2.10. Electrostatic loudspeakers are sometimes used in high-quality audio systems. An idealized representation of an electrostatic speaker is given by a parallel plate capacitor with plates separated by a nominal distance h, as shown in Fig. 2.42. One plate is rigidly mounted while the other, the diaphragm, can move. When a voltage is applied an electrostatic attractive force is generated between the plates, and the resulting movement x of the diaphragm generates acoustic waves.

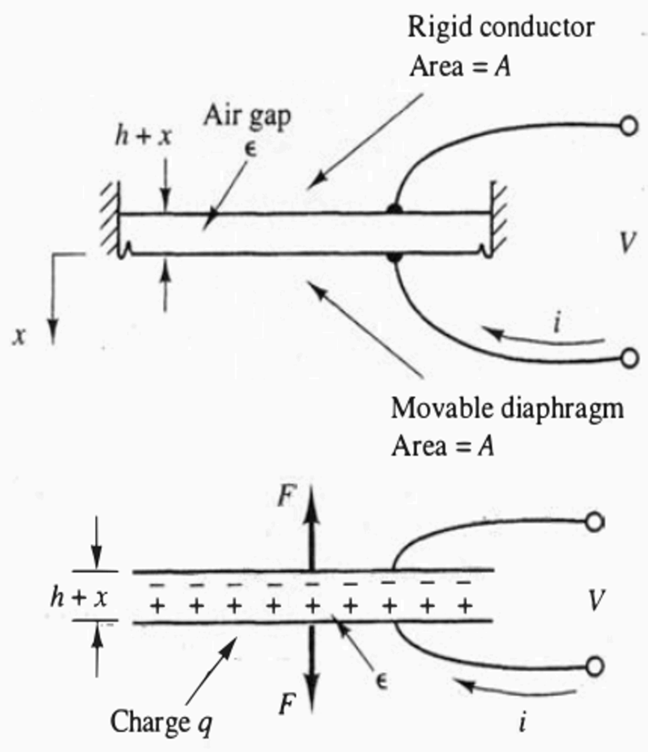

Figure 2.42: An electrostatic loudspeaker.

(a) Assuming that both plates are fixed and unable to move, compute the electrical energy stored and the force F on the plates as a function of the applied voltage V.

(b) Find the capacitance as a function of the plate separation $h + x$.

(c) Find the change in stored electrical energy if the plate separation is increased by a small amount dx while the applied voltage v is held constant.

(d) Repeat (c) with the stored charge q held constant; that is, with $i = 0$.

(e) For a small increase in the gap, from h to $h + dx$, assume that energy is conserved and equate the mechanical work done to the change in stored electrical energy at constant charge; thereby compute F, the electrostatic force as a function of h, A, and v.

$C = \frac{\varepsilon A}{d}$ $\qquad \varepsilon = 8.85 \times 10^{-12}$ F/m

A: area of capacitor plates

d: distance between the plates

C: capacitance

$E = \frac{1}{2} C V^2$ $\qquad$ V: Voltage

E: Energy

$E = \frac{1}{2}\frac{q^2}{C}$ $\qquad$ q: charge

F: force

$E = F v$ — velocity

$dE = F\,dx$ $\qquad$ dx: change in distance

dE: change in Energy