On Visualizing Vector Fields

Assignment 3

PH1050 Computational Physics

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Problem Statement

Given a configuration of current or a vector field, We are supposed to Visualise the field lines using VectorPlot and StreamPlot function. An infinite current carrying wire creates symmetrical magnetic field lines around it.

Aim

–To derive a function for Magnetic field lines for infinite current carrying wire and visualize them using Vector Plot

–Making the wire finite length and then seeing the lines

EXTRAS:

–Plotting the Field lines and equipotential lines for a tilted dipole

–Plotting the Field Lines of any 2–D system of charges

Code Structure

1) Deriving equations for magnetic field for current carrying wire
2) plotting for infinite Length of wire
3) Plotting for Finite length of wire
4) Plotting Field and potential for tilted Dipole
5) Plotting Electric Field for any 2–D system of charges

Code

Deriving the equation for magnetic field due to current carrying wire

In[305]:=

```
Clear["Global`*"]
$Assumptions = { Im[ρ] == 0 && ρ > 0 && Re[L]≥0};
zCap = {0,0,1};
r= {ρ,0,z};
dB[z_] = Cross[zCap,r]/(Norm[r])^3;
B[L_] := Integrate[dB[z], {z,-L,L}]
B[L]
```

Out[311]=

$$\left\{0, \frac{2 L}{\rho \sqrt{L^2+\rho^2}}, 0\right\}$$

In[312]:=

```
BCartInfinite[x_,y_,z_] := TransformedField["Cylindrical" →"Cartesian",Limit[ B[L] , L → Infinit
BCartInfinite = BCartInfinite[x,y,z][[1;;2]]
```

Limit: Warning: Assumptions that involve the limit variable are ignored.

Out[313]=

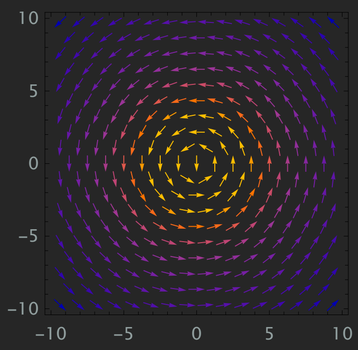
$$\left\{-\frac{2 y}{x^2+y^2}, \frac{2 x}{x^2+y^2}\right\}$$

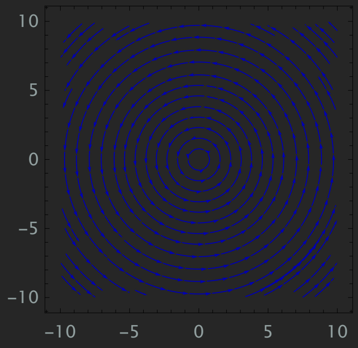
Plotting Field for Infinite wire

In[314]:=

```
Column[{ VectorPlot[BCartInfinite, {x, -10, 10}, {y, -10, 10}], StreamPlot[BCartInfinite, {x, -1
```

Out[314]=





In[315]:=

```
(* for a finite length*)
BCart[x_,y_,z_] := TransformedField["Cylindrical" →"Cartesian", B[L], {ρ,θ,φ}→{x,y,z}][[1;;2]]
BCart = BCart[x,y,z][[1;;2]];
(* when L tends to infinity*)
Limit[BCart, L→ Infinity]
L = 1;
BCart
```

Limit: Warning: Assumptions that involve the limit variable are ignored.

Out[317]=

$$\left\{-\frac{2\,y}{x^2+y^2},\ \frac{2\,x}{x^2+y^2}\right\}$$

Out[319]=

$$\left\{-\frac{2\,y}{\left(x^2+y^2\right)\sqrt{1+x^2+y^2}},\ \frac{2\,x}{\left(x^2+y^2\right)\sqrt{1+x^2+y^2}}\right\}$$

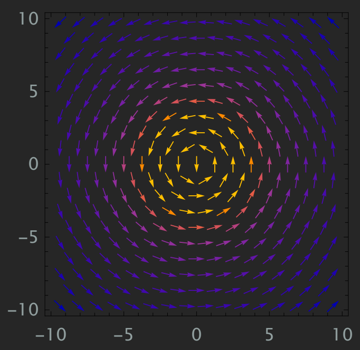
Plotting Lines for Finite wire

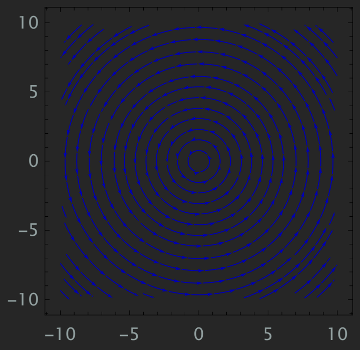
In[320]:=

```
Print["For L = 1"]
Column[{ VectorPlot[BCart, {x,-10,10}, {y,-10,10}],StreamPlot[BCart, {x,-10,10}, {y,-10,10}]}]
```

For L = 1

Out[321]=





Plotting Field Lines and equipotential region for magnetic dipole

In[322]:=

```
Clear["Global`*"]
potentialSpherical = (p Cos[θ]+p Sin[θ] Sin[φ])/ρ^2/. p → 1
fieldSpherical = -Grad[potentialSpherical, {ρ,θ,φ} , "Spherical"]

potentialCart[x_,y_,z_] := TransformedField["Spherical" →"Cartesian", potentialSpherical, {ρ,θ,φ
fieldCart[x_,y_,z_]:=TransformedField["Spherical"→"Cartesian",fieldSpherical,{ρ,θ,φ}→{x,y,z}]/.
```

Out[323]=

$$\frac{\text{Cos}[\theta] + \text{Sin}[\theta]\ \text{Sin}[\varphi]}{\rho^2}$$

Out[324]=

$$\left\{\frac{2\ (\text{Cos}[\theta] + \text{Sin}[\theta]\ \text{Sin}[\varphi])}{\rho^3},\ -\frac{-\text{Sin}[\theta] + \text{Cos}[\theta]\ \text{Sin}[\varphi]}{\rho^3},\ -\frac{\text{Cos}[\varphi]}{\rho^3}\right\}$$

In[327]:=

```
fieldYZ[y_,z_]:=fieldCart[x,y,z]/. x→0
fieldYZ[y,z]//FullSimplify;
potential = potentialCart[x,y,z]/.x→0
field=FullSimplify[fieldYZ[y,z][[2;;3]]]
```

Out[329]=

$$\frac{y+z}{\left(y^2+z^2\right)^{3/2}}$$

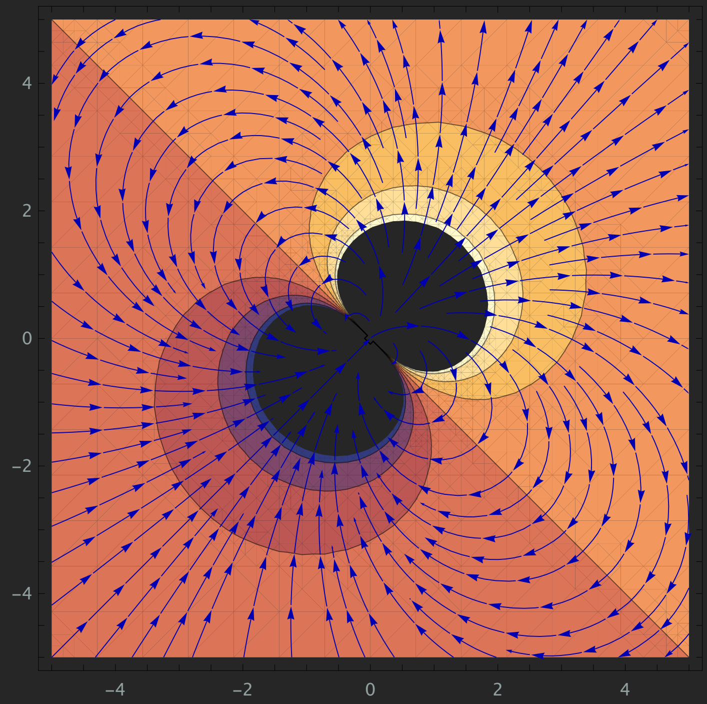
Out[330]=

$$\left\{\frac{2\,y^2+3\,y\,z-z^2}{\left(y^2+z^2\right)^{5/2}},\ \frac{-y^2+3\,y\,z+2\,z^2}{\left(y^2+z^2\right)^{5/2}}\right\}$$

In[331]:=

```
plt1 = StreamPlot[field, {y,-5,5} , {z,-5,5}];
plt2 = ContourPlot[potential,{y,-5,5} , {z,-5,5}];
Show[{plt2,plt1}]
```

Out[333]=



Plotting Electric Field Lines for any system of 2-D charge

In[334]:=

```
Clear["Global`*"]
charges = {};
addCharge[q_, x_, y_] := AppendTo[charges, {q, {x, y}}]
addCharge[2, 3, 4];
addCharge[-5, -3, -5];
charges
```

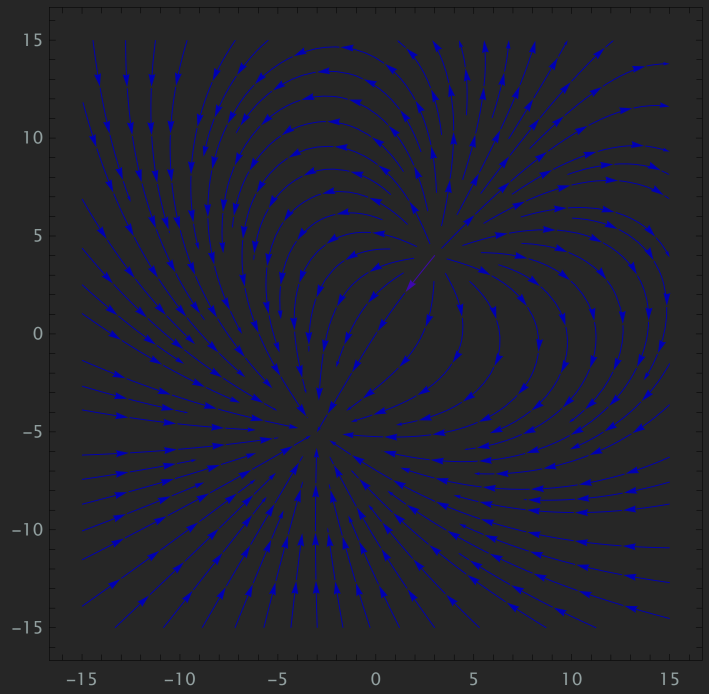
Out[339]=

{{2, {3, 4}}, {-5, {-3, -5}}}

In[340]:=

```
e = {0,0};
For[i=1,i≤Length[charges],i++, e = e + charges⟦i⟧⟦1⟧ * ({x,y} - charges⟦i⟧⟦2⟧)/Norm[({x,y} - ch
StreamPlot[e,{x,-15,15} , {y,-15,15}]
```

Out[342]=



Result

1)For an infinite wire, Magnetic field lines are co centric circle

2) For a finite wire, the field is again co centric circles, but it is not uniform for all z

3) Field lines are more dense near the wire which we can see from inverse ρ relation

4) There cannot be any magnetic monopoles, they must complete a loop

5) ElectricField However do exist in monopoles and lines extend to infinity