CHAPTER Rev

Midterm Review

Remember, your cheat sheet can have no worked problems or derivations and no essays (or even complete sentences). It should just have equations on it with maybe a couple of words by each one.

1. Class overview and chapter 1

I am likely to ask you an essay question on this material such as ”Draw a cross section of the Earth identifying it's major structural divisions. How did the Earth get this way and how do we know this?” I could also ask a question on how we know the time history of early earth evolution.

2. Seismology (chapter 2)

Be able to derive the wave equation:

$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2} \qquad (Rev.1)$$

You do this by considering a small segment of a spring. I'm mainly interested in the physics involved which is Hooke's Law and Newton's second law. Be able to reproduce some properties of solutions to the wave equation such as we did in class and homework problems.

Ray theory came next. Remember, all this is based on Snell's Law which leads to the concept of ray parameter:

$$p = u \sin\theta = u_{TP} = \frac{dT}{dX}$$

and is a constant along a ray. By considering a small segment of a ray, you should be able to derive the following equations:

$$X(p) = 2p \int_0^{Z_{TP}} \frac{dz}{(u^2 - p^2)^{1/2}} \qquad (Rev.2)$$

$$T(p) = 2 \int_0^{Z_{TP}} \frac{u^2(z)}{(u^2 - p^2)^{1/2}} dz \qquad (Rev.3)$$

$$\tau(p) = 2 \int_0^{Z_{TP}} (u^2 - p^2)^{1/2} dz \qquad (Rev.4)$$

You should be able to draw $T(X)$, $\tau(p)$ and $X(p)$ for a variety of velocity structures (low velocity zones, rapid velocity increases and any combination thereof). For structures composed of homogeneous layers, these equations become:

$$X(p) = 2p \sum_i \frac{h_i}{(u_i^2 - p^2)^{1/2}} \quad \text{for} \quad u_i > p$$

$$T(p) = 2\sum_i \frac{h_i u_i^2}{(u_i^2 - p^2)^{1/2}} \quad \text{for} \quad u_i > p$$

$$\tau(p) = 2\sum_i h_i (u_i^2 - p^2)^{1/2} \quad \text{for} \quad u_i > p$$

For such structures, we have the concept of direct waves and head waves which are straight line segments on the travel time curves. Be able to estimate $\tau(p)$ data from such travel time curves and use the last equation above to estimate velocity structures.

Know how to locate earthquakes and how to estimate travel time curves. Know how to identify when earthquakes are deep. Be able to name rays on cross sections such as $P'P'$.

The next portion of the class dealt with what we know about specific regions of the Earth and what we have learned from seismic tomography. I could ask an essay question on this material which would probably involve the reconciliation of geochemical issues with the images developed by seismic tomography.

We then turned to source mechanisms and seismicity. I would expect you to know how earthquakes are distributed inside the Earth and there might be an essay question on the subject of deep earthqaukes (see the Green paper on the web). You should know what the "elastic rebound theory", the different types of faulting and the different types of "beach balls" they produce. I may ask you to construct a beach ball solution from a pattern of first motions on the focal sphere. Knowing how to keep the fault plane and auxilliary plane perpendicular is essential. Be able to measure strike and dip from beach balls and make an intelligent guess of slip. Know the tectonic regions where you are likely to get specific types of faulting. P and T axes are also likely candidates for part of a "source mechanism" question.

Finally, I could ask you an essay question on seismic hazard, particularly in the San Diego region.

3. Heat flow (chapter 3)

We began with a brief inventory of energy sources and then a detailed discussion of how the heat flow out of the earth is determined – this is a natural for an essay question.

The mechanisms of continental and oceanic heat flow are quite different so we considered them separately. When considering continental heat flow, the contribution of cooling is small and can be neglected. We are then dealing with a "steady-state" regime. Be able to derive the equation governing steady state heat conduction where there is a balance between conductive heat loss and heat generated by radioactive decay:

$$k\frac{d^2T}{dz^2} + \rho H = 0 \qquad (Rev.5)$$

This requires the use of Fourier's Law:

$$q = -k\frac{dT}{dz} \qquad (Rev.6)$$

and the law of conservation of energy (I am sure a Taylor series will also appear somewhere). Be able to do this in cartesian and spherical geometry.

We solved this equation for a variety of $H(z)$ functions (constant, linear, exponential). If you integrate equation 5 once you will get an equation involving dT/dz which has something to do with heat flow. Look for a boundary condition involving heat flow to evaluate your constant of integration. If you are asked about $T(z)$, you will have to integrate a second time – look for a boundary condition on T to evaluate this second constant of integration. It is possible that both boundary conditions will involve $T(z)$ so you would have to integrate twice before being able to evaluate any constants of integration.

Know about heat flow provinces and linear $q/\rho H_s$ equations. These are what allow us to estimate the reduced heat flow – the heat flow coming out of the mantle.

Next we considered oceanic heat flow where we made the approximation that we can ignore radioactivity and all the oceanic heat flow is due to cooling. Be able to derive the diffusion equation which governs this situation:

$$\frac{\partial T}{\partial t} = \kappa \frac{\partial^2 T}{\partial z^2} \quad \text{where} \quad \kappa = \frac{k}{\rho C_p} \qquad (Rev.7)$$

and also be able to do this in spherical geometry.

I don't expect you to be able to derive the solution for the temperature in cooling oceanic lithosphere:

$$T(z,t) = T_s + (T_m - T_s)\,\text{erf}\left(\frac{z}{2\sqrt{\kappa t}}\right) \qquad (Rev.8)$$

but you should understand the properties of this solution (which requires knowing a little about the properties of error functions). In particular, you should be able to get the heat flow as a function of age and know that it is inversely proportional to the square root of age. Be able to discuss how well this model fits the observations. Finally we used the principle of isostasy and the connection between a temperature perturbation and a density perturbation:

$$\delta\rho = -\alpha\rho\delta T$$

(where α is the coefficient of thermal expansion) to compute the bathymetry of the ocean floor. You should know that it has the form:

$$H = h_0 + Ct^{1/2}$$

where h_0 is the ocean depth at the ridge, and you should be able to discuss how well this fits the observations – particularly for old oceans.

4. Summary

The equations on this review sheet and the math cheat sheet given out earlier are strong contenders for your cheat sheet. I recommend practicing for the midterm by redoing the problem sheets. Remember to look for key words in questions such as ”homogeneous”, ”linear”, ”exponential”, etc. Remember to tell me how you are going to solve a problem before getting lost in algebra: a couple of sentences describing what you are going to do at the beginning of a question could well earn you most of the marks!

The exam will consist of a choice of 3 out of 4 short questions and 1 out of 3 long questions (one of which will be an essay question). The short questions should take you about 15 minutes and the long question should take about 30 minutes. Total time should be about 75 minutes though you will be given 90 minutes to finish the test.

Remember to read the questions carefully and to answer all parts of all questions (some questions will have parts a,b,c, etc.). Indicate on the top of the test which questions you want to be graded – and don't forget to put your name on the test! Remember to bring a calculator to the exam – the final part of a question may require plugging in some numbers to get a real answer – and I will expect you to get the units of your answer correct!