

Exam Edge

A rally car travelling at 60 m s^{-1} approaches a stationary observer. As the car passes, its engine is emitting a note with a pitch of 1400 Hz .

What is the change in pitch observed as the car moves away?

(speed of sound in air = 340 m s^{-1})

(08 HL)

As the car approaches the observer, the observed frequency (pitch) is:

$$f' = \frac{f c}{c - u} = \frac{(1400)(340)}{340 - 60} = 1700 \text{ Hz}$$

As the car moves away from the observer the observed frequency (pitch) is:

$$f' = \frac{f c}{c + u} = \frac{(1400)(340)}{340 + 60} = 1190 \text{ Hz}$$

Change in frequency (pitch) observed
= $1700 - 1190 = 510 \text{ Hz}$

Note: The wording of this question was slightly unclear. An answer of $1190 - 1400 = 210 \text{ Hz}$ was also acceptable for "the change in pitch observed as the car moves away".

Note: Christian Johann Doppler argued in 1842 that if a star was moving away from the Earth then lines in its spectrum should be shifted towards the red end (the lower frequency end) of the spectrum. This was confirmed experimentally in 1868 and is now known as the "red shift".

Higher Level 2007 Question 7 (part)

The red line emitted by a hydrogen discharge tube in the laboratory has a wavelength of 656 nm . The same red line in the hydrogen spectrum of a moving star has a wavelength of 663 nm .

Is the star approaching the Earth? Justify your answer. (8)

Calculate:

- (i) the frequency of the red line in the star's spectrum;
- (ii) the speed of the moving star. (18)

(speed of light = $3.00 \times 10^8 \text{ m s}^{-1}$)

Is the star approaching? No. (3)

Because its wavelength has increased (or its frequency has decreased) (5) which tells us it is moving away.

- (i) **Frequency of red line in star's spectrum:**

$$663 \text{ nm} = 663 \times 10^{-9} \text{ m}$$

$$c = f \lambda \quad \text{or} \quad f' = \frac{c}{\lambda'} \quad (3)$$

$$f' = \frac{3 \times 10^8}{663 \times 10^{-9}} = 4.52 \times 10^{14} \text{ Hz} \quad (-1 \text{ for omission of units or incorrect units; no penalty here if } 650 \text{ nm used instead) (3)$$

- (ii) **Speed of moving star:**

Frequency of red line from hydrogen discharge tube in the laboratory

$$= f = \frac{c}{\lambda} = \frac{3 \times 10^8}{656 \times 10^{-9}} = 4.57 \times 10^{14} \text{ Hz}$$

$$f' = \frac{f c}{c + u} \quad (3) \Rightarrow 4.52 \times 10^{14} = \frac{(4.57 \times 10^{14})(3.00 \times 10^8)}{(3.00 \times 10^8 + u)} \quad (-3 \text{ for incorrect substitution) (3 + 3)$$

$$3.00 \times 10^8 + u = \frac{(4.57 \times 10^{14})(3.00 \times 10^8)}{4.52 \times 10^{14}} \Rightarrow 3.00 \times 10^8 + u = 3.03 \times 10^8$$

$$\Rightarrow u = 3.32 \times 10^6 \text{ m s}^{-1} \quad (-1 \text{ for omission of units or incorrect units) (3)$$