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PHYSICS TODAY

Many facets of light pollution FREE

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Physics Today **63** (6), 8–10 (2010);
https://doi.org/10.1063/1.3455266

letters

Tone-deaf Feynman took on stiff strings, piano tuning

Richard Feynman's exercise on stiff strings (PHYSICS TODAY, December 2009, page 46) illustrates well his many interests. He and author John Bryner might have saved themselves a lot of trouble (and maybe missed out on some fun) by examining the substantial literature on the subject. The fact that the stiffness of a string stretches the frequencies of the harmonics has long been known. Lord Rayleigh in 1894 treated the case in which the string is free to tilt at the bridge.[1] He also calculated the effect of movement of the end pins, of which Feynman says, "It is too hard for me to figure how big these effects would be." In 1939 Robert Shankland and I gave formulas for that and for the case in which the string is clamped at the end,[2] and he presented experimental evidence that the piano string acted with a combination of these. Altogether, piano tuning by ear has always had the effect of taking into account the stiffness of the strings.

References

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[Editors' note: With sadness, we have learned that John Coltman passed away on 10 February 2010.]

I was fascinated by Richard Feynman's letter on piano tuning. While the author's assertion that "had he wanted to, Feynman would have been a fine piano tuner" is understandable, readers might be amused to know that Feynman was seriously tone deaf: Not only could he not carry a tune, he could not reliably tell whether one note on the piano was the same as, higher than, or lower than another played a few seconds earlier. For example, in experiments we did together, he would often misinterpret the same note played louder as being higher in pitch. Nevertheless, we enjoyed playing on the piano together—1.2 hands, one might say, with me providing chords in the lower register and Feynman playing a very passable improvised melody, using one finger from each hand, a transfer of his marimba skills. Feynman's piano playing was analogous to his drumming, in which he never counted out rhythms or phrases; rather, he captured the feel of the patterns—those unquantifiable aspects of a rhythm that make it human.

That a tone-deaf Feynman could expound on piano tuning so deeply—like a colorblind amateur pointing out intricacies of hue to a professional artist—makes his letter all the more remarkable, and it reminds me once again how much we miss him.

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Element 117 fits a pattern

The announcement on 7 April of the discovery of element 117 (see the news story on page 11 of this issue) completes row 7 of the periodic table. The discovery of elements 93 and 94 started a 65-year quest to extend the table to higher and higher atomic numbers. Omitting the "trigger" elements 93 and 94, the 24 elements 95–118 have a rather amazing distribution of discovery.

The first six (95–100) were discovered in the US by Albert Ghiorso, Glenn Seaborg, and collaborators. The next six (101–106) were discovered in the US by Ghiorso and collaborators. The next six (107–112) were discovered in Germany by Peter Armbruster and collaborators. The last six (113–118) were discovered in Russia by Yuri Oganessian and collaborators. Although the description is slightly simplified, it is nevertheless significant: US (6), US (6), Germany (6), and Russia (6). The cause of that pattern is easily traceable to the experimental facilities available and the irresistible urge to try just a bit harder to add one more proton. Another amazing fact is that Ghiorso is codiscoverer of 10% of the periodic table. Of course, not every element is as useful as carbon or copper, but who knows? Forever isn't over yet.

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Many facets of light pollution

The article "Lighting and Astronomy" by Chris Luginbuhl, Connie Walker, and Richard Wainscoat (PHYSICS TODAY, December 2009, page 32) is a welcome and important discussion of the impact of outdoor lighting on astronomical observation. It seems to fall short, however, with regard to actual practice and the effects outdoor lighting has on communities other than astronomers. Light pollution is wasted light and should be minimized for both environmental and financial reasons. Despite good intentions, many outdoor lighting applications waste light. The following important questions are not addressed in the article: How much light are we wasting now? How do we measure wasted light? And what can be done to reduce that waste?

People complain about three aspects of outdoor lighting: sky glow, light trespass, and glare. In terms of sky glow, the topic addressed by the authors, reflected light, rather than light directly leaving the fixture, typically contributes more than 80% of the light leaving the property.[1] As the authors correctly point out, however, the direction of that escaping light matters for astronomical observations; low-angle light is relatively more important than high-angle light, but proximity to and absolute levels of the light sources are even more important. That point is also made indirectly by the data the authors present from Flagstaff and Phoenix in their figure 4. More stray light comes to the US Naval Observatory Flagstaff Station from Flagstaff, a close, small city with very stringent fixture requirements in place, than from Phoenix, a distant, large city with less stringent requirements.

The impact of fully shielded fixtures is rather small. The authors use 10% as the amount of light directed upward for "typical" community lighting fixtures, but a sample of commonly installed fixtures tested by the National Lighting Product Information Program[2] had uplight values averaging less than 0.3%. Counting only partially cut-off fixtures like the one illustrated in figure 3 of the article, the average uplight value was still less than 0.5%. Therefore, a value of 10% misrepresents what is actually being installed. Limiting the typical value of 0.3% uplight to 0% from fully shielded fixtures will have little incremental effect on reducing sky glow beyond current practice. Parenthetically, the statement attributed by the authors to members of the lighting profession that partially shielded fixtures permit wider spacing than fully shielded ones is incorrect; many fully shielded fixtures can be spaced farther apart than many unshielded ones.[3]

The direction of light leaving the property matters most in terms of light trespass and glare. Both are also measures of wasted light and to some communities can be just as important as sky glow is to astronomers. The outdoor site-lighting performance (OSP) system[1] has been used to develop methods to measure and limit light trespass onto adjacent windows from the lights illuminating, for example, a car dealer's lot. Similarly, glare into the eyes of automobile drivers from a fixture on a golf driving range can be measured, and limits can be established.

Our systematic review of current outdoor lighting practice and of the reasons people complain about light pollution[1] shows the state of outdoor lighting with regard to glow, trespass, and glare and suggests how to make improvements using the OSP system. Fully shielded fixtures are one way to limit wasted light, but they are not sufficient to reverse any of the three problems called light pollution. Luginbuhl and coauthors point out that unintentional use of vegetation and other structures reduces by 50–60% the impact of wasted light contributing to sky glow. Given that value, intentional use of vegetation and structures to prevent light from leaving a property could be more effective at controlling sky glow than the use of fully shielded fixtures advocated by the authors.

The OSP system is a practical computational tool to compare proposed and existing designs that limit wasted light with those used in current practice. It also gives owners and communities practical methods and effective criteria for minimizing glow, trespass, and glare not only to slow the growth of wasted light—including encroachment on the night sky—but to reverse it. We therefore applaud the authors for making the case to reduce wasted light as it affects astronomical observations, but many more issues associated with outdoor lighting need to be considered, including its benefits. With practical and effective tools, each community can best decide how to address the multifaceted issues of light pollution.

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Luginbuhl, Walker, and Wainscoat reply: We appreciate the concern of Mark Rea, John Bullough, and Jennifer Brons for aspects of light pollution other than sky glow, and we support increased awareness and reduction of all forms of light pollution and energy waste. Our article was explicitly about the impacts on astronomical observatories and science, though to a large extent the careless lighting practices that increase sky glow over observatories also cause light trespass, glare, and energy waste. Nevertheless, many techniques used to protect observatories, in particular the full shielding of fixtures to control direct uplight, have wide applicability for national parks, coastlines, and anywhere citizens want to preserve or restore their ability to see stars in the night sky.

Of course, distance and lighting amounts are critical factors. If direct uplight were a tiny fraction of total light output, approaches other than improving shielding might be more productive for reducing sky glow. But the observational evidence does not support the low uplight fraction Rea and coauthors suggest. Using measurements of how sky glow varies with distance and inventories of light fixtures, other researchers find uplight percentages of 8–15%.[1–3] So direct upward emission, whatever the distance or amount, dominates sky glow. Eliminating it in communities with typical shielding and near-ground blocking would reduce sky glow by 35–75% for observation distances of 50–200 km.

The writers' suggestion that vegetation could be intentionally used to decrease light pollution impacts may have some merit, though vegetation is not something on which astronomers or lighting designers have much influence. In any case, the modeling shows that the impact of direct upward emissions remains disproportionate even in the presence of substantial blocking by structures or vegetation.

Whatever uses the outdoor site-lighting performance metric may have for evaluating other aspects of light pollution, it is not a good metric for evaluating sky glow. It contains no information about the direction light is propagating away from a lighting installation, nor does it distinguish between upward- and downward-directed light. As our work and that of others[1,2,4] demonstrate, direction is critical in considering most aspects of light pollution.

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Hot topics in cold fusion

In his letter to PHYSICS TODAY (February 2010, page 10), Jacques Read raises an

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