ECE 162B
HW #2 SOLUTIONS

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5.1 THE TYPES OF BONDS DISCUSSED IN CLASS AND THE TEXT ARE AS FOLLOWS:

IONIC BONDS: ATOMS EXCHANGE VALENCE ELECTRONS TO ACHIEVE FULL VALENCE SHELLS. THE RESULTING IONS ARE BOUND BY ELECTROSTATIC FORCES. IONIC COMPOUNDS ARE TYPICALLY SALTS, RIGID ELECTRICAL INSULATORS WITH HIGH MELTING POINTS, eg NaCl, LiF

METALLIC BONDS: ELECTROPOSITIVE ATOMS DONATE ONE OR MORE VALENCE ELECTRONS TO ACHIEVE A FULL OUTER SHELL. RESULTING POSITIVE LATTICE IONS ARE HELD IN PLACE BY LONG-RANGE NON-DIRECTIONAL ATTRACTION TO THE "SEA OF ELECTRONS". METALS ARE CONDUCTORS DUE TO ABUNDANT MOBILE CHARGE CARRIERS, eg Cu, Al, Fe

COVALENT BONDS: NEIGHBORING ATOMS SHARE VALENCE ELECTRONS TO APPROXIMATE FULL VALENCE SHELLS. THE RESULTING BONDS ARE DIRECTIONAL AND STRONG, RESULTING IN RIGID CRYSTAL STRUCTURES WITH HIGH MELTING POINT, HARDNESS, BULK ELASTIC MODULUS AND ELECTRICAL RESISTIVITY. EXAMPLES ARE ELEMENTAL SEMICONDUCTORS LIKE C, Si, Ge.

VAN DER WAALS BONDS: WEAK BONDS RESULTING FROM THE ATTRACTION BETWEEN INDUCED DIPOLE MOMENTS. THESE DIPOLE MOMENTS ARE THE RESULT OF SMALL OSCILLATING SEPARATIONS OF AN ATOM'S POSITIVE NUCLEUS AND NEGATIVE ELECTRON CLOUD, AS IN NOBLE GASES, eg Ne, Ar.

MIXED BONDS: MOST PRACTICAL MATERIALS EXHIBIT A MIXTURE OF BONDING CHARACTERISTICS. STEEL HAS BOTH IONIC BONDS AND METALLIC BONDS. COMPOUND SEMICONDUCTORS HAVE MIXED IONIC AND COVALENT CHARACTER, SUCH AS III-V eg GaN, GaAs, InP OR II-VI eg ZnS.

5.2

CONSIDER FORCES BETWEEN DIPOLE CHARGES TO GET NET FORCE F BETWEEN TWO ALIGNED DIPOLES:

$$F = \frac{q}{4\pi\epsilon_0}\left[\frac{+q}{r^2} - \frac{q}{(r+d)^2}\right] - \frac{q}{4\pi\epsilon_0}\left[\frac{+q}{(r-d)^2} - \frac{q}{r^2}\right]$$

$$= \frac{q^2}{4\pi\epsilon_0}\left[\frac{2}{r^2} - \frac{1}{(r+d)^2} - \frac{1}{(r-d)^2}\right]$$

EXPAND THESE TERMS IN TAYLOR SERIES ABOUT $\frac{d}{r} = 0$.

$$-\frac{1}{(r+d)^2} - \frac{1}{(r-d)^2} = -\frac{1}{r^2}\left[1 - \frac{2d}{r} + \frac{3d^2}{r^2} - \dots\right] - \frac{1}{r^2}\left[1 + \frac{2d}{r} + \frac{3d^2}{r^2} + \dots\right]$$

$$\Rightarrow F = \frac{q^2}{4\pi\epsilon_0 r^2}\left[2 - \left(1 - \cancel{\frac{2d}{r}} + \frac{3d^2}{r^2} - \dots\right) - \left(1 + \cancel{\frac{2d}{r}} + \frac{3d^2}{r^2} + \dots\right)\right]$$

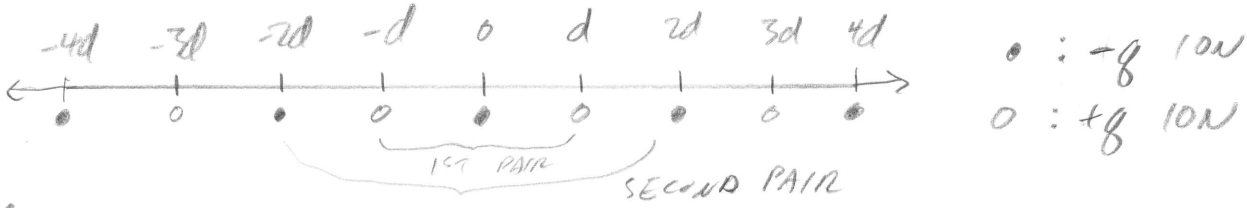
$$\boxed{F \approx \frac{-3q^2d^2}{2\pi\epsilon_0 r^4}}$$

THE TAYLOR SERIES EXPANSION ABOUT $\frac{d}{r} = 0$ IS VALID AS LONG AS $\left(\frac{d}{r}\right) << 1$, SINCE TERMS OF LOWEST ORDER IN $\left(\frac{d}{r}\right)$ WILL DOMINATE THE SERIES.

NOTICE THE $(d/r)^3$ TERMS WILL ALSO CANCEL, SO THE SERIES FOR F WILL BE:

$$F = -\frac{q^2}{2\pi\epsilon_0 r^2}\left[\frac{3d^2}{r^2} + \frac{5d^4}{r^4} + \frac{7d^6}{r^6} + \dots\right]$$

5.6



CONSIDER INTERACTION INTERACTION ENERGY OF NEGATIVE ION AT ZERO WITH EACH PAIR OF IONS CENTERED ABOUT ZERO:

$$E = (-q)V \qquad V = \frac{1}{4\pi\epsilon_0}\left[\frac{2q}{d} - \frac{2q}{2d} + \frac{2q}{3d} - \frac{2q}{4d} + \dots\right]$$

$$\Rightarrow E = \frac{(-q)}{2\pi\epsilon_0}\cdot\left(\frac{q}{d}\right)\cdot\left[1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \dots\right]$$

$$\boxed{E = \frac{-q^2 \ln(2)}{2\pi\epsilon_0 d}} \quad \text{SINCE } \ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3}$$