ES1101 : Earth and Planetary Sciences

Satvik Saha, 19MS154 November 27, 2021

Problem 1 How do we know that Earth is a zoned planet?

Solution After calculating the density and the moment of inertia of the rotating Earth, we observe the following discrepancies.

1. The mean density of Earth is 5.5 g/cm^3, while that of the crust is 2.7 g/cm^3.
2. The rotational moment of inertia of the Earth is 0.331, while a theoretical calculation assuming a uniform Earth would give 0.4.

Further observations, primarily through seismology, reveal that the Earth's density, temperature and material constituents do not remain uniform with depth, but have their own characteristic gradients and discontinuities.

Problem 2 How old is the oldest oceanic and continental crust? Why is the oldest oceanic crust so much younger than the continental crust?

Solution The oldest oceanic crust is 200 million years old, while the oldest continental crust is 4.2 billion years old.

Oceanic crust is so young because of seafloor spreading. New oceanic crust is formed continuously at mid-oceanic ridges (divergent plate boundaries) from magma, which is then pushed outwards by convection currents in the mantle. The old oceanic crust subducts at ocean-continent, or ocean-ocean plate boundaries. This process is analogous to a system of conveyor belts, in which ocean crust takes a maximum of 200 million years to travel from a divergent to a convergent plate boundary. This explains the relative youth of oceanic crust.

Problem 3 What are the different types of seismic waves?

Solution The different type of seismic waves are as follows.

1. Body waves:
   (a) Primary (P) waves
   (b) Secondary or Shear (S) waves
2. Surface waves:
   (a) Love waves
   (b) Rayleigh waves

Problem 4 State at least two differences between P and S waves.

Solution

P waves	S waves
Longitudinal waves – particles oscillate in a direction parallel to the direction of propagation.	Transverse waves – particles oscillate in a plane perpendicluar to the direction of propagation.
Can propagate through both solids and liquids.	Can propagate through solids, but not liquids.

Problem 5 What are the physical properties of the material that controls the propagation of seismic waves?

Solution The physical properties of the material which control the propagation of seismic waves within it are its density (ρ), bulk modulus (κ) and its shear modulus (μ).
For example, the velocities of P and S waves are as follows.

$$v_p = \sqrt{\frac{\kappa + \frac{4}{3}\mu}{\rho}} \qquad v_s = \sqrt{\frac{\mu}{\rho}}$$

Problem 6 What are the heat sources present in the Earth?

Solution The heat sources present in the Earth are as follows.

1. Heat from the accretion and differentiation of the early Earth after its formation.
2. Heat from the radiactive deacy of unstable elements in the Earth.

Problem 7 What is the pressure at the crust-mantle boundary?
(*The rate of change of pressure beneath the earth is* 30 MPa/km. 1 MPa = 10 bar)

Solution Oceanic crust is 6 km thick, while continental crust is 40 km thick on average. This gives us core mantle pressures of 1800 bar and 12000 bar respectively.
The average thickness of crust is 15 km, giving a core-mantle pressure of 4500 bar.

Problem 8 If the focus of an earthquake is at 0° from the centre of the Earth, what are the intervals of the shadow zones for P and S waves?

Solution The shadow zone intervals for seismic waves are as follows.

1. P waves : $-105°$ to $-142°$, $+105°$ to $+142°$.
2. S waves : $-105°$ to $+105°$.