Goal: *Uniformly magnetized square ferromagnetic plate.* A uniformly magnetized square ferromagnetic plate of side length a and thickness d ($d \ll a$) is situated in air. With reference to the coordinate system in Fig. 5.36, the magnetization vector in the plate is given by $\mathbf{M} = M_o\mathbf{a}_z$, where M_o is a constant. Determine the magnetic flux density vector at an arbitrary point on the z axis.

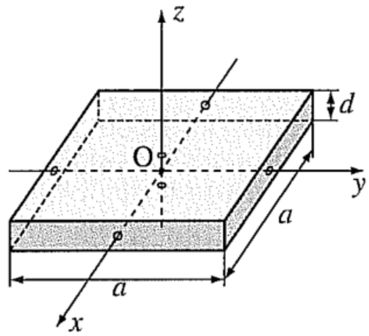

Figure 5.36 Uniformly magnetized square ferromagnetic plate; for Problem 5.3.

Steps:

1. Determine the current densities $\mathbf{J}_m$ and $\mathbf{J}_{m,s}$ equivalent to magnetization, and sketch them in Fig. 5.36.
   Solution: Since $\mathbf{M}$ is a constant, $\mathbf{J}_m = 0$. The red arrow indicate the direction of $\mathbf{J}_{ms}$ on each of the four sides. They each have a magnitude of M_o. The $\mathbf{J}_{ms}$ on the top and bottom surfaces are zero.

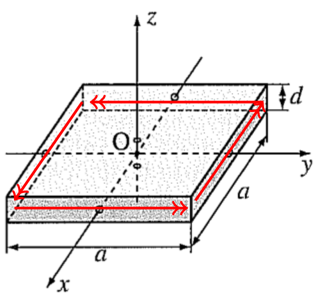

Figure 5.36 Uniformly magnetized square ferromagnetic plate; for Problem 5.3.

2. By symmetry, determine what is the direction of the $\mathbf{B}$ field on a point on the z axis.
   Solution: The z-component is non-zero. All other components are zero.

3. Determine the magnetic flux density vector at an arbitrary point on the z axis.
   Solution: We add up the contributions of B-field from the four sides, and knowing that the current on each of the four sides is $M_o d$, to give

$$\mathbf{B} = \frac{2\sqrt{2}\mu_o M_o a^2 d}{\pi(4z^2 + a^2)\sqrt{2z^2 + a^2}}\mathbf{a}_z$$

Answer:

$$\mathbf{B} = \frac{2\sqrt{2}\mu_o M_o a^2 d}{\pi(4z^2 + a^2)\sqrt{2z^2 + a^2}}\mathbf{a}_z$$