1 Introduction

The definition of magnetic flux is

$$\Phi_B = \int \mathbf{B} \cdot d\mathbf{A}$$

When the magnitude and direction of $\vec{\mathbf{B}}$ is the same at all points on the surface, the integral simplifies to

$$\Phi_B = \mathbf{B} \cdot \mathbf{A}$$

or, equivalently,

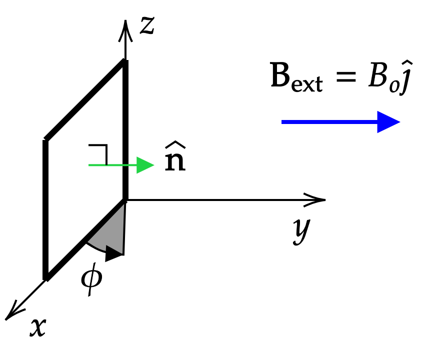
$$\Phi_B = BA\cos\phi$$

where θ is the angle between the $\vec{\mathbf{B}}$ and $\vec{\mathbf{A}}$ vectors.

Note that previously electric flux was covered. The same techniques that apply to computing electric flux apply to magnetic flux.See the Electric Flux activity for additional discussion.

2 Computing Φ_B

In the following figure, a square loop of area A that can be rotated about the z axis is shown. Assume that the normal direction of the loop is as shown in the diagram. A uniform external magnetic field points in the $\hat{\jmath}$ direction.



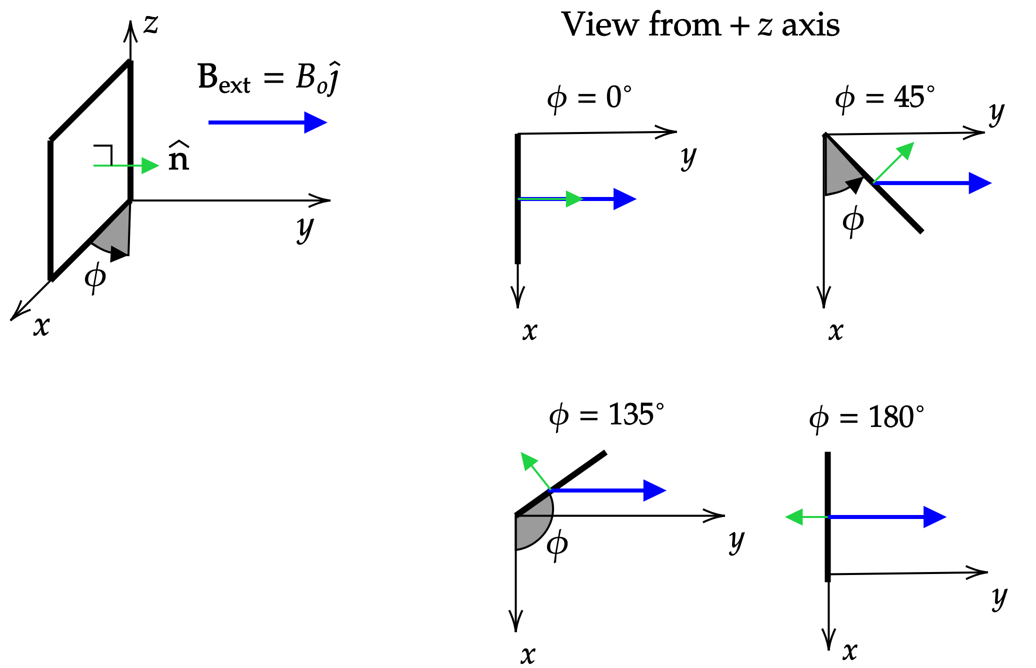
1. At what angles in the range of $\phi = [0, 360°]$ is the magnetic flux zero?
2. Draw the loop, $\hat{\mathbf{n}}$, and $\vec{\mathbf{B}}_{\text{ext}}$ as they would appear when viewed from large z when $\phi = 0°$, $\phi = 45°$, $\phi = 135°$, and $\phi = 180°$.
3. When $\phi = 45°$, is the magnetic flux positive or negative? What is its value in terms of B_oA?
4. When $\phi = 135°$, is the magnetic flux positive or negative? What is its value in terms of B_oA?
5. Sketch a plot of the magnetic flux, Φ, as a function of ϕ.

Answer:

1. The magnetic flux will be zero when the normal vector is perpendicular to $\vec{\mathbf{B}}_{\text{ext}}$. This corresponds to

$\phi = 90^\circ$ and $\phi = 270^\circ$

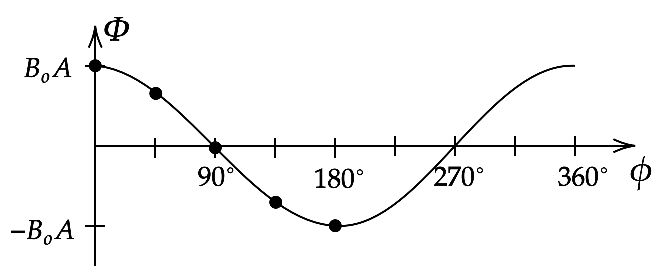
2.



3. As shown in the diagram, the dot product of the normal vector and $\mathbf{B}_{\text{ext}}$ will be positive when $\phi = 45^\circ$, so the flux will be positive. Its value will be $B_o A \cos 45^\circ = B_o A/\sqrt{2}$.

4. As shown in the diagram above, when $\phi = 135^\circ$ the dot product of the normal vector and $\mathbf{B}_{\text{ext}}$ will be negative, so the flux will be negative. Its value will be $B_o A \cos 135^\circ = -B_o A \cos 45^\circ = -B_o A/\sqrt{2}$.

5. The curve is $\Phi = B_o A \cos\phi$ is sketched below along with dots that were used to help determine the shape of the curve.



3 Computing $d\Phi_B/dt$

The time rate of change of magnetic flux through a closed loop is a quantity that will be used when Faraday's law is covered.

Suppose the loop in the previous problem rotates at a constant rate.

1. At what angles is $d\Phi_B/dt = 0$?
2. For what angle range is $d\Phi_B/dt$ increasing?

3. For what angle range is $d\Phi_B/dt$ decreasing?
4. What is the formula for $d\Phi_B/dt$?