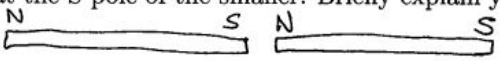
10. (15 pts) Two identical bar magnets of length 20 cm and square pole face of area 9 cm$^2$ have magnetization $M = 0.5 \times 10^6$ A/m. Determine their pole strengths. If the magnets are placed in a line, with the N pole of one 1 cm from the S pole of the other, estimate their force of attraction. Estimate the field that the large N pole makes at the S pole of the smaller. Briefly explain your reasoning.



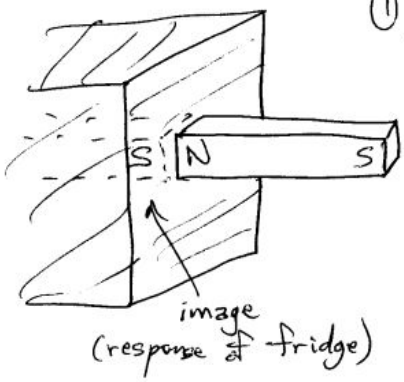

(1) $M = \sigma_m = \frac{q_m}{A}$, so $q_m = MA = \left(0.5\times10^6 \frac{A}{m}\right)\left(9\times10^{-4}\,m^2\right) = 450\,A\text{-}m$

(2) $|\vec{F}| = \frac{k_m q_m^2}{r^2} = \frac{\left(10^{-7}\frac{N}{A^2}\right)(450\,A\text{-}m)^2}{(.01m)^2} = 202.5\,N$

(3) $|\vec{B}| = \frac{k_m q_m}{r^2} = \frac{\left(10^{-7}\frac{N}{A^2}\right)(450\,A\text{-}m)}{(.01m)^2} = 0.45\,\frac{N}{A\text{-}m} = 0.45\,T$

(4) We are treating the poles as points

11. (15 pts) A 20 cm long permanent magnet has a 0.4 cm-by-0.4 cm cross-section. Its north pole is placed against a refrigerator door (made of 'soft' iron). A force of .05 N is required to pull the magnet off the door. Estimate its magnetization (magnetic moment per unit volume). Briefly explain your reasoning.




(1) Treat the pole faces as planes, with the response of the refrigerator being an equal and opposite sheet of charge. Neglect the other poles.

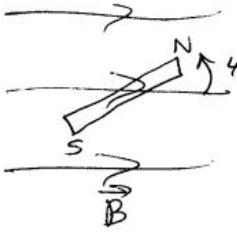
(2) Then the force on the S image is of magnitude $|\vec{F}| = |Q_S||\vec{B}_N|$.

Here $|Q_S| = \underbrace{MA}_{\sigma_m}$ and $|\vec{B}_N| = 2\pi k_m \sigma_m = 2\pi k_m M$

Thus $|\vec{F}| = (MA)(2\pi k_m M) = 2\pi k_m A M^2$,

so $M = \sqrt{\frac{|F|}{2\pi k_m A}} = \sqrt{\frac{.05\,N}{2\pi\times10^{-7}\frac{N}{A^2}\,\pi(.004m)^2}} = 7.05\times10^4\,\frac{A}{m}$

12. (10 pts) A magnet of length 6 cm, mass 45 g, and magnetic moment 1.2 A-m$^2$ is in a horizontal magnetic field. Find its pole strength. If the torque on it is 0.004 N-m when its axis is at 40° to the field, determine the field strength.




(1) $\mu = q_m l$, so $q_m = \frac{M}{l} = 20\,A\text{-}m$

(2) $|\vec{\tau}| = |\vec{\mu}||\vec{B}|\sin\theta$

$|\vec{B}| = \frac{|\vec{\tau}|}{|\vec{\mu}|\sin\theta} = \frac{.004\,N\text{-}m}{1.20\,A\text{-}m^2\sin40^\circ} = 5.19\times10^{-3}\,T$