OFFICE MEMORANDUM ◇ STAR LABORATORY

January 21, 2000

To: Diane Shankle

From: Tony Fraser-Smith ACFS

Subject: Ph.D. Quals Question, January 2000

Probing the Surface of Europa

The student is told about NASA's latest discoveries on Europa, the fourth largest moon of Jupiter: (1) images acquired during recent spaceprobe flybys show a surface covered with 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 is therefore planning a mission specifically to Europa that will place a space probe in orbit around the moon (it will be called the Europa Orbiter) and which may land microprobes on the surface to learn more about the ice layer and – it is hoped – about the ocean underneath.

Question: Discuss what NASA might learn about the ice, and possibly ocean, by electromagnetic probing from a microprobe on the surface.

To get full marks for this question, the student was expected to draw attention, at some time during the discussion, to techniques other than electromagnetic probing that might be used. Obviously it would be impractical to drill through a thick layer of ice, given the logistics involved, but acoustic or seismic signals might be used to measure the thickness of the ice.

The student was then expected to consider what kind of frequencies would be best for electromagnetic probing. 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 is probably somewhat contaminated and "salty." With this information, they would first look to see when the ice could be considered to be a good or poor conductor. For this they could start with the quantity $\sigma/\omega\epsilon$, which is a measure of the relative magnitude of the conduction current to the displacement current in a medium (σ is the electrical conductivity, ω is the angular frequency, and ϵ is the permittivity), and discuss the "good conductor" approximation $\sigma/\omega\epsilon \gg 1$. Alternatively, they could start with the transition frequency $\boxed{\omega_c = \sigma/\epsilon,}$ below which frequency the medium acts as a good conductor.

The Europan ice probably has a conductivity $\sigma < 4$ S/m, where 4 S/m is typical for sea water on Earth, and a permittivity of around $\epsilon = 81 \times 8.85 \times 10^{-12}$ F/m. Out of this the students should conclude that they are likely to be dealing with the good conductor approximation for frequencies less than 890 MHz. Knowing that high frequency electromagnetic waves are usually rapidly attenuated in conducting materials, the student should conclude that NASA would have to use the lowest possible frequencies, and that they would be operating with ice that acted electromagnetically as a good conductor.

In the subsequent discussion the student is either asked about or derives the skin depth (δ) and inevitably he/she can write it down as $\delta = \sqrt{2/(\omega\mu\sigma)}$, where μ is the permeability. We discuss the significance of each of the factors in the expression for δ and its applicability.