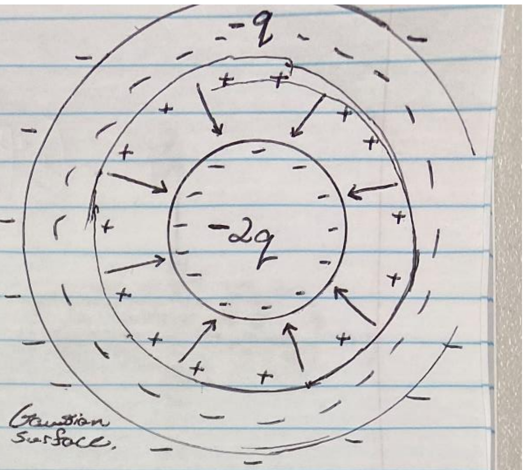
Q1)

a)



b) $\int E \cdot dA = \frac{Q_{in}}{\varepsilon_0}$ (Gauss's law)

$EA = \frac{Q_{in}}{\varepsilon_0}$

Since surface area of a cylinder with length l is A

~~length~~ ∴ Draw bigger cylinder as Gaussian surface.

$A = 2\pi r l$

$E = \frac{Q_{in}}{\varepsilon_0} \frac{1}{2\pi r l}$ since charge per unit length $= \lambda l$

$$E(r) = \frac{\lambda l}{2\pi r \varepsilon_0}$$

c) The above expression does not depend on the charge of the outer conductor as Gauss's law states that it is only dependent on the charge within the surface.

d) Consider a surface inside the outer conducting shell. The Electric fields within can be found using Gauss's law:

$\int E \cdot dS = \frac{Q_{in}}{\varepsilon_0} = \Phi_E$ The flux within a conductor will be 0 :

$\frac{Q_{in}}{\varepsilon_0} = 0 = \frac{-2q + q_{inner}}{\varepsilon_0}$ where q_{inner} is the charge on the inside edge of the outer shell.

∴ $q_{inner} = 2q = 2\lambda L$

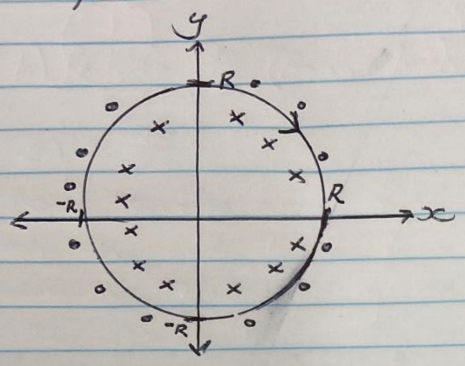
As the charge on the outer shell is is $-Q$:

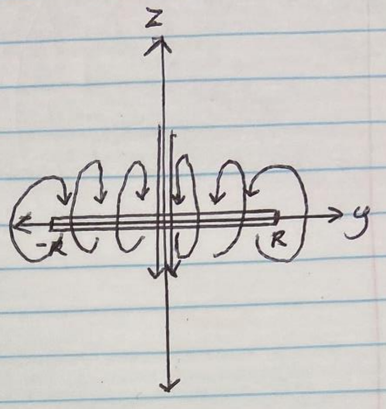
$-Q = q_{outer} + q_{inner} = q_{outer} + 2q$ ∴ $q_{outer} = -3q = -3\lambda L$

∴ $-3q$ lies on the outer shell: inner : outer = 2 : -3

Q2)

Top Down:





b) Biot-Savarts law states that the magnetic field at a point from a part of a current carrying wire is equal to:

$$dB = \frac{\mu_0}{4\pi} \frac{I\,dl \times \hat{r}}{R^2}$$ since In a loop, the vector $\hat{r}$ is always perpendicular to the length:

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{R^2} dl \Rightarrow \int d\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{R^2} \int dl$$ since $l = 2\pi r$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{R^2} 2\pi R \Rightarrow \vec{B} = \frac{\mu_0}{2} \frac{I}{R}$$ QED.

Q3) To solve this we can use motional Emf to solve for the magnitude of the magnetic field.

~~B~~ $emf = Blv$ where $emf = 0.01V$ (Induced voltage due to move)

$l = 0.1m$ and $V = 6m/s$

$\therefore B = \frac{0.01}{0.6} \approx 0.017$.

The direction can be deduced using the right hand slap rule: Given the wire moves to the right, and the force is down, (as the potential is highest at the bottom, indicating the force must be pushing positive particles down - negatives up), the magnetic fields must be moving towards the observer.