Ph.D. Quals Question
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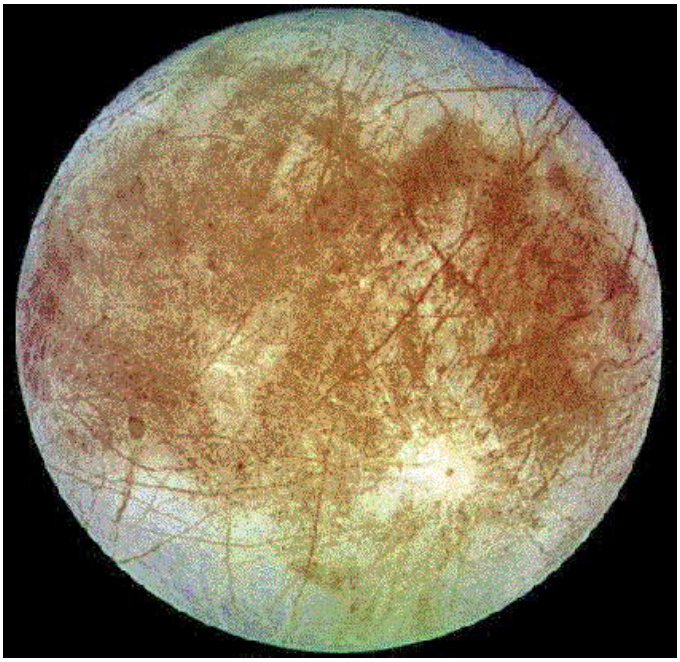
Europa's Ice and "Ocean"

The students enter the examiner's office and find a recent picture of Jupiter's moon Europa sitting on the table in front of them. Here it is:



The students were then given the following information concerning NASA's discoveries with respect to Europa (Jupiter's fourth largest moon): (1) images acquired during spaceprobe flybys show a surface covered with relatively-new water ice (discolored ice in some places) and the layer of ice appears to be quite thick, and (2) magnetic and gravity measurements suggest very strongly that there is a liquid ocean beneath the ice. Liquid oceans are very unusual in the solar system, and the existence of one on Europa suggests the possibility of life. NASA has therefore placed the highest priority on a mission to Europa to see what can be learned about life in the ocean. First, however, NASA has to access the water under the ice, and even before it can reach the water it has to determine the thickness of the ice.

Question: What methods might NASA use to determine the thickness of the Europan ice – and possibly also the depth of its ocean? Remember that neither the ice nor the water may be pure. Remember also that the ice may be very thick. And, finally, remember that NASA has limited financial resources and there is no possibility whatsoever of a manned expedition to Europa.

Answer. To get full marks for this question, the student was expected to, first, discuss some of the many possible methods that might be used to determine the thickness of the ice and depth of water and then, second, to discuss the most feasible appearing method in greater detail, as indicated below.

Possible methods could include (1) flying a drill rig to Europa and using it to drill through the ice. But it should have been decided that this was infeasible due to the weight and size of the rig; (2) measuring the attenuation of a radio signal passing between a satellite orbiting Europa and the Earth as the satellite becomes occulted by Europa (i.e., passes behind it); (3) beaming electromagnetic waves down to the surface from an orbiting satellite and receiving echoes back; (4) landing a probe on the surface of Europa and carrying out a seismic or acoustic sounding experiment; (5) landing a probe on the surface and carrying out an acoustic sounding experiment; (6) landing a probe on the surface and having it melt its way through the ice; (7) landing a probe on the surface and carrying out an electromagnetic sounding experiment; (9) landing several probes at different distances apart on the surface and transmitting various kinds of signals between them to probe the surface.

The above list covers many more possibilities than students were expected to discuss. In general, it should have been decided, quickly, and with some guidance from the examiner, that landing anything on the surface of Europa would involve a much heavier, and thus more expensive, spacecraft to Europa, leaving methods (2) and (3) as the most feasible. Ultimately method (2), if chosen, would be dismissed because the radio signals would have to propagate obliquely through the ice (and water) and thus subject to greater attenuation. This left (3) as the most likely method.

The student was expected to consider what kind of frequencies would be best for electromagnetic probing method (3). For this they would have their attention drawn to the discolorations in the ice and the likelihood that the ocean had salts dissolved in it – in other words, the ice and its underlying water are probably contaminated with salts and therefore electrically conducting. This should then lead into a discussion of the skin depth (definition?) and its inverse dependence on (the square root of) conductivity and frequency. Also looked for was some sensitivity to reflections/transmissions at interfaces.

Note: This Quals question was a repeat of the one given in 2001.