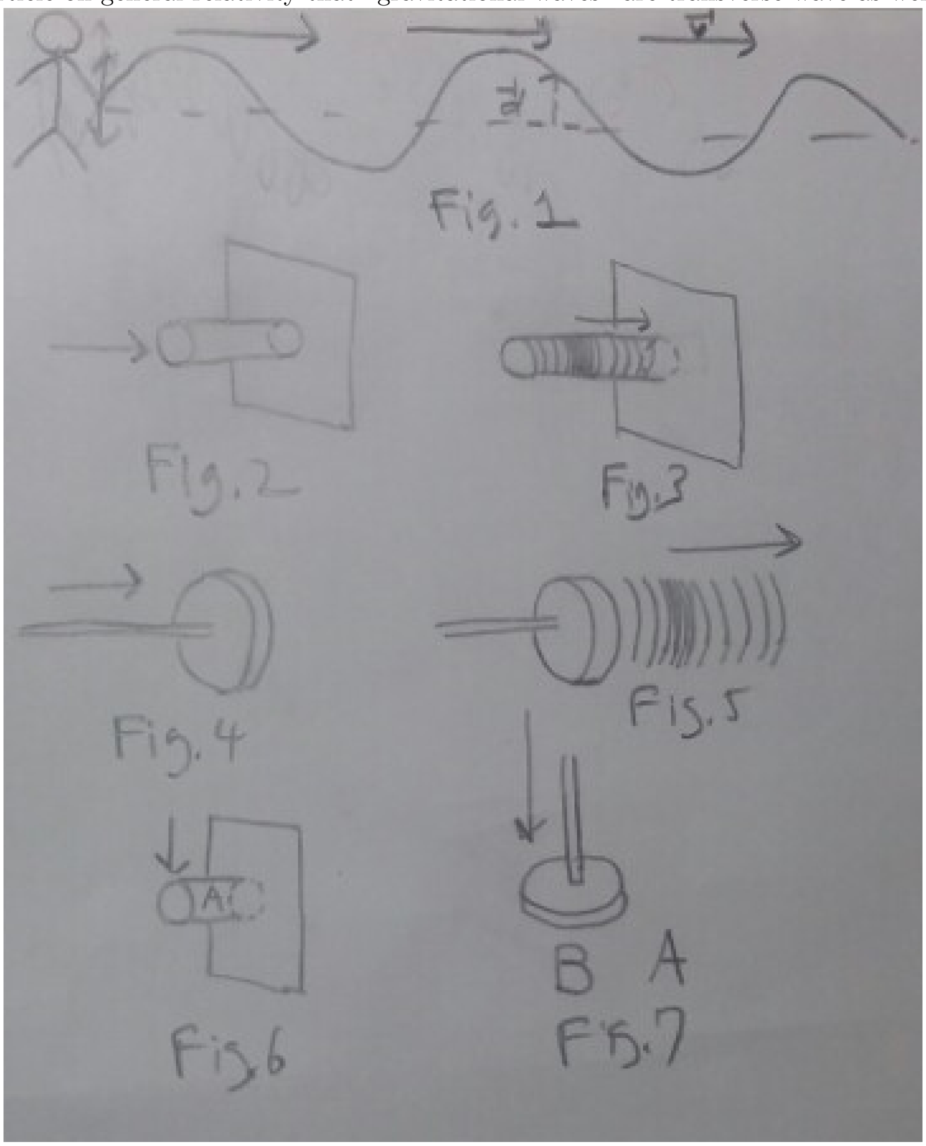
Transverse waves and longitudinal waves

Every wave is either transverse wave or longitudinal wave. For transverse wave, the oscillation direction is perpendicular to the propagation direction. See Fig. 1. The propagation direction is denoted by $\vec{v}$ and the displacement is denoted by $\vec{d}$. You see that $\vec{v}$ and $\vec{d}$ are perpendicular.

For longitudinal wave, the oscillation direction is parallel to the propagation direction. If you think closely, you will see that the spring wave and the sound wave we have considered in our earlier articles are longitudinal waves. Actually, there are transverse modes for the spring wave as well, but we haven't considered it. In general, if both transverse modes and longitudinal modes are possible for certain oscillations, their propagation speeds are different. Seismic wave (i.e. earthquake wave) is a good example.

In case of seismic wave, the longitudinal wave can propagate through both solid and liquid, but the transverse wave can propagate only through solid, but not through liquid. Let's see why. First, consider, the longitudinal wave. See Fig. 2. You have a solid bar of which one end is fixed to a wall. If you push the solid bar at one end, the bar will be compressed at that end, and the position of the compressed region will travel toward the wall. See Fig. 3. (If you think of the solid bar as a very stiff spring, it would be easier to imagine. The compressed part would be the "dense" region in Fig. 1. in "Travelling spring waves.") The same is true for liquid as well. See Fig. 4. Let's say that you are in a swimming pool, and you push the water horizontally using a piston. Initially, the liquid near the piston will be horizontally compressed, but the position of the compressed region will move horizontally. See Fig. 5. You must be already familiar with this, if you read our earlier article "The speed of sound."Now, let's think about the transverse wave. See Fig. 6. If you displace the left end of bar slightly by pressing down the bar vertically for a short amount of time, it would be easy to imagine that the bar will begin to oscillate vertically due to the restoring force which wants to restore the original shape of solid bar. In the figure, the part marked with A will want to partially restore the position of the left end by providing the force upward. However, the same cannot be true for liquid. Liquid does not have a definite shape, and there is no restoring force, unless it's compressed. See Fig. 7. Suppose you are in a swimming pool, and you push the water vertically. Then, the water will be displaced downward, and we will have the longitudinal wave propagating downward. How about the transverse wave? Even though the water in the region B is displaced downward, the water in the region marked A won't be able to provide enough upward force to restore the water in the region B to original position. When I learned about the seismic wave in the eight grade, I asked my science teacher why transverse wave cannot propagate through liquid. He said that it was just the property of the transverse seismic wave! Now, I am sorry that we were forced to memorize the fact that transverse seismic wave cannot propagate through liquid, without understanding the reason why.

Final comments. In our later article "light as electromagnetic waves," you will see that electromagnetic waves, called "light" is a transverse wave. You will also learn in our later article on general relativity that "gravitational waves" are transverse wave as well.



Summary

- For transverse wave, the oscillation direction is perpendicular to the propagation direction.
- For longitudinal wave, the oscillation direction is parallel to the propagation direction.

- For seismic waves, transverse wave can only travel through solid, while longitudinal wave can travel through solid, and liquid.