

# 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:

Parameter	Description	Value
$V$	Speed of sound in water	1450m/s
$V_e$	Speed of enemy submarine	100m/s
$V_{rel}$	Relative velocity between both submarine	1550m/s
$f$	Frequency of SONAR wave	40kHz
$y(x, t)$	Equation of SONAR wave	$A \sin(2\pi f t - \frac{2\pi}{\lambda} x + \phi)$
$\lambda$	Wavelength of SONAR wave	3.625cm
$f'$	Frequency observed by enemy submarine	42.76kHz
$\lambda_2$	Wavelength of reflected wave	3.157cm
$y_2(x, t)$	Equation of reflected wave as observed from submarine	$A \sin(2\pi * f'' t - \frac{2\pi}{\lambda_2} x + \phi)$

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

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

Frequency observed by the enemy submarine would be

$$f' = V_{rel}/\lambda \quad (2)$$

$$= \left(\frac{V + V_e}{V}\right)f \quad (3)$$

$$= \left(\frac{1450 + 100}{1450}\right)40 \quad (4)$$

$$= 42.76kHz \quad (5)$$

This frequency ( $f'$ ) is reflected by the enemy ship and is observed by the SONAR (which now acts as observer). Now the 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

$$\lambda_2 = T(V - V_e) \quad (6)$$

$$T = 1/f' \quad (7)$$

$$\lambda_2 = \left(\frac{V - V_e}{f'}\right) \quad (8)$$

$$f'' = V/\lambda_2 \quad (9)$$

$$= \left(\frac{V}{V - V_e}\right)f' \quad (10)$$

Parameter	Description	Value
$f'' = \left(\frac{V}{V - V_e}\right)f'$	Frequency of reflected wave	45.93kHz