Nanotube guitars and graphene machines: pushing the boundaries with carbon nanomaterials

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With their remarkable structural, thermal, mechanical, optical, chemical, and electronic properties, carbon nanomaterials cross many disciplinary boundaries. For example, a graphene sheet can be made into a high-performance transistor, but it is also the ultimate realization of a thin mechanical sheet. Such sheets, first studied in detail by August Föppl over a hundred years ago, are notoriously complex, since they can bend, buckle, and crumple in a variety of ways. The problem gets more interesting with graphene and nanotubes, as they undergo thermal fluctuations that completely alter their emergent "macro" properties. In this talk, we will discuss experiments to probe these unusual materials. First, individual carbon nanotubes are picked up and strained with micron-sized tweezers, allowing us to simultaneously study their optical, electronic, and vibrational properties, including recording the "sound" of a single nanotube. Similar tricks are performed with graphene to probe decades-old predictions of the stiffness of 2D membranes. Finally, we discuss how the Japanese paper art of kirigami (kiru = 'to cut', kami = 'paper') applied to graphene offers a route to mechanical metamaterials and opens the door to meeting Feynman's last, as yet unmet, challenge: the construction of nanoscale machines.