6 In recent years, seismology and an understanding of wave motion have produced many benefits. One consequence has been a much clearer picture of the internal structure of the Earth. Two different types of seismic waves are generated by the sudden movement on a fault: P-waves (primary waves) and S-waves (secondary waves). The speed of the waves depends on wave type and the properties of the rock; the denser the rock, the faster the waves travel.

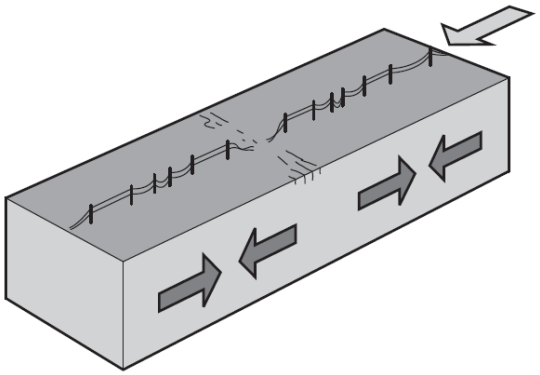

Fig 6.1

P-waves, shown in Fig. 6.1, travel fastest. They consist of successive contractions and rarefactions, just like sound waves in air. The motion of the particles in the rocks that the waves travel through is parallel to the direction of the wave.

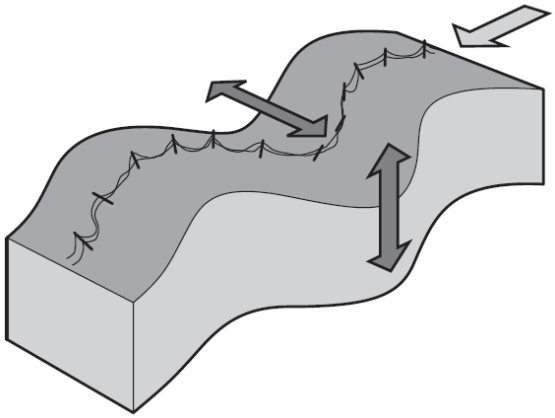

Fig 6.2

S-waves, shown in Fig. 6.2, are slower than P-waves. They are transverse waves, which means that the particle motion is at right angles to the direction of travel. S-waves cannot travel through air or liquids.

By studying the propagation characteristics of seismic waves we have learned much about the detailed nature of Earth's interior. Fig. 6.3 shows the velocity and density variations within Earth (from the surface to the centre) based on seismic observations. The main regions of Earth and important boundaries are labelled.

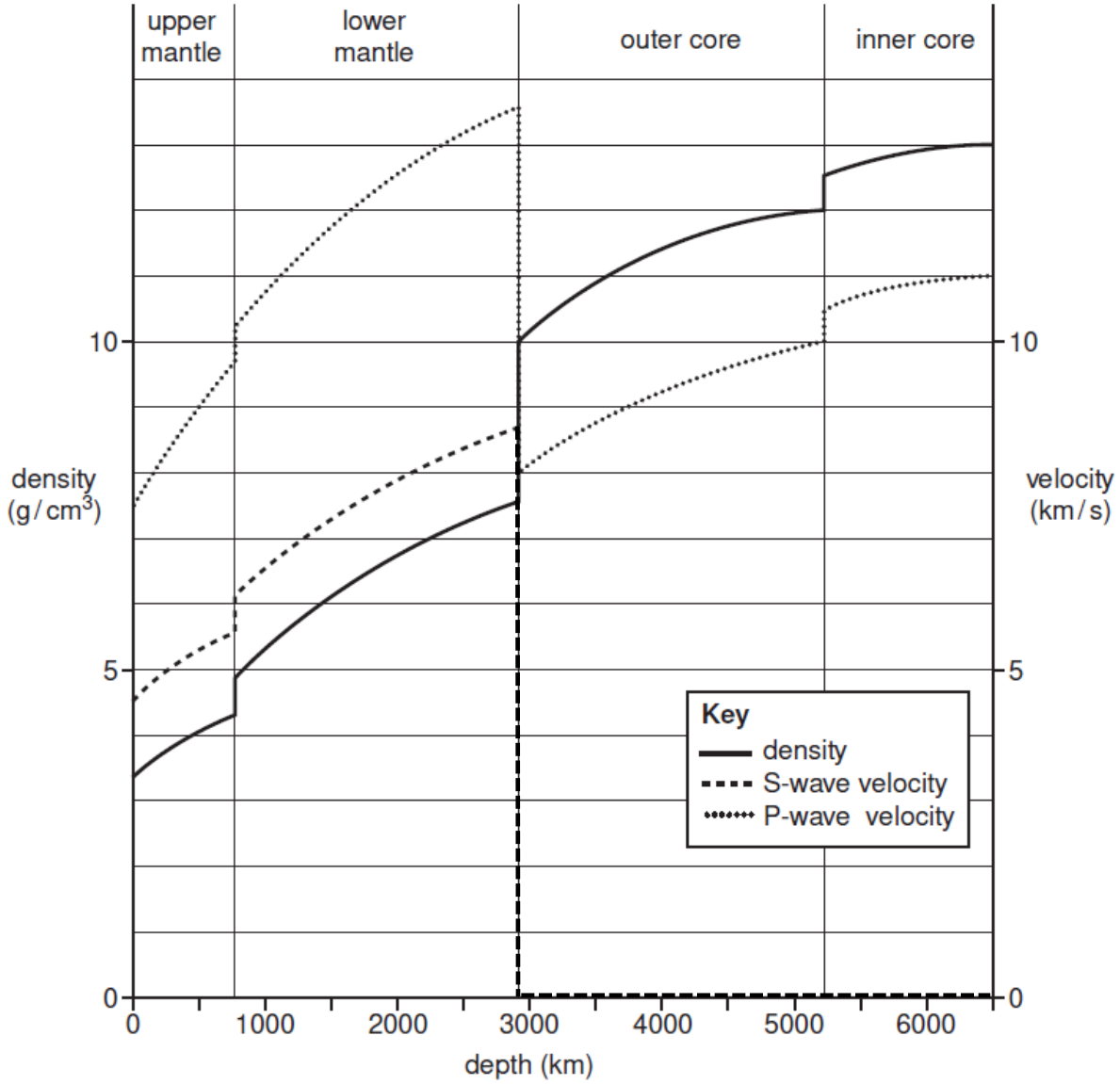

Fig 6.3

Several characteristics of Earth's structure are illustrated in the Fig. 6.3. In several large regions such as in the lower mantle, the outer core, and inner core, the velocity smoothly increases with depth. The increase is a result of the effects of pressure on the seismic wave speed. Although temperature also increases with depth, the pressure increase resulting from the weight of the rocks above has a greater impact and the speed increases smoothly in these regions of uniform composition. The atoms in these rocks rearrange themselves into compact structures that are stable at the high pressures and the result of the rearrangement is an increase in density and elastic moduli, producing an overall increase in wave speed.

As seismic waves pass through the Earth, they are refracted, or bent, like rays of light bend when they pass through a glass prism, as shown in Fig. 6.4.

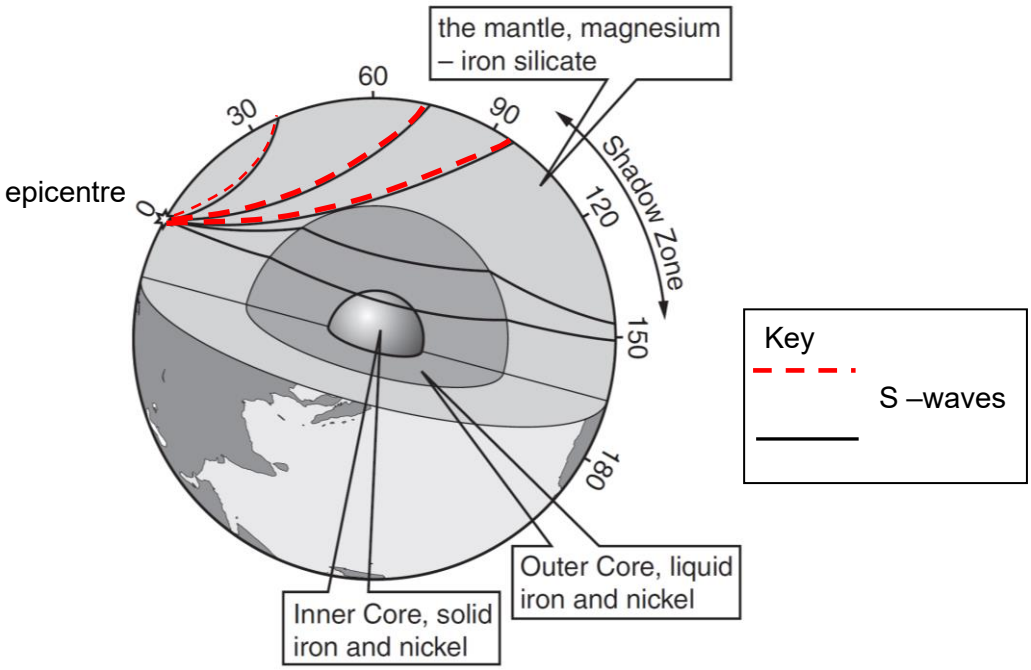

Fig 6.4

Seismology is the analysis of little measurements, which allows us to understand big events – earthquakes, tsunamis, volcanoes, and landslides. Basically, it is all about seismic waves or vibration waves occurring naturally from earthquakes. Sometimes scientists create them by sending energy into the ground to see how it bounces off underground layers. Geophysicists who explore for oil, natural gas, minerals, and groundwater do this. We can also use these techniques in other situations, such as looking for sunken treasures deep below the ocean or finding abandoned oil tanks that can contaminate soil.

(a) Explain what is meant by

1. a *longitudinal wave*,

……..……..

……..…… [1]

2. a *transverse wave*.

……..……..

……..…… [1]

(b) A large earthquake occurs near the surface of the Earth at a particular location and both seismic P-waves and S-waves are produced. The P-waves and S-waves travel through the Earth away from the epicentre of the earthquake.

The average speed of the P-waves is 7.98 km s^{-1} and the average speed of the S-waves is 4.75 km s^{-1}. A seismograph at a different location detects the arrival of the S-waves 2 minutes 50 seconds after the arrival of the P-waves.

(i) Calculate the time taken, in minutes, for the S-waves to travel from the epicentre of the earthquake to the seismograph,

time = ... min [2]

(ii) Calculate the distance of the epicentre of the earthquake from the seismograph.

distance = ... km [1]

(c) **(i)** Seismic waves produced by the earthquake are detected by seismographs in many different countries. In certain parts of the world, however, seismographs do not detect any of the S-waves produced by the earthquake.

Using Fig. 6.3 and other information, explain why these seismographs do not detect the S-waves.

……..

……..

……..

……..

……..

……..

……..…… [3]

(ii) State where relative to the epicentre of the earthquake, these seismographs are located.

……..…

……..…… [1]

(d) As the seismic waves travel through regions deeper within the mantle, the speeds of the waves change.

(i) Describe and explain this change in speed.

……..

……..

……..

……..

……..…… [3]

(ii) Describe the effect of this change in speed on the path taken through the mantle by the waves

……..

……..

……..

……..…… [2]

(e) **(i)** Explain why there are parts of the Earth's surface, named "Shadow Zone", at distances between 103° and 143° in Fig. 6.4, where it is not possible for seismographs to detect the P-waves produced by the earthquake.

……..

……..

……..

……..…… [2]

(ii) **1.** Estimate the radius of the Earth from Fig. 6.3,

radius of Earth = ... km [1]

2. Hence provide an estimate of the length of the “Shadow Zone” for P-waves.

length = ... km [2]

(f) The temperatures and pressures within the Earth reach very high values within a few kilometres of the surface. It is difficult, therefore, to imagine that human beings will ever be able to reach regions further than a few kilometres from the surface. Both public and private money are used to support the study of geophysics and seismology.

Suggest why this expenditure is justified. Your answer could take into considerations the social, technological and economic effects of such research.

……..……..

……..……..

……..……..…… [1]

[Total: 20]

End of paper