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## P1_2 Quake, Rattle and Roll


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**Abstract**

In this paper, the feasibility of using bass frequencies from sub-woofer speakers to create earthquakes registering as a 9.0 on the Richter scale was explored. To answer this question, we calculated the displacement caused by the speakers that were situated just under the Earth's surface, which produced an amplitude value of $3 * 10^{-8} m$. The final conclusion that we came to was that, while it would be theoretically possible to release the same amount of energy as a 9.0 quake, without an unfeasibly large area to accommodate a group of speakers of immense physical dimensions, the displacement value would be too low to be felt compared natural quakes.


### Introduction

Earthquakes are caused by the release of energy from the Earth's crust which is then dissipated in the form of longitudinal waves. Speakers also produce longitudinal waves and cause vibrations in matter, therefore it may be possible to use the speakers as the wave generator as opposed to the movement of tectonic plates. We decided to simulate a Richter scale 9.0 Earthquake in basalt, the most common rock in the Earth's crust, to determine how possible this would be [1].

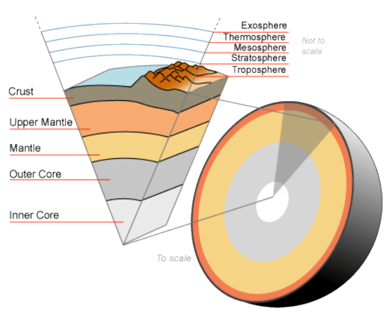


Figure 1: Visualisation of the layers of Earth [2]

The speakers being used would have a power output of $1000W$, producing a frequency of $C_3$ or $130.8Hz$ (a typical mid-bass frequency) [3], with its dimensions being a cube with all sides being of length $0.5m$. The speakers would be tightly packed into an area below a thin layer of basalt, with the speakers pointing towards the surface. This negates any energy dispersing effects of the sound waves, reducing the system's effectiveness in vibrating the ground.

### Method and Results

In order to determine the possibility of using this method to create earthquakes, first a propagation medium would need to be chosen. We decided upon basalt as it is the most common rock contained in the Earth's crust. In order to simplify the problem, it was assumed that all of the acoustic energy produced by the speakers would propagate through the rock and that the rock would have a uniform density to mitigate any reflection of the waves caused by density boundaries.

Furthermore, an assumption was made that the speakers would be under a thin layer of basalt, with their sound cones facing the surface. This would maximise the effectiveness of the speakers, by removing any energy dispersion effects. Acoustic resonance effects were not accounted for, due to the low elasticity of the rock. In order to calculate the displacement of the rock from a magnitude 9.0 earthquake, the released energy would need to be $2 * 10^{18} J$ [4], with this energy being released over a time of $20s$ [5]. Using these values, the earthquake's power output would be $1 * 10^{17} W$. We now know the power output of the earthquake, the power output of the speakers and the dimensions of the speakers. This means that the area that the speakers would cover on the ground can be found by finding the product of the speakers top area, the power of the earthquake and the inverse of the speakers' power, which gives a value of $2.5 * 10^{13}\ m^2$.

The equation for the displacement of the ground due to the vibrations of the earthquake is:

$$\Delta s = \frac{I}{2\pi^2 \rho f^2 v} \quad [6]$$

Where $\Delta s$ is the displacement amplitude of the ground in metres, $\rho$ is the density of the propagation medium in $kgm^{-3}$, f is the time frequency of the wave in $Hz$, $v$ is the velocity of the wave in the medium in $ms^{-1}$, and I is the energy intensity of the wave in the medium measured in $Wm^{-2}$. The intensity of the wave can be found by using the calculated speaker area above and the total power of the earthquake (also calculated above), to find a value of $1.6 * 10^5 Wm^{-2}$. The density of the medium was found to be $2600 kgm^{-3}$ [1], the frequency used was $130.8 Hz$ (as above), and the velocity of the wave in the medium was found to be $6000 ms^{-1}$ [7]. Inputting these values, the displacement amplitude of the basalt can be calculated as $3 * 10^{-8}\ m$

**Conclusion**

Although the production of a Richter scale 9.0 earthquake would be possible, due to the physical size of the speakers, the resulting oscillations would have an amplitude of $3 * 10^{-8} m$ so displacement of the ground would be very small and barely even noticeable. The area that the speakers would cover is $2.5 * 10^{13}\ m^2$. In a natural earthquake, the oscillations are spread over a much smaller area since they originate from a point rather than over an area, as would be the case with the speakers.

Furthermore, the physical effects felt would be reduced by the dissipation of the energy away from the surface. In order to increase the size of the oscillations, the energy would need to be contained in the area that is to be shaken, and speakers with a greater power per top area would need to be used. Different materials could be used other than those commonly found in the earth's crust. Materials with a lower density would cause greater oscillations, so by using a material such as chalk, the effects would be much more noticeable to an observer.

**References**


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[3] `https://pages.mtu.edu/~suits/notefreqs.html`[Accessed 21/10/2020]

[4] `https://www.volcanodiscovery.com/earthquakes/energy.html`[Accessed 15/10/2020]

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[6] `https://physics.info/intensity/` [Accessed 15/10/2020]

[7] `https://manoa.hawaii.edu/exploringourfluidearth/node/1336` [Accessed 15/10/2020]