Magnetic Field of a Current Loop

Mini Project | Computational Physics (PHY4602) | Semester 1 2023/2024

Chapter : Electromagnetism (pg. 67)

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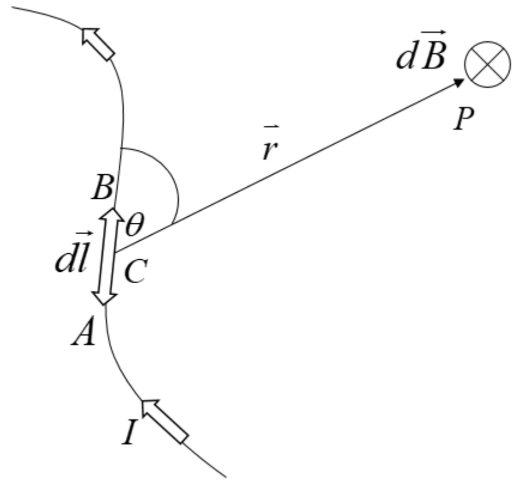
Introduction

Magnetostatics is a branch of classical electromagnetism that deals with the study of magnetic fields in systems where charges are not in motion. In other words, it focuses on the behavior of magnetic fields in situations where electric currents are either constant or not changing with time.

Biot-Savart Law

Biot-Savart Law : A fundamental principle in electromagnetism, defining how a magnetic field generates electric current. This law stated that this magnetic field produced by a current carrying current is directly proportional to the current , the length of the wire, and the sine of the angle between the current direction and measurement point.



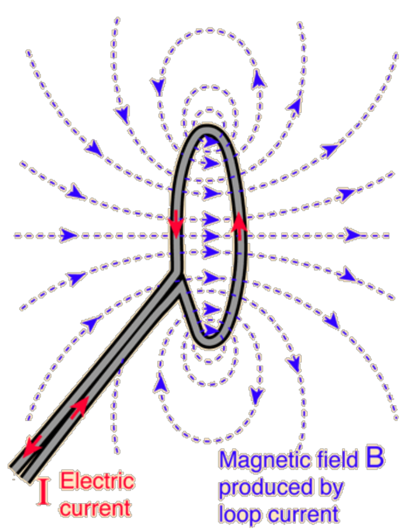
$$d\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{I \cdot \mathrm{dL} \times \vec{r}}{R^3}$$

where :

- μ_0 is the permeability of space
- I is the current
- dL is the length of wire
- $\vec{r}$ is the vector pointing from the current element to the point where the magnetic field is being measured
- R^3 is the distance between the current element and the point where the magnetic field is being measured

Magnetic Field of Current Loop

Electric current in a circular loop creates a magnetic field which is more concentrated in the center of the loop than outside the loop. If there is current, there is a magnetic field.



Documenting Magnetic Field of Current Loop

```
clear all;
help Current_Loop;  % Clear memory and print header
```

```
Current_Loop not found.

    Search the documentation for Current_Loop
```

```
fprintf(' B Field for a Current Loop, Radius a, for r >> a \n');
```

```
 B Field for a Current Loop, Radius a, for r >> a
```

```
fprintf(' Dipole Moment = pi*I*a^2 \n');
```

```
 Dipole Moment = pi*I*a^2
```

Magnetic field is calculated at a point further than a, the radius of current loop. r >> a means than the radius from the observation point (r) is further away from the radius of the current loop.

$$\mathrm{Br} = \sqrt{1-\sin(\theta)} \cdot \frac{2+2r^2+r\sin(\theta)}{(1+r^2+2r\sin(\theta))^{2.5}}$$

$$\mathrm{Br} = -\sin(\theta) \cdot \frac{2-r^2+r\sin(\theta)}{(1+r^2+2r\sin(\theta))^{2.5}}$$

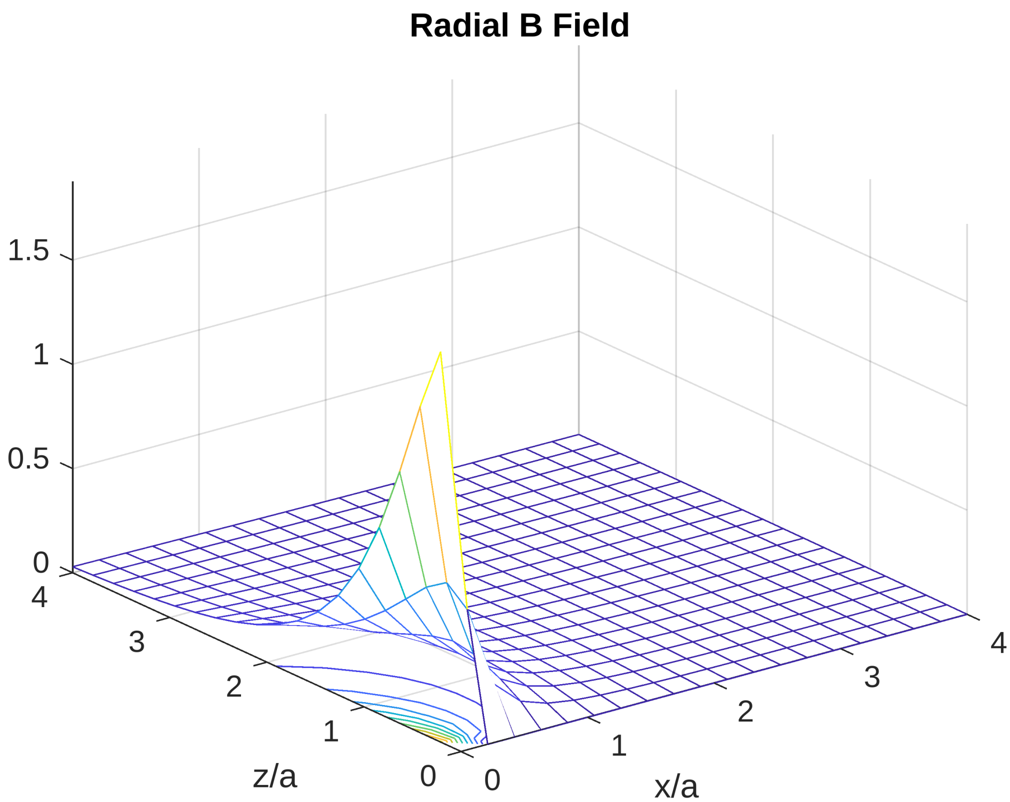
```
xx = linspace(0,4,20);   % radius in units of a
zz = linspace(0,4,20);
%
fprintf(' Current Loop in x,y Plane. Theta is the Angle with respect to the
z Axis \n');
```

```
 Current Loop in x,y Plane. Theta is the Angle with respect to the z Axis
```

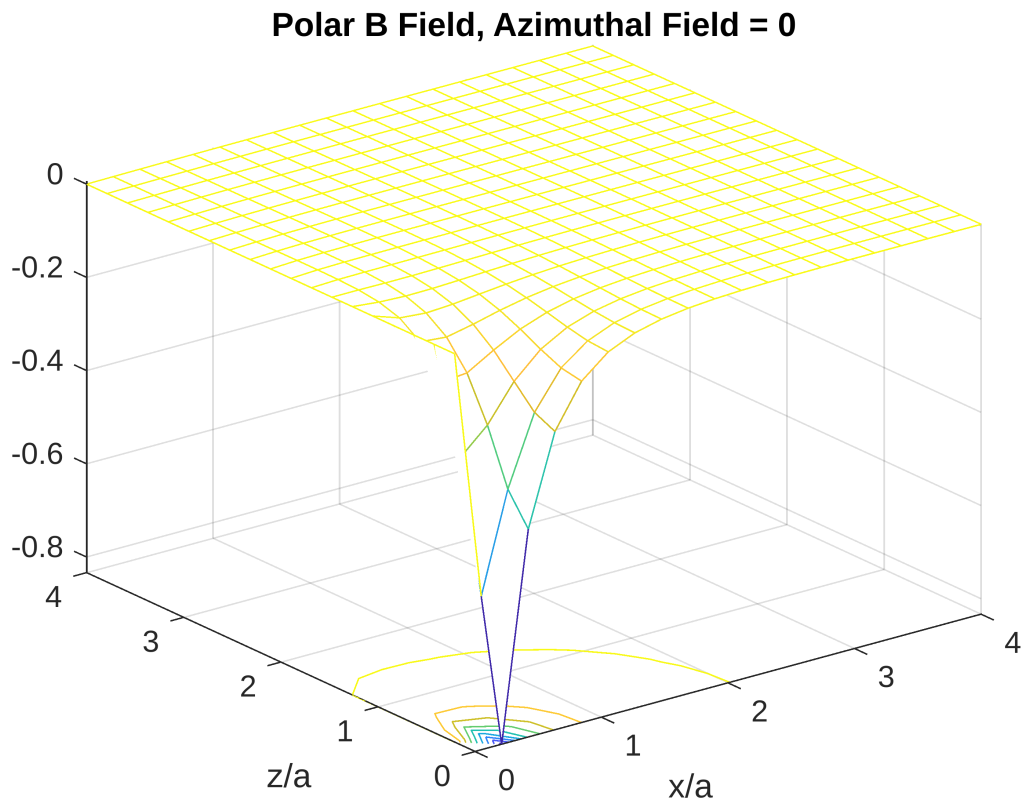
```
%
for i = 1:length(xx)
    for j = 1:length(zz)
        r = sqrt(xx(i) .^2 + zz(j) .^2); % hypotenuse using phytagoras
theorem % length x to z
        st = xx(i) ./r;
        Br(i,j) = sqrt(1.0 - st .*st) .*(2.0 + 2.0 .*r .*r + r .*st)....
          ./(1 + r .*r + 2 .*r .*st) .^2.5  ;
        Bth(i,j) = - st .*(2.0 - r .*r + r .*st)....
          ./(1 + r .*r + 2 .*r .*st) .^2.5  ;
    end
end
```

```
% Magnetic field for radial point
figure(1)
```

```
meshc(xx,zz,Br')
title('Radial B Field')
xlabel('x/a')
ylabel('z/a')
```




```
% Magnetic field for polar point
figure(2)
meshc(xx,zz,Bth')
title('Polar B Field, Azimuthal Field = 0')
xlabel('x/a')
ylabel('z/a')
```



Magnetic Field for All Point

```
fprintf(' B Field for All Points - Biot-Savart \n');
```

```
 B Field for All Points - Biot-Savart
```

```
%
xx = linspace(-2,2,20);   % radius in units of a
zz = linspace(-2,2,20);
phi = linspace(0,2.0 .*pi);     % azimuthal angle (0 to 2pi)
Bx = zeros(length(xx),length(zz));
By = zeros(length(xx),length(zz));
Bz = zeros(length(xx),length(zz));
%
for i = 1:length(xx)
    for j = 1:length(zz);         % grid of field points
        for k = 1:length(phi) ;   % intergate over source
            cp = cos(phi(k));
            sp = sin(phi(k));
            rr32 = (xx(i) .^2 + 1 - 2.0 .*xx(i) .*cp + zz(j) .^2) .^1.5 ;
            Bx(i,j) = Bx(i,j) + (zz(j) .*cp) ./rr32;
            By(i,j) = By(i,j) + (zz(j) .*sp) ./rr32;
            Bz(i,j) = Bz(i,j) + (1.0 - xx(i) .*cp) ./rr32;
        end
    end
```

```
end
```

```
figure(3)
contour(xx,zz,Bz',40);
xlabel('x/a')
ylabel('z/a')
title('Contour for Bz')
```