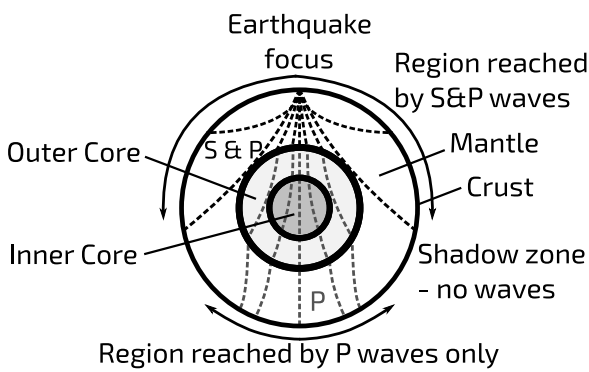
45 Seismic Waves and Earthquakes ♡

When a geological plate moves suddenly during an earthquake, it sets off waves which travel through the rocks. Some waves travel along the Earth's surface (e.g. Love waves). Others, P and S waves, travel through the Earth.

Primary (P) Waves	**Secondary (S) Waves**
Longitudinal wave - oscillations parallel to direction of energy transfer.	Transverse wave - oscillations perpendicular to direction of energy transfer.
Faster (typical speed near surface of 8 km/s). These are the first waves to reach seismometers - this gives them their name 'primary'.	Slower (typical speed near surface of 5 km/s). These waves reach the seismometers later - this gives them their name 'secondary'.
Can travel through liquids (such as the Earth's outer core).	Cannot travel through liquids (such as the Earth's outer core) - this is because they are transverse.
Can be reflected at any boundary between two different regions.	
Can be refracted (or bent) by any change in rock compressibility or density. Generally as waves get deeper (and the pressure rises), their speed rises and they bend away from the 'normal' (the vertical). When P waves pass from the (solid) mantle to the (liquid) outer core, they slow down, and bend towards the vertical. When they reach the (solid) inner core, they speed up, and bend away from the vertical.	



45.1 The average speed of S waves in the mantle is 6.0 km/s and the average speed of P waves in the mantle is 11 km/s. Ignore the crust, and treat the mantle as being 2900 km deep.

(a) How much time would an S wave take to travel from a seismic event and return to the focus after having reflected once from the mantle-outer core boundary?

(b) How much earlier would the reflected P waves be detected than the S waves?

Typical speeds of seismic waves and rock densities are shown in the table.

Region	Depth (km)	Density (kg/m^3)	Speed (km/s)	
			P	S
Crust	$0 \sim 10$	3.0×10^3	8.0	5.0
Mantle	$\sim 10 - 2\,900$	$(3.0 - 5.0) \times 10^3$	$8.0 - 13$	$5.0 - 8.0$
Outer Core	$2\,900 - 5\,200$	10^4	$8.0 - 10$	-
Inner Core	$5\,200 - 6\,400$	1.2×10^4	11	$3.0 - 4.0$

(eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/waves_and_interior.html)

Example 1 – What is the delay between receiving P and S waves travelling through the crust to a seismometer 200 km from the earthquake's focus?
Time for P wave = Distance / Speed = 200 km$/8.0$ km/s = 25 s.
Time for S wave = Distance / Speed = 200 km$/5.0$ km/s = 40 s.
Delay = 40 s $- 25$ s = 15 s.

Example 2 – If the delay between receiving P and S waves is 5 s, how far away is the earthquake's focus?
We call the distance d, taken in km where time will be in seconds.
For the P wave, the time take to arrive is $t_p = d/8$.
For the S wave, the time taken to arrive is $t_s = d/5$.
We are told the delay is 5 s. Thus $t_s - t_p = 5$.
Therefore $d/5 - d/8 = 5$. So, $0.2d - 0.125d = 5$, and accordingly $0.075d = 5$.
We finally get $d = 5/0.075 = 67$ km (70 km to 1sf).

45.2 For speeds of 5.0 km/s for S and 8.0 km/s for P waves, complete the table.

Distance	P wave Time	S wave Time	Delay
30 km	(a)	(b)	(c)
60 km	(d)	(e)	(f)
150 km	(g)	(h)	(i)
200 km	(j)	(k)	(l)
(m)	(n)	(o)	8.0 s

45.3 Explain how the location of an earthquake's focus can be worked out from distance measurements made from three seismometers.

45.4 For each of the following questions, give your answer as 'S wave', 'P wave', 'neither' or 'both'. Which seismic waves:

(a) are longitudinal?

(b) can travel through a part of the Earth which is liquid?

(c) can travel through the mantle?

(d) are generated by an Earthquake?

(e) will cause the rock next to the focus (at the same depth) to move up and down?

(f) will cause the ground above the focus to move up and down?

(g) will be detected by a seismometer in the 'shadow zone' of an earthquake?

(h) travel faster at a given depth in the mantle?

(i) arrive at a seismometer last from a particular earthquake?

(j) can change direction at a boundary between two parts of the mantle?

(k) can be detected on the opposite side of the Earth from the focus?