PHYSICS ESSAY on Acoustic Levitation

Acoustic Levitation is the act of suspending an object in air against gravity, solely through high intensity sound waves being produced onto the object. Ultrasonic frequencies are needed to be able to counteract the force of gravity on the object. Piezoelectric transducers are most commonly used as they can efficiently generate high amplitude outputs at desired frequencies. As the forces of these waves via acoustic radiation on any surface are weak, only small and light objects are able to be levitated efficiently.

The first demonstration of the possibility of acoustic levitation was made in Kundt's Tube experiments in 1866. The experiment in a resonant chamber demonstrated that the particles could be gathered at the nodes of a standing wave by the acoustic radiation forces. Sound waves are longitudinal waves that produce oscillations parallel to the direction of travel. They produce compressions and rarefactions of particles that create points of maximum and minimum pressure. A standing wave is where oscillations are in a fixed space where regions of significant oscillation (antinode) and regions with 0 oscillation (node) remain in a constant location. This can be caused by sound reflecting off a surface instigating interactions between its compressions and rarefactions causing interference. Compressions that meet rarefactions cancel each other out and produce zero displacements at the nodes of a standing wave. These nodes have minimum pressure of wave particles and antinodes have maximum pressure.

In space, where there is little gravity, floating particles collect in the standing wave's antinodes, which are stationary. On Earth, objects collect just below the antinodes, where the acoustic radiation pressure, or the amount of pressure that a sound wave can exert on a surface, balances the pull of gravity.
There is a relationship between the intensity of sound in decibels and magnitude of pressure in the wave:

$$I = 20\log\left(\frac{P}{P_0}\right)$$

$$P_0 = 2 \times 10^{-5}\ \mathrm{N/m^2}$$

An object can be placed above the antinode such that the pressure below the object is greater than the pressure below it. Higher pressure means more collisions with the object underneath. This collisions mean that there will be a resultant buoyancy force upwards, keeping it afloat. However, the object needs to be small enough that it doesn't extend into another pressure compression area as it could exert a downward force.

If we wanted to levitate a human, the wavelength must be at least as long as they are tall. This is because the space between antinodes are equivalent to the wavelength.
The average mass of a person is 62kg and the average height is 1.77m.
Pressure = Force/Area. Assuming a human to be a cube, P = $(62\mathrm{x}9.81)/(1.77^2)$ = 194 Pa
I = 20 log (194/2x10^(-5)) = 140dB. Therefore an intensity of at least 140dB is needed to levitate a man. This volume is very loud and is equivalent to an aircraft carrier deck, therefore frequencies outside our hearing range are much preferred such as 40kHz.
However at 40kHz, the distance between antinodes is 8mm.
As a light's intensity is not directly related to a light's wavelength, we can separately workout the maximum frequency required to levitate the man using the man's height:
Frequency = Wavespeed / Wavelength = 330 / 1.77 = 186Hz.

Theoretically, a frequency below 186Hz and an intensity above 140dB would levitate a man but it would be difficult to achieve this.