The sound source of a ship's sonar system operates at a frequency of 22.0 kHz. The speed of sound in water (assumed to be at a uniform 20 °C) is 1482 m/s.
a) What is the wavelength of the waves emitted by the source?
b) What is the difference in frequency between the directly radiated waves and the waves reflected from a whale traveling directly toward the ship at 4.95 mi/s? The ship is at rest in the water.

a)

$$\lambda = v/f = (1482\,\text{m/s})/(22.0\times10^{3}\ \text{Hz}) = 6.74\times10^{-2}\ \text{m}.$$

b) The waves from a stationary sonar hit the whale with a frequency

$$f' = \frac{v + v_w}{v} f$$

The whale, acting as a secondary source of waves, reflects the waves back toward the sonar set with frequency

$$f'' = \frac{v}{v - v_w} f'$$

The difference between f" and f is

$$\Delta f = f\left(\frac{2v_W}{v - v_W}\right) = (22.0\times10^{3}\,\text{Hz})\frac{2(4.95\,\text{m/s})}{(1482\,\text{m/s}) - (4.95\,\text{m/s})} = 147\,\text{Hz}.$$

The reflected waves have higher frequency.