Assignment 7
Physics of Music - 2016
Physics 341

1. What would you expect to happen to the sound of a violin if you made the bridge much heavier? (This is done by clipping a "mute" to the bridge of the violin.) Recall two features– how well would a heavier bridge do in transmitting the vibrations, and what would happen to the primary bridge resonance of one did this?

The violin string would find it harder to move the heavy bridge, and thus less vibration would be transmitted to the body and thence to the air. Also the heavier bridge would lower the resonance of the bridge on the body and also resonances in the bridge itself, which would alter amplitudes of the various harmonics delivered to the body. (reduce the high frequency ones and increase some of the lower frequency ones which are now close to the new resonant frequencies of the bridge.

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2. What would happen to the playing of a violin if one put soap instead of rosin on the bow?

The peculiar behaviour of the string is because of the strange property of rosin in having a high friction when the string is moving slowly with respect to teh bow and very low when it is moving fast. This gives rise to the amplification of the oscillation of the string, and finally the stick slip mechanism.

With soap this behaviour is reversed. At low speeds the soap is very slipperly (as anyone who has stepped on a bar of soap knows, while at high speeds its friction force increases. Thus, as the velocity increases the force increases opposing the motion. This is exaclty like pushing the kid on the swing when she is swinging toward you. This stops her, and similarly the behaviour of the soap damps out the motion of the string. Soap on the string thus does not result in amplification of the oscillation, and does not result in any particularly pleasing sound.

3. At times in an auditorium, the speakers "howl" or whistle due to "feedback" especially if the microphone is in front of the speaker(s)? What do you think is happening? what would be the important features which would determine the frequency at which the speakers howled?

This comes about because the loudspeaker is adding to the sound in the auditorium when that sound pressure is already high, and decreases when it is low. This means that at the frequency of the howl, the wave going from the speaker to the microphone must be such that the pressure at the microphone is high just as the sound coming out of the speaker is also at its highest pressure (since that high pressure gets amplified and then emitted by the speaker just when the pressure would naturally be high). Ie the howl frequency is just such that the time it takes the sound to travel from the speaker to the microphone is one period (assuming that a high pressure at the microphone produced a high pressure coming out of the speaker.) You can stop it either by decreasing the amplification of the amplifier (so that the natural decay of the sound in the room was greater than the additional amplification because of the "round trip".) or by changing the distance of the microphone from the speaker (of course that would just tend to produce that same howl at a different frequency).

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4. The London Millenium Footbridge was opened in 2000 and closed a day later due to severe instability. The bridge had a mode of side to side oscillation with a period of about 1.2 sec. What would your reaction be if the bridge suddenly moved to the side, and how long would you estimate it take you. Predict the behaviour of the bridge with a large number of people on it.(Think about the bridge moving to one side, the reaction of the people to that, and the motion of the bridge by the time your reaction was finished, and your sugsequent reaction.)

(This sort of delayed feedback is a very common source of instability.)

The London Millenium FootBridge is one of the greatest Engineering embarassments of the last 100 years. The bridge, built with special funds of the UK government to highlight the engineering prowess and triumfs of the UK in the year of the Millenium (2000), turned out to sway from side to side with an uncomfortably large amplitude (about 1/4 of a foot, but very disconcerting to the people walking over it). This swaying was seen and experienced as the bridge filled up with many hundreds of people on its opening. By the next afternoon, the complaints of the pedestrians and worries of the engineers had mounted so that it was closed, and remained closed for almost the next two years, and the engineers tried to figure out what happened and how to fix it.

The explanation is very simple. As the bridge sways to the right, a pedestrian will naturally put his left foot out to the left to try to keep balance as the bridge sways. But the period of the bridge was such that by the time the pedestrian's left foot came down again, half a period had passed and teh bridge was now moving to the left. The left foot coming down now gave the bridge push to the left, increasing the sway. Also now the brige was moving to the left, and the people were in danger of falling to the right, so they put out their right foot to balance themselves. The completion of this action was again delayed, just due to the natural reaction time and motion of the human body and step, for a half period and teh right foot came down when the bridge was laready moving to the right, increasing that motion. While the natural damping of the bridge was sufficient to damp out the motion if only a few people were on the bridge, it was was not up to doing so with many hundreds. The bridge would begin to sway dangerously as people walked across almost duck legged, and causing some people to fall down.

Ie, the kind of delayed reaction, as happens in a clarinet, a flute, etc, or even in the violin, can often cause instabilities. Sometimes, as in a musical instrument, these are welcome. Sometimes they are a disaster.

The solution that the engineers finally implimented was to install huge shock absorbers under the bridge to increase the damping of this mode of motion so that even hundreds of people could not amplify this mode of vibration. Had the engineers realised that this could happen, they could have made sure that the frequency of this mode was either much higher or lower (eg, as it is on the Lynn Canyon or Capilano suspension bridges) than this natural time scale of people's stepping.

It turned out afterwards that a foot bridge across an arm of the Sydney Harbour had also displayed this same kind of instability a few years earlier, but in that case the engineers had hushed it up, and "fixed" the problem without telling anyone. This meant that other engineers did not learn from these engineer's mistakes and made the same ones all over again. The Engineers of the Millenium bridge publicised the problem and the solution. Thus, just as the Tacoma Narrows film publicised the dangers of wind caused unstable motion, and made sure that future bridges would not suffer from that same instability, the Millenium bridge will (one hopes) ensure that this pedestrian caused instability does not occur again.

(As an aside, I was in London during the two years that they were fixing the bridge. There were these big bales of hay hanging under the bridge and a plaque which explained that by a law passed in somthing like 1570, hay bales had to be hung under any bridge that was geing repaired to warn the river traffic that things (bricks in 1570, but screws, pieces of metal, etc now) could be falling from the bridge and presenting a real danger to anyone passing under the bridge.)