The hydraulic-thermal characteristics of 3D pinned heat sink designs have been numerically compared as the first part of a three-part investigation. Five different pin geometries (circular, square, triangular, strip, and elliptic pins) and an unpinned heat sink with three types of nanofluids (Al_2O_3–H_2O, SiO_2–H_2O, and CuO–H_2O) are considered for laminar forced convection. The range of Reynolds number is from 100 to 1000, and volume fractions vary between 0% and 5%. The finite volume method is employed to solve the Navier–Stokes and energy equations by employing a SIMPLE algorithm for a computational solution. Three parameters are presented—the Nusselt number, the bottom temperature, and the hydrothermal performance of the heat sink with pressure drop data. The findings indicated that the overall hydrothermal performance of elliptic-pinned (EP) heat sinks produces the most substantial value of 3.10 for pure water. For different nanofluids, the SiO_2–water nanofluids with EPs have the most significant hydrothermal performance. Also, this factor is enhanced with an increase in nanofluid concentration up to nearly 3.34 for 5% of SiO_2–water. Consequently, applying the elliptic-pinned heat sinks is recommended with pure water for considering an increase in the pressure drop, with 5% of SiO_2–water nanofluids, regardless of an enlargement of pressure drop for heat-dissipation applications.