

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

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.

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

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

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

2.5 Approaching: $f' = fv/(v - u_s) = 500 \times 340/306 = 556$ Hz; receding: $f' = 500 \times 340/374 = 455$ Hz.

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.

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.

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.

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.

3.5 Moving source: $f' = 400 \times 340/320 = 425$ Hz; moving observer: $f' = 400 \times 360/340 = 424$ Hz; the moving source changes the wavelength in the medium – fronts are physically crowded – while the moving observer only crosses the unchanged wavefronts faster, so the two shifts are not identical.