Exercise walk-through

# 12.2
# Doppler effect (full C.5, SL)

International Baccalaureate · IB Diploma · Physics · SL

# Light Doppler · 2.1

## Reasoning

Relative source-observer motion changes observed frequency or wavelength. For light at a relative speed much smaller than c, the magnitude of the fractional wavelength shift is approximately v/c. Recession corresponds to longer wavelength, and approach to shorter wavelength. redshift : Shift of an identified line toward longer wavelength. rest wavelength : Wavelength of the line measured with no relative source motion.

# Exercises 2.1·2.3

**2.1** Describe, in terms of wavefronts, why the pitch of a siren rises as it approaches a stationary listener. [2]

**2.2** State what is meant by a redshift, and what it indicates about the motion of the source. [2]

**2.3** State the condition under which the relation $\Delta\lambda/\lambda \approx v/c$ may be used for light. [1]

# Exercises 2.1·2.3

**2.1** Describe, in terms of wavefronts, why the pitch of a siren rises as it approaches a stationary listener. [2]

**2.1** The moving source chases the wavefronts it emits ahead of itself, so the fronts are bunched together ahead – more fronts reach the listener per second and the observed frequency (pitch) rises.

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**2.2** State what is meant by a redshift, and what it indicates about the motion of the source. [2]

**2.2** A shift of spectral lines to longer wavelengths than the rest values; the source is moving away from the observer.

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**2.3** State the condition under which the relation $\Delta\lambda/\lambda \approx v/c$ may be used for light. [1]

**2.3** The relative speed $v$ must be much smaller than the speed of light.

# Exercises 2.4·3.2

**2.4** Name two applications of the Doppler effect, one in medicine and one outside it. [2]

**3.1** A distant star's hydrogen line, rest wavelength 486 nm, is observed at 484 nm. Calculate the fractional shift and the radial velocity, and state the direction of motion. [3]

**3.2** Explain how comparing several spectral lines from a galaxy with laboratory rest wavelengths gives both the direction and the speed of its motion. [4]

# Exercises 2.4·3.2

**2.4** Name two applications of the Doppler effect, one in medicine and one outside it. [2]

**2.4** Medical: Doppler ultrasound measuring blood-flow speed; any other: radar speed guns, weather radar, astronomy redshifts.

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**3.1** A distant star's hydrogen line, rest wavelength 486 nm, is observed at 484 nm. Calculate the fractional shift and the radial velocity, and state the direction of motion. [3]

**3.1** $\Delta\lambda/\lambda = (484 - 486)/486 = -4.1 \times 10^{-3}$; $v = 4.1 \times 10^{-3} \times 3.0 \times 10^{8} = 1.2 \times 10^{6}$ m/s; the negative shift is a blueshift – the star approaches.

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**3.2** Explain how comparing several spectral lines from a galaxy with laboratory rest wavelengths gives both the direction and the speed of its motion. [4]

**3.2** Each element emits at known rest wavelengths, so matching the observed pattern identifies the lines and the shift is measured line by line; all lines shifting together by the same fraction confirms real motion rather than an instrumental effect; shift to longer wavelengths = recession, shorter = approach; the fractional shift times $c$ gives the radial speed.

# Exercises 3.3·3.4

**3.3** A radar speed gun emits radio waves that reflect from a moving car and return with a shifted frequency. Explain why the reflected wave is shifted, and why the car's speed can be found from the size of the shift. [3]

**3.4** A police siren passes a stationary observer. Describe how the observed pitch changes as the siren approaches, passes and recedes, explaining the change at each stage in terms of wavefronts. [4]

# Exercises 3.3·3.4

**3.3** A radar speed gun emits radio waves that reflect from a moving car and return with a shifted frequency. Explain why the reflected wave is shifted, and why the car's speed can be found from the size of the shift. [3]

**3.3** The reflection from the moving car acts like a re-emitting moving source, so the returned wave's frequency differs from the emitted one; the shift grows with the car's speed – $\Delta f/f \approx v/c$; comparing returned and emitted frequencies therefore yields the speed.

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**3.4** A police siren passes a stationary observer. Describe how the observed pitch changes as the siren approaches, passes and recedes, explaining the change at each stage in terms of wavefronts. [4]

**3.4** Approaching: fronts bunch at the listener – pitch high; at the moment of passing: relative radial speed passes through zero – the pitch slides down through its true value; receding: fronts stretch behind the siren – pitch low; the source frequency never changes; only the observed frequency does.