UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	**:**	**AAB4033 - SMART AND FUNCTIONAL MATERIALS**
DATE	**:**	**9 AUGUST 2024 (FRIDAY)**
TIME	**:**	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SIX (6)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. a. Consider a piezoelectric material with a piezoelectric strain coefficient of 550×10^{-12} m/V and a mechanical compliance of 23×10^{-12} m^2/N. The material has a rectangular shape with a length of 6.5 mm and a width of 6 mm.

   i. With the absence of electric field, determine the strain produced when 150 N force is applied to the face of the material.

   [4 marks]

   ii. Determine the electric field required to produce an equivalent amount of strain as determined in **part (a)** under zero-stress condition.

   [3 marks]

   b. Piezoelectric materials commonly utilized as a sensor or an actuator. As a materials engineer, you are tasked to design a new piezoelectric material for a high-sensitivity pressure sensor.

   i. Propose the **TWO (2)** key characteristics and the significance for high-sensitivity pressure sensor application and suggest **ONE (1)** suitable material.

   [10 marks]

   ii. Sketch and explain the process of producing the piezoelectric materials mentioned in **part (a).**

   [8 marks]

2. A shape memory alloy (SMA) can be used directly in many applications without additional mechanisms and power circuitry needed for actuation is comparatively simple.

   a. Compare **TWO (2)** key advantages of SMA actuators with conventional actuators.

   [5 marks]

   b. Propose and explain **ONE (1)** appropriate method to fabricate the SMA with high specific actuation energy and damping capacity.

   [8 marks]

   d. The SMA has been used as a wire in replacement of a conventional wire by Raychem Corporation. The SMA wire is required to be tested prior to use it in any devices. Propose **THREE (3)** methods to test the performance of SMA wire.

   [12 marks]

3. A ferromagnetic material placed in a magnetic field generally undergoes a change in shape. The internal structure of a ferromagnetic material consists of randomly oriented magnetic domains.

   a. Analyze the mechanism of magnetostriction that occurs on ferromagnetic materials under application of stress.

   [10 marks]

   b. Using schematic diagrams, analyze the effects of **THREE (3)** significant parameters on the magnetostriction.

   [15 marks]

4. **FIGURE Q4** depicts one commercialized smart material which has been developed extensively due to the uniqueness in the sense that their properties such as viscosity, elasticity, and plasticity can be altered within the order of milliseconds in response to external stimuli.

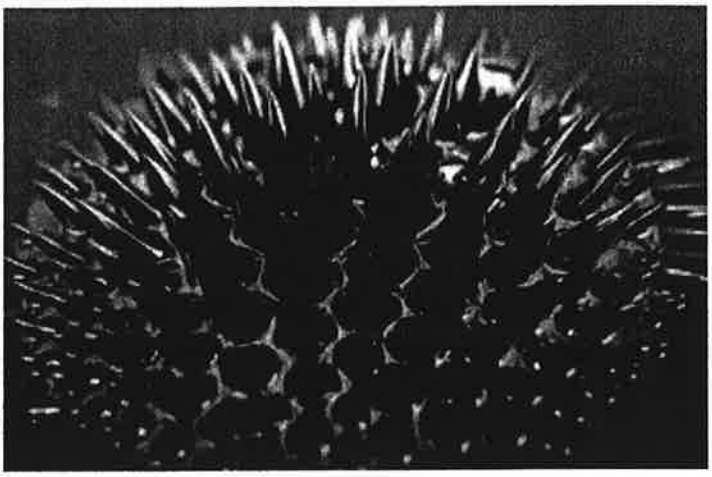

FIGURE Q4

a. Based on **FIGURE Q4,** recommend **THREE (3)** methods to measure the viscosity of the smart material.

[6 marks]

b. Propose **ONE (1)** suitable device that uses the material shown in **FIGURE Q4** and possible working mode(s).

[12 marks]

c. The material shown in **FIGURE Q4** encounters issues for long term performance. Discuss these issues and suggest **TWO (2)** methods to improve the material's long term performance.

[7 marks]

- END OF PAPER-

Appendix

Strain: $\mathbf{S} = \frac{1}{Y}\mathbf{T} = s\mathbf{T},$

$$\mathbf{S} = d\mathbf{E}$$

Electric displacement: $\mathbf{D} = d\mathbf{T},$

$$\mathbf{D} = \varepsilon\mathbf{E}$$

Actuator: $\epsilon_1 = s_{11}^{\mathbf{E}}\sigma_1 + d_{31}\mathbf{E}_3$

Sensor: $D_3 = d_{31}\sigma_1 + e_{33}^{\sigma}\mathbf{E}$

magnetic field intensity, H $H_3 = ni$

magnetic flux density, B $B_3 = \mu_{33}^{\sigma}H_3$

inductance $L_f = \mu_{33}^{\sigma}N^2A/l$

capacitance $V_c = q/C_p$