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Acoustics of multiuse spaces FREE

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Acoustics of multiuse spaces

The article "Exploring cultural heritage through acoustic digital reconstructions" by Brian Katz, Damian Murphy, and Angelo Farina (PHYSICS TODAY, December 2020, page 32) gives an excellent review of the state of the art in computer simulation of room acoustics. However, the authors seem unfamiliar with the revolution in concert-hall, theater, and worship-space design that started with Peter Parkin and J. H. Taylor's work in London's St Paul's Cathedral[1] in 1952. Beginning with that pioneering effort, room-acoustics designers have found that the ratio of early-arriving sound energy to reverberant sound energy at the listener's ears is at least as important as reverberation for speech and music acoustics.[2,3] The usual division between early and reverberant sound is 50 ms for speech and 80 ms for music. "Usual" is an important word.

At one extreme, an acoustically "dry"—that is, nonreverberant—thrust-stage or in-the-round theater needs special electroacoustic or sound-reflecting surfaces to ensure enough early sound energy reaches a listener who is seeing the back of someone speaking rather than his or her face. Otherwise, with no real departure from previous practice, echoes usually reduce intelligibility.[4]

A more relevant and frequent application is the reconciliation of speech and music in the same space. A multiuse auditorium can, of course, have variable acoustics, but moving drapes, curtains, and sound-absorbing panels in the middle of worship services is hardly practical. Thus the greatest value of the early-to-reverberant energy-ratio concept has been for houses of worship, particularly large Christian churches and cathedrals, and for places where sound-absorbing treatments are not suited architecturally.[4]

Perhaps the best demonstration of the concept is the Sultan Salahuddin Abdul Aziz Shah Mosque, known as the Blue Mosque, in Shah Alam, Malaysia. It has the largest dome—more than 51 m in diameter, rising 75 m above the prayer hall—of any religious building. It also has the largest and most complex sound-reinforcement system. Designed by Larry Philbrick, the system uses the directional properties of loudspeakers rather than sound-absorbing treatments to control echo and reverberation and to increase clarity. Two large, central loudspeaker clusters—one for close worshippers, one for middle and far worshippers—cover the main prayer area under the dome. Additional line-source loudspeakers are built into the interior and courtyard columns. The mosque can accommodate 24 000 worshippers at one time.

B.O'KANE/ALAMY STOCK PHOTO

THE SULTAN SALAHUDDIN ABDUL AZIZ SHAH MOSQUE in Shah Alam, Malaysia, has the largest dome of any religious building. Behind the two sets of tan tiles in the central section of the sloped ceiling seen here are large clusters of loudspeakers that together cover the main prayer area under the dome.

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▶ **Katz, Murphy, and Farina reply:** Please note that our article was an overview of research in virtual heritage acoustics, not a presentation of modern acoustical design methods. The letter by David Klepper focuses on electroacoustic solutions to difficult acoustic situations.

Contrary to assumptions by the letter writer, we are very familiar with energy-ratio metrics in room acoustics,[1] including their limitations.[2] Although not relevant for our introductory article, we have used energy ratios—together with other measures—not only for characterizing acoustic spaces but also for calibrating and validating acoustic simulations and auralizations.[3] In particular, characterizations of Venice's La Fenice theater[4] and Paris's Notre Dame Cathedral[5] before each burned (in 1996 and 2019, respectively) inspired the name of the Past Has Ears (PHE, for the constellation Phoenix) project.

These days, other measurable quantities are often preferable to energy-ratio metrics and more reliable as refined design criteria, especially regarding natural room acoustics. For example, temporal and spatial energy-repartition measures, such as interaural cross correlation and lateral energy fraction, and the sound strength, or gain, are of growing importance in representing the quality of experience and preference among audience members, musicians, and actors alike.

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Life and signs of the Casimir effect

We would like to offer a few comments in connection with the article "Science and technology of the Casimir effect" by Alex Stange, David Campbell, and David Bishop (PHYSICS TODAY, January 2021, page 42). First, as Steve Lamoreaux mentioned in another excellent article on the Casimir effect (PHYSICS TODAY, February 2007, page 40), Niels Bohr played a brief but seminal role in Hendrik Casimir's thinking. With Dirk Polder, Casimir calculated the large-distance van der Waals interaction without reference to zero-point energy.

In a 1992 letter to one of us (Milonni), Casimir recalled mentioning his results to Bohr during a walk sometime around 1947. When Casimir said that he was "puzzled by the extremely simple form of the expressions for the interaction at very large distance," Bohr mumbled something about zero-point energy. "That was all," Casimir wrote, "but it put me on a new track." That track led Casimir to use the zero-point electromagnetic energy of the modes of a resonant cavity to calculate the force between conducting plates. In his letter, Casimir said that he was "somewhat familiar with the theory of modes of resonant cavities and their perturbations" because of his position at the Philips Research Laboratories in the Netherlands.

Casimir remarked in a 1948 paper that the force between the plates "may be interpreted as a zero point pressure of electromagnetic waves,"[1] an interpretation fully supported by a calculation of the vacuum stress tensor.[2] That perspective might suggest, as do Stange and his coauthors, that the net inward pressure results from a "higher density of modes outside the plates" than inside. But such an argument is superficial in that the calculated inward and outward forces on the plates both diverge. In fact, the spectral mode density of the field between the plates can be greater at some frequencies than it is outside the plates. And it depends, of course, on the boundary conditions for the electric and magnetic fields.[3]

Stange and his coauthors highlight the major role Casimir forces play in microelectromechanical systems (MEMS) today. Interestingly, when one of us (Maclay) and two coauthors tried in 1994 to publish the first paper on the potential role of quantum forces in MEMS,[4] the reviewers initially rejected it on the grounds that the dimensions of MEMS, typically in the tens or hundreds of microns, made the discussion irrelevant.

Stange and his coauthors describe how repulsive Casimir forces can result from different dielectric properties of the interacting objects. Repulsive Casimir forces can also arise from combinations of dielectric and permeable materials, as shown in 1974 by Timothy Boyer. When one of two parallel plates is a perfect conductor and the other is infinitely permeable, for example, the force between them is repulsive. And whether the Casimir force is attractive or repulsive generally depends on the geometrical configuration of the interacting bodies. The Casimir force on a perfectly conducting sphere, for example, is repulsive, in contrast to Casimir's assumption that it should be attractive. More recently, researchers have focused on the possibility of realizing repulsive Casimir forces with metamaterials and chiral media. Qing-Dong Jiang and Frank Wilczek, for instance, have shown that chirality can be employed to obtain Casimir forces that are "repulsive," "enhanced," and "tunable."[5]

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Algebra-based high school physics

About 60% of all physics majors chose the field because of their positive experience in high school