AS-74.3136 Introduction to Microsystems

Examination 20.05.2010

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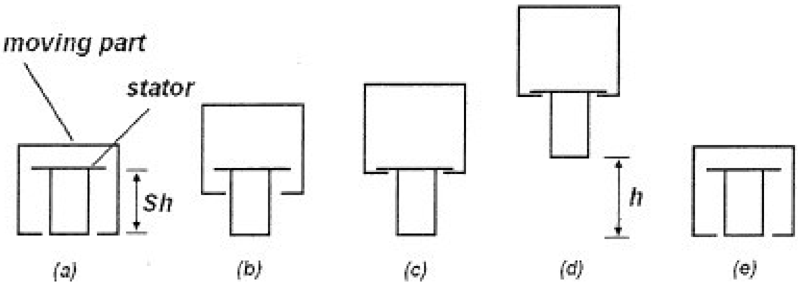
No Books are allowed in the exam.

1. What are microsystems? What is the difference between microsystems and microelectronics? (4 points)
2. What is lithography? Explain the difference between surface and bulk micromachining, with graphical illustrations. (4 points)
3. Explain the working principles of the piezoresistive and the capacitive pressure sensors, with graphical illustrations. (4 points)
4. Explain the working principle of an electrostatic actuator, with graphical illustrations. (4 points)
5. What is micromanipulator? What is mobile microrobot? Give one typical examples of each, and explain their working principle and design concept, with graphical illustrations. (4 points)
6. (10 points)

   Consider we have a voice coil placed on flat ground, powered by on-board battery through electronic circuits, which jumps upwards (see figure below).



Based on basic theories of magnetic force, electromotive force, Kirchhoff's voltage law, and Newton's second law, we obtained the jumping speed of the device (in the air) as following:

$$u = \int_0 \frac{BL}{M} I(t)\,dt - gt \qquad (1)$$

where u is jumping speed, B is magnetic flux density, L is the effective wire length, M is the mass of the moving part, I is electrical current, g is gravity, t is time.

Based on numerical simulation, the magnetic flux density B is almost constant when the moving part and the stator move relatively, and B can thus be assumed dimensionless.

The maximum displacement of the acceleration is limited (S_h, see the figure). Therefore, after time T_h, where the moving part moved upward for a displacement of S_h, the whole device enters free fly phase.

If we ignore the mass of the stator and the damping of air and assume constant acceleration, the maximum jumping height h is:

$$h = \frac{u_0^2}{2g} \qquad (2)$$

where u_0 is the initial jumping speed of the device when it leaves ground.

Questions:

a) What is the scaling law of the initial jumping speed u_0 if the current I is constant but having a scaling law of L^i?
b) What is the scaling law of the jumping height h if the current I is kept constant? What is the scaling law of the jumping height h if the driving voltage U for the coil is kept constant?
c) What is the scaling law of the jumping height h if the driving voltage U for the coil is kept constant and the diameter of the coil d is kept constant?
d) What is the scaling law of the maximum number of jumps N_j the device can work using onboard battery, if we keep the voltage constant?
e) What is the scaling law of the maximum jumping frequency f, if we have to keep the device below a critical temperature T_c?

Remark:

1. All variables will scale proportionally if dimension related if it is not otherwise specified.
2. All the scaling laws should be given with clearly stated reason.