Chapter 2
Perspective in Space, Time and Causality

Ferdinand Magellan led the first expedition to travel around the world. Though he did not live to complete the journey, he set sail westward from Spain in August 1519 and several members of his crew returned in September 1522. Careful records were kept, so the returning men were surprised to find the date one day later than the date indicated by the logs. Eventually this problem was solved and a changing series of imaginary lines were drawn on world maps; the most recent of them we recognize today as the International Date Line (IDL). Crossing this line from east to west means going forward one calendar day; crossing in the opposite direction means going back one day. Most of the time, then, there are two different current days on earth. From the IDL westward through whichever time zones are *before* midnight, it is one particular day. From the IDL eastward through whichever time zones are *after* midnight, it is another day.

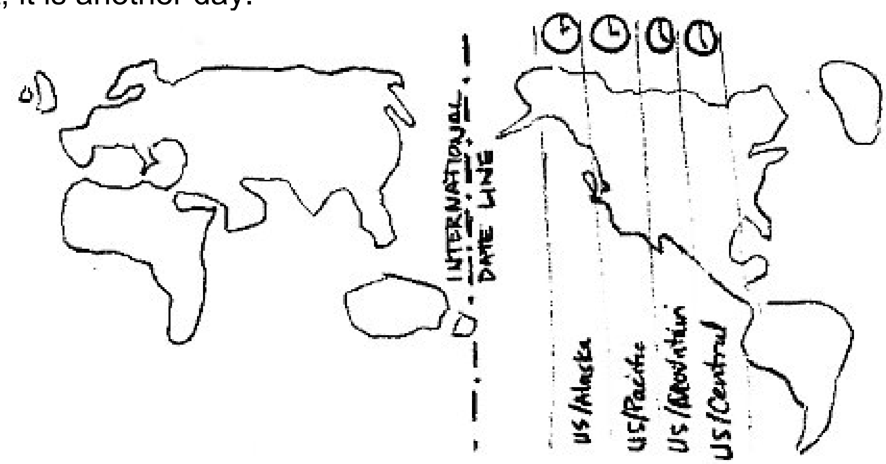


Figure 2-1. The International Date Line and several time zones.

In Jules Verne's 1873 classic, *Around the World in Eighty Days*, Englishman Phileas Fogg wagers that he can travel around the world in eighty days or less. He travels eastward, counting the days as he goes. Returning just after the eightieth day by his reckoning, he is sure that he has lost the bet, but finds to his surprise that it is a day earlier than he supposed. Like Magellan's crew, his spatial travels have affected his measurement of time. We will refer to Mr. Fogg's story several times throughout this book.

Have you ever counted the seconds between lightning and thunder? Since the light from the lightning reaches you almost instantaneously, and because the sound of thunder travels at roughly one-fifth of a mile per second, every five seconds that you count between the lightning and thunder represents a mile of distance between you and the lightning strike. The same math applies to anything visible and audible from far away. For a few summers in a row, I watched an Independence Day fireworks show in Bellingham Bay from a park about a mile away. I noticed about a five-second delay between the flashes and the booms. Some of the drama seemed lost in the delay. But the only way to have experienced the flash and the boom at the same time was to have been where an explosion was occurring, and that would have been too much excitement.

The speed of sound also manifests itself in echoes and microphone feedback. I am sure most readers will be familiar with the awful feedback screech produced by a microphone held too close to a loudspeaker. The speaker feeds the microphone, which feeds the speaker, and so on. This creates a very fast echo which is called feedback. Feedback is what happens when the distinction between beginning and end or between cause and effect becomes blurred. The frequency of microphone feedback (or echo) may fall in the range of human hearing as an audible tone. If the round-trip from the speaker to the microphone and back again is short, the echo is more frequent. For example, a microphone amplified too loudly in a large room with faraway speakers may create a low hum which gradually increases in volume, but still allows the audience to hear whoever may be speaking into the microphone. A microphone held next to the speaker, however, will create a high-pitched screech. The frequency of the echo or feedback depends on the length of the round trip, which depends mostly on two things: the distance in the air between the speaker and the microphone, and the speed of sound.

Most of us have noticed that sound has a limited speed, whether it's the thunder or the fireworks or the echo of our voice in a canyon. What we don't notice as readily is that light has a limited speed too. We think of light as instantaneous, which is the assumption underlying our technique of counting the seconds between the lightning and thunder. If the lightning were as slow to be seen as the thunder is to be heard, this technique wouldn't work. But the speed of light does have definite limits; it just makes itself known more subtly. I thought I saw it in action once when I was on a telephone conference call which was being hosted on a telephone system about two thousand miles away. One of the call participants was using a speaker phone which was turned up too loud, so that whenever anyone spoke, the sound of their voice would come out of the speaker and back into the microphone of the same phone. Since the microphone and speaker were so close, you might be expecting me to tell you that I heard high-frequency feedback, or a screech. But in this case, the other half of the round trip – through the wires, not in the air between speaker and microphone – was longer than usual. Telephone signals travel at the speed of light, which is 186,000 miles per second. There were probably other factors at work, but a four-thousand mile round trip from the microphone to the conferencing system and back to the speaker would have created a delay of at least one or two hundredths of a second. For this and other reasons we all heard an annoying echo instead of a painful screech.

Because everything has a limited speed, our perception of time is completely entangled with our perception of space. As a matter of fact, I will be showing in this chapter that that the very ideas of time, space, and causality are dependent on there being a universal upper limit to speed, which happens to be the speed of light.

As illustrated in Chapter 1, we see space, or distance, in two ways. **Linear distance** is measured in inches or meters and is the distance between two mileposts or the ends of a yardstick. **Angular distance** is measured in degrees or radians and is the irregular distance between the Tower of Pisa and the street, or between the road and the tracks at the railroad crossing. It is the *larger* distance between your head and feet in my field of vision when you are standing close and the *smaller* distance when you are lying down or far away. Angular distance is also the distance between two hands on the face of a clock. It is the distance between our longitude on the globe and the international dateline. Not coincidentally, degrees of angular distance can be split up into minutes and seconds. Distance and time are related.

There is a third type of distance which is only measured relative to a specific point. This is called **radial distance**. Like linear distance, it can be measured in meters or miles, but it is not necessarily the distance between two points. It is more generally the distance between a circle and its center. The importance of the distinction between linear and radial distance will become clearer later on.

How do we know that something is near or far? We have more than one way of perceiving distance and depth, but we have a strong sense of associating "here" with "now" and "there" with "then." We regard distances in terms of the delay time involved in interacting with them. We judge the distance of something by how long it takes us to reach it or for it to reach us. Or by the time it takes for sound or light to pass between us.

How do we differentiate a short span of time from a long one? I believe that we have little - if any - innate sense of time. We depend heavily on our senses of distance and causality. We use distance and movement together to derive a sense of time. When no movement is measured and there is no sequence of events, we lose this sense of time. To keep our sense of time, we may use linear movement by counting the mileposts we pass on the road or keeping track of the length of outdoor shadows; we may use angular movement by counting the minute marks passing on the clock face or by keeping track of the direction of outdoor shadows. When these spatial means of keeping time are withheld from us, we have to fall back on a sense of causality, which means we keep track of a sequence of connected events. For instance, we recall taking a shower, then getting dressed, and then sitting fully dressed as we ate our breakfast, and we estimate the time which has passed since we woke up. But even this means of tracking time ultimately relies on the tracking of movements in space: one trip from the bed to the shower, several trips from the cereal bowl to our mouth, and so on. If we are trapped in an environment where nothing moves, nothing changes, and nothing happens, we experience considerable disorientation and/or strain because the only remaining means of tracking time is an unrelenting effort to create and track a sequence of events in our mind (". . . four hundred and one. . . four hundred and two . . four hundred and three . . . ").

In what other ways are our perceptions of time and space co-dependent? We will now explore this question with several "thought experiments." Imagine several hundred people all lined up to compete in a 100-yard foot race (Figure 2-2). Each one has a place on the starting line, which in this very strange case is about a mile long. We need a way to signal that the race may begin, so at one end of the starting line we place an official with a starting pistol. Since the starting line is a mile long, it will take about five seconds for the sound of the starting pistol to reach the opposite end of the starting line, so there is a clear disadvantage for those starting the race at the end furthest from the official. So we put another official with a starting pistol at the opposite end. Now it gets complicated. For the moment we will ignore the fact that the disadvantage has moved from one end of the starting line to the middle. The new problem is that we have to figure out how to get the officials to fire their pistols at the same time. We gather them together and give each of them a watch. We make sure the watches are synchronized and we send them back to the starting line with instructions to fire exactly at noon.

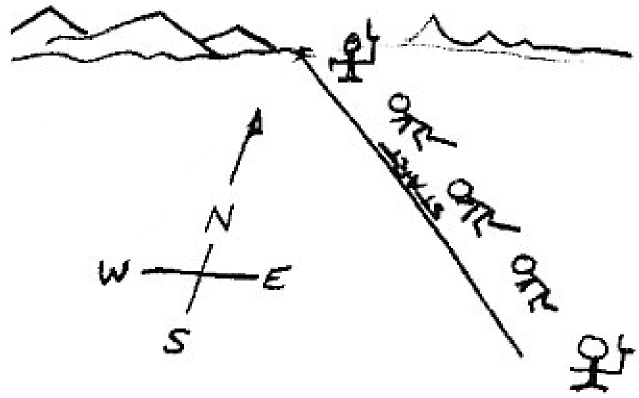


Figure 2-2.

The officials each pull the trigger on their pistol as they see the second hand reach twelve on their watches at noon. But there is disagreement about which official fired first. Let's suppose that it is a westward race and the starting line runs from north to south. Everyone at the north end will hear the pistol at the north first, and the pistol from the south several seconds later. Conversely, everyone at the south end will hear the south pistol first. The people at either end will agree that no one started the race before the first gun and will be generally satisfied. But they will disagree as to which gun fired first. Their perception of time depends on their position in space. It is a matter of perspective. The people in the middle heard both pistol shots at the same time, but they saw the contestants nearest the judges starting to run two or three seconds before they hear the pistols. They may feel that the runners at the ends cheated.

Figure 2-3 shows how the sounds of the pistol shots radiate outward from their origins. If the officials are clever, they can reconcile everyone's observations by taking into account the speed of sound. Each official can note the time she hears the other's pistol, measure the length of the starting line, and do the math to discover that each pistol really did fire at the same time. It was merely the *perceptions* of the events that were affected by the relative displacements of the observers. In the process, they may realize that if they are limited by the speed of sound, they need to add more race officials at equal distances along the starting line until they are satisfied that any advantage associated with starting position is negligible. Let's suppose there are now ten officials with starting pistols equally spaced on the starting line. If they all fire at the exact same time, each of them will hear their own pistol first and then hear a series of shots that come from further away from them, the points of origin progressing towards opposite ends of the line, sort of like two ripples going in opposite directions from a shaken point on a loose rope. Figure 2-4 shows how the pistol shots are heard in sequence from position one. The pistol at one is heard first and the neighboring pistols at positions marked “two” are heard next, then three.

Figure 2-3.

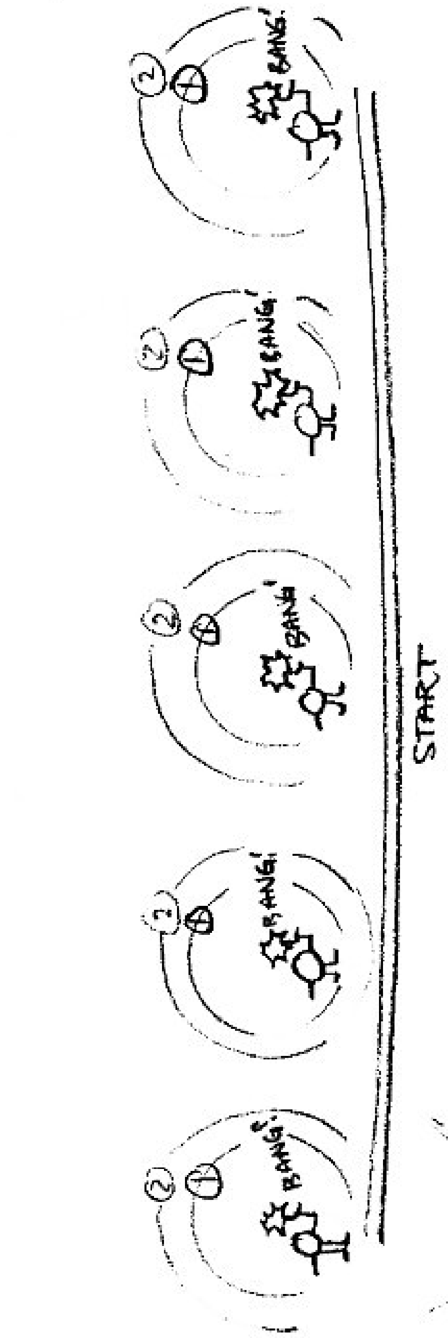
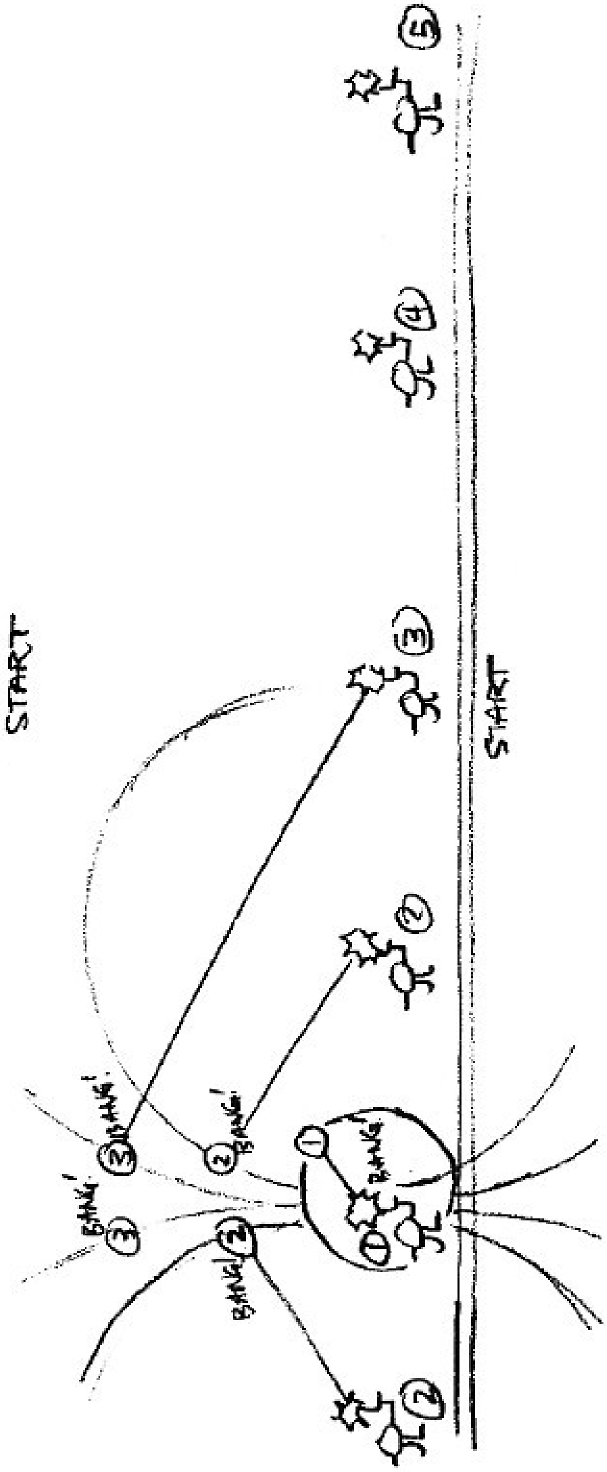


Figure 2-4.



Now let's change the rules a bit; we'll forget the fairness of the race and just have some fun. We can, if we want, reset the officials' watches so that each watch reads a later time from the north end of the starting line to the south. If we do the math, we can even arrange it so each official will fire his pistol at the instant she hears the sound from the pistol to her north. This gives us some interesting results. As the sound of the starting pistols moves down the starting line from north to south, it is slightly louder with each pistol it passes, because each pistol is adding its own noise. If there are eleven officials carefully synchronized in this way, the one at the south end will hear the other ten pistols at the instant she fires her own. We should note that only the official on the south end of the line will hear all eleven pistols firing at once. The sound of all the firing pistols has been moving down the starting line at the speed of sound, building strength as it goes.

Going back to Figure 2-4, imagine that the sound waves from positions one to three (and beyond) all arrive at position one at the same time.

This is somewhat similar to the “sonic boom” effect produced by an aircraft flying faster than the speed of sound. Aircraft make continuous noise. At low speeds, the energy from this noise dissipates away from the aircraft in all directions (Figure 2-5). But when a jet reaches the speed of sound, the sound energy that normally would run away from the front is kept right there in front of it, because the jet is keeping up (Figure 2-6). Furthermore, the aircraft is still making more noise, so the energy builds up to a high level. This compressed sound energy is eventually felt on the ground, but only after the jet has passed overhead.

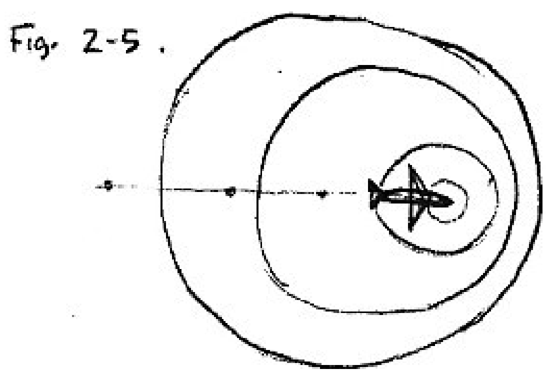


Figure 2-5. Subsonic travel.

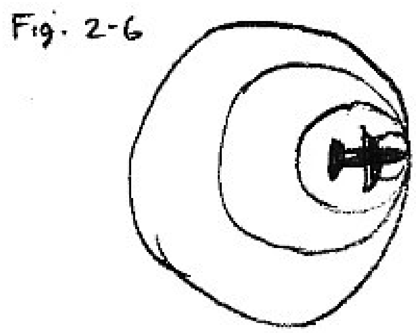


Figure 2-6. Breaking the sound barrier.

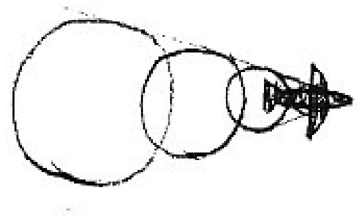


Figure 2-7. Supersonic travel.

Next we will change our imaginary scene in two ways: we will replace the race officials with clock towers, and instead of a starting line, we will add another dimension to create a plane of evenly spaced towers. In our first experiment, all of our clock towers will be set to the exact same time. Each tower has a clock face on all four sides which is too small to be read from the other towers, but each tower also has a bell to strike the hour. There are 10 rows and on each row are 10 towers, for a total of 100 towers. They are spaced about 1000 feet apart; that is, each tower has another tower 1000 feet to its north, its south, east, and west. We have some people in the middle of the field of towers, but not near the edges.

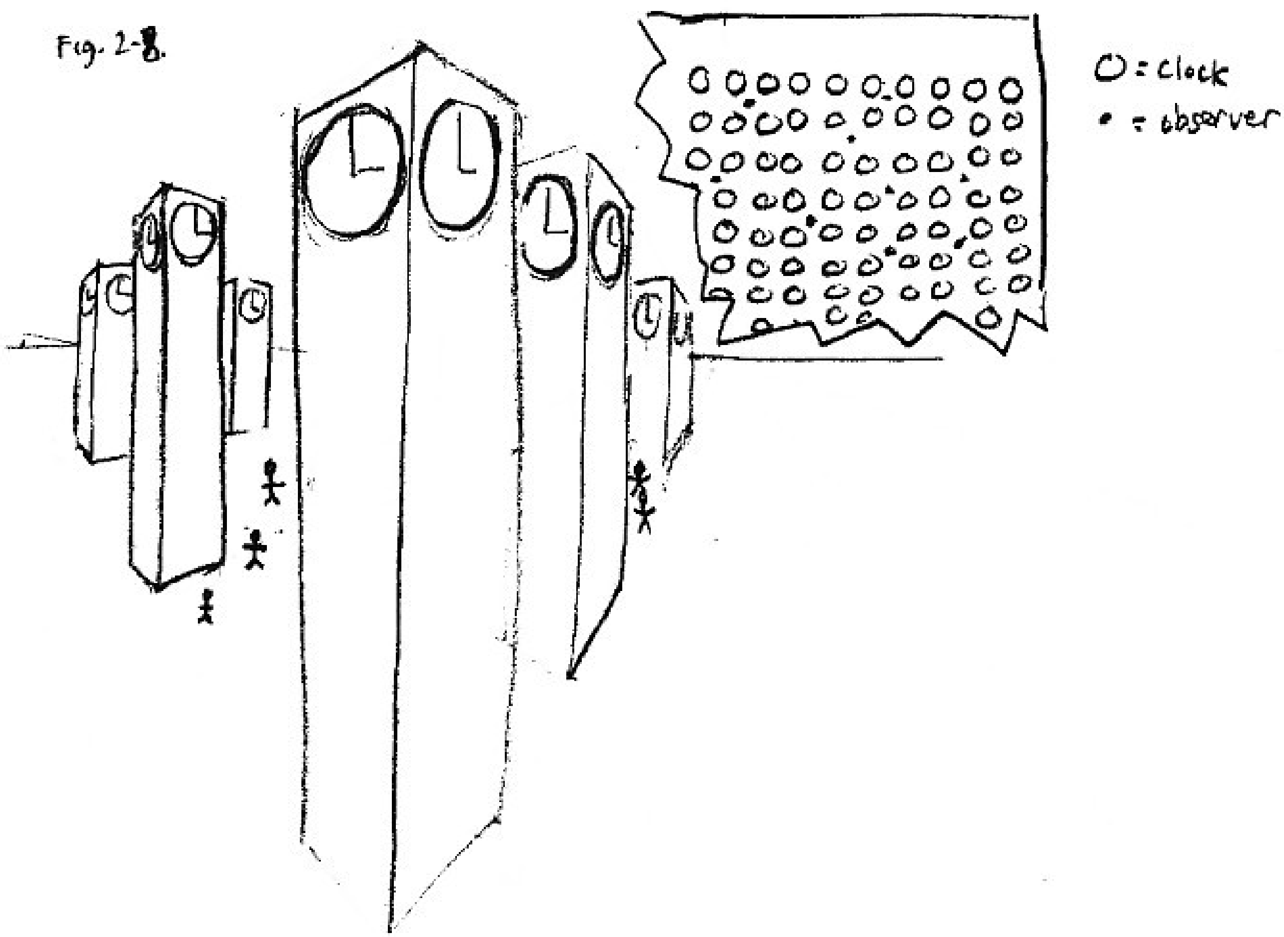


Figure 2-8.

At exactly one o'clock, all 100 bells strike exactly once. Any observers standing at the bottom of any of the towers will hear a series of bells, and this series will be similar as heard from place to place. First, at exactly 1:00, each observer will hear the bell at the top of the tower at which they are standing. At one second past 1:00 they will next hear the four nearest towers (directly to their north, south, east, and west) chiming all in unison, followed closely by the four towers at their northwest, northeast, southwest, and southeast. The towers which lie in the four compass directions will all be heard, four at a time, on each second after the hour, until the limits of the field have been passed. The intensity of the sound will decrease with distance. Likewise, the other clocks will sound off four or more at a time but not always on the second marks. Each observer will hear different clocks at different times and may suppose that the clocks are not properly synchronized. But even though the clocks are not heard at the same time, a regularity can be measured. Any observer can imagine a tiny circular ripple at his feet , like a single wave from a pebble dropped in a pond, which at exactly 1:00 expands radially (in all directions) at a fixed speed, causing the bells to sound off as the ripple's edge crosses underneath the other towers. That theory would be somewhat mystifying but it still might seem workable if the observers do not compare notes. Of course, each observer will think that *his* tower is the one causing the others to ring, and they will not come to agreement.

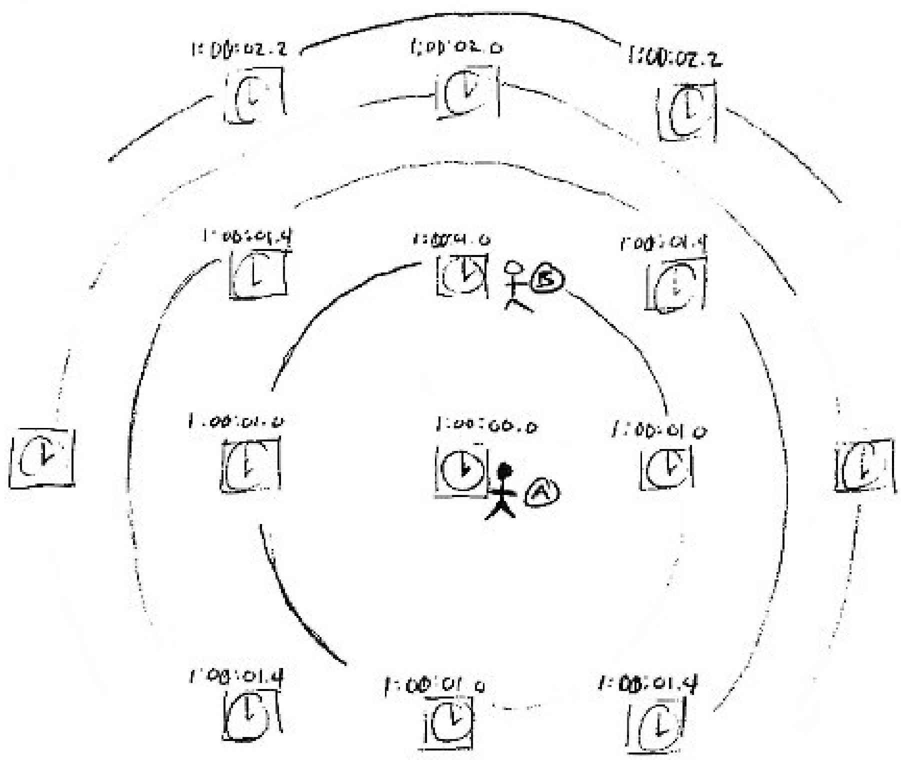


Figure 2-9. Ringing times of the clocks as apparent to an observer at point A.

In Figure 2-9, the observer at point A hears the chime from each clock at the time noted. Notice that each set of clocks heard at the same time lies on a circle centering on point A. An observer at point B will hear the clocks at different times than the observer at A.

If the clock observers are clever like our imaginary race officials, they also will realize that sound has a limited speed and they will measure the distances between towers as well as the time delays. They will discover that all of the clocks really are keeping the same time and that there is, after all, no causal relationship between the bells. We have noticed that each tower will hear bells at successive radial distances as time passes. This is because each tower is also *heard* at successive radial distances as time passes. The imaginary circular ripple which we might have supposed expanded from one tower and caused the other bells to ring should instead be imagined as an expanding circle (a sound wave) which causes the bell of the tower at the center to be heard at the tower on the edge of the circle. The motions of all one hundred ripples play a part in the big picture. This may seem a far more complicated way of explaining everyone's observations, but it alone can reconcile one set of observations to another. And one need not calculate the positions of all one hundred circles to predict which bells will be heard at any given time and place; one circle will tell everything about one specific time and place, and it works in both directions: for any properly calculated circle at any given time, the point at the center will hear any tower on the edge (if its bell was ringing when the circle started with zero width), and any point on the edge will hear the tower at the center (if its bell was ringing when the circle started expanding).

A key point to remember is that what our clock observers and race officials *hear* is quite different from what they *measure*. In other words, *auditory* synchronization is not the same as *actual* synchronization due to the limited speeds of sound, and the spatial separation of events. Our observers *hear* events at different times when they *measure* them to be happening at the same time. Another key point is that if all of the clocks or watches are keeping the same time, and each observer has one nearby, each observer will essentially hear the same thing: a series of bells or shots. What you hear does not change with where you are. Your position only matters if the clocks or watches are not truly and globally synchronized.

As the hours pass, our clock observers begin to reconcile themselves to the idea that the clocks are really keeping the same time and that they are merely being heard from successive radial distances. But by the time six o'clock comes, they realize they can't keep count of the number of chimes from any one clock due to the noise of all the others. Each clock strikes six times at six o'clock, and that means there are six hundred bells heard at various times and volumes. Emboldened by their new understanding of the speed of sound, they tinker with the clocks in an attempt to make them all be heard to chime at the same time. This is similar to the experiment above where all of the starting pistols were heard at one end of the starting line at the same time. Our clock observers quickly discover that this effect can be accomplished, but that it only works when observed from a single tower. If the chimes sound synchronized from one tower, they will sound slightly out of sync at the neighboring tower, and even worse the further away they go from the tower where the bells sound synchronized. The *local* condition of auditory synchronization cannot be made *global*, or applicable to the entire field of clocks. This is not satisfactory at all, because not only are the chimes still out of sync in most places, the clocks are now out of sync as well. The observers will decide, as Einstein did, to abandon the concept of a global or universal time, at least as far as the chiming of the bells is concerned. They may also decide to replace the bells with strobe lights. Light travels faster than sound. Working over the short distances between the clocks, the strobes all appear to flash at the same time at the top of every hour. But this only works over reasonable distances.

Now we come closer to the heart of the matter. Let's suppose our clocks have enormous digital displays on each side and are placed in outer space, each of them 186,000 miles from its nearest neighbor. Each of them has an observatory at the top with several extremely powerful telescopes for reading the other clocks. The problem is much the same as before, but we need not wait for the clock to strike the hour to tell what time it has. We merely look through our telescope. Each of our neighboring clocks, when we look through the telescope, shows a time which is one second behind our clock. It is the same in every direction. Two clocks away in the direction of any of our four nearest neighbors, we read a time exactly two seconds behind ours, and so on. From our earlier discussion of the chimes, we know that every observer at every other clock sees the same delay, and that at these large distances, there is no way to make all of the clocks appear to have the same time to all observers. The bell tower observers solved their problem by switching to a signal which travels much faster than sound. Our space clocks are already using the fastest thing there is: light.

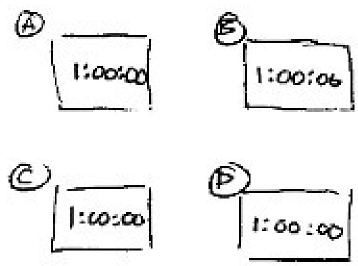


Figure 2-10. Times on four nearby clocks, as *measured* from any point. All read exactly one o'clock.

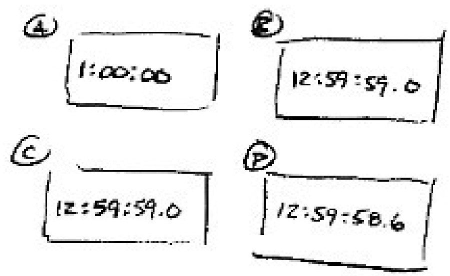


Figure 2-11. Times on the same clocks at the same moment, as they *appear* from point A.

Despite what we see through our telescopes, we know that all the clocks really are in sync because we can take measurements and do the math. Each clock is 186,000 miles from its neighbor (a little less than the distance from the earth to the moon), and light travels at 186,000 miles per second. If there is any doubt about the clock's distance, we can bounce a radar signal off of it, which will also travel at the speed of light, and we can see how much time the radar echo takes to come back to us. If I look at the neighboring clock and see it showing a time one second behind mine, I can be sure that it is actually synchronized. However, if I look at the neighboring clock and see it showing the same time as my clock, I can be sure that it is actually one second ahead of mine. I can also be sure that an observer in that opposite clock will measure the same difference: that my clock is one second behind his. My clock will *appear* to him to be *two* seconds behind. Again, *seeing* is different from *measuring*. You will recall that the same problem existed in chapter one with regard to art. Faraway objects appear smaller than nearby ones, but we can measure them to determine that they are in fact the same size. We looked at how our perception of size was dependent on distance. Here we see that our perception of time also depends on distance. In other words, our measurement of time depends on our measurement of space. Furthermore, this dependency is because of the limited speed of light.

Most good books on relativity include at least one particular type of diagram showing the relationship between time, space, and the speed of light. This diagram is called a *light cone* diagram and like all analytic geometry, it is a lovely hybrid of mathematics and art. It is usually shown this way:

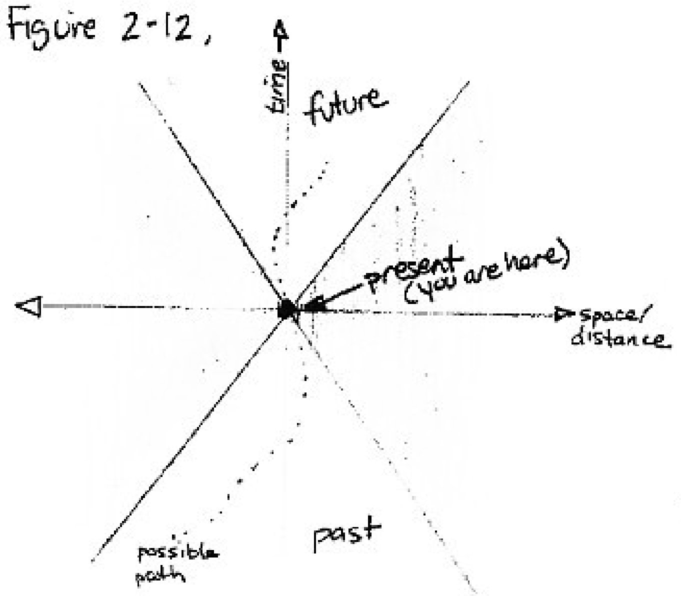


Figure 2-12. Light cone diagram.

The horizontal line represents distance and the vertical one represents time. The center is a "you are here" marker, like on a map. But this is a map of *events*, not merely of places. An event is a place at a specific time. Moving right and left on the map puts you in a different place; up and down puts you in a different time. The corner of Railroad Avenue and Magnolia Street at noon, for instance, is one event. The same street corner at 3 a.m. is a completely different event, as any Bellingham police officer could tell you (that's a little joke). One block away at either time is a separate event from both of them. What might confuse you about this map is that there is only one dimension for distance, or space. It can show you one line in space - all the points down the center of Railroad Avenue, for instance - but the line has no width. The map only shows Magnolia Street where it crosses Railroad Avenue. But that's all right because the purpose of this map is to show you this same line at several times.

Let's suppose you roll a ball down Railroad avenue. If that ball rolls at constant speed, its path will be a diagonal line on our map. Why is it diagonal? It cannot be in two places at the same time, so that rules out a horizontal line. If the ball were not moving, we would map it out as a vertical line; it would be in the same place at all times. But since it is moving in a straight line, it will not be in the same place twice. That rules out the vertical line. That leaves us with the diagonals. The path of the moving ball could be shown by one of several diagonal lines, depending how fast it is rolling. The faster the ball rolls, the more its line is tilted away from the vertical.

The crossing diagonal lines in Figure 2-12 represent light rays going toward you at the bottom of the diagram, intersecting your location at the middle, and going away from you at the top. You are at the center of the map, which is “here” on the distance line and “now” on the time line. You are the “here and now” event. The top half of the map shows light rays starting at “here and now” and moving away in opposite directions. The further you go up the time line, the further they are from you, “here.” In the same way, the further the distance away from you, the later is the time (further from “now”) that the light ray gets there. Each light ray crosses through a definite set of events. Each time in which the light ray exists corresponds to one and only one place, just like the path of the ball. The area between the diagonal lines at the top represents the events that could be intersected by something starting at your “here and now” event and moving *slower* than light, such as the rolling ball. The bottom half of the map shows the light rays which have come from opposite directions and are just reaching “here and now.” The further back you go on the time line, the further away they were, and vice versa.

As I mentioned before, there is a disadvantage to this “map” in that it shows only one dimension of space. If this book had three-dimensional pages and you could tip the top of the page towards you to view Figure 2-12 at a different angle, instead of a “V” at the top, you would be looking down into a cone. That is why these are called “light cone” diagrams. One cone opens upward and the other downward. With the page tilted over slightly now (Figure 2-13), let's set off a flashbulb at “here and now” and see what happens. It starts at the center point and then traces out a circle as the flash goes in all directions; not just up and down Railroad Avenue, for instance, but in both directions of Magnolia street and all the directions in between.

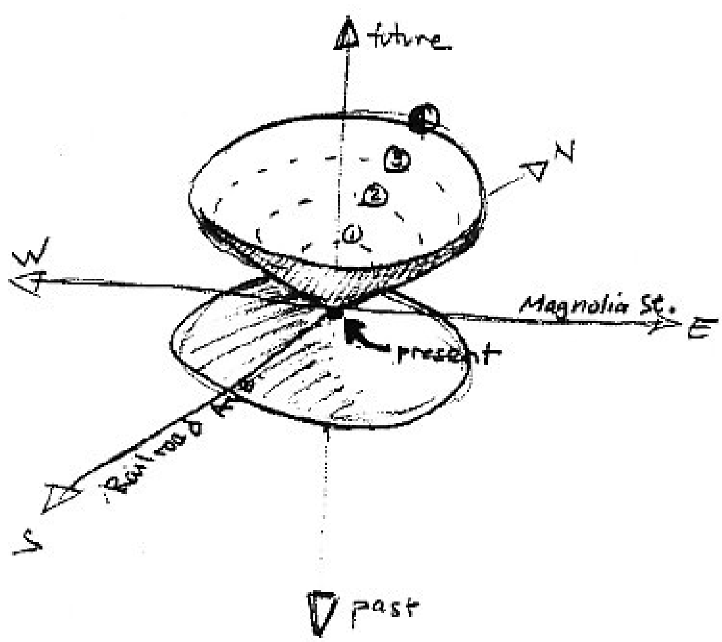


Figure 2-13. A three-dimensional light cone diagram.

The circle gets bigger as we go up the time line, and the flash is seen further and further away (the successive radial distances which are numbered 1 through 4 in Figure 2-13). The path of the light follows the cone. The circle is the same radially expanding circle we imagined in our clock tower experiments. The upper cone, then, is a stack of circles and it is all of the events that we can illuminate with our flashbulb from "here and now." Inside the cone are all of the events that we can intersect with slower-moving signals or objects such as sound waves or rolling balls. It is also the set of events that we could travel to ourselves, leaving the "here and now" and going to some other place or time. The upper cone is *the future*. *Our* future will be some line or curve within that cone.

The lower cone is the past. Our past is likewise a line or curve within that cone (Figure 2-12). The boundary or surface of the cone are all of the events from which someone else could illuminate *us* now with *their* flashbulb. It is all of the events which we see in our "here and now." The lower cone can also be seen as a stack of increasingly large circles. Every radial distance x corresponds to two circles; one in the future and one in the past. This is also the same pairing of circles we noted in our clock experiments. Remember that we said that the same circle works in two directions? On this three-dimensional map, it is actually two circles. They only look like one when you're looking straight down on them. I might say that this is a matter of perspective, but they really are the same circle, because time is not an actual dimension at right angles to space as shown in this diagram. Time is "imaginary" in a very mathematical sense, and I will explain what I mean by this later on. Let's just say for now that the speed of light creates relationships between a given event and a given place. That relationship is defined by not one, but two times: the starting time from the place to the event, and the ending time from the event to that place. The start time and end time are different times, for example, yesterday and tomorrow; that is why two circles appear on our map. But the difference in time, the number of seconds or hours, from the place to the event is the same in both cases, for example, one day; that is why they can be regarded as the same circle. Both circles have the same center (the event) and the same radius (the distance from the event to the place). To use an analogy, the question "What is the square root of four?" has two possible answers: 2 and -2. But the question "What is the absolute value of the square root of four?" has only one answer: two. You might think this analogy is somewhat too abstract, but the "square" function (along with its inverse, the square root) is a golden thread woven throughout the tapestry of physics or – for the musically inclined – a melodic exposition which the fugue of physics repeats in many voices, so I am not at all hesitant to include it here. The square root function is one example of a duality and symmetry in math and physics that we will encounter time after time. It is also the reason we have what are called "imaginary numbers," which are important in understanding light and time.

Misleading as it may be to show time as a dimension perpendicular to space, what makes the light cone diagram so instructive is that it shows that (since nothing can go faster than light) every event is definitely either past, future, or what I call "impresent," unreachable from the present, the "here and now." There is nothing we can do at this moment or at any time in the future that can have any effect on any event outside our future light cone. We certainly cannot affect the past, but neither can we affect any event which is so far away that even a light beam sent by us right now would arrive at that place after the event had already passed. Events outside our future light cone are as beyond our influence as if they had already happened, although we cannot know about them yet unless they are in our past light cone.

We may come to know of them and be affected by them later, but we cannot know of the impresent now. If the sun were to suddenly flicker and be extinguished, we would not know of it for the several minutes it would take for the light and gravity waves to reach us. As far as we were concerned, it would not have happened. Nothing outside our past light cone can have any effect on us. We cannot see it or even know about it. Although we may predict the future or have miraculous foresight, we cannot literally see or know what is still future any more than we can change what is already past. These events are too far away for light from them to have reached us yet. Events outside our past light cone are as beyond our knowledge as if they had not happened yet, although we cannot do anything to change them unless they are in our future light cone. Reread this paragraph until you are confident that you see the symmetry between past and future and the nature of the impresent.

Note that *my* past is not the same as *your* past and neither is my future the same as your future. My past at this time is not what will be my past five minutes from now, and the same is true of my future. Past and future are relative to a particular place and time, an event. Your position in space and time determines your past and future in the sense of your perspective.

To summarize: the past is the set of events which we can know of but not do anything about (any more), the future is the set of events we can do something about but not know of (yet), and the impresent is the set of events which we can neither know of nor do anything about. You may notice that although I have mentioned the “impresent” (the more common term is “elsewhere”, but I feel this one-sidedly leaves out “elsewhen”) but I have not mentioned the “present.” The idea of the present is complicated not only philosophically but mathematically. Even Einstein had his doubts about it. I'll come back to it later.

What I want to do now is to use the light cone diagram to make a very important point. Your typical textbook diagram (Diagram A in Figure 2-14) emphasizes the cone shape, and that's useful. But to make my point I'm going to adjust it quite a bit. The cone shape won't be as obvious any more, but something else happens. As we change the scale of the diagram to better represent how we measure the speed of light (Diagram B in Figure 2-14), we see that the slope of the cone tilts strongly toward the horizontal, meaning that light travels what we regard as a really tremendous distance (186,000 miles) in what we regard as a very short time (one second). More importantly, what happens to this diagram is that the boundary between space and time starts to appear thinner. We might ask ourselves what would happen if the speed of light were 10, 100, or 100,000 times faster. The answer is that the impresent regions of the diagram, the boundary between past and future, would get thinner and thinner.

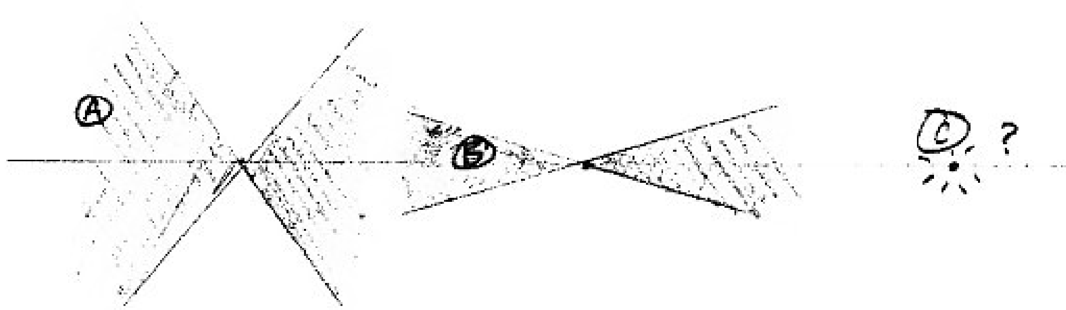


Figure 2-14. When the impresent disappears, so do past and future. All is present.

What then would happen if the speed of light had no limit? What if light had infinite speed? In that case, the impresent would disappear completely. We end up with a blank diagram (C in Figure 2-14). Everything would simply be present, neither “there” nor “then,” but all “here and now.” What would be our boundary between past and future? How would we tell time from space? The inescapable conclusion is that there would *be* no past or future, no time or space. What would that be like? Let's go back to the example of the microphone sitting right next to the amplifier and speaker. Remember, feedback is what you get when the distinction between cause and effect is blurred. If light could travel at infinite speed, cause and effect could no longer be independent, because that echo time we examined earlier would become zero. Feedback would be instant. Even supposing that there could still be a time and space, what meaning would it have? Imagine firing a device that shoots a laser beam at a mirror. The beam travels at this infinite speed of light to bounce back and destroy the device. If the beam traveled at *infinite* speed, how could the beam strike the device *after* the beam was generated? How could the beam be generated *before* it destroyed the device that created it? The same argument would hold for any theoretical phenomenon faster than light. Without an absolute and finite speed limit, space, time and causality would all disappear together.

Meditate on that.