9.3.3: Wave Speeds in Materials

Wave Speed

While it is true that all wave energy travels through the medium at a constant speed given by $v_{wave} = \lambda f$, the same type of wave will have different speeds in different materials (mediums). The properties of the material are important in determining how quickly energy is passed from one atom to the next. Solids produce the fastest wave speeds and gases transmit energy the slowest. Even among solids, there are differences in wave speeds. The more rigid a solid is, the faster the wave travels through it, and 'squishier' objects produce slower wave speeds. Materials with a larger atomic or molecular mass tend to transmit energy more slowly, since the inertia of those atoms prevents rapid changes from taking place.

This should make sense, given our understanding of how masses and springs oscillate. We saw that the period of motion of a mass on a spring was larger for larger masses. That means it will take longer for the mass to complete one cycle, and it is the movement of one atom that transfer the wave energy to the next atom. If the atoms are moving more slowly, then it will take longer for them to transfer their energy to the next atom. Larger periods mean smaller frequencies and those give slower wave speeds.

We also saw that the mass-spring period decreased as the spring constant increased. Larger spring constants means stiffer springs that generate larger forces. Larger forces should produce a greater effect on the movement of the atoms, so we would expect the atoms to transfer their energy more rapidly. Rapid energy transfer between atoms causes wave speed to increase. Smaller periods give larger frequencies and that translates to higher wave speeds.