7. Waves

7.3 Doppler effect for sound waves

Paper 2

Question Paper

1 A train travels at a constant high speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 5.1.

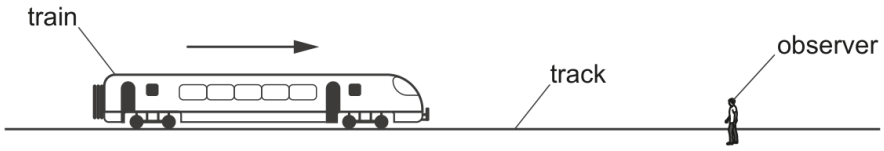


Fig. 5.1

The train sounds its horn continuously as it approaches the observer, from time $t = 0$ until it is well past the observer at time $t = t_2$. The train passes the observer at time $t = t_1$.
The horn emits a sound wave of constant frequency f_S.

(a) On Fig. 5.2, sketch the variation of the frequency of sound heard by the observer with time t, from time $t = 0$ to $t = t_2$.

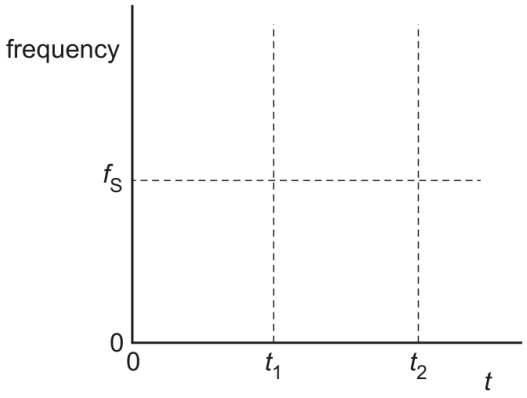


Fig. 5.2

[1]

2 **(b)** A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

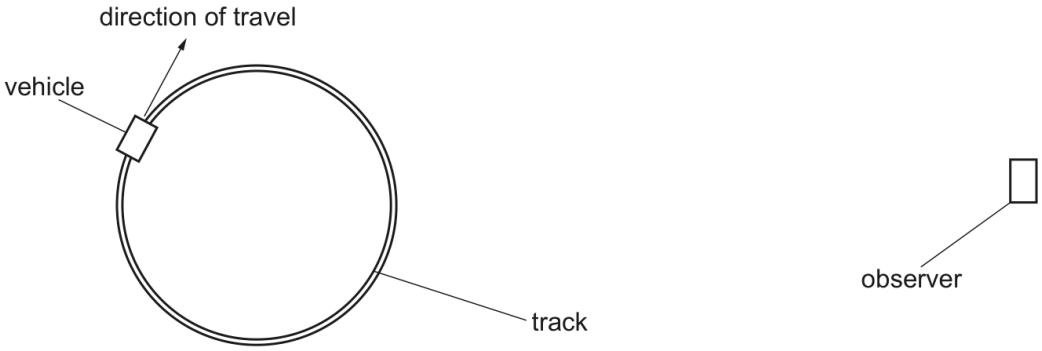


Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency f of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is T.

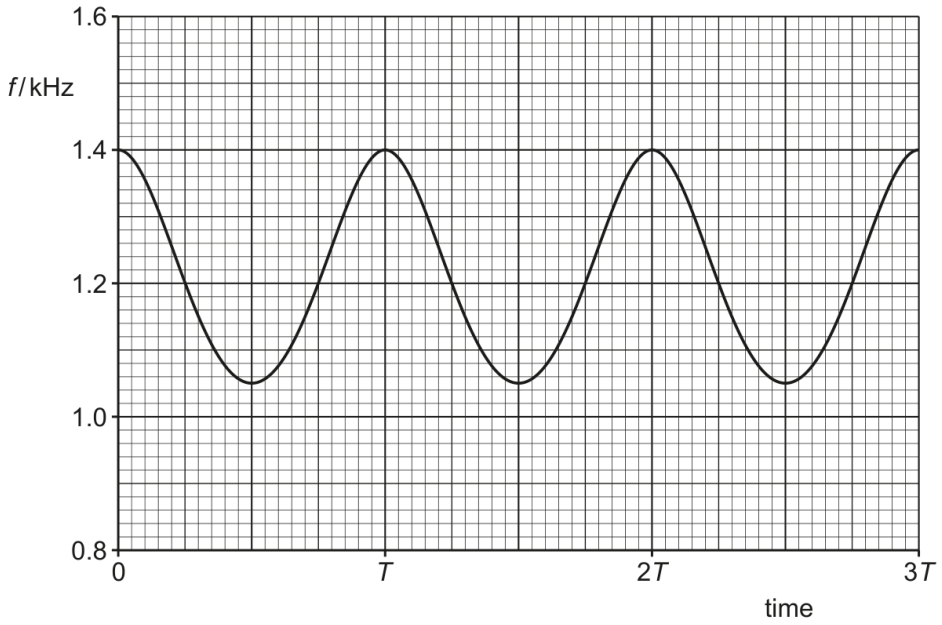


Fig. 4.2

(i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

.....

.....

.....

..... [2]

(ii) State the name of the phenomenon in **(b)(i)**.

..... [1]

(iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time T. [1]

(iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

(c) The speed of the sound in the air is $320\,\text{m}\,\text{s}^{-1}$.

Use Fig. 4.2 to determine the speed of the vehicle in **(b)**.

speed = ... $\text{m}\,\text{s}^{-1}$ [3]

3 A child sits on the ground next to a remote-controlled toy car. At time $t = 0$, the car begins to move in a straight line directly away from the child. The variation with time t of the velocity of the car along this line is shown in Fig. 4.1.

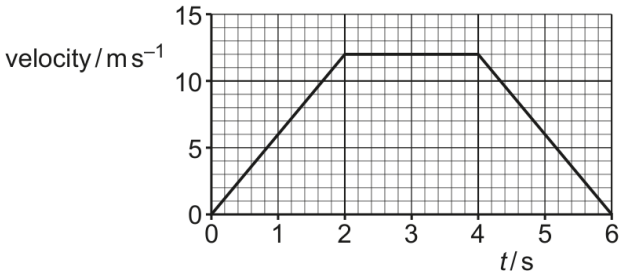


Fig. 4.1

The car's horn continually emits sound of frequency 925 Hz between time $t = 0$ and time $t = 6.0$ s. The speed of the sound in the air is 338 m s^{-1}.

(a) Describe qualitatively the variation, if any, in the frequency of the sound heard, by the child, that was emitted from the car horn:

(i) from time $t = 0$ to time $t = 2.0$ s

..... [1]

(ii) from time $t = 4.0$ s to time $t = 6.0$ s.

..... [1]

(b) Determine the frequency, to three significant figures, of the sound heard, by the child, that was emitted from the car horn at time $t = 3.0$ s.

frequency = ... Hz [2]

4 **(b)** A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

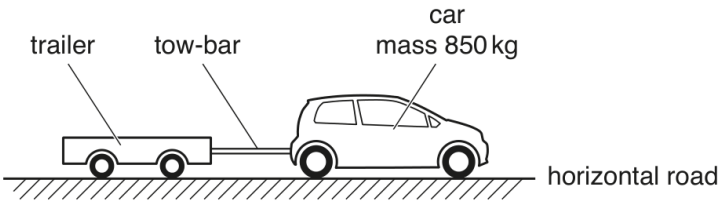


Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time t of the velocity v of the car for a part of its journey is shown in Fig. 2.2.

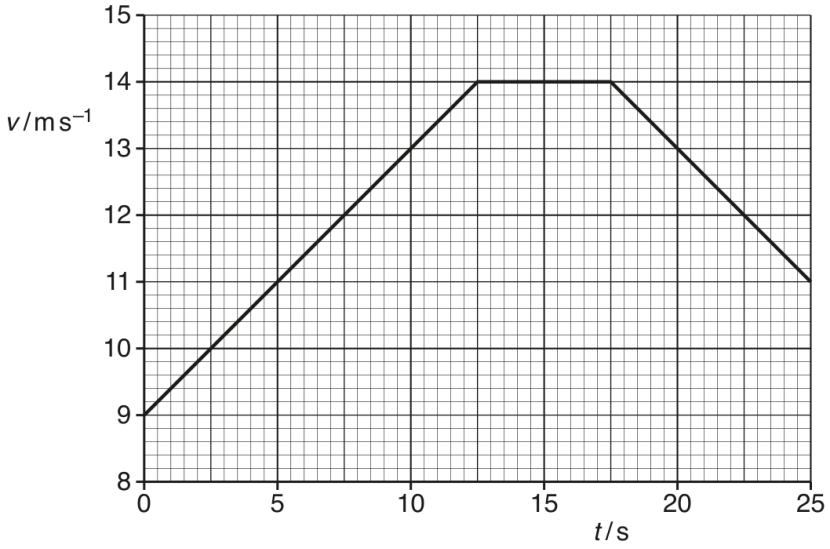


Fig. 2.2

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]

5 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

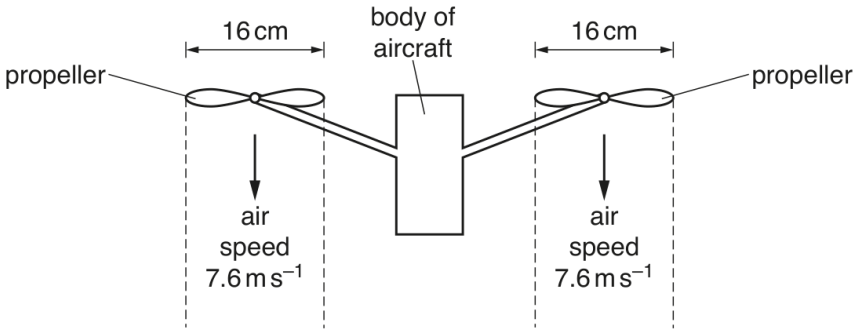


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is 1.2 kg m^{-3}. Assume that the air from each propeller moves with a constant speed of 7.6 m s^{-1} in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of 22 m s^{-1}, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is 340 m s^{-1}.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]

6 A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

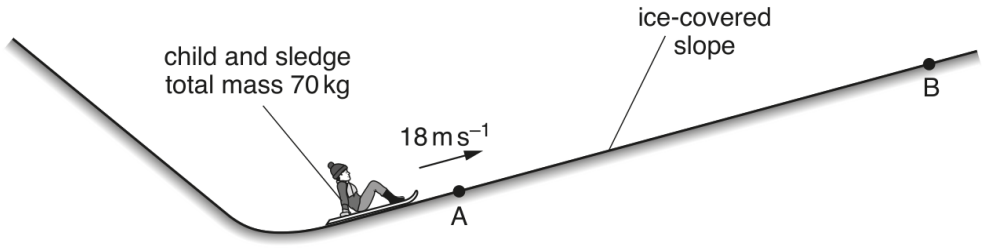


Fig. 3.1 (not to scale)

The sledge passes point A with speed 18 m s^{-1} at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24$ s is shown in Fig. 3.2.

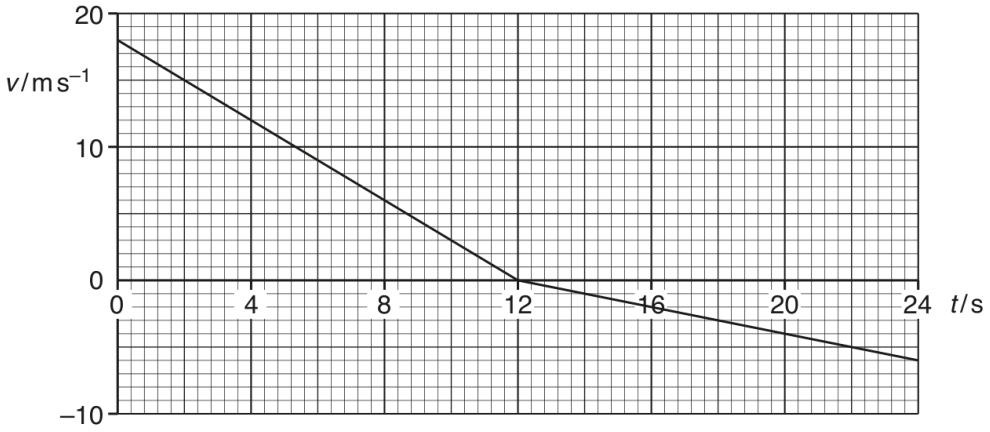


Fig. 3.2

(e) The child on the sledge blows a whistle between $t = 4.0$ s and $t = 8.0$ s. The whistle emits sound of frequency 900 Hz. The speed of the sound in the air is 340 m s^{-1}. A man standing at point A hears the sound.

Use Fig. 3.2 to

(i) determine the initial frequency of the sound heard by the man,

initial frequency = ... Hz [2]

(ii) describe and explain qualitatively the variation, if any, in the frequency of the sound heard by the man.

.....

.....[1]