9. SOLENOIDS

i) The overlapping region has magnetic field $2B$, rest of the coils' insides has B. Let the inner coil have an area of A_2. Energy density, where the magnetic field is B, is $\frac{B^2}{2\mu_0}$. Therefore $E_m = \frac{B^2}{2\mu_0}(A_1 l - A_2(l-x) + A_2 x) + \frac{(2B)^2}{2\mu_0} A_2(l-x) = \frac{B^2}{2\mu_0}[A_1 l + A_2(3l-2x)] = \frac{\mu_0 I^2 N^2}{2l^2}[A_1 l + A_2(3l-2x)]$.

ii) The outer coil is intersected by all the internal coil's magnetic flux BA_2. After time dt this flux is enclosed by fewer turns of the outer coil — by the $Nv\,dt/l$ turns that are on the length $v\,dt$. Thus the flux enclosed by the outer coil changes with a rate $\mathcal{E}_1 = \dot{\Phi}_1 = BA_2 Nv/l = \mu_0 A_2 I N^2 v/l^2$. The inner coil is also intersected by the flux BA_2, thus $\mathcal{E}_2 = \mathcal{E}_1$; those electromotive forces are in the same direction.

iii) The work done when pulling a coil out is balanced in two places: the magnetic field energy decreases and our constant current source dissipates some energy (because our electomotive forces work against it). In total, the applied mechanical power $Fv = \frac{dE_m}{dx} v + I(\mathcal{E}_1 + \mathcal{E}_2)$, from where $F = -\frac{B^2 A_2}{\mu_0} + \frac{2IBA_2 N}{l} = \frac{\mu_0 I^2 N^2 A_2}{l^2}$.