Entrainment

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Abstract

Entrainment is a composition for six percussionists. The piece is in seven movements which explore different aspects of rhythmic and metric perception and cognition. In order to express the different rhythmic techniques used in the *Entrainment*, I develop a theoretical apparatus that allows the analysis of concurrent temporal streams. The first two movements deal with how the brain reconstrues rhythmic material into different meters based on context. The third and fourth movements explore how the brain understands meter when given very little rhythmic information. The fifth and sixth movements explore how the brain understands meters which are out of phase with one another. The final movement serves as a culmination of the various rhythmic techniques used throughout the piece. In addition to the rhythmic elements, the movements contribute to numerous large-scale trajectories pertaining to tempo, timbre, and dynamics, leading to the final movement.

Résumé

Entrainment est une œuvre pour six percussionnistes. L'œuvre en sept mouvements explore plusieurs éléments de la perception et de la cognition du rythme et du mètre. Afin d'exprimer les différentes techniques rythmiques utilisées dans *Entrainment*, j'ai développé un modèle théorique qui permet l'analyse des strates temporelles simultanées. Les deux premiers mouvements examinent comment le cerveau réinterprète un matériel rythmique donné dans une nouvelle organisation métrique en s'appuyant sur le contexte. Les troisième et quatrième mouvements étudient la façon dont le cerveau comprend le mètre quand il y a peu d'information rythmique. Les cinquième et sixième mouvements examinent comment le cerveau comprend le décalage métrique entre les différentes strates temporelles. Le dernier mouvement utilise toutes les techniques employées dans les mouvements précédents. En dehors des éléments rythmiques, le timbre, les nuances et le tempo forment des trajectoires à grande échelle qui mènent au dernier mouvement.

Acknowledgements

I would like to thank Brian Cherney for his guidance as both composition teacher and supervisor for this thesis. Our conversations through my degree on composition, analytical writing, and new music in general have been truly enlightening. Special thanks to Jonathan De Souza for his assistance in the research aspect of the thesis.

I would also like to thank Kristie Ibrahim, Fabrice Marandola, and the rest of the McGill Percussion ensemble for premiering the piece in October of 2018 and providing invaluable feedback throughout the rehearsal process, and the McGill Composition Area for appointing me as Composer in Residence for such a wonderful group of musicians.

Finally, I would like to thank my family for all of their support throughout the years, without whom none of this would be possible.

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1.0 Introduction & Research Background

Entrainment is a piece in seven movements for six percussionists. The piece was composed as part of the Composer in Residence program at McGill University with the McGill Percussion ensemble, and was premiered in October of 2018. For the detailed instrumentation, refer to Section 7.0.

The term “entrainment,” which serves as the title of the thesis composition, refers to “the process by which independent rhythmical systems interact with each other."[1] This piece deals with a very specific kind of entrainment called “metrical entrainment,” referring to the mental process of perception and cognition of periodic stimuli in the environment. This is done through the “attentional rhythm” of the human brain (characterized through periodic enhancement of neural responses) synchronizing to external rhythmic events, which creates the perception of musical meter.[2] This is the process that enables someone to play in time with a conductor, sing in time with an accompaniment, or tap their foot along to music.

Justin London, a researcher in music cognition, asserts that meter is not just a way of indexing events in the environment, but it also "provides a way of capturing the changing aspects of our environment as patterns of *temporal invariance*" [emphasis original].[3] Psychologist James J. Gibson theorizes that when faced with an active environment, the brain tries to filter out what is regular as a means of "optimizing" the perception of external events.[4] This ability to filter information from the environment in order to extract only what is essential is called “economical

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[1] Martin Clayton, “What is Entrainment? Definition and applications in musical research.” *Empirical Musicology Review* 7, no. 1–2 (2012): 49.
[2] See Justin London. *Hearing in Time: Psychological Aspects of Musical Meter*. (New York: Oxford University Press, 2004), 4., and Sylvie Nozaradan, “Exploring how Musical Rhythm Entrains Brain Activity with Electroencephalogram Frequency-Tagging.” *Philosophical Transactions: Biological Sciences* 369, no. 1658 (December 2014), 2. The exact meaning of “meter” will be discussed below.
[3] London, *Hearing in Time*, 5.
[4] Cited in London, *Hearing in Time*, 9.

perception."[5] It is this perception of the regularity of events that allows for the perception of meter.[6]

As part of the process of economical perception, the brain seeks out patterns in the environment and therefore tends to find a meter and entrain to it whenever possible, even without conscious effort.[7] This tendency to hear meter is also suggested by the fact that humans group rhythmic stimuli together in groups of two or three, imposing a meter where there would otherwise be none, in a process called "subjective rhythmization."[8]

In addition, once someone is able to identify a meter (or impose one upon a periodic rhythm), they are able to generate it independently of the external stimulus, even if the external stimulus is stopped or some new stimulus contradicts the established meter.[9] The listener first abstracts a meter from a stimulus and then generates the meter internally as a means of predicting future events.[10] As such, the listener will usually attempt to maintain an established meter even when presented with contradictory stimuli. This kind of persistence applies not only to simultaneous rhythmic patterns, but successive ones as well.[11] Only when presented with strong contradictory information will the listener reconstrue the meter in what David Locke calls a "gestalt flip."[12]

1.1 Metric Frameworks

Thus far I have discussed the perception and cognition of "meter" without properly defining the term. For the purposes of this paper I will be using a variant of the formulation of

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[5] London, *Hearing in Time*, 14.
[6] London, *Hearing in Time*, 10.
[7] London, *Hearing in Time*, 51.
[8] London, *Hearing in Time*, 14.
[9] Justin London, "Some Examples of Complex meters and Their implications for Models of Metric Perception," *Music Perception: An Interdisciplinary Journal* 13, no. 1 (Fall 1995): 60.
[10] London, *Complex Meters*, 62.
[11] London, *Hearing in time*, 85.
[12] As cited in *Hearing in Time*, 84.

meter detailed in London's *Hearing in Time*. London outlines various criteria in order for a meter to be constructed: firstly, it must feature some periodic rhythmic surface, otherwise the passage will be heard as ametric.[13] Secondly, at least two coordinated metrical patterns are necessary, but three are preferred, as London states that a single stream of unaccented pulses is insufficient to create a sense of meter.[14] He illustrates this point using the diagram below:

Figure 1.1: Figure 3 from "Complex meters," indicating the Measure (M), Beat (B) and Subdivision (SD) patterns.[15]

This figure shows three coordinated periodic patterns, one at the beat level (B), a slower one at the measure level (M), and a third, faster one at the subdivision level (SD). All of these periodic patterns form the multileveled structure called a "metrical framework," shown above in Figure 1.1. This framework can be extended in either direction, grouping measures together to form hypermeasures, or further subdividing the subdivision pattern into smaller rhythmic values. However, to the listener, not all levels are equal. Research by Mari Reiss Jones and Marilyn Boltz suggests the idea of a "referent level" that "functions as an anchor or referent time level for the perceiver."[16] London states that it is most often the beat level which functions as the referent.[17]

1.2 Metric determination and well-formedness

Surface articulations of the rhythmic patterns in metric frameworks determine meters. When there are fewer surface articulations than beats, the meter could be said to be

[13] London, *Hearing in Time*, 24.
[14] London, *Hearing in Time*, 17.
[15] London, *Complex Meters*, 63.
[16] From page 470, as cited in London, *Complex Meters*, 64.
[17] London, *Complex Meters*, 64.

"underdetermined," and thus ambiguous.[18] Likewise, passages which contain more articulations than necessary can be said to be "overdetermined," and require the listener to hierarchize rhythmic information to discover the beat level.[19] Overdetermination does not guarantee a lack of ambiguity, as research by McKinney and Moelants shows that different listeners may perceive different meters and different tempi when presented with the same stimulus.[20]

Another property of meter is "well-formedness." Lehrdahl and Jackendoff created a list of well-formedness rules, which any metric framework must follow in order to be perceptible:[21]

1. Every [rhythmic event on the musical surface] must be associated with a beat at the smallest metric level present at that point in the piece.
2. Every beat at a given level must also be a beat at all smaller levels present at that point in the piece.
3. At each metric level, strong beats are spaced either two or three beats apart.
4. The tactus and immediately larger metrical levels must consist of beats equally spaced within a given passage. At subtactus metrical levels, weak beats must be equally spaced between the surrounding strong beats.

These rules ensure that A) all levels are even subdivisions of the level above and that B) no accented beat is immediately followed by another accented beat. Point A requires little justification and is easily demonstrated by Figure 1.2 below:

Figure 1.2: A non-well-formed metric framework

The X layer does not evenly divide into either the B layer or the M layer, and as such it would be heard as separate from the metric framework, possibly as a tuplet or part of another framework

[18] London, *Hearing in Time*, 56.
[19] London, *Hearing in Time*, 56.
[20] Martin McKinney and Dirk Moelants, "Ambiguity in Tempo Perception: What Draws Listeners to Different Metrical Levels?" *Music Perception: And Interdisciplinary Journal* 24, no. 2 (December 2006): 158.
[21] Lehrdahl and Jackendoff (1983) Cited in London, *Hearing in Time*, 70–71.

entirely. Point B is follows from rule 3. In addition to these rules, Lehrdahl and Jackendoff also have "metrical preference rules," one of which is relevant here: listeners prefer metric structures in which the strongest beat in a group appears relatively early.[22] As such, accented beats tend to be heard as the beginnings of metric units.[23]

1.3 Preferences and Limits of Entrainment

As mentioned above, humans naturally divide rhythmic material into groups of two or three. However, it has been shown that humans also have a bias towards binary meters, rather than ternary.[24] Listeners can also only hear a given passage in one meter at a time. When a listener is presented with two or more concurrent metric frameworks, London states that listeners will either 1) extract a "composite pattern" which allows for all of the rhythmic information to fit into a single metric framework, or 2) focus exclusively on one metric framework and treat the other as rhythmic "noise."[25] In either case, one framework will emerge as dominant over the other. Therefore, I will not write about "polymeter" throughout this paper, as it is not a perceivable phenomenon.

In addition to grouping preferences, numerous experiments suggest that humans' ability to entrain to stimuli is dependent on tempo. Specifically, tempi between 70 and 120 beats-per-minute (bpm) are relatively easy to entrain to and remember.[26] In addition, 100 bpm is a special "indifference" tempo, where listeners tend to hear it as "not too long and not too short."[27] Conversely, it is impossible for humans to entrain to tempi faster than 240–300 bpm (depending

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[22] Lehrdahl and Jackendoff (1983) Cited in London, *Hearing in Time*,70–71.
[23] Hugo Riemann argued for an opposite, "end-accented" system, but his "accent" was conceptual, rather than phenomenological. See William Caplin, "Theories of Musical Rhythm in the Eighteenth and Nineteenth Centuries." in *The Cambridge History of Western Music Theory*, ed. Thomas Christensen, (Cambridge: Cambridge University Press, 2002), 657–694.
[24] London, *Hearing in Time*, 45.
[25] London, *Hearing in Time*, 50.
[26] London, *Complex Meters*, 63.
[27] London, *Hearing in Time*, 31.

on the listener) or slower than 30 bpm, with the entrainment process becoming increasingly difficult the closer the tempo gets to either extreme.[28] In the former case, listeners cease to hear events faster than 600 bpm as individual rhythmic events, and so find it impossible to subdivide beats faster than 300 bpm.[29] In the latter case, it becomes difficult for listeners to accurately predict the timing of events further than two seconds apart without subdividing.[30] Therefore, it is difficult to hear either extreme as the "beat" level of a meter, with listeners needing to either half or double the tempo, effectively reinterpreting the articulated rhythmic pattern into either a subdivision or measure-level grouping, respectively, so that it fits in a more comfortable range. This tendency, combined with the idea of the "referent" layer presented above, results in a kind of "tempo equivalency" among tempi related by powers of two, as a piece will sound the same whether it is notated with a tempo of quarter note = 100 or quarter note = 50 with all rhythmic values halved.[31] In the former, the quarter-note pattern will be the referent, whereas it would be the eighth-note pattern in the latter.

Finally, research conducted by Kim Thomas indicates that there is a minimum degree of tempo change required before it is noticeable to a listener. While there is a slight difference depending on whether or not the initial tempo was fast or slow, or if the tempo was increasing or decreasing, this research suggests that in general, a tempo difference of roughly 8% is required for a difference to be noticeable.[32] This will be referred to as the "just-noticeable difference" (JND) of tempo.

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[28] London, *Hearing in Time*, 31.
[29] London, *Hearing in Time*, 27.
[30] London, *Hearing in Time*, 29.
[31] This applies solely to contemporary music, as note values have closer associations to tempo and articulation in earlier traditions. See Johann Philipp Kirnberger, *Die Kunst des reinen Satzes in der Musik*. trans. David Beach and Jurgen Thym as *The Strict Art of Musical Composition*, (New Haven: Yale University Press, 1982).
[32] Thomas, Kim. "Just Noticeable Difference and Tempo Change." *Journal of Scientific Psychology* (2007): 18.

1.4 Compositional Principles

Based on the research above, I have formulated some axioms which serve as guiding principles for the composition. They served to inform the design of rhythm, tempo, and meter throughout *Entrainment*, as well as the overall form. They are as follows:

1. A given listener will perceive a passage with a periodic rhythmic surface to exist within one, and only one, metric framework.
2. Any two listeners may construe the same passage to be within in two different metric frameworks.
3. The tempo of the "beat" level of any metric framework perceived by the listener will be between 30 bpm and 240 bpm, with a tendency towards tempi closer to 100 bpm.
4. Once a listener perceives a metric framework, any further material will still be heard as if it were within the same metric framework until contradictory rhythmic material is presented.

1.5 Rhythmic Functions

In composing *Entrainment*, I created a system of transformations in order to describe my conception of the relationships between different rhythms and tempi. I have formalized this system and turned it into an analytical tool to help facilitate the discussion of temporal elements throughout the analysis. In describing the simultaneous presentation of different rhythms, conventional notation describes the relationship as a ratio. For example, the common triplet rhythm would be written as 3:2.[33] However, this kind of notation is insufficient for my needs as it simply describes each rhythmic layer in terms of the other. It fails to indicate in an elegant way how one rhythmic pattern would move to the other. A more complex example may help to explain this. Consider rhythmic patterns, A, B, C, D, and E, shown in Figure 1.3.

Pattern A is in a 2:3 relationship with pattern B, and pattern B is in a 2:3 relationship with pattern C. As a result, pattern A is in a 4:9 relationship with pattern C. While 4:9 accurately describes the ratio between patterns C and A, it obscures the fact that C was the result of a two-

[33] The ratio expresses the triplet in terms of the beat proper, so 3:2 means three notes in the time of two.

part transformation, of which B was an intermediate step. This also presents a new problem: while it may be possible to intuit that a 4:9 ratio is derived from two 2:3 ratio transformations, it cannot in any way express the order in which those two transformations were done. While the order would be of little relevance going from A to C, consider D, and E.

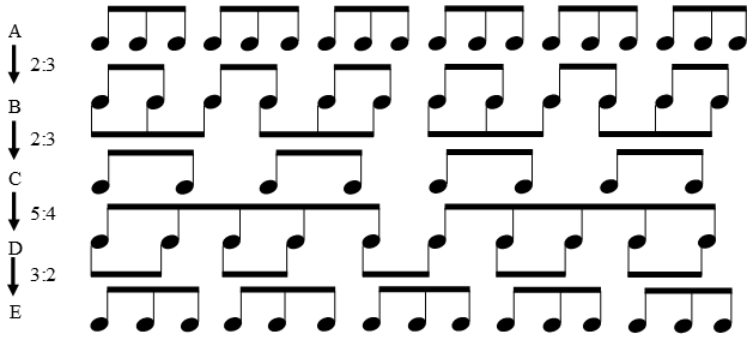

Figure 1.3: Different rhythmic layers.

The ratio between C and E would be 15:8. While it may be possible to deduce that this is the result of a 5:4 and a 3:2 transformation, it would be impossible to determine the order in which the transformations were done. Compare patterns C and D with patterns B and E. In both cases, the ratio between the rhythms is 5:4, but the transformational path to get from B to E is far more complex, which the label fails to indicate. The fact that the ratios show that patterns C and D have the same proportional relationship as patterns B and E may be insightful, but in cases where the transformational path of rhythms is musically relevant, the ratio is insufficient.

To resolve the issues illustrated above, I employ a Lewinian functional-transformational approach in describing the relationships between different rhythmic patterns. This has been done to various degrees by different authors, including Lewin himself, focussing on durational patterns and metric families, but not in any way which I found satisfactory to discuss the

techniques employed in this piece.[34] Therefore, I have created a new system of notating the relationships between metric frameworks based on mathematical functions, outlined below:

- Let B be some rhythmic pattern
- Let *k*B be a rhythmic pattern, where *k* is some number such that the inter-onset interval (IOI) between temporal events is reduced by a factor of *k* when compared to pattern B.
- Let f^a be a function such that f^a(B) is a rhythmic pattern in $(x{:}y)^a$ relationship with rhythmic layer B, where *x* represents the number of attacks in temporal layer f^a(B) needed to take the same duration as some number of attacks *y* in pattern B
- Let H represent the 3:2 relationship, such that the IOI between events in H(B) is 2/3 times as long as those in B
- Let Q represent the 5:4 relationship
- Let q represent the 5:2 relationship

The H, Q, and q functions are defined here because they are most relevant to this piece and represent the simplest rhythmic ratios that do not form part of the same metric framework.[35] To illustrate, consider the rhythmic pattern B from Figure 1.3 above. In this case:

$$A = H(B), \qquad C = H^{-1}(B)$$

Similarly,

$$C = H^{-1}(H^{-1}(A)) = H^{-2}(A)$$

This functional notation more clearly shows that C is the result of two H^{-1} transformations than simply using the ratio 4:9.[36] This also solves the issue of being able to represent order. Take the previous example in which patterns C and D were in the same rhythmic ratio as B and E (5:4). Describing this relationship using this functional notation reveals the different transformational paths taken by the rhythmic patterns:

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[34] See David Lewin, *Generalized Musical Intervals and Transformations*. New York: Oxford University Press, 1987., Mark Gotham, "Meter Metrics: Characterizing Relationships Among (Mixed Metrical Structures)," *Music Theory Online* 21, no. 2 (June 2015)., and Erica Cao, Max Lotstein and Philip N. Johnson-Laird, "Similarity and Families of Musical Rhythms," *Music Perception: An Interdisciplinary Journal* 31, no. 5 (June 2014): 444–469.

[35] "H" and "q" refer to "hemiola" and "quintuplet" respectively. The Q function, while being identical to the 2(q) function, is included separately as the 5:4 ratio is much more common, and as such given its own functional label.

[36] If A were to be made into C with a single transformation, then a new function could be defined. However, such transformations are not relevant to this piece.

$$D = Q(C), \qquad E = H(Q(H^{-1}(B)))$$

This functional notation can also show the similar ratio between the CD and BE pairs, if desired, as the functional notation simply represents arithmetic operations, and as such they are commutative and reduce as would regular multipliers:

$$E = H(Q(H^{-1}(B))) = Q(H(H^{-1}(B))) = Q(H^{0}(B)) = Q(B)$$

For the sake of clarity, the original rhythmic pattern will be omitted from the formula when the referent is understood. For example:

Let C be the referential rhythmic pattern, then

$$D = Q, \qquad E = H(Q), \qquad A = H^{2}$$

In addition to indicating rhythmic relationships, these functions can also describe the relationships between different tempi. Because any metric framework can be understood as having one "referent" rhythmic pattern, of which all other levels are either groupings or subdivisions, the referent level can be taken as representative of the entire framework. As such, this referent pattern is tempo-defining. Therefore, by applying these functions to the referent rhythmic levels of two different metric frameworks, the relationships between their tempi can be described. Furthermore, because of the principle of tempo equivalency described above, any collection of tempi, and thus the metric frameworks which describe them, can be grouped into an equivalency class represented by a single referent pattern. Any two frameworks which contain the same rhythmic pattern (in the same tempo) are contained within this equivalency class. This allows for the grouping of different meters which share common patterns, e.g. 2/4 and 3/4 time. For the sake of clarity, this equivalency class will be called a *temporal layer*, as it represents a plurality of temporal strata present in the music. In summary, for some rhythmic pattern B, the "B metric framework" is some metric framework which contains rhythmic pattern B, and the "B

layer" refers to all frameworks which contain rhythmic pattern B. This can be seen in Figure 1.4, in which the B_1 and B_2 rhythmic patterns articulate the same pattern of attacks (equal quarter notes) at the same tempo, and thus are identical. However, as they are a part of different metric frameworks their corresponding M patterns are different. Nevertheless, since both frameworks contain the same rhythmic pattern, they are both part of the "B" temporal layer. Because the tempo is different in the B_3 framework, the B_1/B_2 pattern does not appear, and thus the B_3 framework is part of a different temporal layer. This new layer and its associated tempo can be described as a function of the tempo of the old layer.[37]

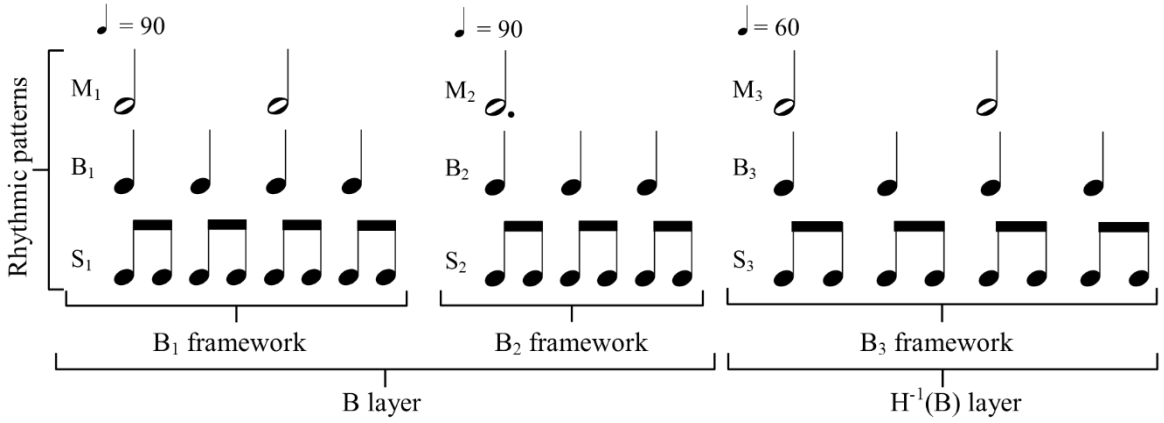

Figure 1.4: The difference between rhythmic patterns, metric frameworks and temporal layers.

2.0 Form

Entrainment consists of seven individual movements, each part of a larger overall structure, shown below in Figure 2.1. The first six movements are grouped into pairs, based on a shared 'focus:' a different aspect of entrainment. The first two movements explore Locke's "gestalt flip," employing techniques designed to make the listener constantly reconstrue the meter. Movements 3 and 4 deal with how the listener understands underdetermined meters. The

[37] Naming the second layer in relation to the first, rather than the opposite, is arbitrary. One could choose to take the second layer as the "B" layer and designate the first layer as H(B) instead.

third pair of movements explore how the listener perceives simultaneous temporal layers which are out-of-phase with one another. The first movement of each pair transitions smoothly into the second, with the arrival of a new pair being marked by a short passage called an "attack." The final movement is also preceded by its own attack. In addition, each movement features a particular instrument, as indicated on Figure 2.1. These instruments serve a structural role in their movement, including, but not limited to, soloistic material.

Various musical parameters of each movement contribute to different trajectories towards the final movement. The main dynamic of each movement is shown at the bottom of Figure 2.1, with the secondary dynamics indicated in parentheses. The overall dynamic shape over the seven movements is a large-scale crescendo, culminating in a *ff* level in the final movement. There are two other trajectories leading to the final movement, which are split between the odd-numbered "slow" movements, and the even numbered "fast" movements. The first of these trajectories pertains to orchestration, specifically the timbre and sustain of the sounds used. I divide all of the possible sounds of the ensemble into either "pad," "dry," or "resonant" and use different combinations of these types throughout the different movements. A more detailed explanation will be provided below in Section 5.0.

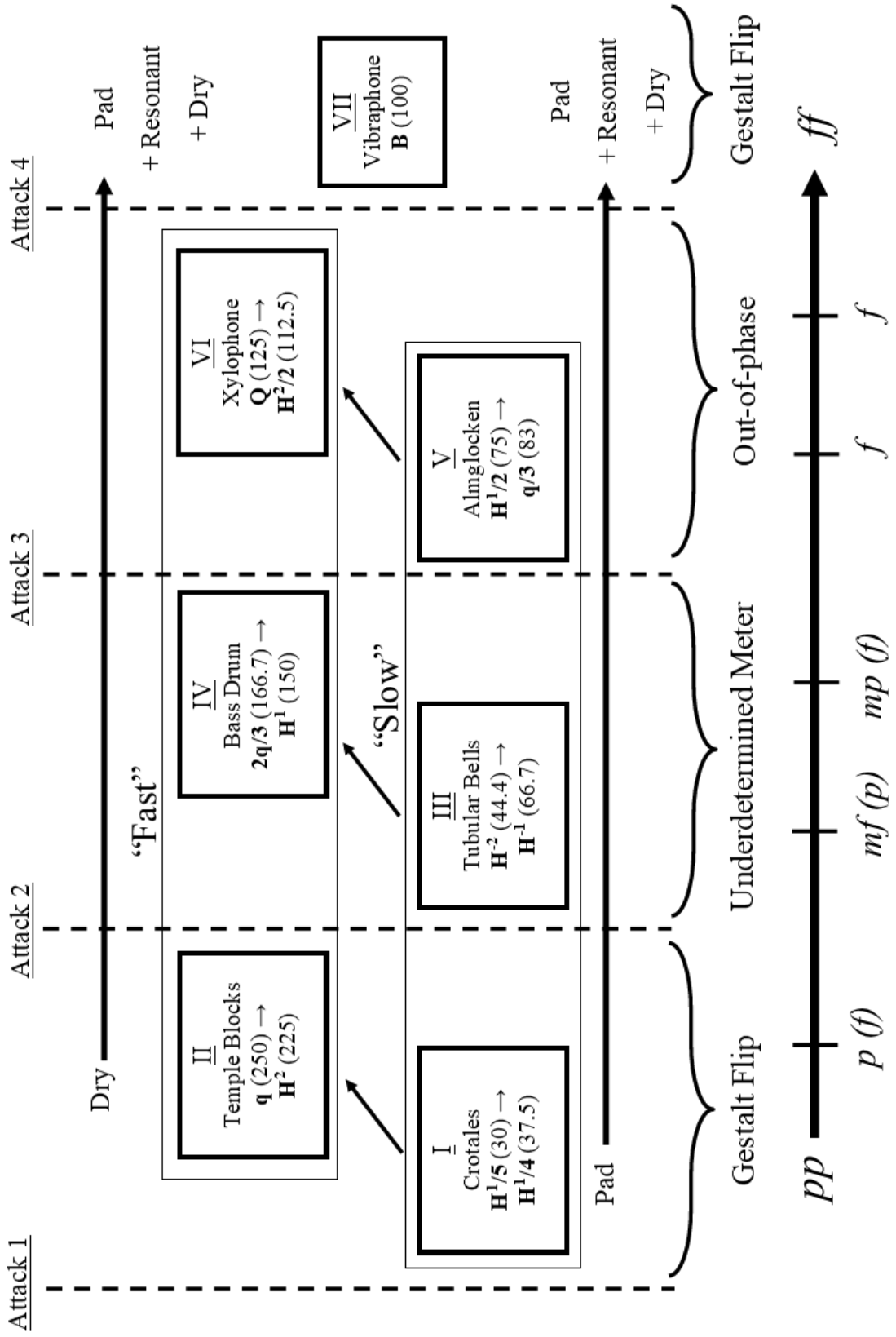

Figure 2.1: Formal outline of *Entrainment*, detailing the various parameters associated with each movement.

The second trajectory pertains to tempo and is divided between the "fast" odd numbered movements and "slow" even numbered movements. The final movement has a tempo of 100 bpm, the "indifference" tempo previously mentioned. This tempo serves as a baseline tempo for the entire piece, and as such it will be called **B**. Each of the other movements has two structural tempi, which will be referred to as B_1 and B_2 (layers in bold font are in relation to the entire piece. Layers in normal font apply only to their respective movements). Both B_1 and B_2 for movements I–VI are derived from **B** using either the H, Q or q functions (see figure 2.1), with the functions chosen to ensure that the difference in tempo is above the tempo JND (just noticeable difference). Throughout the "slow" movements, these structural tempi get faster, with B_2 of movement I being faster than B_1, B_1 of movement III being faster than B_2 of movement I, etc. This process begins at 30 bpm in movement I, the slowest possible tempo for entrainment) speeding up across the movements to arrive at 100 bpm. The "fast" movements function along the same principal, with B_1 of movement II starting at 250 bpm (one of the fastest tempi to which humans can entrain) and slowing down throughout to arrive at **B**.

2.1 Movement I

The first two measures of this movement constitute the first "Attack," and thus introduce the first pair of movements. The first movement proper begins at m. 3 and consists of a unary form developed from a continuous acceleration of rhythmic layers. Although the entire movement operates under this principal, the overall shape could be conceived of as being divided into two sections, based on the kinds of temporal layers used. The first section, mm. 1–43, centers around the B_1 layer (30 bpm), which is accompanied by the H^1 and H^{-1} functions. I call this rhythmic device "flanking," as the central temporal layer (B_1) is "surrounded" by both a faster and a slower temporal layer. It is important that these two temporal layers are in a complex

relationship to one another (in this case by a factor of H^2 or 9:4) so that each discourages the listener from entraining to the other. The second section (mm. 43–64), marked in the score by a metric modulation, focuses on the same rhythmic relationships applied to B_2. Individual subsections within these two parts are delineated through the addition or subtraction of a new temporal layer (see Figure 2.1 below). The introduction of the **B** layer at m. 55 serves as a transition to the next movement.

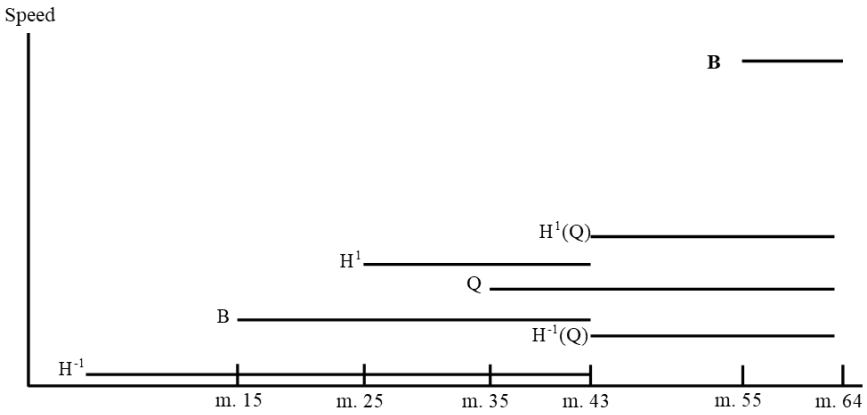

Figure 2.1: Formal chart of Movement I. Lines represent the duration of the indicated rhythmic layer.

As shown in Figure 2.1, the layers generally get faster as the piece progresses, resulting in a large scale acceleration that occurs throughout the movement.

2.2 Movement II

The second movement can be understood as two sections separated by the temple block solo in mm. 39–48. A detailed breakdown of the form is shown in Table 2.1, below. Section 1 remains primarily within a single temporal layer, and consists entirely of the tambourine, drumsticks, and xylophone, with the temple blocks coming in near the end to transition to the solo. Section 2 has more variety in both respects. The music undergoes multiple metric modulations in quick succession, and instrumentally now includes the anvil, multiple drum rims, and the slapstick, with the temple blocks also being more consistently present.

Section	Measures	Notable Features
Transition	1–2	Music picks up the **B** layer transition from last movement.
Introduction	3–5	Introduction of $H^{-1}(B_1)$ layer
Section 1a	6–18	Introduction of B_1 layer Ensemble of Perc. 2 (tambourine), Perc. 4 (drumsticks), and Perc. 5 (xylophone)
Section 1b	19–35	Synchronization of rhythmic materials Alternation between ensemble and soloist (Perc. 6: temple blocks)
Transition	36–38	Transition to solo
Solo	39–48	Temple block solo Transition to Section 2 and B_2 through two metric modulations
Section 2a	49–68	Preparation and modulation to $Q^1(B_2)$
Section 2b	69–80	Preparation and modulation to $H^{-1}(B_2)$
B3	81–103	Preparation and modulation to $½H^1(B_2)$ Duet between Perc. 6 (temple blocks) and Perc. 4 (Snare rim)
Transition	103–108 (end)	Transition to Attack 2 Staggered entrance of Perc. 2, 4, and 5, increasing texture and rhythmic density

Table 2.1: Detailed formal plan of Movement II

2.3 Movement III

This movement is preceded by Attack 2, introducing the second pair of movements. The movement proper, like the first movement, is a unary form, resulting from a single process, which is divided into two sections by the metric modulation from B_1 to B_2. Each section is defined by the number of distinct rhythmic attacks in each measure, as shown in Figure 2.2, below. The form of the movement is thus defined by the increasing rhythmic density. The metric modulation in m. 22 accentuates this process, as the change in tempo results in attacks being closer together. These sections are also articulated through the orchestration, with different sections featuring sustained sounds, resonant strikes, resonant strikes accompanied with sustained sounds, or some combination thereof.

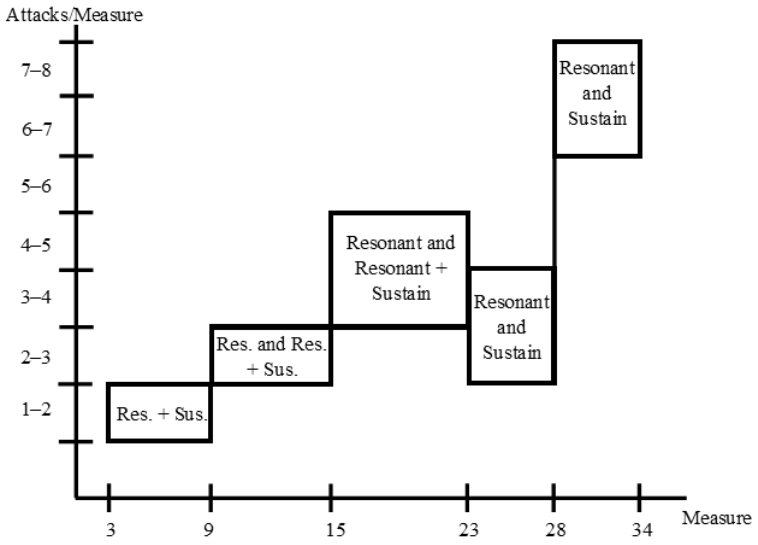

Figure 2.2: Plot of number attacks/measure in throughout Movement III. Orchestrations for each section indicated within the box for each section ("Res." = Resonant, "Sus." = Sustained).

2.4 Movement IV

The form of the fourth movement is based on an alternation between metrically-well-defined solo sections in the bass drum (Perc. 4) and metrically underdetermined tutti sections. As in previous movements, it is divided into two larger units, with the division marked by the metric modulation. In addition to the difference in tempo, the second section is structurally looser than the first. Within the first half, the solo and ensemble sections gradually become longer, and the sections are clearly divided. The second half features sections of varying length, with greater overlap between solo and ensemble sections, as shown below in Figure 2.3.

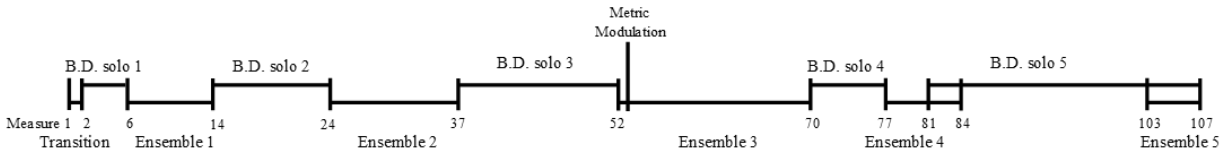

Figure 2.3: Alternation of solo and ensemble sections in Movement IV.

2.5 Movement V

The fifth movement is preceded by Attack 3, which transitions into the movement proper. Like the fourth movement, the movement is sectional, with sections being demarcated through orchestration. The orchestration thickens towards the middle of the movement and becomes thinner towards the end. This, in combination with the Introduction and Coda, creates an arch form for the entire movement. Unlike previous movements, the internal sections (with some exceptions) are based on rhythmic "cycles," created through different rhythmic groupings within triple or quadruple meters. A more detailed explanation of the cycles is provided in Section 3.5. A basic outline of the form is outlined below in Table 2.2.

Section	**Measures**
Attack 3	1
Transition	1–3
Introduction	4–7
Cycle 1	8–18
Cycle 2	19–26
Cycle 3	27–40
Cycle 4	41–50
Cycle 5	51–60
Coda	61–68
Transition	69–74

Table 2.2: Form chart for Movement V.

2.6 Movement VI

The form of the sixth movement is based on the alternation of two soloists (temple blocks and xylophone) and the rest of the ensemble. Table 2.3 details the various subsections of each section, along with the instrumentation and the phase of the temporal frameworks. These sections form a large-scale ternary (ABA') structure, with the A section featuring the ensemble, the B section featuring the soloists, and the A' combining both. Metrically, the A section has the ensemble in phase with one another, followed by the B section which has the soloists move out of phase with one another. The A' section features both the soloists and the ensemble and sees a

return of the material from the A section, but now with all of the material played out of phase. The metrical aspects are explained in further detail in Section 3.6.

Part	Section	Measures	Instrumentation	Phase
	Intro	1–4	Ensemble + soloists	In-phase
A	A1	5–10	Ensemble	In-phase
B	B1	11–18	Soloists	In-phase
	Transition	19–20	Interjection by ensemble, transition from vibraphone	N/A
	B2	21–34	Soloists + Ensemble (interjections)	Out-of-phase
Transition	Transition	35–49	Soloists + ensemble (interjections)	Out of phase → In-phase
A'	A'/transition	50–57	Ensemble + soloists	Out-of-phase

Table 2.3: Form chart for Movement VI.

2.7 Movement VII

The seventh movement is structured like a rondo. After Attack 4, there is a refrain (A), alternating with episodes (B, C). The refrain features a dense texture and is played tutti, while each of the episodes is comprised of a smaller ensemble. After the third refrain, the texture thins and the ensemble builds back up to a texture similar to the refrain, leading to the end of the piece. The refrain uses all of the temporal layers used thus far in the piece (H^1, H^{-1}, and Q), with each of the episodes highlighting one or two of them. This is summarized in Table 2.4, below.

Section	Measures	Notable Features
Attack 4/ Introduction	1–10	Bass Drum leads to movement proper
A1	11–20	Refrain 1
B	21–30	Episode 1 – Focus on H^1 and H^{-1} Reduction to bass drum, almglocken, and tubular bells
A2	31–36	Refrain 2
C	37–46	Episode 2 – Focus on H^{-1} Vibraphone solo with accompaniment
A3	47–53	Refrain 2
D/A4	54–73	Episode/Refrain Initial focus on Q, with all other relationships re-entering in turn

Table 2.4: Form chart for Movement VII.

3.0 Rhythm, Meter and Tempo

The temporal dimension is the most important aspect of each movement within *Entrainment*. As stated in Section 2.0, each pair of movements focuses on a specific aspect of rhythmic entrainment, with each individual movement within the pair exploring that aspect from a different perspective. All of the temporal relationships are based on the H and Q relationships described above, as well as combinations thereof. As such, the rhythmic language of the piece is comprised of standard binary rhythms (eighth-, quarter-, half-notes, etc.), or triplets/quintuplets of various proportion.

3.1 Movement I

The first pair of movements focuses on the phenomenon of the "gestalt flip," in which the listener recontextualizes rhythmic information into a new meter or tempo. The first movement explores this phenomenon in the context of extremely slow tempi, in which entrainment is difficult. The B_1 layer (=$\mathbf{H^1/5}$) moves at a rate of 30 bpm (one half-note = one pulse)—the slowest tempo to which most humans can entrain. The introduction to the movement (3–15) introduces the H^{-1} layer in Perc. 1 and 4, which articulates a rhythmic stream, the pulse of which is too slow to be perceived as a beat. Measures 15–25 introduce the B_1 layer proper in Perc. 2, 3, and 6, resulting in two different temporal streams being articulated. However, the B_1 layer is intended to be heard as the "real" beat, and so it is articulated by two different instruments (vibraphone and triangles). In addition, because the tempo of the H^{-1} layer heard thus far is slower than the threshold for entrainment (moving at 20 bpm), it will not be difficult for listeners to entrain to the new layer (B_1) and reinterpret the earlier rhythms as subordinate. The compound rhythm created by the B_1 layer and the H^{-1} layer also occasionally articulates quarter notes,

which are a binary subdivision of B_1, but a ternary subdivision of H^{-1}, which further reinforces B_1 as the primary temporal layer.

In mm. 25–35, the H^{-1} layer drops out and Perc. 1 and 4 articulate the H layer instead. This mimics the relationship between H^{-1} and B_1 layer ten measures earlier, but now with both temporal layers moving at an entrainable speed. Even though the B_1 layer is more reinforced instrumentally, the listener is likely to reconstrue the tempo again, now with the H layer as the real beat, and the B_1 layer as subordinate. The H layer is faster (moving at 45 bpm) and thus much easier to perceive as a beat, being further away from the lower end of the entrainment threshold. It is still possible that the listener may continue to perceive B_1 as the main layer, because of the instrumentation and the tendency for listeners to remain entrained to a framework.

Measures 35–43 introduce the crotales in Perc. 1, introducing the Q layer and weakening the reinforcement of the H layer. This makes it unlikely that a listener would remain entrained to the H layer, as it is now very weakly reinforced both rhythmically and instrumentally. It is likely that the listener would undergo another gestalt flip, in which the contrast of the crotales against the vibraphones is enough for one to perceive the Q layer as the new primary layer. Is it also possible that the listener continues to hear the passage with B_1 as the "beat," with H and Q being amalgamated into a composite framework, as the B_1 layer is still reinforced by three players.

The metric modulation in m. 43 marks the first notated tempo change in the piece, and reinterprets Q as the new primary temporal stream (B_2=Q(B_1)=$\mathbf{H^1/4}$). As with B_1, B_2 is reinforced instrumentally by three different players (Perc. 1, 3, and 6). The relative H and H^{-1} layers are introduced in m. 45, which "flank" the B_2 layer. In addition, because both layers are in complex relationships with B_1 (either HQ or H^{-1}Q), these new layers reinforce the metric modulation to the listener. The B_2 layers and the two layers flanking it continue for the rest of the

movement. Finally, the **B** layer (100 bpm) is introduced in m. 57 in Perc. 5. This layer serves as a transition to the next movement (acting as a means of metric modulation) and contextualizes the layers present in the first movement with respect to the entire piece.

None of the techniques described above, and those that will be described below, will necessarily have the intended effect on any particular listener. While it is possible to hear five or more tempo changes throughout the first movement, it is also possible to only hear the two which are notated, depending on how much any particular element (instrumentation, speed, etc.) influences one's perception of tempo. The goal of using all of these techniques is to explore the effectiveness of different combinations in influencing a listener's perception of musical time.

3.2 Movement II

The second movement also explores the gestalt flip, now in the context of extremely fast tempi. B_1 (=**q**) moves at a rate of 250 bpm (one eighth-note = one pulse)—one of the fastest tempi to which humans can entrain. After the transition from the previous movement from Perc. 5, the H^{-1} layer is introduced in Perc. 4. At m. 6, the B_1 layer is revealed by Perc. 5. This presentation of H^{-1} followed by B_1 is the same as the beginning of Movement I, but the effect of the gestalt flip is much more noticeable because neither tempi is outside of the entrainable range. Initially, the downbeats of each measure and the pickup to the next are articulated in the tambourines in Perc. 2 in order to clarify the tempo and meter. Beginning at m. 11, however, Perc. 2 stops articulating the downbeat, instead emphasizing later beats in the measure. This confuses the meter because, as per Lehrdahl and Jackendoff's metrical preference rules, accentuations will tend to be heard as the beginnings of metrical groupings. As such, while the B_1 and H^{-1} layers are consistent throughout this passage, the larger metrical groupings are disturbed.

This disturbance is rectified at m. 19, with Perc. 2, 4, and 5 "locking-in" to one another. Between measures 19–35, these three parts clearly articulate the B layer and the notated meter, with the temple blocks in Perc. 6 occasionally interrupting and introducing new layers (Q, H). Measures 36–38 transition into the Perc. 6 solo, which articulates numerous layers in quick succession as a means of destabilizing the tempo and undergoing two metric modulations to lead to B_2 (= $H^1Q^{-1}H^1(B_1)$=$\mathbf{H^2}$) at m. 49.

The second metric modulation begins the second half of the movement, which is comprised of three temporal "zones," each with its own tempo. Measures 49–53 prepare the metric modulation to $Q(B_1)$ in m. 54. This is followed by the section from 54–67, which features an alternation between $HQ(B_1)$ and $H^{-1}Q(B_1)$, horizontalizing the "flanking" technique used in Movement I and serving to both confirm the metric modulation and destabilize the tempo. Measures 68–73 serve to modulate back to B_2 and modulate to $H^{-1}(B_2)$. This new tempo is reinforced through the syncopated material in Perc. 2 starting in m. 76, and the $H^{-1}H^{-1}(B_2)$ layer in Perc. 6. Measures 81–84 modulate back from $H^{-1}(B_2)$ and then move to $H(B_2)$. However, the music from m. 85 until the end of the piece will actually be heard in $H/2(B_2)$, as both of the temporal layers used ($H(B_2)$ and $HH(B_2)$) move at over 300 bpm. As such, the rhythmic articulations will be heard as subdivisions of a slower beat, rather than the beats themselves. Because of the limits of entrainment, the end of this movement will actually be heard as slower than the section which came before, despite having the shortest rhythmic durations of the entire movement.

3.3 Movement III

The next pair of movements focusses on perception of underdetermined meters. Movement III explores a listener's tendency to subconsciously impose a metric framework over

metrically underdetermined passages. The different sections of the movement have a set number of attacks per measure, with that number generally increasing over the course of the movement. Even so, there is never a point in which there is enough rhythmic information to unambiguously define the meter aside from the final two measures of the movement. As the rhythmic density increases, however, it becomes easier for an individual listener to find patterns which they can interpret as a metrically significant, even if only for a short while. The rhythmic texture employed is designed to create such opportunities for entrainment.

Measures 3–8 contain between one and two attacks per measure, and in total articulate every eighth note beat within a 4/4 measure. The number of attacks quickly increases to 2–3 attacks per measure in mm. 9–14. Because the function of the attacks is to articulate different beats within a measure, I only consider it to be one attack when multiple instruments play on the same beat. The next section, mm. 15–22, increases the number of attacks per measure yet again as well as the variance, now with 3–5 attacks per measure. In addition, I add the H layer in Perc. 3. The tubular bells in Perc. 3, being timbrally distinct and the only instrument to play a continuous melodic line, stand out in the texture, bringing prominence to the H layer and preparing the metric modulation that comes in the next section. This preparation is more so for the performers than the listeners, as the lack of rhythmic information makes it unlikely that the metric modulation will be perceived.

The metric modulation from B_1 (=$\mathbf{H}^{-2}$) to B_2 (=H(B_1)=$\mathbf{H}^{-1}$) in m. 23 marks the beginning of the second half of the movement, as well as a reduction of rhythmic density which lasts until m. 28. I introduce the H(B_2) layer to mimic the rhythmic relationships present in the previous sections. In measures 29–34 (end of the movement), the rhythmic density increases to 6–8 attacks/measure, resuming the trend of increasing density from the earlier sections. As in

Movement I, the **B** layer enters near the end of the movement (m. 32) to serve as a link to the next movement.

3.4 Movement IV

The fourth movement continues the exploration of cognition of underdetermined meters, specifically how the human brain attempts to remain entrained to metric frameworks, even once any external rhythmic stimulus has stopped. The movement features the alternation between metrically determined passages to which listeners will entrain, and those which are underdetermined, where the listeners' ability to remain entrained will be tested.

After the low tom articulates the **B** layer in m. 1 as a transition from the last movement, the first bass drum (Perc. 4) solo begins in m. 2, articulating a regular pulse. This is followed by the first metrically-underdetermined section, played by the ensemble in mm. 6–13. The rhythmic attacks are widely spaced and mostly do not occur on the main beats of the measure, and so it is unlikely that any listener would be able to stay entrained to the metric framework established by the bass drum the entirety of the section. However, different listeners will remain entrained for a portion of the underdetermined section, with the size of that portion being unique to each individual. Much like movement III, these passages create an opportunity for the audience to experience the effects of entrainment but cannot reliably create the same result for multiple listeners.

The next bass drum solo lasts from mm. 14–23, and now features syncopations, which facilitates entrainment by articulating subdivisions of the pulse. The next ensemble section (mm. 24–36) contains more rhythmic events which align with the strong beats of the measure, as well as more rhythmic activity overall. However, the length of the section and the overwhelming number of rhythmic events which do not align with the measure make staying entrained to the

bass drum's framework difficult. The following solo section (mm. 37–52) clearly articulates beats and subdivisions of the framework, making it metrically unambiguous. The solo includes various syncopations, tuplets, and ametric accents, but these devices are not prominent enough to imply another framework or temporal layer. The following ensemble section (mm. 52–69) begins with two metric modulations, leading from B_1 (=**2q/3)** to B_2 ($=H^{-1}QH(B_1)=\mathbf{H^1}$). Because of the metric ambiguity of the ensemble sections, the change in tempo will likely not be heard until m. 70 with the return of the bass drum solo. This ensemble section further increases the rhythmic density, and also begins to include longer gestures with multiple rhythmic attacks, either grouped together (m. 60, Perc. 5) or spaced out by short rests between events (mm. 67–69, Perc. 1).

The next solo section (mm. 70–76) features greater rhythmic complexity, that the previous sections, featuring more triplets and offbeat accentuations which destabilize the meter. In order to compensate, the following ensemble section (mm. 77–83) features more regularity in its rhythmic events, with at least one instrument playing on the downbeat of each measure. This facilitates hearing this section within a metric framework, as the framework is less clearly defined by the previous solo. In addition, the bass drum enters in m. 81, serving to both anticipate the next bass drum solo and emphasize to the listener that the ensemble section is still within the same metrical framework.

The following bass drum solo is the most complex, featuring quintuplets and articulating the $H(B_2)$ layer from mm. 93–99. This passage also uses offbeat accentuation to create the effect of displacing the downbeat. The rhythm simplifies to a stream of continuous eighth notes in m. 103, a pattern which is hinted at in the accentuations in mm. 97–102. This simplification accompanies the re-entrance of the rest of the ensemble, now playing with a rhythmic density

similar to the second ensemble section, contextualizing the textures used earlier in the movement.

3.5 Movement V

The third pair of movements focusses on how the brain processes "out of phase" rhythmic material. As mentioned above in section 1.2, the human brain is only able to entrain to one metric framework or layer at a time, and when presented with two contradictory rhythmic stimuli, the brain will either try to hear everything as part of a larger, composite framework, or treat one of the frameworks/layers as rhythmic "noise." When using the relatively simple temporal ratios use thus far in the piece, it is easy for a listener to consolidate different layers into a larger, composite layer. By presenting the same rhythmic relationships so that they are "misaligned" with one another in some way, the same temporal relationships can provide much more complex rhythmic textures.

Movement V presents rhythmic grouping patterns which are out of phase with the notated measure. While the grouping patterns do periodically align with the meter, these occurrences are far enough apart that it would be hard to perceive the two patterns as part of a composite framework. Nevertheless, because of the cyclic recurrence of the alignment of these patterns, I call these rhythmic patterns "cycles." Aside from the introduction and the coda, the movement is comprised of five of such rhythmic cycles, four of which are outlined below in Figure 3.1. The top line of each cycle, labeled "meter," indicates the grouping of eighth notes into either six or eight by the notated meter, which corresponds to either 3/4 or 4/4 meter, respectively. The bottom line, labelled "rhythm," indicates how the eighth notes are grouped in Perc. 2, which is roughly indicated in the score by slurs. For Cycle 1 (mm. 8–18), the Perc. 2 line is slurred in groups of 5+6 eighth notes. Once the larger eleven-note grouping realigns with the notated meter

(after eleven measures), the cycle ends and the next cycle begins. While Perc. 2 is playing the groupings from the "rhythm" line of the cycle, other instruments are playing either free rhythms, or rhythms which align with the "meter" line of the cycle so that both lines are audibly articulated. However, due to the sparsity of the articulation of the "meter" line, the "rhythm" line will likely be heard as primary.

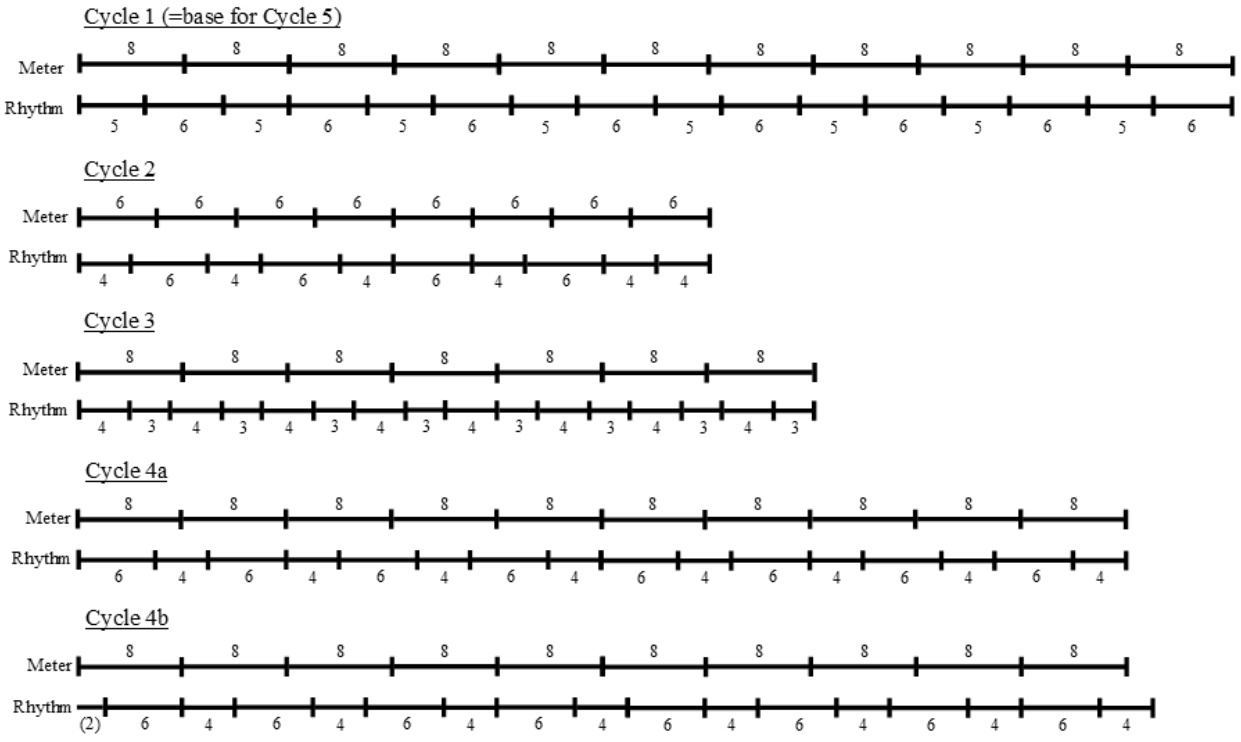

Figure 3.1: Rhythmic cycles used for Movement V.

The second cycle (mm. 19–26) follows a similar principle, but now based on groups of 4+6 within a 3/4 meter. As can be seen in Figure 3.1, the two rhythmic patterns realign before the cycle ends, after only five measures. In order to maintain a more comparable length with the other cycles, Cycle 2 was extended by continuing the pattern. However, the end of the "rhythm" line was altered to have two successive groups of four so as not to overextend the section. Perc. 3 and Perc. 6 are more actively emphasizing the notated meter during this cycle. The H layer is

also introduced during this cycle, with all the attacks aligning with beats of the notated measure, emphasizing the "meter" line further.

The third cycle (mm. 27–40) returns to 4/4 meter, with Perc. 2 grouped as 4+3, slurred in the score as groups of seven eighth notes. The other instrumental parts are now much more active in articulating the notated meter, with Perc. 6 playing straight quarter notes and Perc. 1 articulating subdivisions of the beat. Perc. 5 also articulates the off-beats starting in m. 34, further reinforcing the sense of 4/4. The fourth cycle begins at m. 41 with a sudden tempo change from B_1 (=$\mathbf{H^1/2}$) to B_2 **(=q/3)** (movement V is the only movement in which the move from B_1 to B_2 does not occur through a metric modulation). The model for the fourth cycle is based on rhythmic groupings of 6+4, labelled as Cycle 4a in Figure 3.1. This cycle is rather short, only lasting for five measures before the "meter" line and the "rhythm" line realign, similar to Cycle 2. For this reason, the cycle is played in full twice. In order to obscure this repetition, the initial cycle is offset by two eighth-notes at the beginning, as shown in Cycle 4b. All instruments aside from Perc. 2 play material which emphasizes the notated meter, pushing the "rhythm" line to the background.

The fifth cycle begins at m. 51. This cycle is based on the same rhythmic patterning as Cycle 1, but offset by two eighth notes as a result of Cycle 4. The rhythmic grouping is also less strict than the other sections, with occasional repetitions of rhythmic groups and groupings of seven eighth notes mixed in. Following this, multiple other instruments drop out throughout mm. 51–54, reducing the texture to one similar to Cycle 1. As such, the rhythmic patterning in Perc. 2 becomes prominent again. Finally, after the coda, the end of the movement undergoes a metric modulation directly to the tempo of the next movement, no longer using the **B** layer as a means of transition.

3.6 Movement VI

The sixth movement focuses on entire metric frameworks which begin out of phase with one another. Because the frameworks are not aligned and moving at different tempi, it is difficult for a listener to hear them as part of a composite framework and will likely hear one of the frameworks as rhythmic noise.

As mentioned in Section 2.6, this movement features "ensemble" material, played in Perc. 1–4, and "duet" material, played in Perc. 5 and 6. Measures 1–4 present the main 'ensemble' material of the movement, articulating B_1 (=**Q**) layer with rhythmic unisons and selective doublings. The following passage (mm. 5–10) presents rhythmic variations on the previous material by alternating between articulating the B_1, Q, and H layers. This is followed by the duet which articulates the B_1 and H layers simultaneously.

After a brief interruption by the ensemble, the duet returns in mm. 21–24, presenting the same temporal layers, but now out of phase with one another. The H layer begins on the third triplet of beat 1, which is not only out of phase with the B_1 layer but is also not a beat within the B_1 layer. Because the previous sections were in phase with the B_1 layer, the H layer needs to be emphasized in order for it to be heard as equal. Otherwise, the listener will likely remain entrained to the layer which aligns with what came before. As such, Perc. 6 articulates a simple, regular pattern against the more complex Perc. 5 part. The regular accentuation at the beginning of the H layer rhythmic gestures is also necessary to dissuade the listener from hearing the first note of the three-note groupings as an anacrusis. In addition, Perc. 5 is now playing constantly. By being ever-present, the intent is that the listener pays less attention to Perc. 5 due to principle of economic perception.

The duet continues in mm. 26–30, but with Perc. 6 being more rhythmically varied. The accentuations and rhythms played suggest groupings of three triplet quarter notes, "projecting" a 3/4 meter moving at a different tempo than Perc. 5. Figure 3.2 presents a visualization of the resulting effect. After another brief interruption (mm. 31–34), the H layer is presented alone in Perc. 6 in m. 35, this time projecting a meter of 5/4. Perc. 5 does not articulate any meter from mm. 35–37, giving the listener time to entrain to the H layer; the other instrumental parts provide the occasional rhythmic reinforcement of this layer. The B layer returns in Perc. 5 at m. 38, aligning with the notated meter but out of phase with the layer established in the previous measures.

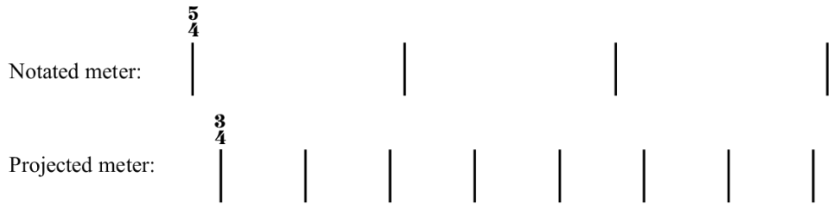

Figure 3.2: Visualisation of the notated meter and the meter projected by Perc. 6 in beginning at m. 26.

In m. 41, the previous interruptions are expanded and lead to a series of metric modulations leading to B_2 ($=1/2HHQ^{-1}(B_1)=$ $\mathbf{H^2/2}$). The relationship between B_1 and B_2 is a ratio of 10:9, and so multiple metric modulations are required to get from one tempo to the other using only H and Q relationships.

Following the metric modulations, the ensemble material from the beginning of the movement returns in m. 50, now with the different layers (B_2, $Q(B_2)$, $H(B_2)$) presented out of phase, with each one starting on a different beat within the measure. In m. 54 Perc. 5 and 6 enter out of phase with one another as in the middle of the movement. The B_2 layer in Perc. 5 is in phase with the $Q(B_2)$ layer in Perc. 3, but the $H(B_2)$ layer in Perc. 6 is not in phase with any of

the other layers, resulting in four out of the five rhythmic layers being out of phase with one another. This overlapping of layers continues until the end of the movement.

3.7 Movement VII

Finally, the seventh movement serves as a culmination of the various techniques and temporal layers used throughout the piece, as will be discussed below. The gestalt flip, used in the first two movements, is used again here to create a cyclic structure to the piece. Furthermore, the tempo of the movement is 100 bpm (=**B**), the "indifference" tempo which is ideal for entrainment. The rhythmic pattern that expresses this tempo, in addition to being the generator for all of the other tempi used in the piece, appeared at numerous times in the transitions between movements.

The movement begins with a straightforward presentation of the **B** layer in mm. 2–10, which leads to the refrain. The refrain presents the **B**, **H**, $\mathbf{H^{-1}}$, and **Q** layers simultaneously. A visualisation of the different frameworks and layers being articulated is presented below in Figure 3.3. Perc. 1 articulates the $\mathbf{H^{-1}}$ layer by accenting every third sixteenth note and playing a pitch pattern that recurs every dotted quarter note. Perc. 2 contains the **H** layer, with the almglocken articulating triplet quarter notes and the tambourine playing the off beats. The pitch pattern creates groups of eight triplet eighth notes, grouping the notes into four triplet beats. As such, not only is Perc. 2 playing on a different layer, but the layer is somewhat out of phase with the others. Perc. 4 continues to articulate the **B** layer. Perc. 5 articulates $\mathbf{H^{-1}}$ layer along with Perc. 1, emphasizing the dotted-quarter note "beats" with the low tom and snare. Perc. 6 plays the **Q** layer as quintuplet eighth notes. Similarly to Perc. 2, the pitch pattern in the upper staff creates larger grouping of twelve quintuplet quarters (7+5). The lower staff, however, articulates a pattern which is grouped in five, aligning with the meter, effectively articulating two different

accentuation patterns. Finally, Perc. 3: begins by articulating **B/2** layer but changes to **H/2** layer at m. 17 to prepare for the next section. While listening to the refrain, it is possible for the listener to entrain to any of the frameworks being presented, and either hear the others as part of a composite framework or treat them as noise. Perc. 3 articulates whichever framework is intended to be most prominent. By changing in the middle of the refrain, the attention of the listener is more likely to be drawn to the change due to economic perception, as all of the other instruments continue in their patterns throughout the entire section.

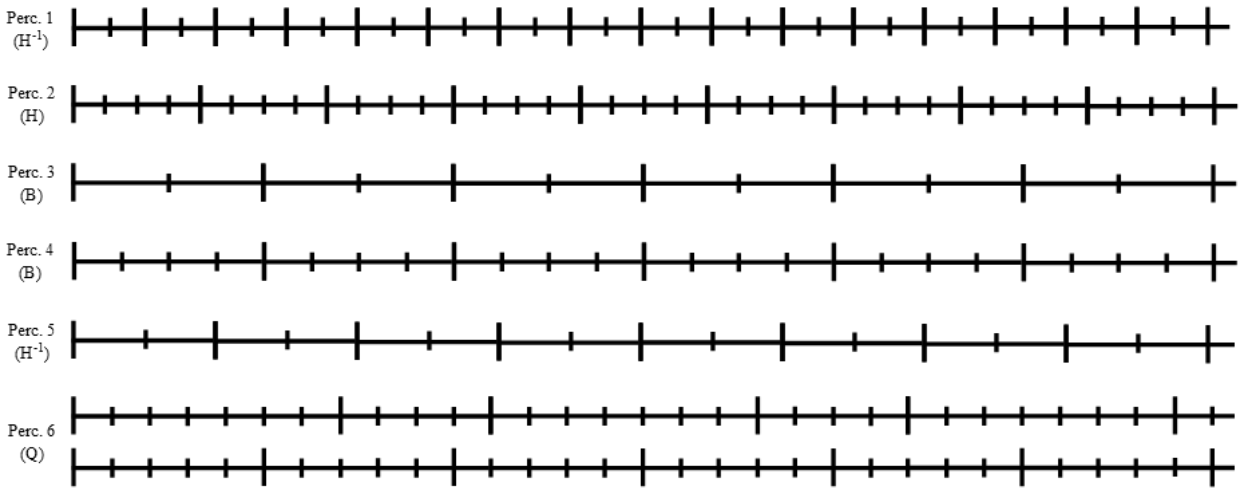

Figure 3.3: Different frameworks and accentuation patterns in the beginning of the first refrain.

When the first episode starts in m. 21, all of the temporal layers drop out except for the **H** layer. Perc. 4 also switches to articulating the **H** layer, rather than the **B** layer, making it very likely that the listener will entrain to the **H** layer. The $\mathbf{H^{-1}}$ layer is added, as was done numerous times earlier in the piece, in m. 23 to destabilize the **H** layer and flank the **B** layer. This also foreshadows the temporal layer in the next episode.

The refrain returns in m. 31 with Perc. 3 articulating the **H** layer, which was the emphasis of the last episode. Perc. 3 then switches to articulating the $\mathbf{H^{-1}}$ layer in m. 33 to prepare for the next episode at m. 37. This episode emphasizes the $\mathbf{H^{-1}}$ layer through the vibraphone solo and the accompaniment. Perc. 5 complicates the rhythmic texture with the low tom articulating $\mathbf{H^{-1}}$ but

the snare articulating **4/5B**. The texture is further complicated as the bass drum comes in in m. 40 playing the **Q** layer, which, like $\mathbf{H^{-1}}$ layer in the previous episode, flanks the **B** layer and foreshadows which layer will be emphasized in the next episode.

The third refrain, beginning at m. 47, is the same as the previous ones except that Perc. 1 now articulates $\mathbf{2H^{-1}}$ though single dotted eighth notes instead of through continuous sixteenth notes. Perc. 3 articulates $\mathbf{H^{-1}}$ and switches to the **Q** layer at m. 51. The final section then begins at m. 53, with all instruments switching to the **Q** layer. They then all drop out, reentering one at a time until the end of the piece, reintroducing the **H** (Perc. 3), then **B** (Perc. 6), and then $\mathbf{H^{-1}}$ (Perc. 1) layers. Some of these layers are grouped in four or eight, as if they were in their own meter. This occurs in m. 64 in the **Q** layers (perc. 4 and perc 6) and the **H** layer (perc. 2). All of these rhythmic layers build back up to the complexity of the refrain to end the piece.

4.0 Pitch

As the structure of the work is defined by its temporal components, pitch and harmony have very little function. All of the pitches throughout the work are drawn from the 11-note collection shown below in Figure 4.1. Each movement features different subsets of this collection and organizes them in different ways.

Figure 4.1: 11-note gamut used throughout *Entrainment*.

The first movement organizes different 3- and 4-note subsets into cells which are repeated in an isorhythmic fashion, with different harmonies developing as the result of the overlapping lines. The four isorhythmic cells used at the beginning of the movement are shown below in Figure 4.2. Similar cells are used throughout the rest of the movement. The only

exception is the crotales solo in Perc. 1, which moves freely through the collection with no set pattern.

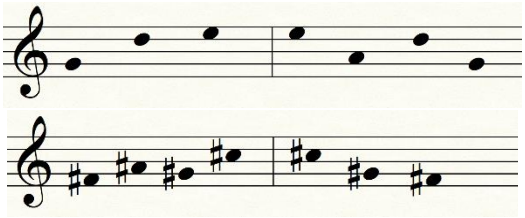

Figure 4.2: Isorhythmic cells used in the beginning of Movement I.

Movement II uses only two pitches: E-flat and E. The xylophone begins on E-flat, as it takes the last note of the first movement in Movement I, which is a D-sharp. The xylophone then goes up to E-natural to increase the tension leading up to the second half of the movement.

Movement III organizes eight of the notes of the larger collection into a 17-note row, shown below in Figure 4.3. The row is not strictly adhered to, however, as notes are occasionally skipped over, or replaced by an attack by a non-pitched instrument. Notes are also sometimes replaced by other notes in the row as well. The row is not always completed before it starts again and does not always start again at the beginning. As such, it works more as a background guideline for the pitches, rather than an audible phenomenon.

Figure 4.3: 17-note row used in Movement III.

The pitches for Movement IV are determined by a similar structure, using the 16-note row shown in Figure 4.4. The loose treatment of the row is similar to Movement III.

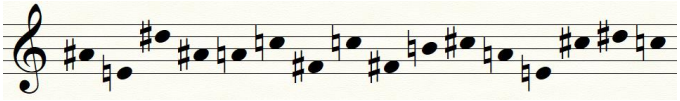

Figure 4.4: 16-note row used in Movement IV.

Movement V uses notes from a pentachord taken from Colin McPhee's *Tabuh-Tabuhan* (shown below in Figure: 4.5), which was based on Balinese gamelan music. These notes are used freely throughout the movement.

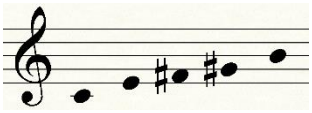

Figure 4.5: Pentachord taken from Colin McPhee's *Tabuh-Tabuhan* and used as the pitch material for Movement V.

Movement VI freely uses the entire 11-note collection of pitches, emphasizing motion by certain intervals. Melodic lines move primarily by 4ths (perfect or augmented), 2nds (minor or major) and their inversions. In addition, successive melodic 2nds are avoided, and large leaps are generally compensated. In order to maintain these rules, melodic thirds are sometimes used.

The final movement also makes use of the entire 11–note collection. Each instrument in the makes use of isorhythmic pitch patterns of various lengths (as explained in Section 3.7), similar to those used in Movement I, which is most clearly seen in the refrain (see Figure 4.6). The two solos are an exception to this, with the first in Perc. 3 (m. 23) moving freely within the gamut, and the second in Perc. 1 (m. 37), which uses chords built from fourths, fifths, and seconds of various qualities.

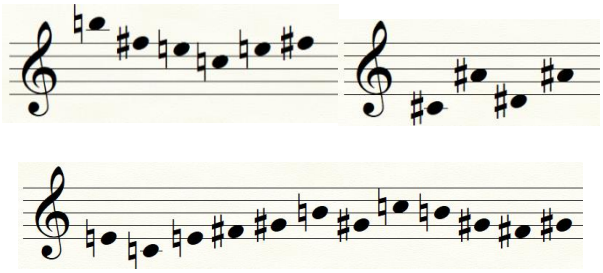

Figure 4.6: Isorhythmic pitch patterns used in the refrain of Movement VII.

5.0 Orchestration

Particular uses of instrumentation as a means of reinforcing specific temporal layers and encouraging entrainment to one or another have been discussed in earlier chapters, and for the sake of brevity will not be discussed here again. This section will instead deal with matters strictly related to orchestration.

As mentioned above in section 2.0, different sounds available to the ensemble were classified into three different categories depending on their Attack/Decay/Sustain/Release (ADSR) profile. The three categories were: “pad” sounds, which had quiet attacks and were capable of being sustained indefinitely (e.g. bowed vibraphone); “resonant” sounds, which had prominent attacks and long decays (e.g. tubular bells), and; “dry” sounds, which had sharp attacks, very fast decays and no sustain (e.g. xylophone). The overall design of the work is that the slow movements (I, III, V) begin with primarily “pad” sounds and that “resonant” and “dry” sounds are added in later movements, and fast movements (II, IV, VI) begin with “dry” sounds and “resonant” and “pad” sounds are added in later movements. In addition to this general plan, each movement has one “highlighted” instrument which features prominently in the movement, often in the form of a solo. The first six movements each have their own unique highlighted instrument played by a different one of the six percussionists. The final movement has a unique instrument (vibraphone), played by Perc. 1 (same player as movement I).

The first movement is comprised mostly of pad sounds, created through either bowing the vibraphone or rolling very gently with soft mallets. The highlighted instrument are the crotales played by Perc. 1; this is a solo, which helps transition from B_1 to B_2. The second movement is comprised of “dry” sounds and uses only one pitched instrument (xylophone). All other sounds are unpitched wood or metal. The temple blocks, played by Perc. 6, are the highlighted

instrument, playing a solo which helps to transition from B_1 to B_2. The third movement extends the palette of the first, combining pad sounds and resonant sounds. The "pad" sounds are often played at the same time as the "resonant" ones, such that the decay of the latter blends into the sustain of the former, such as in m. 9. For example, the bowed crotales in Perc. 1 and the triangle in Perc. 6 begin at the same time, creating the effect of the timbre of the latter morphing into that of the former. The tubular bells are highlighted here, played by Perc. 3. As in the previous movements, this solo helps to prepare the metric modulation from B_1 to B_2. The fourth movement continues from the second, adding resonant sounds to the dry ones. The movement is generally structured to contrast the different timbres, with the bass drum solos being somewhat resonant, and the ensemble sections featuring instruments with longer decay times. The ensemble instruments are also generally pitched, a further contrast to the bass drum. The bass drum, played by Perc. 4, is the highlighted instrument, and plays numerous solos throughout.

The orchestration of the fifth movement was designed to resemble a Balinese gamelan ensemble, and so makes use of many resonant instruments with complex harmonic spectra (gongs, almglocken, triangles), and less focus on pad sounds. The highlighted instruments are the almglocken, played by Perc. 2. Unlike previous movements, this instrument does not have any pronounced soloistic material, but rather is highlighted by playing ceaselessly throughout the entire movement. Even when it is in the background of the texture, the almglocken acts as an orchestral thread, tying together the various sections.

The sixth movement continues to add more resonant sound to the dry ones. The movement is structured as an alternation of ensemble sections and duets, with ensemble sections orchestrated with a focus on volume, resonance, and the complexity of sounds (opera gongs, almglocken, snare, cymbal), with the duets featuring dry, clear sounds (temple blocks and

xylophone). Despite being part of a duet, the emphasized instrument is the xylophone, as it features much more virtuosic material than the temple blocks.

The final movement features a combination of all of the different timbres used throughout the piece within the refrain. The orchestration of the episodes references the previous two movements, with the first episode using resonant instruments with complex spectra (similar to gamelan), and the second episode being orchestrated akin to a jazz ensemble with the vibraphone solo and Perc. 3 and 5 emulating a drum set, which is reminiscent of the raucous orchestration of the previous movement. The highlighted instrument is the vibraphone, played by Perc. 1, as it has the most prominent solo and is the highest in terms of register and is the most rhythmically active part in the refrain. However, the highlighted instrument in this movement is less functionally significant than those of the previous movements, as the final movement is meant to be a culmination of what came before.

6.0 Conclusion

Entrainment for six percussionists is a piece in seven movements, with various trajectories across different musical parameters (rhythm, timbre, dynamic) culminating the final movement. The limits on human perception of rhythm, meter, and tempo serve as the guiding structural principle of the work.

In composing *Entrainment*, I used research on music perception to develop techniques which take advantage of the way the human brain perceives and processes rhythm, meter, and tempo. I also used this research in combination with theories of rhythm and meter to create a theoretical apparatus for understanding the temporal phenomena that appear in the piece.

Composing while keeping empirically proven perceptual constraints in mind was a different experience from writing with conventional techniques. Designing new techniques based

on perceptual research, rather than any kind of theoretical tradition, proved difficult, but created a straight-forward means of evaluating the effectiveness of compositional material. Likewise, developing a theoretical apparatus through which my use of rhythm and meter could be understood and communicated was challenging, but allowed me to fully explore the kinds of devices I was using without any need for conceptual metaphor. While the theory as it is now may be only applicable for this particular piece, a generalized version may be useful for the analysis of other works where simultaneous time-streams are a prominent feature, such as in the work of Charles Ives or Elliott Carter.

In regard to the various aspects of entrainment explored in this piece, I prioritized breadth over depth. Any of the concepts used in the different movements of *Entrainment* could be explored in much greater depth and could serve as the basis for future compositions.

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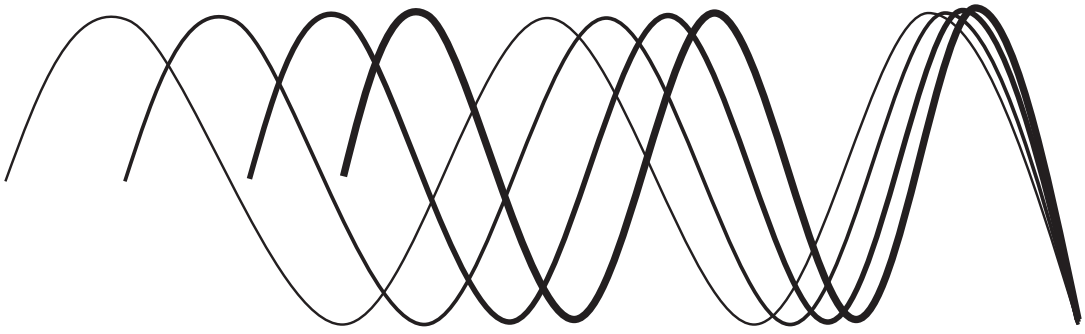
Entrainment

For six percussionists

Jason Mile



Entrainment, for six percussionists was composed as part of the McGill percussion ensemble residency program, to be premiered in the fall of 2018.

Performance notes

The vibraphone motor should be set to off for the duration of the piece.

Unless explicitly indicated, the type of mallets is left to the performers discretion.

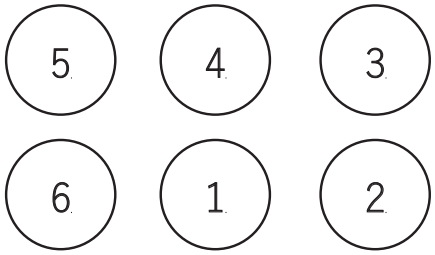
All movements are to be played *attacca*, with no pause in between.

Tempo markings should be strictly observed in order to maintain the rhythmic relationships throughout the piece.

The 'drumsticks' section in movement II is to be played by striking the shaft or neck of one stick against the same part of the other stick.

Instrumentation

The instruments are divided into six "stations" positioned on the stage like so:



Each percussionist is to play at their respective station unless indicated otherwise in the score. Some instruments are shared between stations, and should be positioned accordingly by the performers. Precise instrumentation is as such:

Station 1: slapstick, crotales (2 octaves), vibraphone (3 octaves), tam tam (shared with station 4)

- Tam tam beater, mallets, bow

Station 2: On table: 2 opera gongs (medium and low), anvil, tambourine (with head); Suspended: almglocken (1 chromatic octave, C4–C5)

- Mallets, bow

Station 3: high suspended cymbal, 2 triangles (high, medium, low), tubular bells

- Triangle beater, bow, tubular bell hammers, drumsticks, mallets

Station 4: bass drum (medium or small), low suspended cymbal, tam tam (shared with station 1), Snare drum (shared with station 5)

- Bass drum beater, drumsticks, mallets, tam tam beater, bow

Station 5: low tom, high tom, xylophone, snare drum (shared with station 4)

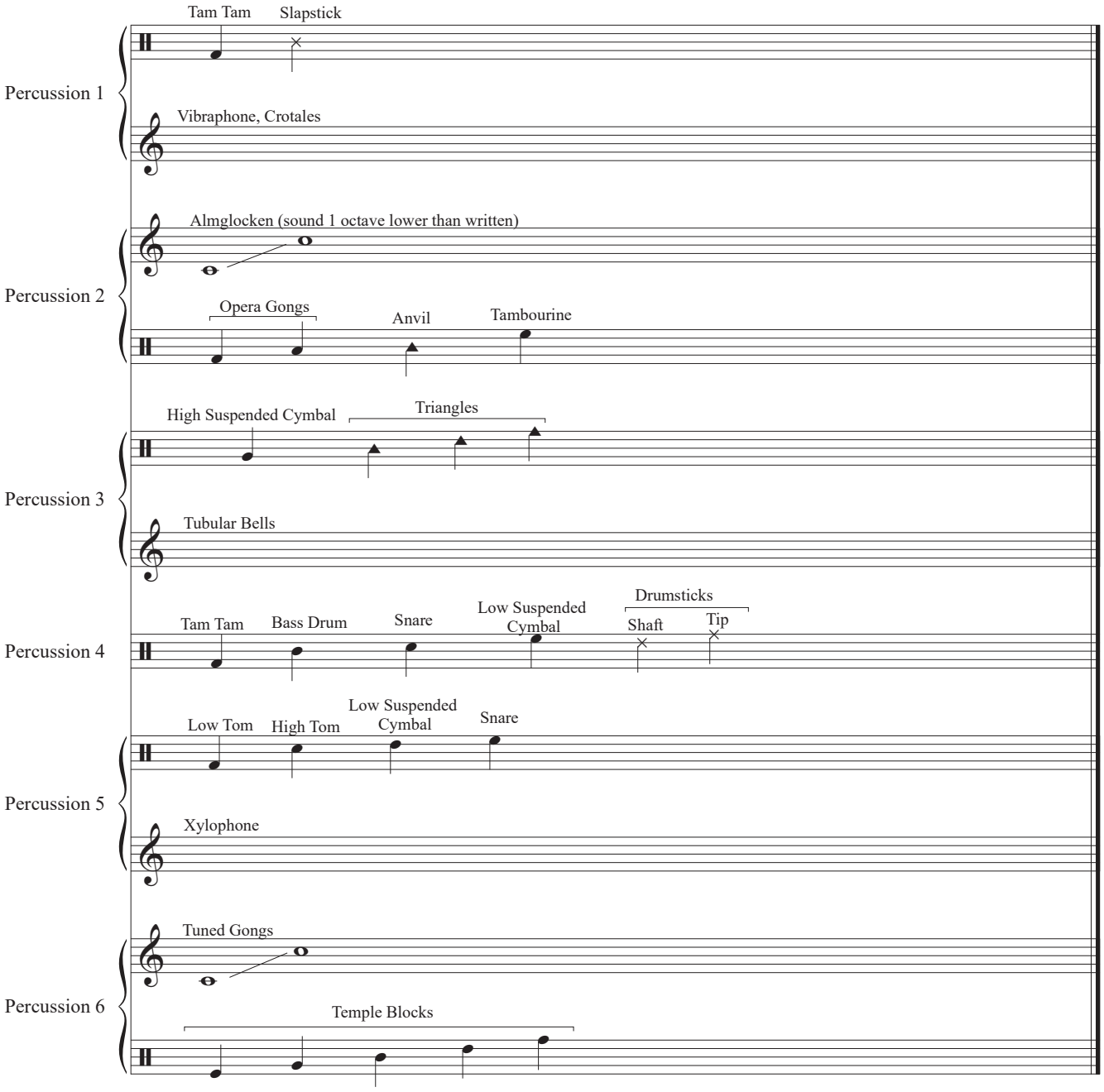
- Mallets, drumsticks

Station 6: temple blocks, tuned gongs (1 chromatic octave, C4–C5)

- Mallets, bow

Approximate Duration: 19' 30"

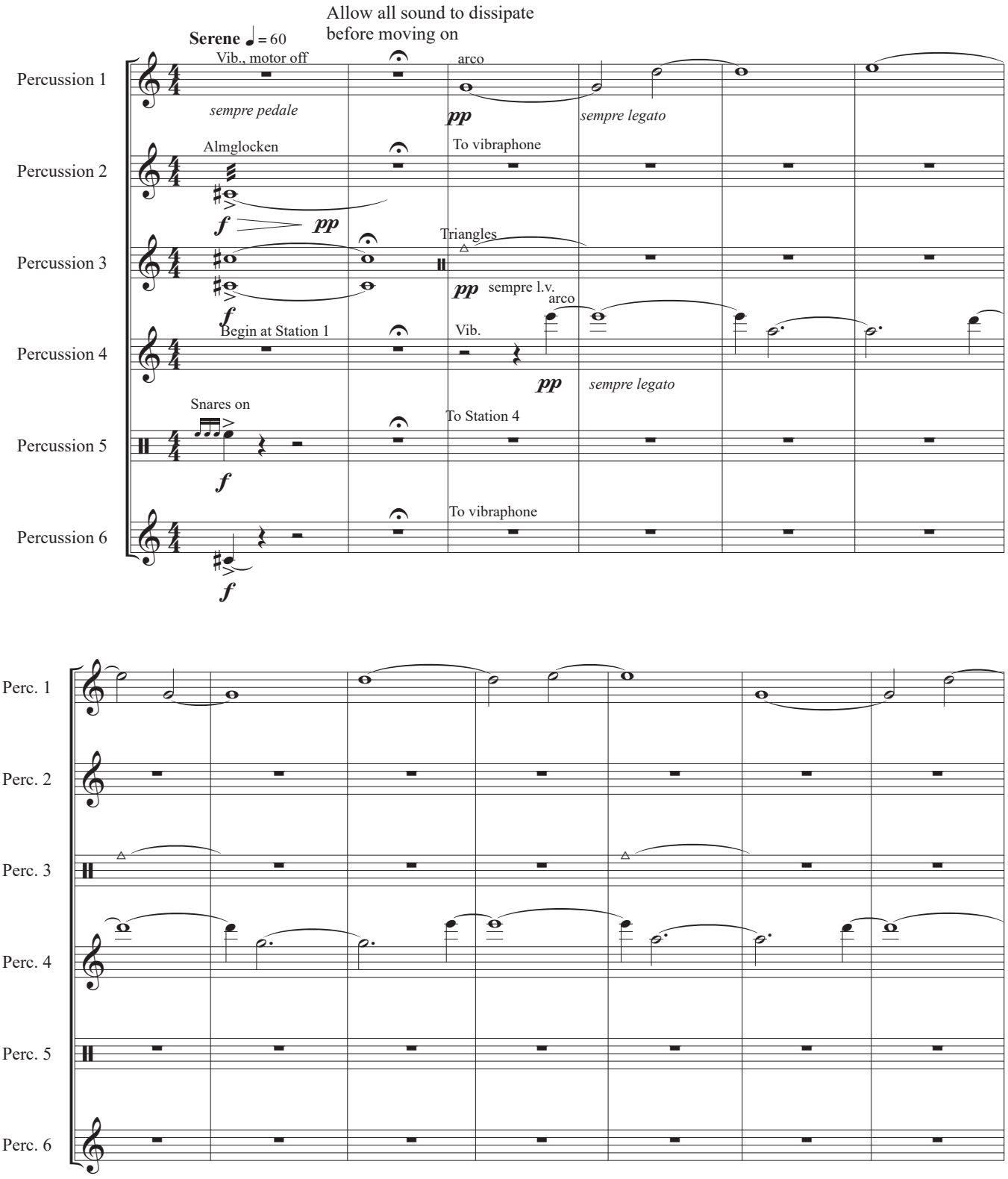
Instrument Layout

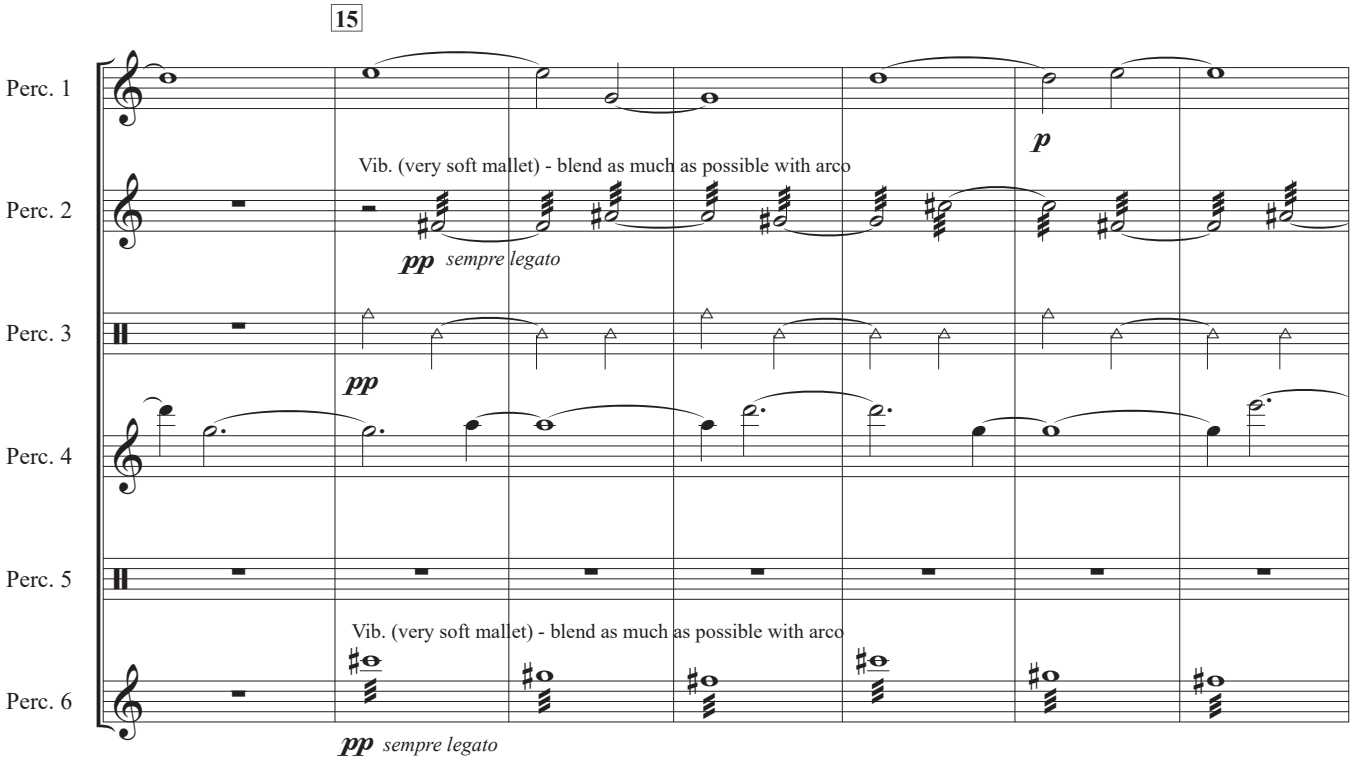


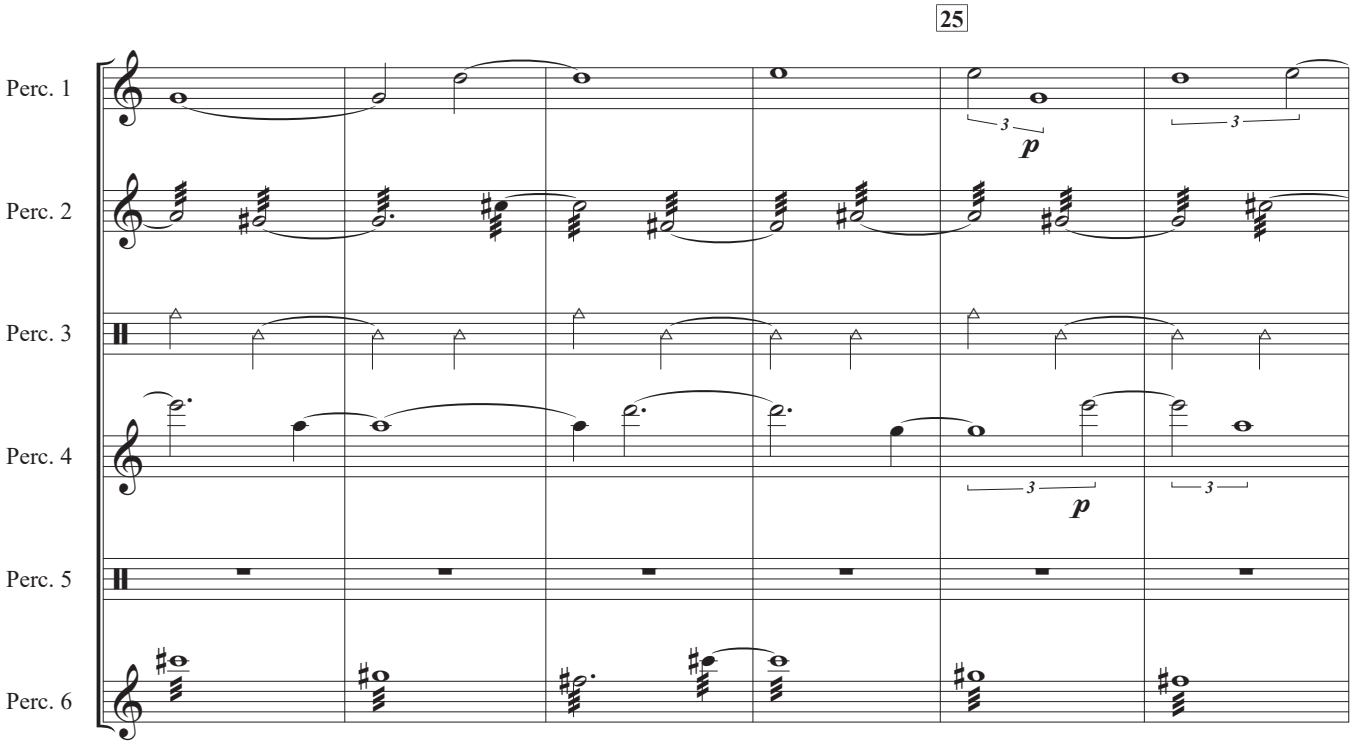
Score

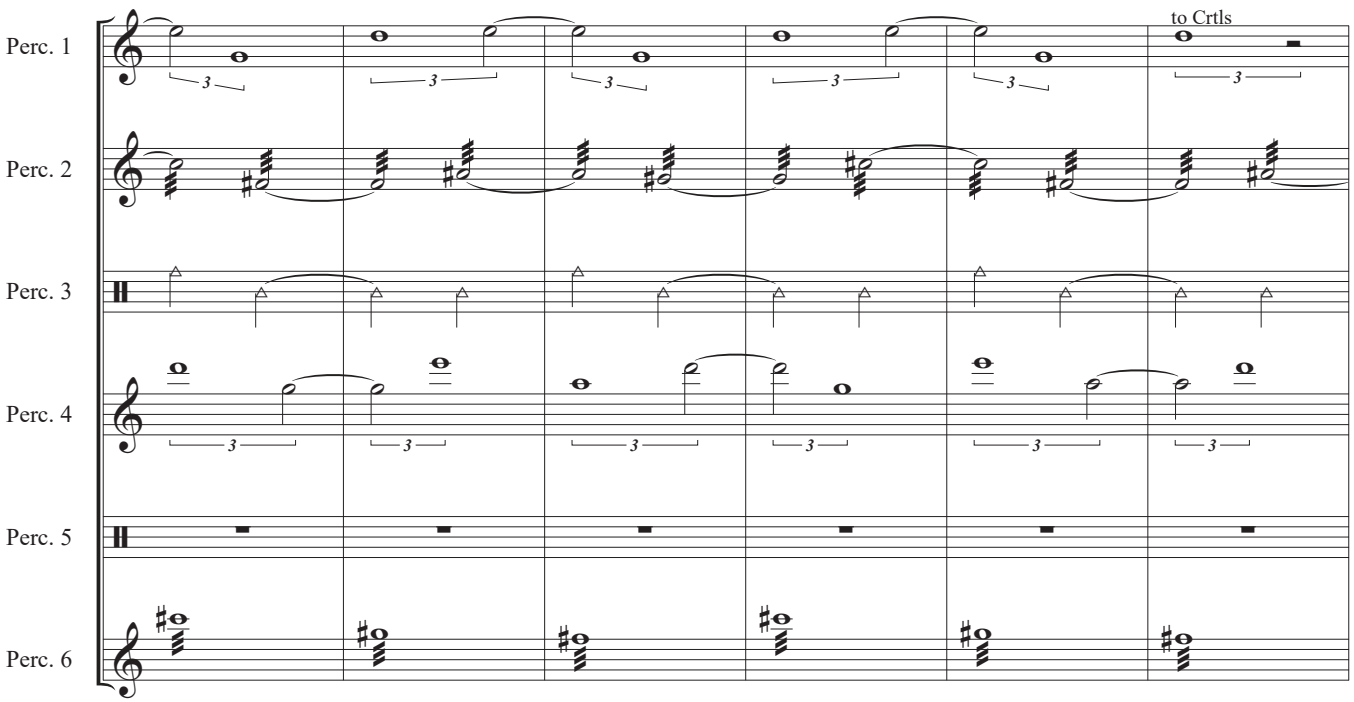
I.

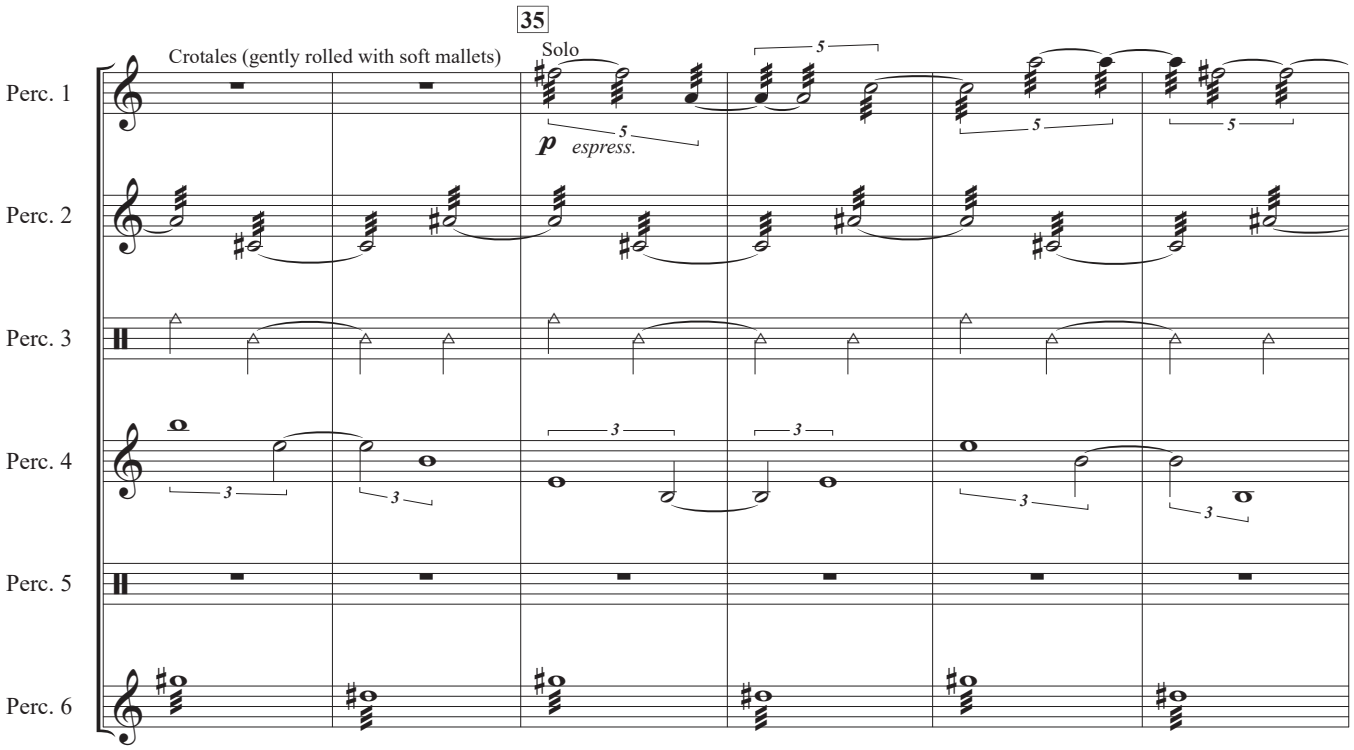
Jason Mile

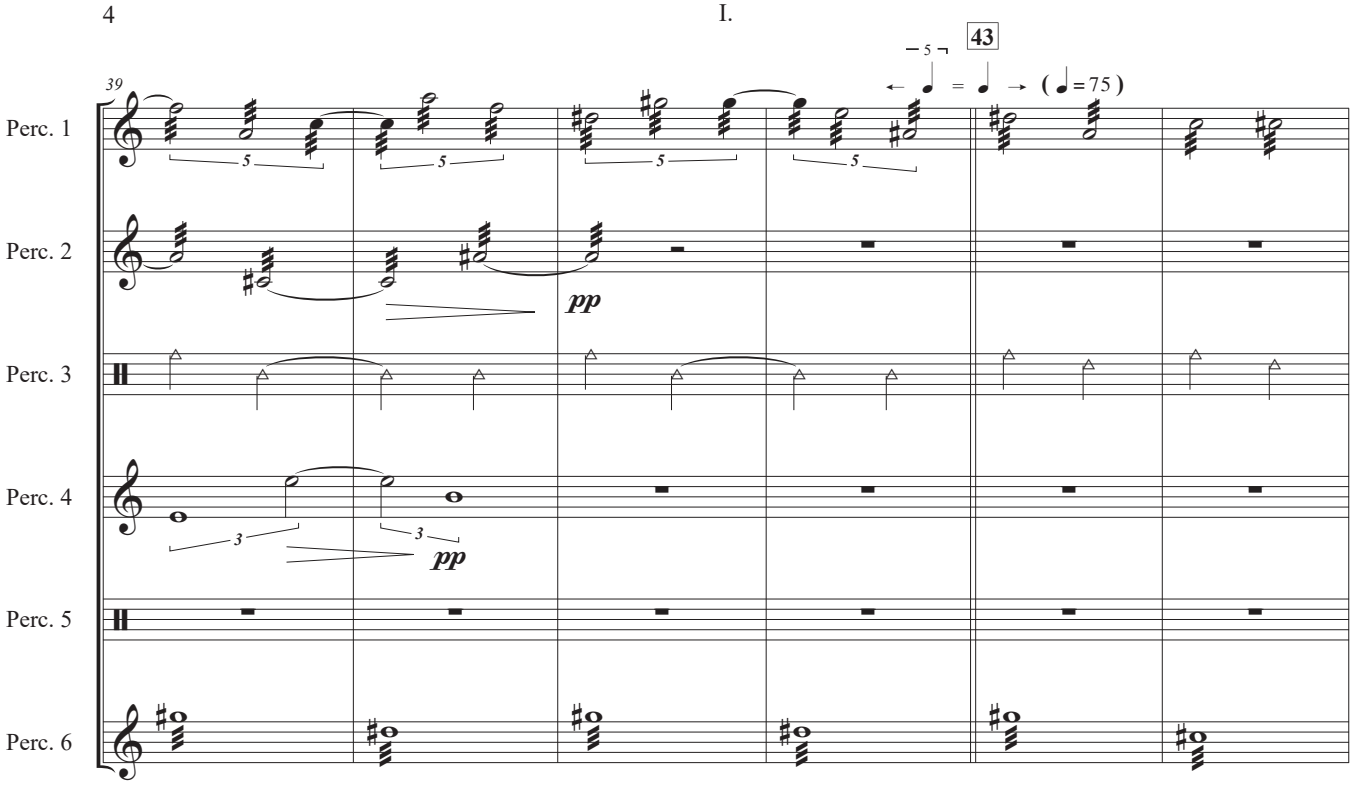


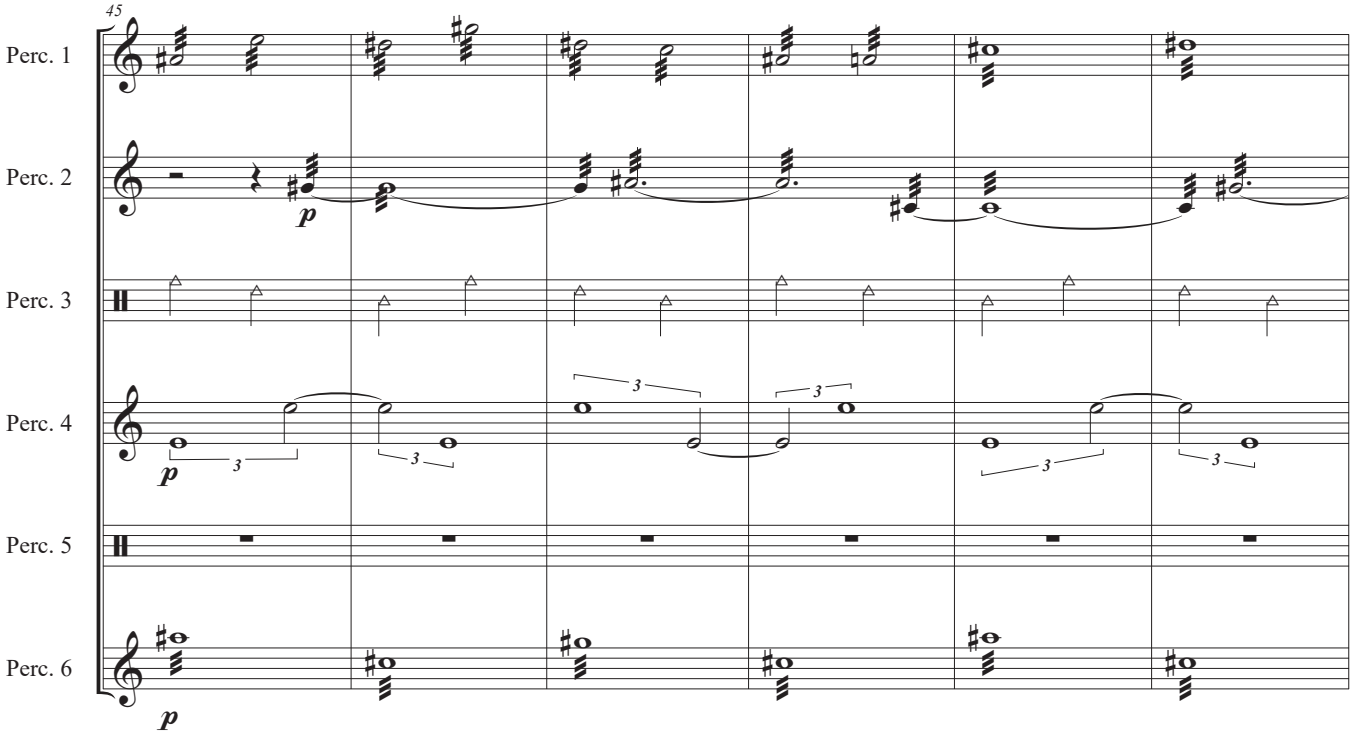

15
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
Vib. (very soft mallet) - blend as much as possible with arco
pp sempre legato
pp
Vib. (very soft mallet) - blend as much as possible with arco
pp sempre legato


25
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
3
p
3
3
p
3

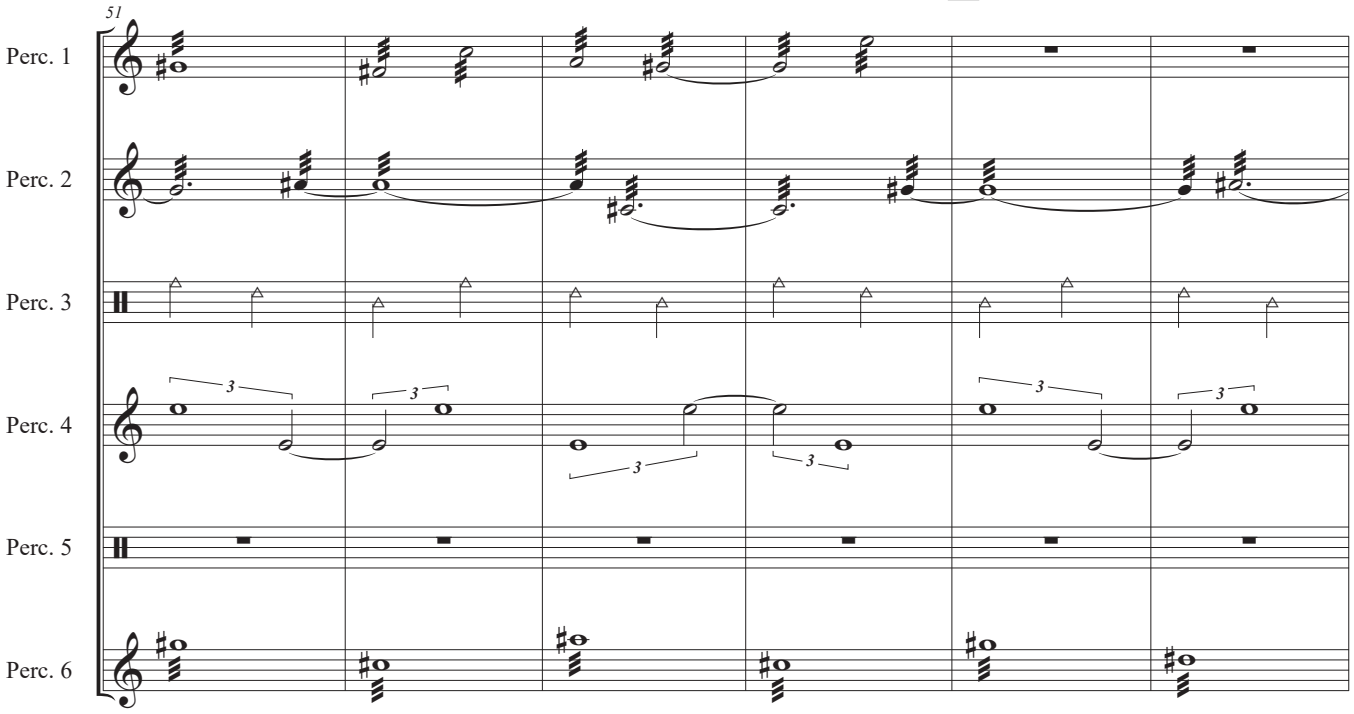

Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
to Crtls

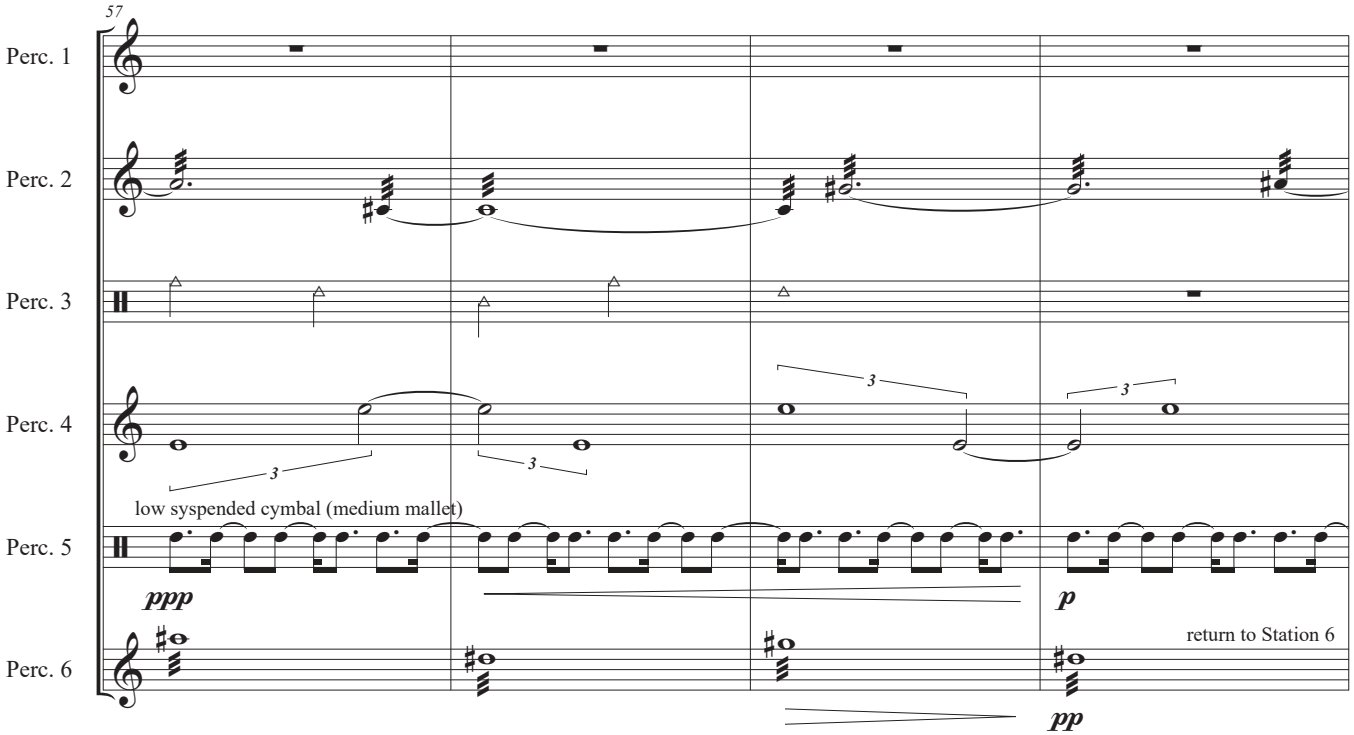

35
Crotales (gently rolled with soft mallets)
Solo
p espress.
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

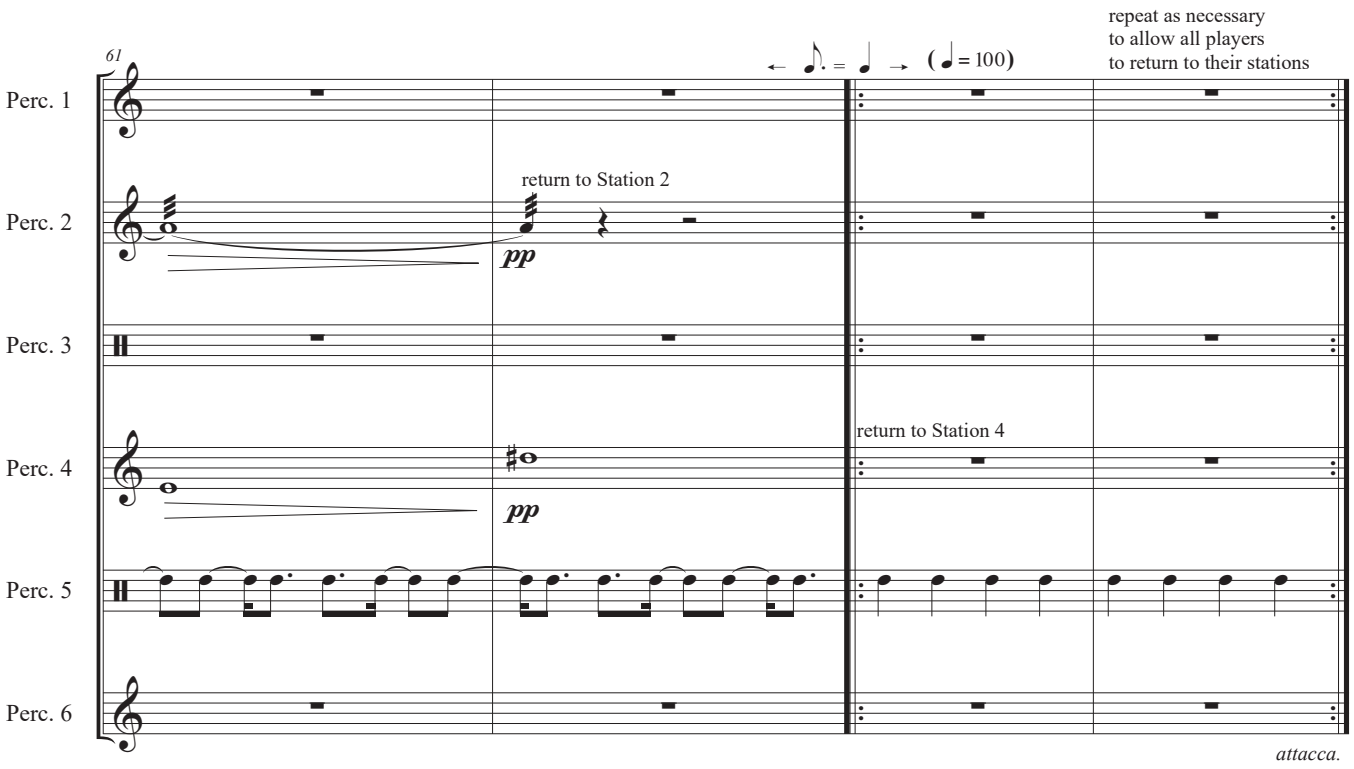

43
5
= (= 75)
39
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
pp
pp


45
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
p
p

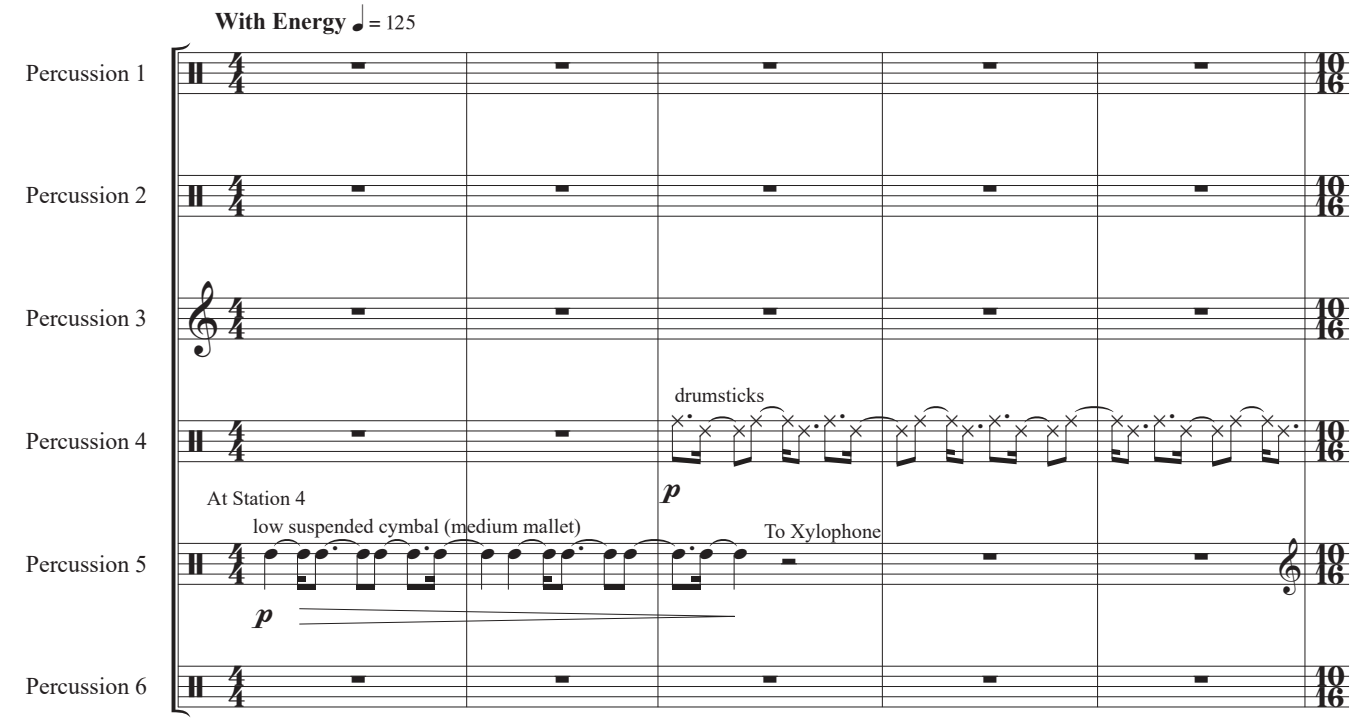
55

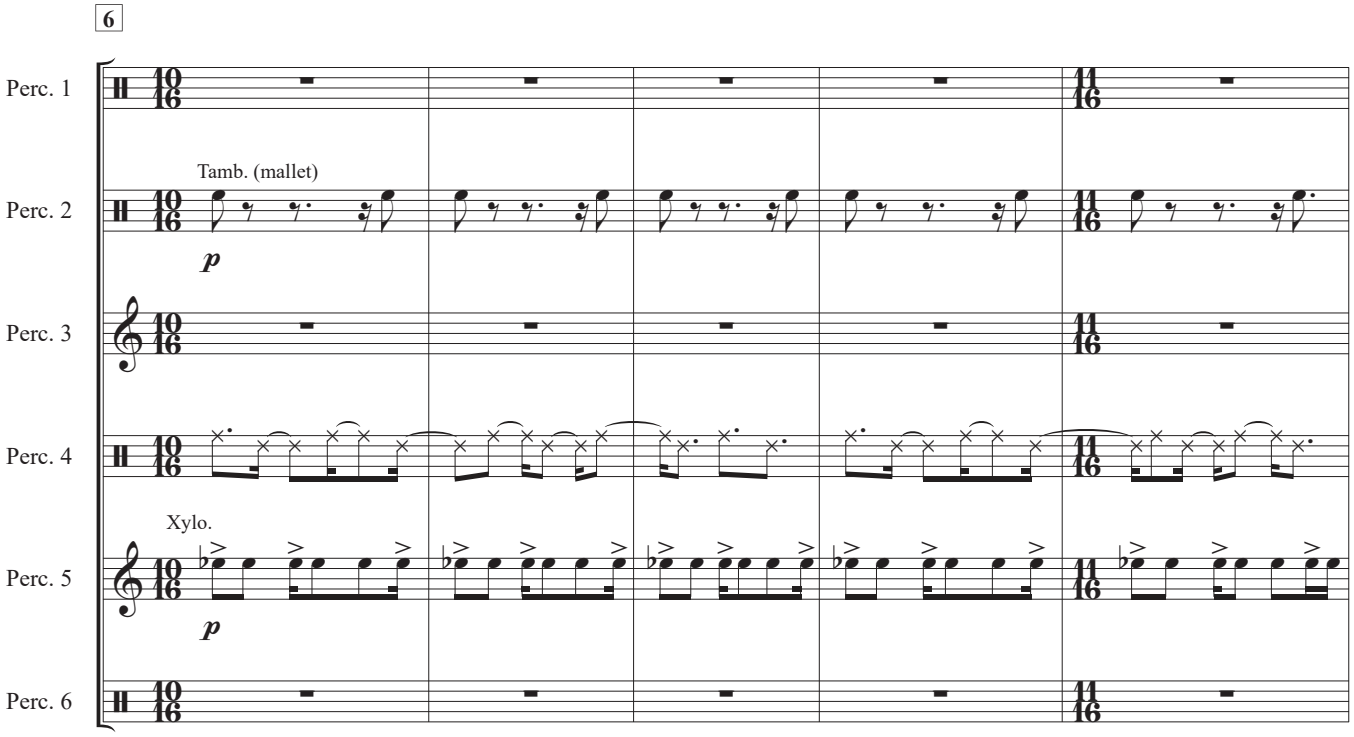

51
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
3

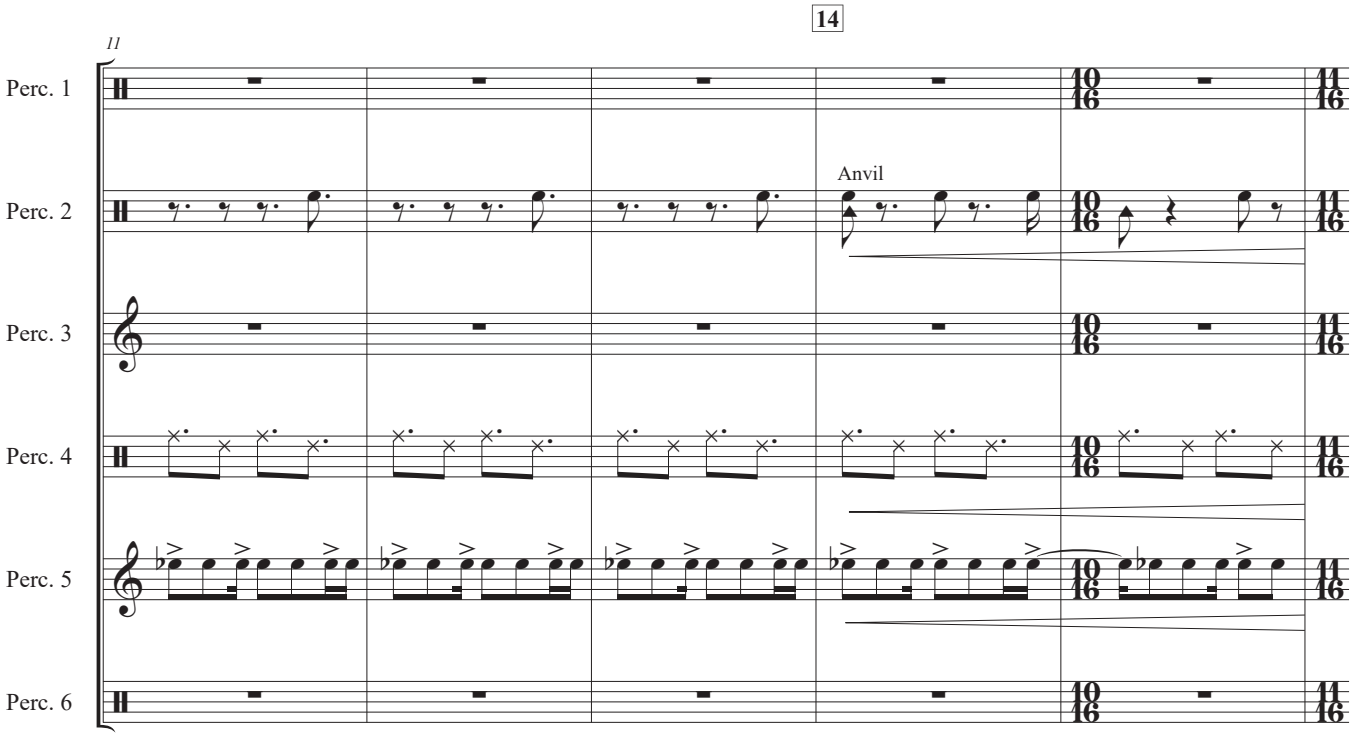

57
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
3
low syspended cymbal (medium mallet)
ppp
p
pp
return to Station 6

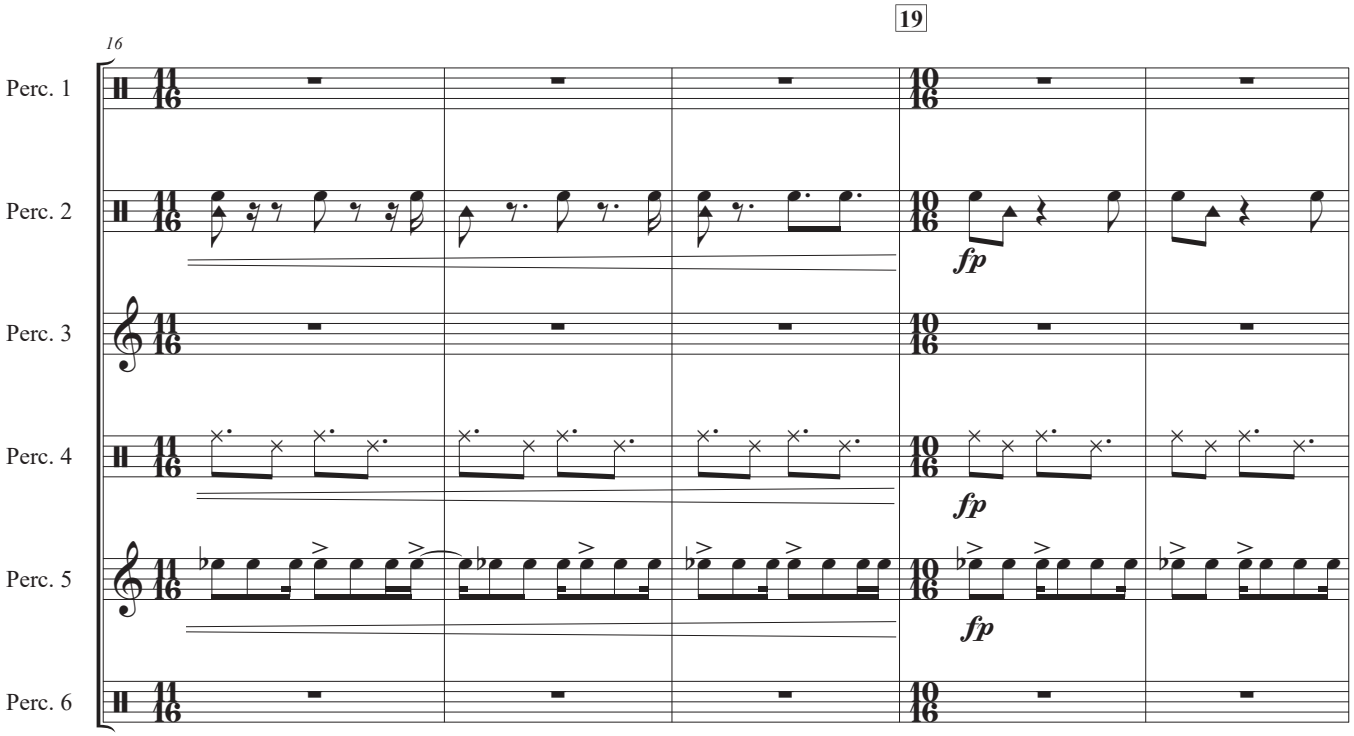

61
repeat as necessary
to allow all players
to return to their stations
(♩ = 100)
Perc. 1
Perc. 2
return to Station 2
pp
Perc. 3
Perc. 4
return to Station 4
pp
Perc. 5
Perc. 6
attacca.

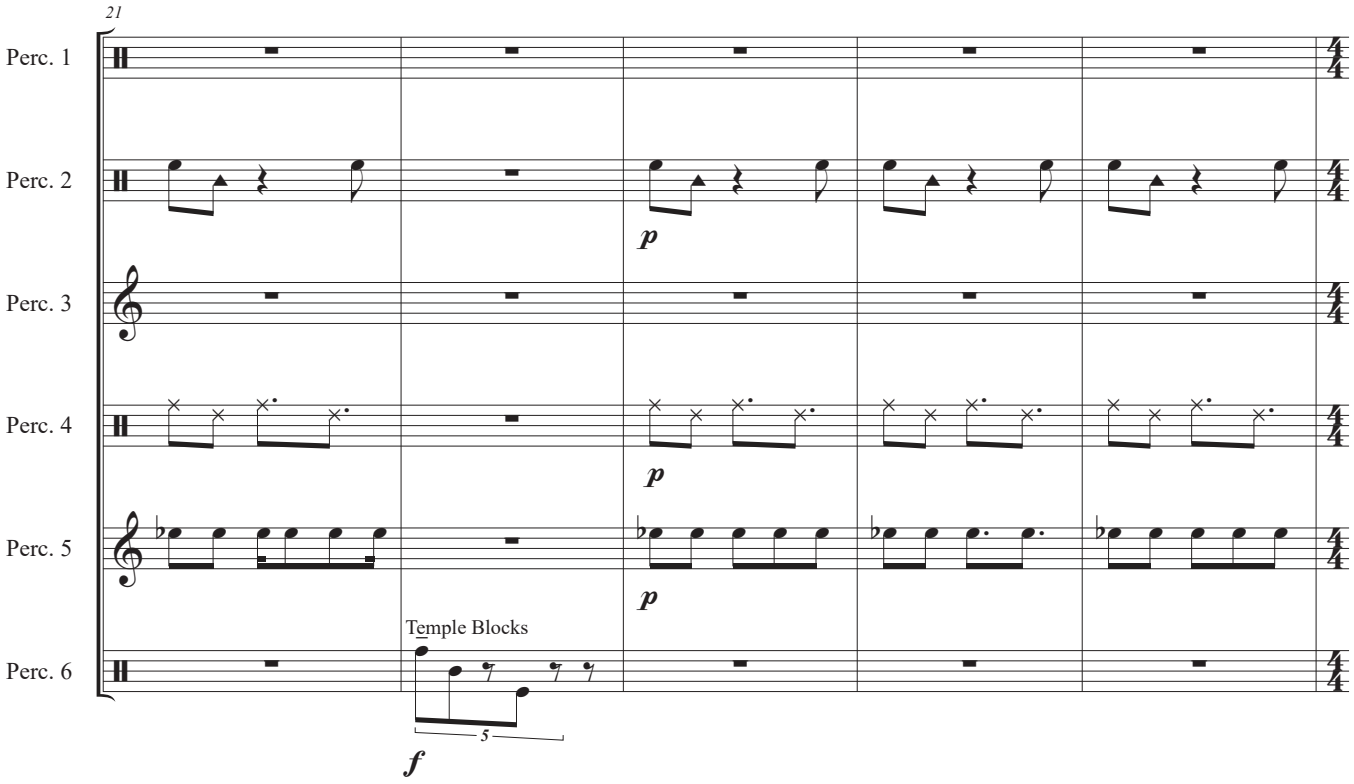
II.

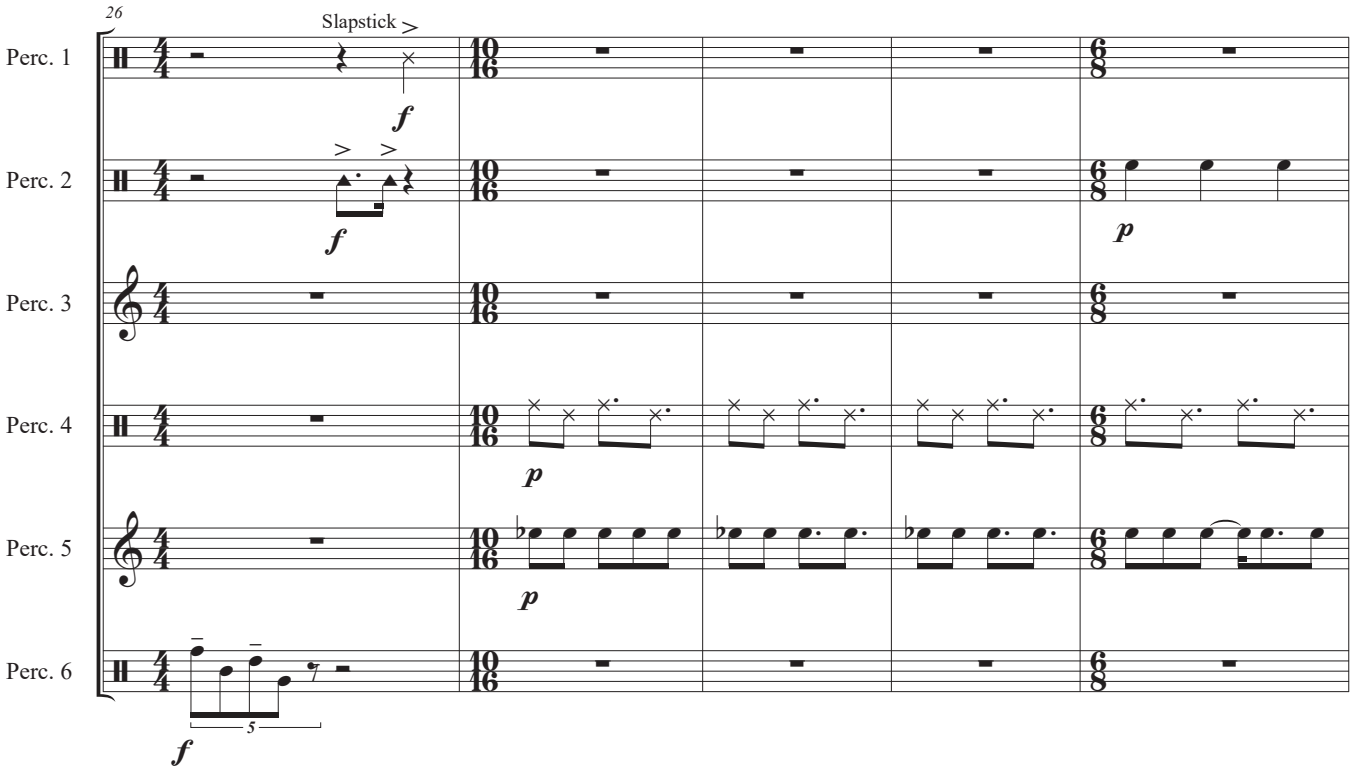

With Energy ♩ = 125
Percussion 1
Percussion 2
Percussion 3
Percussion 4
Percussion 5
Percussion 6
drumsticks
p
At Station 4
low suspended cymbal (medium mallet)
To Xylophone
p

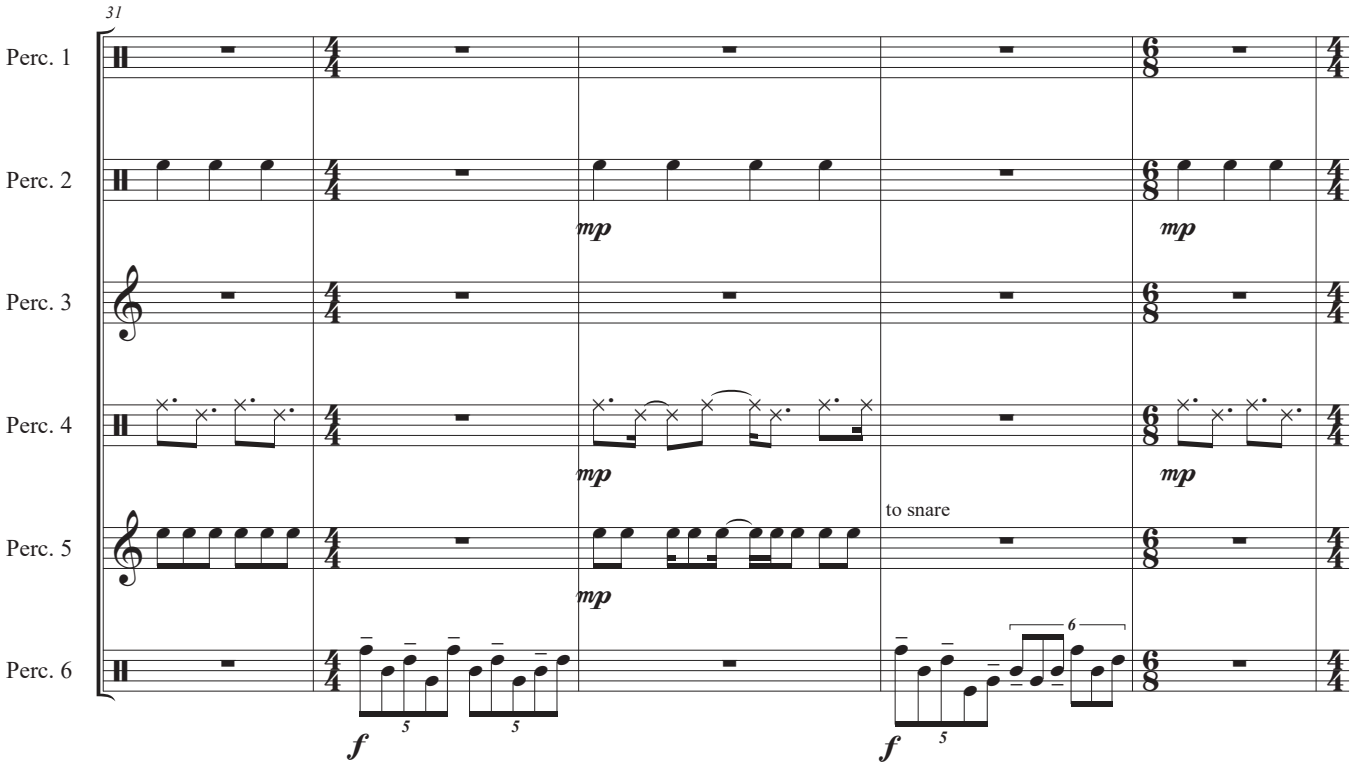

6
Perc. 1
Perc. 2
Tamb. (mallet)
p
Perc. 3
Perc. 4
Perc. 5
Xylo.
p
Perc. 6

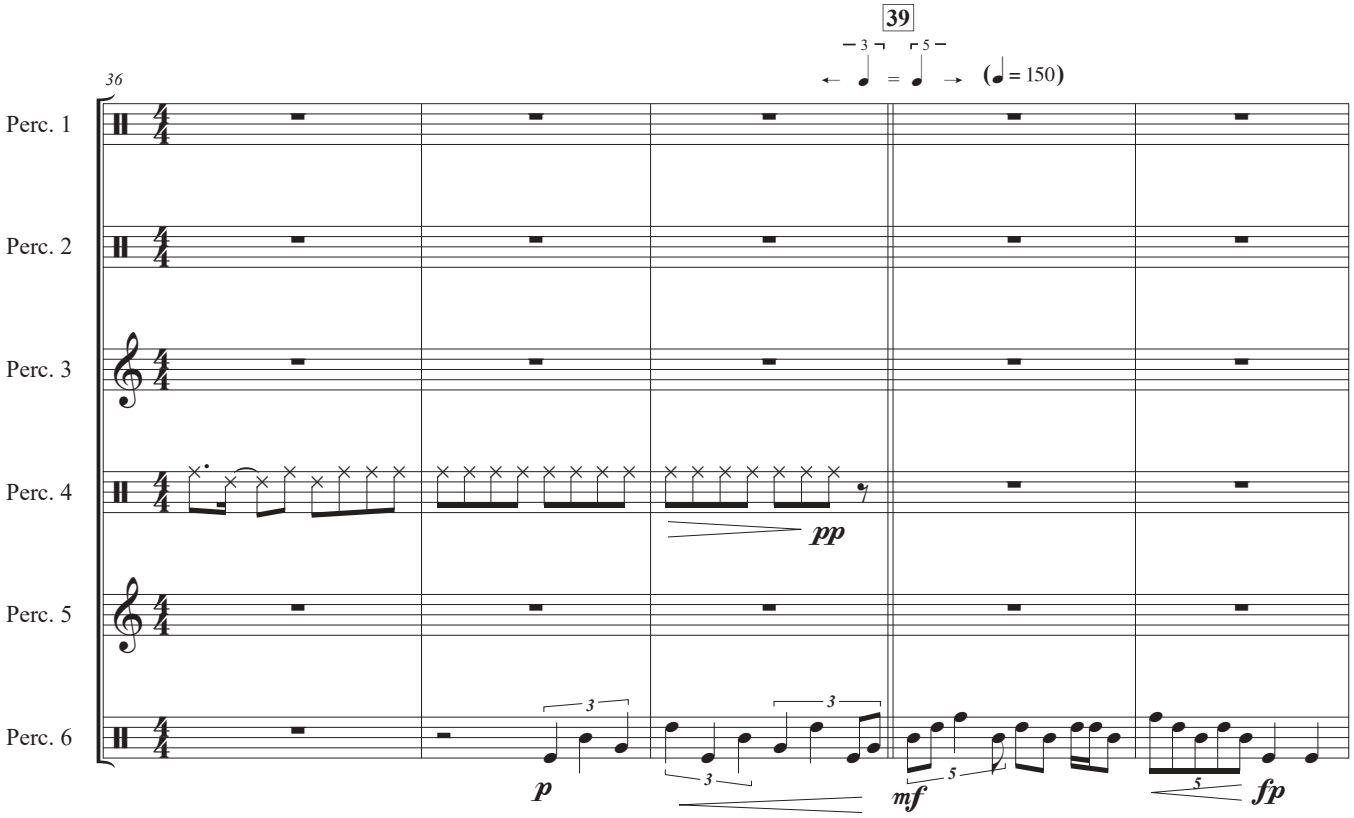

14
11
Perc. 1
Perc. 2
Anvil
Perc. 3
Perc. 4
Perc. 5
Perc. 6

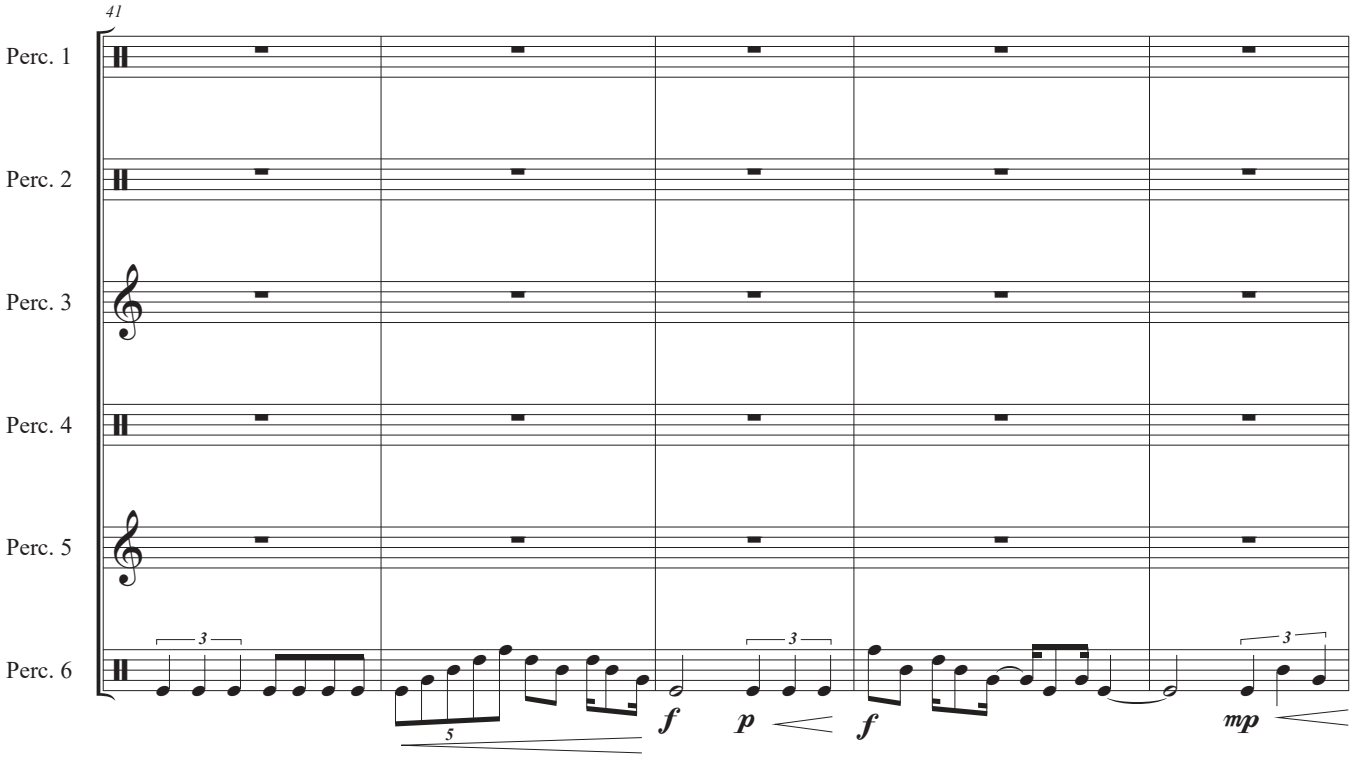

19
16
Perc. 1
Perc. 2
fp
Perc. 3
Perc. 4
fp
Perc. 5
fp
Perc. 6

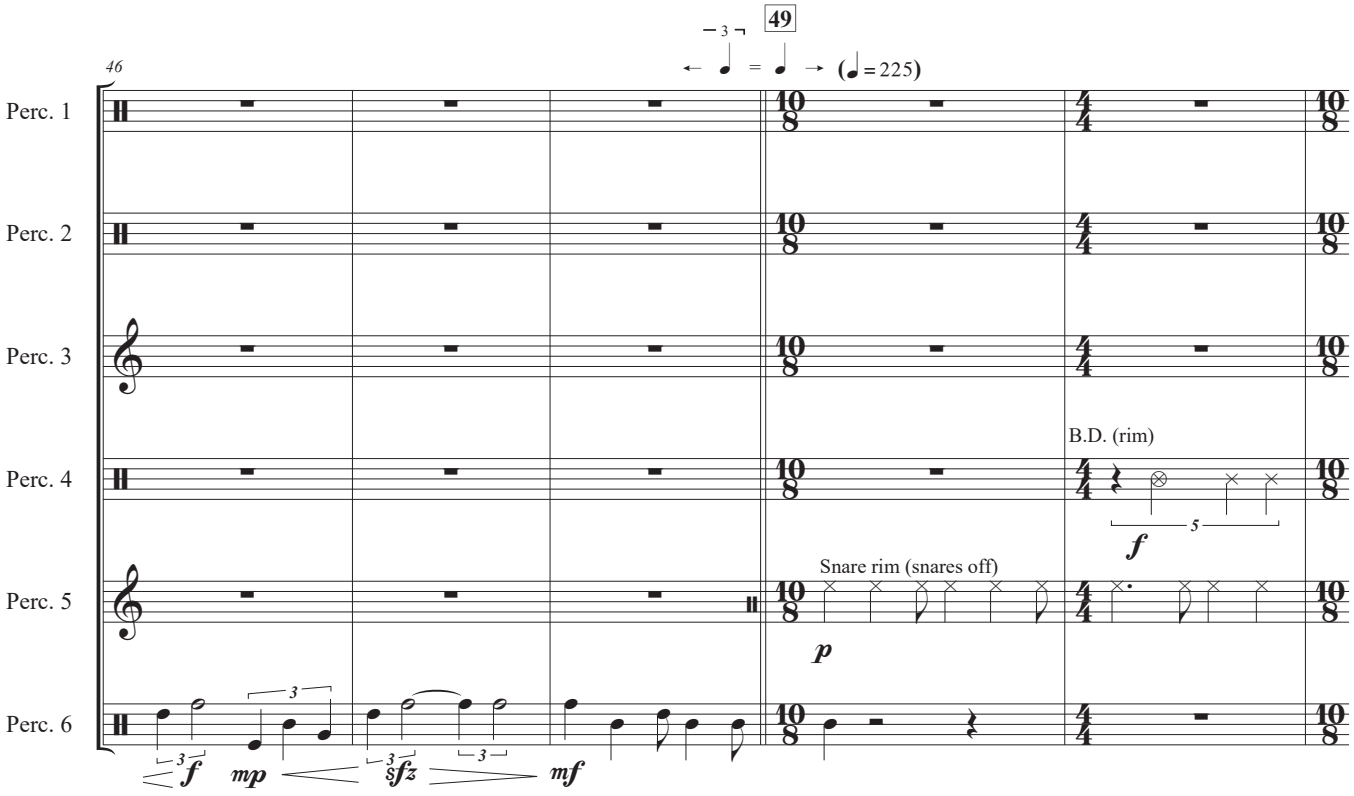

21
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
p
p
Temple Blocks
5
f

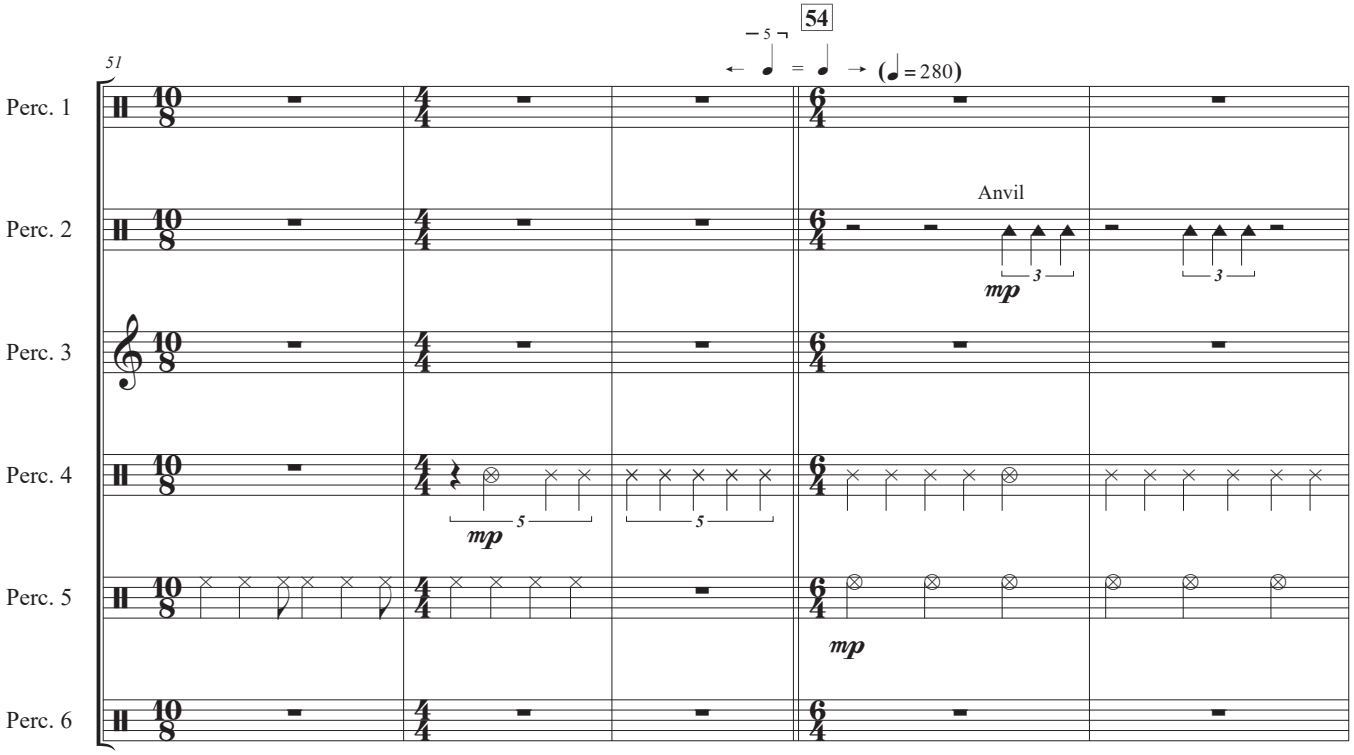

26
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Slapstick
f
f
p
p
p
5
f

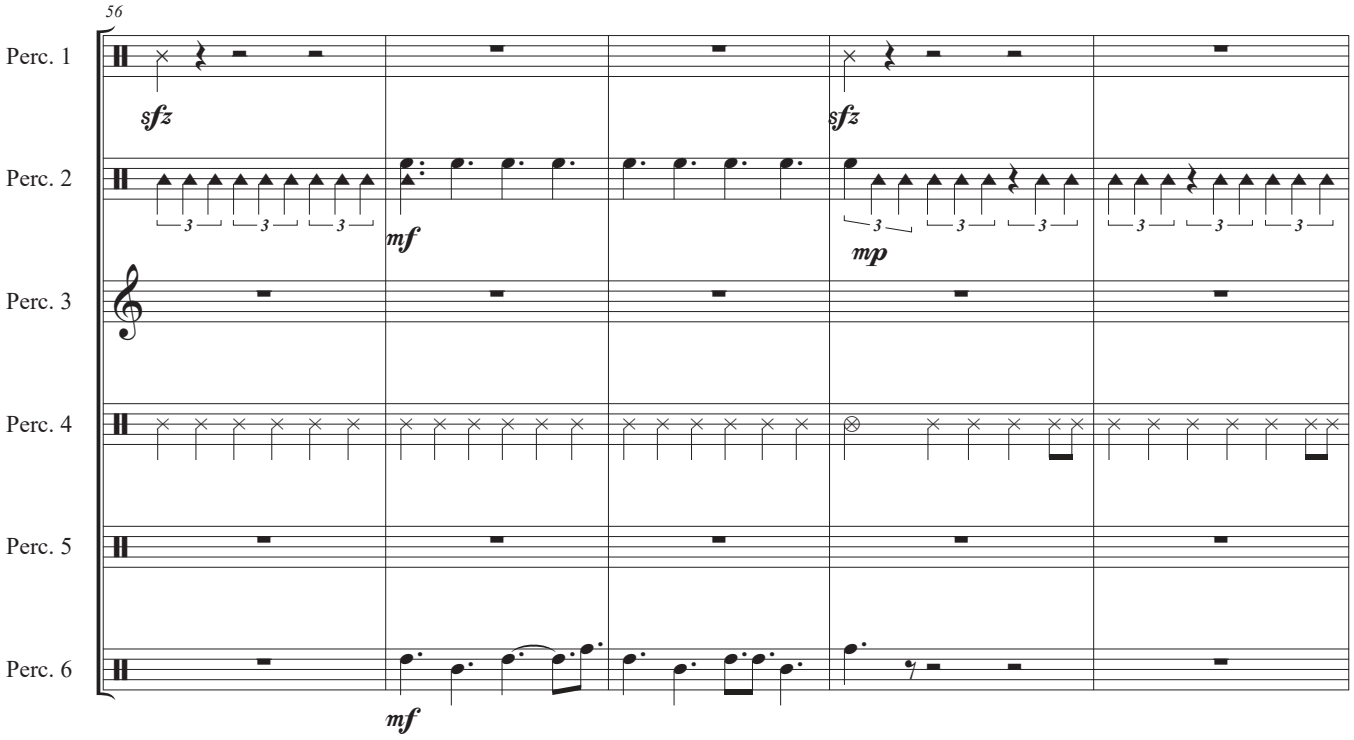

31
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mp
mp
mp
mp
to snare
f
f

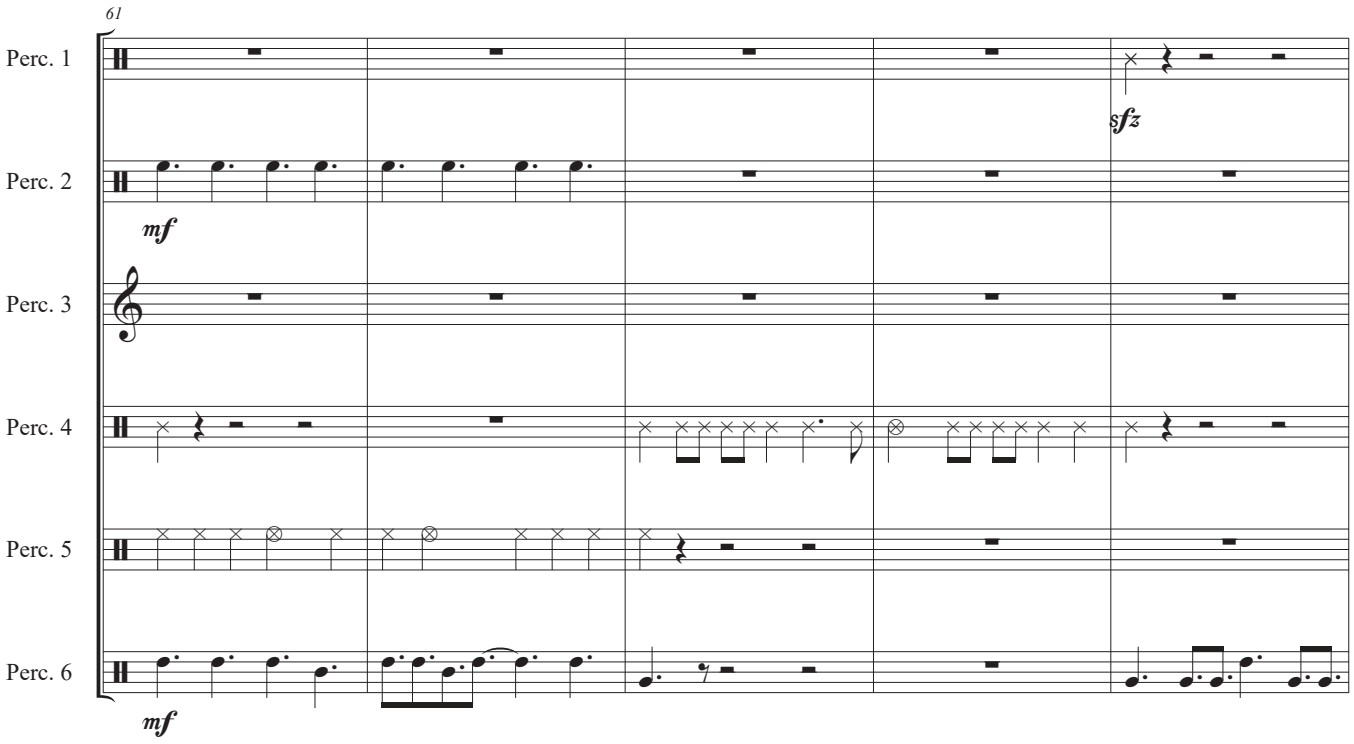

39
(♩= 150)
36
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
pp
p
mf
fp

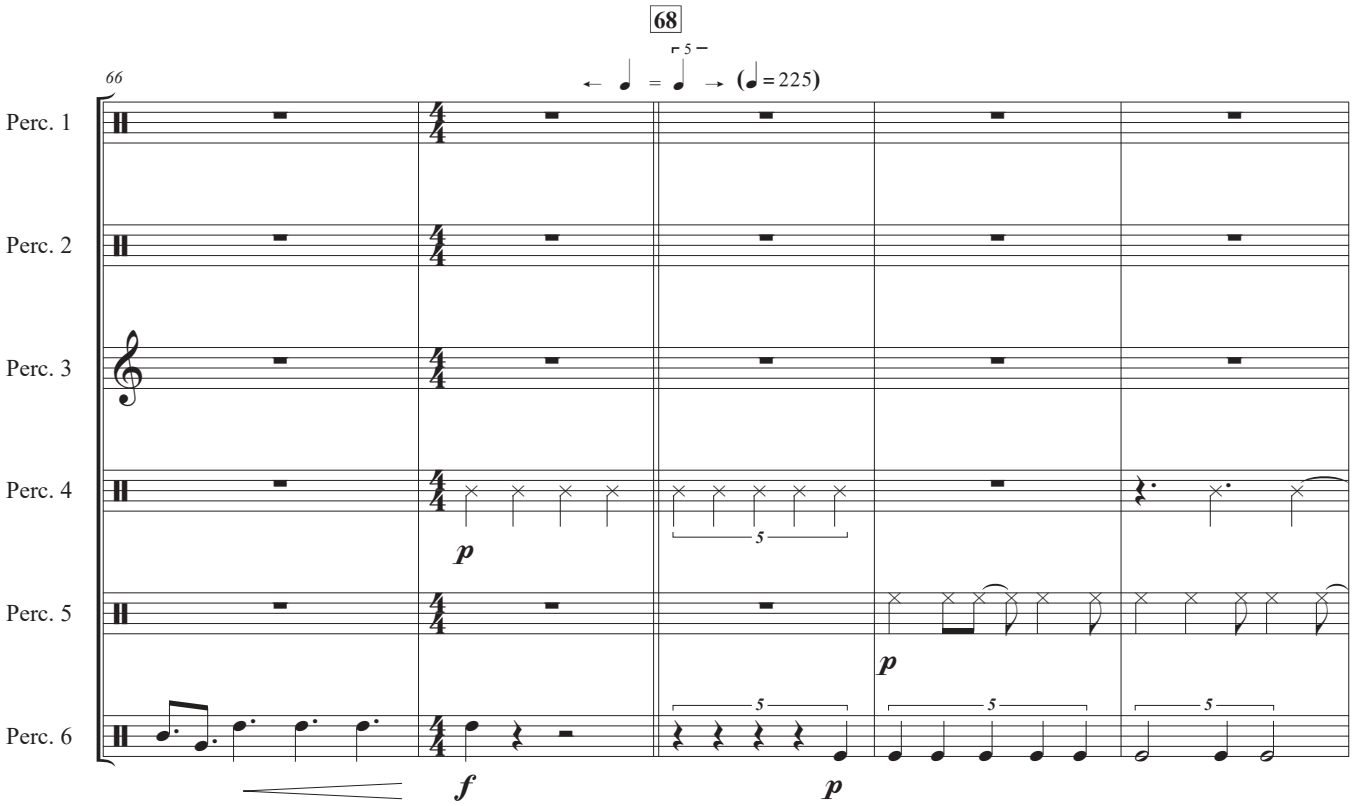

41
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
3
5
f
p
f
3
mp


46
49
(♩= 225)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
B.D. (rim)
5
f
Snare rim (snares off)
p
3
f
mp
sfz
mf


54
5
(♩= 280)
51
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Anvil
mp
mp
mp
mp
5
5
3
3
3


56
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
sfz
sfz
mf
mp
mf
3
3
3
3
3
3
3
3
3


61
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
sfz
mf
mf


68
66
5
(= 225)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
5
p
5
5
5
f
p

II. 74

← ♩. = ♩ → (♩ = 150)

71

Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

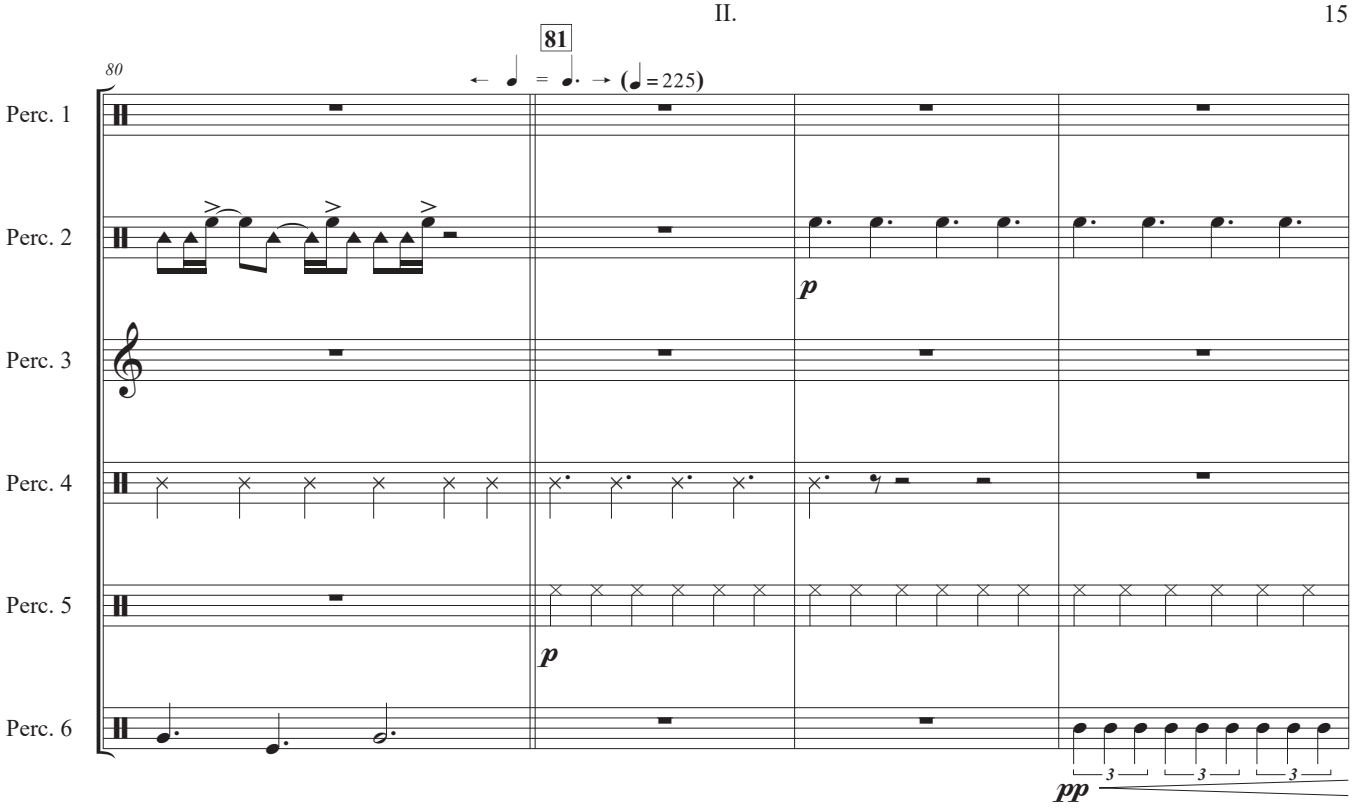
f

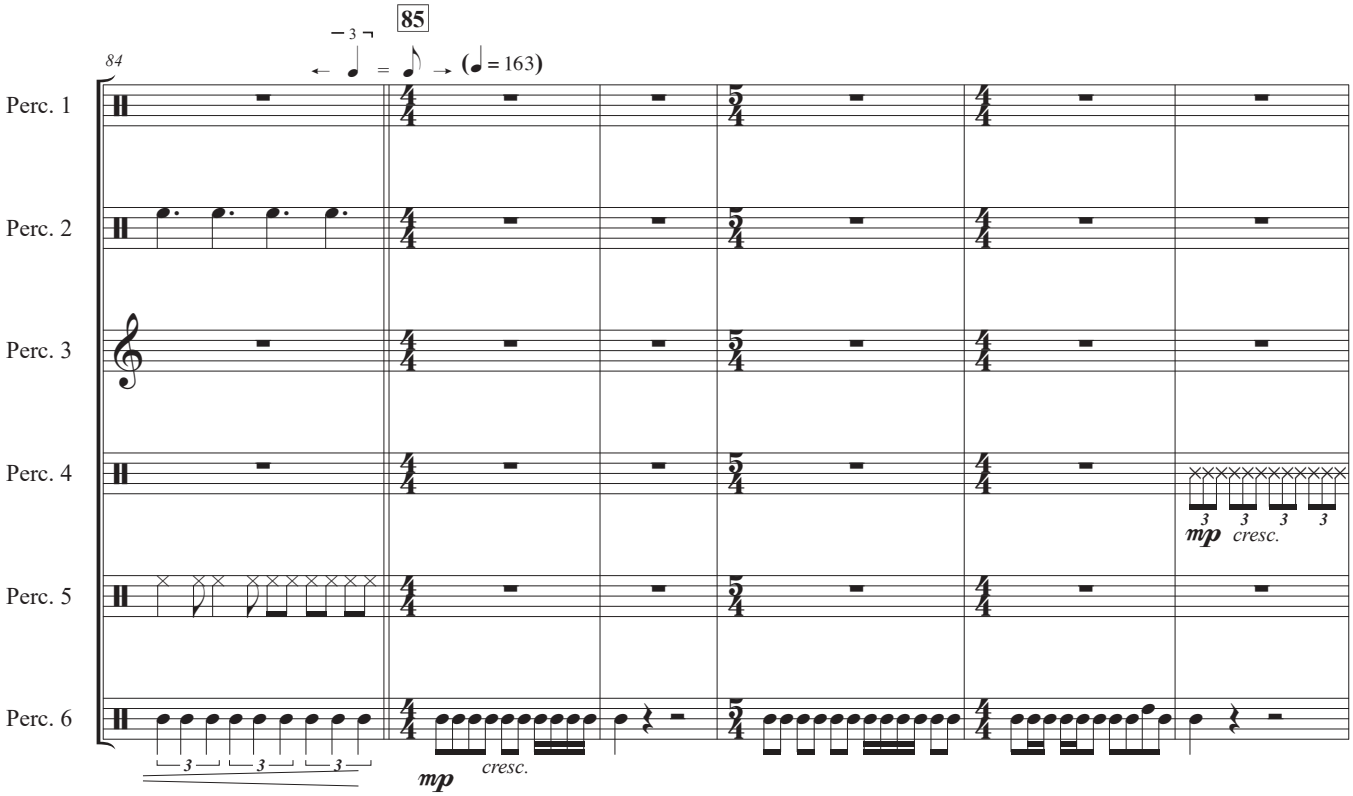
3 3 3

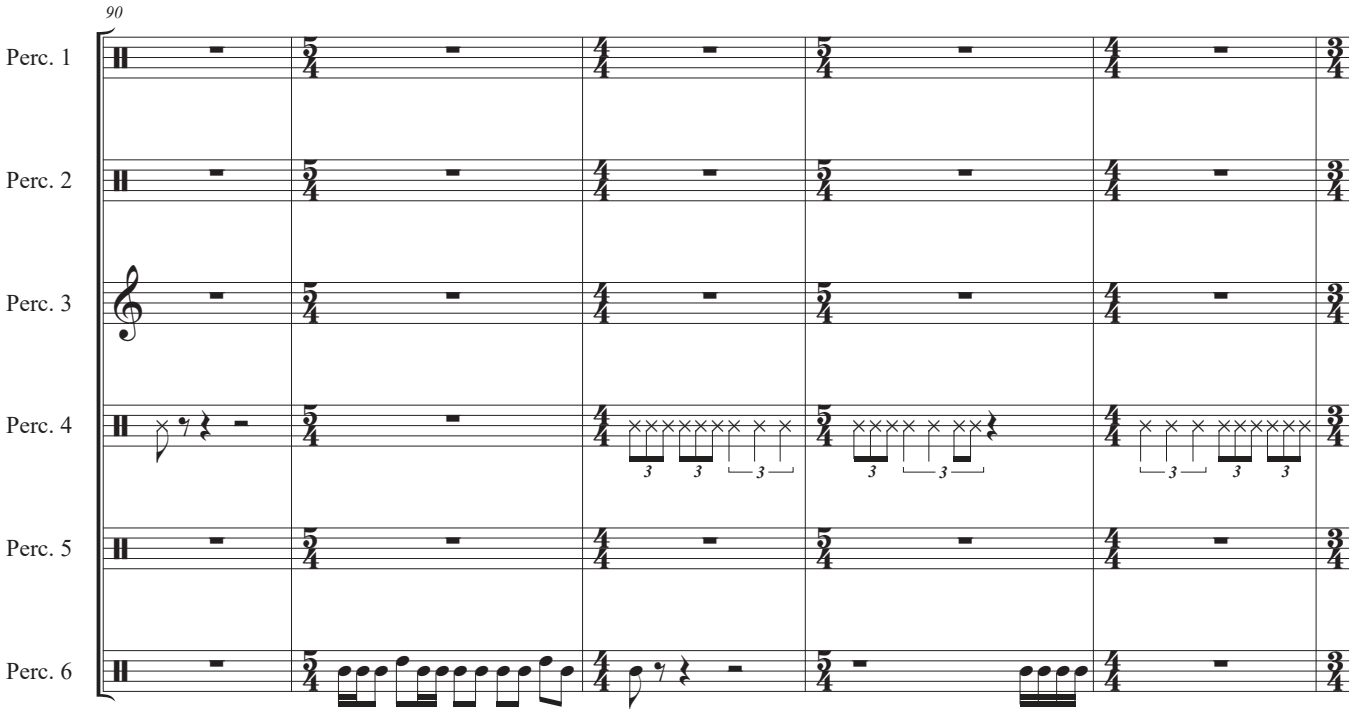
5 5

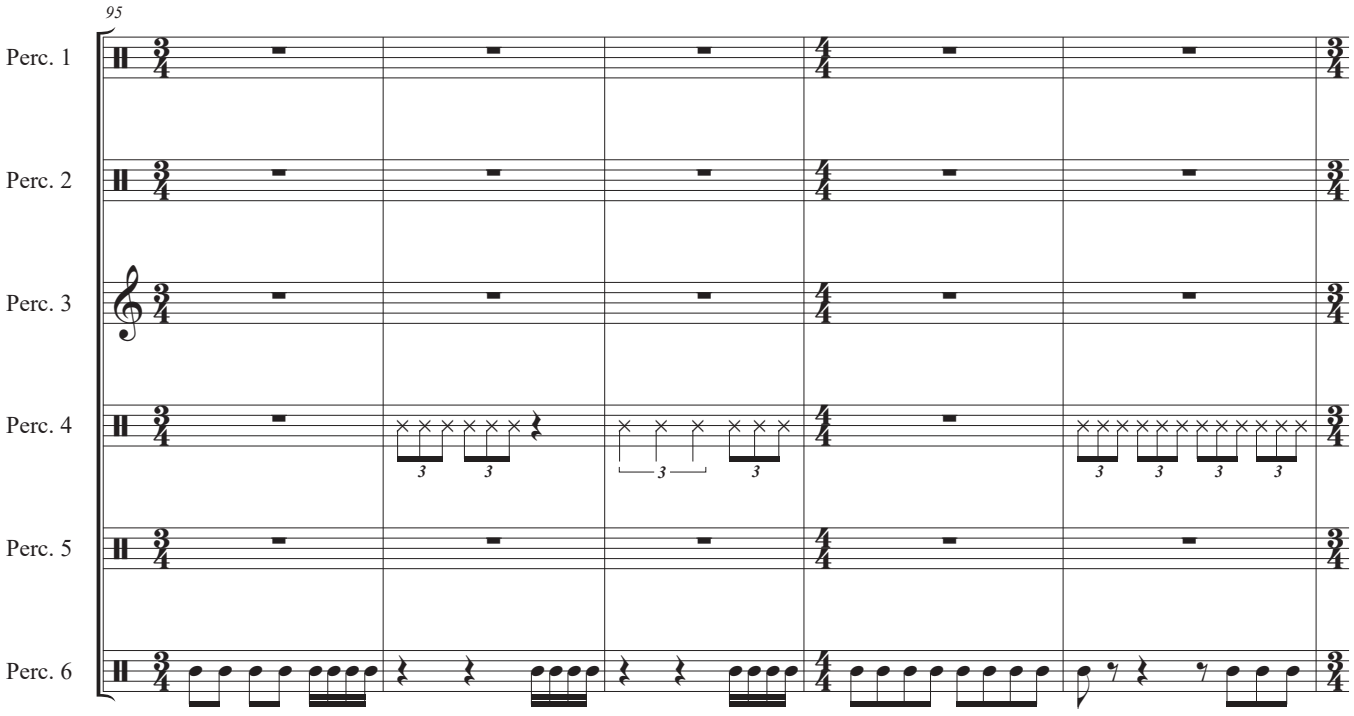
76

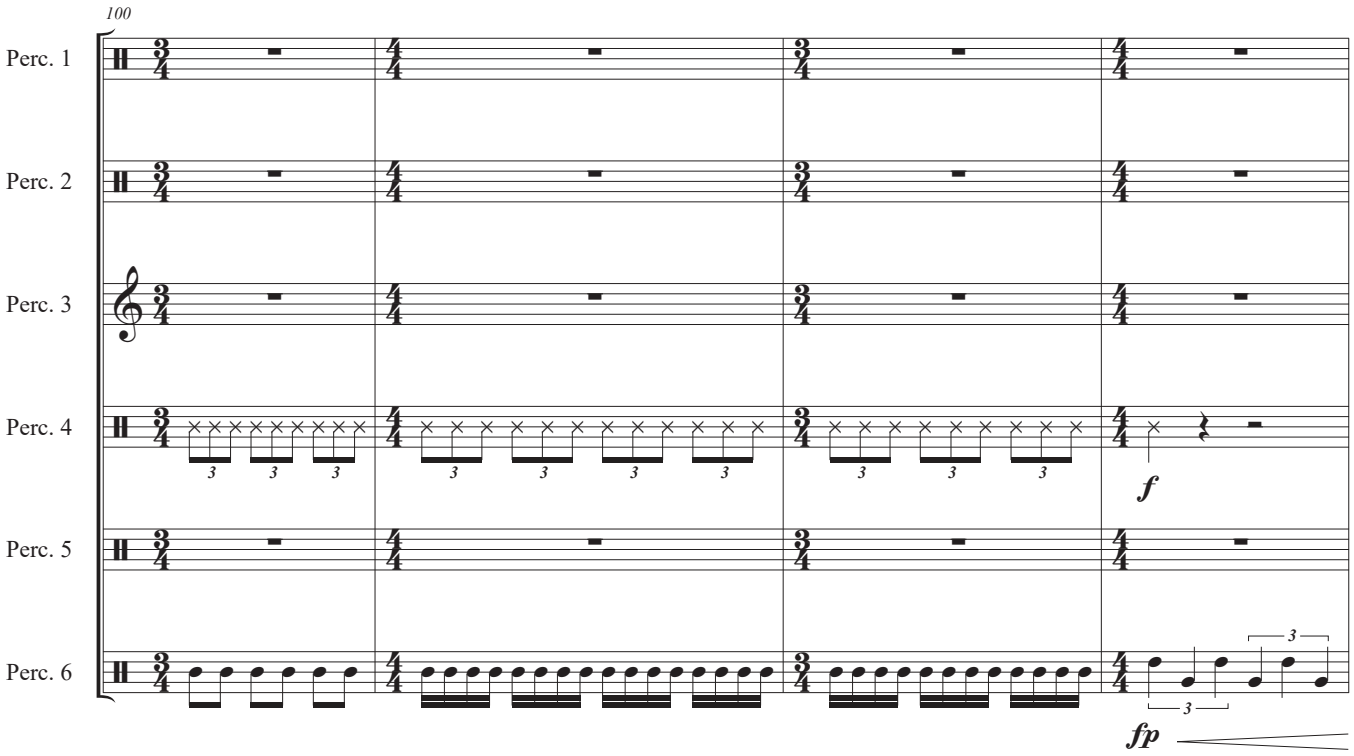
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

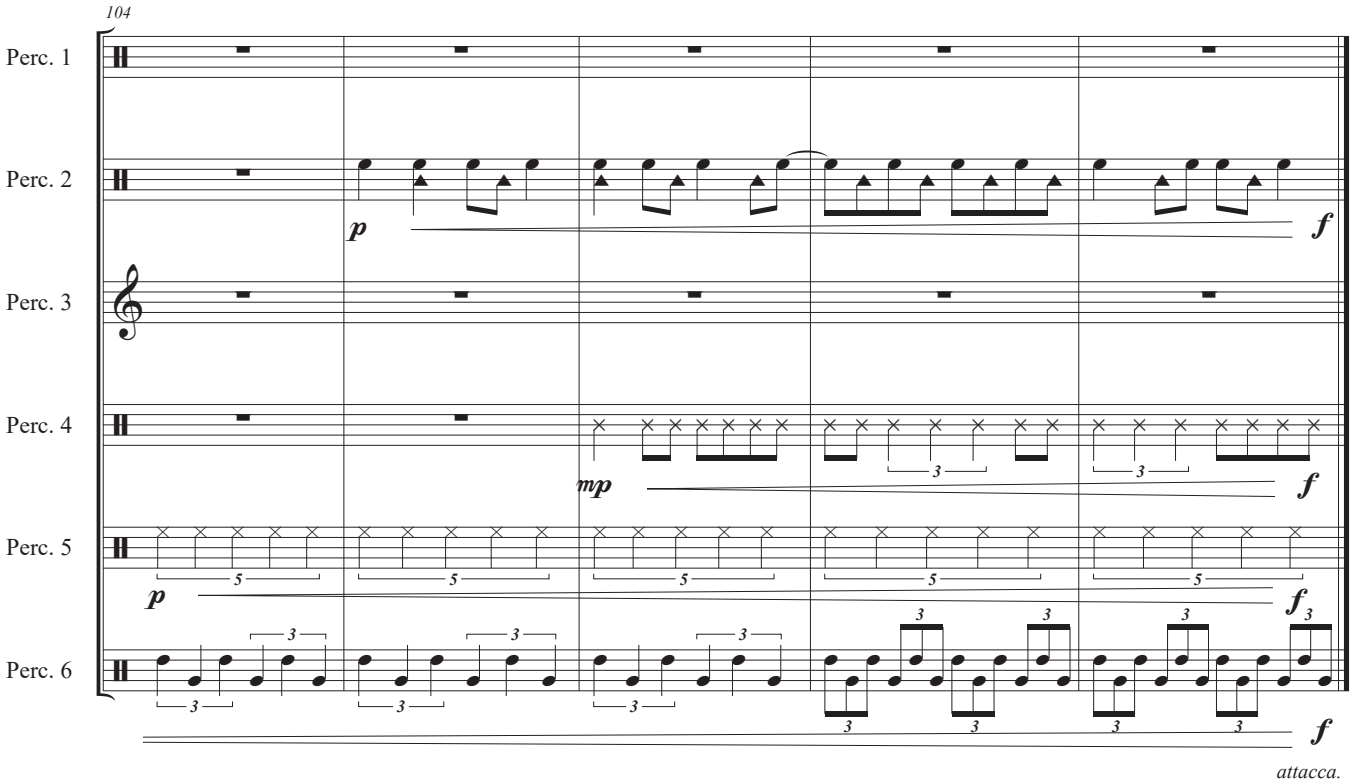

81
80
(♩= 225)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
p
pp
3
3
3


85
84
3
(♩= 163)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
3
3
3
mp
cresc.
3
3
3
3
mp
cresc.

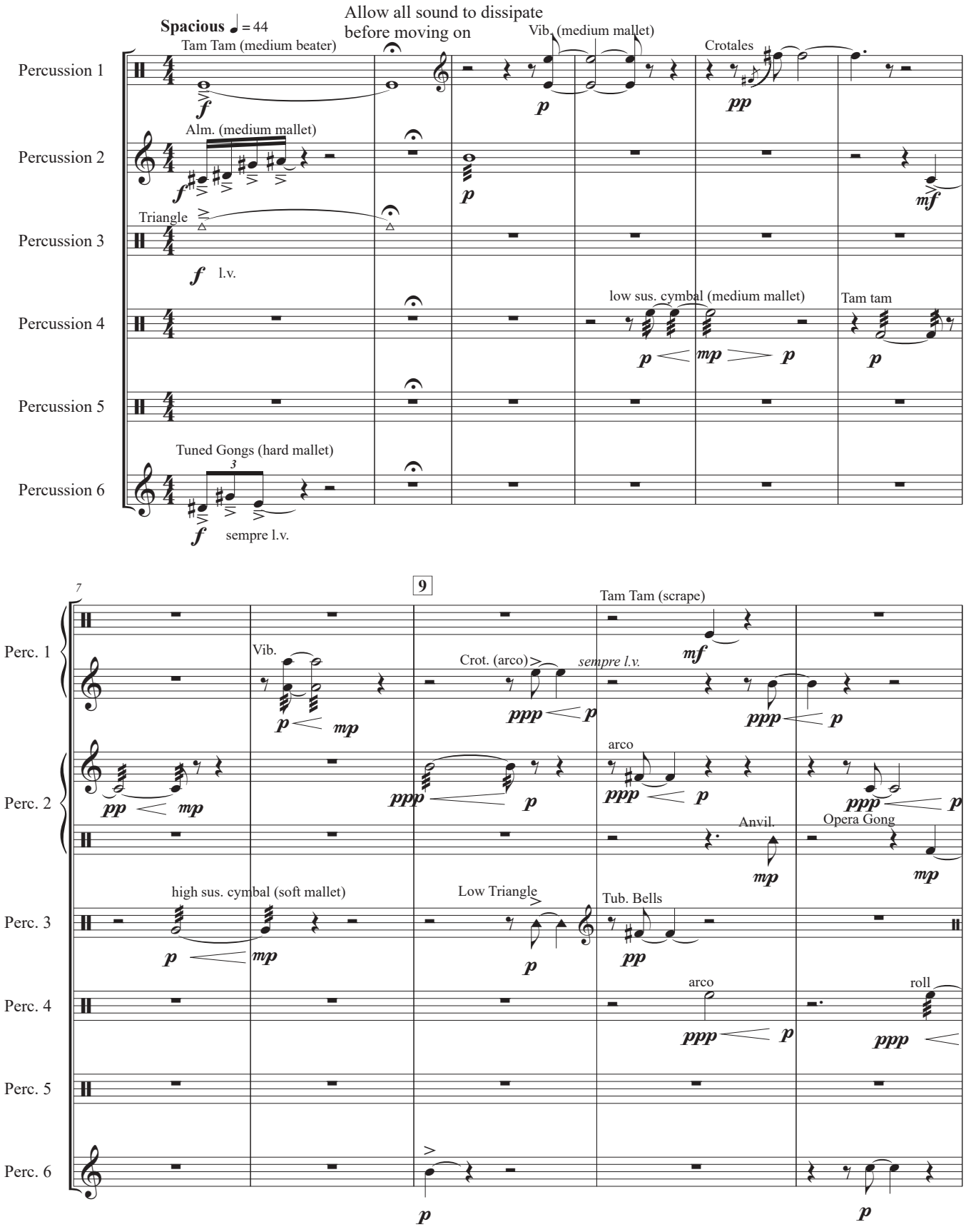

90
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

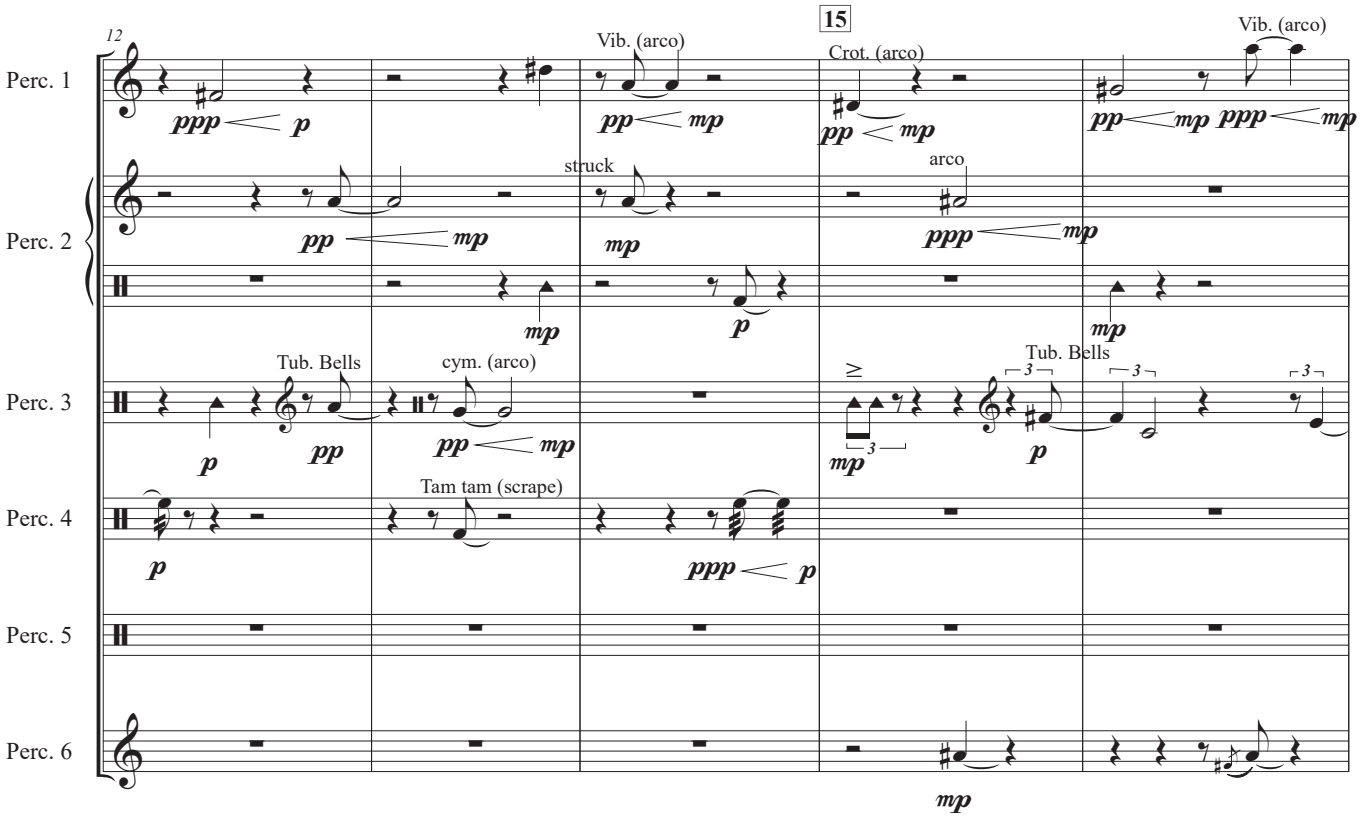

95
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

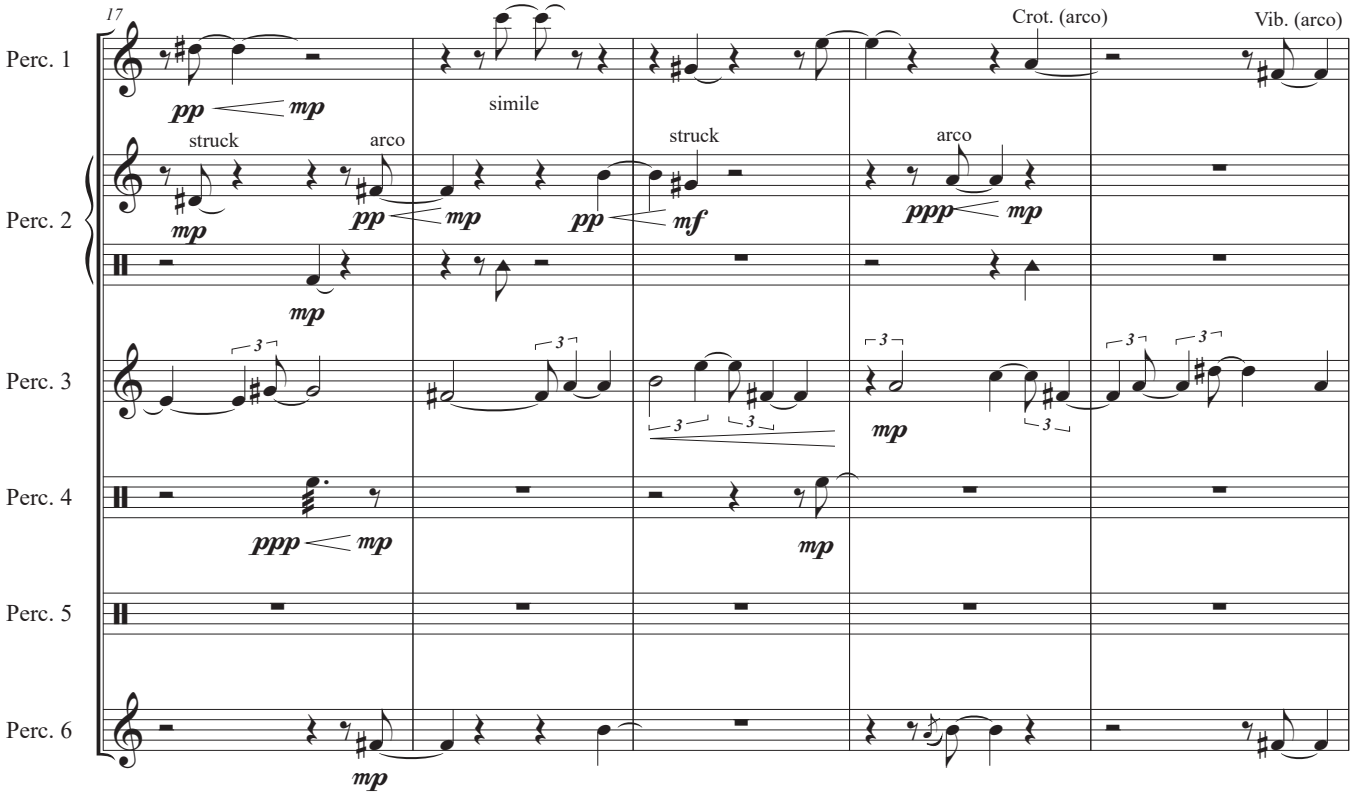

100
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
f
fp

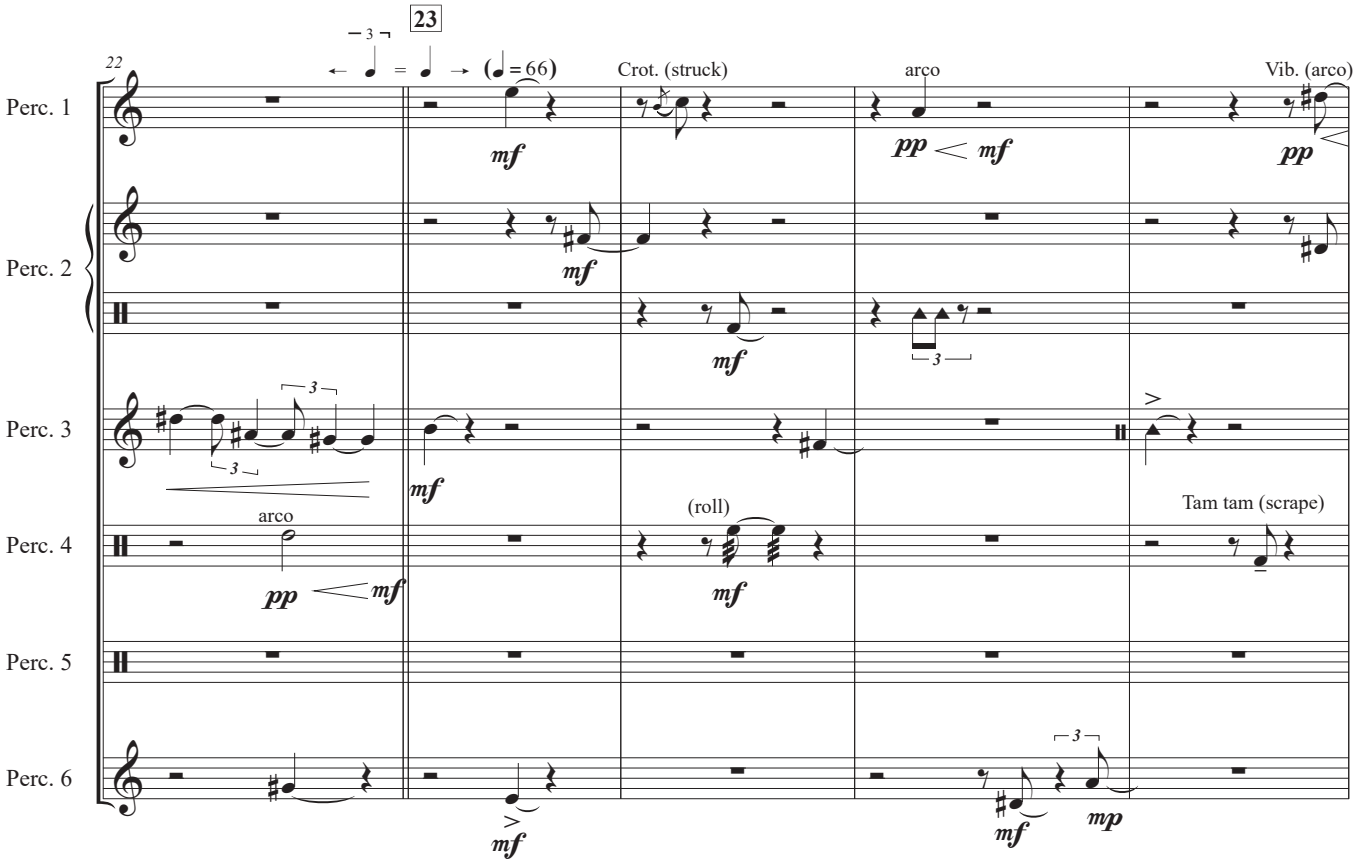

104
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
f
mp
f
p
f
f
attacca.

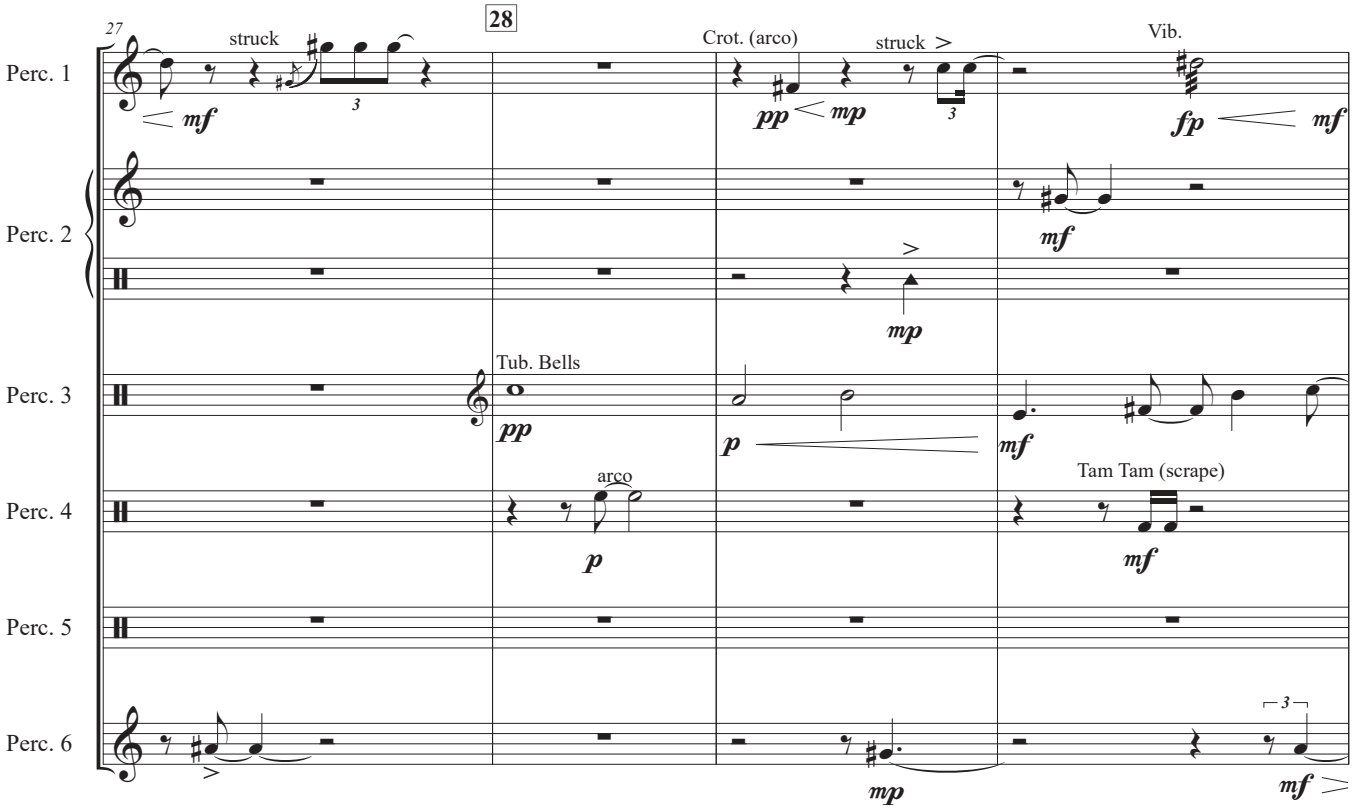
III.

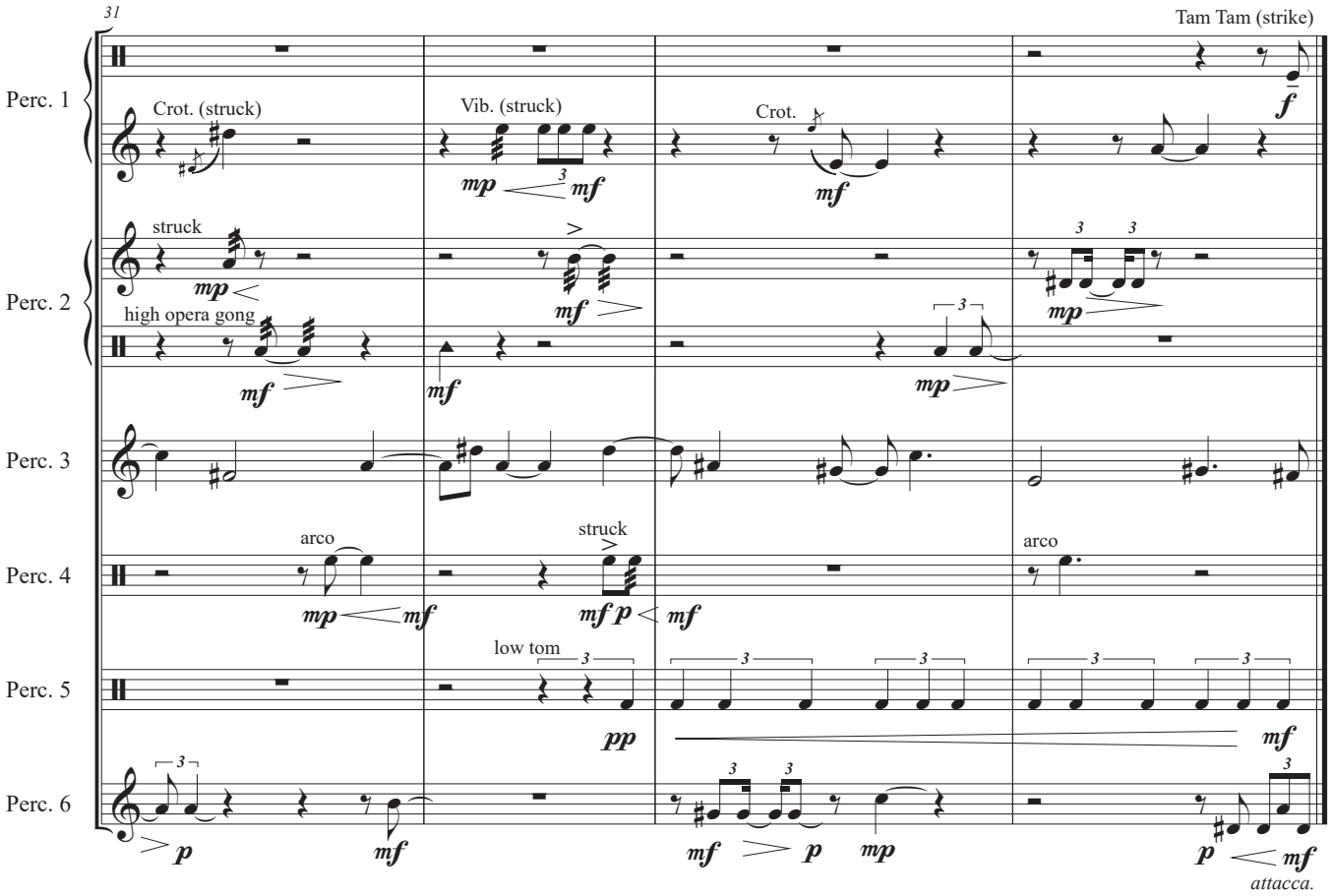

Spacious ♩ = 44
Allow all sound to dissipate before moving on
Tam Tam (medium beater)
Vib. (medium mallet)
Crotales
Alm. (medium mallet)
Triangle
l.v.
low sus. cymbal (medium mallet)
Tam tam
Tuned Gongs (hard mallet)
sempre l.v.
Percussion 1
Percussion 2
Percussion 3
Percussion 4
Percussion 5
Percussion 6
7
9
Tam Tam (scrape)
Vib.
Crot. (arco)
sempre l.v.
arco
Anvil.
Opera Gong
high sus. cymbal (soft mallet)
Low Triangle
Tub. Bells
arco
roll
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6


12
15
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Vib. (arco)
Crot. (arco)
Vib. (arco)
struck
arco
Tub. Bells
cym. (arco)
Tub. Bells
Tam tam (scrape)

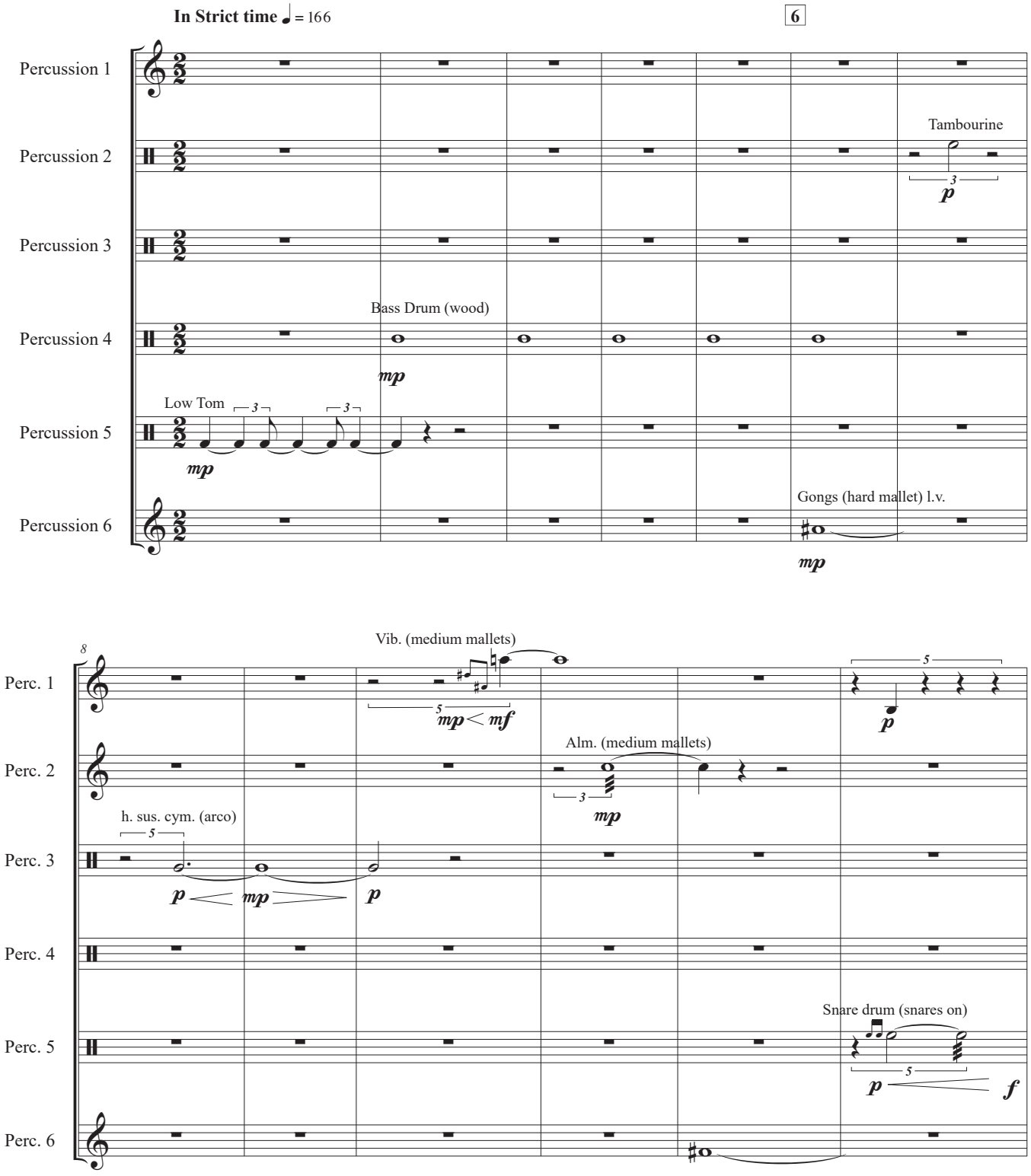

17
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Crot. (arco)
Vib. (arco)
struck
arco
simile
struck
arco

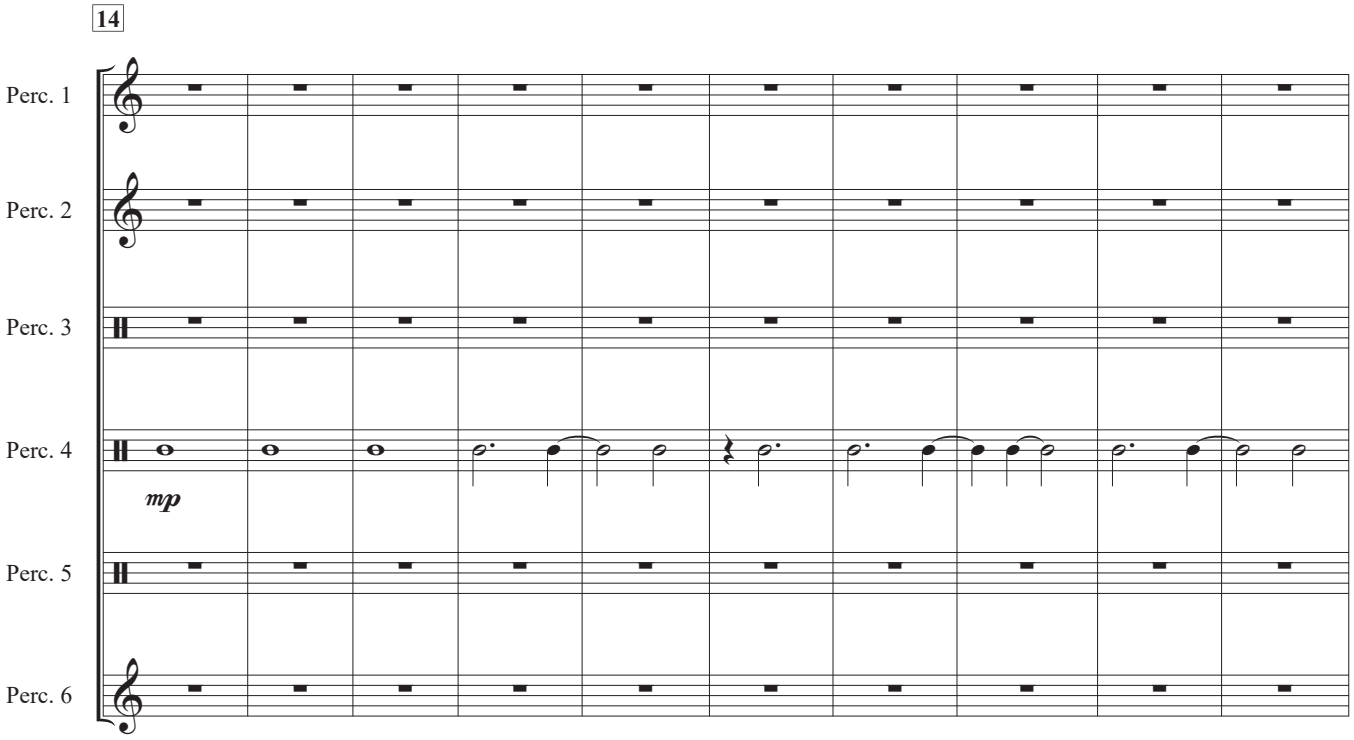

22
23
♩ = ♩ (♩ = 66)
Crot. (struck)
arco
Vib. (arco)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
arco
(roll)
Tam tam (scrape)

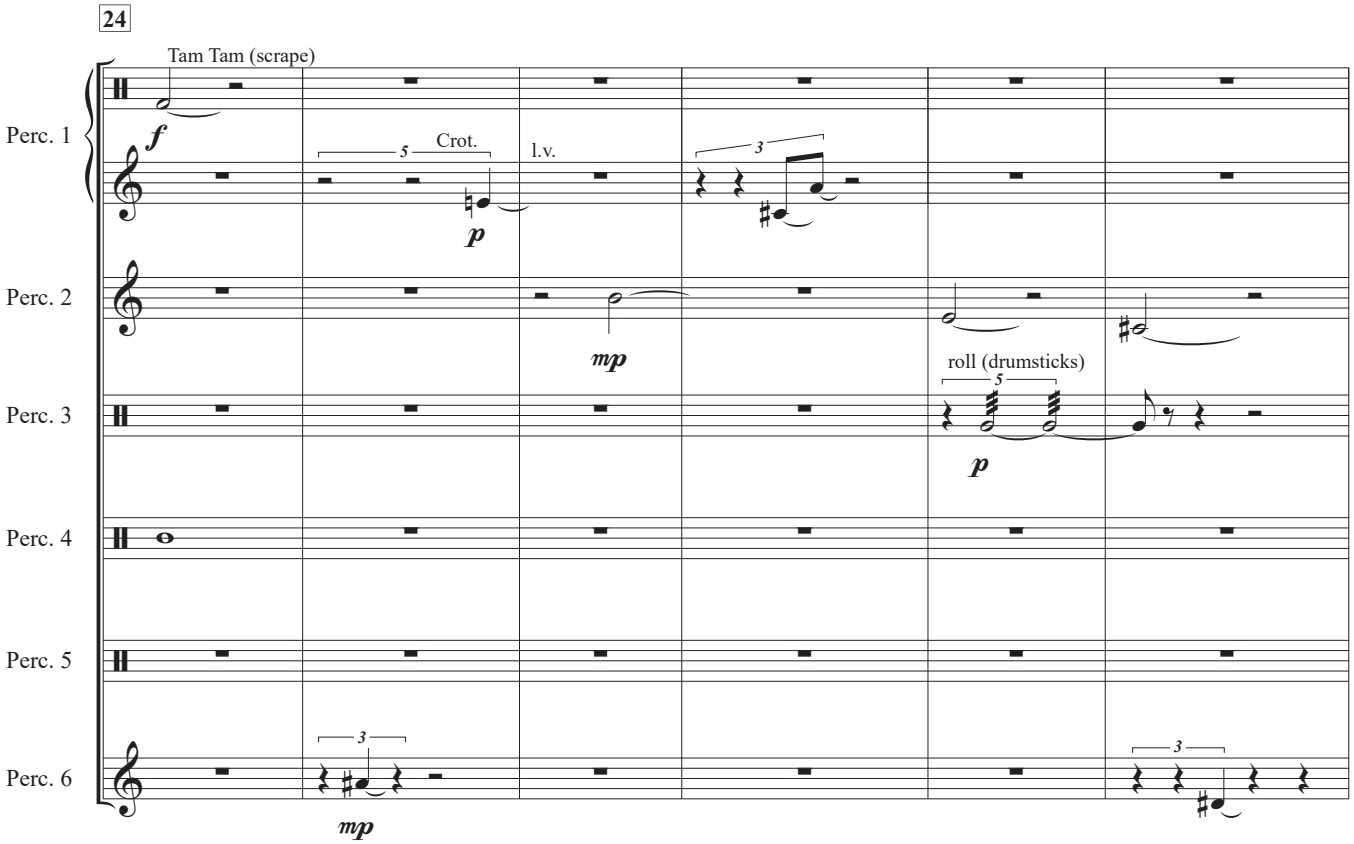

27
28
struck
Crot. (arco)
struck
Vib.
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Tub. Bells
arco
Tam Tam (scrape)

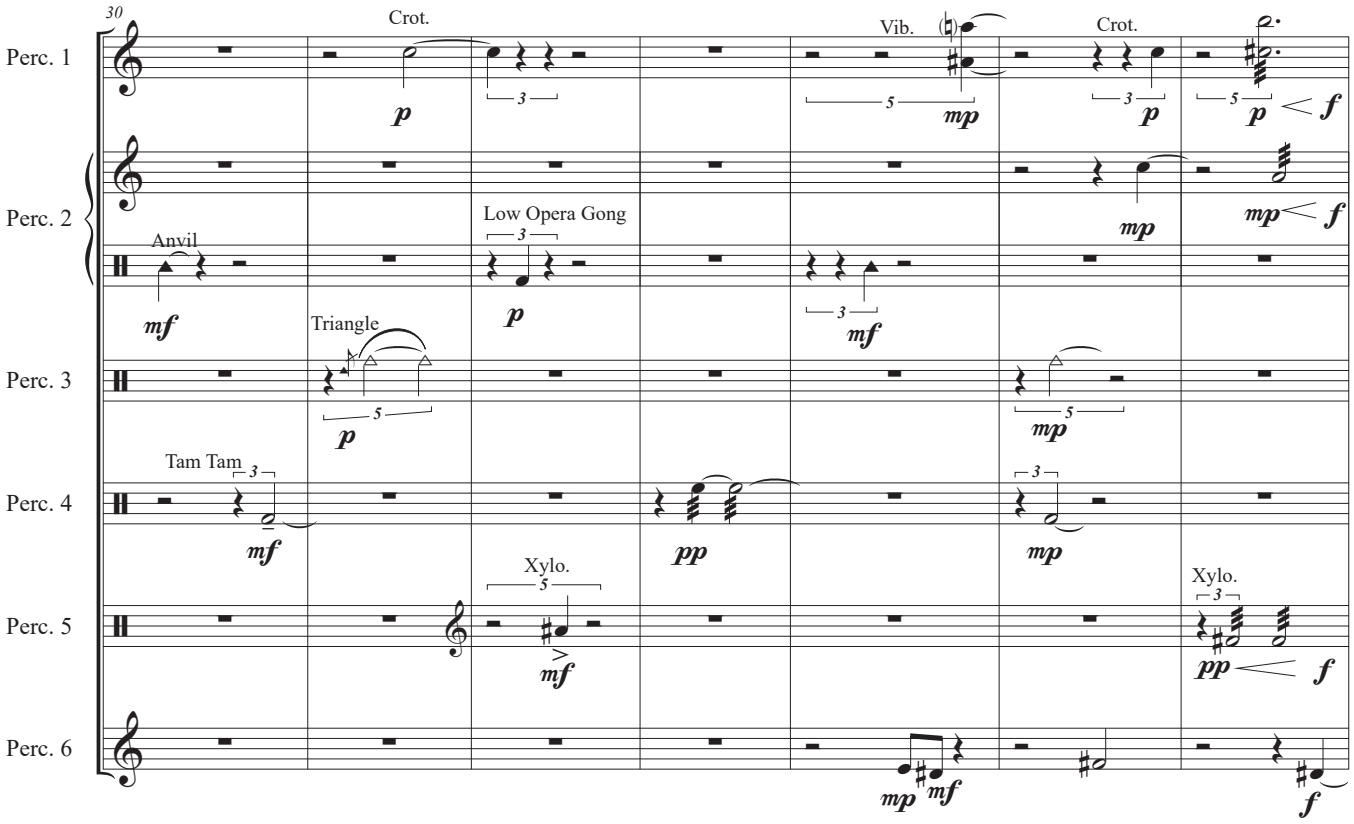

31
Tam Tam (strike)
Perc. 1
Crot. (struck)
Vib. (struck)
Crot.
Perc. 2
struck
high opera gong
Perc. 3
Perc. 4
arco
struck
arco
Perc. 5
low tom
Perc. 6
attacca.

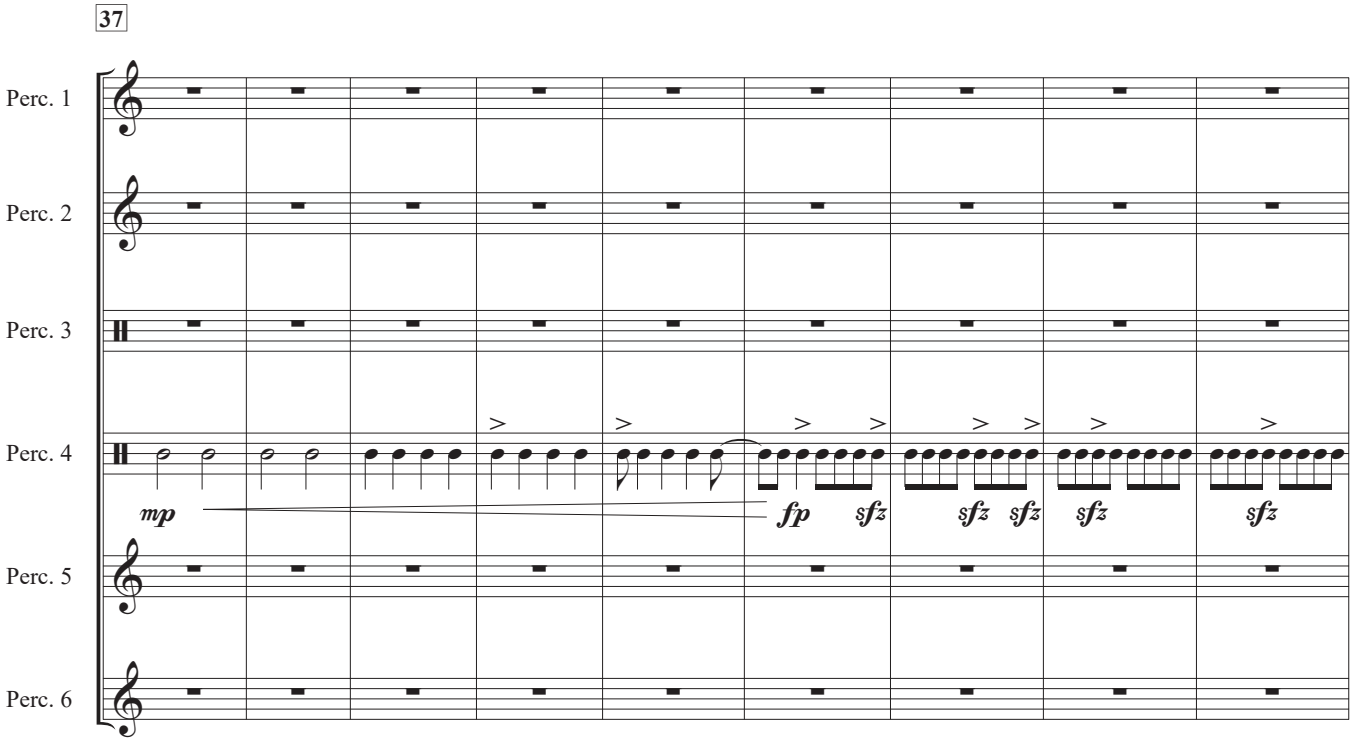
IV.

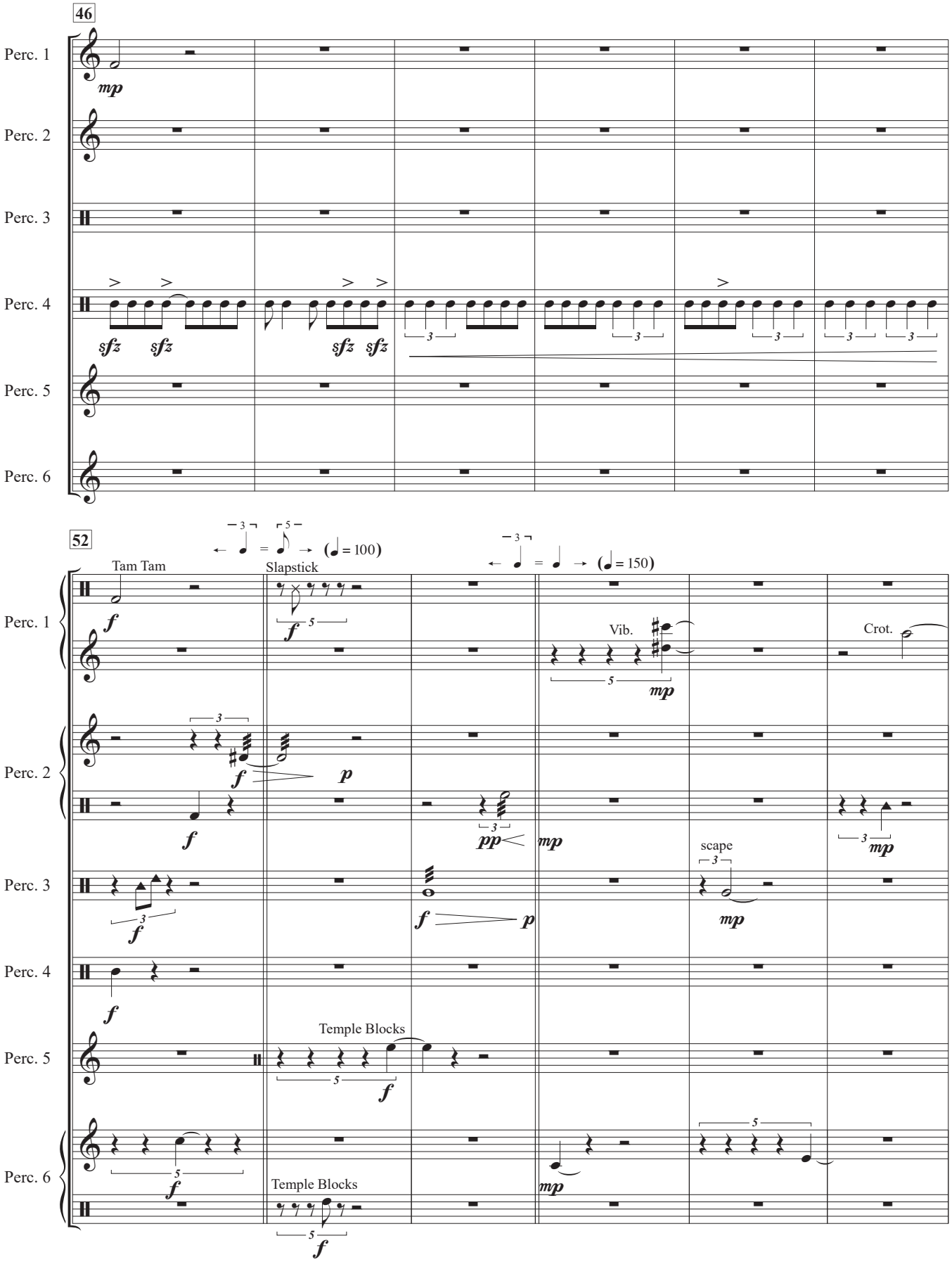

In Strict time ♩ = 166
6
Percussion 1
Percussion 2
Percussion 3
Percussion 4
Percussion 5
Percussion 6
Tambourine
Bass Drum (wood)
Low Tom
Gongs (hard mallet) l.v.
8
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Vib. (medium mallets)
Alm. (medium mallets)
h. sus. cym. (arco)
Snare drum (snares on)

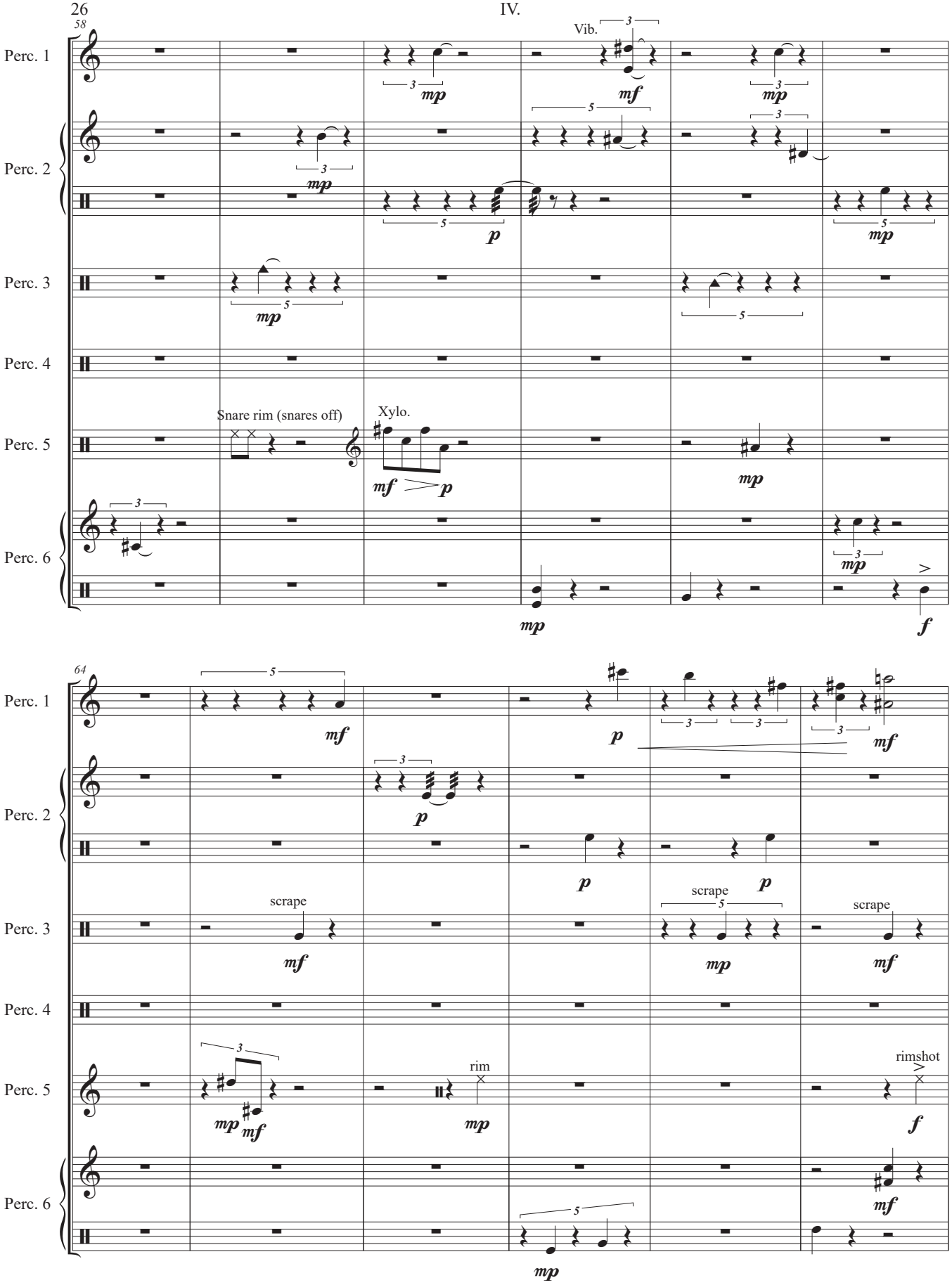

14
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mp

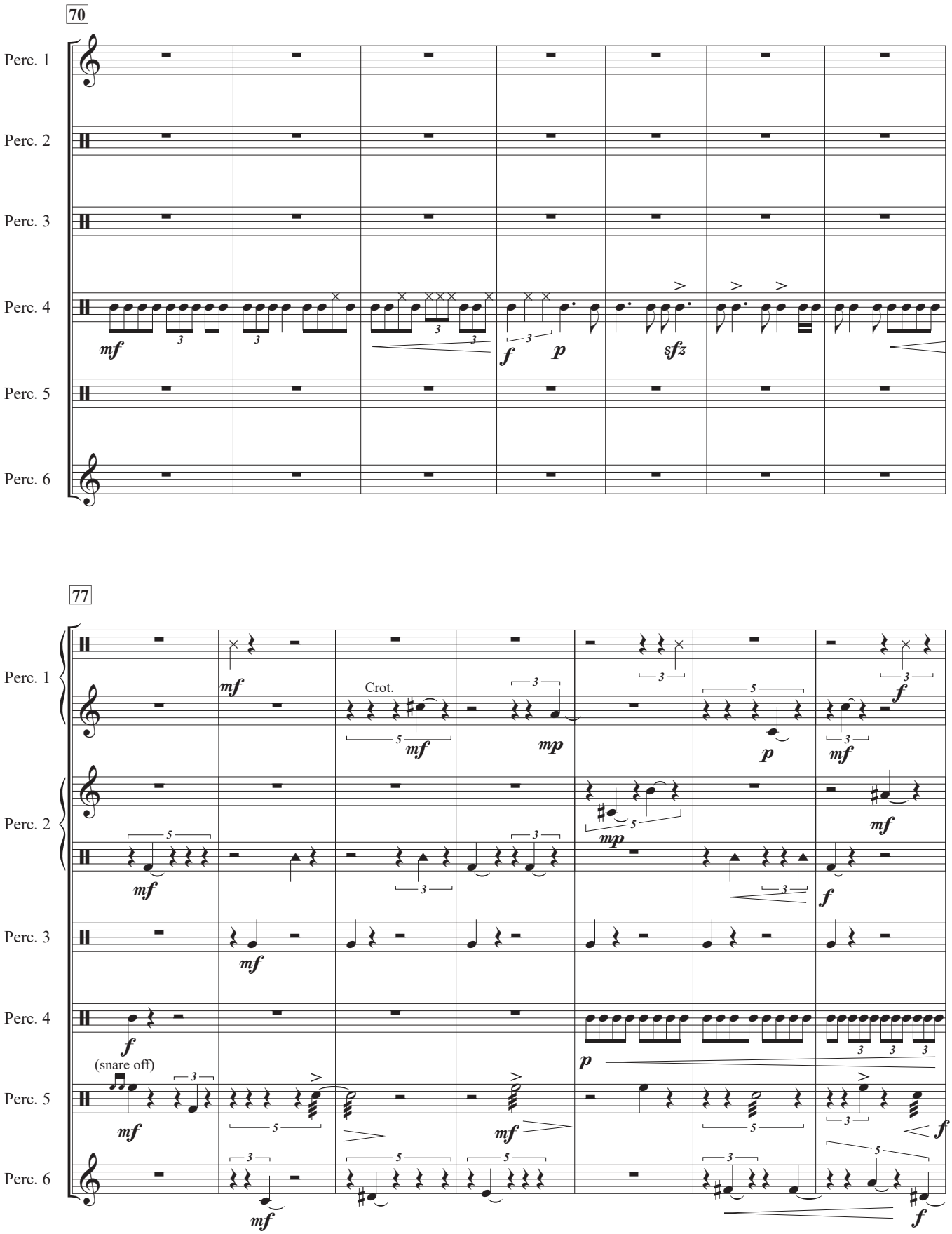

24
Tam Tam (scrape)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
f
5
Crot.
p
l.v.
mp
3
roll (drumsticks)
5
p
3
mp
3


30
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Crot.
Vib.
Crot.
Anvil
Low Opera Gong
Triangle
Tam Tam
Xylo.
Xylo.

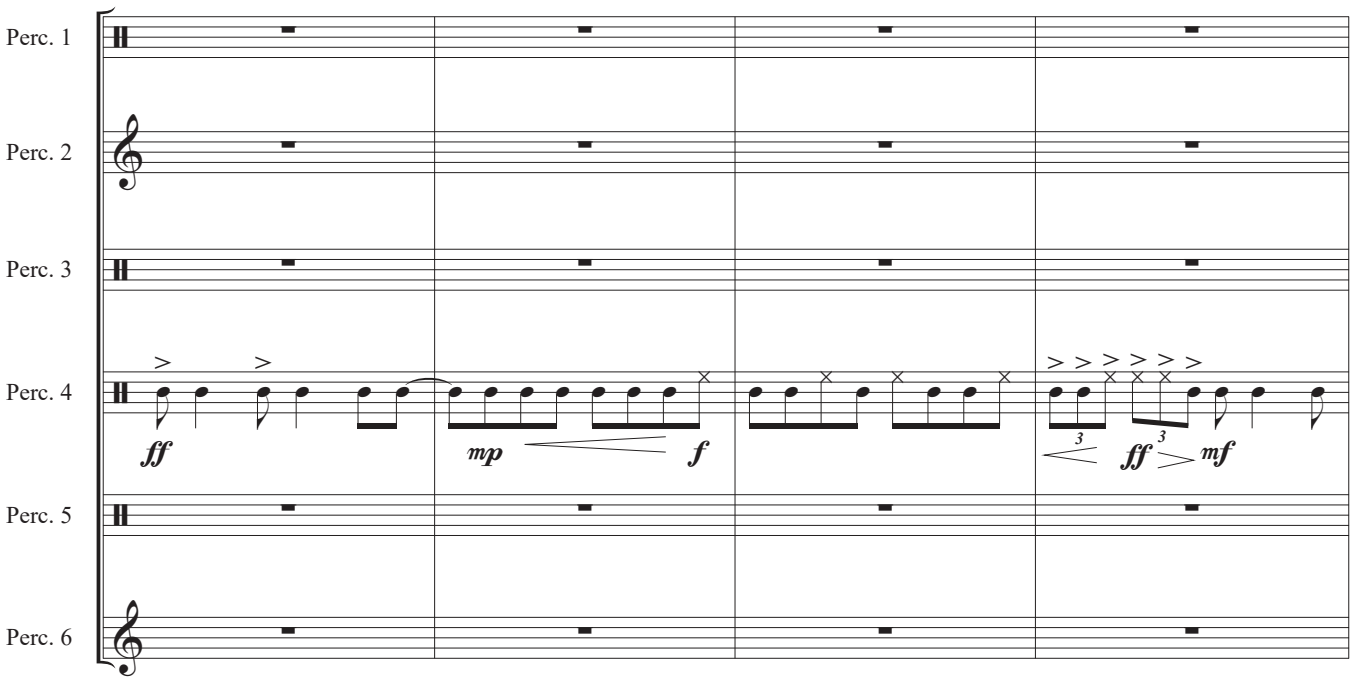

37
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6


46
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mp
sfz sfz sfz sfz
52
Tam Tam
Slapstick
(♩= 100)
(♩= 150)
Vib.
Crot.
scape
Temple Blocks
Temple Blocks

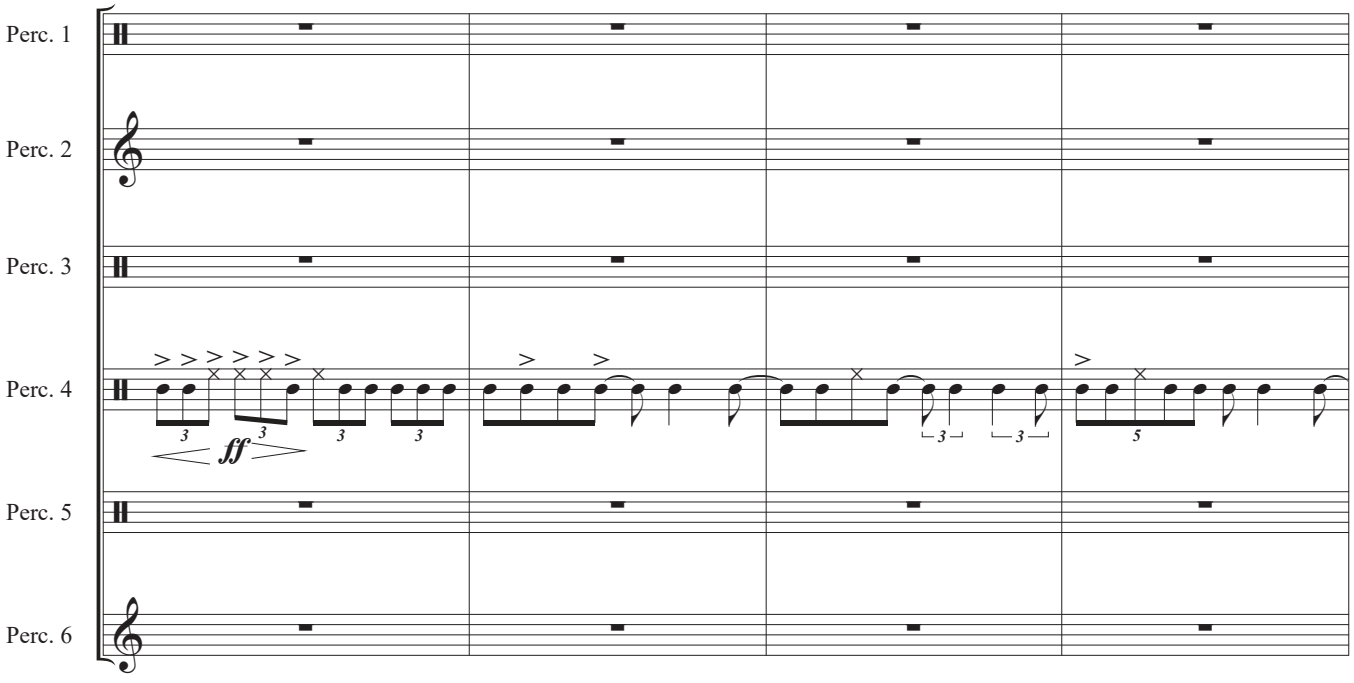

58
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Vib.
Snare rim (snares off)
Xylo.
64
scrape
rim
rimshot

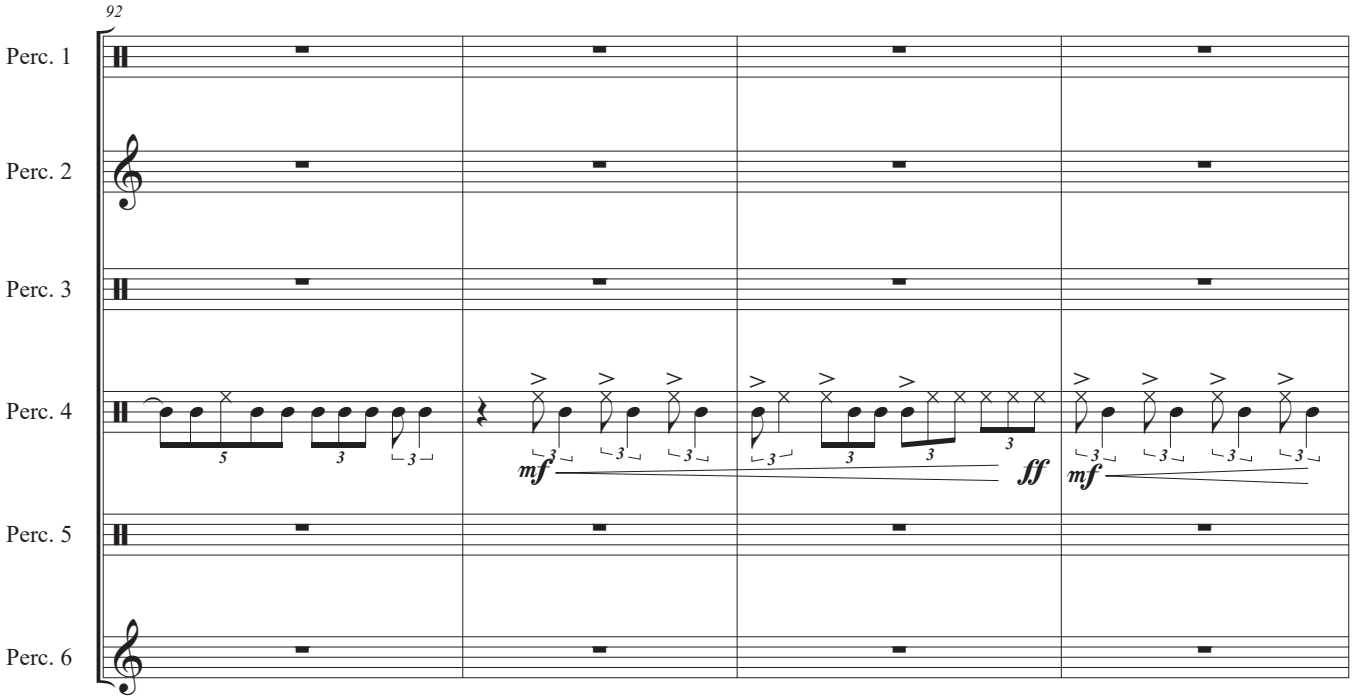

70
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
f
p
sfz
77
Crot.
mp
(snare off)

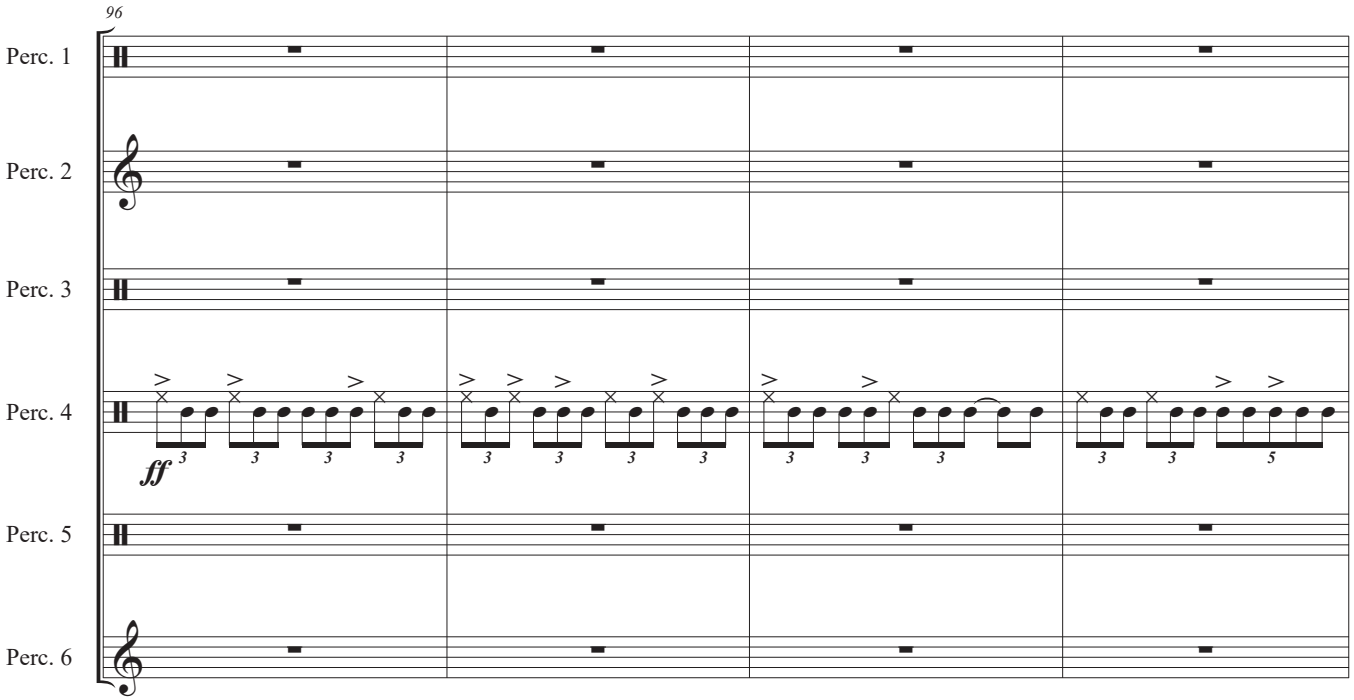
84

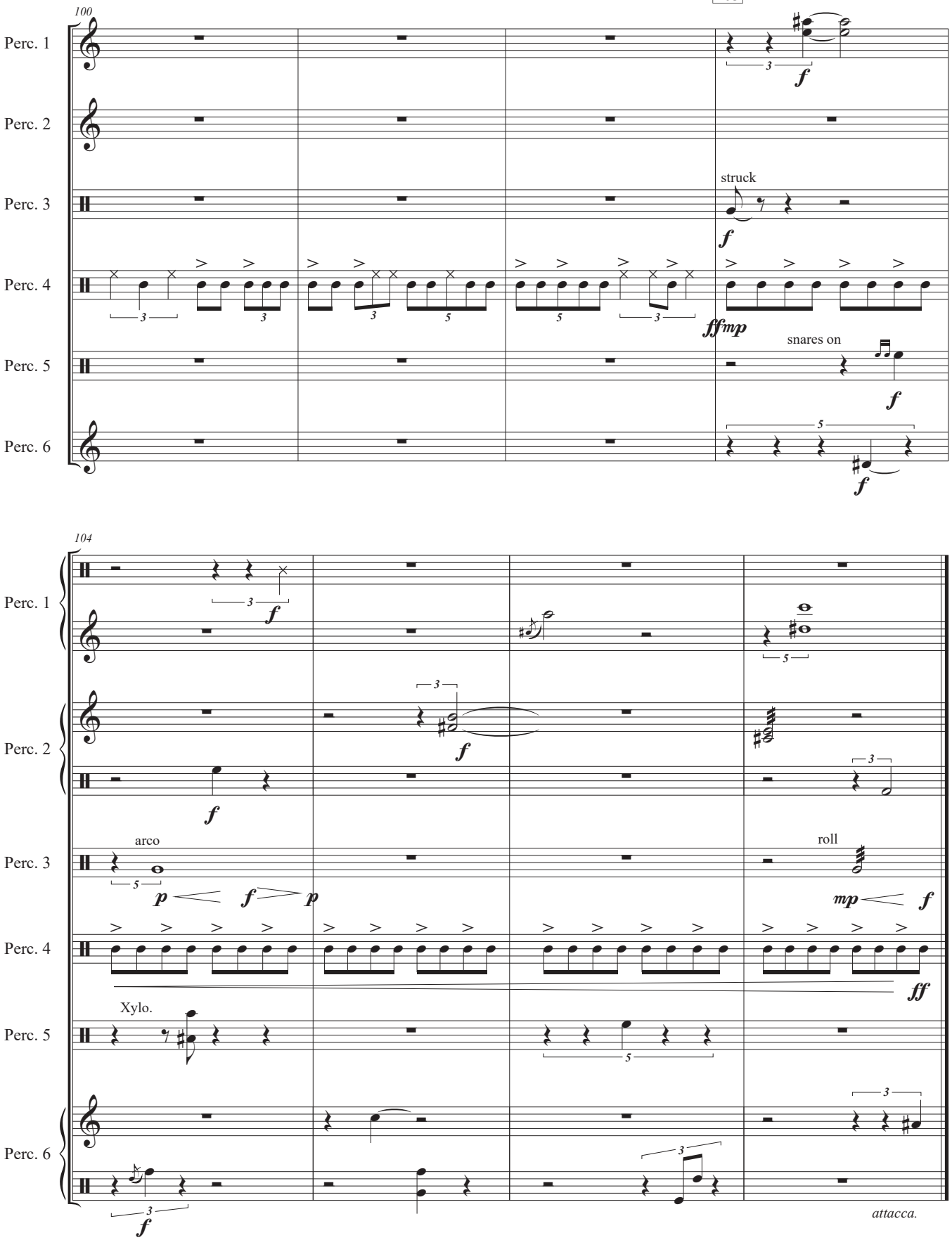

Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff
mp
f
ff
mf

88

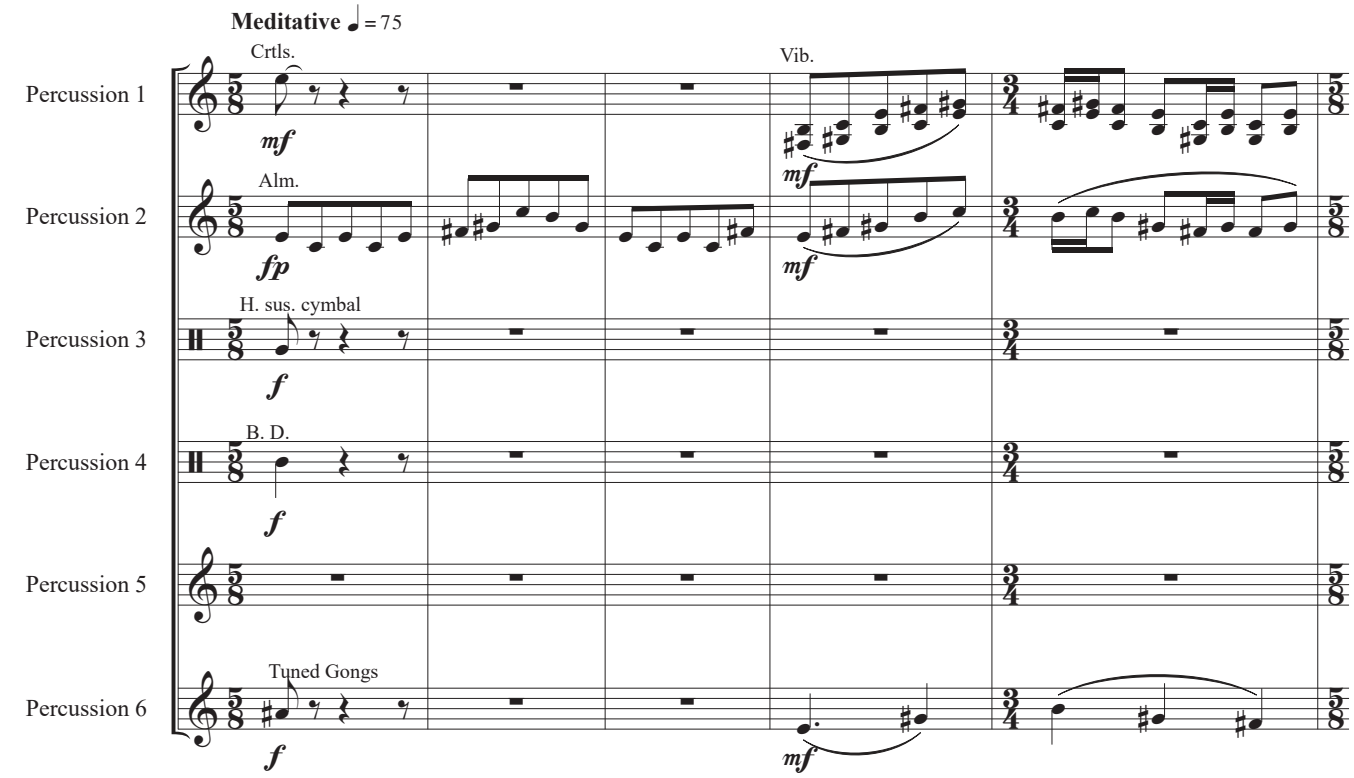

Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff

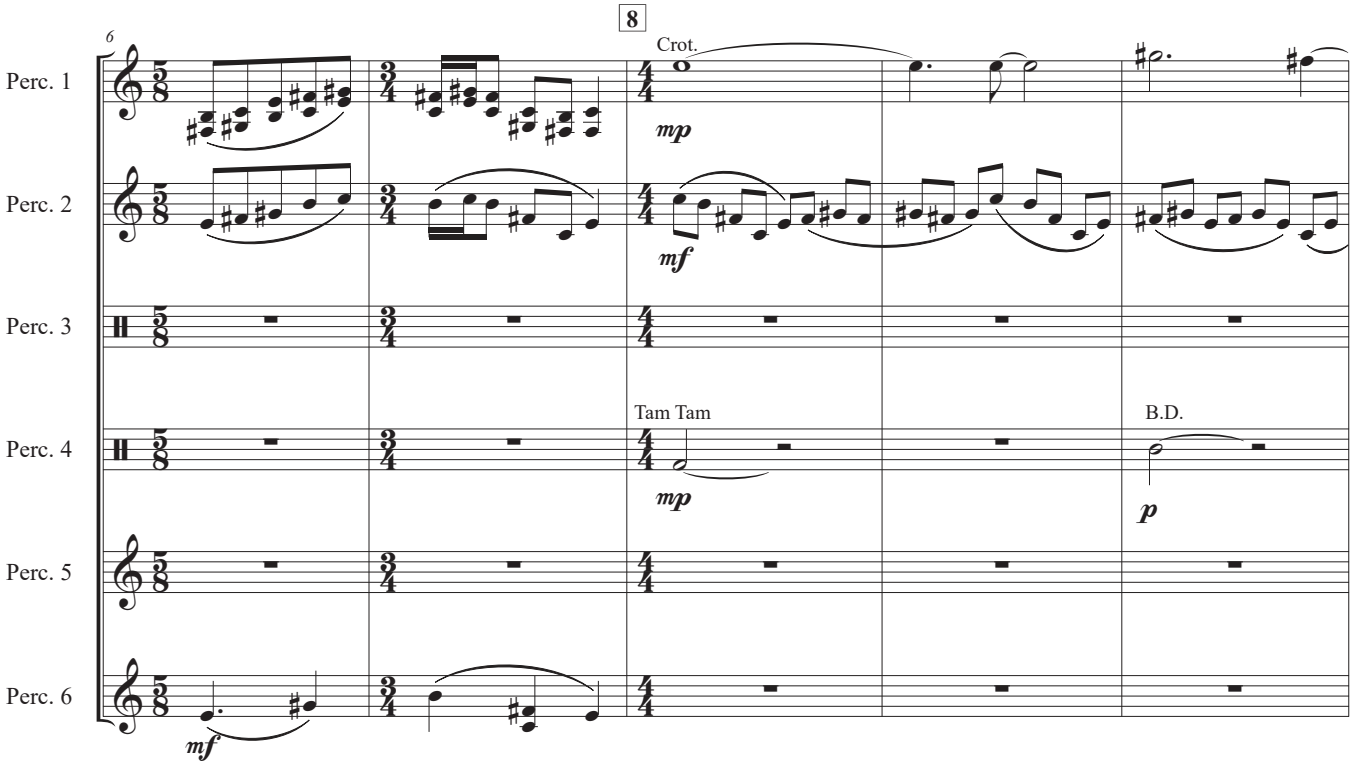

92
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
ff
mf

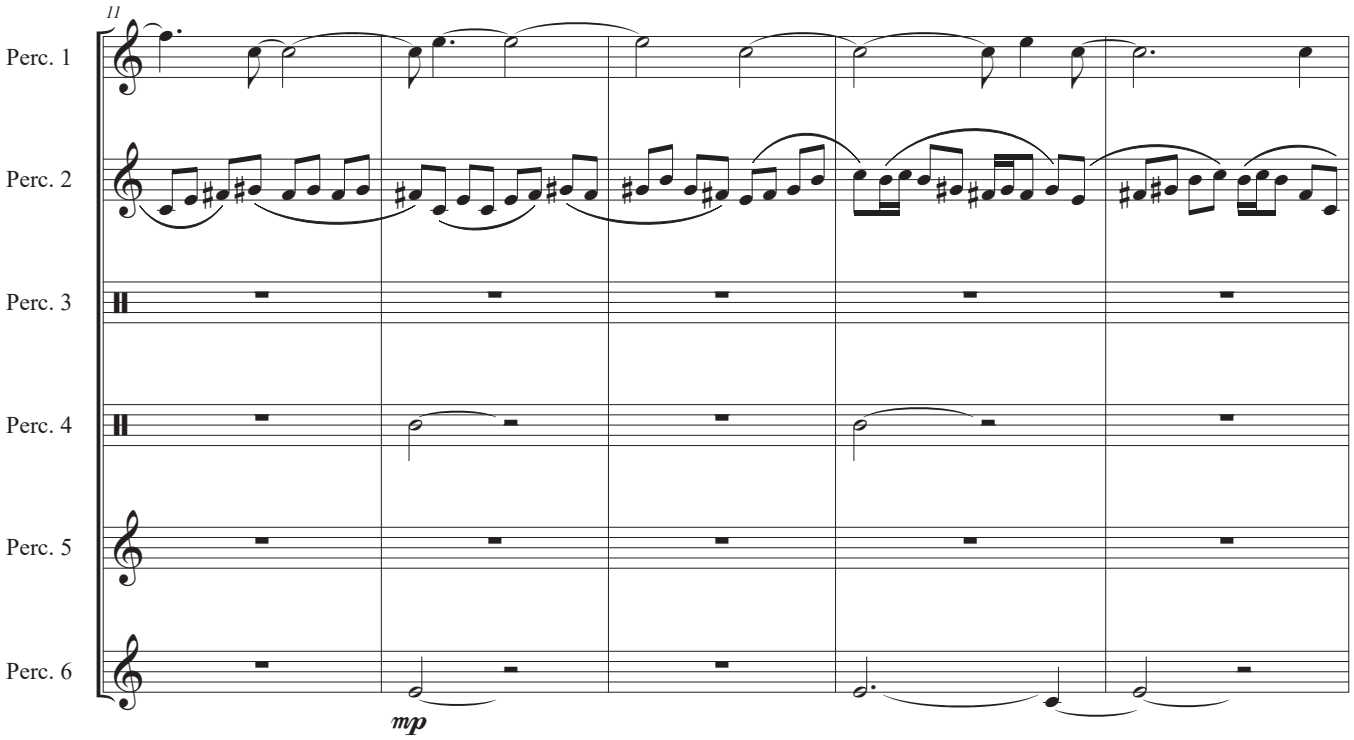

96
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff

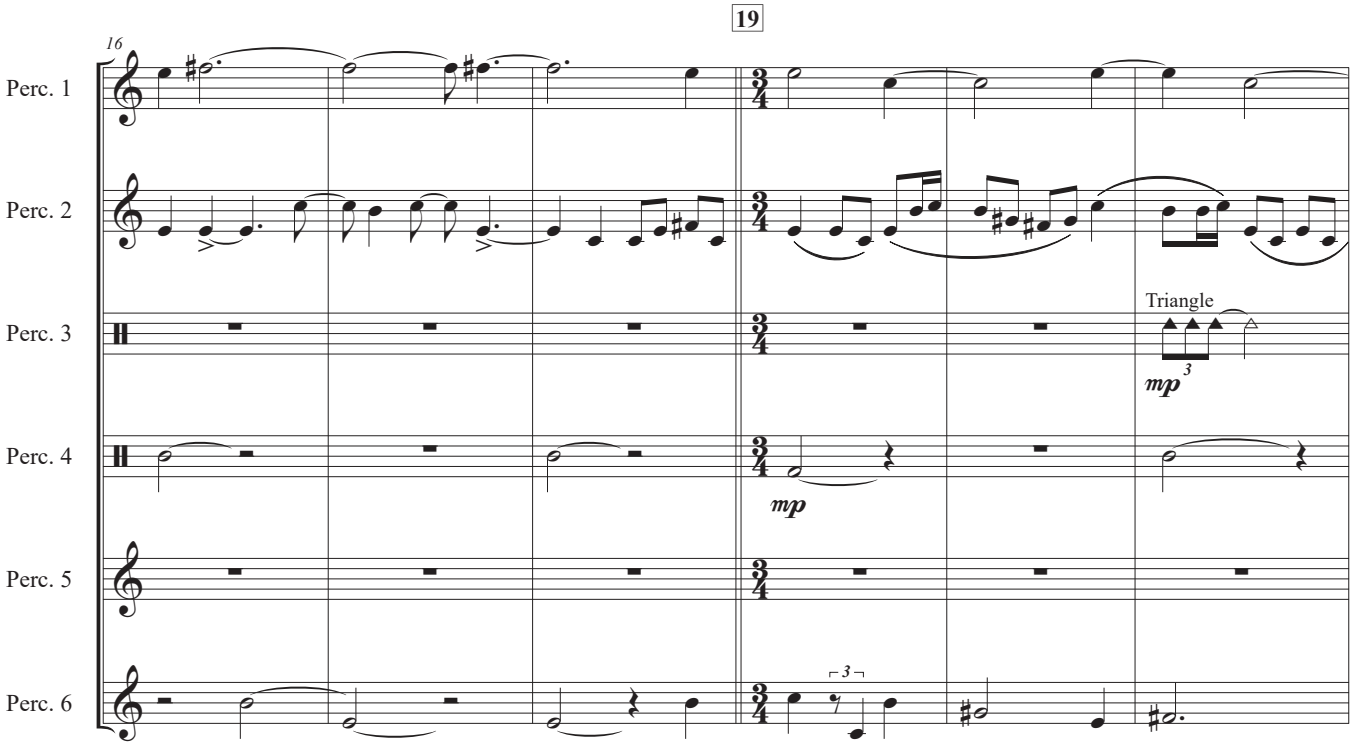

100
103
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
struck
snares on
104
arco
roll
Xylo.
attacca.

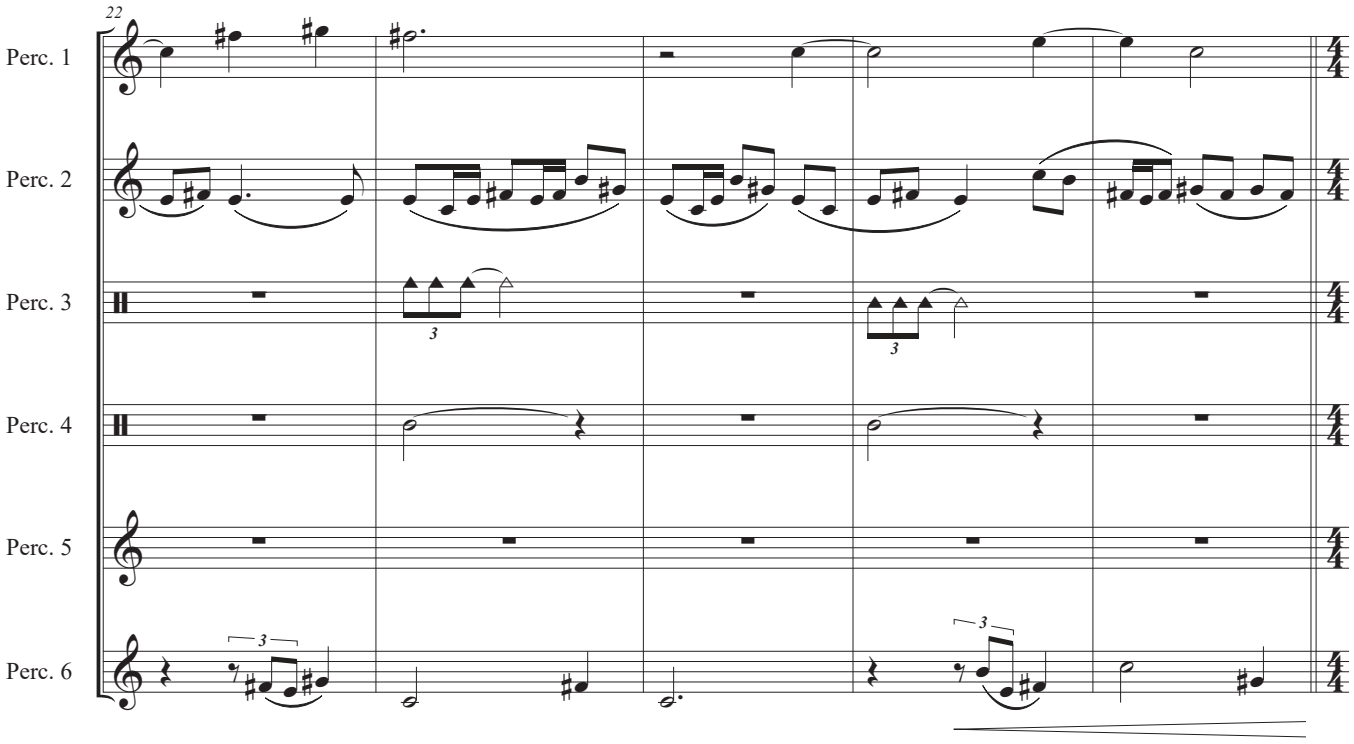
V.

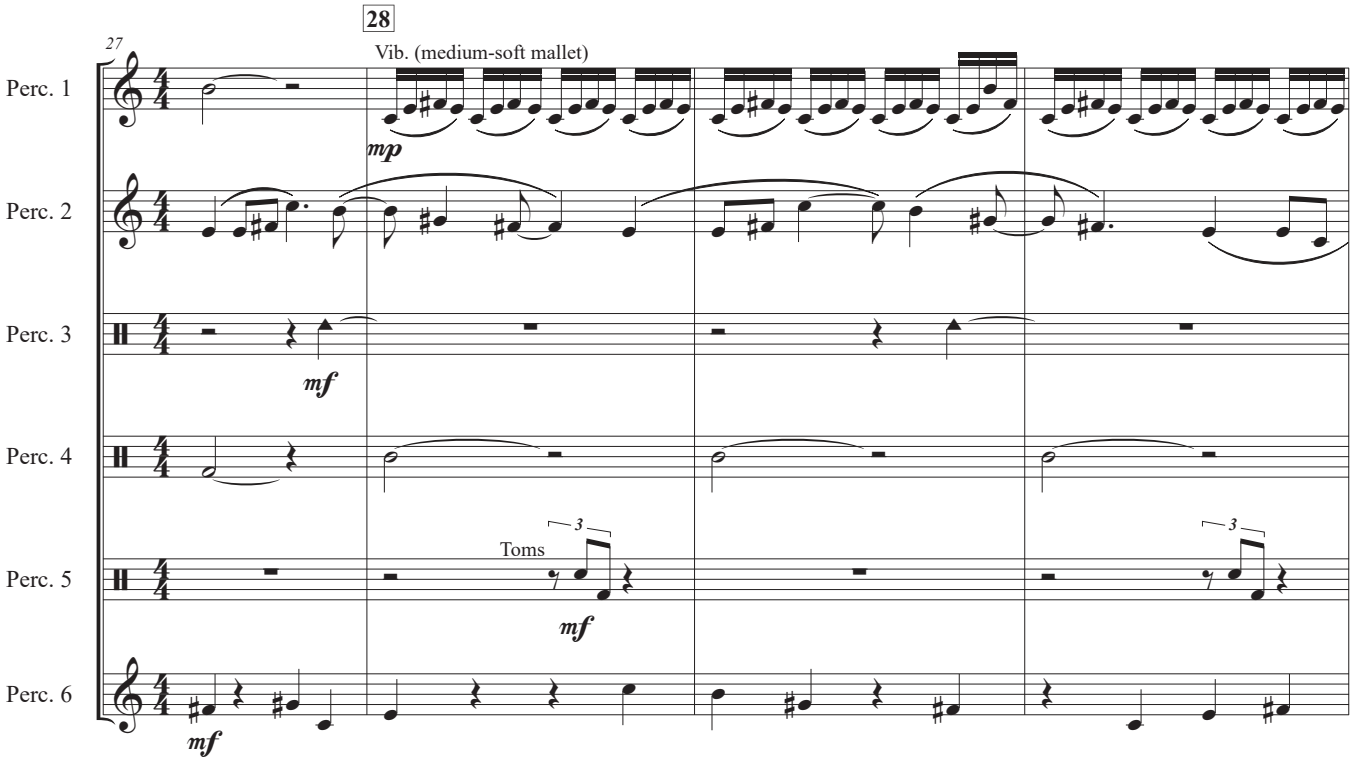

Meditative ♩ = 75
Crtls.
Vib.
Percussion 1
Alm.
Percussion 2
H. sus. cymbal
Percussion 3
B. D.
Percussion 4
Percussion 5
Tuned Gongs
Percussion 6
mf
fp
f

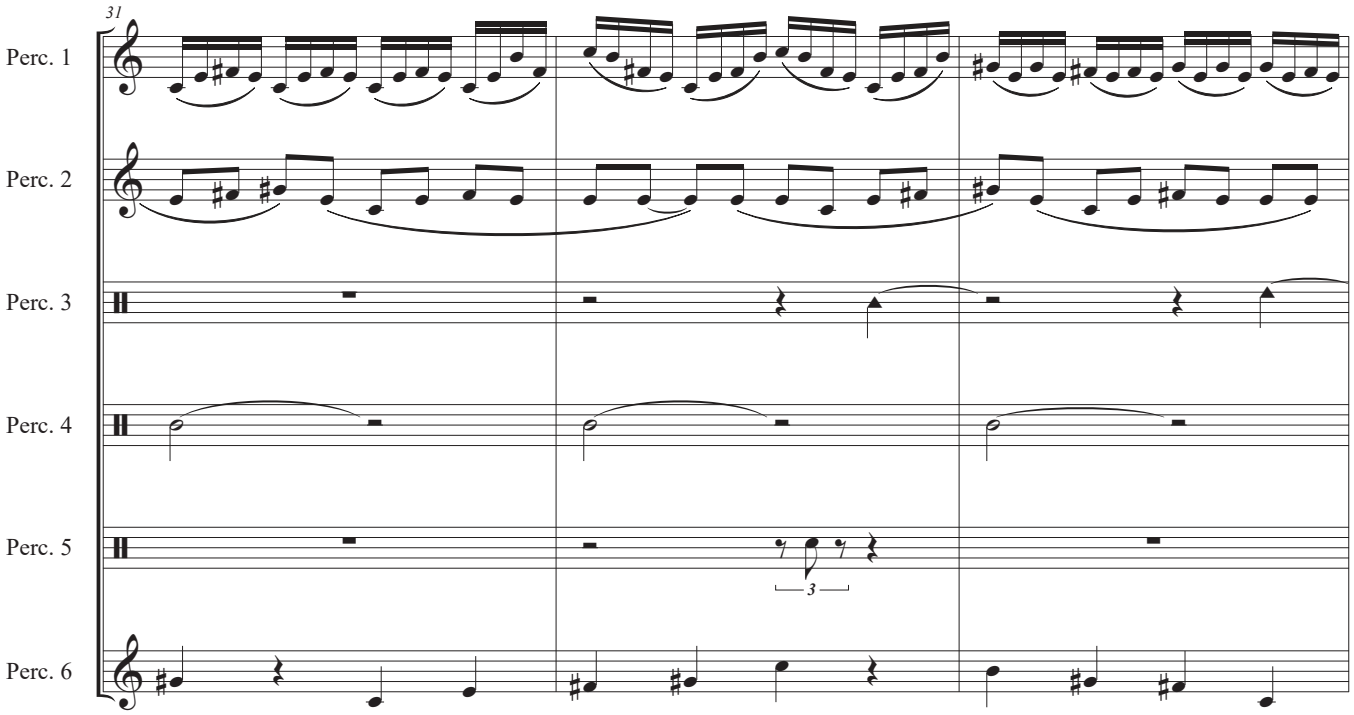

6
8
Crot.
Perc. 1
Perc. 2
Perc. 3
Tam Tam
B.D.
Perc. 4
Perc. 5
Perc. 6
mp
mf
p

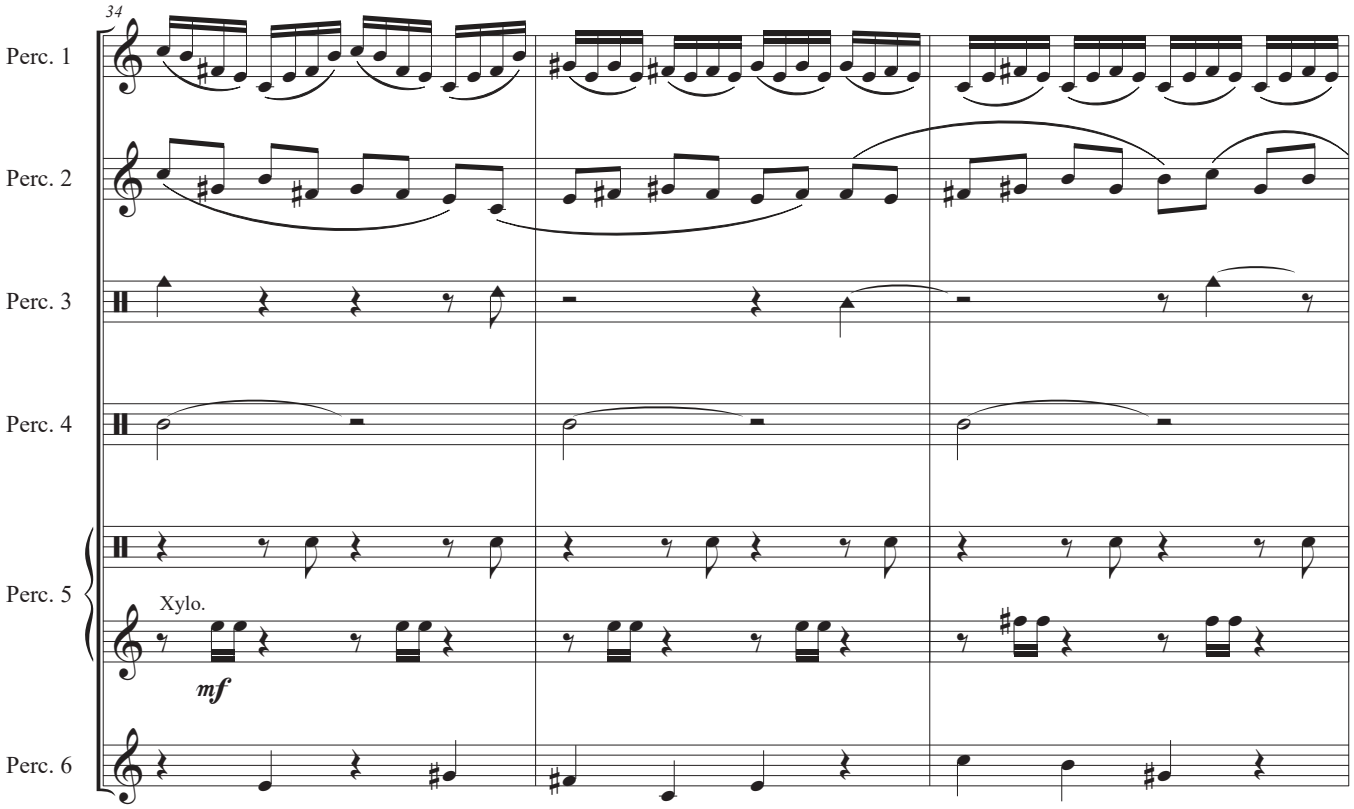

11
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mp

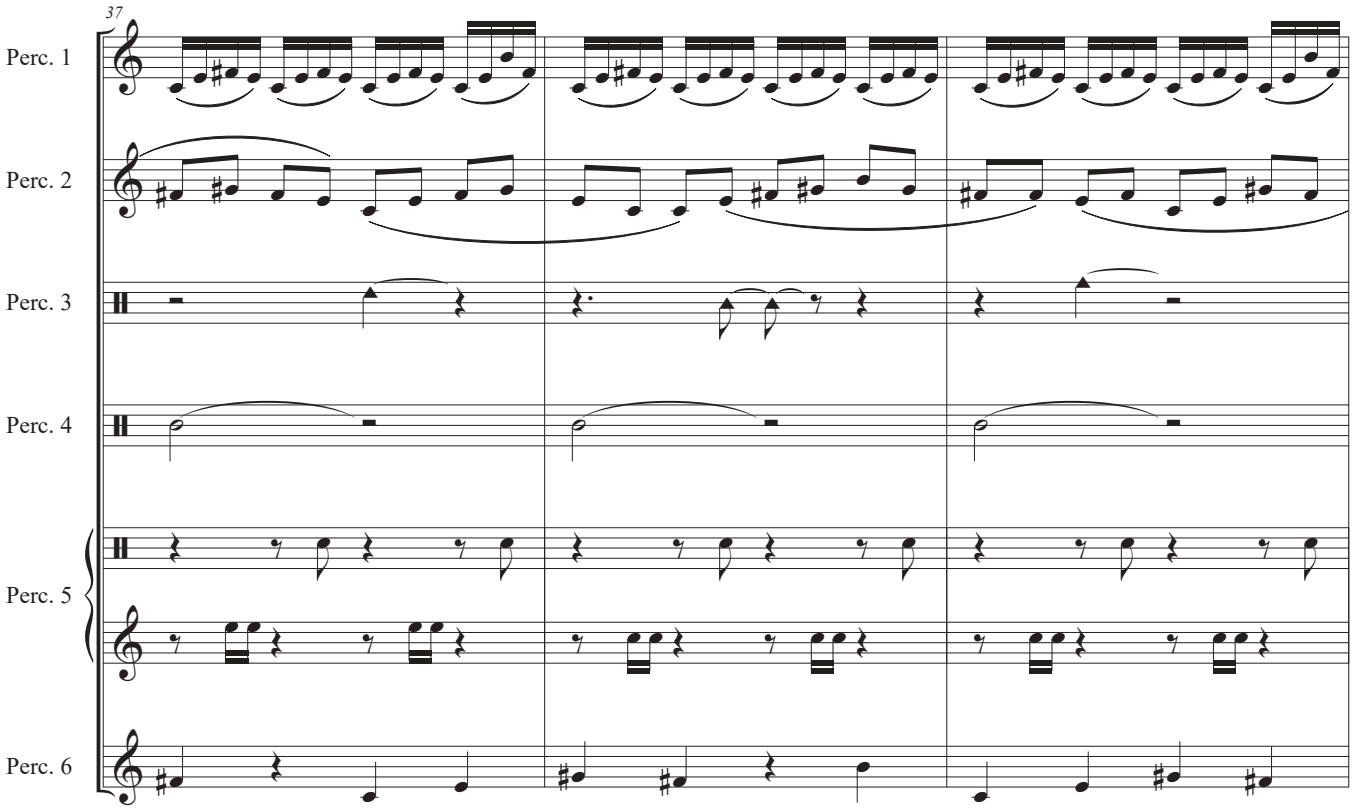

19
16
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
Triangle
mp
3
mp
3

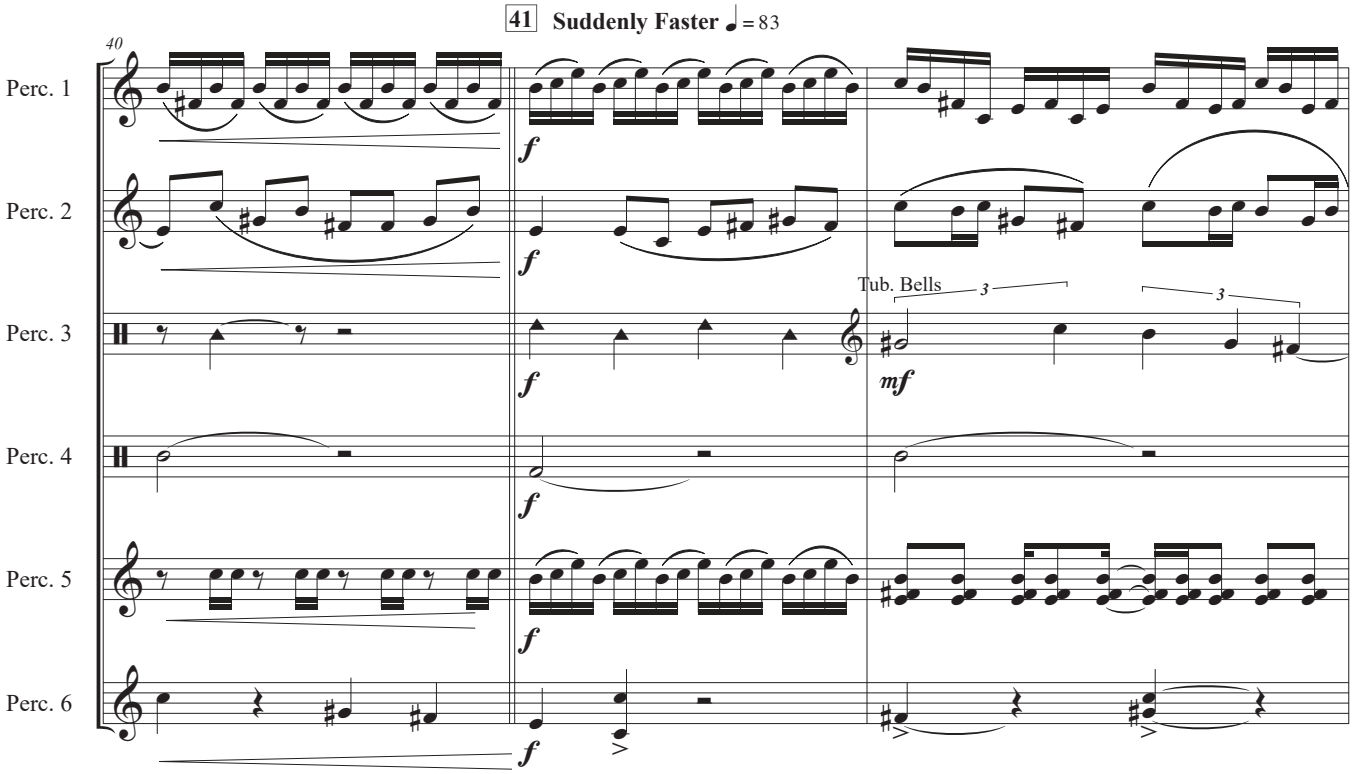

22
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
3
3
3
3

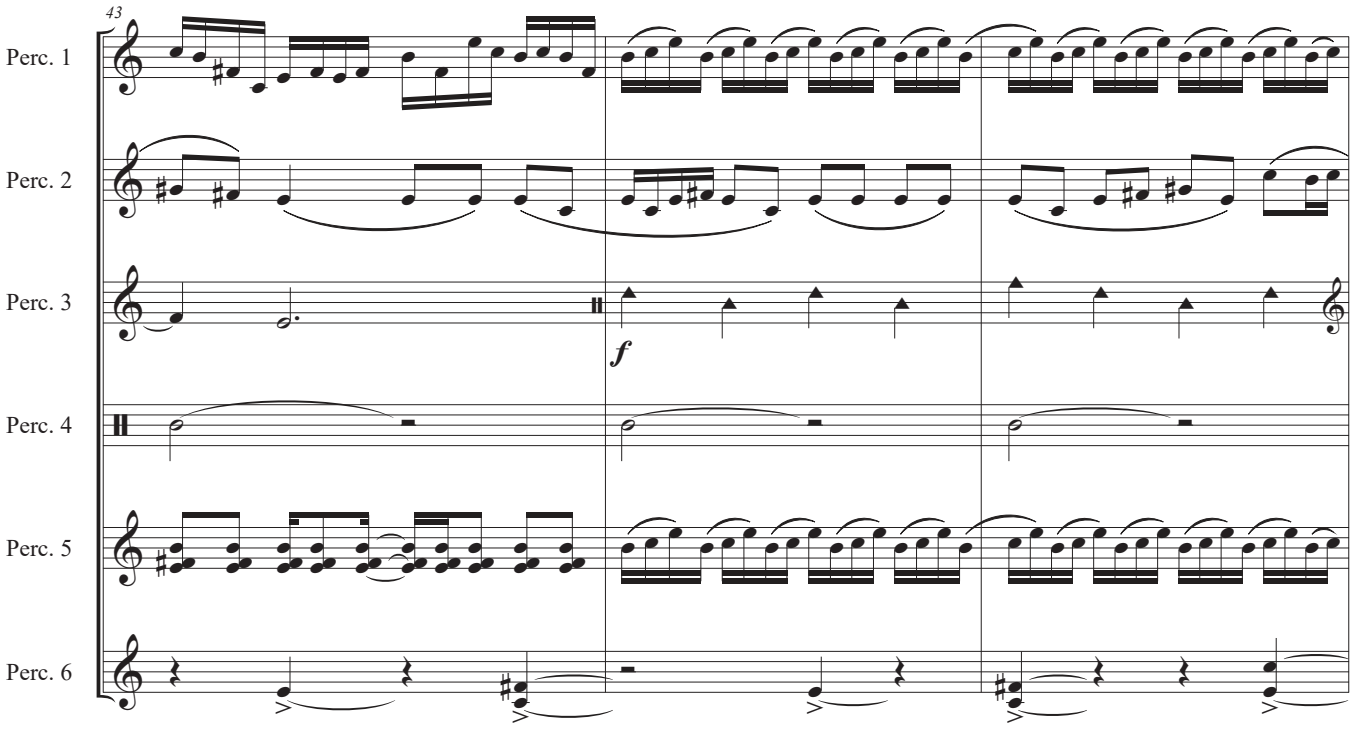

27
28
Vib. (medium-soft mallet)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mp
mf
mf
mf
Toms
3
3

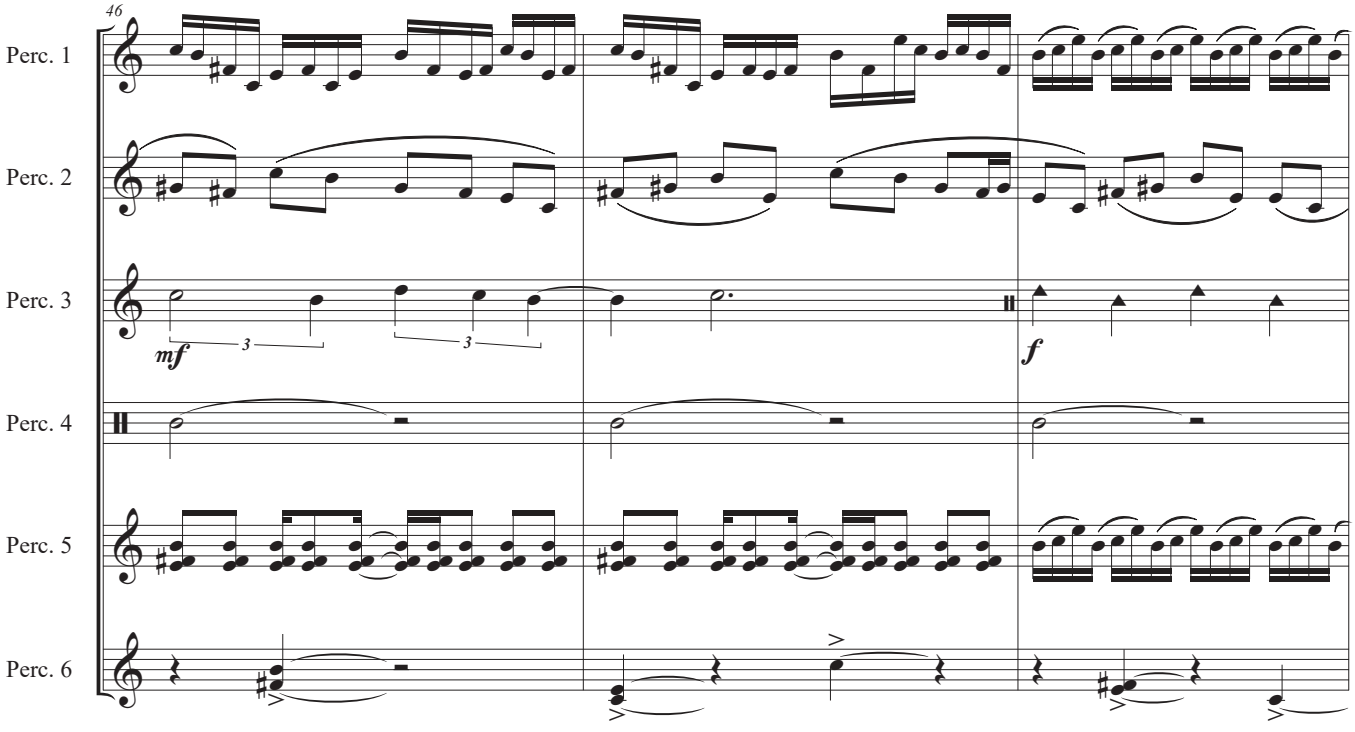

31
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
3
Perc. 6

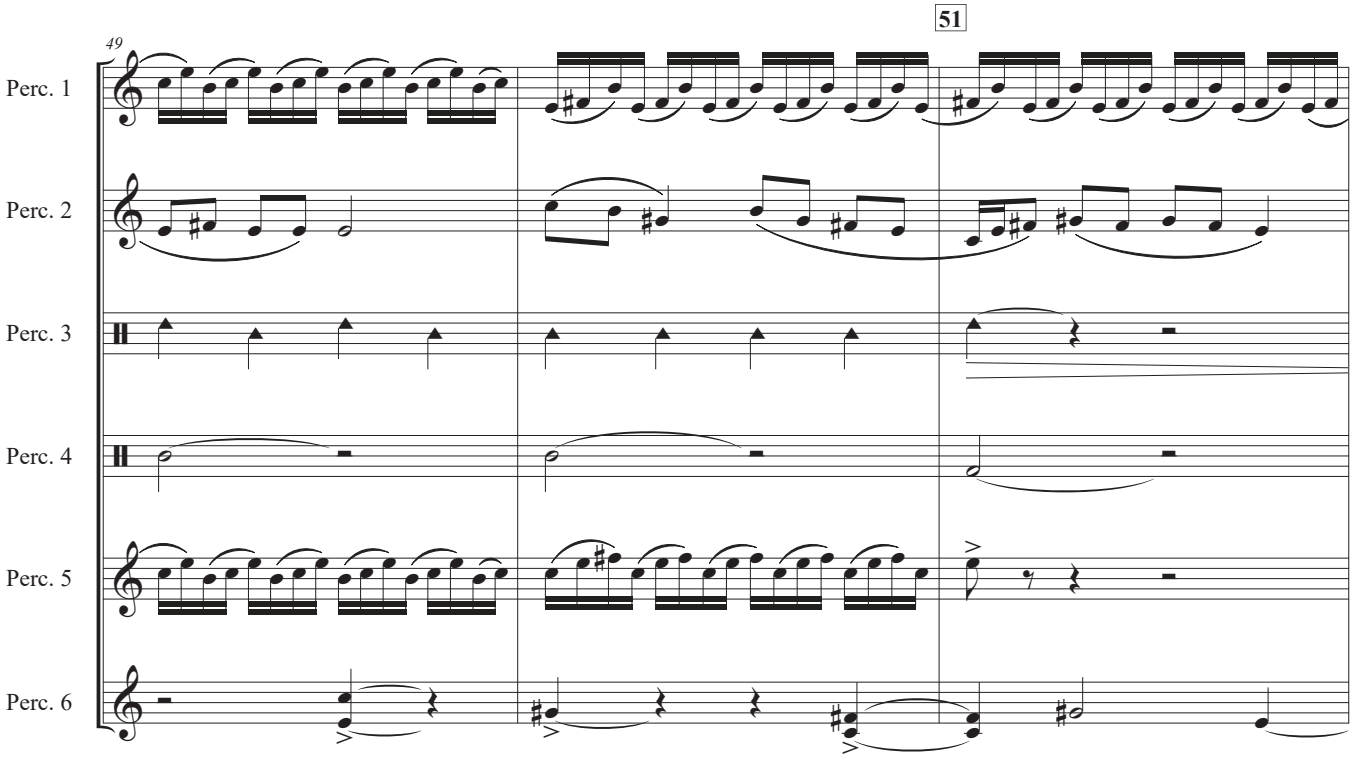

34
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Xylo.
mf
Perc. 6

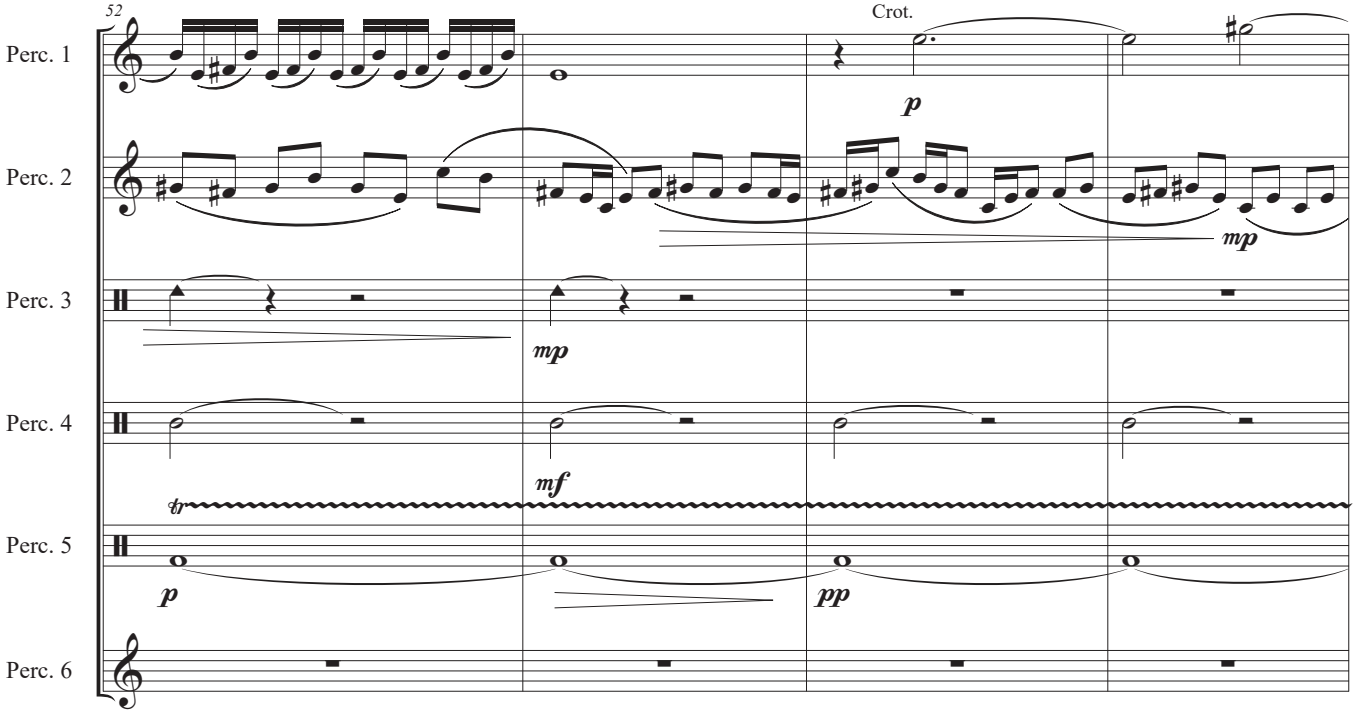

37
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

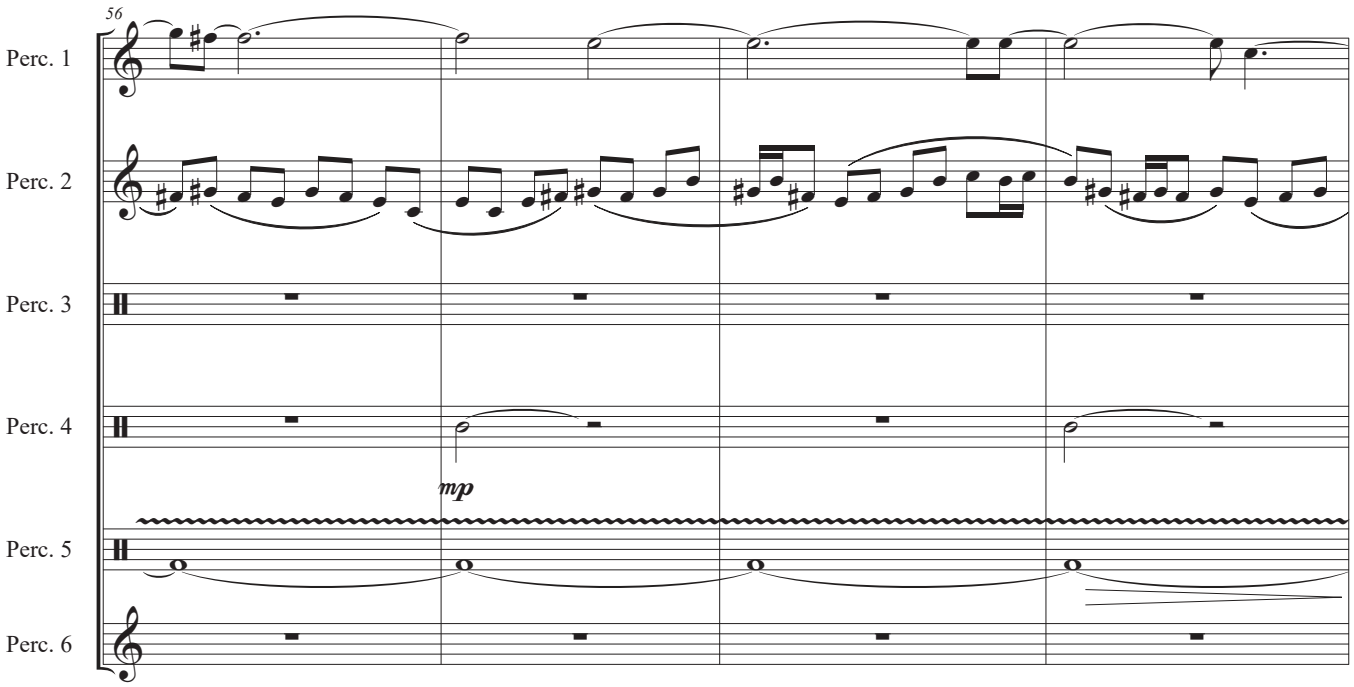

41 Suddenly Faster ♩ = 83
40
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
f
Tub. Bells
3
3
mf

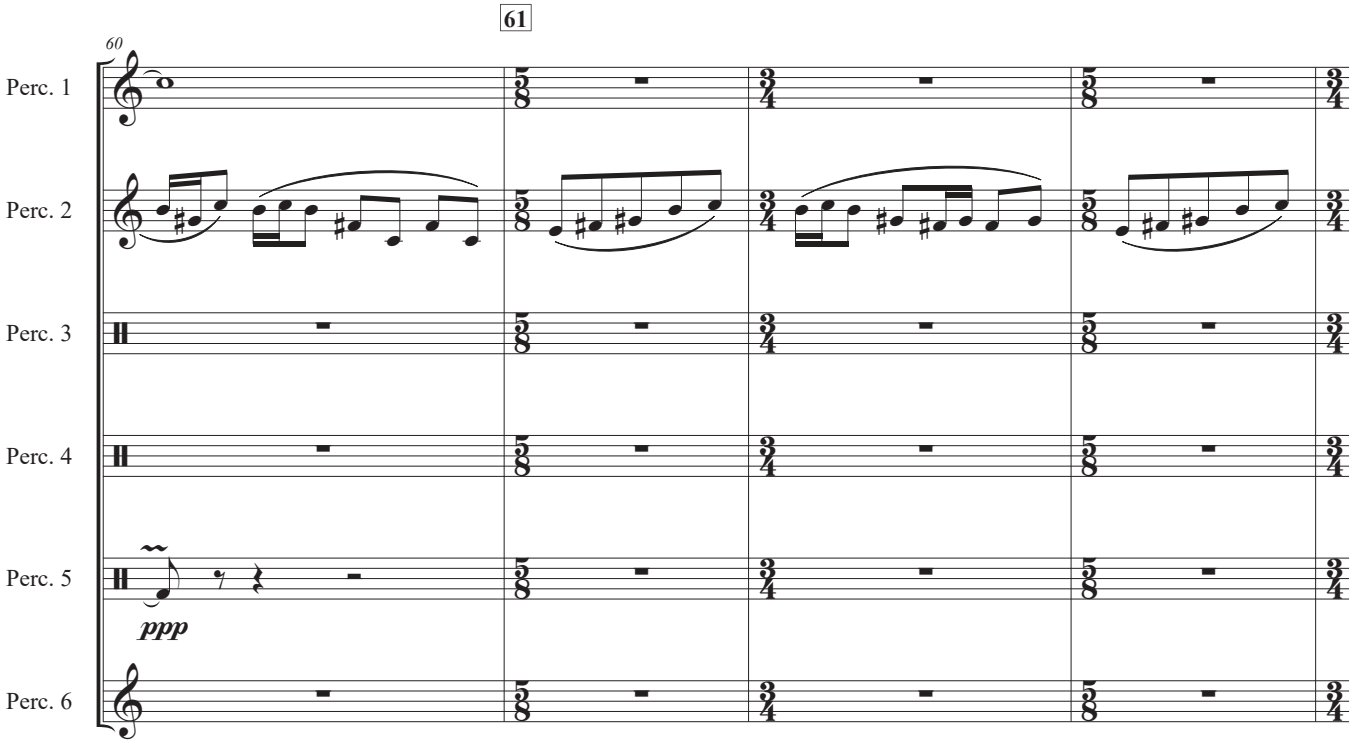

43
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
f

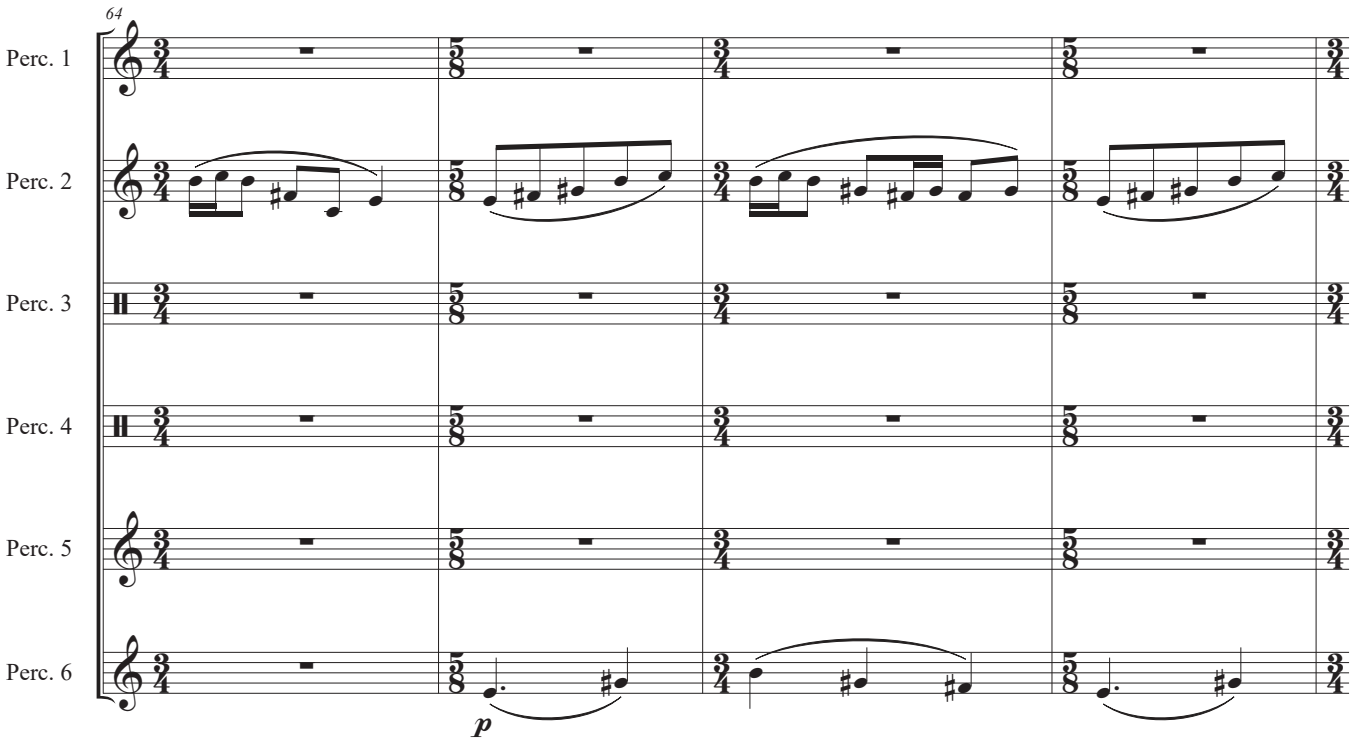

46
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
3
3
f

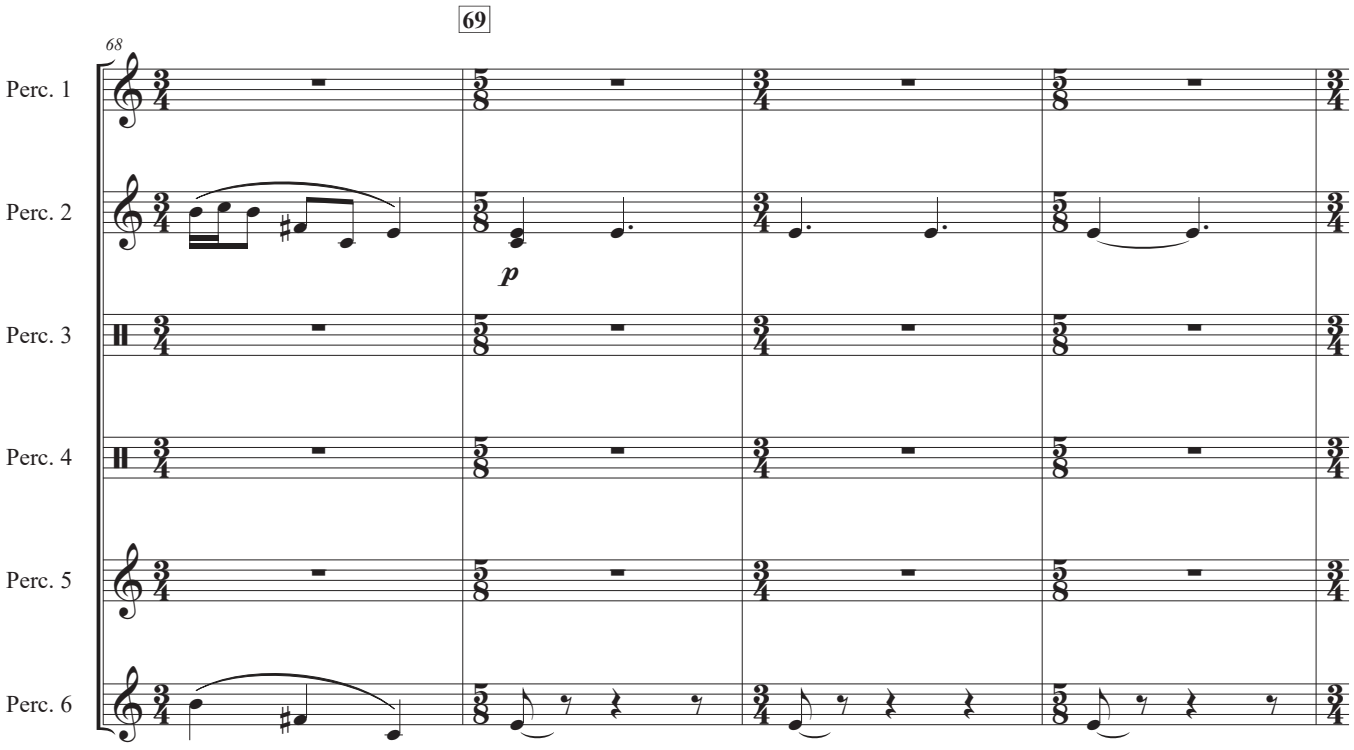

51
49
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

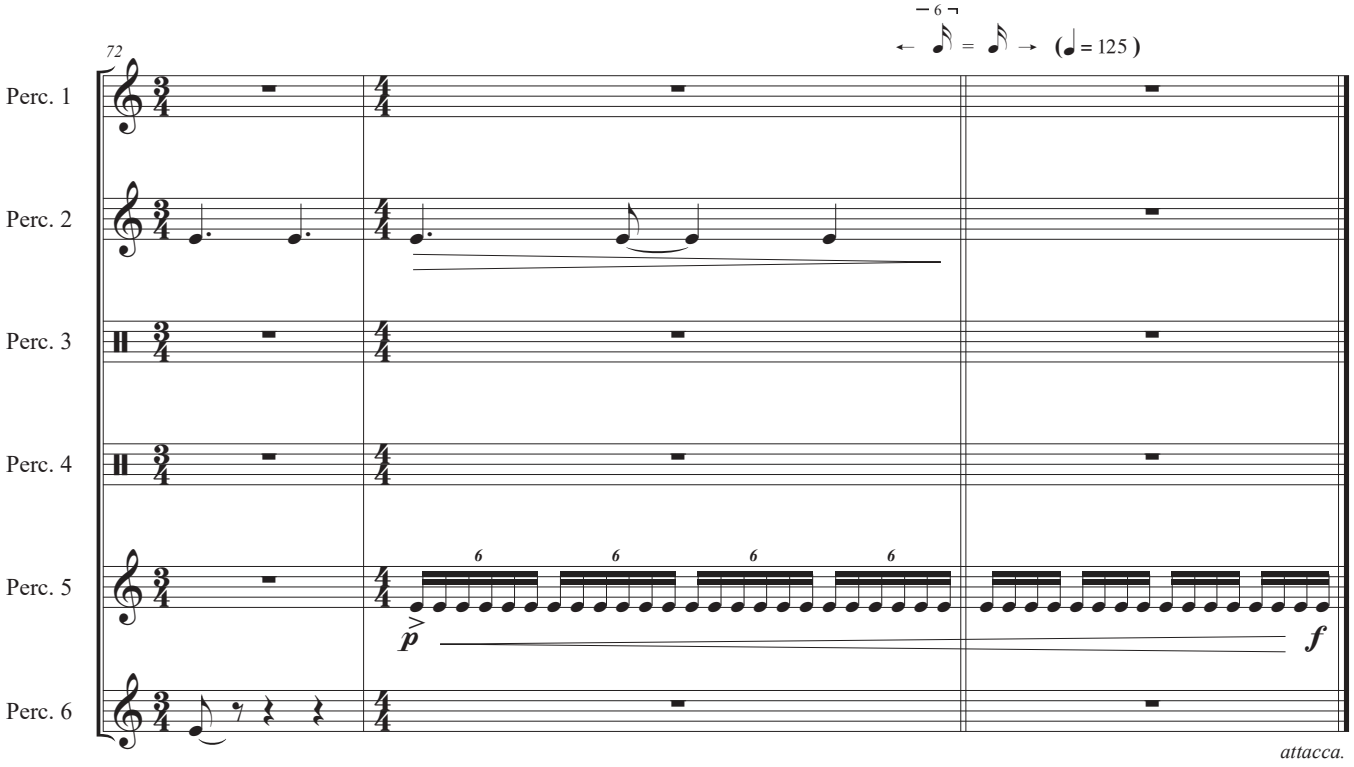

52
Crot.
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
mp
mf
tr
pp


56
Perc. 1
Perc. 2
Perc. 3
Perc. 4
mp
Perc. 5
Perc. 6

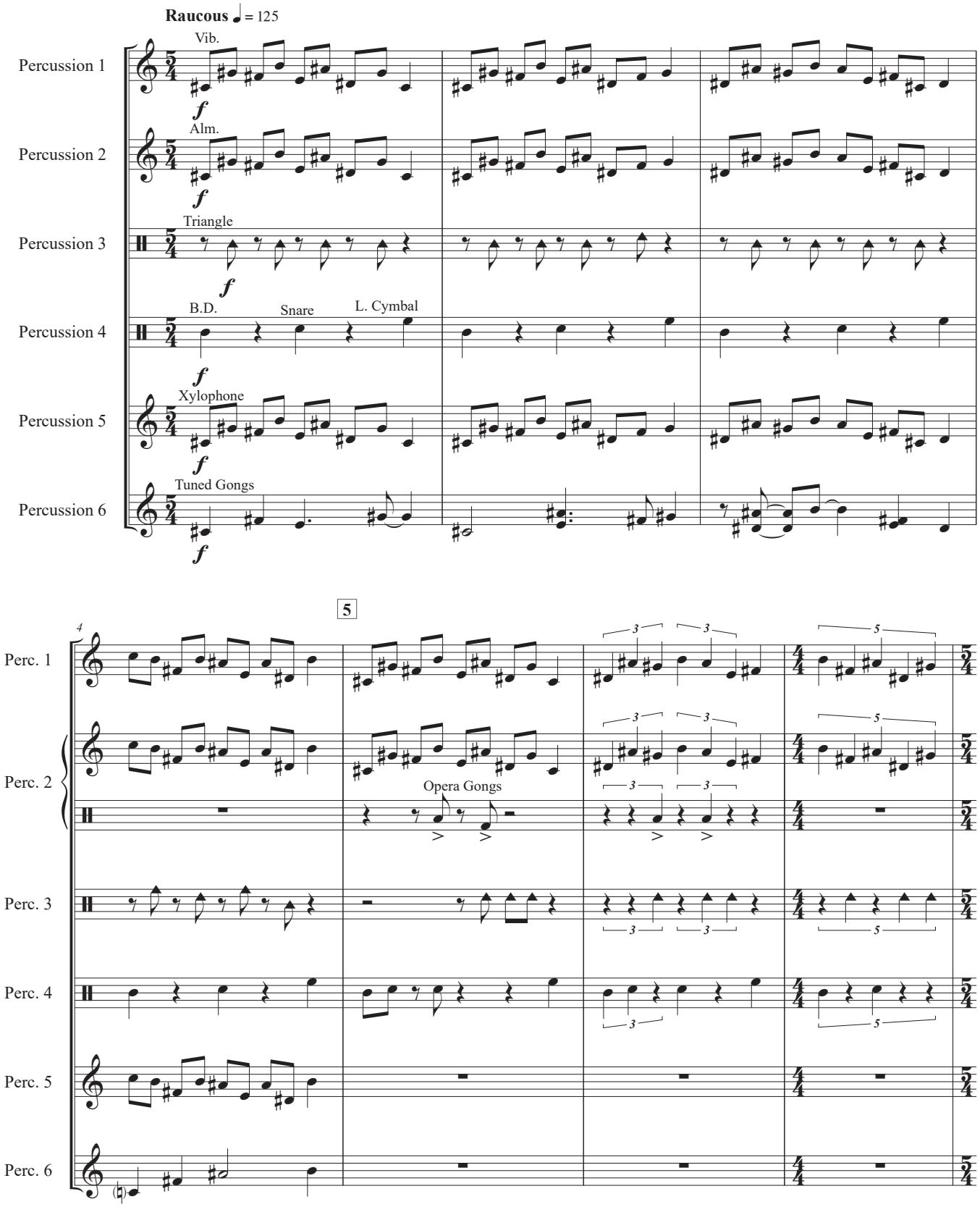

61
60
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
ppp
Perc. 6

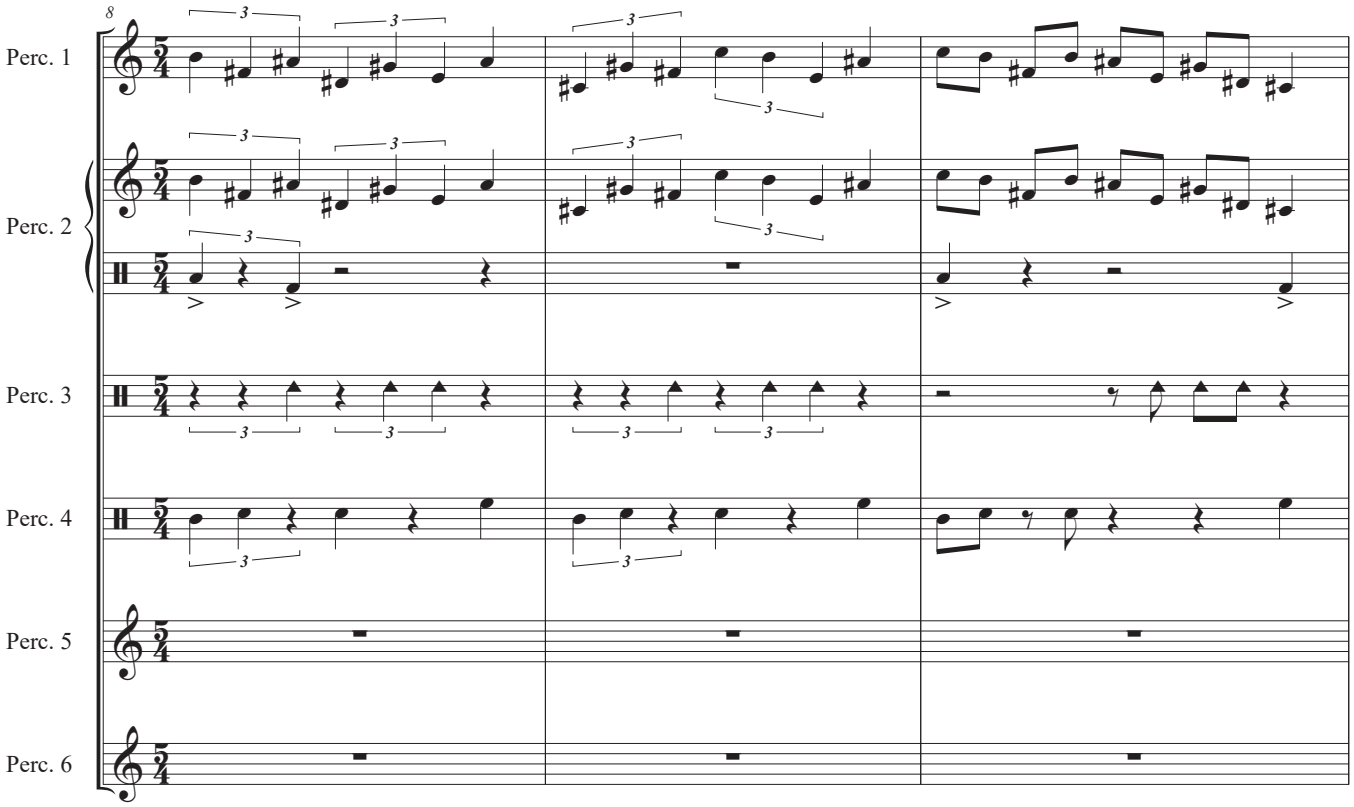

64
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p

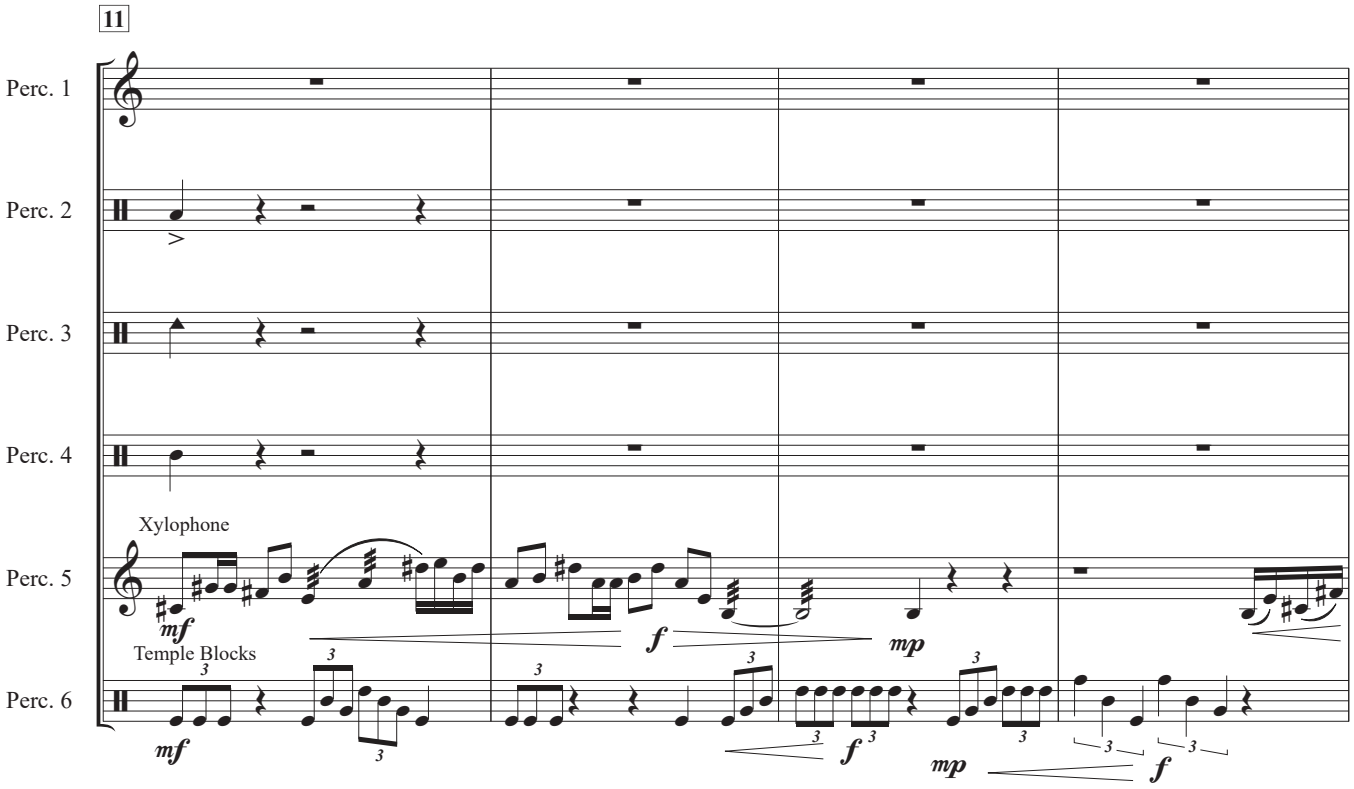

69
68
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p

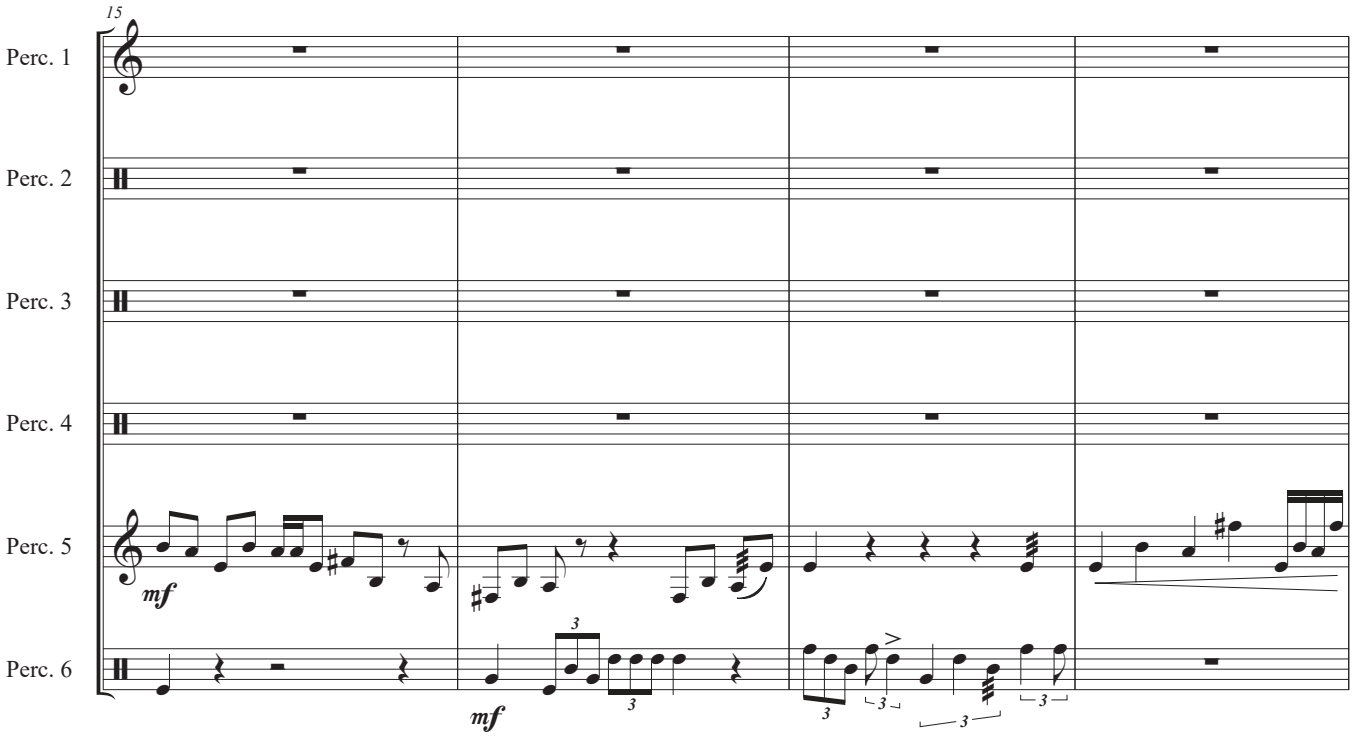

72
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
6
(♩= 125)
p
f
attacca.

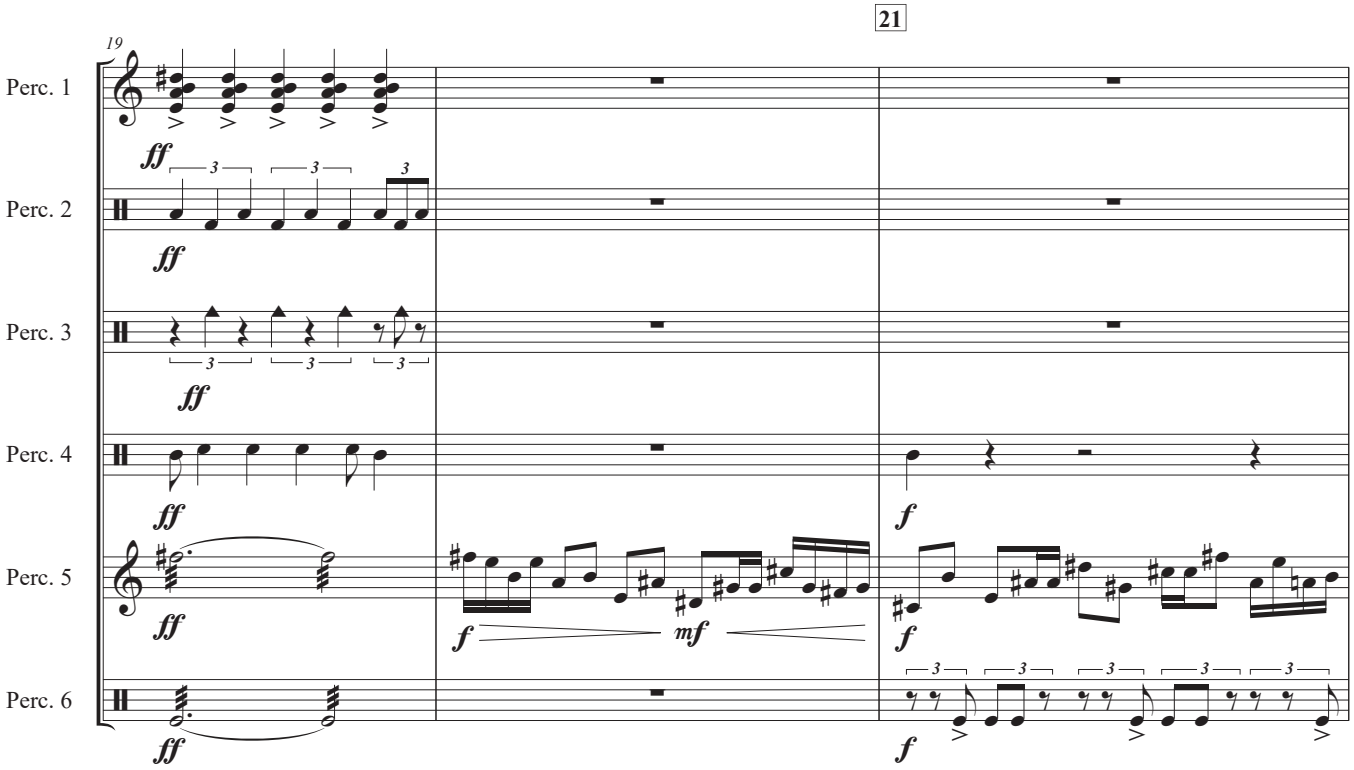
VI.

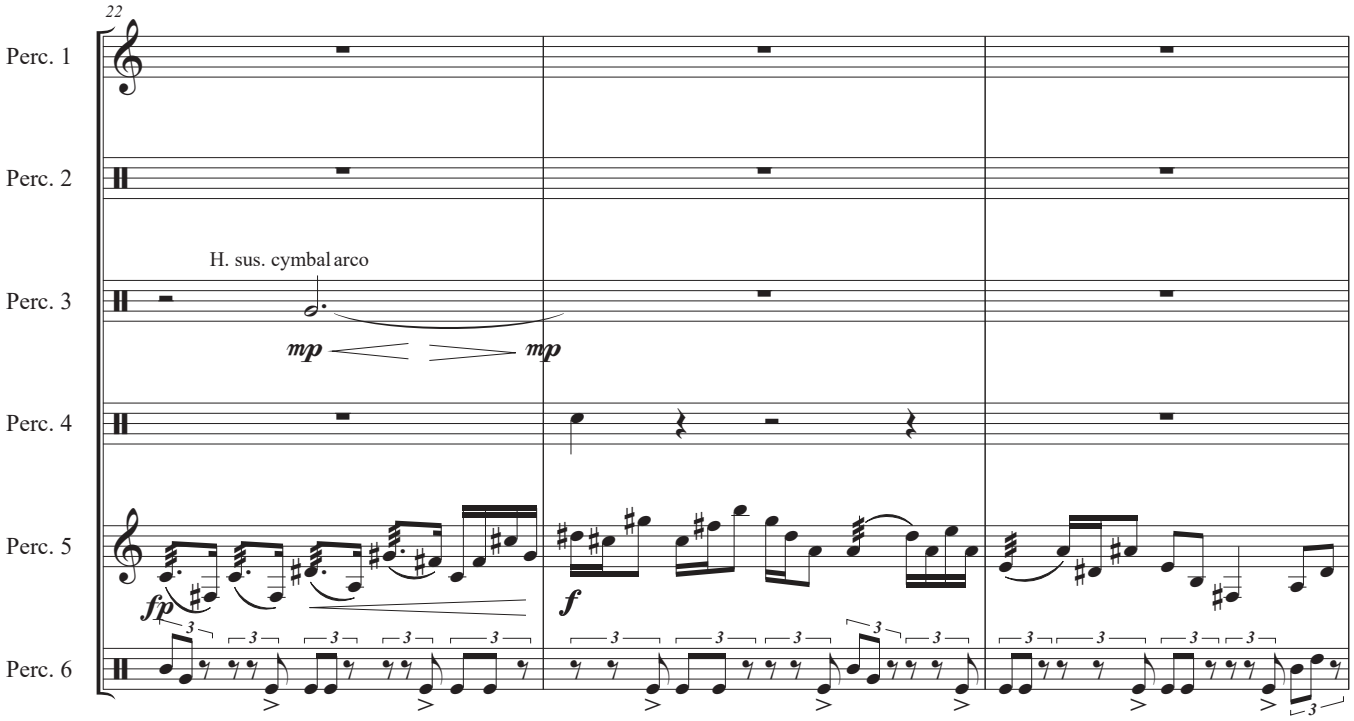

Raucous ♩= 125
Vib.
Percussion 1
Alm.
Percussion 2
Triangle
Percussion 3
B.D.
Snare
L. Cymbal
Percussion 4
Xylophone
Percussion 5
Tuned Gongs
Percussion 6
5
Perc. 1
Perc. 2
Opera Gongs
Perc. 3
Perc. 4
Perc. 5
Perc. 6

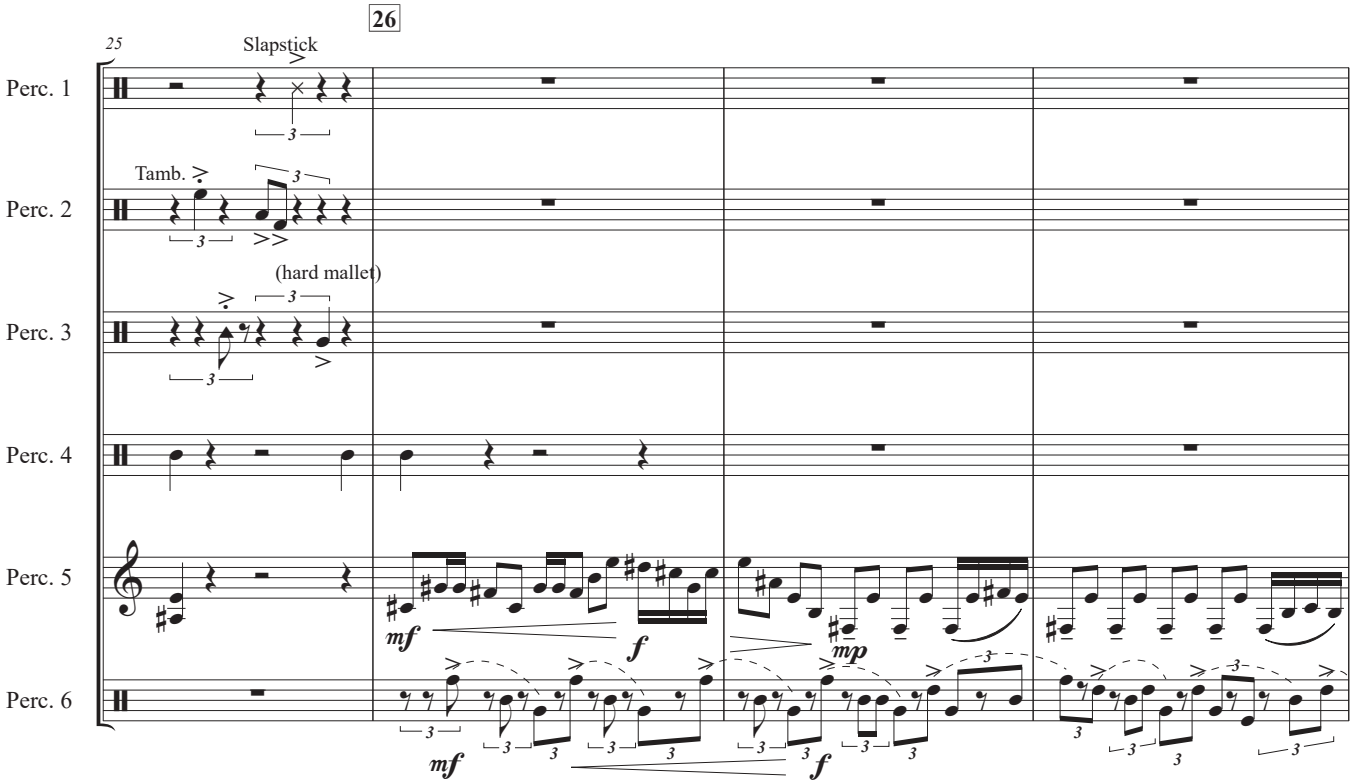

8
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

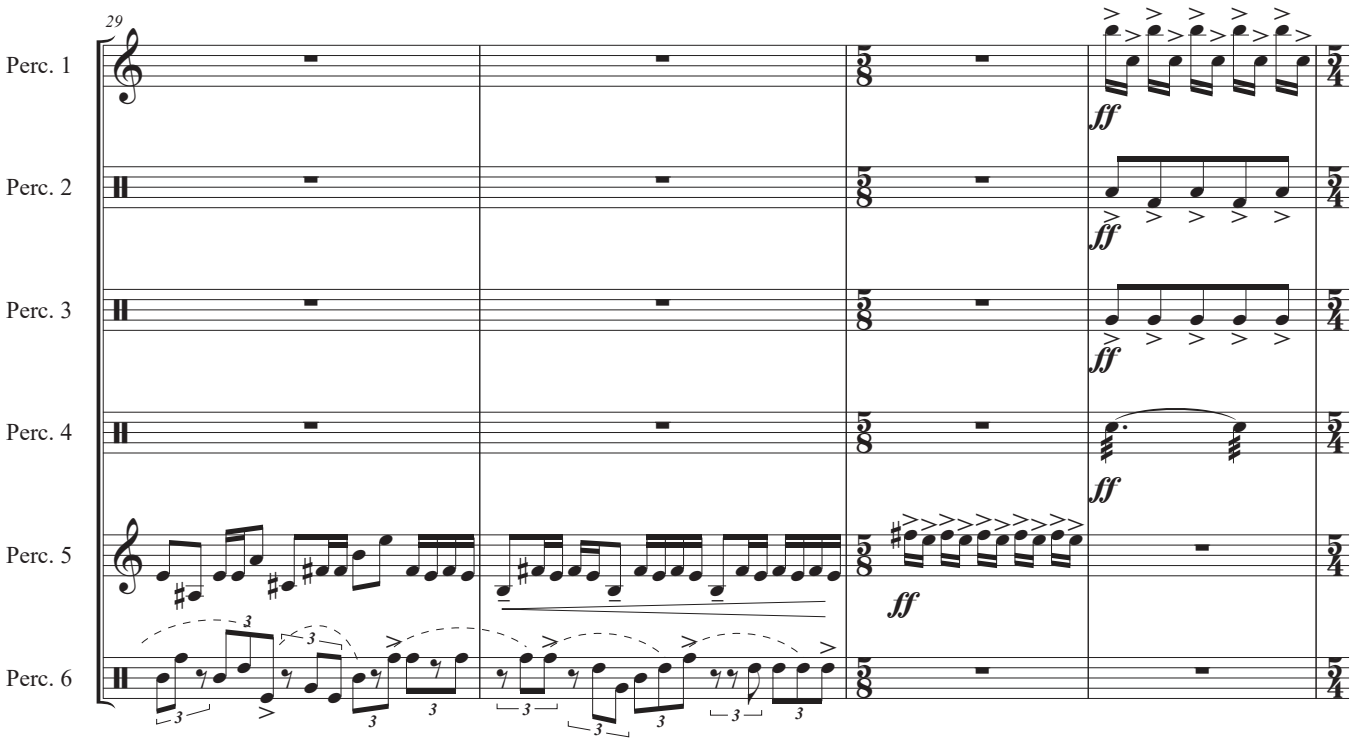

11
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Xylophone
Perc. 5
mf
f
mp
Temple Blocks
Perc. 6
mf
f
mp
f

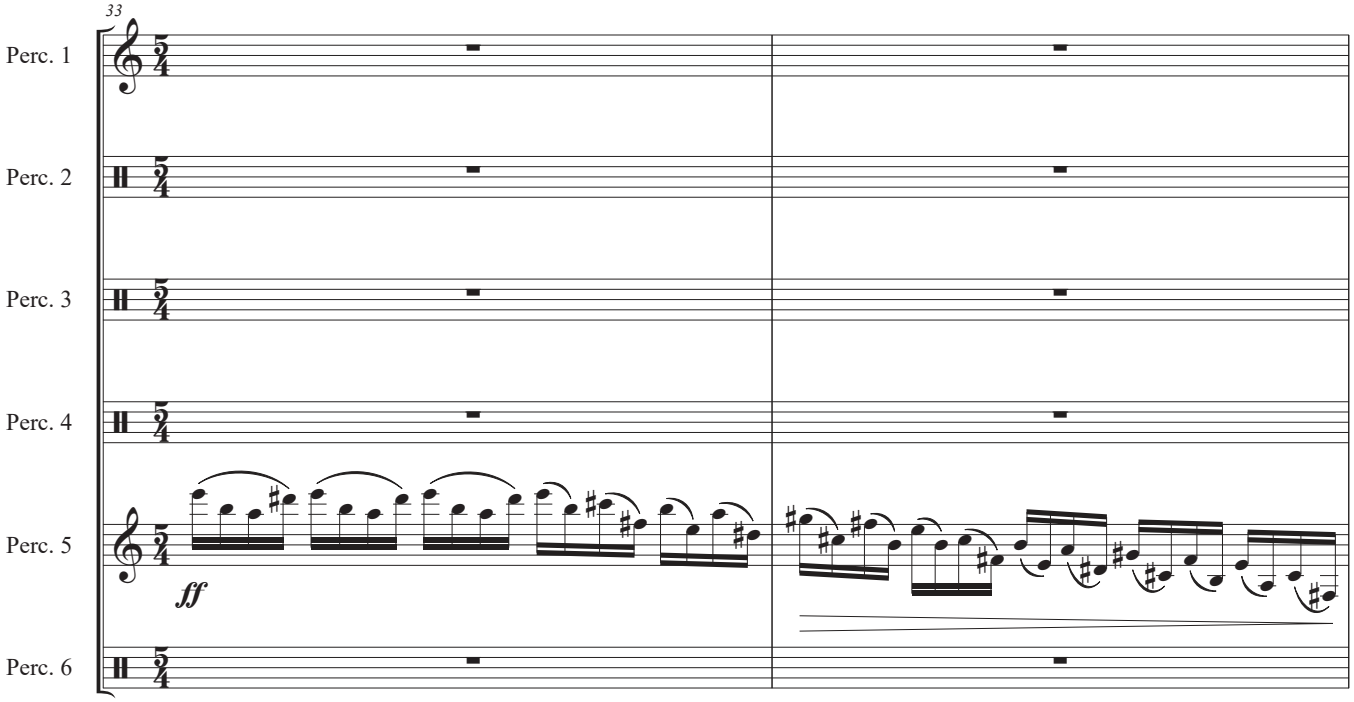

15
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
mf

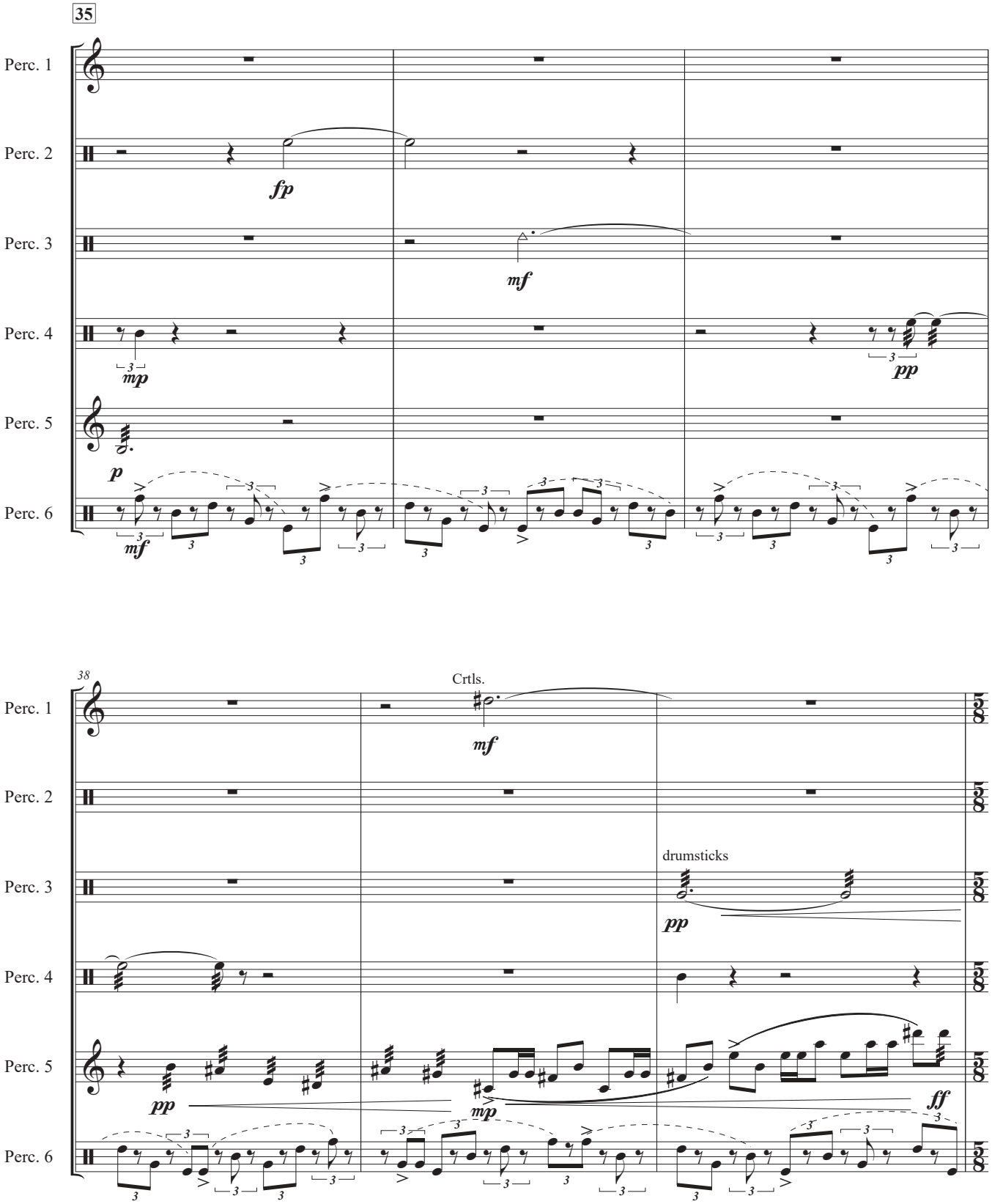

19
21
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff
f
mf

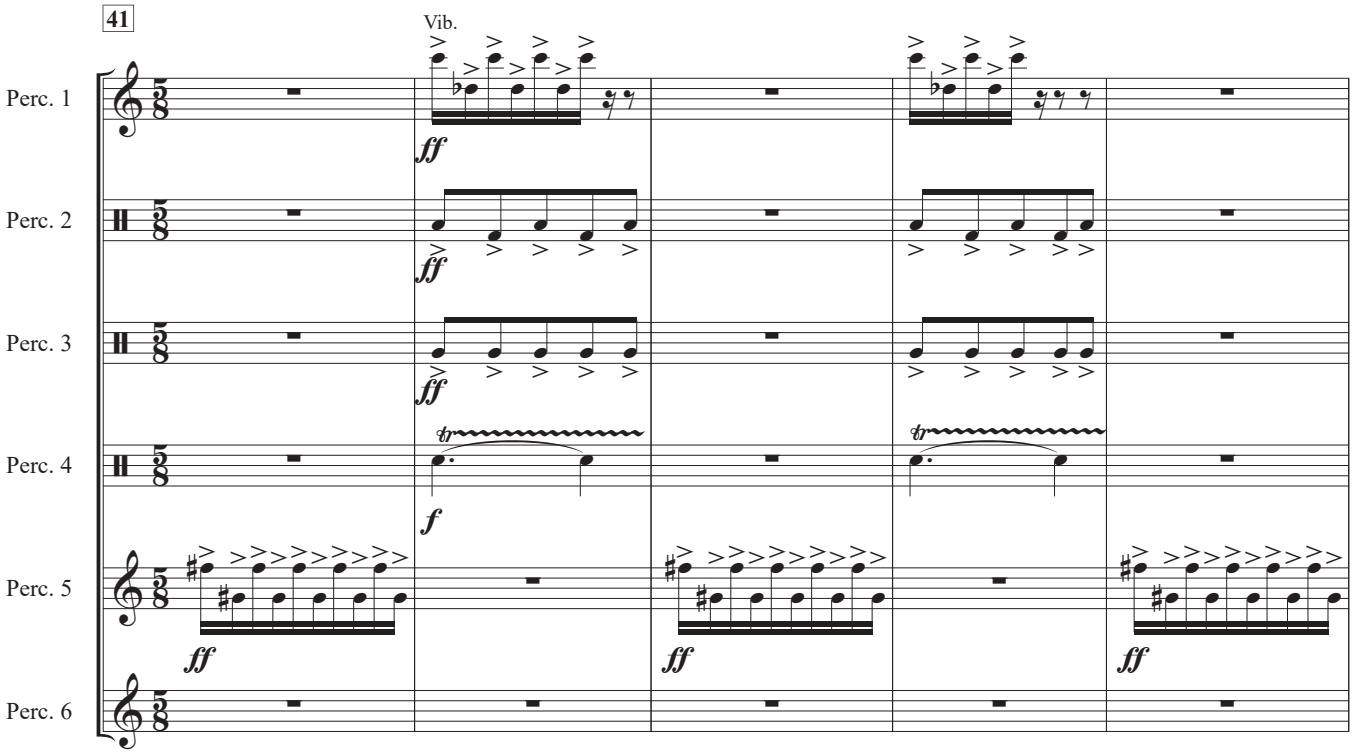

22
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
H. sus. cymbal arco
mp
mp
fp
f

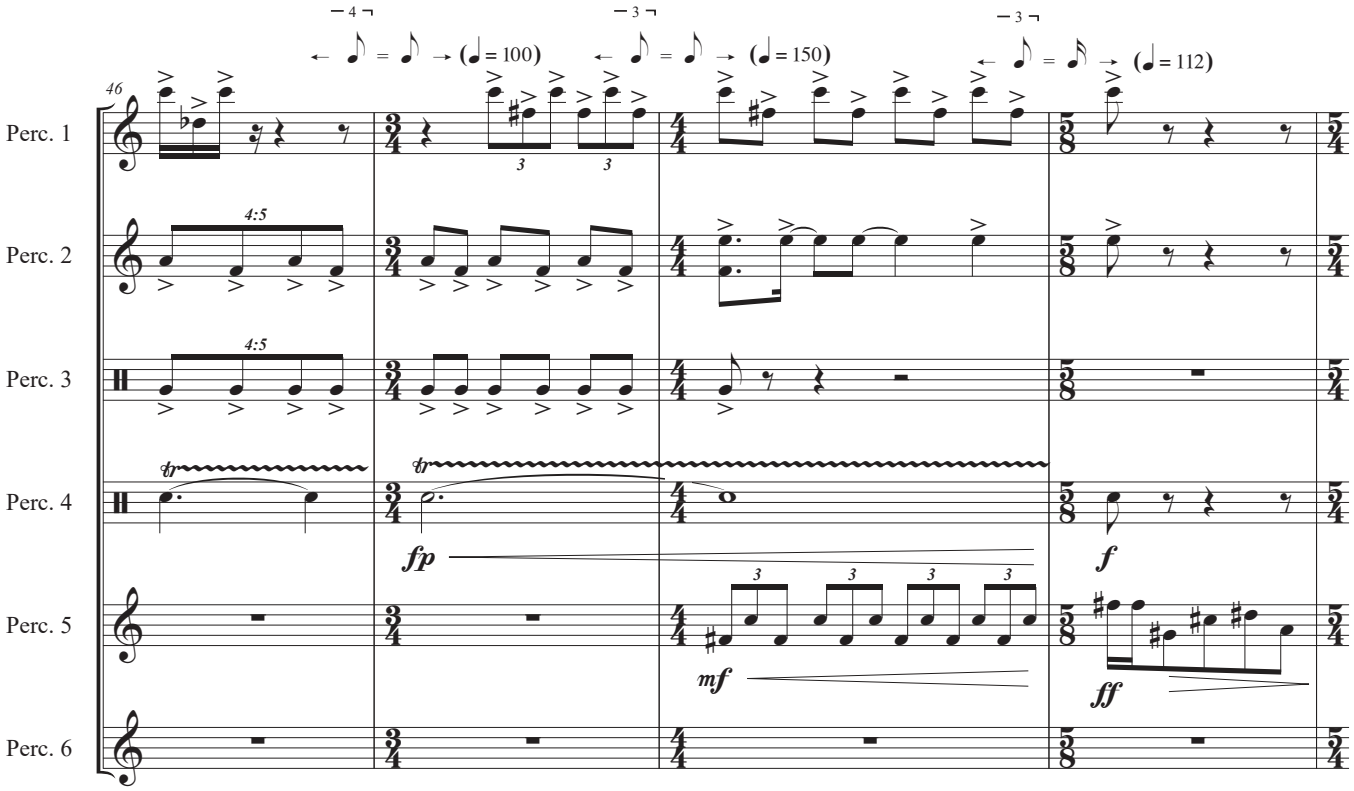

25
26
Slapstick
Perc. 1
Tamb.
Perc. 2
(hard mallet)
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
f
mp
mf
f

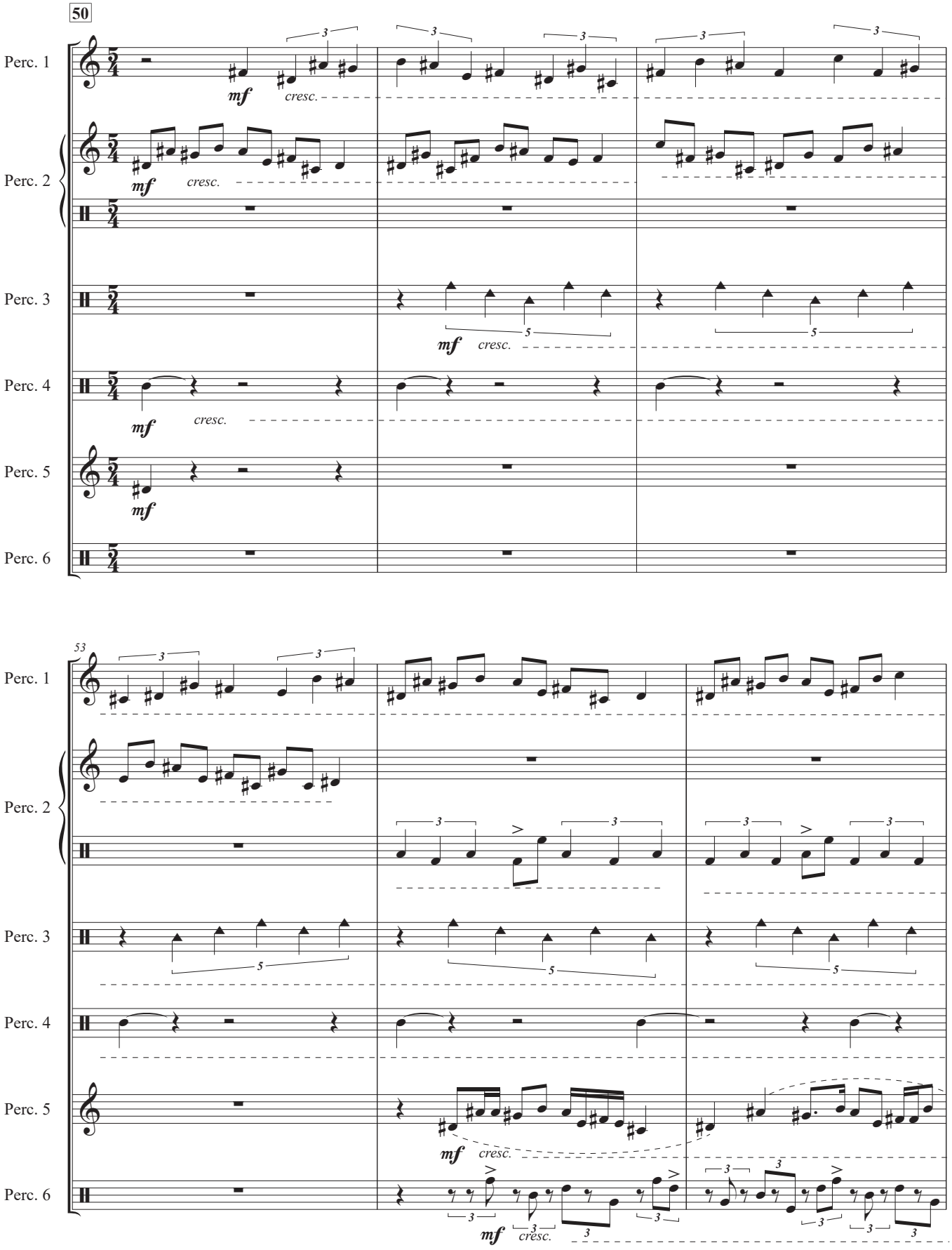

29
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff

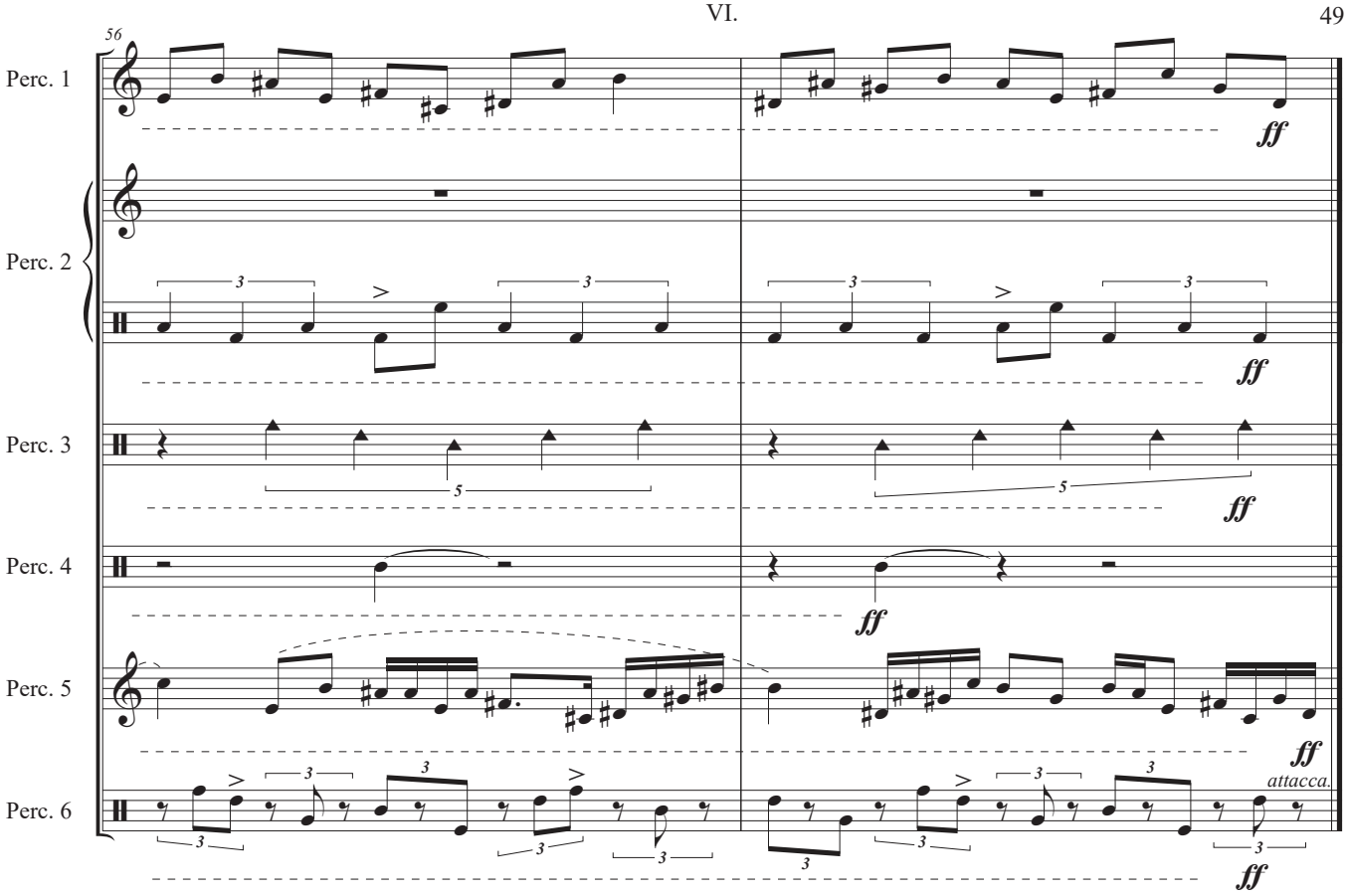

33
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff


35
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
fp
mf
mp
pp
p
mf
38
Crtls.
mf
drumsticks
pp
pp
mp
ff

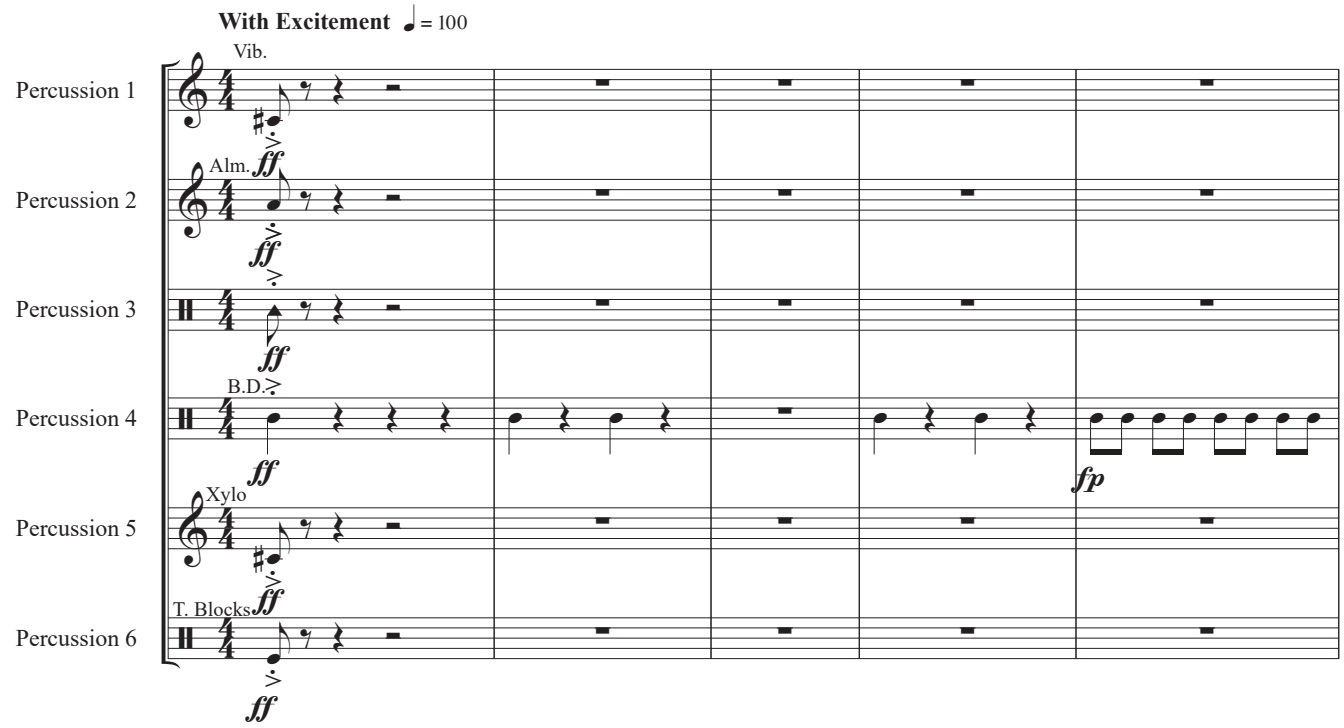

41
Vib.
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff
f
tr

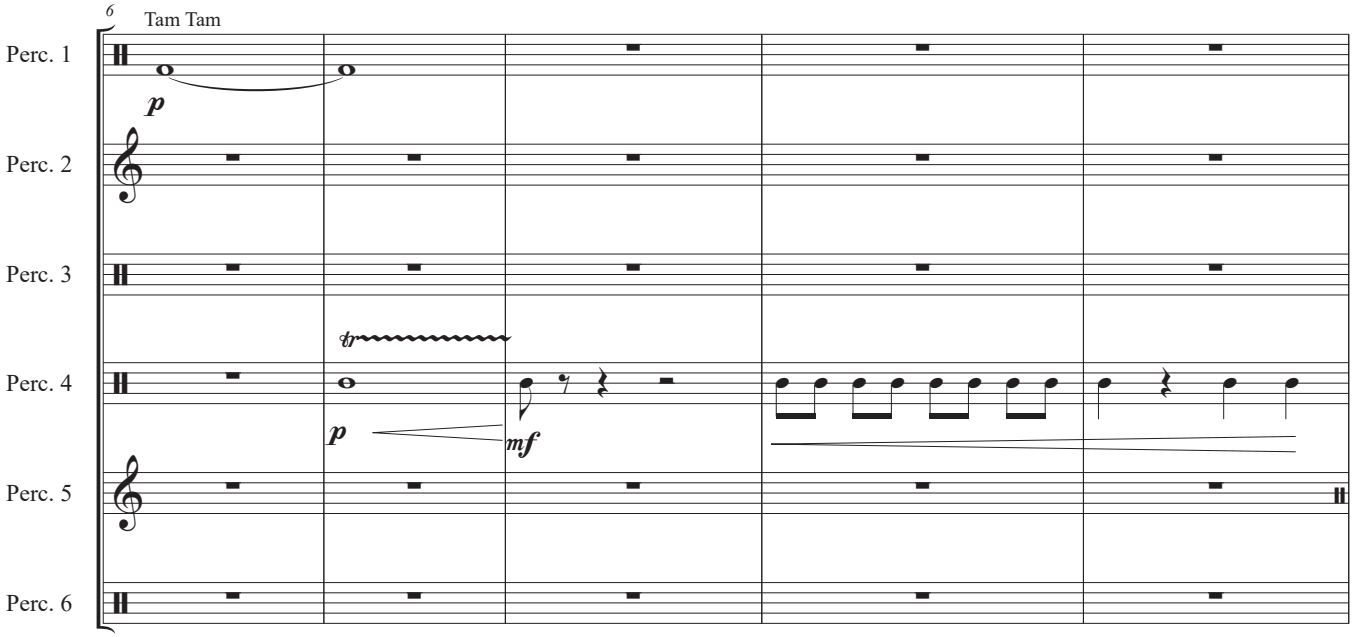

46
4
3
3
(♩ = 100)
(♩ = 150)
(♩ = 112)
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
4:5
fp
mf
f
ff
tr

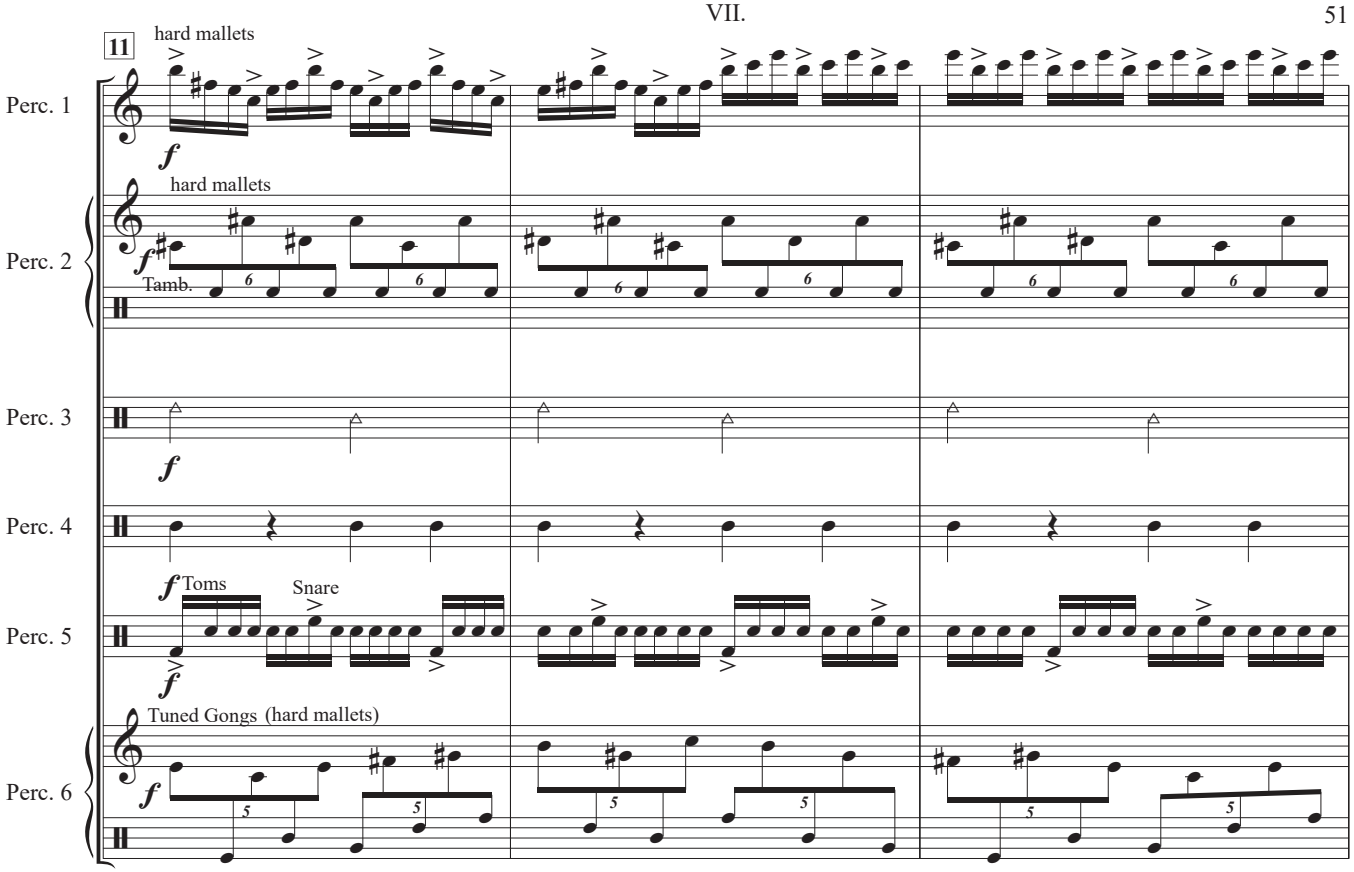

50
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
cresc.
53

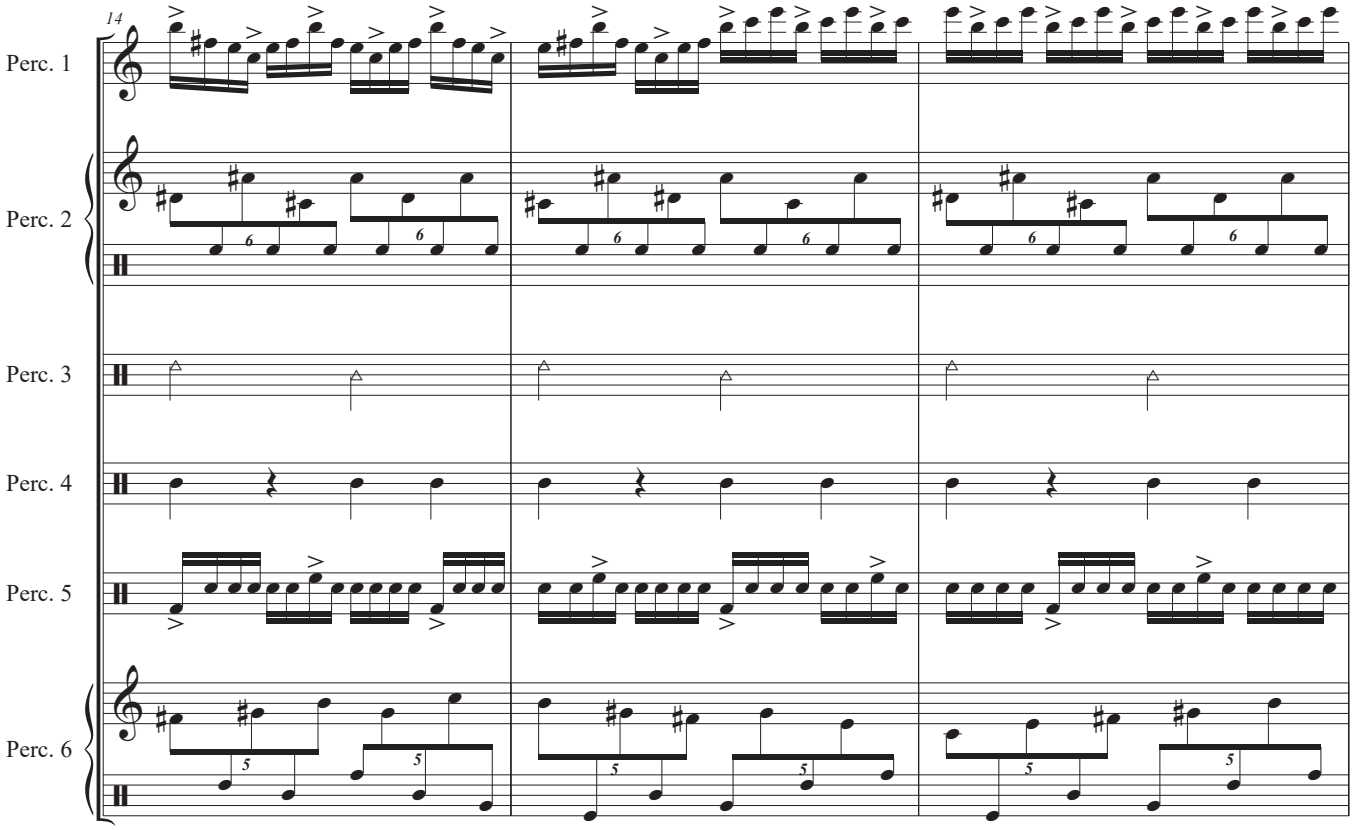

56
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff
attacca.

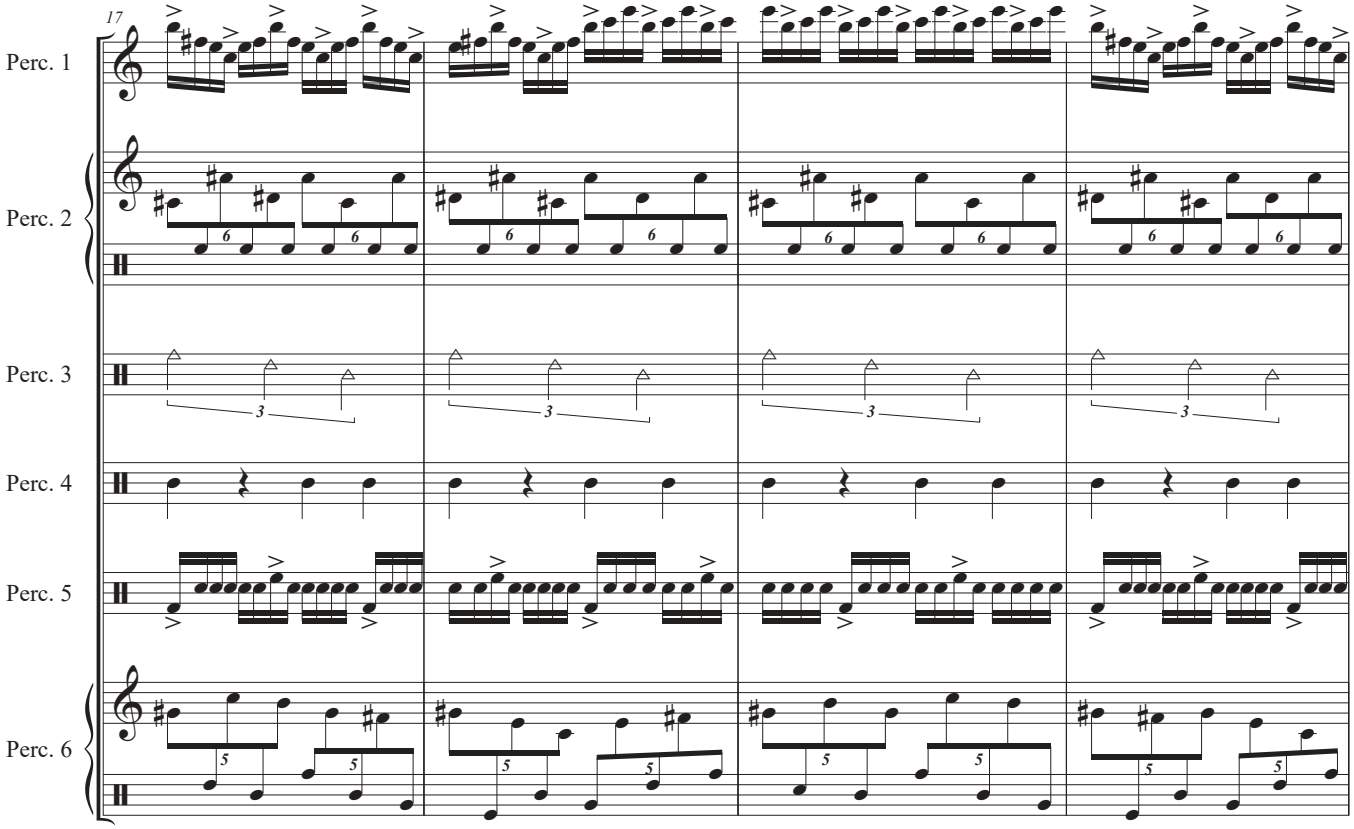
VII.

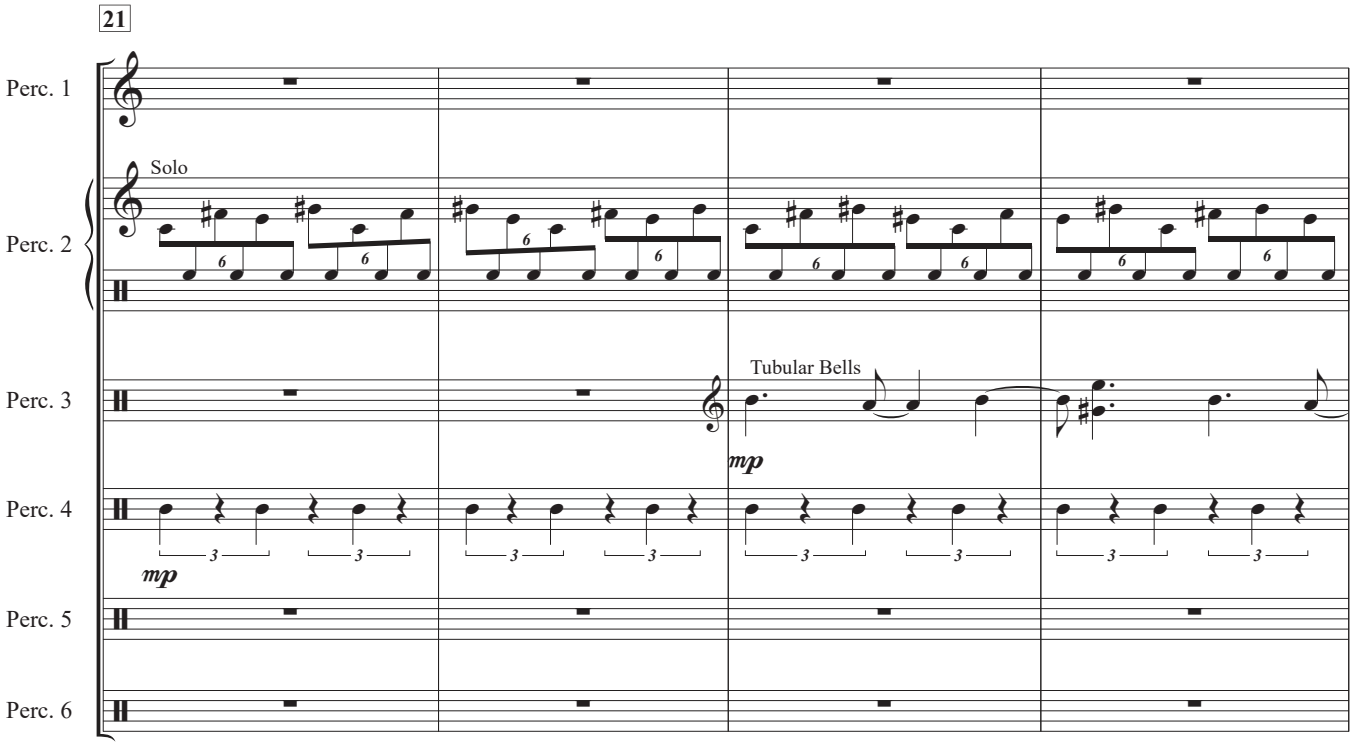

With Excitement ♩ = 100
Vib.
Alm.
B.D.
Xylo
T. Blocks
Percussion 1
Percussion 2
Percussion 3
Percussion 4
Percussion 5
Percussion 6
ff
fp

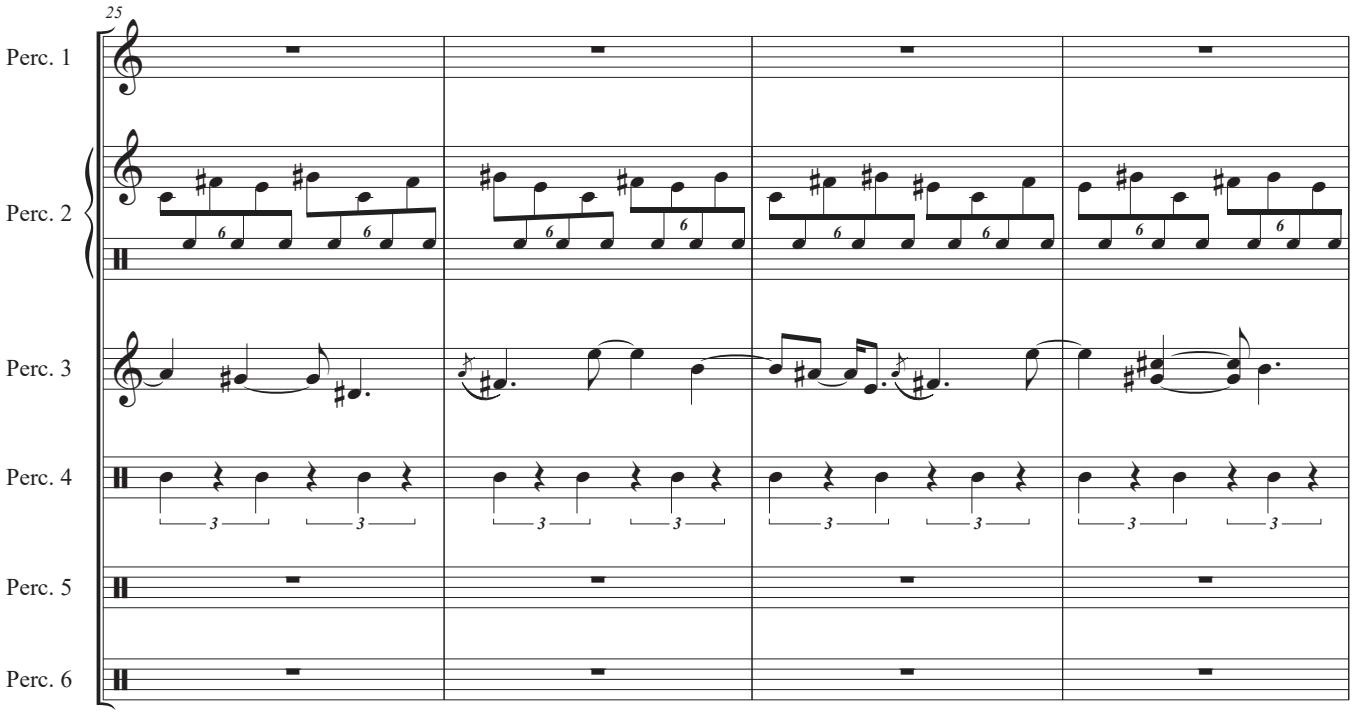

6
Tam Tam
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
p
tr
mf

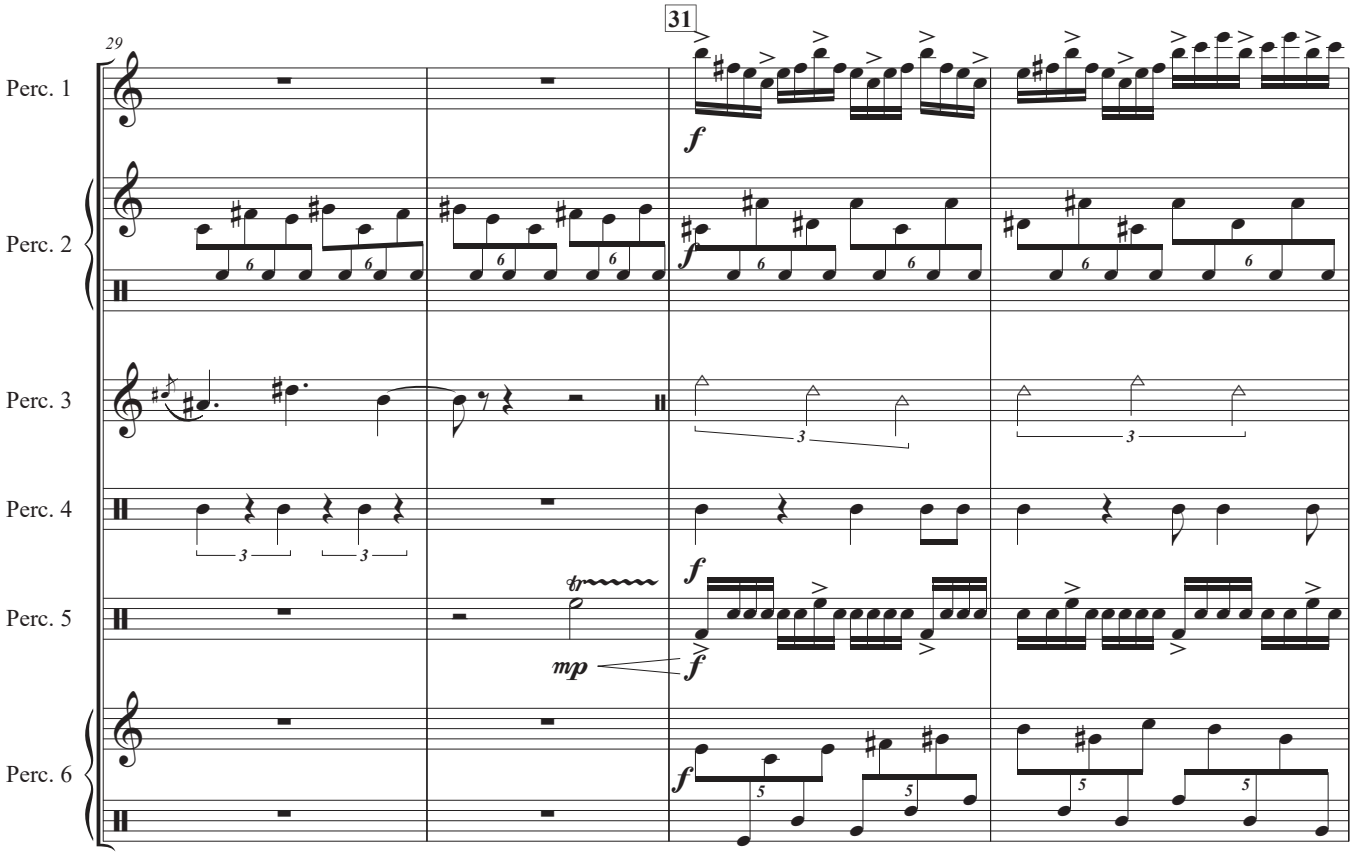

11
hard mallets
Perc. 1
f
hard mallets
Perc. 2
f
Tamb.
Perc. 3
f
Perc. 4
f Toms
Snare
Perc. 5
f
Tuned Gongs (hard mallets)
Perc. 6
f

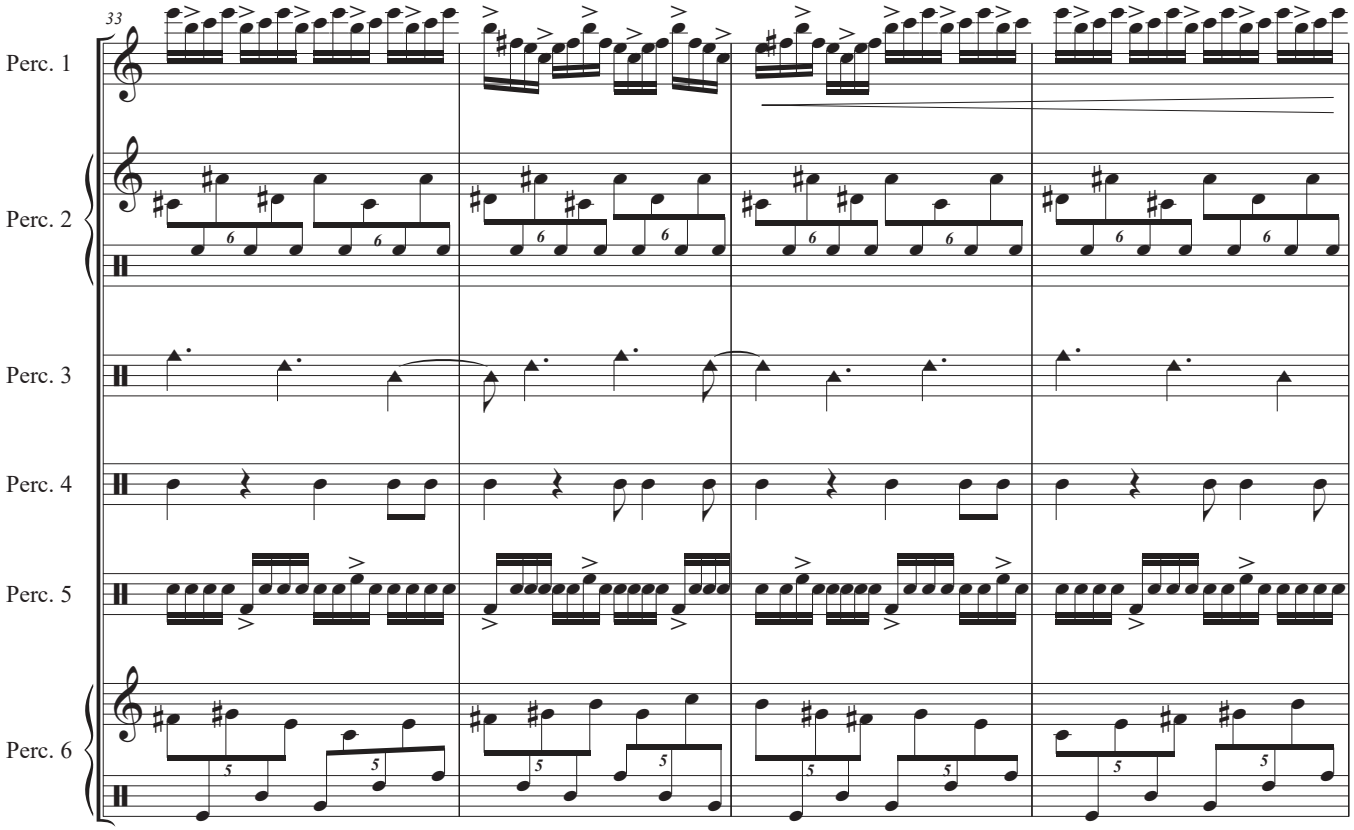

14
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

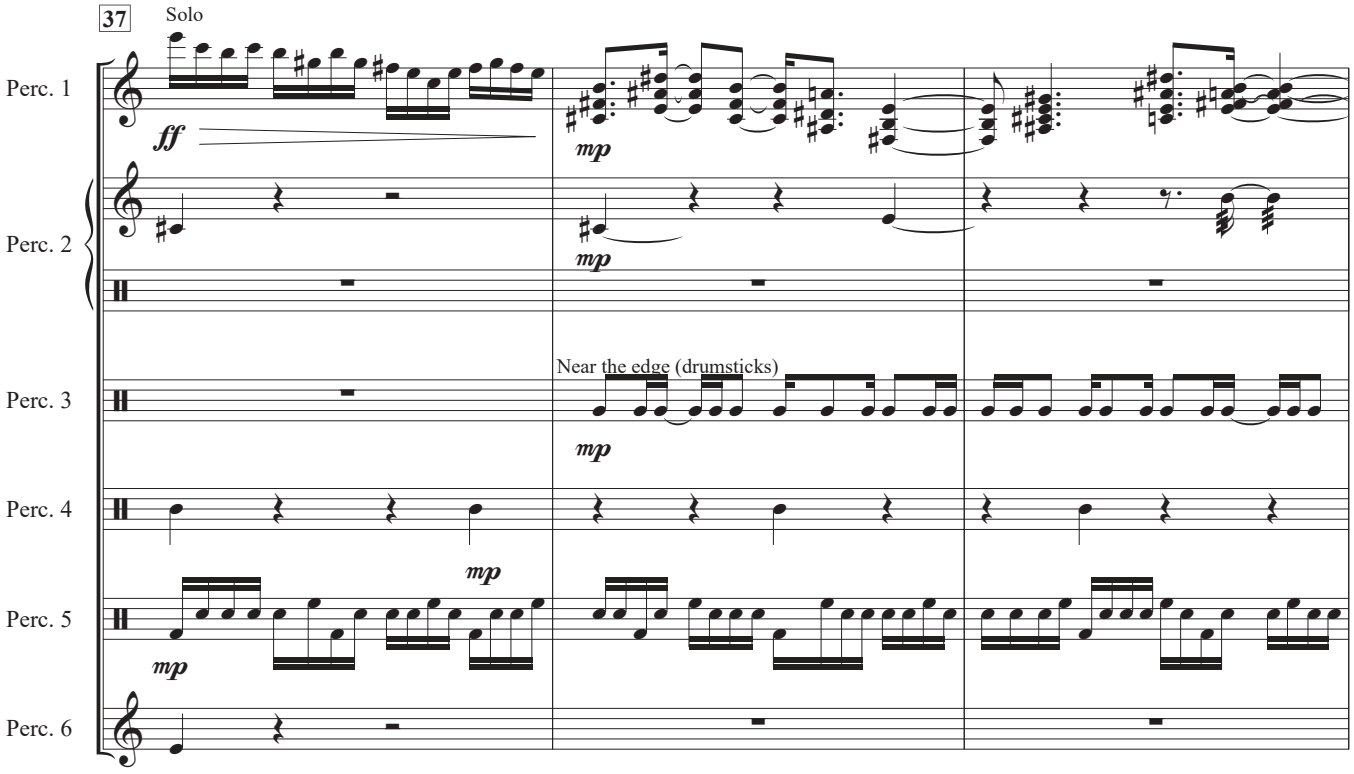

17
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

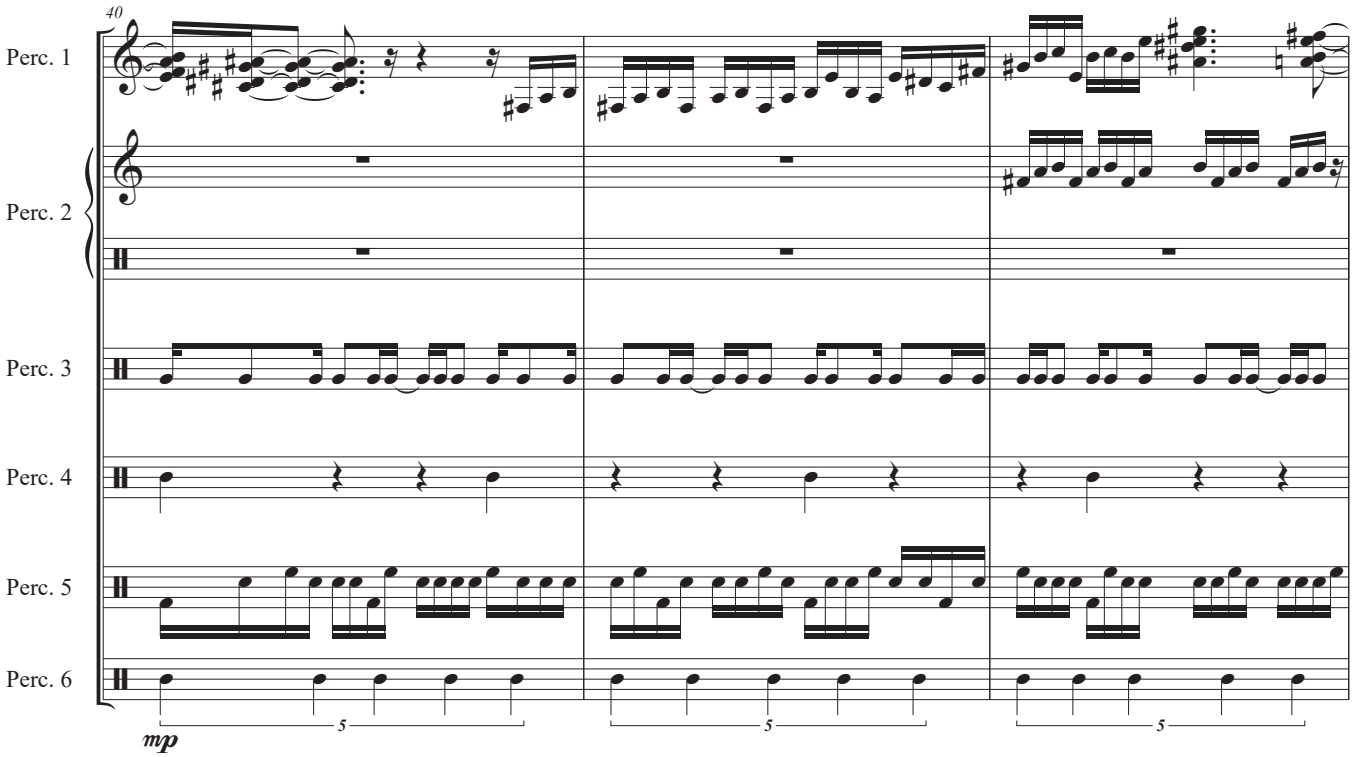

21
Perc. 1
Solo
Perc. 2
Tubular Bells
mp
Perc. 3
mp
Perc. 4
Perc. 5
Perc. 6

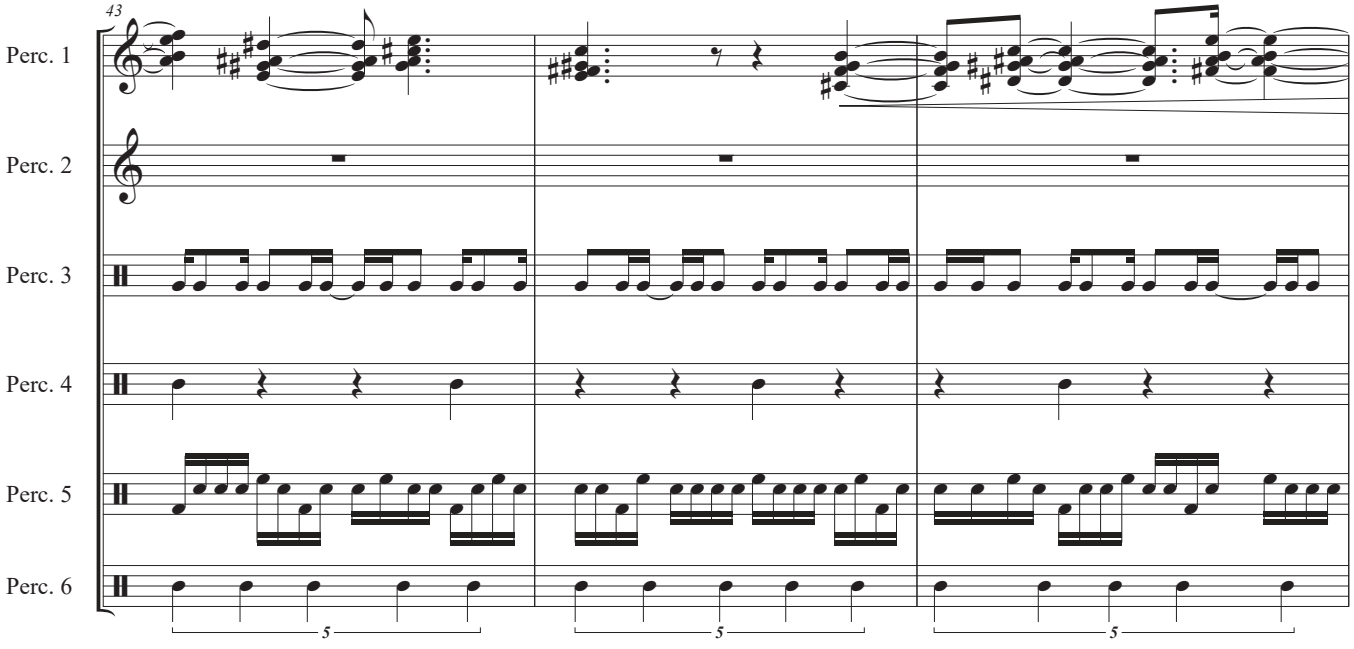

25
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

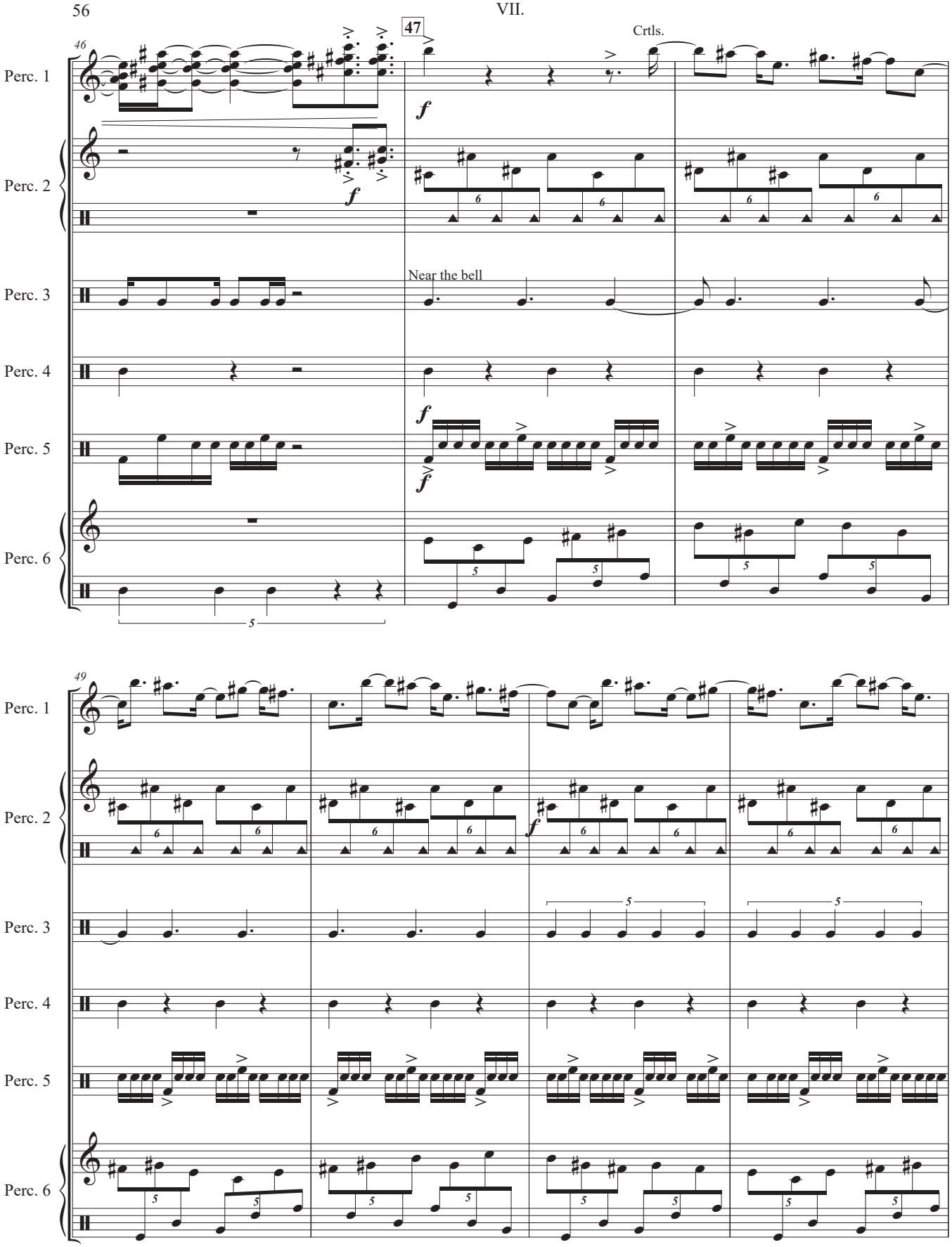

29
31
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
f
mp

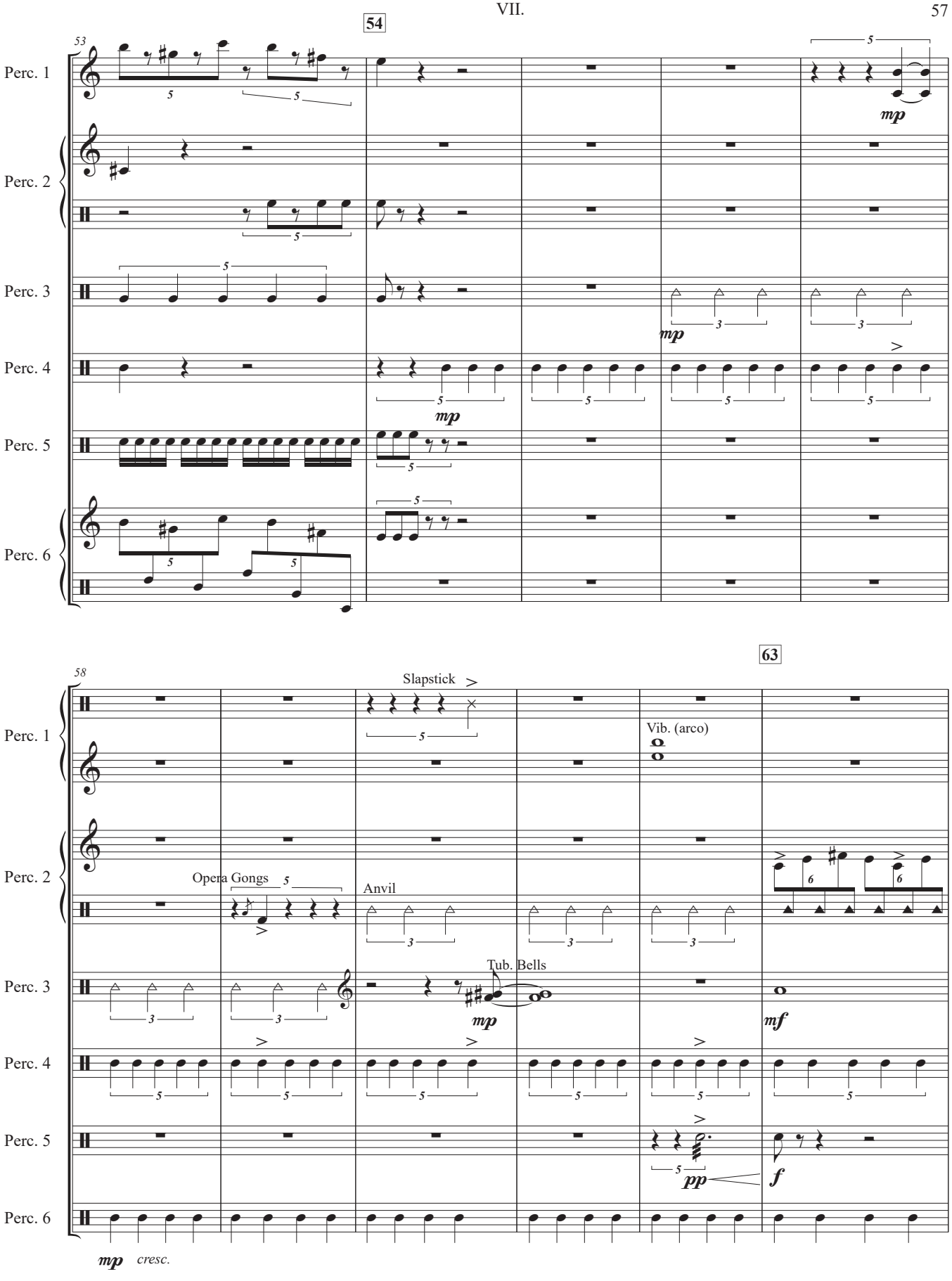

33
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6

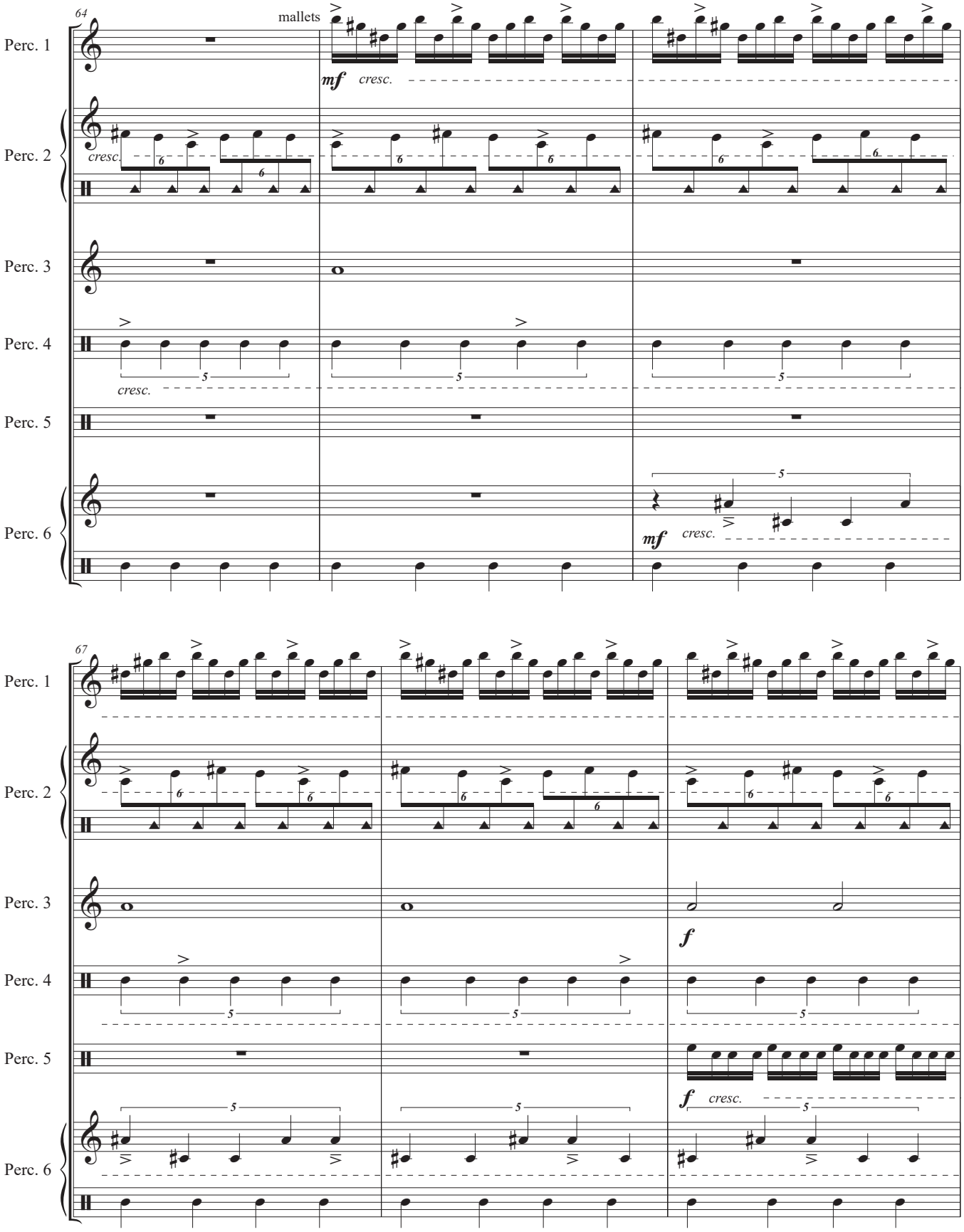

37
Solo
Perc. 1
ff
mp
Perc. 2
mp
Perc. 3
Near the edge (drumsticks)
mp
Perc. 4
Perc. 5
mp
mp
Perc. 6

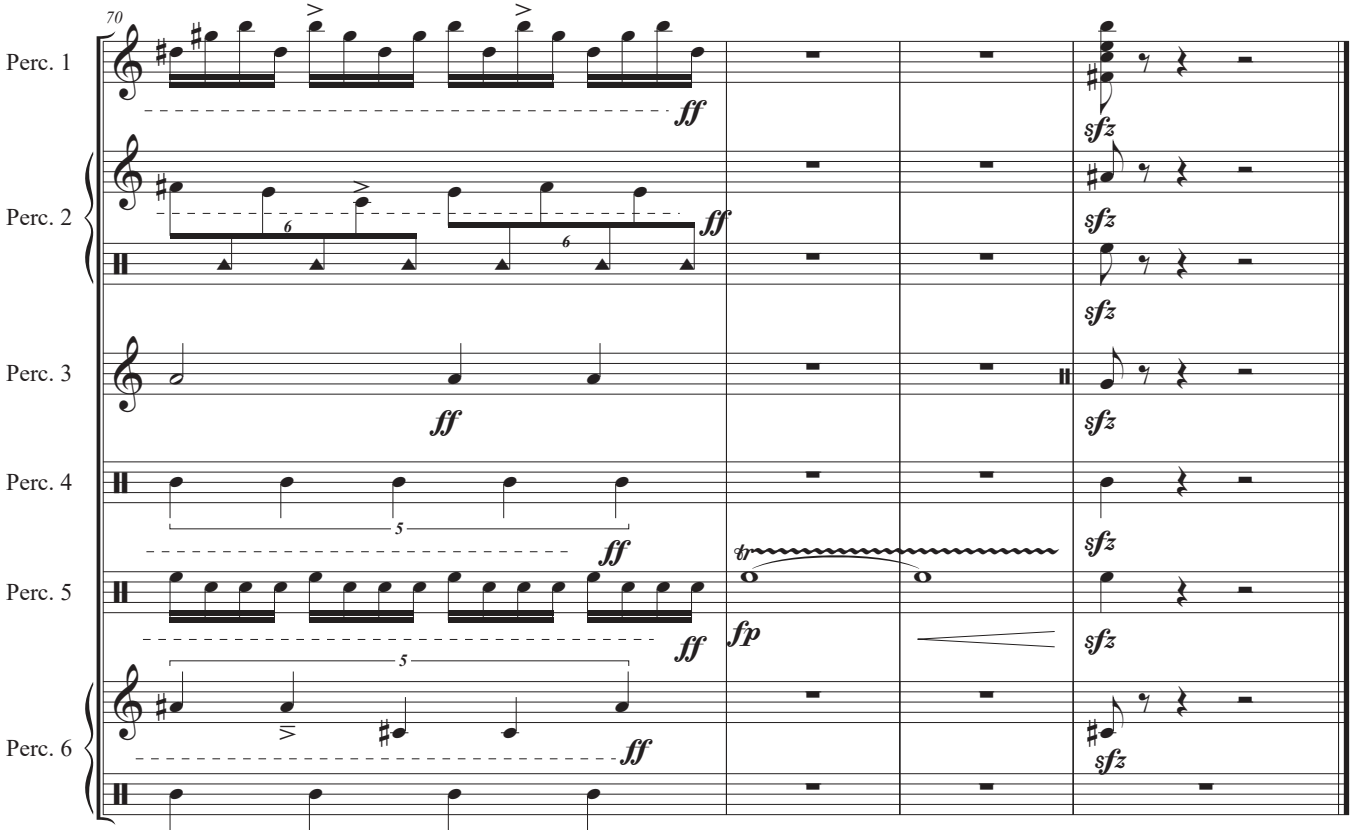

40
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
5
5
5
mp


43
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
5
5
5


46
47
Crtls.
Perc. 1
Perc. 2
Perc. 3
Near the bell
Perc. 4
Perc. 5
Perc. 6
f
49


54
53
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mp
63
58
Slapstick
Vib. (arco)
Opera Gongs
Anvil
Tub. Bells
mf
pp
f
mp
cresc.


64
mallets
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
mf
cresc.
67
f


70
Perc. 1
Perc. 2
Perc. 3
Perc. 4
Perc. 5
Perc. 6
ff
fp
sfz
tr
6
5