Scholarship Physics Waves – Harmonics & Doppler

Take Vsound = 340 ms-1

1. A dog whistle produces 19 kHz, Lisa can only hear up to 18 kHz. Because her dog doesn’t respond to it, she gets her boyfriend to drive along blowing the whistle hoping she can hear the Doppler shifted note. How fast and in what direction does he have to drive? [0.5]
2. (a) The speed of a wave on a string is given by: where x and y are variables. One is the tension and one is the linear density. Write the formula with these two variables in place of x and y.

Justify your answer. [1]

(b) A yacht mast is held up by steel wire rigging. The tension in the wire must be correct. One way of checking it is to bang the forestay and note the frequency of the wave. Consider a forestay with a mass of 2.0 kg and a length of 12 m. What is the fundamental frequency if the tension is 11 000 N? [1]

1. Electric guitars have a *whammy bar* that changes the string tension while playing. The player can “dive bomb” or produce a frequency that gradually changes from high to low. If the guitarist “dive bombs” from 880Hz to 440Hz, by what percentage has the tension changed? [1]
2. A piano string produces a third harmonic of 55 Hz. The wire is 1.1 m long. Calculate the ratio of the speed of the wave on the wire to the speed of the wave heard by the player. The speed of sound in the room is 340 ms-1. [1]
3. A person hums above a well. **Some** of the frequencies that she hears louder are:

84 Hz, 140 Hz and 196 Hz. How deep is the well? ( ground level down to water) (vsound) = 340 ms-1 [1]

speaker

length

1. Zoe places a speaker above a tube of water. She slowly lets the water flow out the bottom of the tube. She measures the length of the air column every time the sound is loud. Her first two lengths are 14 cm and 44 cm. Has she made a mistake? Explain.

Calculate the frequency of the speaker if the speed of sound is 340 ms-1. [1]

5.0 ms-1

600

1. A didgeridooist is skateboarding along

 at 5.0 ms-1 playing the **second** **harmonic**

 as shown above. The didgeridoo is 1.2 m long.

The speed of sound in air is 340 ms-1.

Calculate the frequency Ella hears. [1]

1. The velocity of blood in arteries can be measured using an ultrasonic transmitter/receiver and measuring the Doppler shift of the reflected wave. Reflected ultrasound from the moving blood is detected by the stationary transmitter/receiver probe shown in the diagram. [3]

(i) Does the reflected ultrasound have a lower, higher or the same frequency as the transmitted wave?

Explain.

(ii) Three students derived the following possible equations for the total frequency change recorded by the detector. Only one equation is correct.

Identify the correct equation, giving reasons to justify your choice (a derivation of the correct equation

is not required).

*f* is the transmitted frequency,

Δ*f* is the shift in frequency of the reflected waves,

*v* is the blood velocity,

*c* is the wave velocity

θ is the angle between the blood velocity and wave velocity.

(iii) The velocity of ultrasound in human tissue and blood is 1.5 × 103 m s–1 and a frequency of 5.0 MHz is used for the transmitted ultrasound.

In one particular measurement a Doppler shift of 3.1 kHz was observed with the probe inclined at an angle of 30° to the direction of the blood flow.

Calculate the speed of the blood.

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1. Use the Doppler shift formula,  v = 18.9 ms-1 (away from her)
2.  units give ms-1

(b)

1. * so to halve f,  must halve so decrease by  this is a 75% decrease.*
2. 121 to 340
3. 84 Hz is not 1st harmonic, must be 3rd

 1st harmonic = 84/3 = 28Hz

 λ=v/f = 12.14

 d = λ/4 = 3.0 m

1. No 3 x 14 = 42 but there is an end correction.

44 – 14 = λ/2 so λ = 60 cm, and λ /4 = 15 cm

The end correction is therefore 1 cm

1. Second harmonic, f=340/1.2 = 283 Hz

Vapproach =5.0 cos 600 = 2.5



8 (i) The blood is moving towards the sound source so it “observes” a higher frequency which it reflects. The blood acts a moving sound source, that is approaching the detector, this causes another Doppler shift and the relieved frequency is even higher

(ii)

*Student 1 is correct.*

*As v increases, Doppler shift increases so Δf increases.*

*As θ decreases, Doppler shift increases*

*so Δf increases.*

(iii) 0.54 ms-1