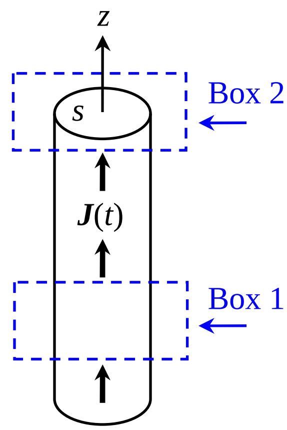
Problem 7) Charge-current continuity equation: $\boldsymbol{\nabla}\cdot\boldsymbol{J}+\partial\rho/\partial t=0$.



For Box 1, the incoming and outgoing $\boldsymbol{J}$ are equal, therefore, $\boldsymbol{\nabla}\cdot\boldsymbol{J}=0$, resulting in $\partial\rho/\partial t=0$. Assuming that the wire has been without charge initially, i.e., $\rho(-\infty)=0$, we conclude that $\rho(t)=0$ along the entire length of the wire.

For Box 2, the current comes in from below, but does not leave the box. Therefore, $\oint \boldsymbol{J}\cdot\mathrm{d}\boldsymbol{s}=-\mathrm{d}Q_1/\mathrm{d}t \quad\rightarrow\quad \mathrm{d}Q_1/\mathrm{d}t=J_o s\sin(2\pi f t)$, where s is the cross-sectional area of the wire. For the accumulated charge at the top of the wire, we thus have $Q_1(t)=-\dfrac{J_o s}{2\pi f}\cos(2\pi f t)$. At the bottom of the wire, $Q_2(t)=+\dfrac{J_o s}{2\pi f}\cos(2\pi f t)$. The dipole moment $\boldsymbol{p}(t)=Q_1(t)\cdot d\cdot\hat{\boldsymbol{z}}$ of the wire (length $=d$) is now given by $\boldsymbol{p}(t)=-[J_o s\,d/(2\pi f)]\cos(2\pi f t)\hat{\boldsymbol{z}}$.