NAME: Key

Exam #1 **ELEC 5760/6760** **Mon 10/3/22**

Constants: $\pi = 3.14159$, $\varepsilon_o = 8.854$ pF/m, $1\ \text{G} = 9.8\ \text{m/s}^2$,

Equations: $F_{inertial} = ma$, $F_{spring} = kx$, $k \approx \dfrac{N_{leg}}{N_{zig}} \dfrac{Ewt^3}{L^3}$, $\rho[T] \approx \rho_o(1+\alpha_T T)$, $V_{CA} = \dfrac{V_S C_S}{C_2}$

$\sigma_T = \sigma_{25}[1 + a(T - 25)]$, $GF = \dfrac{\Delta R/R}{\varepsilon_1}$, $F_{ringosc} = \dfrac{0.455}{RC}$, $\dfrac{d}{dt}\sin(\omega t) = \omega\cos(\omega t)$,

$\dfrac{d}{dt}\cos(\omega t) = -\omega\sin(\omega t)$, $G = \sigma\kappa$

Problems:

1) Circle which answer is the source of a damping force between a moving magnet and a conductor **(5 points)**:

Hydration Sphere, Eddy Current, (circled) Ring Oscillator, Transmissibility

2) What is the accuracy of a sensor with that is correct to within ± 20 mV, but has an output resolution of 1mV? **(5 points)**:

± 20 mV

3) What does "MEMS" stand for **(5 points)**?

Microelectromechanical Systems

Match the question with an answer by writing the letter of the answer in the blank next to the question. No answer is used more than once. (20 points)

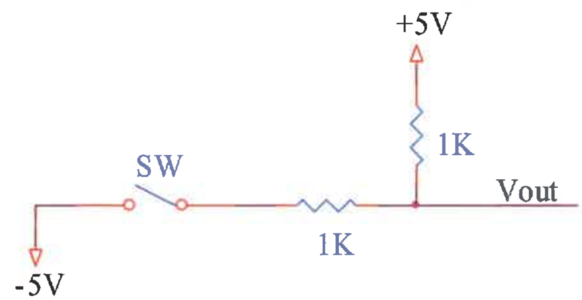
Questions

1) This circuit element can be used to emulate a resistor when appropriately switched: A
2) -1 times the ratio of transverse strain to axial strain: F
3) The magnitude of the output displacement divided by the input displacement: L
4) A hydrated anion is a: E
5) This is a type of fluidic damping: C
6) An input transducer is a: J
7) A ratio of the % change in resistance to % change in length: B
8) A 4 resistor circuit configuration useful for interfacing to differential resistive sensors: G
9) Its resistance decreases as light gets more intense: D
10) Used to convert a variable capacitance to a square wave frequency: N

Answers to choose from

A. Capacitor
B. Gauge Factor
C. Shear-Resistance
D. CdS photoresistor
E. Hydration shell
F. Poisson's ratio
G. Wheatstone bridge
H. Op-amp
I. Young's modulus
J. Sensor
K. Capacitive fringing field sensor
L. Transmissibility
M. SOI wafer
N. Relaxation Oscillator
O. Conductance
P. Charge Amplifier

4) A glucose sensor that uses conductivity sensing is modeled by the circuit shown below, where the switch is closed for a glucose concentration greater than 100 ppm.



(a) What is the measurand for this sensor **(5 points)**?

Glucose or Glucose Concentration

(b) What is Vout for a glucose concentration of 1000 ppm **(5 points)**?

0V

(c) What is Vout for a glucose concentration of 0 ppm **(5 points)**?

+5V

5) A certain piezoresistive sensor was modeled as single resistor with a nominal resistance of 1 kΩ and a gauge factor of -10. What does the resistance become if the sensor experiences a -0.1% axial strain **(5 points)**?

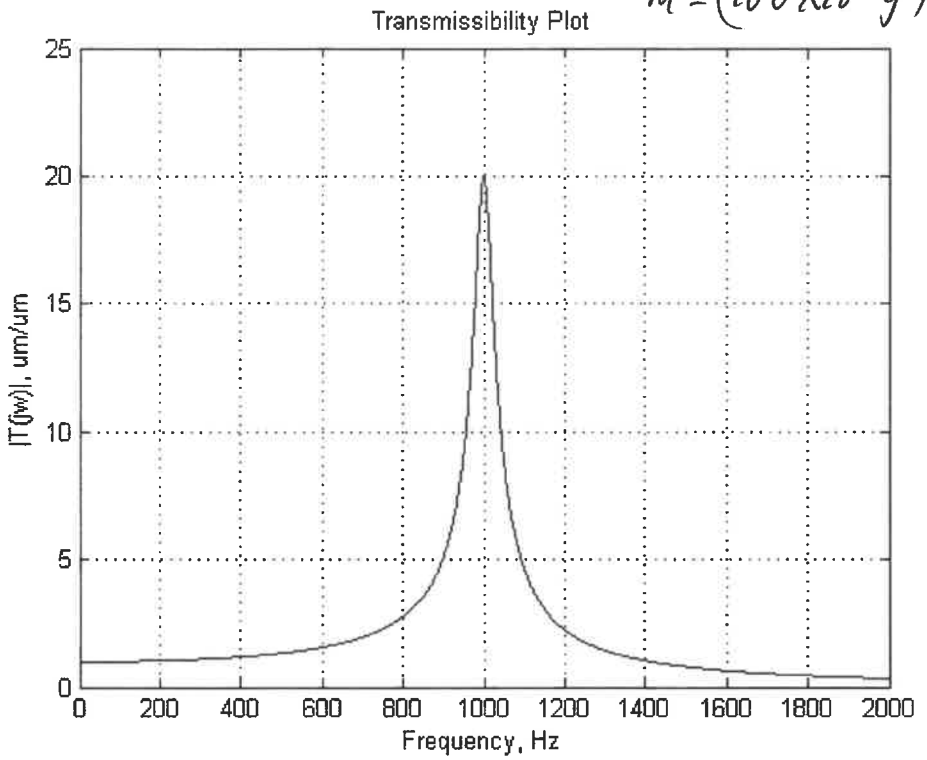
$GF = \frac{\Delta R/R}{\varepsilon_l}$

$\Delta R = R\varepsilon_l GF = (1000)(-0.001)(-10) = 10\Omega$

$R_{new} = R_{old} + \Delta R = 1000 + 10 = 1010\Omega$

6) Examine the transmissibility plot shown below, for a MEMS device with a proof mass of 100 mg. [**NOTE**: mg, *NOT* kg!]

$m = (100 \times 10^{-3} g)\left(\frac{1 kg}{1000 g}\right) = 1 \times 10^{-4} kg$



(a) What is the natural frequency, f_n **(5 points)**?

1 KHz

(b) What is the mechanical quality factor, Q **(5 points)**?

20

(c) What is |T(jω)| at 0 Hz? **(5 points)**?

1

(d) If the frame is sinusoidally excited at 1 KHz with a displacement amplitude of 2 μm, what is the amplitude of the displacement of the proof mass? **(5 points)**?

$d = 2\mu m (20) = 40 \mu m$

(e) What is the system spring constant, k **(5 points)**?

$\omega_n = 2\pi f_n = \sqrt{\frac{k}{m}}$

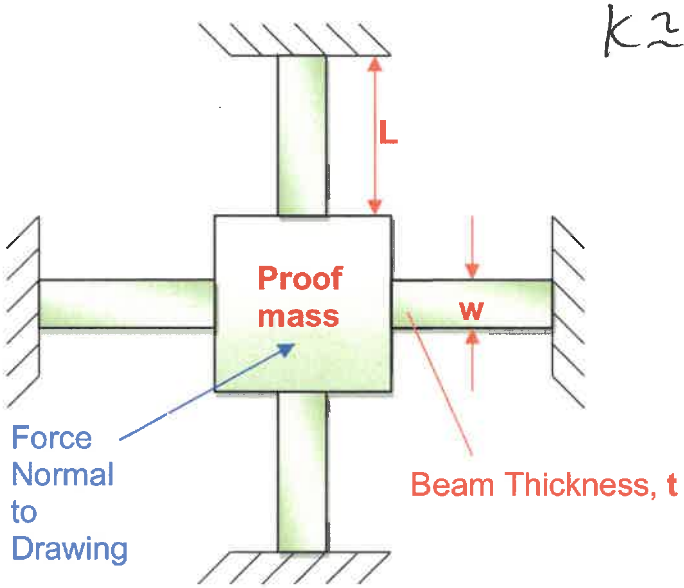
$k = m(2\pi f_n)^2 = 1 \times 10^{-4}(2\pi \cdot 1000)^2 = 3947.84\ N/m$

(f) What is the damping coefficient, c **(5 points)**?

$$\frac{\omega_n}{Q} = \frac{2\pi f_n}{Q} = \frac{c}{m}$$

$$c = \frac{2\pi f_n m}{Q} = \frac{2\pi(1000)(1\times10^{-4})}{20} = 0.0314\ Kg/s$$

7) A drawing of a MEMS spring-mass-damper device is presented below. All beams are the same size. What is an expression for the system spring constant, k, in terms of beam (spring) dimensions, L, w and t **(5 points)**?



$$k \simeq \frac{N_{Leg}}{N_{zig}} \frac{Ewt^3}{L^3}$$

$$N_{Leg} = 4$$

$$N_{zig} = 1$$

$$\therefore k \approx \frac{4Ewt^3}{L^3}$$

8) A resistive sensor measures a conductance of 100 µS in an aqueous solution at 30°C. If your sensor's cell constant is 20 m, what the EC at 25°C, using a temperature compensation factor of 0.02/°C? **(5 points)**?

$$G = \sigma K \rightarrow \sigma = \frac{G}{K} = \frac{100\mu}{20} = 5\mu S/m = \sigma_{30}$$

$$\sigma_{30} = \sigma_{25}[1 + 0.02(30-25)]$$

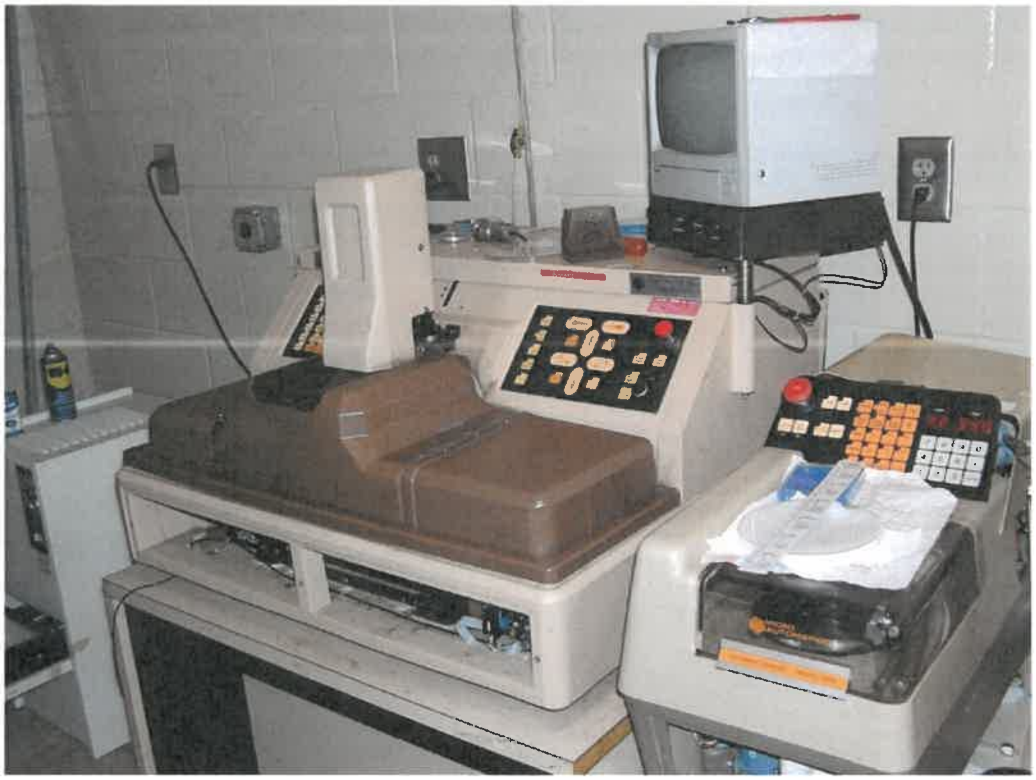
$$\sigma_{25} = \frac{5}{1+0.02(30-25)} = 4.55\mu S/m$$

9) Write a general expression for T(s) in terms of Q, s, and ω_n, where $|T(j\omega)|$ is a transmissibility function **(5 points)**?

$$T(s) = \frac{\frac{\omega_n}{Q}s + \omega_n^2}{s^2 + \frac{\omega_n}{Q}s + \omega_n^2}$$

Bonus Question (5 points)

For the photograph below, in microfabrication, what is this and what is it used for?



Automated Dicing Saw

Used to dice a wafer into die

Blank sheet for Calculations