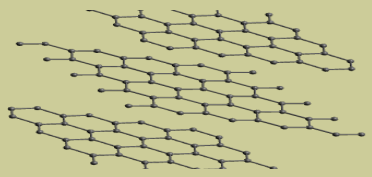
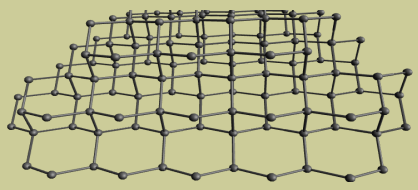
NIPISSING UNIVERSITY - MATHEMATICS

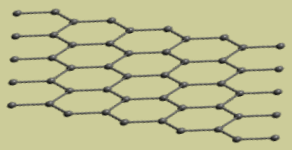
Nanotubes and Geometry



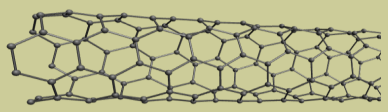
Graphite



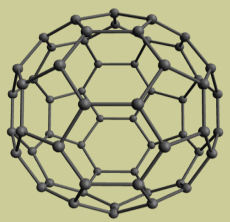
Diamond



Graphene



Nanotube



Fullerene C_{60}

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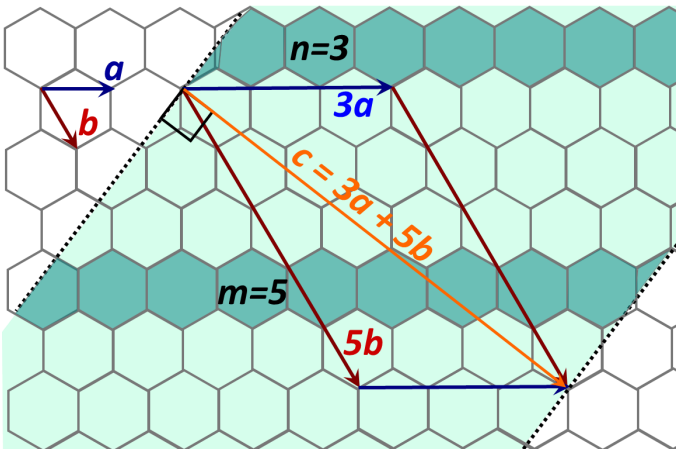

Along with hydrogen and oxygen, carbon is essential for all known life. In nature, carbon exists in several crystal-like forms. Two of them, graphite and diamond, have been known since antiquity. Graphene, a "2-dimensional" carbon, was first observed in 1965. However, the active research of nano-materials did not begin until the late 1980s.

In this research, graphene was thoroughly studied, and several new types of carbon crystal-like structures were discovered. One peculiar type, called fullerenes, consists of compact molecules with a small number of carbon atoms. Carbon nanotubes comprise another type. Nanotubes have unique electrical and physical properties (e.g. conductivity, extreme strength, etc.).

The electrical conductivity of nanotubes is affected by their geometry, which can be described as follows. Two vectors a and b (see the picture) encode the geometry of the nanotube using two non-negative integers m and n. Attach a vector $c = ma + nb$ to any vertex of the graphene cells. Draw through the beginning and the end of this vector two lines, perpendicular to c, and cut the graphene plane along these lines. The resulting strip can be rolled in the direction of c to form a cylinder. This is a nanotube of chirality (m,n). Note that the (m,n)-nanotube is a mirror image of the (n,m)-nanotube, and for $m \neq n > 0$ it cannot be transformed to the other by any combination of spatial rotations and shifts. If $(m - n)$ is divisible by 3, the nanotube has metallic properties, otherwise it acts as a semiconductor. Thus, all (n,n)-nanotubes have metallic properties. In fact, their conductivity is substantially superior to that of copper or silver. The diameter of an ideal nanotube (also affecting conductivity) equals $(f/\pi)(n^2 + nm + m^2)^{1/2}$ where $f \approx 0.246$ nanometers. It is hypothesized that nanotubes can exhibit superconductivity.

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