1. The South Pole-Aitken (SPA) impact basin on the Moon is about 8 km deep. Because it is located mostly on the far side of the Moon, getting information about it has been difficult, until very recently.

   a) Lunar spacecraft see no appreciable gravity anomaly over SPA. What does this imply about the compensation state of the basin, and the lithospheric strength? (2)

   b) Let’s assume that there is no evidence for mantle material at the base of the SPA basin. Use this information to obtain a lower limit on the crustal thickness of the Moon away from SPA. You may assume crustal and mantle densities of 2800 kg m\(^{-3}\) and 3400 kg m\(^{-3}\), respectively. (4)

   c) If SPA was originally 10 km deep, and was then flooded with lavas after the lithosphere cooled and became rigid, how big a gravity anomaly would you see at the surface? At a spacecraft altitude of 300 km, how big would the anomaly be? The basin diameter is 2500 km and the lava density is 2900 kg m\(^{-3}\). (4) (10 total)

2. Here’s a plot of admittance as a function of wavelength derived by the Magellan spacecraft at Venus. Note that the horizontal scale is non-linear. Dots are data (with error bars), dashed line is the best fit model.

   a) Use this plot to determine the crustal density of Venus (2)

   b) The degree of compensation \(C\) is 50% when the admittance is half of the constant value it reaches at short wavelengths. At what wavelength, roughly, does the degree of compensation reach 50%? (1)

   c) Using your answer to b), determine the rigidity \(D\) of the lithosphere of Venus. You may use \(g=9\) ms\(^{-2}\), \(\Delta\rho=500\) kg m\(^{-3}\). (3)
d) What is the corresponding elastic thickness of Venus? Use \( E = 100 \) GPa and Poisson’s ratio = 0.25. (2)
e) How does this value compare to the elastic thickness for continents on Earth? Why is the \( T_e \) value you explain puzzling in view of the high surface temperature of Venus (450°C)? What is one possible resolution of this puzzle? (3)
f) Why do the error bars get bigger at short wavelengths, and what prevents the spacecraft from making better measurements? (3) (14 total)

3. The flexural wavelength is controlled by the flexural parameter \( \alpha \), but what we are more interested in is the elastic thickness \( T_e \).

a) Write down an expression which gives \( T_e \) in terms of \( \alpha \) (2)

b) The figure above shows a rift valley on Miranda, with evidence of flexure on the rift flank. Which symbol in the figure represents the flexural parameter \( \alpha \), and what is the approximate value of \( \alpha \) (in km)? (2).

c) Use your answers to a) and b) to derive the elastic thickness. You may assume a surface density of 1 g/cc, \( g = 0.08 \) ms\(^{-2}\), \( E = 3 \) GPa and Poisson’s ratio = 0.3 (2)

d) Miranda (diameter about 500 km) probably has global long-wavelength variations in ice shell thickness. Would you expect these variations to generate large gravity anomalies? Why? (2)

e) Assume that the base of the elastic layer is at a temperature of 180 K and the surface temperature is 60 K. What is the heat flux if the thermal conductivity is 3 Wm\(^{-1}\)K\(^{-1}\)? (NB look at Turcotte and Schubert chapter 4 if you don’t know how to calculate heat flux). (2)

f) How does the value obtained in e) compare with the Earth’s present day heat flux? Comment on your answer (3) (14 total)
4. Optional, unless you’re a grad student.

Here we’re going to derive an expression for the admittance, symbol $Z(k)$. You may wish to consult the figure below and Slide 14 of Week 4’s lecture notes.

![Diagram of a layered system with surface gravity anomalies due to surface load and deflection of the crust.](image)

a) Write down an expression for the surface gravity anomaly due to the surface load, which has an amplitude $h_0$ and density $\rho_s$. (1)

b) Write down an expression for the gravity anomaly at the surface due to the deflection of the crust, which has an amplitude $w_0$. Don’t forget to include the effect of attenuation (assume that the surface load and deflection both have a wavenumber $k$). (2)

c) Write down an expression for $w_0$ which includes $h_0$, $k$ and the flexural rigidity of the plate $D$. (1)

d) Making use of your answers a-c), write down an expression for the total surface gravity anomaly which includes $h_0$, $\rho_s$, $t_c$, $k$ and $D$. (3)

e) Hence write down an expression for the admittance $Z(k)$. (1)

f) What does $Z(k)$ simplify to in the limit that $kt_c$ or $Dk^4$ become very large? Explain the physical reason for each result. (3)

g) Show that in the limit when $Dk^4$ and $kt_c$ are both <<1, the admittance simplifies to

$$Z(k) \approx 2\pi G \rho_l \left[ \frac{Dk^4}{g \Delta \rho} + kt_c \right]$$

(3) [14 total]