A circular loop of wire (radius R) sits in the xy plane with its center at the origin. The loop carries a current I flowing in the counter-clockwise direction as seen from above (i.e., $z > 0$). Consider an attempt to calculate the resulting magnetic field on the z axis using the formula:

$$\vec{\mathbf{B}}(\vec{\mathbf{r}}) = \frac{\mu_0}{4\pi} \int I d\vec{\boldsymbol{\ell}}' \times \frac{\vec{\mathbf{r}} - \vec{\mathbf{r}}'}{|\vec{\mathbf{r}} - \vec{\mathbf{r}}'|^3}$$

Report expressions for all of the following: $d\vec{\boldsymbol{\ell}}'$, $\vec{\mathbf{r}}$, $\vec{\mathbf{r}}'$, $|\vec{\mathbf{r}} - \vec{\mathbf{r}}'|$. Calculate the cross product. Explain why B_x and B_y are zero. Calculate B_z.

Now expand your considerations to include the magnetic field off-axis. As the problem has cylindrical symmetry, finding $\vec{\mathbf{B}}$ on any plane that includes the z axis tells us what $\vec{\mathbf{B}}$ is everywhere. I select the xz plane so an arbitrary observation point in that plane can be written $\vec{\mathbf{r}} = (x, 0, z)$. Write down the required integrals for B_x and B_z and plug them into Mathematica, something like (where you supply the XXX and ZZZ):

```
bx=Integrate[ XXX ,{theta,-Pi, Pi},Assumptions->R>0&&Element[{x,z},Reals]]
bz=Integrate[ ZZZ ,{theta,-Pi, Pi},Assumptions->R>0&&Element[{x,z},Reals]]
b={bx,bz} /. R->1

Show[VectorPlot[b,{x,-2,2},{z,-2,2},VectorPoints->16,PlotRangePadding->None,
RegionFunction->Function[{x, z, vx, vy, n}, (Abs[x]-1)^2+z^2>.3],
PlotRange->{{-2.2,2.2},{-2.2,2.2}},VectorScale->{.4,.1,Automatic}]]
```

Note: the above code is in `assignments.txt` so you can copy and modify it. The `Integrate` will produce ugly `ConditionalExpression` and unfamiliar `EllipticE` and `EllipticK`, but Mathematica knows these functions. Since the aim is to plot vectors, there is no reason to include the simple scaling factor $\mu_0 I/(4\pi)$. Print out a copy of the plot (which should show the magnetic field swirling around the wire intersections at $x = +1$ and $x = -1$)