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Phonocardiography with a smartphone

To cite this article: Lars-Jochen Thoms et al 2017 Phys. Educ. 52 023004

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In figure 1, the first and the second sounds appear clearly in the phonocardiogram of a healthy heart, but it is difficult to identify them in the second graph, which charts abnormal cardiac sounds, because they are partly obscured by an additional signal.
2. Stethoscope acoustics

Common stethoscopes have a dual-head chest piece consisting of a diaphragm (plastic disc) and a bell (hollow cup), see figure 2. If the diaphragm is placed on the patient, bodily sounds cause vibrations of the diaphragm, leading to acoustic pressure waves that propagate along a hollow tube to the listener’s ears. If the bell is used, the skin functions as a membrane and the vibrations of the skin directly produce acoustic pressure waves. The two attachments differ in the frequency range over which they efficiently transmit sound along the tube: while the diaphragm transmits higher pitched sounds more efficiently, the bell is better suited to the transmission of lower-pitched sounds [5, 6].

The choice of tube length and internal diameter of a stethoscope (ca. 60 cm and 3 mm respectively) involves a compromise of several characteristics: first, the volume of the tubes should be small, to ensure large pressure changes with the motion of the membrane or the skin, when the bell is used). On the other hand, small tube diameters also increase air friction, which reduces the range of pressure modulation.

Figure 2. A traditional stethoscope along with the five main areas for heart auscultation. For simultaneous observation of $S_1$ and $S_2$ sounds, position 2 is the best choice [4].

Figure 3. Three detection methods: heart sounds are captured (a) after transmission through the tube or (b) by a microphone that is placed close to the bell. In either of these cases, the bell is made from a piece of bicycle inner tube with the valve hole covered by a union nut of ca. 3 cm diameter and 1 cm depth. Finally, (c) a headset microphone is covered with double-sided adhesive tape.
3. Low-cost phonocardiography

Electronic stethoscopes convert sound into electrical signals. This permits a great deal of functionality, including amplification, storage, analysis and visual representation of heart sounds. Electronic filters and noise reduction make the tube obsolete as an acoustic apparatus. Thus, sound can be detected most easily by simply placing a microphone in the chest piece [7]. The signal coming from the microphone can then be made audible by means of speakers or headphones, or can be plotted to create a graphical representation called a phonocardiogram. A low-cost system for capturing heart sounds consists of a bell, a tube, and a small microphone connected to a device for processing and creating a graphical record (see figure 3). This device can be a PC, a tablet, a smartphone, or a similar device, such as an iPod touch.

The bell should be placed on the chest with only low pressure at the area of contact. Otherwise, the stretched skin becomes a diaphragm, dampening low frequencies. The bell and the microphone work together to capture sound waves and to convert them into an electrical signal. The microphone is situated inside the flexible tubing at the end of the acoustic pathway, or close to the bell. The microphone must be compatible with the device used and should have good response characteristics for low frequency sounds, preferably from as low as 20 Hz upwards.

When using usual headsets, the microphone can easily be attached to the bell, by means of a piece of double-sided adhesive tape with a hole at the centre (see figure 3(c)).

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1 The stethoscope app may be obtained for free at itunes.apple.com/gb/app/id346239083.
4. Results

The first and second heart sounds appear clearly in the phonocardiogram shown in figure 4. The amplitudes of these sounds depend on the position of the chest piece. The heart rate can be determined and probable arrhythmia can be detected. In general, several factors complicate sound collection. Varying heart rhythms, background noise, respiratory sounds, and noises produced by shifting the stethoscope head on the skin all contribute to the difficulty in isolating cardiac sounds, which are generally low-intensity signals. For this reason, all efforts should be made to maximize the signal and minimize acoustic and electrical noise. Furthermore, improving and testing different options for stethoscopes promotes greater understanding of acoustics.

Note that the devices presented here are only for understanding the underlying physics concepts, and should not be used for medical diagnosis. Noise signals make it difficult for an inexperienced user to distinguish between normal and abnormal cardiac sounds. Nevertheless, the use of new intelligent mobile devices in the field of auscultation is actually a current research topic in several European research projects [8–10]. A thorough review of state-of-the-art products and smartphone stethoscope apps can be found in the literature [7].

References