## 5.5 PROBLEMS

**Problem 5.5.1.** A long glass cylindrical shell made of 4 mm thick Pyrex is used to make a capacitor. The inside and outside of the cylindrical shell is lined with a thin aluminum foil. What is the capacitance per unit length if the inside radius is 5 cm? Ans: 3 nF/m.

**Problem 5.5.2.** A parallel plate capacitor of capacitance 10 pF is connected to a battery and charged to a voltage difference of 12 V. The battery is then disconnected and a dielectric slab made of mica is introduced between the plates. (a) Find the energy stored before mica was introduced. (b) Find the energy stored after mica completely fills the space between the plates. (c) Explain the difference. Ans: (a) 0.72 nJ, (b) 0.1 nJ.

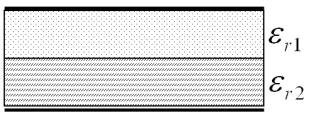
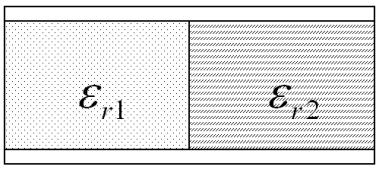


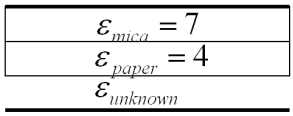

Figure 5.17: Problem 5.5.3.

**Problem 5.5.3.** A parallel plate capacitor is charged so that positive plate has a charge density $+\sigma$ on the side facing the negative plate which has charge density $-\sigma$ on the side facing the positive plate. The plates are separated by a distance $d$ and area of one side of the each plate is $A$. The space between the plates is filled with two slabs made of dielectric materials with dielectric constants $\epsilon_{r1}$ and $\epsilon_{r2}$ respectively of thickness $d/2$ each. (a) Find the electric field in each slab. (b) Find the potential difference between plates. (c) Find the capacitance of the capacitor. (d) Find the polarization P of each dielectric slab. Ans: (c) $\frac{1}{C} = \left(\frac{1}{\epsilon_{r1}} + \frac{1}{\epsilon_{r1}}\right) \frac{d}{2A\epsilon_0}$.

**Problem 5.5.4.** The plates of a parallel plate capacitor are separated by a distance d and area of one side of the each plate is A. The space between the plates is filled with two slabs made of dielectric materials with dielectric constants $\epsilon_{r1}$ and $\epsilon_{r2}$ respectively each of thickness d and occupying half of space. Find the capacitance. Ans: $C = \frac{A\epsilon_0}{d}\left(\frac{\epsilon_{r1}+\epsilon_{r2}}{2}\right)$.



**Problem 5.5.5.** A parallel plate capacitor has plates of area 100 $cm^2$ and separation of plates 3 mm. The gap between the plates is filled with equal thickness (1 mm each) of layers of mica, paper and a material of unknown dielectric constant. The capacitance is then measured with a capacitance meter and found to be 200 pF. What is the dielectric constant of the unknown material? Ans: 19.



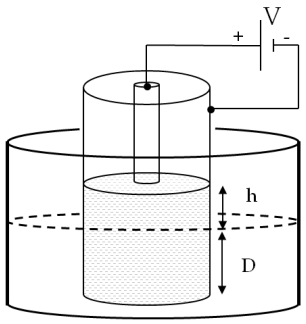




Figure 5.18: Problem 5.5.4.

**Problem 5.5.6.** Consider a cylindrical capacitor that has a metal cylinder of radius $R_1$ in the middle surrounded by a metal cylindrical shell of inner radius $R_2$. Assume the capacitor to be very long. It is dipped in a large tank of motor oil of dielectric constant $\epsilon_r$ so that a height $D$ of the capacitor is under oil. When the inside and outside of the capacitor are connected to constant voltage source of $V$ volts it is found that gasoline rises to a height $h$. Find the value of h in terms of other quantities. Assume the density of motor oil to be $\rho$. Note that a voltage source maintains the voltage difference between its terminals.

**Problem 5.5.7.** Four charges are located at the corners of a square of side a as shown in the figure. Find the leading behavior of electric potential (also called quadrupole potential) at a far away point in the limit $a << r$ at a point P that is in the plane of the charges.

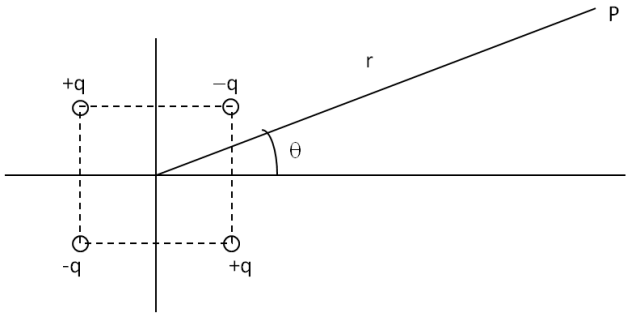



Figure 5.19: Problem 5.5.7.