Class 10: The Quantum in Quantum Dots

1. Take a silicon atom. Like any atom it has a nucleus and a cloud of electrons. The nucleus is positively charged, the electrons negatively charged.
    a. An electron has charge –e = 1.6e-19 C, mass m=9.11e-31 kg.
    b. An atom has discrete *energy levels* where electrons can exist, these are called shells in chemistry.
    c. An electron is a fermion because it is a spin-1/2 particle.
    d. Spin is a quantum mechanical property, magnetic moment of the electron, like a compass needle. In a magnetic field the spin aligns either up or down.
    e. No two fermions can exist in the same state at the same time. So only two electrons per energy level are allowed.
    f. Ionization energy and unbound states.
    g. Valence electrons and core electrons.
2. Why do atoms have discrete energy levels?
    a. Because electrons are waves (wave-particle duality).
    b. All particles obey a wave equation, called the Schrödinger equation. The Schrödinger equation describes the probability of finding an electron in a certain place at a certain time.
    c. Completely analogous to a fixed-length string.
    d. Consider a 1D example. Harmonics on a string.
    e. 1D Particle in a box. Electronics populate box.
    f. Transitions between levels (photons)
    g. Changing the size of the box increases the energy levels.
    h. Cold and Hot, Quantum and Not
        i. Temperature can excite transitions
        ii. Rule of thumb: $k_BT < E$ for it to be quantum or cool
        iii. Smaller the well, the more quantum it is
3. When atoms come together they may form crystals.
    a. Periodic arrangement of atoms.
    b. Energy levels merge to form energy bands (energy vs. position in crystal).
    c. Valence bands vs. conduction bands. (Block them out.)
        i. Valence bands are populated bands (core levels in atoms).
    d. Insulators vs. Semiconductors vs. Metals.
    e. Electrons and Holes.
    f. Bandgaps.
    g. Electron-Hole pairs and radiative recombination.
    h. Solid state lasers.
4. Add an electrostatic potential to the crystal potentional.
    a. Either by cutting the crystal.
    b. Electrostatically by gates.
    c. 3D box
    d. As we shrink the size of the crystal, the levels spread apart.
    e. The bandgap spreads apart.
    f. Light is emitted at different wavelengths depending on size of dot.