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Estimation of a melting probe's penetration velocity range to reach icy moons' subsurface ocean

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In modern space science one of the actual branches is icy satellites explorations. The main interest is concentrated around Jovian's moons Europa and Ganymede, Saturn's moons Titan and Enceladus that are covered by thick icy layer according to "Voyager1", "Voyager2", "Galileo" and "Cassini" missions. There is a big possibility that under icy shell could be a deep ocean. Also conditions on these satellites allow speculating about possible habitability, and considering these moons from an astrobiological point of view.
One of the possible tasks of planned missions is a subsurface study. For this goal it is necessary to design special equipment that could be suitable for planetary application. One of the possible means is to use a melting probe which operates by melting and moves by gravitational force. Such a probe should be relatively small, should not weight too much and should require not too much energy. In terrestrial case such kind of probe has been successfully used for glaciers study. And it is possible to extrapolate the usage of such probe to extraterrestrial application.
One of the tasks is to estimate melting probe's penetration velocity. Although there are other unsolved problems such as analyzing how the probe will move in low gravity and low atmospheric pressure; knowing whether hole will be closed or not when probe penetrate thick enough; and considering what order could be a penetration velocity. This study explores two techniques of melting probe's movement. One of them based on elasto-plastic theory and so-called "solid water" theory, and other one takes phase changing into account. These two techniques allow estimating melting probe's velocity range and study whole process. Based on these technique several cases of melting probe movement were considered, melting probe's velocity range estimated, influence of different factors studied and discussed and an easy way to optimize parameters of the melting probe proposed.