

18.57 (a) This portion of the problem asks that we compute the magnitude of the dipole moment associated with each unit cell of BaTiO_3 , which is illustrated in Figure 18.35. The dipole moment p is defined by Equation 18.28 as $p = qd$ in which q is the magnitude of each dipole charge, and d is the distance of separation between the charges. Each Ti^{4+} ion has four units of charge associated with it, and thus $q = (4)(1.602 \times 10^{-19} \text{ C}) = 6.41 \times 10^{-19} \text{ C}$. Furthermore, d is the distance the Ti^{4+} ion has been displaced from the center of the unit cell, which is just $0.006 \text{ nm} + 0.006 \text{ nm} = 0.012 \text{ nm}$ [Figure 18.35(b)]. Hence

$$\begin{aligned} p &= qd = (6.41 \times 10^{-19} \text{ C})(0.012 \times 10^{-9} \text{ m}) \\ &= 7.69 \times 10^{-30} \text{ C}\cdot\text{m} \end{aligned}$$

(b) Now it becomes necessary to compute the maximum polarization that is possible for this material. The maximum polarization will exist when the dipole moments of all unit cells are aligned in the same direction. Furthermore, it is computed by dividing the above value of p by the volume of each unit cell, which is equal to the product of three unit cell edge lengths, as shown in Figure 18.35. Thus

$$\begin{aligned} P &= \frac{p}{V_C} \\ &= \frac{7.69 \times 10^{-30} \text{ C}\cdot\text{m}}{(0.403 \times 10^{-9} \text{ m})(0.398 \times 10^{-9} \text{ m})(0.398 \times 10^{-9} \text{ m})} \\ &= 0.121 \text{ C/m}^2 \end{aligned}$$