

MMME2045 Functional Materials Practice Question 5-7

Question 5

Table 1 lists the magnetic properties for two magnets.

Material	T_c/K	B_r/T	B_s/T	$H_c/A\ m^{-1}$	$(BH)_{max}/kJ\ m^{-3}$
A	590	1.2	1.5	848,000	255
B	1023	0.8	2.0	10	

(5a) Identify which is a hard magnet and which is a soft magnet and explain your reasons.

(5b) The material B has a saturation magnetic flux density (B_s) of 2.0 T at a magnetic field (H) of 50 A m⁻¹. Sketch the B-H hysteresis loop using the data in Table 2. Label and number the axis including units. Indicate B_s , B_r , H_c .

(5c) Identify which magnet is suitable for power transformer core applications and which magnet is suitable for permanent magnet motor applications and explain your reasons.

Question 6

Typical properties of two common commercial piezoelectric materials, PZT-4 and PZT-5H, based on lead zirconate titanate $\text{Pb}[\text{Zr}_x\text{Ti}_{1-x}]\text{O}_3$ ($0 < x < 1$, PZT), are listed in the Table 2.

	Symbol	Unit	PZT-4	PZT-5H
Piezoelectric coefficient	d_{33}	pm/V	300	600
Piezoelectric coefficient	d_{31}	pm/V	-120	-300
Coercive field	E_c	kV/cm	16	8
Remanent polarisation	P_r	$\mu\text{C}/\text{cm}^2$	31	28
Saturation polarisation	P_s	$\mu\text{C}/\text{cm}^2$	40	43

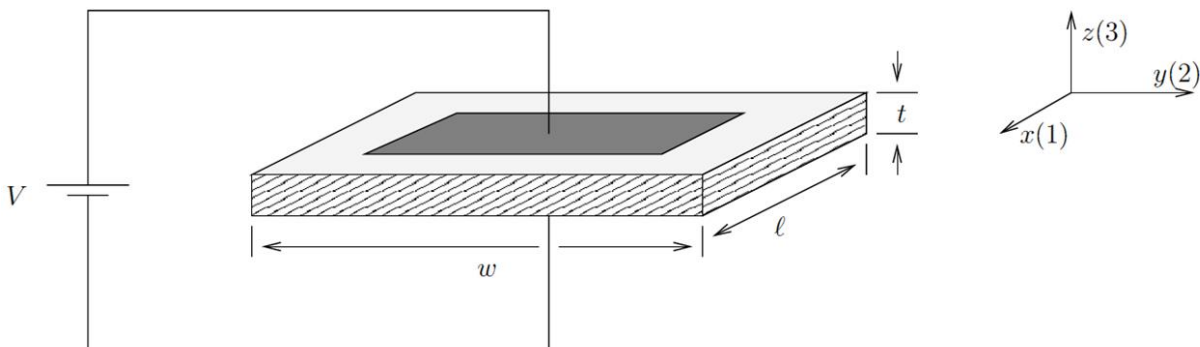
(6a) Identify which material is a hard PZT and which is a soft PZT and explain your reasons.

(6b) According to the data in Table 2, draw one schematic diagram showing the ferroelectric polarisation vs electric field (P-E) hysteresis loops up to an electrical field of 24 kV/cm for both PZT-4 and PZT-5H using the same axis. Label and number the axis including units. Indicate E_c , P_r , P_s . Label which P-E curve relates to which material.

Question 7

A piezoelectric material exhibits d_{31} of -120 pm/V and d_{33} of 300 pm/V . A rectangular ceramic made of this material has length (l) of 10 mm , width (w) of 3 mm and thickness (t) of 1 mm . Electrode is applied on the $10 \text{ mm} \times 3 \text{ mm}$ surfaces. A potential of 10 V is applied between the electrodes and the field direction is the same as the poling direction.

Calculate the dimensional change of length, width and thickness.



$$\Delta l = d_{31} \times V \times (l/t)$$

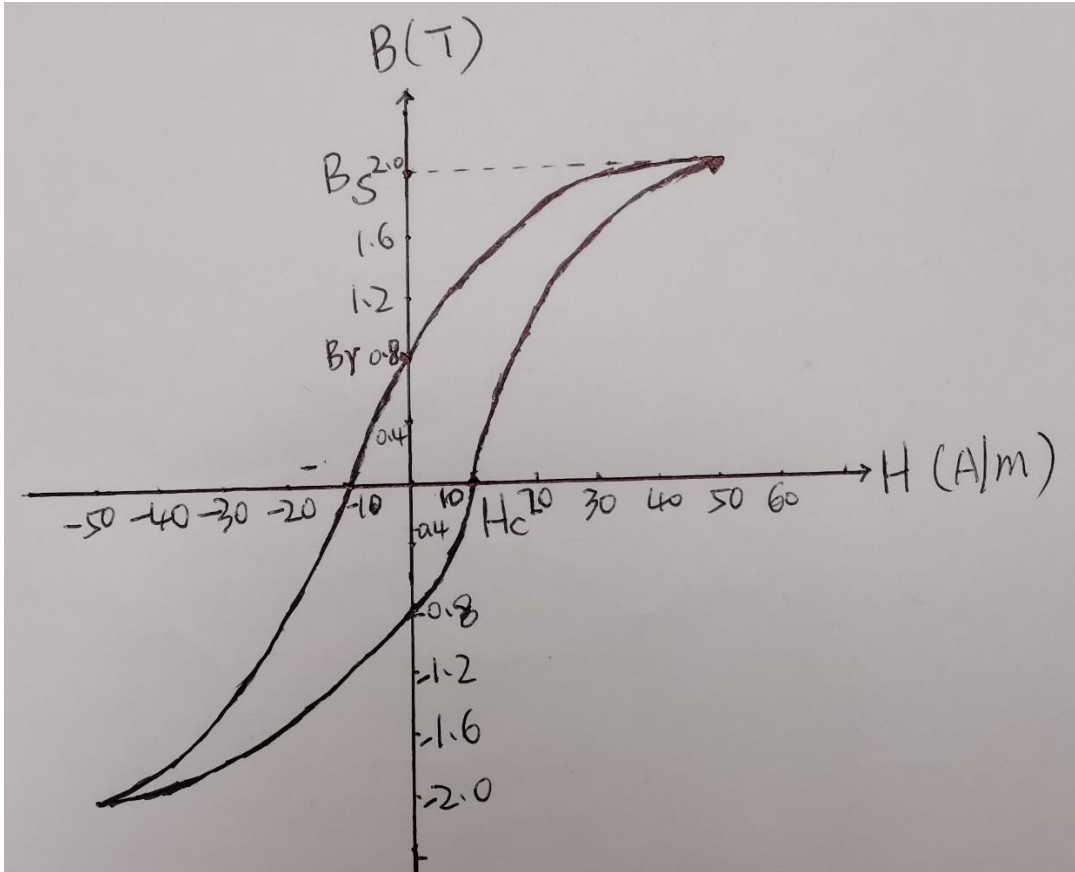
$$\Delta w = d_{31} \times V \times (w/t)$$

$$\Delta t = d_{33} \times V$$

Solutions

(5a) Material A is a hard magnet as it has a high H_c and B is a soft magnet as it has a low H_c .

(5b)



(5c)

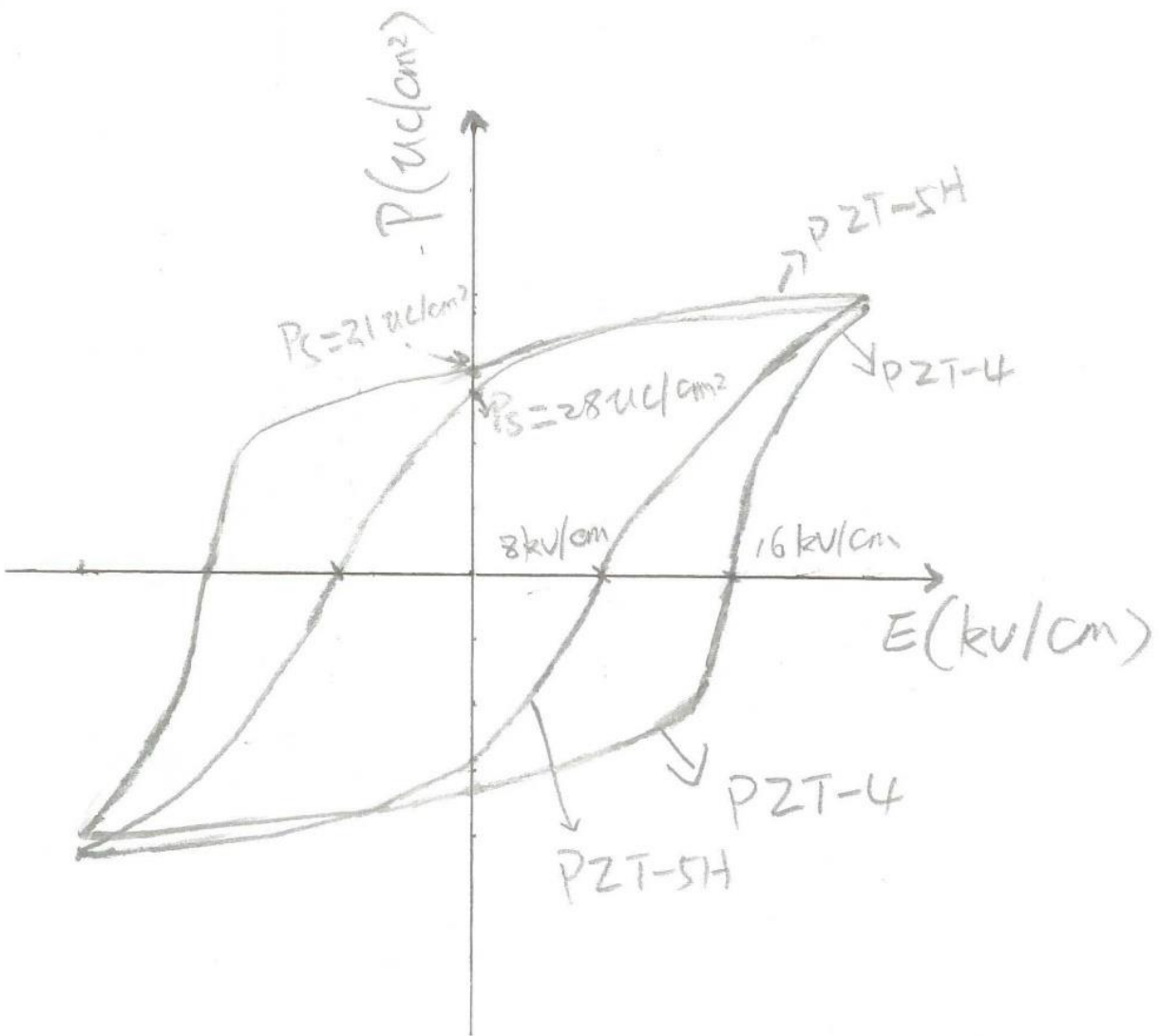
Magnet B is suitable for power transformer core applications. It has a low coercivity and a thin B-H loop, can be easily magnetised and demagnetised with lower energy loss. It has a large saturation flux density B_s which is helpful to reduce device volume.

Magnet A is suitable for permanent magnet motor applications. It has very high coercivity which is helpful to resist demagnetisation. It has high remanence and can retain largely the magnetisation after being magnetised. It also has large Maximum Energy Product $(BH)_{max}$ which is helpful to reduce the required volume of magnet material.

6(a)

PZT 4 is hard PZT whereas PZT 5H is soft PZT. PZT 4 has a larger coercive field (16 kV/cm) than that of PZT 5H (8 kV/cm).

6(b)



Question 7

$$\begin{aligned}\Delta l &= d_{31} \times V \times (l/t) \\ &= -120 \text{ pm/V} \times 10 \text{ V} \times (10 \text{ mm}/1 \text{ mm}) \\ &= -1.2 \times 10^{-8} \text{ m.}\end{aligned}$$

$$\begin{aligned}\Delta w &= d_{31} \times V \times (w/t) \\ &= -120 \text{ pm/V} \times 10 \text{ V} \times (3 \text{ mm}/1 \text{ mm}) \\ &= -3.6 \times 10^{-9} \text{ m.}\end{aligned}$$

$$\begin{aligned}\Delta t &= d_{33} \times V \\ &= 300 \text{ pm/V} \times 10 \text{ V} \\ &= 3 \times 10^{-9} \text{ m.}\end{aligned}$$