- Halbach magnet geometry: An arrangement of permanent magnets which generates a desired field distribution within a confined volume while canceling the field outside.

- Applications include: uniform fields for nuclear magnetic resonance (NMR), particle beam steering (dipole, quadrupole, … lenses), undulators in free electron lasers (FEL), etc.

- Advantages: high fields exceeding 1T, no external power supplies, compact size.

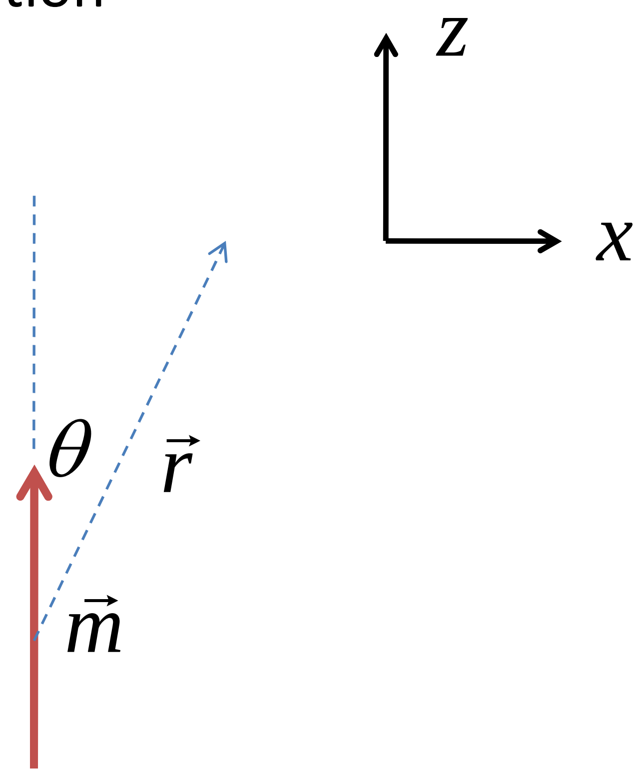
- It’s also pretty cool.

Dipole field distribution

$$B_x = \frac{3m}{r^3}\cos\theta\sin\theta\cos\phi$$

$$B_y = \frac{3m}{r^3}\cos\theta\sin\theta\sin\phi$$

$$B_z = \frac{m}{r^3}(3\cos^2\theta - 1)$$



In the zx-plane, ϕ=0:

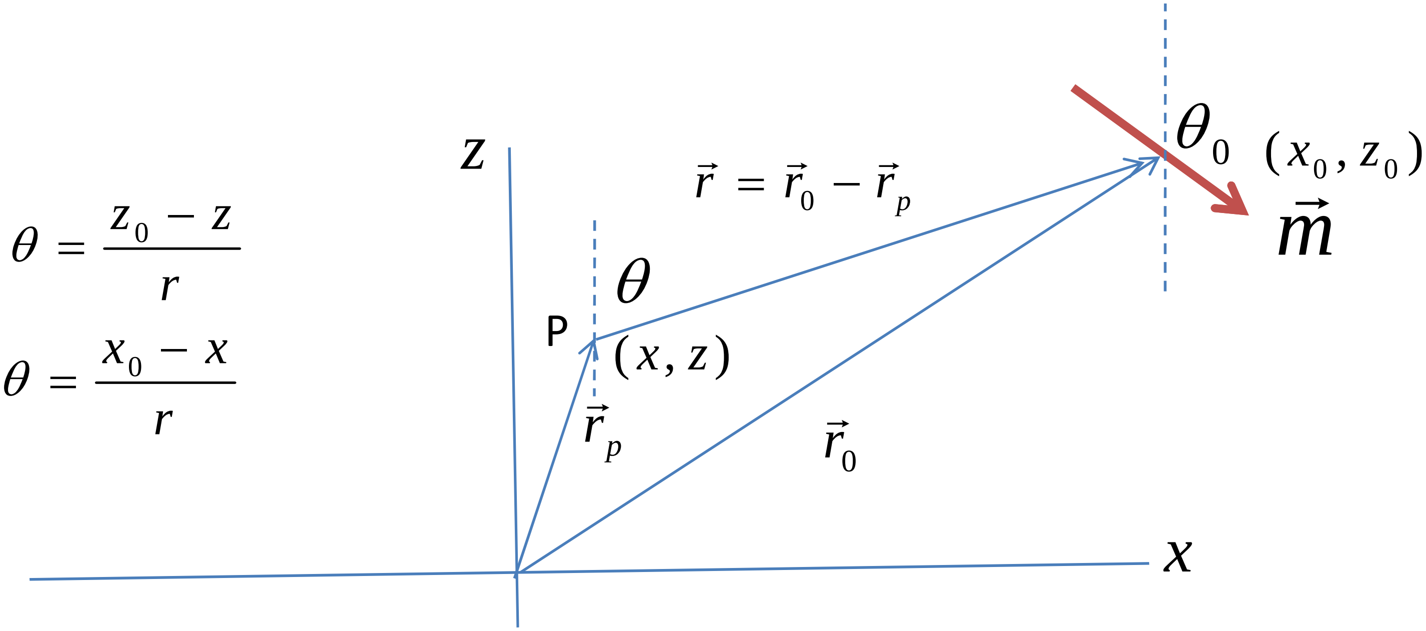
$$B_x = \frac{3m}{r^3}\cos\theta\sin\theta$$

$$B_y = 0$$

$$B_z = \frac{m}{r^3}(3\cos^2\theta - 1)$$

$$\cos\theta = \frac{z_0 - z}{r}$$

$$\sin\theta = \frac{x_0 - x}{r}$$



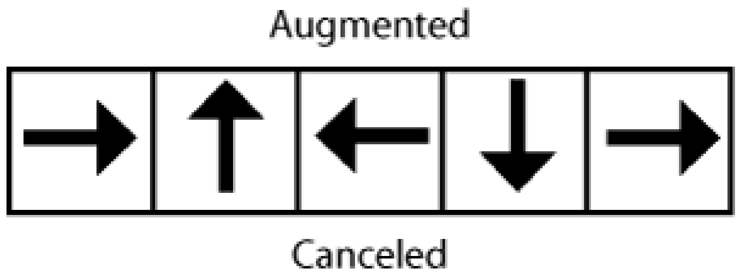
$$B_x' = \frac{3m}{r^3}\cos(\theta + \theta_0)\sin(\theta + \theta_0)$$

$$B_z' = \frac{m}{r^3}(3\cos^2(\theta + \theta_0) - 1)$$

$$B_x(x, z) = B_x' \cos\theta_0 + B_z' \sin\theta_0$$

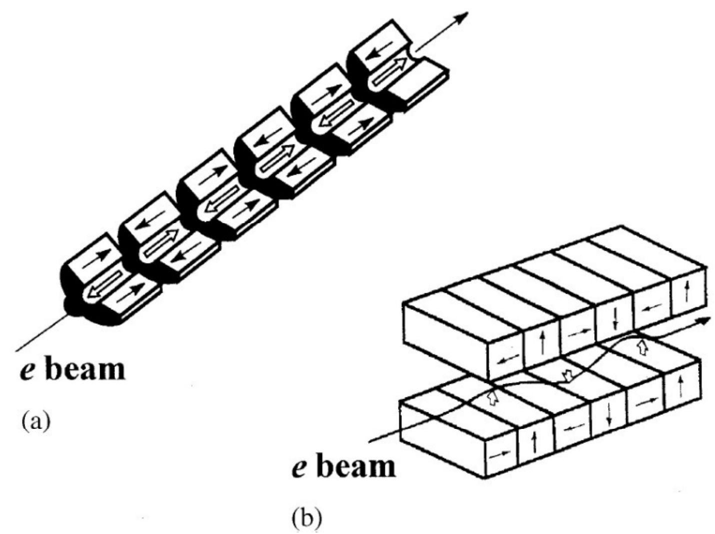
$$B_z(x, z) = -B_x' \sin\theta_0 + B_z' \cos\theta_0$$

Simple Halbach Array

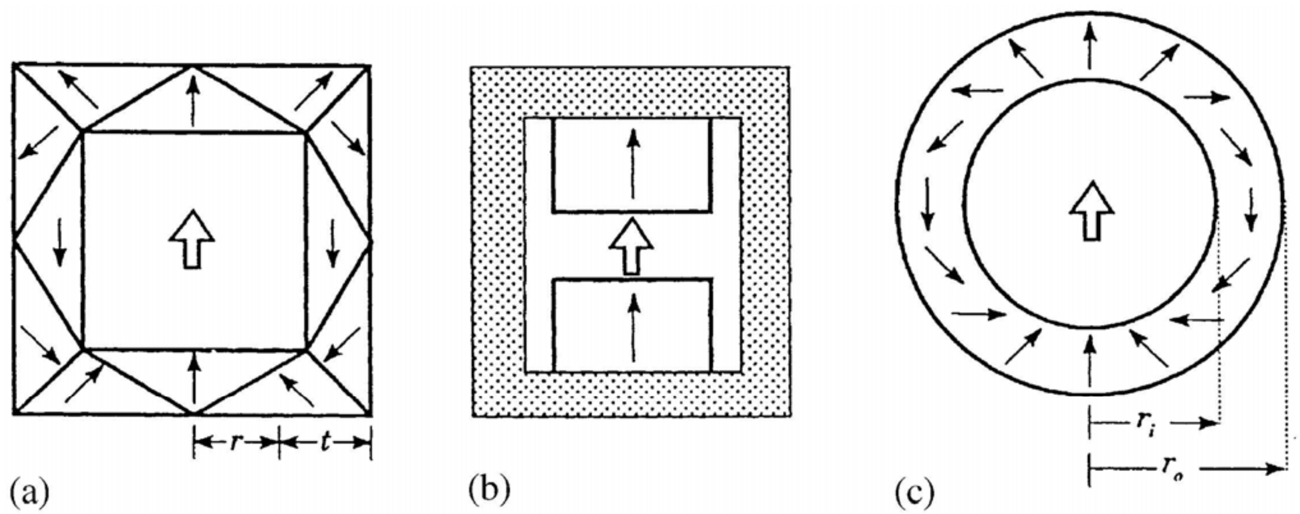


One-sided configuration

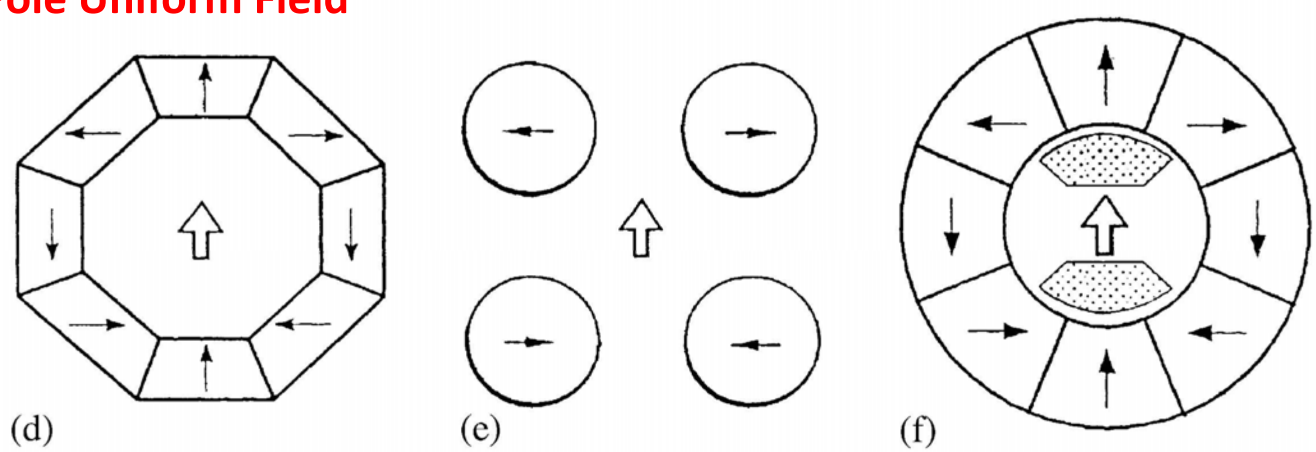
Free electron laser undulator



Dipole Field Configuration

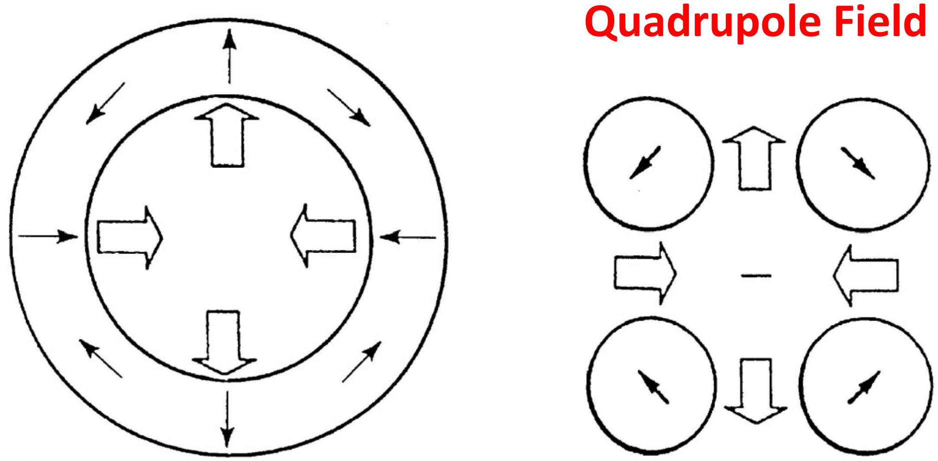


8-Pole Uniform Field



Quadrupole Field

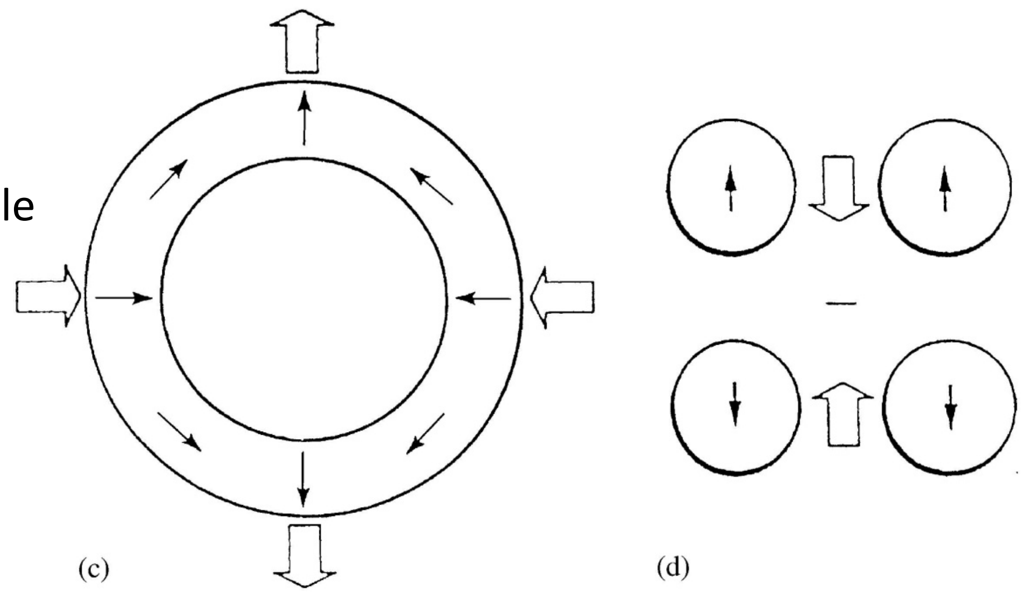
Quadrupole fields



(a) (b)

External quadruple

Field Gradient



(c) (d)

Instructions for Halbach Measurements

- Map out Bz and Bx for **ONE** of the following: (1) quadrupole, (2) 8-pole uniform field, or (3) gradient field. Include your graphs in your report

- Use the transverse hall probe to determine the polling direction of each magnet cube.

- Construct a given Halbach geometry by using the ruler to indicate the location of each magnet on the Styrofoam block then press the magnets into the Styrofoam with your fingers. Keep in mind that the magnets are very strong so don’t place the magnets closer than about 5 cm. The size of the geometry is up to you, but you should aim for each side to be between 5-10 cm.

- Use the transverse Hall probe to scan and map out Bz and Bx (the two components of the magnetic field in the plane of the magnets) as a function of x and z. You will need to make two separate scans to determine Bz and Bx. The probe will need to be rotated by 90° between scans.

- Keep the probe as close to the surface of the Styrofoam as possible in order to determine the in-plane magnetic filed.

- Scan the probe over an area that includes the magnets.

- The scans should include no fewer than 10X10 points. More points will allow you to resolve the spatial variation of the field more accurately.