回答問題時請於試卷上清楚標明答題題目編號。計算機禁止使用，部分給分，請盡量清楚論述或列出計算式。

1. (20%) Explain the following physical terminologies (除了解釋名詞定義外，需描述它們對了解板塊運動或地球內部構造與動力機制的重要含義) : (4%/each)
   (a) flexure isostasy
   (b) D" discontinuity
   (c) Q (quality factor)
   (d) Curie temperature & blocking temperature
   (e) Prandtl number (the ratio of kinematic viscosity to thermal diffusivity)

2. (8%) The observed Earth's gravitational and magnetic field at any given position, $V(r,\theta,\varphi)$ (r: radius; θ: colatitude=90°-latitude; φ: longitude) can be expressed in terms of the expansion of spherical harmonics, i.e.,

$$V(r,\theta,\varphi) = \sum_{l=0}^{\infty}\sum_{m=0}^{l} f_l(r)\, C_l^m P_l^m(\cos\theta)\, e^{-im\varphi},$$

where $P_l^m(\cos\theta)e^{-im\varphi}$ is proportional to spherical harmonics at degree l ($l = 0,\ldots,\infty$) and order m ($m = -l,\ldots,+l$), C_l^m is the corresponding expansion coefficient, and $f_l(r)$ is a function of radius r at degree l. When $m = 0$, there is no longitudinal variation and $P_l^m(\cos\theta) = P_l^0(\cos\theta)$ as shown in **Figure 1** for $l = 0,1,2,3,4,5$.

   (a) Which coefficient C_l^m best represents the geomagnetic field observed on the earth's surface? Give your reasoning. (4%)
   (b) Except for the constant gravitational potential for a spherical earth, which coefficient C_l^m is the **second largest one** describing the variation of the gravitational potential observed on the earth's surface? Which coefficient C_l^m is **zero**? Give your reasoning. (4%)

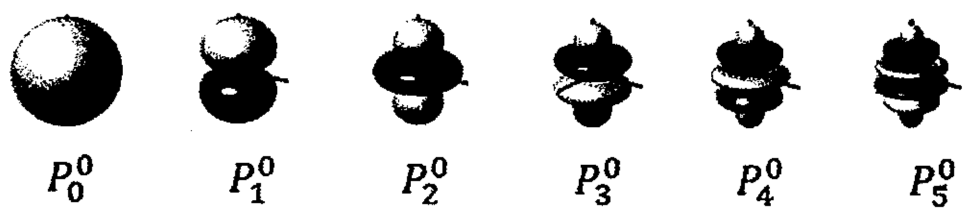

Figure 1

3. (16%) Consider the plane wave propagating along the x_3 direction in a uniform Poisson solid. The displacement of P-wave is written as $u_3 = A\sin(\omega t - k\hat{x}_3)$, parallel to the propagation $\hat{x}_3$-direction, while that of S-wave is written as $u_1 = B\sin(\omega t - k\hat{x}_3)$, parallel to the $\hat{x}_1$-direction (Note: ω and k are angular frequency and wavenumber, respectively, and A and B are the amplitudes for P and S waves).
   (a) The displacement of P and S wave motion can be then expressed as

$$\underline{u} = \underbrace{\underline{\nabla}\Phi}_{P-\text{wave}} + \underbrace{\underline{\nabla}\times\underline{\Psi}}_{S-\text{wave}},\ \Phi = \nabla\cdot\underline{u} = \Theta,\ \underline{\Psi} = \nabla\times\underline{u},$$

where $\underline{u} = u_1\hat{\underline{x}}_1 + u_3\hat{\underline{x}}_3$, Φ is a scalar potential, and $\underline{\Psi}$ vector potential. Prove that both Φ and $\underline{\Psi}$ satisfy the wave equation $\left(\frac{\partial^2}{\partial t^2} - \frac{\omega^2}{k^2}\frac{\partial^2}{\partial x_3{}^2}\right)\Phi = 0$ and $\left(\frac{\partial^2}{\partial t^2} - \frac{\omega^2}{k^2}\frac{\partial^2}{\partial x_3{}^2}\right)\underline{\Psi} = 0$ (8%)
   (b) Based on the relation of the strain and rotation tensor, show the P-wave motion involves deformation of non-zero volume change without undergoing rotation, while S-wave motion undergoes rotation but no volume change. (8%)

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4. (14%) **Figure 2**(a) and (b) show the earth's gravity and density structure as a function of radius or depth, respectively.
   (a) Explain why the gravity is nearly a constant down to 2900 km depth and decreases almost linearly as the depth increases to the center of the earth. Why such the constant gravity in 0-2900 km depth is important for mantle convection modeling? (6%)
   (b) Explain why the density jumps at the four depths marked by the vertical dashed lines and what causes such the sudden increase of density? (8%)

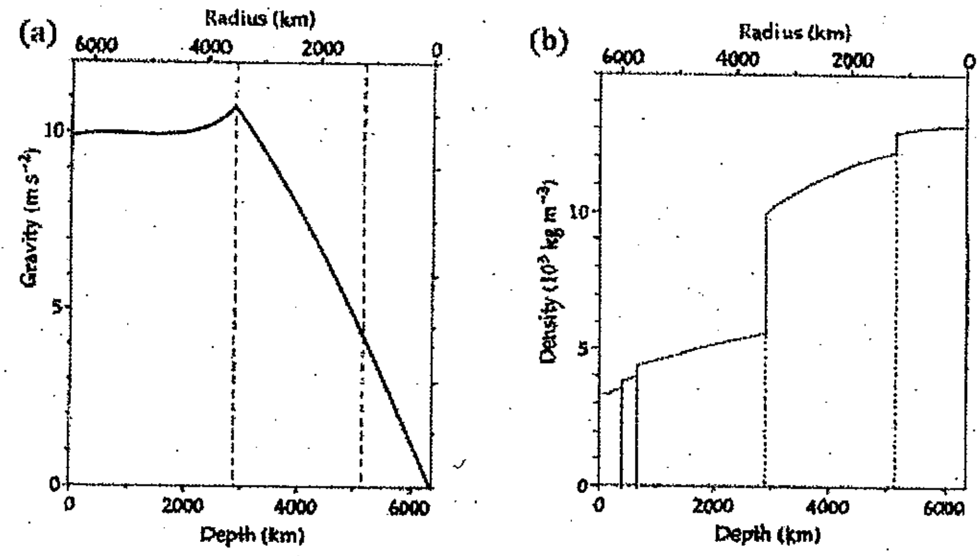

Figure 2

5. (30%) **Figure 3** shows a schematic diagram of tectonic plates (lithospheres) and three kinds of plate boundaries labelled by (1), (2) and (3).
   (a) What are these three plate boundaries? What **types of faulting** along these three plate boundaries? Draw the **focal spheres** (focal mechanisms) of earthquakes that occurred along these three plate boundaries. (9%)
   (b) What are the two parameters used to quantitatively describe the relative plate motion between two rigid plates? Explain why the observed relative velocity of plate motion along the boundary (1) changes from place to place, but the relative velocity of plate motion along the boundary (2) is the same everywhere? (6%)
   (c) What are the **free-air** and **Bouguer gravity anomaly** usually observed along the boundary (3)? How about the **geoid anomaly** observed around the boundary (3)? You have to give the explanations why they look like what you said. (9%)
   (d) The **surface heat flow, seafloor depth**, and **thickness of oceanic lithosphere** are found to depend on its age. Explain what their relations are and what governing mechanism mainly causes such the relations? (6%)

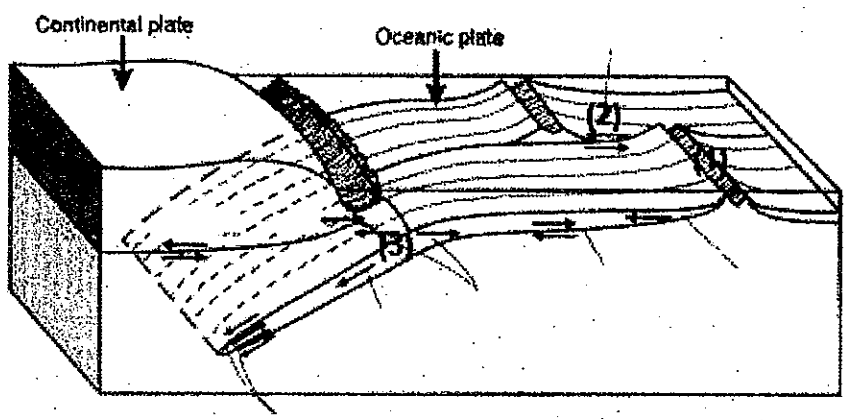

Figure 3

6. (12%) Fundamental-mode surface wave dispersion provides useful information to constrain the thickness and shear wave velocity structure of oceanic and continental lithosphere. **Figure 4** shows fundamental-mode surface-wave phase and group velocity as a function of period in a 1-D reference Earth model.

(a) Can you tell which one of **Figure 4**(a) and (b) is for Rayleigh wave and Love wave? Think what differences are between Rayleigh wave and Love wave and give your reasoning. (3%)

(b) Why is the group velocity slower the phase velocity? Again, think what differences are between phase and group velocity and give your reasoning. (3%)

(c) The two curves shown in **Figure 5** represent the phase velocity of fundamental-mode Rayleigh waves observed in oceanic and continental regions. Can you tell which one of the curves (1) or (2) is for oceanic and continental regions based on your knowledge of the continental and oceanic lithosphere? Can you roughly estimate the thickness of the lithosphere from these two dispersion curves based on your knowledge of the depth of the peak sensitivity of fundamental-mode Rayleigh wave to shear wave velocity? (6%)

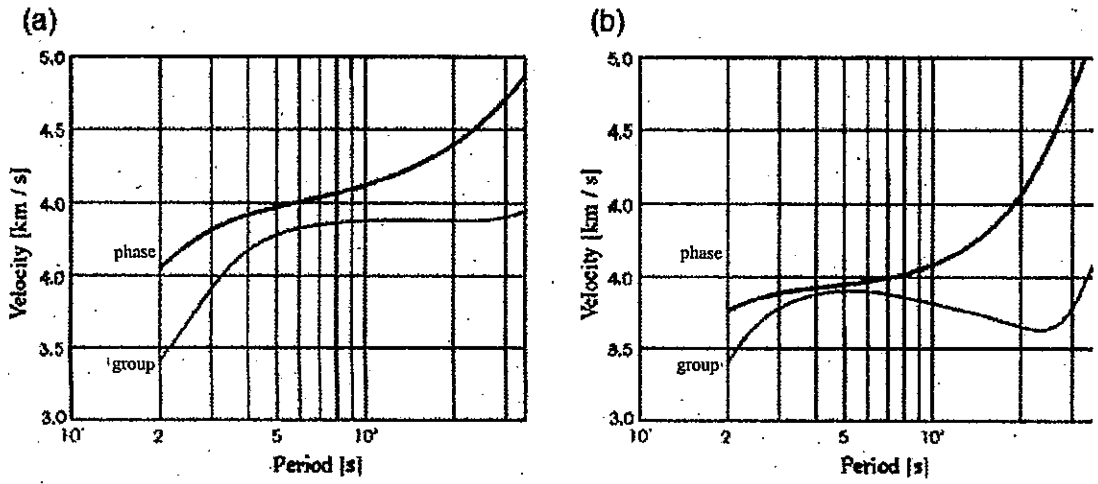

Figure 4

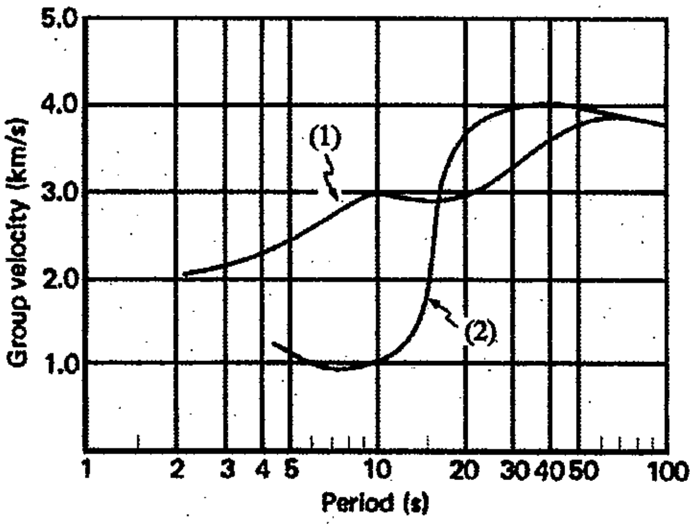

Figure 5

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