EART160 MIDTERM **Mon 9th Feb 2009**

Answer QUESTION 1 and ONE out of questions 2-4. If you attempt more than one, you'll get credit for the best answer. Show all your working for maximum credit. You have until 12:10pm to complete the test. No calculators.

1. a) Name two different observations that allow us to infer the composition of the original solar nebula (2)

b) How long does it take a lava flow 10 km long and 10 m thick to cool? (2)

c) Sketch how pressure and gravity vary with radial distance inside a uniform-density planet (2)

d) Name four solar system bodies that might be expected to have aeolian deposits (2)

e) The heat flow at the Earth's surface is 30 mWm^{-2} and the thermal conductivity of crustal material is 3 Wm^{-1} K^{-1}. What is the temperature gradient in the crust (in K/km)? (2)

f) Explain the physics behind the greenhouse effect which keeps Earth and Venus warm (2)

g) If a planet cools by 20 K and has a thermal expansivity of $3x10^{-5}$ K^{-1}, what is the magnitude of the compressional stresses? Assume Young's modulus=100 GPa (2)

h) Give two reasons why bodies in the outer solar system grow more slowly than in the inner solar system during accretion (2)

i) The Moon has a smaller gravity than Mars, but a similar elastic thickness. Explain whether mountains are more likely to be isostatically compensated on the Moon or Mars. (2)

j) Give two reasons why a planet might show a lack of small impact craters (2) (20 total)

2. Here we're going to consider impact craters.
a) Consider a hemispherical crater of radius *R*. If the density of excavated material is ρ_e, write down an expression for the mass of material excavated (1).
b) In making the crater, this material is raised vertically by a distance *R* and the acceleration due to gravity is *g*. Write down an expression for the gravitational potential energy required to lift the material. (1)

c) Assume that all this energy is supplied by an impactor of radius r, density ρ_i traveling at a velocity v. Write down an expression for the kinetic energy of this impactor (2)
d) Using your answers to b) and c), write down an expression for the radius of the crater R as a function of v, r, ρ_i, ρ_e and g. Explain why your answer makes physical sense. (4).
e) Comets are typically one-third the density of asteroids, but travel three times as fast. Given an asteroid and a comet of equal size, which would make a bigger crater? (1)
f) If you assume that the impactor's speed equals the escape velocity and that $\rho_i=\rho_e$, use your answer to d) to write down an expression for the crater radius R in terms of the impactor radius r and the planetary radius R_p. (2)
g) A large enough impactor can break apart a planet. Assuming that this occurs when the crater radius just equals the planetary radius, write down an expression for the minimum radius of an impactor which just disrupts a planet of radius R_p. (2)
h) Give two examples in this solar system of where very large impacts are inferred to have happened, and the evidence supporting this inference (2) (15 total)

3 The French COROT satellite has just discovered a "super-Earth".
a) Assuming that the planet has a constant density ρ, write down an expression for how gravity varies inside the planet in terms of G, ρ and radial distance r. (2)
b) The planet's radius is R. Use your answer to a) and the hydrostatic assumption to find an expression for the pressure P inside the planet as a function of G, ρ, R and r. (4)
c) Hence or otherwise write down the pressure in the centre of the planet in terms of ρ, R and the surface gravity g_0. (2)
d) If the super-Earth has a radius twice that of the Earth and a bulk density 1.5 times that of the Earth, what is the surface gravity (in ms^{-2}) of the super-Earth? (3)
e) If the pressure at the centre of the Earth is roughly 300 GPa, what is the pressure at the centre of the super-Earth? (2)
f) Assuming that the super-Earth has the same chemical composition as the Earth, explain why should it have a higher bulk density (2) (15 total)

4 a) Use the gas law to write down an expression for how density varies with pressure P, gas constant R, temperature T and molar mass μ (1)
b) Making the hydrostatic assumption and assuming an isothermal atmosphere with constant gravity g, use your answer to a) to derive an expression for how pressure varies with height. Take the surface pressure to be P_0. (4)
c) Your answer to b) should contain the quantity $RT/g\mu$. What is the name for this quantity, and what does it represent physically? (2)
d) Use your answer to b) to show that the total mass contained in a column of atmosphere is $\rho_0\, RT/g\mu$ where ρ_0 is the density at the surface (3)
e) Rewrite your answer to d) in terms of P_0 and g and explain why this answer makes physical sense (2)
e) Venus and Mars both have atmospheric scale heights larger than that of the Earth. For each case, explain why the difference arises (2).
f) Why might Mars have had a bigger atmospheric scale height 4 billion years ago? (1) (15 total)