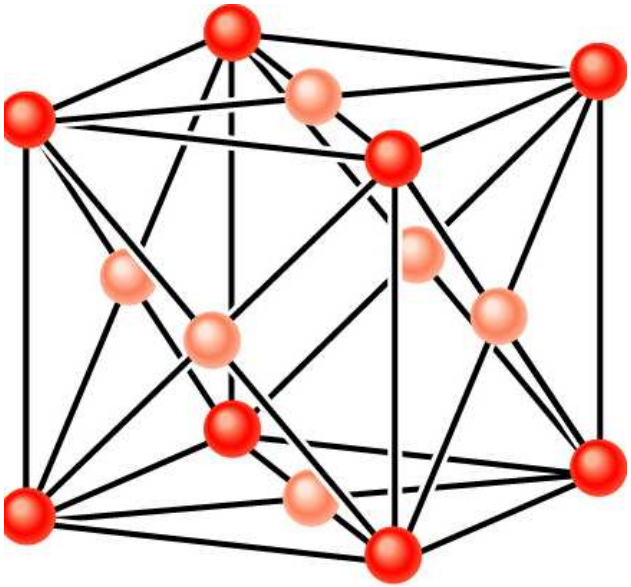
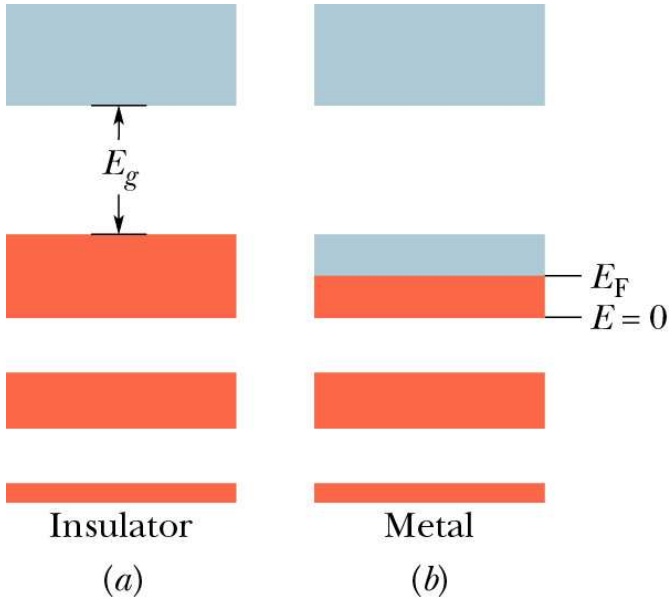
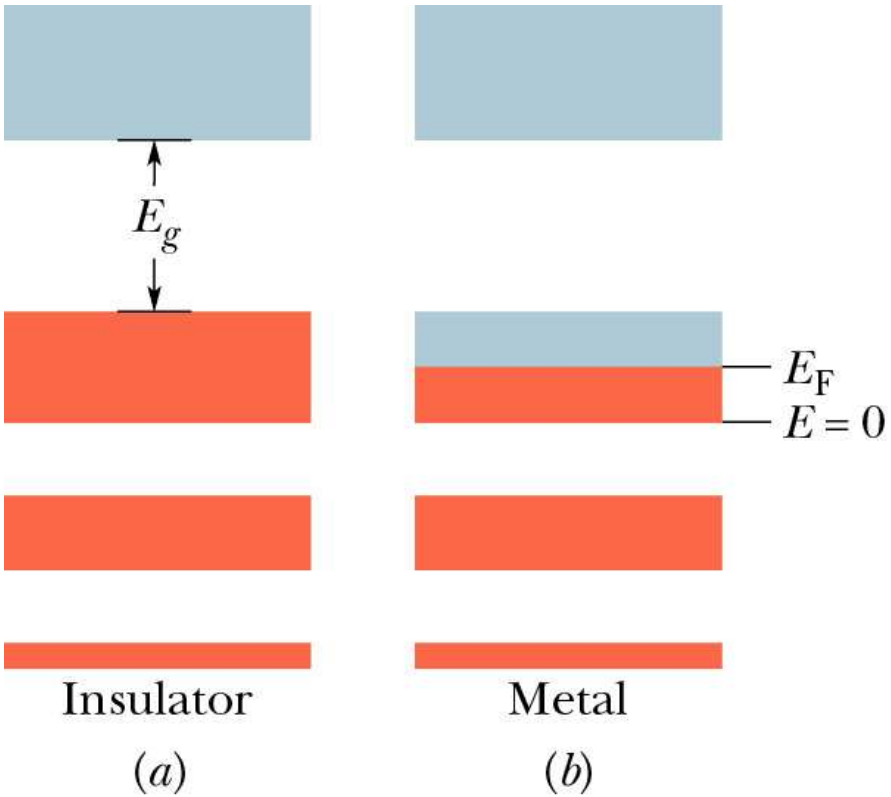
# Why Are Metals Metallic?

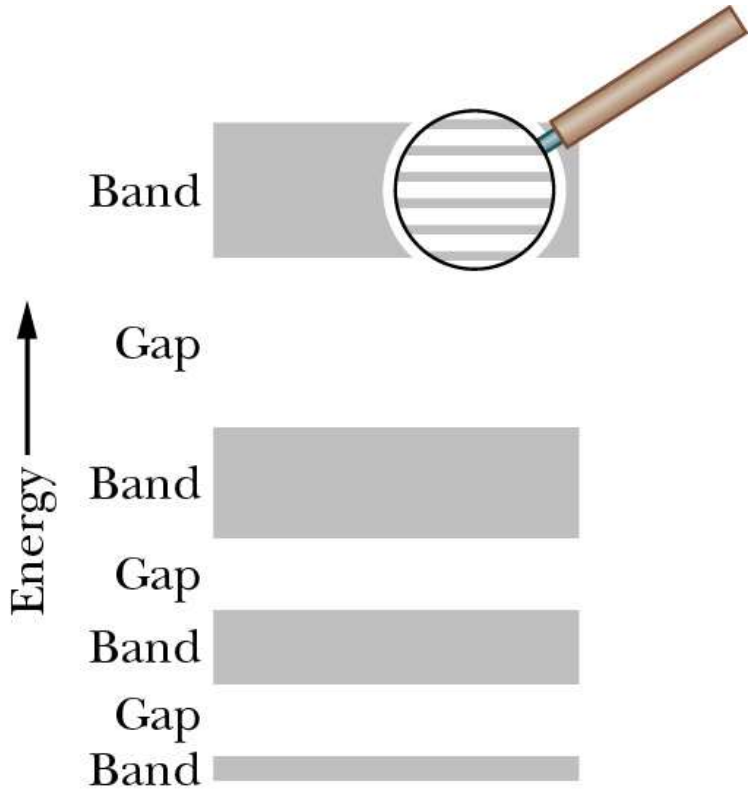
What are the properties of metals? What are the energies of electrons in a metal? The figure below on the left-hand side shows a three-dimensional model of copper which forms a face-centered cubic structure with one atom at each corner and one in the center of each face. On the right-hand side is a schematic picture of the energy states available to electrons in an insulator (a) and a conductor (b).





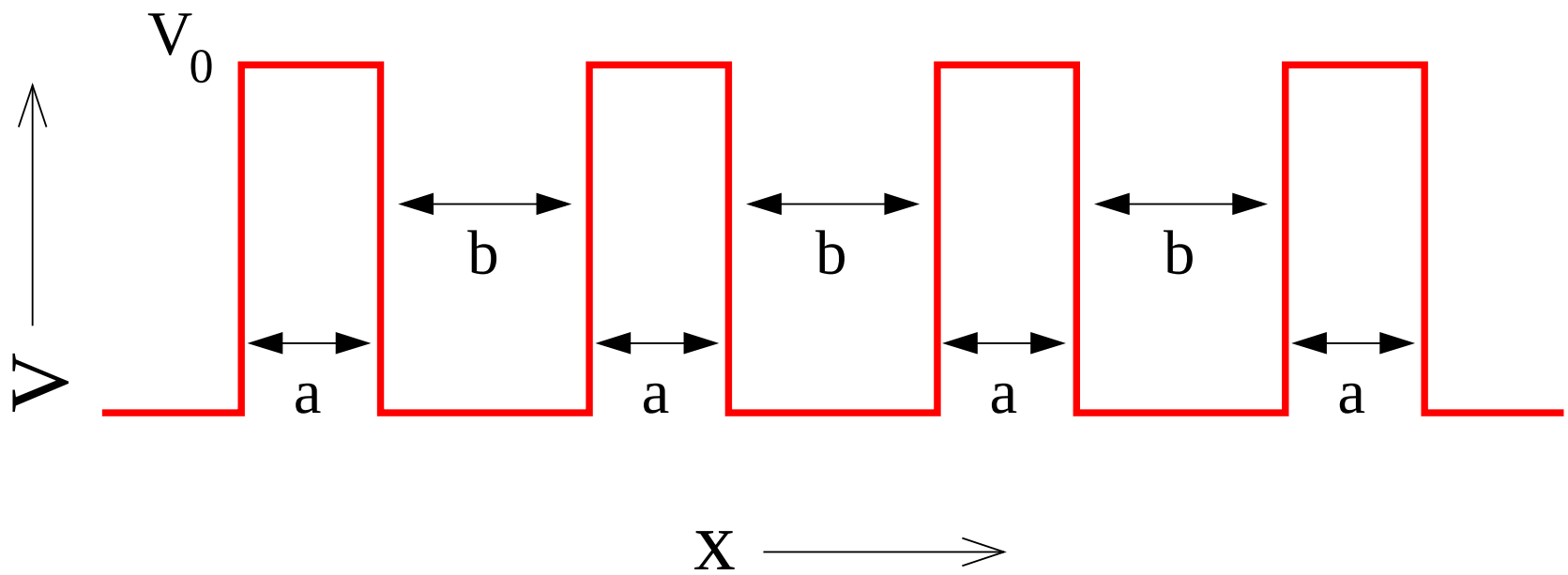
# The Energy States of a Material



# A 1-D Model of a Solid

Consider the potential energy curve for an electron in a one-dimensional model of a solid shown below. What is the transmission coefficient for an electron incident on the solid from the left? Can these results explain the conductivity of metals?



# Tunnelling Matrices

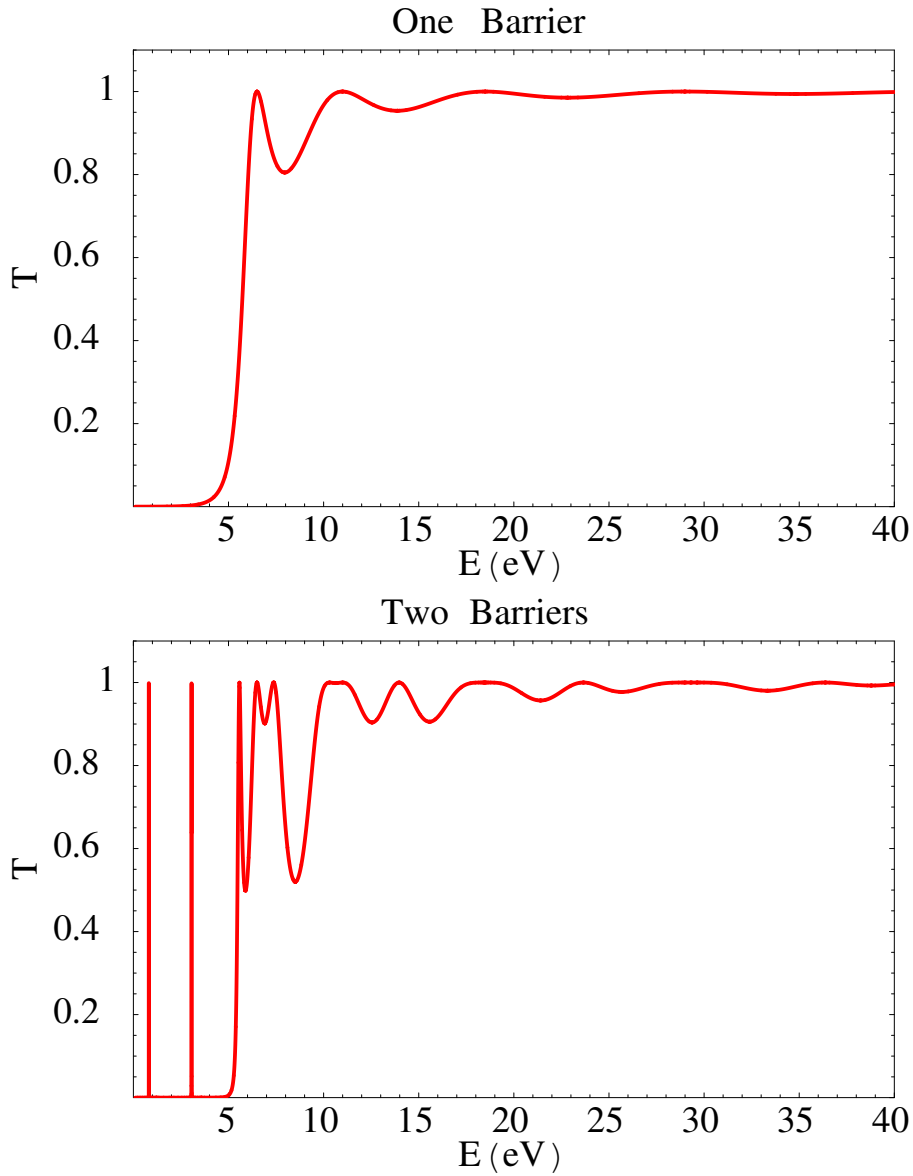
$$\mathbf{d_{12}} = \frac{1}{2}\begin{pmatrix} 1+\frac{k_2}{k_1} & 1-\frac{k_2}{k_1} \\ 1-\frac{k_2}{k_1} & 1+\frac{k_2}{k_1} \end{pmatrix}$$

$$\mathbf{d_{21}} = \frac{1}{2}\begin{pmatrix} 1+\frac{k_1}{k_2} & 1-\frac{k_1}{k_2} \\ 1-\frac{k_1}{k_2} & 1+\frac{k_1}{k_2} \end{pmatrix}$$

$$\mathbf{p_2} = \begin{pmatrix} e^{-ik_2 2a} & 0 \\ 0 & e^{ik_2 2a} \end{pmatrix}$$

$$\mathbf{p_1}^{-1} = \begin{pmatrix} e^{ik_1 2a} & 0 \\ 0 & e^{-ik_1 2a} \end{pmatrix}$$

# Effect of Multiple Barriers, $V_0 = 5$ eV, $a = b = 5.0$ Å



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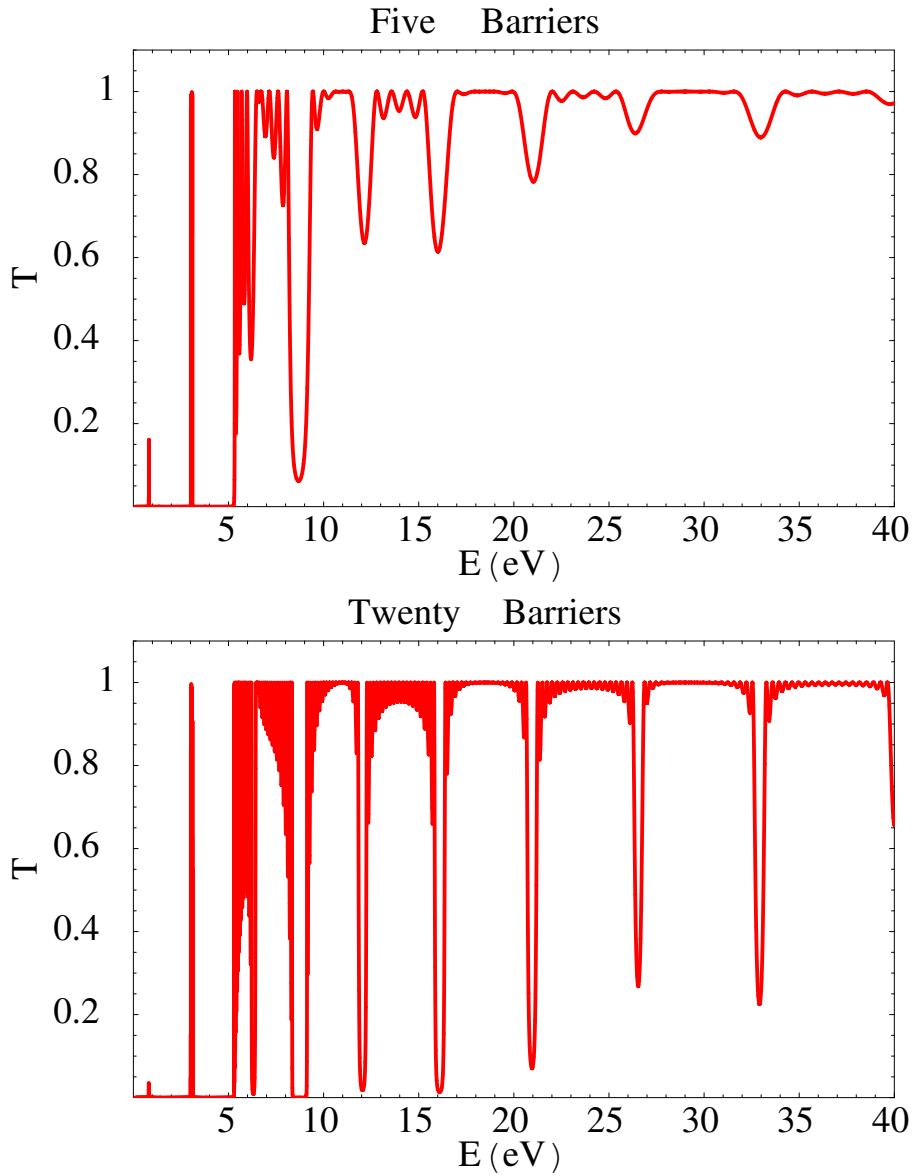

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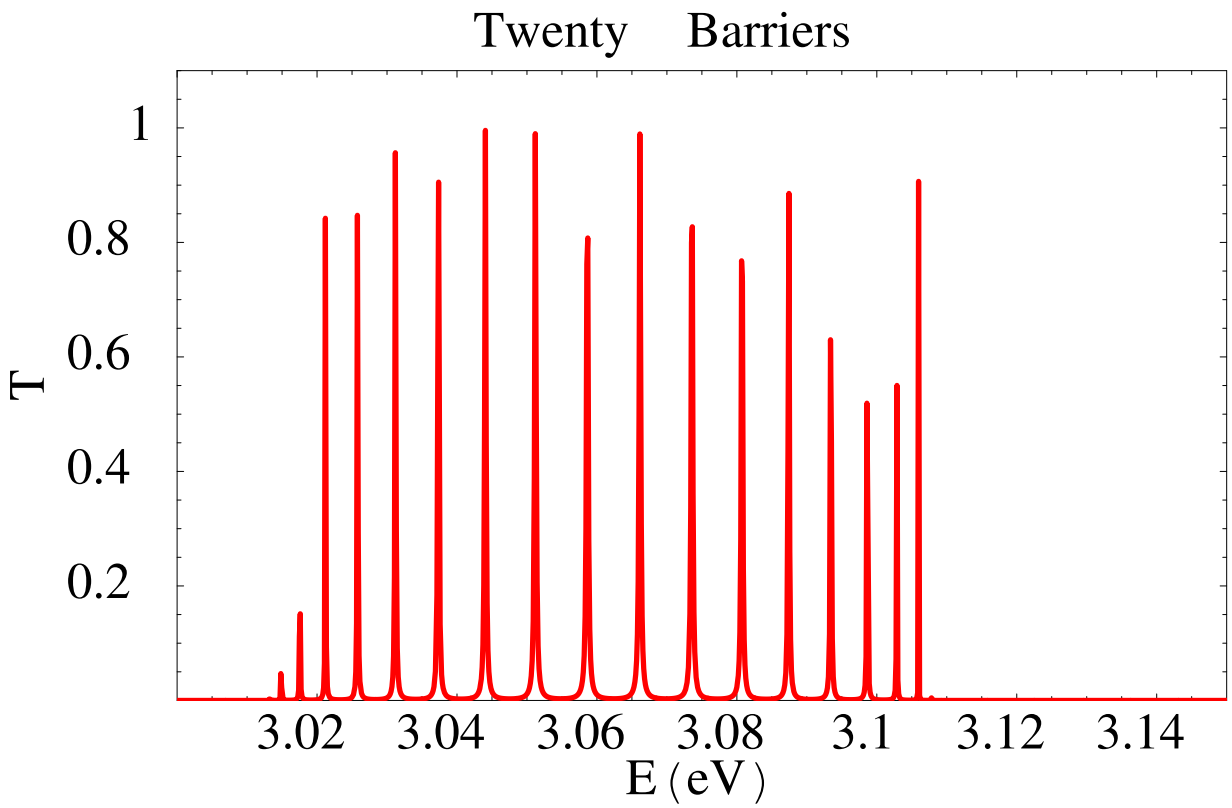
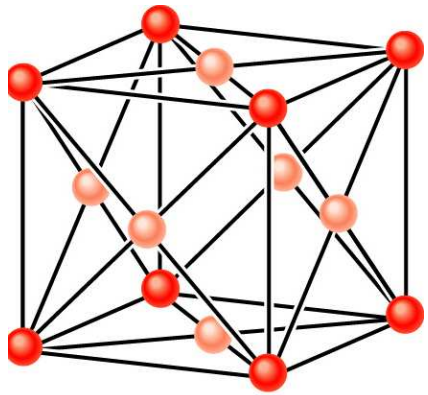


# How fast are the electrons in a metal?

Assume a metal is at a temperature $T = 0\ K$ so that all of the electrons occupy the lowest possibles states in the lattice. For electrons with energies in one of the bands, which one of the quantum models of matter that we have used this semester could be best applied? The electron density of copper (see figure) is measured to be $n_e = 8.49 \times 10^{28}\ m^{-3}$. What is the electron density in our model and how does it depend on the energy of the electron? What is the energy and speed of the fastest electron in copper at $T = 0$? How does this compare with the thermal energy available at a temperature $T = 300\ K$. How good is our assumption that $T = 0$?



# Density of States in Three Dimensions