State Examinations Commission – Physics Higher Level, 2003.

Question 7

Describe an experiment to show that sound is a wave motion. (12)
What is the Doppler effect? Explain, with the aid of labelled diagrams, how this phenomenon occurs. (14)

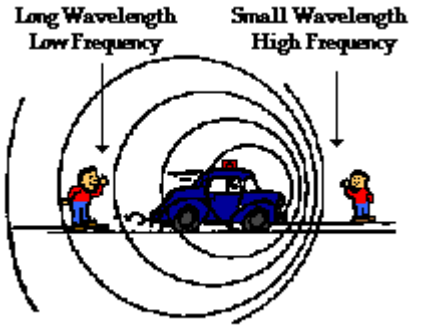
Bats use high frequency waves to detect obstacles. A bat emits a wave of frequency 68 kHz and wavelength 5.0 mm towards the wall of a cave. It detects the reflected wave 20 ms later.
Calculate the speed of the wave and the distance of the bat from the wall. (12)
If the frequency of the reflected wave is 70 kHz, what is the speed of the bat towards the wall? (12)
Give two other applications of the Doppler effect. (6)

Describe an experiment to show that sound is a wave motion. (12)

Strike a tuning fork, hold it to the ear and rotate. The amplitude of the sound you hear rises and falls. The tines of the fork act as coherent sources of sound waves and as they spread out they produce crests and trough in different directions because of interference. This interference shows that sound consists of waves.

What is the Doppler effect? Explain, with the aid of labelled diagrams, how this phenomenon occurs. (14)

The Doppler effect is the apparent change in the frequency of a wave when there is relative motion between the wave source and the observer of the waves. In the accompanying diagram, as the car approached with its siren blasting, the pitch of the siren sound (a measure of the siren's frequency) was high; and then suddenly after the car passed by, the pitch of the siren sound was lower.
The actual frequency at which the waves are emitted does not change; it only appears to do so.



The Doppler Effect for a moving sound source

Bats use high frequency waves to detect obstacles. A bat emits a wave of frequency 68 kHz and wavelength 5.0 mm towards the wall of a cave. It detects the reflected wave 20 ms later.
Calculate the speed of the wave and the distance of the bat from the wall. (12)

$V = f\lambda$
$= 68{,}000 \times 0.005 = 340\ ms^{-1}$

It takes 10 ms (0.01s) for the wave to reach the wall (and 10 ms to get back) so therefore the wall is 340 x 0.01 metres away, i.e., 3.4 m.

If the frequency of the reflected wave is 70 kHz, what is the speed of the bat towards the wall? (12)

$$f' = \frac{c}{c \pm u_s} f$$

$$70 = \frac{340}{340 - u_s} 68$$

$$u_s = 9.71\ ms^{-1}$$

Give two other applications of the Doppler effect. (6)
It is used in speed traps by Gardai to determine the speed of cars. It is used by astronomers to determine the speed at which galaxies are moving away from each other (how fast the Universe is expanding) and the speed with which they rotate (red shift).