s+20)}$$

(3 marks)

$$Y(s) = \frac{1}{2}\left[\frac{1^2+(\sqrt{19})^2}{(s+1)^2+(\sqrt{19})^2}\right]\cdot\frac{1}{s} = \frac{H(s)}{s}$$

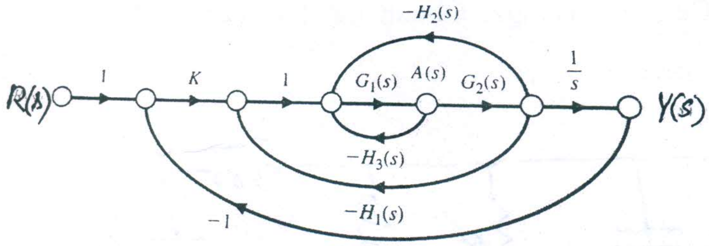
$$y(t) = \frac{1}{2}\left(1 - \sqrt{\frac{20}{19}}\, e^{-t}\sin(\sqrt{19}\,t + 1.345)\right)$$

(3 marks)

$\omega_o = \sqrt{20}$

$\omega_d = \sqrt{19}$

15. Find out the transfer function of the Signal Flow Graph given below which is used in a Sheep Steering System.



$$T(s) = \frac{(KG_1G_2)/s}{\left(1+G_1G_2(H_1+H_2)+G_1H_3+\frac{KG_1G_2}{s}\right)}$$

* No step marking