a) No, since \( \oint \mathbf{E} \cdot d\mathbf{l} = 0 \) over any loop. But \( \int_0^{2\pi} \mathbf{E}(\rho) \rho d\theta = 2\pi C \neq 0 \) in disagreement with it.

b-c) Since angles are now restricted the above argument is not valid. Force lines are obviously concentric circles, while equipotential surfaces are along radii.

Metal planes at some angle \( \Theta \) biased by external voltage source would create such a field distribution.

\( C \) is related to the total potential difference \( V \) according to
\[
C = \frac{V}{\Theta}.
\]

2) The element \( dx \) creates field \( dE \) which at a distance \( z \) is
\[
dE = \frac{\Theta}{2\pi} \frac{dx}{x^2 + z^2} \frac{1}{4\pi \varepsilon_0}.\]
Its component along $z$-axis is

$$dE_z = dE \cos \theta = \frac{Q}{2L} \frac{dx}{\sqrt{x^2 + z^2}} \frac{2}{\sqrt{x^2 + z^2}} \frac{1}{4\pi \varepsilon_0}$$

Finally, integrating over the length of wire,

$$E_z(z) = \frac{1}{L} \int_0^L \frac{dx}{(x^2 + z^2)^{3/2}} \frac{1}{4\pi \varepsilon_0}$$

Using $x = z \tan y$, $x^2 + z^2 = \frac{z^2}{\cos^2 y}$

$$dx = z \frac{dy}{\cos^2 y}$$

we find

$$\arctan \left( \frac{z}{L} \right)$$

$$E_z(z) = \frac{Q}{4\pi \varepsilon_0 L z} \int_0^L dy \cos y = \frac{1}{4\pi \varepsilon_0 L z} \frac{Q}{2} \sin \left( \arctan \frac{L}{z} \right) =$$

$$= \frac{1}{4\pi \varepsilon_0} \frac{Q}{L z} \frac{L/z}{\sqrt{1 + (L/z)^2}} = \frac{Q}{4\pi \varepsilon_0 \sqrt{z^2 + L^2}},$$

and $E_x = E_y = 0$.

For $z \gg L$ 
$$E_z(z) = \frac{Q}{4\pi \varepsilon_0 z^2}$$ — field of a point charge.

For $z \ll L$ 
$$E_z = \frac{Q/2L}{2\pi \varepsilon_0 z}$$ — field of an infinite wire

with the linear charge density $Q/2L$.

3. Since the entire semi-cylinder is equipotential potentials at $A$, $B$, and $C$ must be the same. The potential has to drop by the same value between any point of the cylinder and any point on the plane.
Since $A$ is the closest to the plane electric field there $E = -\frac{dV}{dL}$ will be the strongest and the density of force lines is maximal near $A$: $E_A > E_B$, $E_A > E_C$.

To find out which of $E_B$ and $E_C$ is bigger, consider positive charges near the top (where curvature is small).

Field of nearby positive charges

Field of nearby positive charges

Field of negative charges

Field of distant positive charges

From this picture we observe that at $p, B$ the two fields add up

$$E_B = E(r) + E_C$$

while at $p, C$ they subtract

$$E_C = E(+)_B - E(-)$$

so that $E_B > E_C$.
Magnetic field inside a wire carrying homogeneous density \( \vec{j} = \hat{z} j \) is

\[
2\pi r B_y = \mu_0 \pi r^2 \Rightarrow B_y = \frac{\mu_0 j}{2}, \text{ or in the vector form}
\]

\[
\vec{B} = \frac{\mu_0 j}{2} \hat{z} \times \vec{r}
\]

The hollow can be viewed as a superposition of \( +j \) and \(-j \) current densities.

The negative wire creates magnetic field

\[
\vec{B}' = -\frac{\mu_0 j}{2} \hat{z} \times (\vec{r} - \vec{a})
\]

where \( \vec{r} - \vec{a} \) is the distance to its axis.

Thus,

\[
\vec{B}_{total} = \frac{\mu_0 j}{2} \hat{z} \times \vec{r} - \frac{\mu_0 j}{2} \hat{z} \times (\vec{r} - \vec{a})
\]

\[
= \frac{\mu_0 j}{2} \hat{z} \times \vec{a}
\]

Using \( j = \frac{I}{2\pi (r^2 - a^2)} \), we find that the field is homogeneous and is equal to

\[
\vec{B} = \frac{I \mu_0}{2\pi (r^2 - a^2)} \hat{z} \times \vec{a}
\]