DAY ONE…

Dear Sr. Galileo,

I humbly write to you from a different time and place, and while we may here use words and devices unfamiliar to you, your words and devices are central and essential to that which we know. I have spent, these last few weeks, much time in reading about your discoveries and your world, with hopes that I might come to understand some small portion of the grand ideas that inspired your creations, your explorations, and your perseverance through times and authorities that did not – perhaps could not yet – appreciate the great value in what you observed and deduced from observing. I express my deep gratitude first for your diligent and brilliant legacy, and secondly that you might consider reading this letter that I humbly submit regarding the explorations of myself and my colleagues as inspired by you, as well as our questions and praises of you, developed during these adventures.

We began, weeks ago, with a few simple tools: a wooden frame the first, secured on a stand, and empty, so that we might see through it as though it were a painting of an actual view. The task before us was to investigate the view within the frame and various distances, depending on the placement of the viewer, the frame itself, and the view. With this experimentation, we evaluated paintings, sculptures and other art from your time, paying particular attention to the lines that determined the depth and perspective of the scenes within those artworks. Truly, we noticed some interesting things about these relationships between lines and frames, distance and size, and in fact marveled at those things that were counter-intuitive initially, but required only our keen observation to prove or disprove. While collectively, we struggled to identify the methods used in your time to recreate perspective with lines and angles and devices of which we

have only drawings, I made two notes that continue to be of particular interest to me pertaining to this topic. The first is of a more metaphorical nature, and involves the concept of perspective and demonstrated by parallel lines in reality that appear to converge at a distance, such as one might see standing on a long, straight road and looking far into the distance. Mathematically, we know that parallel lines must not converge, and yet the perspective of miles of road laid out before a traveler would seem to contradict this rule, though walking the path would reveal that, indeed, the lines of the road continue to be parallel. The second idea is that of similar triangles, which seemed in our early explorations to reappear in every exploration we attempted; in measuring the size of a frame and the size of an object, for example, we found that a relationship between the distances between the viewer object and frame might be used to determine when one could see the entirety of an object in a frame, given the basis of similar triangles. We were most pleased to find that similar diagrams to the one we constructed could be found both in books by your colleagues (among them, J. Keppler, who I understand wrote a letter following the release of your viewing device [Dissertatio cum Nuncio Sidereo, 1610]) as well as, to our surprise, in your *Starry Messenger* (Galilei, 1610). The diagram therein, as you well know having constructed and published it, was to our surprise with regard not to a frame and perspective, per se, but rather for your telescope. This provided – as your work often does, I now realize – a clear transition from our work with frames and perspective into exploration with the curious device called the lens. I find myself both then and now, somewhat confused by the "science of refraction" you reference in your *Starry Messenger*. We have had the opportunity to explore with lenses and with mirrors, and have discovered through this work that light behaves in some predictable and other unpredictable (to me at least at this time) ways. The mirrors seem often to be more clear to me – light reflecting off at equal angles, regardless of the shape – while the

lenses, particularly those with a convex or concave plane, are still somewhat confusing. I have learned through experiment alone what changes of the images at these various angles, while the concave lenses seem to shrink an image to a point somewhere inside what would be a circle if the lens extended beyond itself indefinitely – but as I write this, I wonder if that is in fact where the focal point of the lens lies? In the circle? Is this math how you managed to determine how the lenses worked together? Without actually dictating the science of refraction, the geometry itself paired with the relationships as defined in your brilliant compass, could determine the necessary lenses? What amazement if this is true! How to test it? I shall cease the writing of this topic in this letter and return to the idea of lenses at such point when I have tested the theory which only writing to you has brought forth from my thoughts.

From here, then, I should move on to express to you the great fascination we have discovered with your telescope. Through our explorations, we have managed to craft our own versions of the device, using available household items and lenses, which we crafted to magnify but twice the size and twice the distance of an object – not nearly as effective as your device, which eventually magnified one thousand times the size and thirty times closer than with the natural eye, as according to your *Starry Messenger* reporting, but a success for our small explorations nevertheless. We attempted then, as I wonder if you had also done, to measure the various distances between the viewer, lens and object and to determine the relative size of the objects, much as we had done with only the frame, viewer and object with our previous experiments. We wondered at the relationship between the frame situation, as well as the relationships between distances of the three parties in this relationship. I wonder, honorable Sr. Galileo, if you did indeed measure these relationships, and if so, what methods you employed? We had great challenges measuring size and distance until we created an object which we could

divide into an many squares of equal size, and thereby identify at any given distance how many of the squares were visible through our elementary telescope versus through a tube of the same size with no lenses. It was brought to our attention at some point in our learning when we visited a museum of artifacts, many of which might be familiar to you as recent, but to our eyes were sacred in both their age and importance, that "cross hairs" were used at the far lens of a telescope for perhaps such a purpose. I wonder still how you managed to magnify images to such a degree, to calculate and then craft the necessary lenses, and then to determine what magnification had been achieved? It occurs to me to ask whether the magnification was measured by observing, or whether your rules of mathematics and compass instrument aided in the prediction of the magnification, so that then the calculation of 1000 times larger was not necessary to measure once it had been achieved. I admit, sir, that despite many enjoyable and drawn out explorations with lenses of various sizes and shapes, I have yet to entirely understand the details of this "science of refraction" but would be most grateful to know how your experience with mathematics and observation played together to result in that most laudable invention of the telescope, which we only duplicated in a crude and unsophisticated way. Having merely dabbled in this science, we proceeded to use a telescope more professionally crafted to view those sights you reported to have seen yourself. I must say that in this, we felt both awe and camaraderie with those others who had first seen the heavens magnified in such a way. We found your descriptions of the canyons of the moon and the apparent sunrise over its cliffs and valleys to be even more delightful when we experienced it ourselves, on the steps of a great University building with a half moon overhead. It speaks, perhaps, to the stubbornness of man that it was hard to accept the rough and cavernous surface of the moon to the degree to which you described it until we looked upon it with our own eyes magnified through the

telescope. Perhaps the most astonishing of the discoveries in that evening, however, was the great speed with which the moon escaped the view of the telescope. My colleagues and I had barely taken our turns at viewing it before it was nearly out of sight and the tube needed readjustment to focus on it again. It was at this point when I recognized that not only had this great device brought us closer to the detailed appearance of heavenly bodies, but brought to light in a quite literal way, the movements that characterize those bodies, and the very earth itself. My first wondering, when we finally captured Jupiter and one tiny moon in the view of our scope and it ran across the sky so quickly that we could scarcely chase after it, was how it could move so very quickly, when it struck me rather suddenly that perhaps it wasn't Jupiter that was moving after all. Admittedly, in my time and place there is not skepticism regarding movement of the earth itself, and I was therefore predisposed to be willing to accept such a theory, but I wondered at the series of thoughts that brought you to explore and then embrace theories of Copernicus, which indicated that perhaps the heavens did not revolve around a stationary earth after all. I have wondered a great many nights, Sir Galileo, at the sequence of your mind that brought you to such a realization, and if it was as connected to the light and the telescope then as I perceive it to be now.

We tried as well some further experimentation with motion, which in my thinking was now very well connected to the ideas of the motion of the heavens, and discovered that in fact, I cannot detach them either from the moon and stars, nor from the creation of sound. I notice the rhythm in swinging motion, the noise from an accelerating breeze, the persistent rolling sound of a marble on the floor or a table surface or in a bowl. And the sound seems to me inextricable from the motion itself. I wonder if you experienced these things as intertwined as well, since your theories and writings have helped me to connect them so. Our colleague from yet another

time, Sr. Thomas Settle, poses a similar query in an anecdote that he proposes might represent a similar circumstance to that which encouraged you to notice the timing of a pendulum swing, in keeping time to music in a chapel. Indeed, while his story is but a fictional possibility, he writes in this same work the very notion that each of your ingenious discoveries is somehow connected to the next:

"Never did any of Galileo's research lines remain isolated. They were always part of a complex network of only apparently isolated lines, each having its own story, but heavily cross-linked among themselves. […] it is this network of heavily cross-linked lines of development which constitutes Galileo's experimental research." (Settle, 1996, p 9)

I wonder, honorable Sir, what you see as the common thread to the ideas of the world you revealed to the future, if there is an underlying theme of mathematics, of relativity, as seems to be the basis for your compass. If some idea of perspective, both literal and metaphorical runs throughout, and if there is some grand thread running through them all, apart from the inimitable brilliance of your thoughts.

Indeed, your thoughts , Sir, are so grand to me that I find great difficulty imagining that you are a man who existed in an actual place and time, and not instead the hero of some terrific legend. This is perhaps most inspiring to me, when I remind myself of this fact, and that rather than magic or miracle, you possessed such keen instincts in mathematics and nature that using the tools of your senses and mind alone you discovered these things through observation and deduction.

Sincerely,

LJ

DAY 2…

A Poem

Impedimentus chased the moon across the field and through the skies
In hopes that he could capture her and keep her beauty for his eyes.
"No other circle," he proclaimed, "as radiant or smooth or still
Has e'er been seen, and I am sure none other ever will."

They offered him a gem instead, but he refused them, amply vexed,
"This gem may shine in light, but has none of its own, it but reflects
The light nearby, and therefore cannot match the lunar pearly tone!"
"But sir," they said, "as does the moon; she has no light to call her own."

They brought him to a looking glass of silver sheen for his reflection
"The mirror smooth though it may be," he said, "won't match the moon's perfection!"
But they said "Sir, the moon is rough! With canyons deep and mountains high!"

and offered him a crystal ball to hold against the evening sky.
"Its radiance is bright, it's true, but resting on the window sill
It tumbles with a gentle breeze; my perfect moon is ever still."
"But, sir!" they said, "the moon, she moves! Around the world and back again."

They offered him a shining pearl suspended from a silver chain,
And as he watched the gleaming ball, swing to and fro from place to place
He saw its radiance keeping time, and wondered at its even pace –
"But how," he asked, "can all this be?" and stared at it in awe,
"that all that now I think I see, is hardly what I thought I saw?"

A Dialogue

Impetus: what of a mirror sphere, I wonder? What should one see if one could – though I imagine, one cannot – be suspended within a sphere the inside surface of which were entirely reflective like that of a looking glass?

Impedimus: The entire inner surface, then, would be concave, would it not?

Impetus: yes, sir.

Impedimus: then everything within the reflection would be inverted, as ones face is inverted when looking into the face of a spoon.

Impressio: this might indeed be the case in some instances, however, further exploration reveals that objects are inverted in such surfaces only within a certain distance. Therefore, the view from the inside of such a sphere would depend on both the size of the sphere and the size of the object inside it, or alternately, the relative size of the two.

Impedimentus: indeed the view would depend on these things, though an enclosed sphere without any source of light would have no view at all. There is not only no reflection then, but would be no proof of it if there were.

Impressio: you get ahead of me in your perspicacity my friend, as indeed the placement of a light source would affect the view from the inner sphere. Moreover, an open mirror sphere which would allow such a light from an outside source produces an entirely different and in fact almost magical appearance when an object is placed inside.

Impetus: I have seen such a thing once - it seems to close the sphere itself and place the object atop it, as though displayed there. But when one tries to reach for it, one finds that it cannot be touched.

Impressio: this is indeed the magical appearance to which I refer.

Impedimentus: Surely there is some trickery involved in any such magic.

Impressio: Ah, but if this is magic, does not such 'magic' occur in any reflecting glass?

Impedimentus: I fear, sir, that I do not understand you. My looking glass is as common place as the next, with no magic in it.

Impressio: no real magic, it is true. But can you also not see yourself represented in it, when in fact, the you in the glass cannot be touched or reached?

Impetus: I suppose this is true. One can see many images in the smooth surface of a looking glass that cannot be grasped or removed.

Impedimentus: I must admit that your argument is convincing. But what is the effect, then, if the object is moving within the open mirror sphere you describe? Can you then not see that the view is unreal, and determining this otherwise endeavor to reach and touch it?

Impetus: indeed – this experiment I have not yet attempted. I have noticed something else of interest, though, when a moving object is placed within such a bowl - the pattern traveled by a small circular object such as a marble when placed in a bowl or an arc. I wonder, Impressio, if the ball travels in a circular path, as I imagine the moon takes around the earth, or is it but my imagination that makes it seem so?

Impedimentus: I have seen a ball stay within the track of a single arc and not roll off to one side or the other, in fact swinging back and forth like a pearl from a chain. If this is true, why would it not travel the same path in a bowl?

Impressio: Do you not stay on the road rather than veering into the pastures when traveling through the country?

Impetus: I do.

Impressio: and were there no road or path, and you still had to travel, would you then veer into the pasture in order to continue your motion?

Impedimentus: I suppose given no defined path, I would continue in some direction through the pasture.

Impressio: then does it not also stand to reason that a ball given the specified path of an arc would stay upon it, while veering in other directions in its absence?

Impedimentus: In some manner, this makes sense. But why, then, a circular path?

Impetus: perhaps it is everything in the universe that travels in such a way. Even the swinging of a pearl or a watch on a chain takes some arc, which is some part of a circular path, is it not so?

Impressio: an excellent thought, my dear Impetus. Indeed the circular path you identify is ubiquitous in the world around us. Just as the arc and the circle are connected to earth and heavens, to motion and sound, and even to light. Our dear friend Sagredo taught us well how a pendulum swings on its arc and yet keeps time with music, however low or high it might swing on that same arc.

Impetus: indeed, I notice with frequency the connection between motion and sound. Why, the very speed of the wind itself makes sounds, as air through a pipe. Or the string of a lute humming as it moves back and forth so quickly.

Impedimentus: almost too quickly to be sure it moves, I say. And provided I agree even with this statement that the motion and the circle and the sound are united in some way, how is it that you say the light and the heavens share this bond? I see nothing circular about light, save the sun and the moon seeming to take such a shape, and the moon only on some occasions taking the full circle.

Impetus: I have seen much of the moon, these past weeks, and drawn her patterns, and I must say she is always in some sense of a circle, save when she is not apparent to us at all. Indeed, her journey across the sky is an arc as well, though looking through the telescope of our friend Galileo will show that she is not as perfectly smooth and circular as she seems.

Impressio: Ah, the telescope! My dear Impetus, you get ahead of me again. The telescope is indeed where the circle and the light unite in our story. The very lenses through which we look to seek the wonders of the heavens are where we find the arc and the light together.

Impedimentus: The lenses themselves and the tube are clearly circles, but this hardly demonstrates the strong connection you profess.

Impressio: my friend, this would make a poor connection indeed, though their round shape lens aid to the watching eye. The true relation between these lenses and the arc is in their shape within that circle – in the concavity or convexity of the cut of the lens.

Impedimentus: this connection still seems to me superficial at best.

Impressio: alas, Impedimentus, you do not see. I say, truly do not *see.* Take this lens, of concave nature and view the objects on the table. What happens?

Impedimentus: the shapes appear to shrink. That can hardly be of use in a magnifying device.

Impressio: now try this, the convex lens, and tell me, what do you see?

Impetus: the shapes distort – and then invert!

Impedimentus: I agree that they appear so.

Impetus: but how can this be? When in a magnifying device in which both are used, the shapes are neither shrunken nor upside down – in fact, they must be larger for us to see them from such a distance!

Impressio: though some such devices do invert an object's appearance, you are correct that the brilliance of the device is in its ability to enlarge the appearance for our eyes. Indeed, it is the combination of the lenses, measured and aligned in a specific way, that results in the view that we see, magnified and closer than with the eye alone.

Impedimentus: but how is such a thing related to circles?

Impetus: Perhaps, it may be that the arc of a concave or convex lens, being rounded, might provide some alternate path for the light as compared to a lens which is flat – like the ball in the arc, perhaps it directs it in a different direction?

Impressio: You may well have made a discovery on your own, my friend Impetus. Go on.

Impetus: and perhaps, then there is a way to measure these paths without as much knowing the exact path of the light, but rather, telling it where to go.

Impressio: and what of the circles?

Impetus: It may be, though I have not tried such a theory, that because the arc of a concave or convex lens is part of a circle, one might find and trace what the full circle would be, should it be completed.

Impressio: and what then?

Impetus: perhaps there is some geometric explanation, within the center of the drawn circle, for where the light would travel?

Impressio: it is possible that it is so, my friend.

Impedimentus: I am unconvinced, but admit to being curious about your theory, Impetus. Shall we construct an experiment to test it?

Impetus: indeed, let us create one!

Impressio: a fine idea! Much knowledge can only be created by discovering the question and testing for more questions.

Impetus: if it provides us with the perspective of each lens, we can proceed with this new found understanding.

Impressio: ah, you are correct in that it is perspective that you seek. In fact, it is the very thing that allows you to ask what you see and why, to determine whether what you saw is what you think you saw.

Impedimentus: I'm afraid you again confuse me, Impressio.

Impressio: Confusion is a great part of the path to understanding, my friend. And perspective will help you travel it. Indeed, one might think that two opposing views are parallel and may never meet, like the opposite sides of a road to be traveled, and yet, it is perspective that allows those parallel lines to meet and intersect at some point in the distance.

DAY THREE…

Dear Sr. Galileo,

I fear that news of trial has reached us, and it pains me deeply to hear that the renouncing of some of your most brilliant discoveries was demanded and received. While that space within our minds and hearts should be impenetrable by such forces as law, I feel that what they have insisted upon must trespass far into this territory, and I with my colleagues in this time and place have been truly saddened by this great injustice. A comparable sadness might be felt for they who have deprived themselves and the world of your wisdom, were it not for its having been at their own hands. It causes me, therefore to think on the future of spreading your wisdom, and my own learning as well as what I might hope to apply to those other circumstances in which your great process and discoveries might continue to flourish and do great good.

I think of your great fable in which *The Cicada* with its song of unknown origin, silenced in careless curiosity, and I liken this to the carelessness of those who have silenced you. This fable, I feel, serves as a lesson in many ways, and I propose, in the attached documents, a series of lessons for your view, that I hope to implement with regard to this lovely and most relevant story.

I think also of how very much I have learned of context in my explorations of your work and writings, Sir, and how the details of your life and background must have folded into your thoughts and discoveries – the music and mathematics above all, perhaps, but what other details must have entered and left your experience ever so subtly, only to prove drastic catalysts for your next great idea – so many that I imagine an unfolded parchment of these details would reveal a spider web pattern more intricate than the finest tapestry. I imagine even beyond what I have

read that the events of your time and place must have guided your path in some grand, some small ways, and that the proximity of glass for lenses, or the climate for cicadas, or a request from the noble family of a student, must impact the course of things.

In this same way, that in trying to separate these ideas from one another we deprive them of their very essence, and remove some element that gives richness to world. I feel this must be applied to my future teachings, this understanding of connectedness and context, and how much more readily both reason and sentiment flow when the context has not been removed.

It has been tremendously inspiring to consider that beyond the considerable aid of your brilliance, the tools for your discovery were available to you as they are to many of us. Your amazing attention to the smallest features, keen observance of each detail, and application then of mathematics and deduction to draw and support conclusions is most inspirational, even as we are humbled by your abilities, we are encouraged to proceed, and to encourage our students in turn, that they might employ their own powers of observation and deduction to reach their own grand discoveries.

I have witnessed my colleagues, each of whom approaches the investigation of your ideas in such a different manner; while some focus intently on a single object or motion, others write and take measurements and plan and theorize before constructing very specific experiments, while others observe and ask questions to pursue further understanding. I expect that you did not employ such a variety of methodologies in a single mind, and understand that there were some you chose not to consult, such as Sr. Keppler, whose work was said to be sent to you and unread, for reasons of which I am unaware, but for which I believe you had some valid justification that is beyond my humble understanding. We did, in our explorations, however, have such limited

time and resources, that we found it most helpful to consult one another and on occasion work in small groups in pursuit of the knowledge that you so skillfully acquired on your own. And in doing so, we learned more of our selves as well as the subject, all of which, though you might have advised against some portion of our methods, would not have been within the realm of possibility if not for the path you traveled first.

Though in such times of injustice there may be little comfort, I hope that some spark of hope remains for you in that your work has continued into our time and place, and that we aspire to extend its influence far into even our future.

It is with deepest gratitude and humble admiration that I sign this, which may be my final letter to you, though be certain that in all times and many variant circumstances, I will have your memory and your legacy in my most prominent thoughts.

Sincerely,

LJ,

Aspiring student of philosophy, science, and the mysteries of the heavens

Lessons for the elementary classroom, based on *The Cicada* by Galileo Galilei

An Overview:

MONDAY

Listen to musical piece by Galileo's father.

Students will use visual art materials to draw what they hear in the music.

The class will discuss the sounds they heard and how they believe the sounds were made, giving examples of other sounds that they hear both indoors and outside.

Students will listen to the musical piece again, adding movement as though they were making the sounds themselves.

Students will then add to their drawings illustrations of other things that create sound.

TUESDAY

The class will read "The Cicada" by Galileo Galilei.

The class will discuss and identify the beginning, middle and end of the story, and review the different types of sounds they noticed.

Given materials such as a drinking glass, various percussive tools, recorders, small stringed instruments, and bells, the class will explore the creation of sound.

As a group, the class will discuss the sounds they made, what they discovered, and what they noticed from the story and tried in the explorations.

WEDNESDAY

Taking clues from Tuesday's exploration, additional new materials will be supplied on Wednesday, and the class will divide into smaller groups each to explore with new materials and create a new sound or song.

Each group will create a scene or story about the sound they create, and present it by telling, performing, or drawing their idea.

THURSDAY

The class will read "The Cicada" again, this time engaging in a narrative pantomime of the story, demonstrating with their bodies how they might portray each sound, how the main character might have felt on his journey of discovery.

The class will discuss the what they believe was a lesson of the fable. Each group (from Wednesday) will add a lesson (one they identified from the Cicada or another of their choosing) to the story about their sound.

FRIDAY

Each group will present their story to the class using methods of their choosing.

The class will mention things that they noticed from each group presentation, and discuss what new types of sound were discovered? What did we learn from the stories? What questions do we still have?

The class will create a mural about sound, including the questions that remain in our minds.

ADDITIONAL LESSONS WITHIN THIS UNIT MAY INCLUDE:

Further exploration on sound directed in response to the questions posed at the end of week one.

A day of lenses and mirror exploration, including a periscope and telescope exploration.

A Starry Messenger (the children's book version) lesson, including scenes from pivotal moments in Galileo's life.

Motion explorations with balls and water, ramps, and arcs.

UNIT CONCLUSIONS:

By the end of the unit, each student will have performed in a scene from Galileo's life, and written him a letter, as well as crafting his/her own fable involving the creation of a sound. AT the end of the unit, each student (or group of students) will use what he or she has learned and explored to craft a monument or exhibit for a "Galileo Museum" that the class will construct. The exhibit can take any form, including a performance, song, dialogue, written piece, artwork, or other presentation, but must represent a connection between Galileo's work and life and the student's experience.

EC.050 Recreate Experiments from History: Inform the Future from the Past: Galileo
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