

11.15

EE23BTECH11029 - Kanishk

Question:

A SONAR system fixed in a submarine operates at a frequency 40.0 kHz. An enemy submarine moves towards the SONAR with a speed of 360 km/hr. What is the frequency of sound reflected by the submarine? Take the speed of sound in water to be 1450 m/s.

Solution:

Operating frequency of the SONAR system, $f = 40\text{kHz}$

Speed of the enemy submarine, $V_e = 360\text{km/h} = 100\text{m/s}$

Speed of sound in water, $V = 1450\text{m/s}$

The source (SONAR system) is at rest and the observer (enemy submarine) is moving toward it.

Enemy submarine (observer) is approaching the SONAR (source), So

$$V_{rel} = V + V_e \quad (1)$$

As we know,

$$\lambda = \frac{V}{f} \quad (2)$$

Frequency observed by the enemy submarine would be

$$f' = V_{rel}/\lambda \quad (3)$$

Now by putting equation 1 and equation 2 in equation 3 we got

$$f' = \left(\frac{V + V_e}{V}\right)f \quad (4)$$

$$= \left(\frac{1450 + 100}{1450}\right)40 = 42.76\text{kHz}$$

This frequency (f') is reflected by the enemy ship and is observed by the SONAR (which now acts as observer). Now the enemy submarine has become source,

In time period T the wave reflected by source (enemy submarine) will travel distance VT and source will travel by distance $V_e T$

So the change in displacement by the wave and source would be the wavelength of the wave

$$\lambda_2 = T(V - V_e) \quad (5)$$

$$T = 1/f' \quad (6)$$

Putting equation 6 in equation 5 we get,

$$\lambda_2 = \left(\frac{V - V_e}{f'}\right) \quad (7)$$

As we know,

$$f'' = V/\lambda_2 \quad (8)$$

By putting equation 7 in equation 8 we got,

$$f'' = \left(\frac{V}{V - V_e}\right)f' \quad (9)$$

$$f'' = \left(\frac{1450}{1450 - 100}\right)42.76$$

$$= 45.93\text{kHz}$$

The equation of reflected wave is given as:

$$y = A \sin(2\pi * f''t + -\frac{2\pi}{\lambda}x) \quad (10)$$

where A is amplitude of wave generated.

Input:	40kHz
Output:	45.93kHz