

## Answer on Question 65309, Physics, Electric Circuits

### Question:

Inspector Clouseau has found a clue in his pursuit of The Phantom 5: a sheet of some unknown material. He has a parallel plate capacitor and can measure the maximum charge held by the plates. With air between them, this maximum charge is  $23.9 \text{ pF}$ . He then slips the unknown material between them and finds a maximum charge of  $134 \text{ pF}$ . Using this information, find the dielectric constant of the unknown material and determine its identity using the Table 16.1 in your text.

### Solution:

Let's first write the charge stored on the plates of both capacitors:

$$Q_{1max} = C_1 V,$$

$$Q_{2max} = C_2 V,$$

here,  $Q_{1max}$  is the maximum charge stored on the plates of air-filled capacitor;  $Q_{2max}$  is the maximum charge stored on the plates of the capacitor filled with unknown material;  $C_1$  is the capacity of air-filled capacitor;  $C_2$  is the capacity of the capacitor filled with unknown material and  $V$  is the voltage across the plates of the capacitor (we assume that we connect the same voltage source to both capacitors).

Then, we can rewrite the expressions for  $Q_{1max}$  and  $Q_{2max}$ :

$$Q_{1max} = C_1 V = \epsilon_0 \frac{A}{d} V,$$

$$Q_{2max} = C_2 V = \kappa \epsilon_0 \frac{A}{d} V,$$

here,  $\kappa$  is the dielectric constant of the unknown material,  $\epsilon_0$  is the permittivity of free space,  $A$  is the area of plate overlap,  $d$  is the plate separation.

Let's express  $V$  from both expressions:

$$V = \frac{Q_{1max}}{\epsilon_0 A} d,$$

$$V = \frac{Q_{2max}}{\kappa \epsilon_0 A} d.$$

Since  $V$  is the same we can equate both expressions:

$$\frac{Q_{1max}}{\epsilon_0 A} d = \frac{Q_{2max}}{\kappa \epsilon_0 A} d,$$

$$Q_{1max} = \frac{Q_{2max}}{\kappa}.$$

From the last expression we can find the dielectric constant of the unknown material:

$$\kappa = \frac{Q_{2max}}{Q_{1max}} = \frac{134 \text{ pF}}{23.9 \text{ pF}} = 5.6.$$

Unfortunately, there is no table attached to this question, but knowing the dielectric constant you can determine the identity of the unknown material using your textbook.

**Answer:**

$$\kappa = 5.6.$$