NAME: Key

Exam #1 **ELEC 5760/6760** **Wed 10/4/21**

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

Equations: $F_{inertial} = ma$, $F_{spring} = kx$, $k \approx \frac{N_{leg}}{N_{zig}} \frac{Ewt^3}{L^3}$, $\rho[T] \approx \rho_o(1 + \alpha_T T)$, $V_{charge\_amp} = \frac{-V_s C_s}{C_2}$

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

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

Problems:

1) Circle the other name for a Synchronous Demodulator **(5 points)**:

Ring Oscillator, Varactor, (Lock-in Amplifier,) Forced Inductor

2) What is the accuracy of a sensor with that is correct to within ± 10 mV, but has an output resolution of 1mV? **(5 points)**:

± 10mV

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

Silicon On Insulator

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)

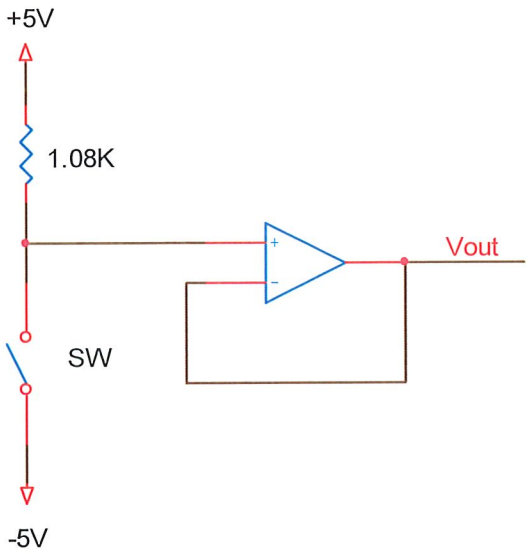
Questions

1) This is a beam that is fixed (or anchored) at only one end: F
2) The magnitude of the output displacement divided by the input displacement: L
3) This is a type of fluidic damping: C
4) A device made from bonding 2 materials together with different CTE's: D
5) An output transducer is an: J
6) The ratio of stored energy to lost energy in an oscillator: B
7) A 4 resistor circuit configuration useful for interfacing to differential resistive sensors: G
8) An appropriately switched capacitor can be used to emulate a: A
9) A circuit that can convert a modulated AC signal to baseband (DC): E
10) This often utilizes an interdigitated electrode structure: K

Answers to choose from

A. Resistor
B. Mechanical quality factor
C. Squeeze-film
D. Bimorph
E. Synchronous demodulator
F. Cantilever
G. Wheatstone bridge
H. Op-amp
I. Young's modulus
J. Actuator
K. Capacitive fringing field sensor
L. Transmissibility
M. SOI wafer
N. Photodiode

4) A mechanical shock sensor that uses conductivity sensing can be modeled by the circuit shown below, where the switch is closed for acceleration > 10 G's.



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

mechanical shock

(b) What is Vout for acceleration < 10 G's **(5 points)**?

+5V

(c) What is Vout for acceleration > 10 G's **(5 points)**?

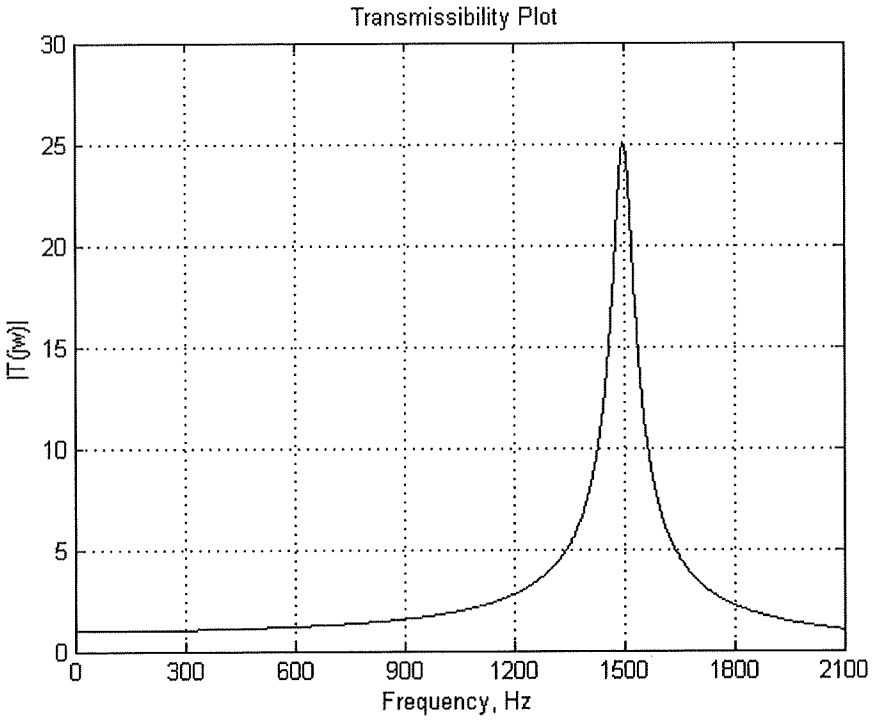
−5V

5) A certain piezoresistive sensor can be 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)**?

$$GF = \frac{\Delta R/R}{\varepsilon_1} \rightarrow \Delta R = (GF)(R)(\varepsilon_1) = (10)(1000)(-0.001)$$
$$= -10\Omega$$

$$R_{new} = R_{old} + \Delta R = 1000 - 10 = 990\Omega$$

6) Examine the transmissibility plot shown below, for a MEMS device with a proof mass of 100 mg. [**NOTE**: mg, *NOT* kg!] $100mg = 100\times10^{-3}g = 100\times10^{-6}kg$



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

1500 Hz

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

25

(c) What is $|T(j\omega)|$ at 0 Hz? **(5 points)**?

1

(d) If the frame is sinusoidally excited at 1.5 KHz with a displacement amplitude of 1 μm, what is the amplitude of the displacement of the proof mass? **(5 points)**?

25 μm

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

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

$$c = \frac{2\pi f_n m}{Q} = \frac{2\pi(1500)100\times10^{-6}}{25} = 0.038 \text{ kg/s}$$

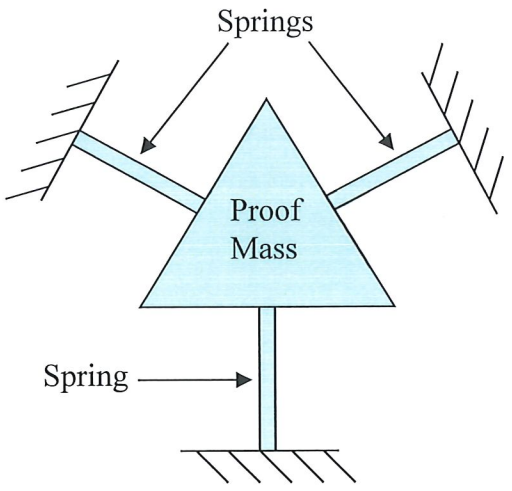
(f) What is the spring constant, k **(5 points)**?

$$\frac{K}{m} = \omega_n^2$$

$$K = m\omega_n^2 = m(2\pi f_n)^2 = 100\times10^{-6}(2\pi 1500)^2$$

$$= 8882.63\ N/m$$

7) A drawing of a MEMS spring-mass-damper device is presented below, where motion is perpendicular to the sheet of paper. 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)**?



$N_{Leg} = 3$

$N_{Leg} = 1$

$$K = \frac{3}{1}\frac{Ewt^3}{L^3}$$

8) A resistive sensor measures a conductance of 200μS in an aqueous solution at 32°C. If your sensor's cell constant is 25 m, what the EC at 25°C, using a temperature compensation factor of 0.02/°C? **(5 points)**?

$$G = \sigma K \rightarrow \sigma = \frac{G}{K} = \frac{200\times10^{-6}}{25} = 8\times10^{-6}\ S/m$$

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

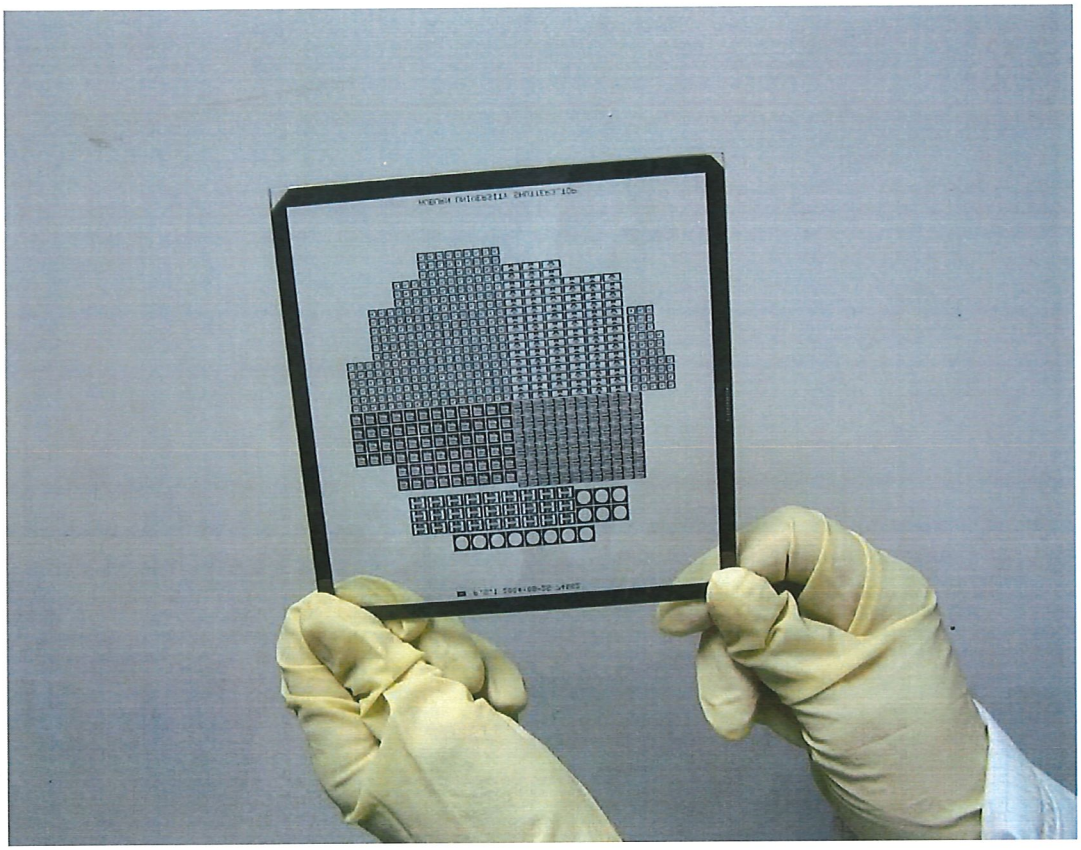
$$\sigma_{25} = \frac{\sigma_T}{1+0.02(32-25)} = \frac{8\times10^{-6}}{1+0.02(32-25)} = 7.02\ \mu S/m$$

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

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

Bonus Question (5 points)

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



A photolithography mask.

It is used in photolithography to transfer a designed pattern to a photoresist layer.

Blank sheet for Calculations