



To what extent is the application of mathematical and scientific knowledge relevant in theatre?

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Abstract

The history of theatre can be traced back to as far as the 6th Century B.C. with much evidence pointing towards the Greeks presenting dramatic presentations in large amphitheatre-style arenas. There is no doubt that as the years have gone by, the theatre has seen a great deal of evolution in all aspects; the genres on offer, the theatre designs, the light and sound design etc. This research paper looks particularly at the latter two aspects i.e., light and sound design in theatre. The aim is to conduct and present a thorough analysis of how scientific and mathematical knowledge has played and continues to play an important role in the facilitation of sound and light in the theatre.

Introduction

Theatre is a collaborative art form which combines words, voice, movement and visual elements to tell stories and evoke emotions in the audience. The use of sets, props, lighting, and sound all add to the atmosphere of the show and help the audience to visualize the story (forum-theatre, 2022). In fact, the theatre has been an integral part of human culture since ancient times, changing and evolving to reflect the political and social conditions of the time. Japanese Kabuki, Indian Shadow Puppetry, Italian Opera, and British Pantomime are just some of the unique theatrical forms that have emerged in different parts of the world, providing joy, entertainment, and satisfaction to many (Fox, n.d.).

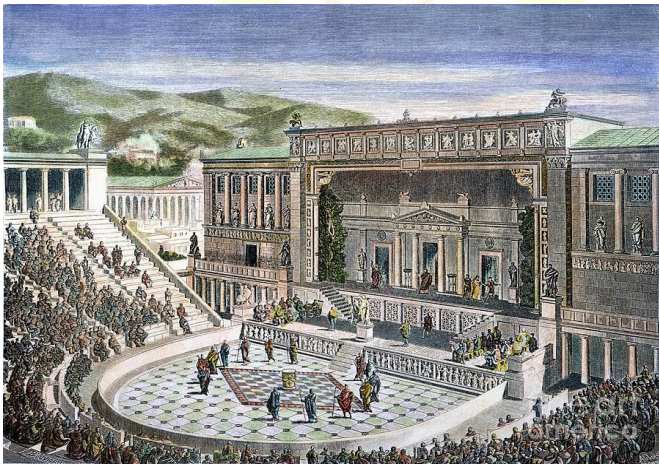
Interestingly, scientific and mathematical elements have been used in theatre for many years, although it is often not as visible as other elements such as music, dance, or acting. Scientific and mathematical elements are important as they have the potential to create certain angles to a story, support the plot, and deliver complex messages. In line with

the aforementioned, the research question posed for this paper is **“To what extent is the application of mathematical and scientific knowledge relevant in theatre?”**

The aim of the paper is to shed light on the integration of mathematical and scientific knowledge and theory in theatre with a particular focus on aspects such as sound and lighting. This will be facilitated by an in-depth analysis of both the history and evolution of these aspects.

Lighting in theatre

Lighting is essential in theatre as it helps to set the mood, environment, and time of day for the scene. Other than this, lighting in theatre is also important for illuminating the actors and set and creating a sense of movement, as lights can be used to fade in and out or change colours, in order to direct the audience’s attention to different areas of the stage (Cummings, 2017). By using different colours, patterns, and intensities of light, the lighting designer can give the audience a unique visual experience that wouldn’t be possible without the use of lighting. There is, therefore, no doubt that good lighting can make or break a production and has a great impact on the audience's experience.

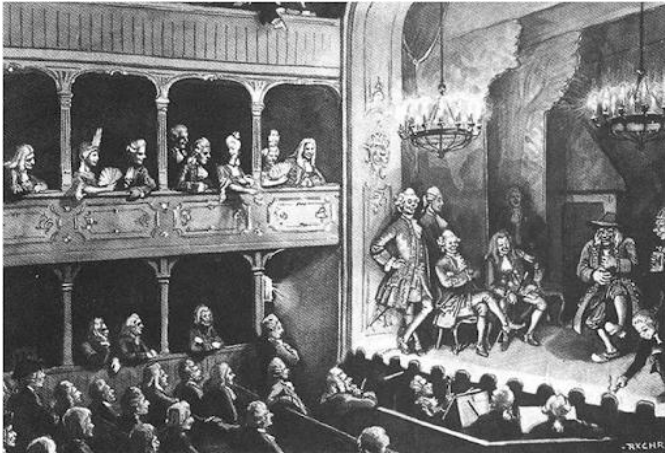


The use of lighting cues can be traced all the way back to the very early days of theatre. Greek plays, for example, had to use cues to truly deliver the full experience. However, being within the confines of a world without electric lighting did not stop the Greeks, instead, different strategies were used to ensure suitable lighting. For instance, drama festivals were coordinated around the time between dawn and dusk with the performances taking place in large amphitheatres that were lit only by the sun. Though there was minimal control over the

lighting, there is evidence of the Greeks becoming innovative and using mirrors to either alter or reflect the sun’s rays (Eaton, 2017).

During the Renaissance, candles were said to have been one of the biggest sources of stage lighting. Thousands of tallow candles, made of animal fats, were used to light stages by being placed in chandeliers or footlights (Ray, Roe and Basko, 2021). However, since tallow candles would burn rather quickly, there would always have to be

stagehands on call to monitor and subsequently trim the wicks or relight the candles as required. Up till this point, lighting was viewed as a mere requirement in theatre to ensure satisfactory audience viewing and not an art.



Sebastiano Serlio was in fact one of the first innovators of his time to recognize lighting as an art form. In 1545, for example, Serlio detailed the use of rudimentary colour filters or ‘bozze’ to produce coloured lighting in the theatre. Bozze were glass vessels filled with liquids such as coloured water or wine and were controlled and placed in front of sources of light (candles) to produce various hues and intensities of light (Palmer, 2013).

Additionally, Leone Di Somi Portaleone, a Jewish playwright and producer, discussed the use of stage lighting in his writings in 1556. He too was popularly recognized as an innovator of lighting as an art form and took a strong interest in how lighting could be used to manipulate and intensify the mood set in a theatre. Di Somi believed that the purpose of lighting in theatre “is to bring light, diversion and joy to the stage”. He specifically focused on how the lighting would differ for plays that belonged to the comedy and tragedy genre. As an example, he points to how the light would be dimmed in a tragic piece as this “... creates a feeling of terror among the spectators and the characters are glorified” (Clivner, 1966).

Candles remained the most popular and widely used source of stage lights until 1783 - when the kerosene lamp was invented. Kerosene lamps work through a process called capillary action i.e., liquid rises up through a narrow tube or wick due to surface tension. The capillary action of the wick draws up fuel from a reservoir, which is then vaporized in the burner and ignited by a flame producing light, heat, and soot (Britannica, 2019). Kerosene lamps also have a glass



chimney or globe, which helps to protect the flame from being blown out and to create a thermally induced draft. This draft carries more oxygen past the flame, which helps to produce a brighter, smokeless light (Kalpana, 2017). The advantages of kerosene lamps for theatre included better control of the lighting. However, there were some evident drawbacks including; the emission of black carbon or soot which posed a risk for indoor pollution and could expose audiences to respiratory illnesses (Ahlberg, 2012); there remained a high risk of indoor fires starting especially if the lamps were in the presence of candles; the lamps were known to contain sulphur and other impurities that gave them an unpleasant and oily smell when burnt.

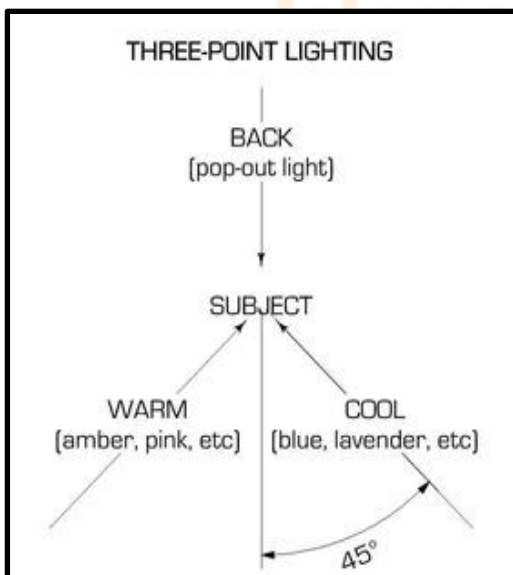
The invention of a practical electric lamp by Thomas Edison in 1879 marked the beginning of the modern era of stage lighting. Henry Irving initiated the first lighting rehearsals to practice stage lighting before a performance. Irving also began the use of transparent scenery and backdrops, which allowed for the use of various lighting techniques (Tripp,

2015). By 1882, the Savoy Theatre in London was the first to install a lighting system of incandescent bulbs fed by an electric power source (Wallace, Healey and Goodman, 2017). As time has passed, lighting has become more and more advanced in theatre. There has also been a great amount of research into some of the best lighting techniques to ensure that stage lighting is fulfilling its task of enhancing the theatre for audiences. Some of the most popular techniques used in theatre today include front lighting, high-side lighting, spotlights, chiaroscuro lighting, projected effects, and coloured lighting. Some of these have been detailed below.

Front lighting in the theatre

This stage lighting is used to provide a wash of light to the performers and the set. Lights are hung in the Front of House positions: catwalks, truss or beam positions over the heads of the audience, and pointed at the stage so that actors can be clearly visible to the audience (Illuminated Integration, 2020). One of the downsides of this type of lighting is that it can make performers seem flat i.e., there is not much three-dimensionality. Therefore, it is typically suggested that front lighting be combined with other angles to make it most effective. One example of this is the McCandless Method which relies on diagonal front light at 45° up from the actor and 45° off of the centre (Salzberg and Kupferman, 2011). The diagonal front light provided from both sides is able to give good facial visibility to the actors but with the added advantage of adjusting the intensity and/or colour of the two lights to establish a strong directional key. For instance, if one of the front lights is coloured with a warm colour filter and the other with a complementary cool colour filter (as can be seen in the image) then the designer can achieve a strong facsimile of 'natural' lighting.

High side lighting



This form of lighting refers specifically to side lighting that is positioned high at an angle creating a hybrid system that offers both visibility and shaping. These lights are usually lanterns located above spectators – on high tripods, under the ceiling or on a balcony of a theatre and come in at an angle of 30° and 60° (Stage Electrics, 2021). This provides a 3-dimensional look to the stage and allows the audience to see different sides of the actors. High-side lighting is helpful for sculpting the body and face of the performer and can help create unique and dynamic lighting effects.

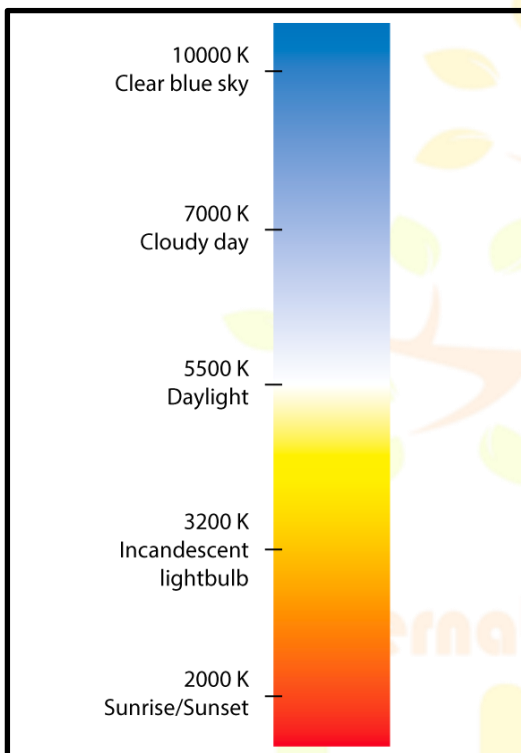
Spotlights

These are commonly used in theatre to highlight a character or element on the stage, set the mood and tone for scenes, and to simulate different times of the day. They are powerful stage lighting instruments which project a bright beam of light onto the performance space and are controlled by a spotlight operator who tracks actors around the stage. Spotlights may be arranged in a variety of patterns for coverage and are sometimes located overhead on catwalks or in purpose-built "spot booths" in

addition to the catwalk. Other characteristics of a typical spotlight include a strong light source, often a high-intensity discharge lamp with a high colour temperature, a lens which can be manually focused, a manual device to change the intensity of the beam, an "iris" to adjust the size of the spot/angle of the beam, and a colour magazine or "boomerang" consisting of several gel frames which can be swung in front of the beam.

Coloured lighting

Theatre lighting often involves the use of colour. Colour mixing is a key concept in theatrical lighting design, as it allows for the creation of interesting and complex effects. There are two ways to mix colours in lighting: additive and subtractive colour mixing. Additive colour mixing adds additional light sources of different colours until white light is achieved. Subtractive colour mixing is when you start with white light and then block some of the wavelengths,

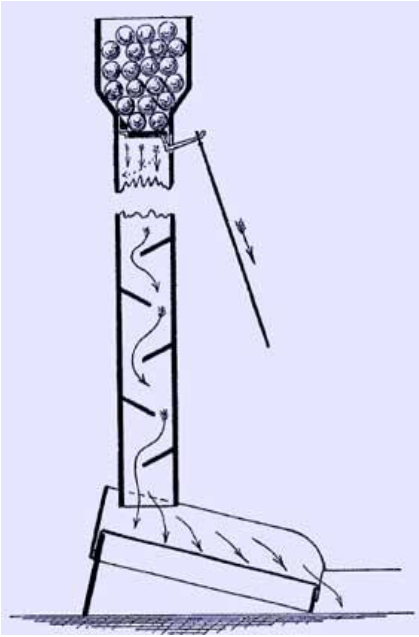


leaving coloured light (Schiller, 2016). This can be achieved through the use of gels, or filters, which are placed in front of light sources to remove specific wavelengths. Furthermore, the Kelvin scale (as seen in the picture on the left) is used to measure the colour temperature of a light source, and different colour temperatures affect the appearance of coloured lighting (McGregor, 2019). A candlelight or warm orange colour, for instance, can be obtained at around 1500K whilst the colour of a bright blue sky is achieved at 10,000K and above. It is said that two relevant points on the scale for stage lighting, particularly, are 3200K to achieve a tungsten light bulb colour and 6500K for sunlight (McGregor, 2019).

Sound in theatre

Much like lighting, the sound design also plays an integral role in creating an effective theatrical production. It is used to create a moody atmosphere that can range from light-hearted comedy to sombre tragedy (SSRC, 2018). Music has been used in theatre in the West since ancient Greek times, and with advances in technology, wireless microphones have been used in every type of theatrical presentation. Theatre sound design includes everything the audience hears, such as sound effects, music, props, and more. Directionality is an important part of sound design, as sound should originate from the same direction as the performers to provide a cohesive viewing and listening experience (Illuminated Integration, 2020). Amplifiers, mixers, and other input devices are also used to create a sound system that produces high-quality sound.

Historically, sound was produced in theatre through the use of machinery. Heron of Alexandria's thunder machine, for instance, was designed to create a realistic thunder sound in the theatre. The machine was composed of metal balls that were dropped onto a hidden drum, producing a deep bass tone. The drum was made of dried hides arranged in a kettledrum configuration, allowing the balls to create a loud, realistic thunder effect (TSDCA, 2014). The machine



was also capable of producing other sound effects, such as the sound of rain, by altering the speed at which the balls were dropped. Heron's thunder machine was a revolutionary invention for its time, allowing theatre-goers to experience thunder and other natural sound effects as if they were really there.

During the Roman Empire, Aristotle made several discoveries related to theatre sound. He noted that the chorus could be heard better on a hard surface rather than when they stood on sand or straw (TSDCA, 2014). This is because hard surfaces reflect the sound waves better, which amplifies the sound of the chorus and allows it to be heard more easily by the audience. This was a true turning point as it marked the beginning of the understanding of reflection and absorption for audience cognition.

In Elizabethan theatre, sound effects and music were used to create atmosphere, reproducing pistols, clocks, horses, fanfares, or alarms; but also, the sound was now being used for the symbolic effect of the supernatural and to help create drama. These sound effects were created using a variety of methods. The easiest way to create the sound of thunder was by banging drums in the Tiring House behind the stage (Reeves, 2019). Unusual sound effects could be made from 'Hell' including different sounds using various musical instruments such as the trumpet, chimes, bells or drums (Alchin, 2018). Actors also used their voices to create sound effects, and some theatre companies even employed musicians to accompany the plays who were strategically placed on the theatre stage and were even known to play during the action of the play. Firecrackers filled with gunpowder were also used to create sound effects and could be bought from grocers or ironmongers.

The first use of recorded sound in the theatre was documented in Michael Booth's book *Theatre in the Victorian Age*. It involved a phonograph playing a baby's cry, which was 13 years after Thomas Edison patented the phonograph in 1877 (Curtin, 2014). The first use of the term Sound Designer was in the 1968-1969 theatrical season of the American Conservatory Theatre and was bestowed upon Dan Dugan (Finan, 2019). Productions like *Don Juan* in 1926 featured a score and sound effects but no dialogue, and the first film to have recorded sound was *The Dickson Experimental Sound Film* in 1894 (Babiolakis, 2020).

Technology has had a profound impact on the sound of theatrical plays. Binaural sound, for instance, is a process of recording that mimics the way we hear and understand sound (Malinverno, 2022). It is used in theatre to create a 3-D stereo sound sensation for the audience. Additionally, binaural sound also creates directionality in sound design, a very important part of the sound in theatre as mentioned previously. Because binaural recordings are closer to the way human ears pick up sound than recordings made with conventional microphone techniques - the viewing experience of audiences is improved. The BBC has experimented extensively with binaural in recent years, including

a production at the Donmar Warehouse in London which uses headphones to create an immersive sound experience (Hilton, 2020).

Moreover, microphones have also become an essential part of any live theatre performance. They help to amplify the actors' voices and ensure that every word can be heard clearly by the audience. Broadway shows often use over \$100,000 worth of mics for production (Fox, 2019). Musicals may need microphones depending on if you are using a live orchestra or not. Of all the different microphones invented, wireless microphones are the “go-to” choice for theatre productions as they provide better audio isolation and a greater range of movement for the actors. There are a variety of mic placements, but it is generally accepted that the best-sounding placement is with an omnidirectional microphone (Masque, 2016). Omnidirectional microphones are microphones that pick-up sound with equal gain from all sides or directions of the microphone. This means that whether a user speaks into the microphone from the front, back, left or right side, the microphone will record the signals all with equal gain (Nymand and Tonmeister, 2015).

Conclusion

Theatre is a type of performing art that allows performers from all parts of the world to come together on a stage and tell a story. That being said, it does take a lot to put on a mesmerizing show with every little detail from the lighting to the sound to the set-up of the actual theatre having to be thought out closely. In line with the aforementioned, this paper aimed to specifically look at two of the main aspects of theatre i.e., lighting and sound design.

Lighting and sound design in theatre share some obvious similarities such as their role in creating and enhancing the required mood in a theatre. However, there are also some not-so-obvious similarities that are shared between the two, such as the application and importance of mathematical and scientific knowledge in making effective choices. In lighting, for instance, it is evident how mathematical angles play an important role in the choices made regarding the direction of the light. Scientific knowledge also has been extensively applied to make lighting at times when electricity did not exist and to date when integrating colours into the stage lighting. When considering sound design, the application of science has been evident from the very early years of theatre till now as seen in the machines designed and discoveries made by Heron of Alexandria and Aristotle respectively and the development and design of new equipment such as binaural sounds and wireless microphones.

It is, therefore, evident that the application of mathematical and scientific knowledge has been and continues to be relevant to the theatre to a great extent. It would be worthwhile for researchers to consider other aspects of theatre and deduce if mathematics and science play an important role beyond the two aspects explored in this paper.

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