**Conduction Lesson Plan (Final)**

**I:**

1. Insulators have a high electrical resistance, meaning charge carriers cannot move over long distances, even when a voltage is applied. This means no measurable current can flow inside an insulator.
2. Charge carriers, such as electrons, are immobile in insulators and they are said not to be free. For example, in diamond, the electrons form strong covalent bonds between the nuclei and cannot move to carry the current.
3. Conductors have a low electrical resistance so that very little opposes the motion of charge carriers that are forced to flow by an applied voltage. This can be measured as a current.
4. Most people know that metals are conductors but any material with free charge carriers can be conductive. In metals, some electrons are not bound to any particular atomic nuclei so they are free to move and allow for conduction, but molten sodium chloride is also a conductor because the charged ions that are bound to each other as a solid become free to move.
5. Depending on the conditions, semiconductors can behave either as an insulator or a conductor. If the conditions provide enough energy (e.g. with high temperatures), charge carriers in semiconductors can become mobile and conduction can occur, but otherwise the semiconductor will behave as an insulator.
6. In covalent semiconductors, the outermost electrons form bonds to neighbouring atoms and therefore aren’t free, but with extra energy (e.g. heat) some bonds can break and free up electrons to allow for conduction. When the electron breaks free, it leaves behind a “hole”. This hole acts like a positively charged particle which can also move to carry the current.

**II:**

1. Quantum physics can be very scary but one of the most important results from it is that electrons can only exist in certain orbits around an atomic nucleus. An electron must have the right amount of energy (no more, no less) to be in an orbit, and each orbit for atoms of each element is associated with a unique energy value. These are called the energy levels of an atom.
2. Within the energy levels, electrons can only occupy certain states defined by (amongst other things) their energy and position. The Pauli Exclusion Principle tells us that in each state we can only have two electrons, one with spin up and one with spin down.
3. In bulk materials, where there can be 1028 atoms per m3, the energy levels of each atom will shift slightly away from that of a completely independent atom so that the Pauli exclusion principle is obeyed.
4. This means that the energy levels that electrons can occupy in a bulk material are very tightly bunched together in bands. They are so closely bunched together that in many cases, the bands behave as continuous regions where electrons can have any energy within the band.

**III:**

1. We can now describe conduction in terms of these electron bands, where electrons can occupy states inside the bands but they are forbidden from occupying states between these bands. This forbidden region, where electrons cannot occupy states, is called the band gap.
2. In order for a material to be conductive, the band structure must be such that there is a band which is not completely filled with electrons: a partially filled band. This allows some electrons to gain energy and move throughout the material.
3. In metals, the highest energy band with electrons in is always partially filled which is why metals are always conductive. This is true at all temperatures.
4. Semiconductors have a full band of electrons at absolute zero (very low temperature), but they also have a small band gap so that as the semiconductor heats up, electrons are excited across the bandgap, creating partially filled bands and allowing the semiconductor to conduct.
5. In insulators, the band gap is very large. This means that even at relatively high temperatures, electrons do not have enough energy to cross the gap and conduction cannot occur.
6. In semiconductors, the lower energy band, which is full at absolute zero, is called the valence band, and the higher energy band that electrons are excited into is called the conduction band.